Four new species of *Triodia* (Poaceae) from the Pilbara and adjacent bioregions, Western Australia

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Abstract

Barrett, M.D., de Kock, P.-L. & Dillon, S.J. Four new species of *Triodia* (Poaceae) from the Pilbara and adjacent bioregions, Western Australia. *Nuytsia* 34: 261–294 (2023). The Australian hummock genus *Triodia* R.Br. is currently undergoing taxonomic revision in light of new collections from surveys of remote Australia and increased resolution provided by molecular methods. This paper describes four new species of *Triodia* from the Pilbara and adjacent IBRA bioregions: *T. avenoides* M.D.Barrett, *T. degreyensis* M.D.Barrett, *T. karijini* M.D.Barrett & S.J.Dillon, and *T. lutiteana* M.D.Barrett & P.-L. de Kock. All four species are 'soft' spinifexes with elongate glumes and lemma lobes subulate to awned, and are only known from the Pilbara and adjacent Carnarvon and Gascoyne regions of Western Australia. *Triodia degreyensis* is known from a single range system in the north-eastern Pilbara. The taxon formerly known by the phrase name *T.* sp. Karijini (S. van Leeuwen 4111) is formally described here as *T. karijini*, and is restricted to mountains above 900 m altitude in the eastern Hamersley Range. *Triodia lutiteana* is only known from shale substrates north-west of Tom Price, and may be a polyploid species. The new species *T. avenoides* is segregated from *T. schinzii* (Henrard) Lazarides based on morphological and molecular differences and a disjunct distribution on sand sheets and dunes of the Carnarvon basin. The central Australian species *T. helmsii* (C.E.Hubb.) Lazarides is newly synonymised with *T. schinzii*, since no clear morphological or genetic differences between the two could be established. An amended description of *T. schinzii* is provided to accommodate these alterations to the species concept. Diagnostic character combinations for each species are given to allow discrimination from all other *Triodia* species. *Triodia degreyensis*, *T. karijini* and *T. lutiteana* are known from between one and four localities, and have priority conservation statuses, while *T. avenoides* and *T. schinzii* are not considered threatened. With the species described here, a total of 29 species and one hybrid are now known from the Pilbara bioregion and its immediate surrounds.

Introduction

Triodia R.Br. hummock grasses are restricted to mainland Australia, where they are characteristic components of many arid and semi-arid communities. The genus currently consists of 83 described and accepted species (Lazarides 1997; Lazarides *et al.* 2005; Armstrong 2008; Barrett & Barrett 2011,

2015; Hurry *et al*. 2012; Crisp *et al*. 2015; Anderson *et al*. 2017a; Barrett & Trudgen 2018; Barrett 2019). However, a further 21 putative undescribed species are listed using phrase names in the state checklists of Western Australia (7 species; https://florabase.dbca.wa.gov.au, accessed 19 Aug. 2021) and the Northern Territory (14 species; http://eflora.nt.gov.au/, accessed 19 Aug. 2021). *Triodia* is undergoing systematic revision in the light of intensive botanical survey in remote Australia and new molecular phylogenetic data, as exemplified by the molecular and morphological investigations of Anderson *et al*. (2016; 2017a, b; 2019) for the *T. basedowii* E.Pritz. complex. A phylogenetic overview of *Triodia* was provided by Toon *et al*. (2015); however, names and distributions used in that paper should be used with caution given recent and on-going taxonomic changes in the genus. The current paper treats four taxa of 'soft' spinifex with epistomatous leaf blades (see Toon *et al*. 2015; Barrett 2019) and lobed to awned lemmas (Schinzii or Pungens groups *sensu* Lazarides 1997) from the Pilbara and adjacent IBRA bioregions (Department of Environment 2013). Two of the new species are morphologically similar to *T. schinzii* (Henrard) Lazarides, while the other two are both morphologically similar to *T. melvillei* (C.E.Hubb.) Lazarides, *T. pisoliticola* Trudgen & M.D.Barrett and *T. veniciae* M.D.Barrett. The taxonomic changes effected here (four new species and a synonym) bring the total number of described and accepted *Triodia* species to 86.

Triodia schinzii has long been considered a widespread species occurring throughout much of arid Australia, where it is common on red sand dunes and deeper sand swales. In the course of reviewing *Triodia* type specimens, and as part of a concurrent intensive review of the variation in Pilbara *Triodia*, two anomalies were detected relating to *T. schinzii*: (1) in central Australia, no clear distinction could be found between *T. schinzii* and *T. helmsii* (C.E.Hubb.) Lazarides; and (2) a western disjunct population of *T. schinzii* was found to be morphologically and genetically distinct. Consequently, *T. helmsii* is synonymised with *T. schinzii*, and a new species, *T. avenoides* M.D.Barrett, is segregated from *T. schinzii*.

In 2010, a specimen (PERTH 008365547) of an unusual spinifex was collected from a high mountain in the eastern Hamersley Range by Jerome Bull and flagged as unusual by one of us (SJD). It was subsequently determined to be morphologically discrete from all known species of *Triodia*, several additional matching collections from nearby mountains were located filed under *T. melvillei*, and the taxon was formally listed using the phrase name *T.* sp. Karijini (S. van Leeuwen 4111). DNA sequences from the ITS and ETS regions confirmed that the collections from mountains formed a novel lineage (M.D. Barrett, unpublished data), remote from *T. melvillei* and closer to *T. pisoliticola*. *Triodia* sp. Karijini (S. van Leeuwen 4111) is here formally described as a new species, *T. karijini* M.D.Barrett & S.J.Dillon.

In 2012, a population of *Triodia* from near the De Grey River was located by one of us (MDB) on gravelly slopes, co-occurring with *T. schinzii*. Although initially attributed to *T. bitextura* Lazarides *s. lat.*, unpublished molecular data placed it closer to *T. avenoides*, which was corroborated by glume nerve number (7–13, similar to *T. avenoides*, rather than 3–5 as in *T. bitextura*). The new population differed from *T. avenoides* in plant height, a broadly acute to shortly pungent callus (long-pungent callus in *T. avenoides* and *T. schinzii*), glumes shorter or subequal to the spikelet (glumes usually longer than the spikelet excluding awns in *T. avenoides* and *T. schinzii*), hairy palea (glabrous or rarely hairy in *T. avenoides* and *T. schinzii*), and by substrate preference. This taxon is here described as a new species, *T. degreyensis* M.D.Barrett.

In 2017, during surveys in the Nammuldi-Silvergrass area north-west of Tom Price by P.-L. de Kock, then at Biota Environmental Sciences, an unusual *Triodia* was found forming monocultures on small shale hills. This taxon was subsequently listed on the WA census under the phrase name *T.* sp. Silvergrass (P.-L. de Kock BES 00808). The lemma lobes of this form are similar to those of *T. karijini* and *T. veniciae* in being acuminate but not produced into awns. Although morphologically similar to *T. veniciae*,

which is also restricted to shale substrates, the sheath submarginal surfaces of *T*. sp. Silvergrass differ in having long and densely woolly hairs, compared to the glabrous or straight-hairy surfaces of *T. veniciae*. Comparisons of ITS and ETS sequences indicated a close relationship with *T. karijini*, which differs in having a much smaller stature, different sheath hairs, longer lemma mid-lobe, shorter ligule and is restricted to banded iron formation (BIF) substrates on mountains above 900 m. Accordingly, it is described here as a new species, *T. lutiteana* M.D.Barrett & P.-L.de Kock, and incomplete evidence consistent with the possibility of a polyploid origin is discussed.

All of the new species, except *T. lutiteana*, are covered in the multi-access Lucid identification app for Pilbara *Triodia*, SPIKEY (Barrett *et al*. 2017).

Methods

Morphological methods follow those of Barrett *et al*. (2017), Barrett and Trudgen (2018) and Barrett (2019), except as discussed below. Measurements were made to the nearest 0.5 mm, unless indicated more precisely.

Leaf anatomy was assessed by sectioning fresh or dried leaves with a double-sided razor blade after soaking in hot water with a small amount of detergent. Leaf anatomy was classified as epistomatous or amphistomatous, following previous definitions (see Toon *et al*. 2015; Barrett 2019). Amphistomatous leaf blades have a more or less equal number of stomatal grooves on the abaxial and adaxial surfaces, the grooves evenly spaced over each surface, and in section the grooves surrounded by green chlorenchyma tissue and bundle sheath cells, reducing the colourless spongy mesophyll cells to small ribs between the vascular bundles. Amphistomatous leaves typically have well-developed sclerenchyma below the epidermis, and leaves are usually rigid and needle-like; they are colloquially known as 'hard' spinifexes (e.g. Gamage *et al.* 2012, Fig. 2b). Epistomatous leaf blades lack stomatal grooves on the lateral abaxial faces, in section also lacking chlorenchyma and bundle sheath cells that would typically (in amphistomatous leaves) surround each stomatal groove; the corresponding space is instead occupied by large areas of colourless spongy mesophyll in section (e.g. Gamage *et al.* 2012, Fig 2a; Fig. 1J here). Species with epistomatous leaves typically have a thin layer of sclerenchyma tissue below the epidermis, and the blades are consequently usually more flexible at least when fresh; they are colloquially known as 'soft' spinifexes (e.g. Gamage *et al.* 2012). The terms epistomatous and amphistomatous are used in preference to, but are synonymous with, 'soft' and 'hard' terminology sometimes applied to leaf anatomy prior to Toon *et al.* (2015). Lemma lobes are measured from the deepest point of sinus (both sides measured if asymmetrical), as used by Barrett *et al*. (2017).

Species of the genus *Triodia* are often called *hummock grasses*, for the tendency of culms to form above ground-level, with clusters of leaves and short shoots appearing to be heaped on each other in a tight to loose pile. This *hummock* characteristic is in contrast to many perennial grasses with rhizomes at or below the soil surface, producing tufts of leaves arising near ground level, the resulting architecture termed a *tussock*. Very young *Triodia* plants can appear somewhat like a tussock, but usually soon develop the distinctive hummock form; although the distinction is not always clear-cut, the term hummock is typically applied to *Triodia*, regardless of its exact form. However, in a few *Triodia* species, such as *T. karijini* described here, even mature and old plants produce leaves and short shoots arising in a dense tuft from ground level, with the wiry rhizomes and internodes at ground level, in a typical tussock form. Such plants are here referred to as *hummocks with a tussock form*, to both retain homologous connection with typical *Triodia* plants, but to emphasise the form difference in these species.

A clarification of inflorescence axis terminology is required to precisely describe different orders of branching. The term *rachis* is frequently used for plant inflorescence axes, and in grasses is often used for any axis to which spikelets are attached (Sharp & Simon 2002), which does not allow easy distinction between primary and secondary axes. Lazarides (1970; 1997) did not use the term rachis in *Triodia* and other grasses, but instead referred to axes of the inflorescence, especially for the 'main stem' of the inflorescence, but also to refer to the branches of a panicle. Here we slightly modify Lazarides' terminology and use the term *primary axis*, with *primary branches* diverging off the primary axis. To avoid confusion, the terminology *axis of the primary branches* is used rather than 'secondary axes'. Where the primary branches are further divided (nearly always once-divided, if at all), the inflorescence is referred to as ternate. Characters used to describe the inflorescence branches include *longest primary branch length* (from its divergence from the primary axis to the apex of the intact spikelets, following the longer branch if ternate; measuring three longest branches per specimen); *number of spikelets on longest primary branches* (ignoring the shorter branches if ternate; three measurements per specimen), and *internodes between pedicels on longest primary branches* (measured on three longest lower branches per specimen).

Pedicels typically decrease in length along a panicle branch, while the terminal 'pedicel' (the continuation of the branch axis) is frequently longer than all lateral pedicels. The basic architecture makes pedicel length an extremely variable character. In order to tighten the definition of pedicel length used by Lazarides (1997), the terminal pedicel length is reported separately, while only the longest lateral pedicels at the base of longest primary branches were measured as a character, termed *longest pedicels at base of longest panicle branches*. Care was taken to identify and exclude short ternate branches, which can occur near the base of long primary branches and may have only two spikelets, which can lead to a terminal pedicel in a short branch being mistaken for a long lateral pedicel. Three terminal pedicels per primary branch and *longest pedicels at base of longest panicle branches* were measured per specimen. In species with few specimens available for descriptions, up to 10 units were measured for each branch and pedicel character per specimen, to better capture the range of variation.

Flow cytometry of two species (see notes under *T. lutiteana* for reference samples) was performed using the methodology of Anderson *et al*. (2017b).

All specimens cited were viewed (at least by MB), except for some duplicates indicated accordingly (*n.v.*).

Results and Discussion

Review of the taxonomic concept of T. schinzii

Plectrachne schinzii Henrard (now *T. schinzii*) was first described by Henrard (1929) as the type species of his new genus *Plectrachne* Henrard, based on a G.F. Hill collection from Lander Creek (now Lander River) in central Northern Territory. Hubbard (1941) later described *Plectrachne helmsii* C.E.Hubb. (now *T. helmsii* (C.E.Hubb.) Lazarides) as a new species from Everard Range, also in central Australia. In the protologue, Hubbard (1941) specifically compared *T. helmsii* to *Plectrachne pungens* (R.Br.) C.E.Hubb. (now *T. bitextura* Lazarides), differing by the longer glumes and lemmas, and a membranous palea (by inference compared with the shorter glumes and lemmas, and partially indurated palea, in *P. pungens*). However, no mention was made by Henrard (1941) of any similarity of *P. helmsii* to *P. schinzii*, despite a closer geographical proximity and more similar glume length (than to *T. bitextura*). *Triodia helmsii* and *T. schinzii* are more recently described as differing in few

and subtle characters (e.g. Lazarides *et al.* 2005). This prompted a review of whether *T. helmsii* could actually be a synonym of *T. schinzii*.

Lazarides (1970), in treating the grasses of Central Australia, also did not compare the two species, since *T. helmsii* was not treated there. The first time that *T. schinzii* and *T. helmsii* were directly compared was in the Gramineae treatment (as *Plectrachne*) for Flora of Central Australia (Lazarides 1981), wherein *P. helmsii* was differentiated from both *P. schinzii* and *P. pungens* (now *T. bitextura*) by 'Palea membranous throughout; rhachilla between glumes with tooth-like projection; glumes subequal or lower much shorter', compared to 'Palea coriaceous in lower half to two-thirds, abruptly hyaline above; rhachilla [sic] without a projection; glumes subequal' in the other two species. The relative glume length is an inconstant feature, while the rachilla projection was later noted as only being present in the type specimen of *T. helmsii* (Lazarides 1997) and is therefore at least inconstant and may even be a singleton aberration, since it has not been observed in other specimens. Lazarides (1997) added an anther length difference (2–2.8 mm in *T. helmsii*, 3–4 mm long in *T. schinzii*). Lazarides *et al.* (2005) utilised a different character to separate *T. schinzii* (from many others, including *T. helmsii*): 'Pedicels of terminal spikelets much longer than those of the lateral ones (up to 20 mm, versus about 2 mm)' in *T. schinzii*, compared to 'Pedicels usually variable in length (but not in the consistent pattern described above), or of similar length and all short' in *T. helmsii* (and others). However, in the text Lazarides *et al.* (2005) stated that *T. helmsii* differs from *T. schinzii* 'by its uniformly textured palea and smaller spikelets'. In treating the grasses of South Australia, Jessop *et al.* (2006) specifically followed Lazarides (1997) for their treatment of *T. helmsii*, with only slight clarification in their key compared to Lazarides (1997): 'Palea uniformly membranous or hyaline; anthers 2–2.8 mm long' in *T. helmsii*, compared to 'Palea cartilaginous or hardened in the lower part (usually about three-quarters), abruptly hyaline above; anthers 2.5–4 mm long' in *T. schinzii*. Spikelets (excluding awns, and implicitly excluding glumes, since spikelet measures were shorter and glumes stated to exceed spikelets) were reported to be 11–15 mm long in *T. helmsii*, and 10–30 mm long in *T. schinzii* by Lazarides (1997). Lazarides *et al.* (2005) reported slightly different lengths: 12–21 mm long in *T. helmsii*, and 10–30 mm long in *T. schinzii*; however, the measurement for *T. helmsii* is identical to their reported glume length, and almost certainly this was intended to include glumes, presumably standardising 'spikelet length' to include glumes across the Flora, although the same was not done for *T. schinzii*, since their cited spikelet lengths match Lazarides (1997) spikelet length (implicitly excluding glumes) rather than glume length in same. In either case spikelet length difference is also therefore predominantly overlapping and cannot be used to discriminate *T. helmsii* from the more variable *T. schinzii*. In the dichotomous key to *Triodia* of Sharp and Simon (2002), *T. helmsii* (along with *T. acutispicula* Lazarides) is separated by 'Body of lemma at least 4.5 mm long [later more specific, 4.5–5 mm long]' from *T. schinzii* (and others) by 'Body of lemma up to 3 mm long'. However, this difference must be based on incomplete data, since Lazarides (1997) had previously described the lemma body of *T. helmsii* as '4.5–6.5 mm long (body and callus)', which includes a callus '1–1.5 mm long', and that of *T. schinzii* as 3–6(–9) mm long (without stating whether that included the 1–1.5 mm long callus). There is therefore very broad overlap in lemma body length between *T. helmsii* and *T. schinzii*. From these works, only four characters seem to be potentially or partially diagnostic: (1) pedicel length differences, (2) spikelets 11–15 mm long in *T. helmsii*, versus 10–30 mm long in *T. schinzii*; (3) anther length 2–2.8 mm in *T. helmsii*, versus 3–4 mm long in *T. schinzii*; and (4) palea membranous in *T. helmsii*, versus bitextured (i.e. both indurated and membranous) in *T. schinzii*. Note that all *T. schinzii* measurements cited by previous authors include both *T. avenoides* and *T. schinzii s. str.* as separated in this paper, requiring re-measurement of all taxa. The same specimens of *T. helmsii* were cited by Lazarides (1997) and Lazarides *et al.* (2005); only a subset of these *T. helmsii* specimens were examined here: *Beauglehole* 60786, *Beauglehole* 60601, *Dunlop* 1916, and the type *Helms* s.n. (see under *T. schinzii* for full citation). The specimen *George* 8387 was also listed under *T. helmsii* by Lazarides (1997), but on examination was found to have

a bitextured palea, placing it in *T. schinzii*, so is discussed under the latter species. In all specimens the most mature florets available were examined, to minimise developmental artefacts to the extent possible. Anther and palea observations in particular can only be conducted on one or a few spikelets per specimen, and they vary with maturity; consequently different results can be obtained from the same specimen simply through dissecting different florets. Consequently, for *T. helmsii*, measurements by Lazarides were also included in character ranges for that species (although they differed only slightly from measurements made for this study), with the exclusion of the doubtful spikelet length in Lazarides (2005) discussed above. Pedicel lengths were defined as described in the methods, in order to delimit a character with lower variance than used by Lazarides (1997).

Observations on these characters with a range of collections found:

(1) Pedicel length cannot be reliably used to discriminate *T. helmsii* relative to *T. avenoides* or *T. schinzii*. Longest pedicels at base of longest panicle branches were (2.0–)4.0–15.0 mm long in *T. avenoides* and (1.0–)1.4–8.5 mm long in *T. schinzii*, while terminal pedicels were 9.5–34.0 mm long in *T. avenoides* and 8.0–32.0 mm long in *T. schinzii*. In the type of *T. helmsii*, the longer basal lateral pedicels were 1.0–4.8 mm long, and terminal pedicels 7.0–15.5 mm long. In all three taxa, the terminal pedicels were consistently longer than the lateral pedicels, and considerable variation was observed in lateral pedicel length, even when restricted to the longer basal pedicels (not all lateral pedicels measured by Lazarides). Although there is some tendency toward shorter pedicel lengths in the type (at least) of *T. helmsii* relative to *T. avenoides* and *T. schinzii*, lengths show considerable overlap between the three taxa, and almost complete overlap of *T. helmsii* (type specimen) with the lower end of the range of both *T. avenoides* and *T. schinzii*. Furthermore, all examined specimens of *T. helmsii* are incompletely mature (see (3) and (4) below), which may contribute to their smaller dimensions.

(2) Spikelet lengths could not discriminate between *T. helmsii* and *T. schinzii s. str.*, as their ranges almost complete overlap. This is partly complicated by some uncertainty whether only the combined florets were measured (excluding glumes, which are usually longer than the combined florets) in Lazarides *et al.* (2005), while spikelet measurements in Lazarides (1997) implicitly exclude glumes, by reporting spikelet lengths shorter than glume lengths and that glumes exceed spikelets. The combined florets, without glumes, were here found to be 8.5–13 mm long in *T. avenoides* and (6–)7.5–19 mm long in *T. schinzii*, compared with 11–15 mm in *T. helmsii* (agreeing with Lazarides 1997, but not Lazarides *et al.* 2005, which is presumably an error, see earlier discussion). The fact we could not find combined florets exceeding 20 mm suggests that the upper range of spikelet length reported by Lazarides (1997) for *T. schinzii* (to 30 mm long) does include glume length. Either way, there is nearly complete overlap between *T. helmsii* and *T. schinzii s. str.* in combined floret length. If the 'spikelet' measurement includes glumes, then glume length would actually be the determining criterion in these species with glumes longer than the combined florets. Glume lengths were here found to be (12.5–)15–30 mm in *T. avenoides*, (12–)14–26 mm in *T. schinzii s. str.* and 12–21 mm in *T. helmsii*; these values are again completely overlapping.

(3) Anther length overlapped more than reported by Lazarides (2–2.8 mm long in *T. helmsii*, versus 3–4 mm long in *T. schinzii*). Anthers were here found to be 2.3–4.4 mm long in *T. avenoides*, 2.0–3.8 mm long in *T. schinzii*, and 2.0–2.8 in *T. helmsii*. Anthers present on specimens span a range of developmental conditions, and unless exserted and dehisced cannot be easily recognised as mature or immature. Exserted anthers are soon deciduous, and not often present on specimens. Consequently, reported ranges of anthers in *Triodia* are

expected to include immature anthers at the lower end. The anthers in specimens of *T. helmsii* observed here appeared to be immature, and this likely also applies to measurements made by Lazarides (1997), who examined the same specimens and only a few additional ones, although the exact anthers (and paleas) examined by Lazarides can never be determined. The immaturity of the anthers may thus have biased the range of lengths reported by Lazarides (1997). In *T. schinzii*, anthers as small as 2.0 mm long were regularly observed from non-basal florets, and occasionally in basal florets, although their maturity is unknown. In conclusion, although the measured *T. helmsii* anther length is consistently within the lower end of the range in *T. schinzii*, there is very broad, or even complete, overlap in measured anther length between *T. schinzii, T. avenoides* and *T. helmsii*, and the difference in range extremes is likely developmental.

Note that although many grasses produce cleistogamous flowers, usually with smaller anther size than chasmogamous flowers, no such condition has yet been observed in *Triodia*, and as far as is known, all *Triodia* species are chasmogamous and exsert their anthers at maturity (Thompson 2021; M.D. Barrett, pers. obs.). It is therefore unlikely, but not impossible, that *T. helmsii* represents a cleistogamous form of *T. schinzii*.

(4) The reported palea texture difference is likely an artefact of maturity; immature paleas of *T. schinzii* can be uniformly textured, while available specimens of *T. helmsii* are at least incompletely mature. The palea of the basal floret in mature specimens (those with florets turgid and diverging from the rachilla axis, not obviously under-developed anthers and styles, some rachillas beginning to fragment, and/or some florets with exserted anther filaments) of *T. schinzii* and *T. avenoides* was always bitextured, and usually distinctly so, as described by Lazarides (1997). A similar condition was observed in *A.S. George* 8387 (PERTH), which has an immature inflorescence, and was cited by Lazarides (1997) under *T. helmsii*, but has a bitextured palea, so belongs in *T. schinzii* following Lazarides' characters. In *T. schinzii*, the demarcation of the two textures in the palea is more diffuse than that of the lemma, and occasionally paleas are more obscurely bitextured even in well-developed florets, especially when the membranous upper part was small (*c.* 0.5–0.7 mm long), blurring the line between bitextured and uniformly textured palea.

In *T. schinzii* specimens with immature spikelets (identified as those with even the most mature florets not yet swelling, turgid or becoming loose from each other and/or, anthers and styles scarcely developed), a range of somewhat intermediate development and texture conditions were observed. For example, *Barrett & Anderson* 4072 and *George* ASG 3454 (both PERTH) had a clearly bitextured palea with truncate membranous apex, but scarcely indurated lower part, the demarcation due to a sharp change in colour and translucency. In *Mathews & Orifici* BES BDM 032 (PERTH) the palea was bitextured, with a sharp transition line, the upper and lower parts differing in both colour and texture. However, in *D. Pearson* DJP712, *K.F. Kenneally* 9852 and *Y. Power* 186 (all cited by Lazarides 1997 under *T. schinzii*; both with immature inflorescences; PERTH duplicates examined) the palea was found to be entirely membranous, with only a gradual change in colour between brown lower half and upper translucent *c.* 1/4 – these paleas may have developed into a more obviously bitextured condition with maturity. A specimen of *T. schinzii* from 50 miles east of Docker Settlement (*Latz* 830, PERTH, DNA, CANB; not cited by Lazarides (1997) or Lazarides *et al.* (2005)) had smaller spikelets and florets than other examined specimens, but had a clearly bitextured palea in the lowermost floret, with a distinct membranous upper third. The second-lowest (and less mature) palea in this specimen was scarcely bitextured at all, with an obscurely

indurated (almost chartaceous) lower part, and a membranous apex, with a very diffuse boundary between them (very similar to the condition in *T. helmsii*, see below). This serves as an example of a developmental series in *T. schinzii*, from immature very weakly bitextured to strongly bitextured palea; the same transition from uniform to bitextured also occurs in both the lemma and palea of other species with bitextured lemmas (e.g. *T. basitricha*, *T. bitextura*; M.D. Barrett, pers. obs., which require mature florets for accurate discrimination from species lacking a bitextured lemma such as *T. bynoei* C.E.Hubb.).

Examination of the palea in the type of *T. helmsii* did not reveal any clear division in texture, but the palea had a membranous apex gradually thickening toward the chartaceous base, i.e. was weakly 2-textured but lacked a sharp demarcation line; this is the same condition observed in immature florets of *T. schinzii*. All examined specimens determined as *T. helmsii* by Lazarides (1997), including the type (*Helms s.n.*; see under *T. schinzii* for duplicates examined) appear to be immature, as evidenced by the fact that even the most developed florets showed no signs of having exserted any of their anthers, and frequently had very poorly developed anthers and styles. The lemma bitexture line was never callused on the reverse side in any of the *T. helmsii* specimens, similar to immature *T. bitextura* and *T. schinzii*, while a callused reverse side of the bitexture line is present in mature lemmas of all other species with a bitextured lemma. Furthermore, in the examined *T. helmsii* specimens nearly all florets remained tightly appressed to each other, not becoming turgid and diverging in angle as in mature spikelets. The florets in examined *T. helmsii* specimens are therefore here interpreted as developmental stages prior to full formation of the bitextured lemma, and it can be expected that the palea will be similarly underdeveloped, as observed in some *T. schinzii*.

Although the palea difference between the most common mature condition in *T. schinzii* (and *T. avenoides*) and the few (immature) specimens of *T. helmsii* studied by Lazarides is stark on first encounter, it is clear that *T. helmsii* has been described based on incompletely mature specimens, and when compared with a range of developmental material of *T. schinzii*, the range of palea variation is completely overlapping.

Since all characters previously indicated as distinguishing *T. helmsii* from *T. schinzii* (*s. lat.*) show almost complete overlap, their separation cannot be supported on morphological grounds.

DNA sequencing of ITS and ETS regions of ribosomal DNA (Toon *et al.* 2015; M.D. Barrett, unpublished data) showed no consistent difference in ITS between *T. helmsii* and *T. schinzii* samples (e.g. in the Toon *et al.* 2015 Supplementary data 3.3 ITS tree, *T. schinzii* 9773 is identical to *T. helmsii* 60601 (and also to *T. salina* 8814; the identity of this *T. salina* specimen requires investigation, since the ITS sequence does not match other *T. salina* specimens, M.D. Barrett unpublished data); note that their divergent *T. schinzii* 9722 is here placed under the new species *T. avenoides*). The *mat*K tree of Toon *et al.* (2015, Supplementary data 3.4) places their *T. helmsii* sample identical to 9722 and in the same clade as *T. salina* 8814, rather than *T. schinzii* 9773, with low support, and little variation between species. In addition, chloroplast loci must be interpreted with caution, since chloroplast capture has been observed in *Triodia*, while nrDNA exhibits considerably less introgression (Anderson *et al.* 2016; M.D. Barrett, unpublished data). Ribosomal DNA phylogenies show that the *T. helmsii* sample is very close to, if not identical with, *T. schinzii*. However, ribosomal DNA is not always sufficient to distinguish between closely related species (e.g. Lee *et al.* 2007; Hammer *et al.* 2018).

Geographically, the distribution of *T. helmsii sensu* Lazarides *et al.* (2005) (central WA and southern NT, into northern SA) overlaps almost entirely with *T. schinzii*. At least one of the specimens attributed

to *T. helmsii* (5 miles east of Docker Settlement, *Dunlop* 1916, CANB, DNA) was collected from within a large, continuous, undifferentiated population (P.K. Latz, pers. comm.), from which all other collections (*Albrecht* 9668 (NT), *Latz* 22930 (NT), and *Anderson* BMA 86 (PERTH)) are attributed to *T. schinzii*. Distribution therefore cannot be used to differentiate *T. helmsii* and *T. schinzii*.

Both *T. helmsii* and *T. schinzii* primarily occur on the same substrate, red sand dunes, deep red sands, or occasionally on red sandy loam, and are not obviously ecologically separated. *Triodia schinzii* can occasionally occur on sand overlying or adjacent to rocky substrates, and these are presumably responsible for the rock-based substrates included in Lazarides' (1997) habitat description 'Chiefly on plains, dunes, sandhills, swales and pindan in deep, red sands, sandy loams, clayey sands and sandy red earths; also on shallow stony soils, alluvial creek levees, coastal pindan and beach sands; associated with sandstone, laterite, limestone and slates.' Lazarides' (1997) reported the habitat for *T. helmsii* as 'Skeletal rocky hillslopes; also on sand dunes and plains in red sands and sandy loams', and the same wording was rehashed by Lazarides *et al.* (2005) and Jessop *et al.* (2006). All three references thus include 'rocky slopes' among the habitat for *T. helmsii*; however, we were unable to locate any specimen determined as *T. helmsii* (by Lazarides or anyone else) that did not describe the habitat as some variant of sand, sand dunes or sandy loam, nor any that mention a rocky slope. Substrate was not mentioned in the protologue (Hubbard 1941), so it is unclear where Lazarides' reference to rocky slopes originated. The collection *Vonow et al.* 3098 (DNA, PERTH), described from '[Pangkupirri] Rockhole, Walter James Range, c. 200 m E from rockhole' was determined as *T. helmsii*, but is *T. melvillei* (an AD duplicate numbered *Vonow et al.* 3098 B has not been seen by us, but likely also represents *T. melvillei*, since all '3098' were initially determined as *T. helmsii* by D. Symon); however this collection was made in 2006, so it did not contribute to the habitat descriptions discussed above.

The lack of clear morphological and genetic distinction between *T. schinzii* and *T. helmsii*, coupled with overlapping geographic distributions and habitats suggests they belong to a single taxon. They are synonymised here under the older name, *T. schinzii*. It is concluded here that *T. helmsii* represents slightly immature specimens at the diminutive extreme of variation in *T. schinzii*.

In contrast to the broadly overlapping distributions of *T. schinzii* and *T. helmsii* in central Australia, populations of *T. schinzii* on sand dunes and plains in the Carnarvon Basin at the western-most range of *T. schinzii* are disjunct from those of sand deserts to the east, with the rocky Pilbara ranges forming a biogeographic barrier. Comparison of morphological features revealed several consistent differences between plants in the two disjunct areas (east and west of the Pilbara), in particular the widths of lemmas and glumes are non-overlapping, or scarcely overlapping, respectively. DNA sequencing of the ITS and ETS region (Toon *et al*. 2015; M.D. Barrett, unpublished data) from representative samples from the two disjunct regions revealed the presence of two clades corresponding to the two morphological forms, (e.g. in the Toon *et al*. 2015 Supplementary data 3.3 ITS tree, *T. schinzii* 9773 from central Australia, representing *T. schinzii s. str.*, is divergent from *T. schinzii* 9722 representing *T. avenoides*, with the former supported as closer to other species such as *T. pungens* by posterior probability >0.95, although bootstrap support was <80%). Since these two molecular clades can be defined by consistent morphological differences, they are considered to represent two allopatric species. The western form of *T. schinzii* is described here as a new species, *T. avenoides*.

Triodia schinzii as treated here remains similar to the core concept of Lazarides (1997). Alterations to the range of some character states were made to accommodate *T. helmsii* and the removal of the western populations, described below as *T. avenoides*. A revised description of *T. schinzii* is therefore also provided.

Genome size and ploidy estimation in T. lutiteana

Ten plants from a single population of *T. lutiteana* were measured for genome size (voucher *P.L. de Kock* 1108) and found to have 8.37 ± 0.06 pg 2C DNA (mean ± s.d.). This genome size is the largest of any *Triodia* measured to date (more than 2500 *Triodia* individuals have been measured, representing over 400 populations and more than 50 species; M.D. Barrett, unpublished data). *Triodia lutiteana* had approximately 3.3 times as much DNA as the related *T. pisoliticola* reference (2C value of 2.55 ± 0.08 pg, inferred diploid, voucher *M.D. Barrett* 4546, PERTH 08618836), the most closely related species measured for genome size. *Triodia karijini* has not been accurately measured, but measurements from seeds extracted from one plant (voucher *M.D. Barrett* MDB 4475, PERTH 08776253) were approximately 2.5 pg 2C, close to the diploid value for *T. pisoliticola*. *Triodia pisoliticola*, as a close relative rather than an ancestor, can only be used as an approximation of the ancestral DNA content of *T. lutiteana*, and chromosome counts are required to accurately determine its ploidy. Nevertheless, the sampled population of *T. lutiteana* is uniformly composed of, or at least dominated by, highly polyploid individuals, likely either hexaploids or octoploids. Since higher ploidy is often associated with larger plant dimensions (e.g. Rios *et al*. 2015), a high ploidy level is consistent with the more robust habit and taller inflorescences observed in *T. lutiteana* relative to its apparent closest relatives *T. karijini* and *T. pisoliticola*. Given the restricted distribution of *T. lutiteana*, it is possible that the entire species is polyploid (hexaploid or octoploid).

Taxonomy

Triodia avenoides M.D.Barrett, *sp. nov.*

Type: Uaroo Station, *c*. 5 km west of Uaroo Turnoff on North West Coastal Highway, West Pilbara region, Western Australia, 22 March 2013, *M.D. Barrett & B.M. Anderson* MDB 4121 (*holo*: PERTH 08776261; *iso*: CANB).

Triodia sp. Nanutarra (S. van Leeuwen 5037) Western Australian Herbarium, in *Florabase*, https://florabase.dbca.wa.gov.au/ [accessed 16 October 2023].

Hummock-forming *perennial*, resinous at least on leaf blades, not obviously stoloniferous (stolons mostly shorter than the hummock margins); *hummocks* compact, 40–70 cm high, 50–150 cm wide; *flowering culms* 120–150 cm high. *Vegetative culm internodes* all short, 0.4–4.0 cm long, obscured by subtending foliage, dull red-brown, glabrous or minutely hairy with appressed short white hairs; aerial roots absent or few and short, up to 5 cm long. *Leaf sheaths* 2.8–7.6 cm long, 2.1–4.0(–6.0) mm wide near apex, glabrous on surfaces and lateral margins, resinous or not, straw-coloured, obscurely to prominently nerved especially near margins; margins glabrous; margins of *orifice* ±truncate to shortly auriculate with auricle up to 0.3 mm long, with a dense fringe of hairs, the longest hairs 0.5–4.0 mm long. *Ligule* a dense fringe of hairs 0.4–0.6 mm long. *Pseudopetiole* not distinct. *Leaf blades* flattened-V-shaped when fresh, conduplicate and tightly in-rolled when dry, initially straight but becoming slightly curved in older and dead leaves, 9.0–25.0 cm long, 0.6–1.1 mm wide when rolled, relatively soft when fresh, moderately pungent, glabrous abaxially, densely papillose adaxially, often resinous over abaxial surface, bright green drying dull green; stomatal grooves on abaxial surface confined to central part, (2–)4 ((1–)2 either side of a moderately wide mid-rib), ±equally spaced in the central part, absent on marginal *c*. 1/3 but obscure fine ribs present; stomatal grooves on adaxial surface 10–14 (5–7 each side of mid-rib); margins sparsely minutely scaberulous with prickle hairs *c*. 0.03–0.10 mm long. *Flag-leaf* sheaths 11.5–19.3 cm long, involute, glabrous; blade 2.3–3.9 cm

long. *Panicle* 12.5–20.0 cm long, 3.0–6.0 cm wide, with 12–44 spikelets total, narrowly lanceolate to lanceolate; primary axis angular to ribbed or flattened, glabrous except for minute tufts of hairs *c.* 1.0–2.0 mm long in branch axils, non-resinous; primary branches openly racemose (extreme base of longest branches never ternate). Longest primary panicle branches 2.4–5.0 cm long, with 2–5 ±uniform-sized spikelets in a loose arrangement (adjacent glumes partly overlapping), axis terete to weakly flattened and internodes between pedicels 12.0–20.0 mm long; longest *pedicels* at base of longest panicle branches (2.0–)4.0–15.0 mm long, 0.12–0.17 mm wide, becoming slightly thicker to 0.35–0.45 mm wide just below spikelet, ±filiform, terete or slightly flattened, minutely scabrous; upper lateral pedicels on branch slightly to substantially shorter than lowest ones; terminal pedicel 9.5–34.0 mm long. *Spikelet* 8.5–30.0 mm long, 3.5–10.0 mm wide (excluding awns but including glumes), the combined florets without glumes 8.5–13.0 mm long (excluding awns), loosely 5–9-flowered with 3–5 fertile florets (1–4 apparently sterile florets at apex, but these possibly immature), linear to narrowly oblong or narrowly lanceolate, terete or slightly laterally compressed at maturity; lowest rachilla internode 1.4–1.9 mm long, *c.* 0.4–0.6 mm diam., smooth or minutely scabrous, apex oblique with a marginal fringe of hairs; spikelets disarticulating above glumes and at rachilla internodes at maturity. *Lower glume* (12.5–)15.0–30.0 mm long, (2.0–)2.2–3.6 mm wide *in situ* (without flattening), narrowly lanceolate, L:W 6.2–13.0, with long-acuminate apex, distinctly longer than the combined florets (excluding awns), scarious, with narrow membranous margins, completely lacking scabrosities, prominently 7–13-nerved; mid-nerve slightly raised; lateral nerves slightly raised; margins glabrous. *Upper glume* inserted *c.* 0.3–0.6 mm above lower glume, (13.5–)15.0–30.0 mm long, similar to and subequal to lower glume, distinctly longer than the combined florets (excluding awns). *Lemma* of basal floret 15.0–34.0 mm long including awns, narrowly oblanceolate, deeply 3-lobed, 3-awned; body 5.0–6.2 mm long including callus, 1.3–1.9 mm wide, bitextured (lower part indurated, upper part chartaceous) with a sharp transition line between the two textures; indurated part with moderately dense and ±uniformly distributed appressed to lifting hairs 0.2–0.5 mm long; chartaceous part 1.0–2.1 mm long above the bitextured line, with 9 nerves in 3 groups of 3 obscure nerves radiating into the lobes; mid-lobe 10.2–26.0 mm long (including awn), very narrowly triangular at base and gradually narrowing into an awn, subequal in width to the lateral lobes; lateral lobes 14.5–16.0 mm long (including awn), narrowly triangular at base and gradually narrowing into an awn, margins lacking a membranous wing; reverse face of lemma with a transverse thickened callus of tissue across the bitexture line. *Callus of basal floret* 0.8–1.1 mm long, straight, attached obliquely, sharply pungent in face view, sharply pungent in profile, white-bearded except in midline with the longest hairs 0.2–0.5 mm long. *Upper lemmas* similar to but smaller than lowest lemma. *Palea* of basal floret distinctly shorter than lemma body, 3.2–4.0 mm long, 0.7–1.1 mm wide, obtrullate to narrowly elliptic, 2-keeled, bitextured with a ±sharp transition, lower part indurated, upper part translucent-membranous, glabrous or rarely hairy (e.g. *Craven* 7601), apex variable within same inflorescence from broadly truncate to muticous or ±acute; keels raised but not winged, margin minutely ciliate with hairs *c.* 0.2 mm long; flaps at *c.* 90° to body, *c.* 0.3–0.5 mm wide, broadest in basal part, narrower than 1/2 width of the palea body and not overlapping, entire. *Lodicules* 0.45–0.95 mm long; apex truncate, undulate, glabrous. *Anthers* 3, 2.3–4.4 mm long, exserted at maturity. *Styles* 2, *c.* 2.3–3.2 mm long. *Caryopsis* 2.0 mm long, 0.85 mm wide (only one seen). (Figures 1, 2)

Diagnostic features. Foliage resinous. Leaf sheaths glabrous on surfaces and margins. Leaves epistomatous, lacking stomatal grooves on the lateral margins of the abaxial surface. Glumes narrowly lanceolate (L:W>6), 12.5–30.0 mm long, (2.0–)2.2–3.6 mm wide. Lemmas 3-awned; callus 0.8–1.0 mm long; lemma body 1.3–1.8 mm wide, bitextured with upper membranous part appressed-hairy all over and sharply demarcated from lower indurated part by a transverse line. Palea bitextured, usually glabrous (rarely hairy). Distributed in Carnarvon and adjacent bioregions in subcoastal central Western Australia.
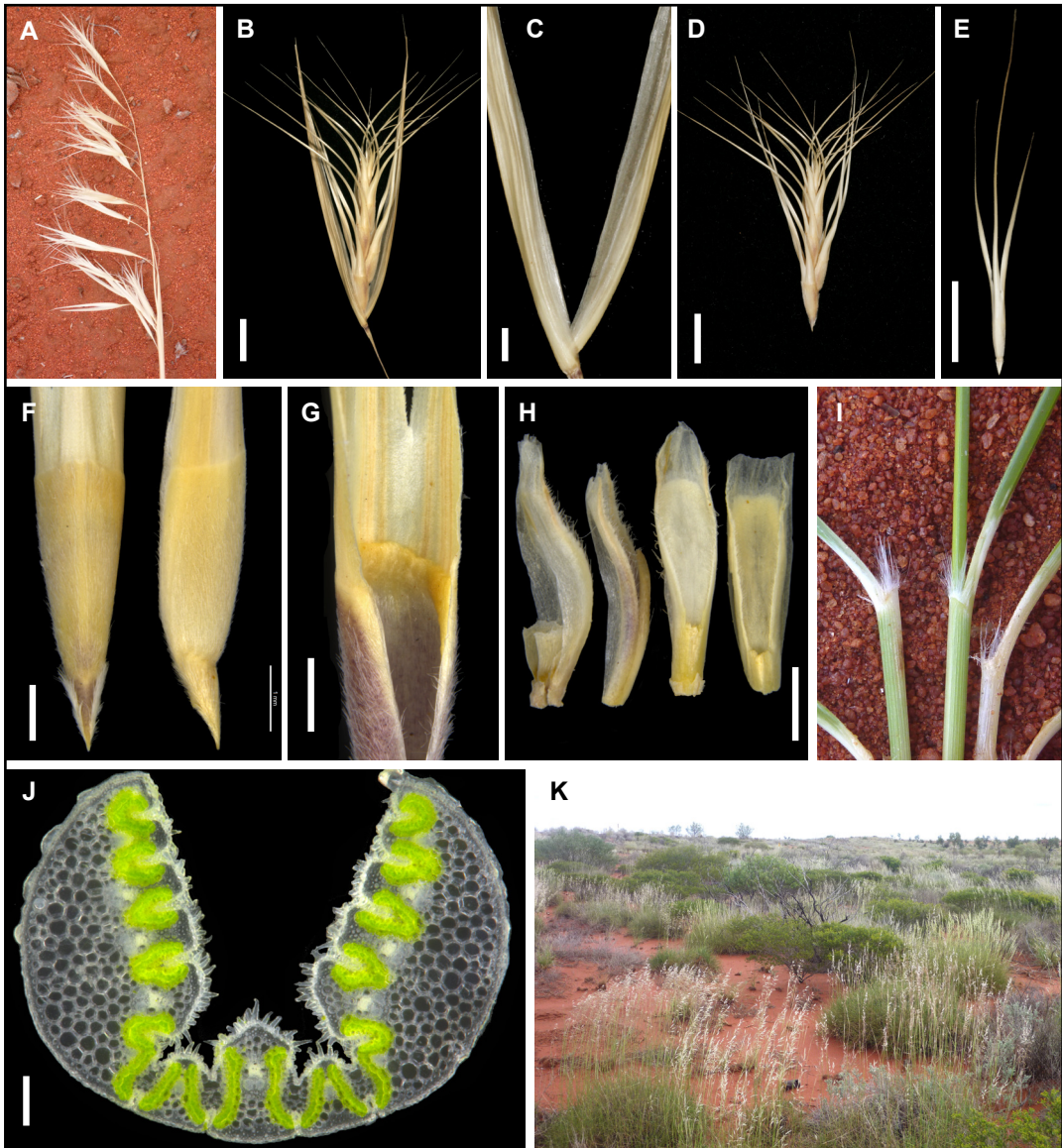
Figure 1. *Triodia avenoides*. A – inflorescence *in situ* showing typical loose form; B – spikelet, showing glumes exceeding the combined florets (excluding awns); C – close-up of glumes showing multiple nerves; D – spikelet without glumes, showing the relative position of florets; E – basal lemma showing relative awn and body lengths; F – lemma body in face and side view, showing appressed hairs on the indurated lower part and a sharp transverse line demarcating the upper membranous part; G – lemma from underside, showing the thickened callus formed at the line of change in texture (lemma bitextured); H – palea in face and side view, showing sharply differentiated texture and variation in apex; I – leaf orifice, showing resin, orifice hairs, and glabrous sheath margins; J – leaf blade in section, showing epistomatous leaf anatomy and four abaxial stomatal grooves; K – flowering plant *in situ* showing red sand plain habitat. Scale bars = 5 mm (B, D, E); 1 mm (C, E–H); 0.1 mm (J). Images from *M.D. Barrett & W. Lewandrowski* MDB 3979 (B–H), *M.D. Barrett & W. Lewandrowski* MDB 3980 (A, K), and *M.D. Barrett & B.M. Anderson* MDB 4121 (I, J). Images by M.D. Barrett; images A–C, E, F, H, J and K modified from SᴘɪKᴇʏ (Barrett *et al*. 2017), used with permission.
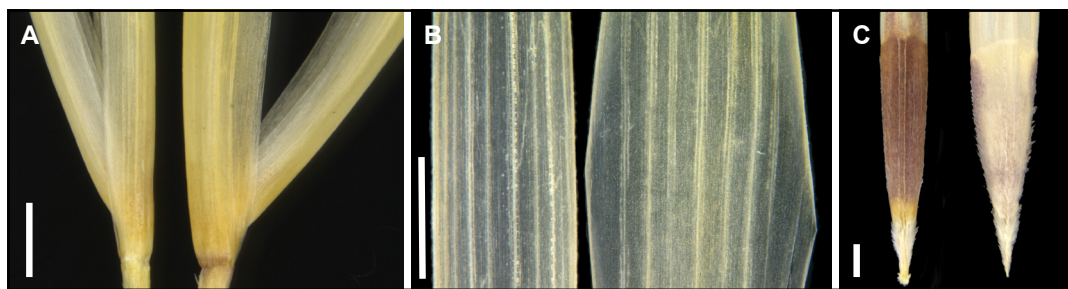
Figure 2. Comparison of critical characters distinguishing *Triodia schinzii* (left in each comparison) and *T. avenoides* (right). A – glumes in side view, showing difference in width; B – glumes boiled and flattened, showing difference in width; C – lemmas in face view without flattening, showing difference in width. Scale bars = 1 mm. Images of *T. avenoides* from *M.D. Barrett & W. Lewandrowski* MDB 3979 (A–C, right of each pair). Images of *T. schinzii* from *M.D. Barrett & W. Lewandrowski* MDB 3917 (A–C, left of each pair). Images by M.D. Barrett; images A and C modified from SᴘɪKᴇʏ (Barrett *et al.* 2017), used with permission.

Selected specimens examined. WESTERN AUSTRALIA: *c.* 50 km SW of Nanutarra, 13 Mar. 2012, *M.D. Barrett & W. Lewandrowski* MDB 3979 (PERTH); *c.* 20 km north of Nanutarra, 13 Mar. 2012, *M.D. Barrett & W. Lewandrowski* MDB 3980 (PERTH); Mardathuna Homestead, 24 Apr. 1995, *A.H. Burbidge* 4301 (PERTH); Site WH29, 20.7 km SW of Onslow, 9 Apr. 2009, *R. Butler & J. Fairhead* RB 021 (PERTH); SE of Five Mile Well, Cape Range, 26 May 1965, *Y. Chadwick* 2293 (PERTH); 17 km S of the Onslow South road (Koordarrie road) on the highway, 16 Sep. 1982, *L.A. Craven* 7601 (CANB, 2 sheets, MEL *n.v.*, PERTH); 34 km NE of Minilya, 11 Sep. 2004, *M.D. Crisp* 9722 (CANB, PERTH); Cane River Station, 80 km SE of Onslow, 23 May 1999, *D.J. Edinger* 1493 (PERTH); Wogoola, [Woggola] Ashburton River, 28 Aug. 1932, *C.A. Gardner* 3189 (PERTH, 4 sheets); 4 miles N of Exmouth township, 28 May 1965, *A.S. George* 6701 (PERTH); 25 km W of Learmonth, 12 July 1964, *D.W. Goodall* 1176 (PERTH); Uaroo Station, 6 July 2002, *S. van Leeuwen* 5037 (CANB, PERTH); Giralia Station, 13 Jun. 2004, *M. Maier* GIR 02-12 (DNA [DNA D0185370, as *Maier s.n.*], PERTH); 6.85 km NNW of Exmouth, 30 Sep. 2009, *R. Meissner* 2881 (PERTH); 30 km E of Nanutarra Homestead, 23 June 1976, *A.A. Mitchell* 76/122 (PERTH); 30 km N of Minilya Roadhouse, 19 Oct. 1984, *A.A. Mitchell* 1315 (PERTH); Mia Mia Station, E of Hwy between Carnarvon and Onslow, Oct. 1968, *R. O'Farrell* 6 (PERTH); Manberry Station, May 1967, *R. O'Farrell* 12 (PERTH); North West Coastal Hwy, 39 km SW of Onslow junction, 26 Mar. 1980, *B.K. Simon & J.K. Stretch* 3778 (BRI *n.v.*, NSW *n.v.*, PERTH); 13 km NE of Yannarie River along NW Coastal Hwy, 13 Feb. 1979, *A.S. Weston* 10902 (PERTH, 2 sheets).

Phenology. Fertile collections have been made between March and September, however most flowering and seeding probably occurs January–March (presence of flowering plants in January and February inferred from mature florets dehiscing in early March).

Distribution and habitat. Endemic to deep red sands and sand dunes of the Carnarvon Basin in the Carnarvon and western part of the Pilbara bioregions. It does not appear to occur on adjacent rocky ridges, gravelly soils or clay soils. A distribution map of *T. avenoides* can be found in Barrett *et al.* (2017) or Florabase (Western Australian Herbarium (1998–).

Conservation status. Not considered at risk. It is known from at least 20 locations over a 300 km range extent. Collection notes report it as 'locally dominant' (*Crisp* 9722), 'common' (*van Leeuwen* 5037) or 'not common' (*Maier* GIR 02-12), 'hundreds of plants but only on dune, not on surrounding sandplain' (*Barrett & Lewandrowski* MDB 3980), or 'many plants restricted to a small sandy area' (type, *Barrett & Anderson* MDB 4121).

Etymology. The epithet is derived from the Latin *avena* (wild oat) and *-oides* (Greek adjectival suffix indicating similarity), in reference to the similarity of the open inflorescence, especially when the glumes are empty, to members of the genus *Avena*, especially the Common Oat, *A. sativa*. This continues a long-term practice of naming *Triodia* species, which exhibit highly plastic spikelet morphology, after superficially similar genera of grasses, including *Briza*, *Bromus*, *Danthonia*, *Stipa* and *Triticum*.

Notes. *Triodia avenoides* belongs to a morphologically-defined, but probably polyphyletic (Toon *et al*. 2015), group of (epistomatous) *Triodia* species sharing awned, bitextured lemmas, including *T. acutispicula*, *T. basitricha* M.D.Barrett, *T. bitextura*, *T. caelestialis* G.Armstrong, *T. claytonii*, *T. degreyensis*, *T. schinzii* (including *T. helmsii*), and *T.* sp. Mt Ella (M.E. Trudgen 12739). *Triodia acutispicula* and *T. caelestialis* have glabrous lemma surfaces, except for 2 rows of minute hairs either side of the midline in *T. caelestialis*; all other species in the *T. bitextura* group have appressed-hairy lemma surfaces. *Triodia claytonii* has only one fertile floret per spikelet, and the lemma transverse line at the change of texture is level with the base of the lobe sinus (2-many fertile florets and transverse line at the change of texture positioned distinctly below the sinus level in other species).

Triodia basitricha, *T. bitextura s. lat.*, *T. degreyensis* and *T.* sp. Mt Ella have a blunt callus 0.25–0.7 mm long (0.8–1.7 mm long in *T. avenoides* and *T. schinzii*), and usually occur on rocky substrates (sandy substrates in *T. avenoides* and *T. schinzii*). *Triodia basitricha*, *T. bitextura s. lat.*, and *T.* sp. Mt Ella also usually have shorter glumes (which are 6.3–13.0(–15.0) mm long) while *T. avenoides* and *T. schinzii* glumes are (12.0–)14.0–30.0 mm long.

Triodia avenoides and *T. schinzii* are similar and treated by Lazarides (1997) and Lazarides *et al*. (2005) under a single species, *T. schinzii*. Both species share several characters: callus long-pungent; panicle racemose in uppermost part (2–6 nodes); indurated part of lemma appressed-pubescent, with 2 rows of slightly denser and slightly longer hairs along either side of midline (tangential light needed, sometimes obscure); margins of sheath glabrous below orifice; and substrate preference for red sand dunes and swales. *Triodia avenoides* differs from *T. schinzii* in having glumes (2.0–)2.2–3.6 mm wide (1.5–2.4 mm wide in *T. schinzii*), and lemma body 1.3–1.9 mm wide (0.80–1.25 mm wide in *T. schinzii*), all illustrated in Figure 2. The two species are allopatric. *Triodia avenoides* occurs in the Carnarvon and western Pilbara IBRA regions (Department of Environment 2013). *Triodia schinzii* is widespread in central Australia, entering the Pilbara region in the eastern half and along the northern margin (to about Point Sampson); it is also scattered in the Gascoyne bioregion to the south of the Pilbara.

The vernacular name Western Feathertop Spinifex has been suggested (Barrett *et al*. 2017), to differentiate it from true Feathertop Spinifex (*T. schinzii*).

Triodia degreyensis M.D.Barrett, *sp. nov.*

Type: De Grey Station, Pilbara region, Western Australia [precise locality withheld for conservation reasons], 22 February 2014, *M.D. Barrett & B.M. Anderson* MDB 4432 (*holo*: PERTH 08776288; *iso*: BRI, CANB, DNA).

Triodia sp. De Grey River (M.D. Barrett & B.M. Anderson MDB 4432) Western Australian Herbarium, in *Florabase*, https://florabase.dbca.wa.gov.au/ [accessed 16 October 2023].

Hummock-forming *perennial*, non-resinous to weakly resinous, not obviously stoloniferous; *hummocks* compact, 30–40 cm high, 30–70 cm wide; *flowering culms* 70–100 cm high. *Vegetative culm internodes*

all short (never elongated as in *T. claytonii*), 0.3–1.0 cm long, and mostly obscured by subtending foliage, red-brown, glabrous or minutely hairy at nodes; aerial roots absent or sparse. *Leaf sheaths* 1.7–4.9 cm long, 2.0–3.0 mm wide near apex, glabrous, not or weakly resinous, straw-coloured, weakly to moderately nerved; margins glabrous; margins of *orifice* truncate or oblique, with a dense fringe of ±straight or undulating hairs, the longest hairs 2.5–4.5 mm long. *Ligule* a dense fringe of hairs *c.* 0.2–0.6 mm long. *Pseudopetiole* not distinct. *Leaf blades* V-shaped when fresh, conduplicate and tightly in-rolled when dry, initially straight becoming curved in older and dead leaves, 7.3–20.2 cm long, 0.6–0.8 mm wide when rolled, when fresh relatively soft, pungent, glabrous abaxially, densely papillose adaxially, non-resinous or lightly resinous over abaxial surface, bright green when fresh, drying dull green; stomatal grooves on abaxial surface confined to central part, uniformly 2 (1 either side of small mid-rib), absent on marginal *c.* 3/4 but sometimes finely obscurely ribbed; stomatal grooves on adaxial surface 10–12 (5–6 each side of mid-rib); margins minutely scaberulous with prickle hairs *c.* 0.05 mm long. *Flag-leaf* sheaths 8.5–9.0 cm long, involute, glabrous; blade not seen. *Panicle* 9.0–13.5 cm long, 1.2–3.5(–8.0) cm wide, with 12–25 spikelets total, linear to lanceolate; primary axis angular to ribbed or flattened, glabrous except minute tufts of hairs *c.* 0.3–0.9 mm long in branch axils, non-resinous; primary branches openly racemose. Longest primary panicle branches 4.0–6.5 cm long, with 2–4 ±uniform-sized spikelets in a loose arrangement (adjacent glumes not or shortly overlapping); axis terete to angular or flattened, with internodes between pedicels 12.5–18.0 mm long; longest *pedicels* at base of longest panicle branches 7.0–15.5 mm long, 0.15–0.20 mm wide, filiform, becoming slightly thicker just below spikelet, sub-terete to angular or flattened, minutely scabrous; upper lateral pedicels on branch subequal or shorter than lowest ones; terminal pedicel 18.0–27.0 mm long. *Spikelet* 9.0–17.0 mm long, 2.0–3.0 mm wide (excluding awns), 15.0–21.0 mm long, 5.0–12.0 mm wide (including awns), loosely 6–8-flowered with 4–6 fertile florets (apparently 1–3 sterile florets at apex, but these possibly immature), linear to narrowly lanceolate (excluding awns), ±terete at maturity; lowest rachilla internode 1.2–1.7 mm long, *c.* 0.15–0.20 mm diam., smooth and not scabrous, glabrous or seemingly with a tuft of hairs 0.4–0.5 mm long at the apex when the tip of the callus from the second lemma remains attached; spikelets disarticulating above glumes and at rachilla internodes at maturity. *Lower glume* 12.4–16.0 mm long, 1.8–2.5 mm wide, shorter than or subequal to the combined florets (excluding awns), narrowly lanceolate, L:W 5.4–8.9, with long-acuminate or mucronate apex, scarious, with narrow membranous margins, completely lacking scabrosities (present only as extremely minute rounded tubercles) or with minute appressed scabers *c.* 0.05 mm long only on membranous margins and apex, distinctly 7–13-nerved; mid-nerve slightly raised; lateral nerves thin and slightly raised; margins glabrous. *Upper glume* inserted 0.4–0.5 mm above lower glume, 12.4–17.0 mm long, similar to and subequal to lower glume, shorter than or subequal to the combined florets (excluding awns). *Lemma* of basal floret 13.5–19.0 mm long including awns, narrowly oblanceolate, deeply 3-lobed, 3-awned; body 3.3–4.2 mm long including callus, 1.1–1.6 mm wide *in situ*, bitextured (lower part indurated, upper part chartaceous); indurated part 2.6–3.6 mm long and almost completely covered with moderately dense and uniformly distributed appressed to lifting hairs 0.15–0.30 mm long; chartaceous part 0.5–1.0 mm long above bitextured line, glabrous, with 9 nerves in 3 groups of 3 obscure nerves radiating into lobes; mid-lobe 10.3–16.2 mm long (including awn), very narrowly triangular at base and gradually narrowing into an awn, subequal in width to the lateral lobes; lateral lobes 9.2–11.5 mm long (including awn), narrowly triangular at base and gradually narrowing into an awn, margins lacking or with only a very narrow membranous wing; reverse face of lemma with a transverse thickened callus of tissue across the bitexture line. *Callus* of basal floret 0.25–0.70 mm long, straight to curved forward, attached obliquely, acute to sharply pungent at *c.* 20–40° in face view, acute to sharply pungent in profile, white-bearded except in mid-line with the longest hairs *c.* 0.3–0.6 mm long. *Upper lemmas* similar to but smaller than lowest lemma. *Palea* of basal floret slightly longer than or subequal to the lemma body, 3.0–4.2 mm long, 0.8–1.0 mm wide, narrowly elliptic to narrowly obovate, 2-keeled, bitextured with a ±sharp transition, lower part indurated, upper part translucent-membranous, appressed-hairy over lower *c.* 3/4–5/6 of indurated part

but glabrous above, apex acute to slightly erose; keels raised and thickened but not winged, margin minutely ciliate with hairs *c.* 0.2 mm long; flaps at *c.* 90° to body, *c.* 0.15–0.40 mm wide, broadest in basal part, narrower than 1/2 width of the palea body and not overlapping, entire. *Lodicules c.* 0.4 mm long, apex truncate, undulate, glabrous. *Anthers* not seen. *Style*s 2, *c.* 1.5–2.0 mm long. *Caryopsis* 2.0–2.3 mm long, 1.0–1.1 mm wide, L:W ratio 1.9–2.1:1, obovate to narrowly obovate, broadly acute to obtuse at apex, acute at base, slightly to distinctly dorsiventrally flattened in TS, pale reddish straw-coloured, base of styles not thickened; hilum 0.8–1.0 mm long, *c.* 2/5 as long as caryopsis. (Figure 3)

Diagnostic features. Foliage not or weakly resinous. Leaf sheaths glabrous on surfaces and margins. Leaves epistomatous, with uniformly one central pair of abaxial stomatal grooves and lacking stomatal grooves on the lateral margins of the abaxial surface. Glumes 12.4–17.0 mm long, 7–13 nerved, lacking scabers except near margins. Lemmas with short callus 0.25–0.70 mm long, acute to pungent but not long-pungent; lemma body bitextured with upper membranous part sharply demarcated from lower indurated part by a transverse line, the indurated part with appressed to lifting hairs; lemma lobes awned. Palea bitextured, hairy.

Other specimens examined. WESTERN AUSTRALIA [localities withheld for conservation reasons]: 11 Mar. 2012, *M.D. Barrett & W. Lewandrowski* MDB 3962 (PERTH, K, MEL); 20 Mar. 2010, *D. Coultas* PM-16 (PERTH).

Phenology. Fertile collections have been made between February and March.

Distribution and habitat. Only known from three collections 4 km apart along a single small range (probably from a ±continuous population); the same range system extends 11 km to the north but has not been surveyed. Another poorly surveyed range system 25–40 km to the east offers additional potential habitat in the relatively featureless north-east Pilbara. A distribution map of *T. degreyensis* can be found in Barrett *et al.* (2017) or Florabase (Western Australian Herbarium (1998–).

Conservation status. *Triodia degreyensis* is listed as Priority One under Conservation Codes for Western Australian Flora (Western Australian Herbarium 1998–), as *T.* sp. De Grey River (M.D. Barrett & B.M. Anderson MDB 4432). Collection notes report it as abundant with thousands of plants, but it is restricted to lower slopes of a single known range system. Active phosphate and iron ore mining leases exist on the range system. Gravel scrapes for road building have also disturbed parts of the only known population.

Etymology. The species epithet is derived from the De Grey River, in the general vicinity of the only known locality for this species.

Notes. Four other species in the Pilbara share the combination of epistomatous leaves, narrowly-lanceolate glumes, awned lemma lobes and bitextured lemmas with a transverse line at maturity: *Triodia avenoides*, *T. basitricha*, *T. schinzii* and *T.* sp. Mt Ella (M.E. Trudgen 12739). *Triodia basitricha* has shorter glumes 10.0–12.5 mm long (12.4–16.0 mm long in *T. degreyensis*) and hairs on the leaf sheath surfaces (glabrous in *T. degreyensis*). *Triodia degreyensis* differs from all of these by consistently having only two abaxial stomatal grooves (usually four in the other species).

Triodia avenoides and *T. schinzii* are larger plants with inflorescences 100–170 cm tall (70–100 cm tall in *T. degreyensis*), and have a long-pungent callus 0.8–1.5 mm long (broadly acute to shortly pungent and 0.25–0.70 mm long in *T. degreyensis*), glumes usually longer than the spikelet excluding awns (glumes shorter than to subequal to the spikelet in *T. degreyensis*), glabrous or rarely hairy palea
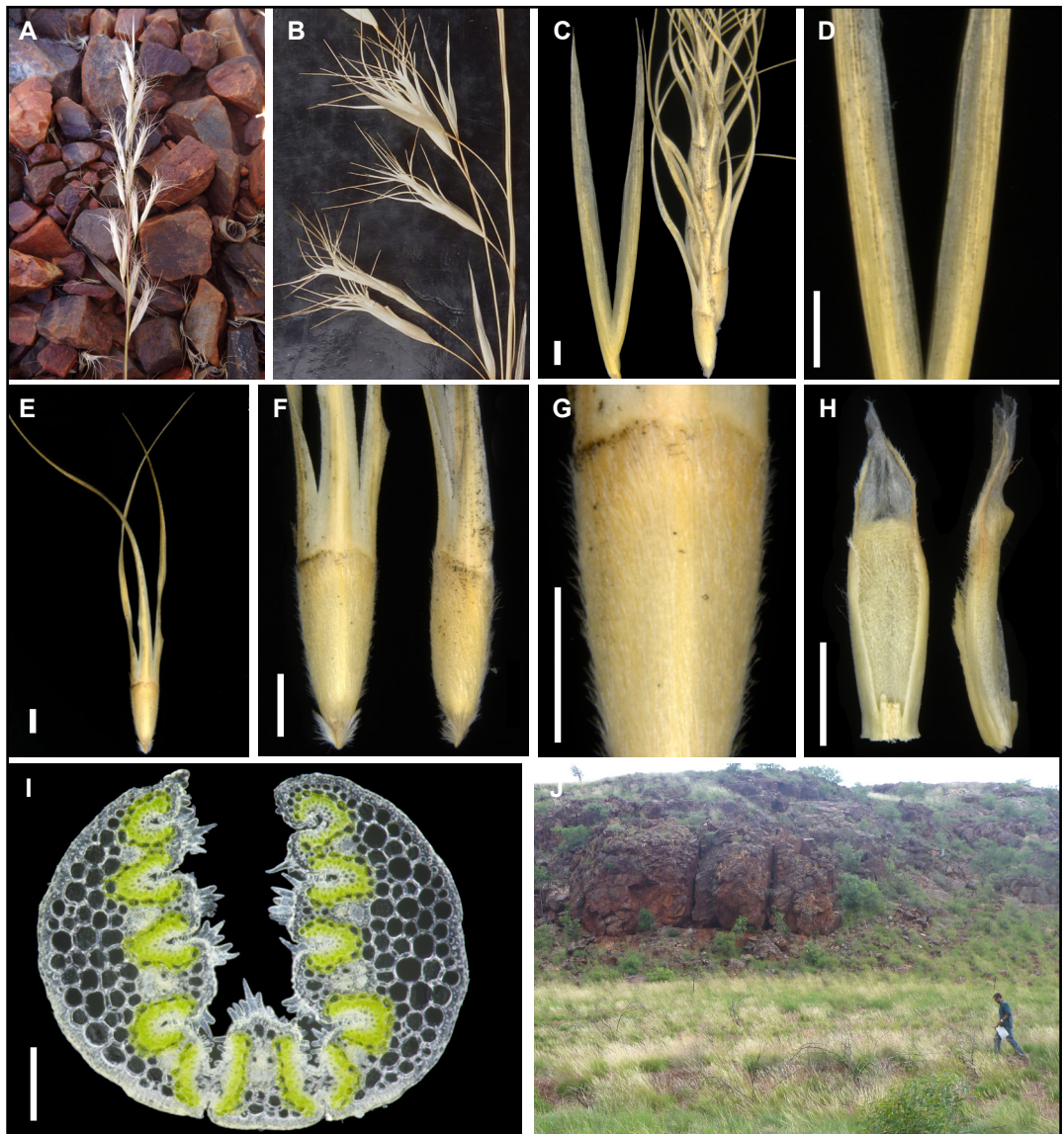
Figure 3. *Triodia degreyensis*. A – inflorescence *in situ* showing typical form; B – basal branches of inflorescence showing elongated pedicels; C – spikelet with glumes separated, showing glumes subequal to the combined florets; D – close-up of glumes showing multiple nerves, a key difference to *T. bitextura s. lat.* which usually has 3–5 nerves; E – basal lemma showing relative awn and body lengths; F – lemma body in face and side view, showing appressed hairs on the indurated lower part, and a sharp transverse line demarcating the upper membranous part (lemma bitextured); also note the callus which is shorter and more broadly acute than in *T. avenoides* and *T. schinzii* (cf. Figs. 1, 2, 5); G – close up of lemma body in face view, detailing the indumentum of appressed hairs; H – palea in face and side view, showing sharply differentiated (bitextured) texture, and indumentum; I – leaf blade in section, showing epistomatous leaf anatomy and two abaxial stomatal grooves; J – flowering plants *in situ* (straw coloured inflorescences in the mid-ground) showing habitat on gravel at foot of rocky slope (gravel substrate visible in background of A). Scale bars = 1 mm (C–H); 0.1 mm (I). Images from *M.D. Barrett & W. Lewandrowski* MDB 3962 (B–H), and *M.D. Barrett & B.M. Anderson* MDB 4432 (A, I, J). Images by M.D. Barrett; images C, F, G and I modified from SᴘɪKᴇʏ (Barrett *et al*. 2017), used with permission.

(palea hairy in *T. degreyensis*) and grow on sand flats and dunes (*T. degreyensis* grows on rocky or gravelly slopes).

Triodia sp. Mt Ella (M.E. Trudgen 12739) has shorter glumes up to 7.5–12.0 mm long (12.4–16.0 mm long in *T. degreyensis*) and is copiously resinous (not or weakly resinous in *T. degreyensis*).

Outside of the Pilbara region, four other species with awned, bitextured lemmas have been described: *T. acutispicula*, *T. bitextura*, *T. caelestialis* and *T. claytonii*. *Triodia acutispicula* and *T. caelestialis* have lemmas glabrous or with only 2 rows of minute hairs along the midline (hairy all over the lower surface in *T. degreyensis*). *Triodia claytonii* has only 1 fertile floret per spikelet and glumes 4.6–8.5 mm long (4–6 fertile florets and glumes 12.4–17.0 mm long in *T. degreyensis*). *Triodia bitextura* is a very variable species, but shares the short callus (0.25–0.70 mm long in *T. bitextura*) and abundant appressed lemma body hairs with *T. degreyensis*. *Triodia bitextura* is an extremely widespread and variable species as currently treated (Barrett & Trudgen 2018) that is polyphyletic in both nuclear ribosomal and chloroplast phylogenies (e.g. Toon *et al*. 2015, Supplementary data 3.1–3.4), and will require detailed investigation to stabilise its circumscription. Although most characters of *T. bitextura s. lat.* overlap those of *T. degreyensis* when taken as a whole, various forms of *T. bitextura* can be distinguished by having at least one, and usually two or more, of the following characters: glumes 3–5-nerved or 5–sub-7-nerved with at least 2 nerves indistinct (7–13-nerved in *T. degreyensis*, at least 7 nerves strong), glumes <12.5 mm long (12.4–17.0 mm in *T. degreyensis*), glumes scabrous all over surface (lacking scabers or scabrous only near margin in *T. degreyensis*), leaf sheaths ciliate (glabrous in *T. degreyensis*), or foliage copiously resinous (not or only weakly resinous in *T. degreyensis*).

DNA sequences (ITS and ETS regions; M.D. Barrett, unpublished data) indicate that the closest relative of *T. degreyensis* is *T. avenoides*, which occurs on sand in the west Pilbara.

The vernacular name De Grey Spinifex has been suggested (Barrett *et al.* 2017).

Triodia karijini M.D.Barrett & S.J.Dillon, *sp. nov.*

Type: Hamersley Range, Western Australia [precise locality withheld for conservation reasons], 26 February 2014, *M.D. Barrett & B.M. Anderson* MDB 4475 (*holo*: PERTH 08776253; *iso*: BRI, CANB, DNA, K, NSW).

Triodia sp. Karijini (S. van Leeuwen 4111), Western Australian Herbarium, in *Florabase*, https://florabase.dbca.wa.gov.au/ [accessed 16 October 2023].

Perennial, not resinous to weakly resinous, not obviously stoloniferous; *hummocks* with a tussock form, dense, compact, 20–60 cm high, 20–70 cm wide; *flowering culms* 35–120 cm high. *Vegetative culm internodes* all short (never elongated as in *T. claytonii*), 1.0–3.0 mm long, obscured by subtending foliage, red-brown, shiny, glabrous; aerial roots absent. *Leaf sheaths* 4.7–11.3 cm long, 3.5–4.4 mm wide near apex, surface glabrous or sparsely to moderately densely pilose with hairs 3.0–4.5 mm long and most dense over central areas, not resinous, straw-coloured, distinctly nerved in central 2/3 or nearly to margin; margins glabrous or pilose with hairs 0.5–3.0 mm long; margins of *orifice* oblique to truncate, with a dense fringe of hairs, the longest hairs 0.6–4.5 mm long. *Ligule* a dense fringe of hairs *c.* 0.3–1.0 mm long. *Pseudopetiole* not distinct. *Leaf blades* V-shaped when fresh, conduplicate and tightly in-rolled when dry, initially straight but becoming curved in older and dead leaves, 19.0–33.5 cm long, 0.3–0.7 mm wide when rolled, when fresh relatively soft, weakly pungent,

non-resinous or with slight traces of resin limited to the line of resin-producing cells on lateral faces of the blade, glabrous abaxially, densely papillose adaxially, mid-green, drying dull green; stomatal grooves on abaxial surface confined to central part, (2–)4 ((1–)2 either side of moderately broad mid-rib), unequally spaced, absent on marginal *c.* 1/3 but sometimes very finely streaked; stomatal grooves on adaxial surface 10–16 (5–8 each side of mid-rib); margins smooth (scabrosities absent or extremely minute and ±indistinguishable from papillae). *Flag-leaf* sheaths 9.8–15.0 cm long, involute, glabrous; blade 2.7–3.4 cm long. *Panicle* 12.5–20.5 cm long, 1.0–3.0 cm wide, with 48–93 spikelets total, moderately dense to loose, linear to narrowly lanceolate, glabrous or very rarely with a few minute hairs *c.* 0.5 mm long in branch axils, non-resinous; primary axis angular to ribbed; primary branches openly racemose or longest branches also sparsely branched (ternate). Longest primary panicle branches 1.5–4.4 cm long, with 3–6 uniform-sized spikelets in a loose arrangement (adjacent glumes partly overlapping); axis sub-terete to angular, internodes between pedicels 3.0–8.0 mm long; longest *pedicels* at base of longest panicle branches 2.5–11.0 mm long, 0.1–0.2 mm wide, becoming slightly thicker just below spikelet, sub-terete to angular, minutely scabrous; terminal pedicel 4.7–10.0 mm long. *Spikelet* 5.5–9.5 mm long, 1.0–4.1 mm wide (including lobes), loosely 5–6-flowered with 4–5 fertile florets (apparently 0–2 sterile florets at apex, but these possibly immature), narrowly lanceolate to narrowly elliptic, not or weakly compressed at maturity; lowest rachilla internode 0.5–1.0 mm long, *c.* 0.15 mm diam., smooth, glabrous; spikelets disarticulating above glumes and at rachilla internodes at maturity. *Lower glume* 3.0–6.3 mm long, 0.7–1.2 mm wide, narrowly lanceolate, L:W (3.0–)5.1–7.8, apex narrowly acute, shorter than the combined florets, scarious, lacking membranous margins, with minute scabrosities less than 0.08 mm long over whole surface, 3–5-nerved; mid-nerve very narrow and slightly raised; lateral nerves narrow and scarcely raised; margins glabrous or sparsely ciliate (cilia to 0.2 mm long). *Upper glume* inserted *c.* 0.2–1.5 mm above lower glume, 3.4–6.3 mm long, similar to and subequal or slightly longer than lower glume, shorter than the combined florets. *Lemma* of basal floret 5.7–7.1 mm long including lobes, lanceolate, deeply 3-lobed with mid-lobe longer and drawn out into a short awnlet (which could be interpreted as either a long lobe or a short awn); body 3.7–4.2 mm long including callus, not bitextured, chartaceous throughout except for a very narrow membranous margin the lower 1/3–5/6 of body with dense appressed to ascending hairs 0.1–0.4 mm long confined to *c.* 11 longitudinal rows, the upper part with 9 nerves in 3 groups of 3 obscure nerves radiating into lobes; mid-lobe 2.0–3.0 mm long (including 'awn' if interpreted as such), narrowly triangular at base, narrowing into a short awnlet, subequal in width or slightly narrower than lateral lobes; lateral lobes 0.9–1.7 mm long, narrowly triangular at base lacking an awnlet or with a very short awnlet, margins lacking a membranous wing. *Callus* of basal floret 0.2–0.4 mm long, slightly curved, attached obliquely, acute but abruptly blunt at tip in face view, acute in side view, white-bearded in two lines either side in midline with the longest hairs 0.1–0.4 mm long. *Upper lemmas* similar to but smaller than lowest lemma, but lobes becoming progressively more awn-like as lemma body decreases in size. *Palea* of basal floret slightly longer than lemma body, 3.4–4.5 mm long, 0.5–0.8 mm wide, oblanceolate to narrowly oblanceolate, 2-keeled, uniformly textured, ±chartaceous, glabrous, apex acute to erose; keels raised but not winged or with a minute wing *c.* 0.05 mm wide, margin scabrous with scabrosities up to 0.15 mm long; flaps *c.* 0.10–0.25 mm wide, broadest just below middle, narrower than 1/2 width of the palea body and not overlapping, entire. *Lodicules* 0.6–0.8 mm long, falcate to broadly obovate, at apex ±truncate to obliquely 2-lobed, entire to undulate, glabrous or sparsely ciliate. *Anthers* 3, 2.2–2.5 mm long, exserted at maturity (field observations on type specimen). *Style*s 2, *c.* 1.4 mm long. *Caryopsis* not seen. (Figure 4)

Diagnostic features. Hummocks with dense tussock form habit. Leaf sheaths glabrous or sparsely to moderately densely pilose on surfaces and/or margins, the hairs up to 4.5 mm long. Ligule 0.3–1.0 mm long. Leaf blades epistomatous, not or weakly resinous. Inflorescence 12.5–20.5 cm long. Glumes narrowly lanceolate, L:W (3.0–)5.1–7.8. Lemmas not bitextured, 3-lobed, not awned or with a short awnlet, the mid lobe 2.0–3.0 mm long. Habit on outcropping banded iron ridges above 900 m altitude.
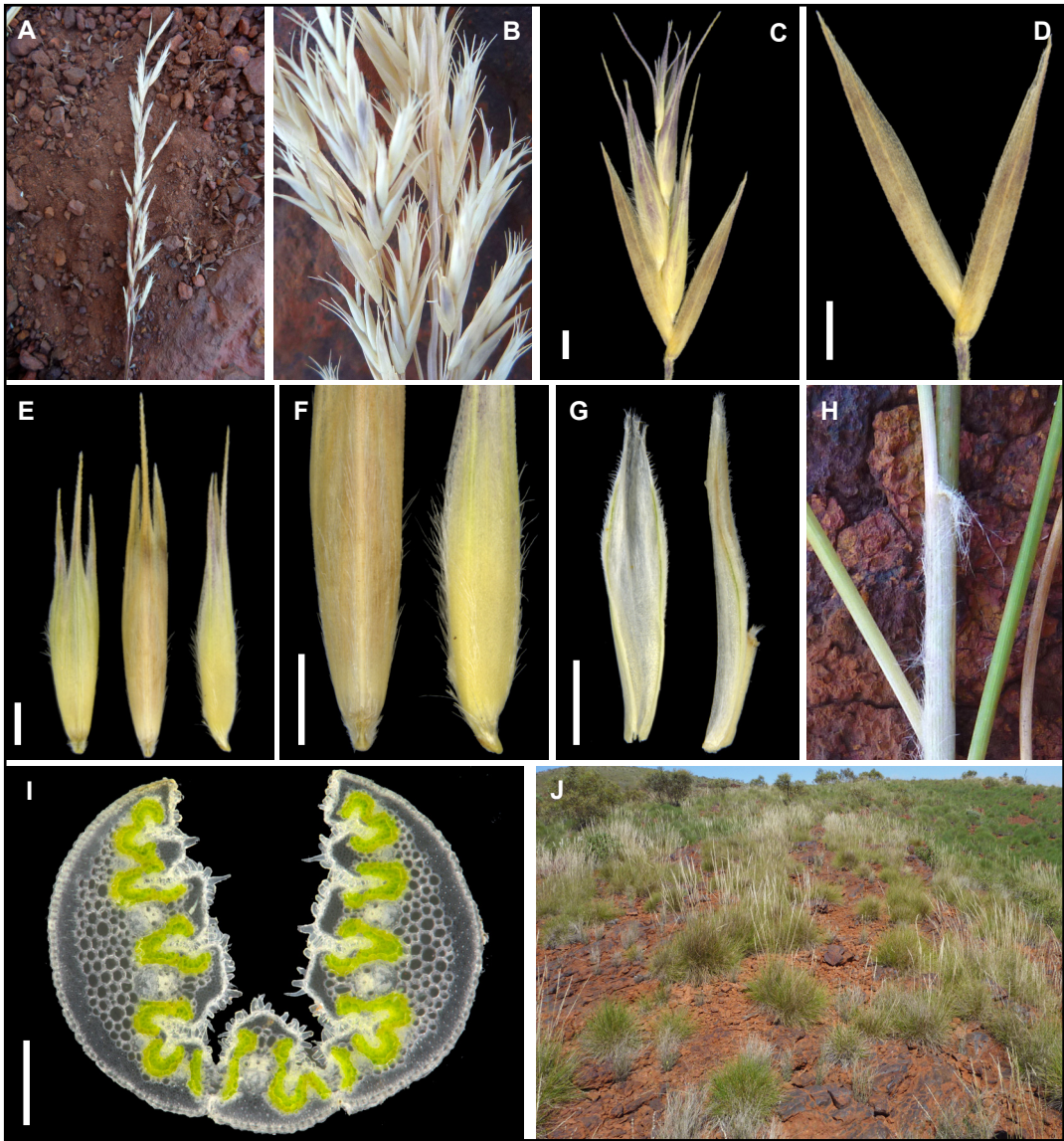
Figure 4. *Triodia karijini*. A – inflorescence showing typical form; B – close up of inflorescence showing spikelet variation; C – spikelet, showing glumes shorter than the combined florets, and lemma awnlets; D – glumes showing narrowly lanceolate shape; E – basal lemmas in face and side view showing variation in relative lobe/awnlet and body lengths; F – close up of lemma body in face and side view, showing appressed hairs arranged in longitudinal rows and uniform texture; G – palea in face and side view, showing uniform texture and lack of indumentum; H – leaf sheath and orifice, showing lack of resin (in this plant; lightly resinous in others), orifice hairs, and hairy sheath surfaces and margins; I – leaf blade in section, showing epistomatous leaf anatomy and two abaxial stomatal grooves; J – flowering plants *in situ* showing habit on ridge of BIF on a mountain plateau (greener plants visible in the top right are *T. pungens*, on non-BIF substrate). Scale bars = 1 mm (C–G); 0.1 mm (I). Images from *M.D. Barrett & B.M. Anderson* MDB 4475. Images by M.D. Barrett; images B–J modified from SᴘɪKᴇʏ (Barrett *et al.* 2017), used with permission.

Other specimens examined. WESTERN AUSTRALIA [localities withheld for conservation reasons]: 18 May 2010, *J. Bull* ONS SFC 109.01 (PERTH, 2 sheets); 23 Sept 2010, *J. Bull* ONS SFD 194.03 (PERTH); 30 July 1998, *S. van Leeuwen* 3502 (CANB – currently as *T. melvillei*, PERTH); 18 Aug. 1998, *S. van Leeuwen* 3817 (AD *n.v.* – currently as *T. melvillei*, CANB – currently as *T. melvillei*, PERTH); 29 Sep. 1998, *S. van Leeuwen* 4111 (PERTH, CANB – currently as *T. brizoides*).

Phenology. Fertile collections have been made between February and May.

Distribution and habitat. *Triodia karijini* occurs in the central Hamersley Range. Its distribution is centred on Karijini National Park, and also on mountains adjacent to the north and east of the Park. A distribution map of *T. karijini* can be found in Barrett *et al.* (2017) or Florabase (Western Australian Herbarium (1998–).

Conservation status. *Triodia karijini* is listed as Priority Two under Conservation Codes for Western Australian Flora (Western Australian Herbarium 1998–), under the name *T.* sp. Karijini (S. van Leeuwen 4111). It is known from just four locations over a 100 km distance in the Hamersley Range, all over 900 m altitude. Collection notes report it as 'common' (*S. van Leeuwen* 3502, 3817, 4111), '9%' [of a 50 × 50 quadrat] (*J. Bull* ONS SFC 109.01), or 'scattered plants' (*J. Bull* ONS SFD 194.03). An estimated 400 plants were found restricted to a single BIF outcrop at the type locality (*Barrett & Anderson* MDB 4475), however other populations are known elsewhere on the same mountain.

Etymology. The epithet is from *Karijini* meaning 'hilly place' in the Banyjima language, in reference to both the habitat on hills and the nearby Karijini National Park, and is used here as a noun in apposition.

Notes. The sub-awned lemma lobes of *T. karijini* provide yet another example of an intermediate between the old concepts of *Plectrachne* and *Triodia*, delimited by the presence or absence of awns. As noted by Lazarides (1995), this character state is untenable as a generic character, and the presence of an awn is homoplastic across *Triodia s. lat.* (Toon *et al.* 2015).

Triodia karijini was included in the phylogenetic trees of Toon *et al*. (2015) under the name *T. melvillei* (voucher *S. van Leeuwen* 3817), divergent from *T. melvillei s. str.* (represented by the specimen *M.D. Crisp* 9731, which was in turn labelled *T. bynoei* in Toon *et al*. (2015)).

Since lemma lobes of *T. karijini* are not obviously awned, *T. karijini* might be compared to taxa around *T. pungens* R.Br.; however, glumes and lemma lobes are more elongate than in *T. pungens* and allies, reminiscent of awned *Triodia* species, so workers familiar with *T. melvillei* and *T. pisoliticola* might look for it there (where its phylogenetic affinities lie).

Morphologically, *T. karijini* is most similar to *T. veniciae* (Barrett 2019); both species share narrow lemma lobes 2.0–3.2(4.5) mm long that could be interpreted as awnlets. *Triodia karijini* has non-resinous to weakly resinous foliage (copiously resinous in *T. veniciae*); palea always glabrous (usually some hairs present in *T. veniciae*); and 3–6 spikelets on longest primary panicle branches (7–14 in *T. veniciae*). *Triodia karijini* is only known from above 900 m on ironstone ridges on mountains in the Hamersley Range, south of the Fortescue River valley, while *T. veniciae* is only known from shale slopes in the Chichester range north of the Fortescue River valley, at 450–520 m altitude.

Triodia karijini is also similar to *T. lutiteana*, but differs in more compact, tussocky clumps to 30–60 cm high and inflorescences 35–120 cm high (more tangled hummocks 60–80 cm high and inflorescences to 160 cm high in *T. lutiteana*); not or weakly resinous foliage (copiously resinous in *T. lutiteana*); longer lemma lobes 2.0–3.0 mm long (0.3–2.1 mm long in *T. lutiteana*); glabrous sheath margins or with hairs to 3.0 mm long scattered over the surface (densely woolly with hairs 3–5 mm long on sub-margins in *T. lutiteana*); ligule hairs 0.3–1.0 mm long (1.5–4.0 mm long in *T. lutiteana*); leaf blades 0.3–0.7 mm wide in rolled leaves (0.9–1.3 mm wide in *T. lutiteana*); shorter inflorescences 12.5–20.0 mm long with fewer (48–93) total spikelets (30.0–37.5 mm long with 112–259 spikelets in

T. lutiteana); and habitat on banded iron ridges above 900 m altitude (*T. lutiteana* is restricted to shale, 430–600 m altitude). The two species are allopatric along the Hamersley Range, with *T. lutiteana* restricted to the west of the constriction in the Hamersley Range where the Nanutarra-Munjina Road passes near Hamersley Gorge, while *T. karijini* only occurs to the east.

Although superficially similar to *T. melvillei*, which grows in the vicinity, *T. karijini* differs in having dense compact tussocks (larger, more open hummocks in *T. melvillei*), being non-resinous to weakly resinous (conspicuously resinous in *T. melvillei*), and having lemma lobes 2.0–3.0 mm long and not awned (lobes 5–14 long and prominently awned in *T. melvillei*). In the Hamersley Range their habitats are usually discrete, with *T. karijini* restricted to outcropping banded iron ridges above 900 m and *T. melvillei* usually on loam or gravelly plains; however, an anomalous cluster of *T. melvillei* was found on a banded iron ridge about 1 km from the type locality of *T. karijini*. South and east of the Pilbara, *T. melvillei* is usually found on rocky substrates, so the Pilbara habitat preference seems to be a local phenomenon.

Phylogenetically, ITS and ETS phylogenies (M.D. Barrett, unpublished data) place *T. karijini* remote from *T. melvillei*, in a group with *T. lutiteana* and *T. pisoliticola*. *Triodia karijini* differs from *T. pisoliticola* by its shorter lemma lobes 2–3 mm long in lowest lemma and lacking awns (lemma lobes in lowest lemma 4.2–9.0 mm long with a distinct awn in *T. pisoliticola*), erect and shorter leaves 19.0–33.5 cm long (leaves becoming lax and curved at maturity and 24–59 cm long in *T. pisoliticola*), and having a distribution in the central Hamersley Range, while *T. pisoliticola* is disjunct in the Millstream-Pannawonica area in the west Pilbara. Anatomically, the abaxial band of sclerenchyma below the abaxial epidermis is unusually thick in both *T. karijini* and *T. pisoliticola* (compare images of leaf sections in Barrett *et al.* (2017) and Fig. 4I here).

Triodia karijini differs from *T. pungens* and *T. epactia* by having non-resinous to weakly resinous foliage (versus strongly resinous in the other two species); forming denser, more compact hummocks; and having narrower glumes, lemmas and lemma lobes.

Some plants in the type population were observed with partially burnt bases, indicating that the species is able to resprout after fire.

Co-occurring species. Co-occurring species are the Pilbara form of *T. pungens*, and the amphistomatous species *T. wiseana* C.A.Gardner. At the type locality of *T. karijini*, a single plant of the larger, resinous species *T. melvillei* was found on the same mountain (about 1 km away), an aberrant habitat since the species is nearly always found on plains in the Pilbara (but often on rocky hills south and east of the Pilbara). *Triodia* sp. Mt Ella also occurs nearby at the type locality, but is highly resinous and has bitextured, awned lemmas.

The vernacular name Pilbara Mountain Spinifex has been suggested (Barrett *et al.* 2017).

Triodia lutiteana M.D.Barrett & P.-L.de Kock, *sp. nov.*

Type: Near Silvergrass Mine, Western Australia [precise locality withheld for conservation reasons], 5 March 2018, *P.-L. de Kock* PLDK 1107 (*holo*: PERTH 09180141; *iso*: BRI, CANB, DNA, K, MEL, NSW).

Triodia sp. Silvergrass (P.-L. de Kock BES 00808) Western Australian Herbarium, in *Florabase*, https://florabase.dbca.wa.gov.au/ [accessed 16 October 2023].

Hummocks with tussock form, *perennial*, copiously resinous and highly aromatic, not obviously stoloniferous; *hummocks* densely compact, 60–80 cm high, 60–80 cm wide; *flowering culms* 150–160 cm high. *Vegetative culm internodes* all short (never elongated as in *T. claytonii*), 4.0–24.0 mm long, and obscured by subtending foliage, dark red-brown, sparsely to moderately pilose becoming glabrous; aerial roots absent. *Leaf sheaths* very narrowly triangular, 10.0–16.0 cm long, 2.5–6.5 mm wide near apex, 4.0–9.0 mm wide near base, strongly aromatic-resinous at least near apex, straw-coloured, moderately strongly nerved, glabrous on surface except sparsely to densely hirsute with straight to tangled hairs 3.0–5.0 mm long in a sub-marginal zone 0.5–1.5 mm wide, the hairs with a visible lumen; lateral sheath margins densely hirsute with straight to crisped somewhat thickened hairs 3.5–9.0 mm long, on lower sheath margins close to nodes these tangled with the sub-marginal hairs into a thick, dense woolly band; margins of *orifice* ±truncate to shortly auriculate, with a dense fringe of straight to crisped hairs, the longest hairs 3.2–8.0 mm long. *Ligule* a dense, thick band of hairs 1.5–4.0 mm long, usually partly embedded in resin. *Pseudopetiole* not distinct. *Leaf blades* V-shaped when fresh, conduplicate and tightly in-rolled when dry, initially straight but becoming curved or sinuate in older and dead leaves, 21.0–42.0 cm long, 0.9–1.3 mm high when rolled, 0.8–1.2 mm wide when rolled, *c.* 2.0 mm wide in unrolled leaves, when fresh relatively soft, moderately pungent, glabrous abaxially, densely papillose adaxially, resinous over abaxial surface, mid- to dark green when fresh, drying pale green; stomatal grooves on abaxial surface confined to central part, 4 (2 either side of a scarcely raised mid-rib), absent on marginal *c.* 2/5 but sometimes finely obscurely ribbed; stomatal grooves on adaxial surface 10–12 (5–6 each side of mid-rib); margins minutely scaberulous with prickle hairs *c.* 0.05–0.10 mm long. *Flag-leaf* sheaths 14.0–23.0 cm long, involute, densely ciliate with hairs 2.5–4.0 mm long on exposed margin; blade 4.0–34.0 cm long. *Panicle* 30.0–37.3 cm long, (3.0–)6.0–28.0 cm wide, with 112–259 spikelets total, lanceolate to ovate, moderately dense to loose; primary axis angular and ribbed or flattened, glabrous except for minute tufts of hairs *c.* 1.5–3.0 mm long in branch axils, non-resinous; primary branches openly racemose except for base of branches in the lower half prominently ternate. Longest primary panicle branches 9.5–20.0 cm long, terete to angular or weakly flattened, with 9–19 loosely arranged, ±uniform-sized spikelets in a loose arrangement (adjacent glumes not or slightly overlapping); axis terete to angular or prominently flattened, with internodes between pedicels 13.0–16.5 mm long; longest *pedicels* at base of longest panicle branches 0.7–6.0 mm long, 0.2–0.3 mm wide, filiform to slender, becoming slightly thicker just below spikelet, minutely antrorsely scabrous; upper lateral pedicels on branch often gradually becoming shorter than lowest ones, down to 1.0 mm long; terminal pedicel 4.0–14.5 mm long. *Spikelet* 6.0–13.0 mm long, 1.2–2.0 mm wide, loosely 3–7-flowered with 3–6 fertile florets (apparently 0–2 sterile florets at apex, but these possibly immature), narrowly lanceolate, sub-terete to slightly laterally compressed at maturity; lowest rachilla internode 0.9–1.5 mm long, *c.* 0.2 mm diam., slightly laterally compressed in section, not ribbed, minutely scabrous or smooth, glabrous; spikelets disarticulating above glumes and at rachilla internodes at maturity. *Lower glume* 4.5–8.0 mm long, 1.1–2.1 mm wide, narrowly lanceolate to lanceolate, L:W 3.2–6.4, apex muticous, acute or acuminate and usually shortly mucronate with mucro 0.2 mm long, 0.5–0.9 as long as the combined florets (including lobes), scarious, chartaceous, margins undifferentiated and not membranous, with minute scabrosities over whole surface, 3–5-nerved; mid-nerve raised into a narrow thickened keel; lateral nerves scarcely to moderately raised; margins glabrous. *Upper glume* inserted *c.* 0.3–0.5 mm above lower glume, 4.4–7.8 mm long, 1.6–2.1 mm wide, similar to and subequal to lower glume, much shorter than the combined florets (excluding awns). *Lemma of basal floret* 4.8–7.2 mm long including lobes, narrowly lanceolate to narrowly oblong, shortly to deeply 3-lobed; body 4.5–5.6 mm long including callus, 1.0–1.5 mm wide without flattening, uniformly chartaceous to somewhat indurated, not bitextured, with scattered sparse to moderately dense appressed to ascending hairs 0.3–0.7 mm long somewhat obscurely arranged in lines between the nerves all over the lower 2/3–3/4 of body, 9 nerves in 3 groups of 3 obscure nerves radiating into base of lobes; mid-lobe 0.2–2.1 mm long (on most specimens less than 1 mm long), triangular to narrowly triangular, acute, not awned but sometimes shortly acuminate, subequal or slightly

longer and slightly to distinctly narrower than lateral lobes; lateral lobes 0.3–0.8 mm long, triangular, acute, not awned, margins with lacking a membranous wing. *Callus* of basal floret 0.2–0.5 mm long, straight to slightly curved, attached obliquely, broadly to sharply acute in face view, sharply acute in profile, white-bearded either side of a broad glabrous midline with the longest hairs *c.* 0.4–0.6 mm long. *Upper lemmas* similar to but smaller than lowest lemma. *Palea* of basal floret subequal to or slightly longer than lemma body (shorter than body in rare specimens with stunted or immature paleas), 4.5–5.7 mm long, 0.80–0.95 mm wide, lanceolate to oblanceolate, 2-keeled, not bitextured, membranous-chartaceous, sparsely to moderately densely ascending-hairy in basal 1/3–2/3, glabrous in apical part, apex acute to broadly acute or notched; keels raised but not winged or with a narrow membranous wing to 0.1 mm wide, margin densely minutely ciliate for most of length with cilia up to *c.* 0.05-0.10 mm long; flaps *c.* 0.1–0.2 mm wide, broadest in central part, much narrower than 1/2 width of the palea body and not overlapping, entire. *Lodicules* 0.5–0.9 mm long, apex broadly and obliquely rounded-truncate, ±entire, glabrous. *Anthers* 3, 2.5–2.8 mm long, exserted at maturity. *Style*s 2, *c.* 1.5–2.0 mm long. *Caryopsis* not seen. (Figure 5)

Diagnostic characters. Sheaths densely resinous, margins densely hirsute, submargins sparsely to moderately hirsute; ligule hairs 1.5–4.0 mm long. Glume 4.4–8.0 mm long, narrowly lanceolate to lanceolate, L:W 3.2–6.4. Lowest lemma 4.8–7.2 mm long including lobes, shortly to deeply 3-lobed, not bitextured, with scattered sparse to moderately dense appressed to ascending hairs 0.3–0.7 mm long somewhat obscurely arranged in lines, not awned, the mid-lobe 0.2–2.1 mm long (on most specimens less than 1 mm long), lateral lobes 0.3–0.8 mm long. Restricted to shale or mudstone substrate.

Other specimens examined. WESTERN AUSTRALIA: [localities withheld for conservation reasons] 13 Oct. 2018, *S. Colwill* BES 00956 (PERTH); 22 Sep. 2017, *C. Flaherty* BES 00948 (PERTH); 27 May 2018, *M. Hay* 1803_04-02 (PERTH); 25 May 2018, *M. Hay & M. Macdonald* 1803_R9-01 (PERTH); 5 Mar. 2018, *P.-L. de Kock* PLDK 1108 (CANB, PERTH); 5 Mar. 2018, *P.-L. de Kock* PLDK 1109 (AD; PERTH); 16 Sep. 2017, *P.-L. de Kock* BES 00808 (PERTH); 27 June 2017, *P.-L. de Kock* BES 00952 (PERTH); 10 Oct. 2018, *P.-L. de Kock* BES 00953 (PERTH); 21 Sep. 2017, *P.-L. de Kock* BES 00954 (PERTH); 25 Apr. 2017, *P.-L. de Kock* BES 00957 (PERTH); 16 Sep. 2017, *P.-L. de Kock & M. Greenham* BES 00949 (PERTH); 16 Sep. 2017, *P.-L. de Kock & M. Greenham* BES 00950 (PERTH); 10 Oct. 2018, *M. Maier* BES 00947 (PERTH); 21 Sep. 2017, *B. Morgan & S. Colwill* BES 00955 (PERTH); 30 June 2017, *B. Morgan & B. Eckermann* BES 00951 (PERTH).

Phenology. Fertile collections have been made in March.

Distribution and habitat. Occurs exclusively on shale hills and slopes of the Nammuldi-Silvergrass area with a known range of 75 km from north-east of Nammuldi Airport to south-west of east Mt Farquhar in the western Hamersley Range, Pilbara Region, Western Australia. In this highly restricted habitat it is typically the dominant species, growing in near monocultures. Total census of known populations was 31,330 plants in 2019.

Conservation status. *Triodia lutiteana* is listed as Priority One under Conservation Codes for Western Australian Flora (Western Australian Herbarium 1998–), under the name *T*. sp. Silvergrass (P.-L. de Kock BES 00808). It is known from six discrete areas over about 75 km distance. Collection notes report it as '15% cover', '25% cover' [of 50 × 50 m quadrats] or 'locally abundant' (*M. Hay* 1803_04-02, *M. Hay & M. Macdonald* 1803_R9-01, *P.L. de Kock* PLDK 1109, respectively).
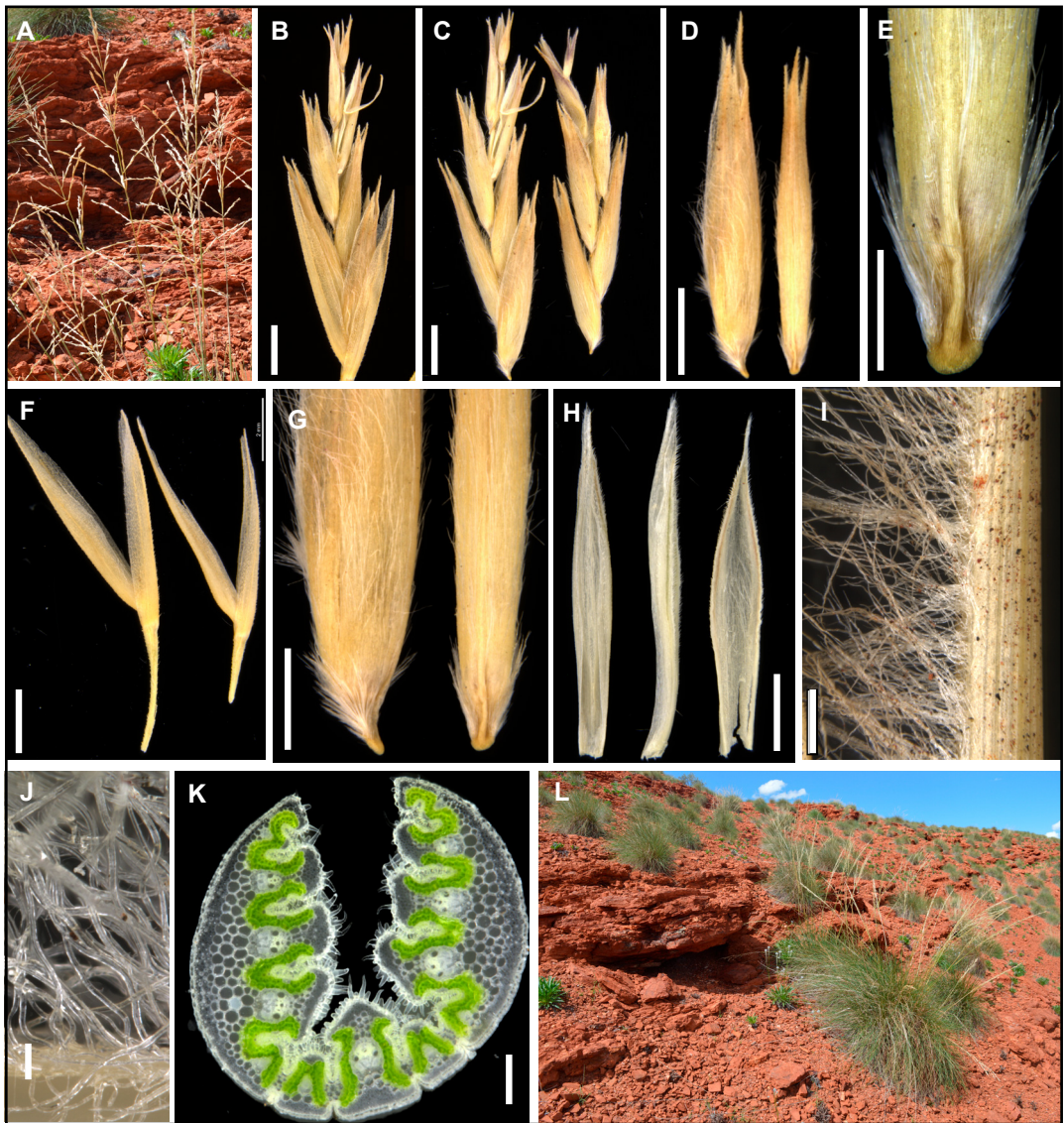
Figure 5. *Triodia lutiteana*. A – inflorescences *in situ* showing typical form; B – spikelet, showing glumes shorter than the combined florets; C – spikelets without glumes showing variation in florets and lemma lobes; D – basal lemmas in side and face view showing indumentum and lemma lobes; E – close up of basal lemma body showing hairs somewhat arranged in lines; F – glumes, showing shape and variation; G – close up of lemma body in side and face view, detailing the indumentum of appressed to ascending hairs, and difficulty observing the tendency of hairs to occur in lines when the indumentum is denser (*cf.* image E); H – palea in face and side view, showing uniform texture and indumentum; I – leaf sheath surface, showing diagnostic glabrous and resinous face, with densely hirsute sheath margins and sub-margins; J – leaf sheath marginal hairs magnified, showing undulate, tangled form, and hollow lumen; K – leaf blade in section, showing epistomatous leaf anatomy and two abaxial stomatal grooves; J – flowering plants *in situ*, showing typical sparse occurrence in near monocultures, restricted to specific shale / mudstone substrate. Scale bars = 1 mm (B–I); 0.5 mm (E); 0.1 mm (J); 0.2 mm (K). Images from *P.L- de Kock* 1109. Images by M.D. Barrett (B–K) and P.-L. de Kock (A, L).

Etymology. The epithet is from *lutite*, an old geological term referring to any type of mudstone (including shale), which in turn is derived from Latin *lutum*, mud, and the suffix -*ana*, indicating a connection, all in reference to the very tight association of this species with shale geology.

Notes. *Triodia lutiteana* was unknown before April 2017, when it was discovered by P.-L. de Kock, then at Biota Environmental Sciences, conducting a survey for Fortescue Metals Group Ltd.

Triodia lutiteana, along with *T. karijini* and *T. veniciae*, is one of three Pilbara species that share the combination of epistomatous leaf anatomy, narrowly lanceolate glumes [L:W>(3.2–)4.0] with central lobe of lowest lemma 0.3–3.2 mm long, and lemma lobes not awned or with at most a short awnlet. The only other species of *Triodia* with these characteristics is *T. hubbardii* N.T.Burb. from central Australia. *Triodia triaristata* Lazarides from central Australia is also similar but has a longer lemma mid-lobe (2–)3.5–5 mm long (Lazarides *et al*. 2005).

Differences between *Triodia lutiteana* and *T. karijini* are given under the latter species.

Triodia lutiteana shares the robust resinous hummocks and the same shale habitat of *T. veniciae*, but differs in having dense woolly hairs 3–5 mm long restricted to a submarginal zone (leaf sheath margin glabrous in *T. veniciae*, although sheath *surface* can have scattered hairs 1.5–3.2 mm long all over; see Figure 7B); longer ligule hairs 1.5–4.0 mm long (0.5–0.9 mm long in *T. veniciae*), longer lemma lobes 0.3–2.1 mm long (1.8–3.2 mm long in *T. veniciae*), and 3–7 florets (6–15 in *T. veniciae*). *Triodia lutiteana* only occurs south of the of the Fortescue River valley, while *T. veniciae* is restricted to the north side of the Fortescue River valley.

Triodia hubbardii has narrowly lanceolate glumes and lowest lemma lobes 1.5–2.0 mm long, similar to *T. lutiteana*. However *T. hubbardii* has leaf sheaths glabrous or at most sparsely hairy between ribs (densely woolly on submargins in *T. lutiteana*), rachilla internodes flattened and with a median rib (terete to slightly compressed in *T. lutiteana*), palea body indurated and keels winged (palea membranous-chartaceous and not winged or with a very narrow wing to 0.1 mm wide in *T. lutiteana*), florets 5–12 (3–7 in *T. lutiteana*), and is disjunct from *T. lutiteana* in rocky hills of central Australia (Lazarides 1997; Lazarides *et al*. 2005).

Three species of Pilbara *Triodia* are now known only from shale: *T. lutiteana*, *T. mallota* B.M.Anderson & M.D.Barrett (Anderson *et al*. 2017a), and *T. veniciae* (Barrett 2019). *Triodia mallota* differs from *T. lutiteana* in most characters, especially in having shorter, non-resinous leaf blades, spicate inflorescences, and many-nerved glumes (Anderson 2017a; Barrett *et al*. 2017) (leaves longer, resinous, inflorescences paniculate, glumes 3–5-nerved in *T. lutiteana*).

Phylogenetic trees of ITS and ETS data (M.D. Barrett, unpublished data) indicate *T. karijini* and *T. pisoliticola* are the closest relatives of *T. lutiteana*. *Triodia pisoliticola* is distinct among these species in having awned lemmas (versus not awned) and consistently non-resinous foliage (versus conspicuously or variably resinous), but otherwise is morphologically similar. Phylogenies from ITS and ETS data place *T. veniciae* in a distant clade, with *T. bynoei* (M.D. Barrett, unpublished data).

At least one population appears fixed at a high ploidy level (hexaploid or octoploid), as discussed above, suggesting *Triodia lutiteana* may have a polyploid origin.

The vernacular name Woolly Shale Spinifex is suggested.

Co-occurring species. Grows in open woodland of *Eucalyptus leucophloia* subsp. *leucophloia* and/ or *E. pilbarensis* open shrublands with *Acacia atkinsiana*, *Acacia marramamba*, *Dampiera dentata*, *Grevillea saxicola* and/or *Petalostylis labicheoies*, or in hummock grassland with *T. lutiteana* dominating

or mixed with *T. wiseana* and other species. Co-occurring *Triodia* species are *T. epactia* and *T. wiseana*, and less commonly *T. angusta* and *T. longiceps*.

Triodia schinzii (Henrard) Lazarides, *Austral. Syst. Bot*. 10: 474 (1997).

Plectrachne schinzii Henrard, *Vierleljahrsschr. Naturf Ges. Zürich* 74: 134 (1929).

Type: AUSTRALIA: North Territory, prope Lander Creek, 14 June 1911, *G.F. Hill* 344 (holo: Z 000018542 *n.v.*; iso: BRI AQ0340008 image, K 000912342 [as *G.F. Hill* s.n.] image MEL 725882, PERTH 03912108 [photo of MEL isotype], US 00140959).

Plectrachne helmsii C.E.Hubb., *Bull. Misc. Inform. Kew* 1941(1): 29–30 (1941), *syn. nov.*; *Triodia helmsii* (C.E.Hubb.) Lazarides, *Austral. Syst. Bot*. 10: 434 (1997), *syn. nov. Type*: Mt Illillinna, Everard Ra., S.A., Elder Exploring Expedition, Camp 4, 8 June 1891, *R. Helms s.n.* (*holo*: K 000912420 *n.v.* (photo PERTH 03912094); *iso*: AD *n.v.*, BRI AQ0340006, MEL 725889, NSW 330590, NSW 330591, PERTH 00388335).

Hummock-forming *perennial*, foliage resinous, not obviously stoloniferous; *hummocks* compact, 30–100(–130) cm high, 50–200 cm wide; *flowering culms* 100–160 cm high. *Vegetative culm internodes* all short (not or only slightly elongated), 0.4–6.1 cm long, and obscured by subtending foliage, pale to dark red-brown, glabrous or with sparse minute appressed hairs; aerial roots absent or obscure. *Leaf sheaths* 3.2–6.5 cm long, 2.8–5.0 mm wide near apex, glabrous, at least some resinous on each plant, green to straw, obscurely to prominently nerved; margins glabrous; margins of *orifice* truncate to shallowly rounded, with a dense fringe of hairs, the longest hairs 0.5–4.0 mm long. *Ligule* a dense fringe of hairs 0.2–1.0 mm long. *Pseudopetiole* not distinct, but with a subtly narrowed paler base lacking veins and 1.0–7.5 mm long that could be interpreted as a pseudopetiole. *Leaf blades* flattened-V-shaped when fresh, conduplicate and tightly in-rolled when dry, initially straight and remaining so, scarcely recurved in older and dead leaves, 8.0–25.0 cm long (longest leaves per specimen 12.0–25.0 cm), 0.9–1.2 mm wide when rolled, unrolled leaves 1.5–3.0 mm wide, when fresh relatively soft, moderately pungent, glabrous abaxially, surface densely papillose adaxially, patchily or copiously resinous over abaxial surface, bright green when fresh, drying pale green or straw; stomatal grooves on abaxial surface confined to central part, 4 (2 either side of rounded mid-rib), equally spaced within the central zone (mid-rib space slightly wider), absent on marginal *c.* 1/3 but finely obscurely ribbed; stomatal grooves on adaxial surface 10–14 (5–7 each side of mid-rib); margins minutely scaberulous with minute prickle hairs *c.* 0.05–0.10 mm long. *Flag-leaf* sheaths 7.5–34.0 cm long, involute, glabrous; blade 1.4–4.1 cm long. *Panicle* (9.0–)12.5–30.5 cm long, 1.7–8.5 cm wide, with 25–72 spikelets total, linear to lanceolate, or ovate at anthesis, dense to moderately loose; primary axis sub-terete to angular to ribbed or flattened, glabrous except minute tufts of hairs 0.1–0.4 mm long sometimes present in branch axils, non-resinous; primary branches densely to openly racemose (or extreme base of longest branches very briefly ternate). Longest primary panicle branches 1.9–7.8 cm long with (1–)3–5 ±uniform-sized spikelets in a moderately dense to loose arrangement (adjacent glumes slightly or strongly overlapping); axis sub-terete to angular or weakly flattened with internodes between pedicels 8.0–17.0 mm long; longest *pedicels* at base of longest panicle branches (1.0–)1.4–8.5 mm long, 0.10–0.25 mm wide, the longest ones ±filiform, becoming slightly thicker and 0.25–0.45 mm diam. just below spikelet, terete to sub-angular, minutely scabrous; upper lateral pedicels on branch gradually becoming shorter than lowest one; terminal pedicel 8.0–32.0 mm long. *Spikelet* (12.0*–)14.0–26.0 mm long and 1.0–6.0 mm wide (excluding awns but including glumes), the combined florets without glumes (6.0*–)7.5–19.0 mm long (excluding awns), loosely 4–7-flowered with 3–5 fertile florets (apparently 1–3 sterile florets at apex, but these possibly immature), narrowly lanceolate to lanceolate

or obtriangular, sub-terete or more usually laterally compressed at maturity; lowest rachilla internode 1.1–2.7 mm long, *c.* 0.15–0.20 mm diam., terete to depressed-terete, minutely scabrous or sparsely short-hairy; spikelets disarticulating above glumes and at rachilla internodes at maturity. *Lower glume* (12.0–)14.0–26.0 mm long, 1.5–2.4 mm wide, narrowly lanceolate, L:W (6.6*–)7.2–12.2 with apex narrowly acute to acuminate, distinctly longer than the combined florets (excluding awns), scarious, with narrow membranous margins 0.1–0.3 mm wide, with sparse to moderately dense very minute scabrosities less than 0.05 mm long over whole surface (appearing smooth without tangential lighting), (5–)7–11-nerved; mid-nerve moderately raised; lateral nerves scarcely to moderately raised; margins glabrous. *Upper glume* inserted 0.4–1.2 mm above lower glume, (12.0–)14.0–22.0 mm long, similar to and subequal to lower glume, distinctly longer than the combined florets (excluding awns). *Lemma* of basal floret (15.0*–)17.0–29.5 mm long including lobes, narrowly lanceolate to narrowly elliptic, deeply 3-lobed, 3-awned; body (4.0*–)5.2–7.0 mm long including callus, 0.80–1.25 mm wide *in situ* (without flattening), strongly bitextured (with lower part indurated and upper part membranous-chartaceous) with a sharp transverse transition line, fracturing at the transverse line in age; indurated lower part (3.2–)4.0–5.8 mm long (including callus) with moderately dense to dense appressed hairs 0.2–0.4 mm long (sometimes also with smaller hairs *c.* 0.1 mm long) over most of surface, or sometimes sparse to glabrous along a broad midline and/or with more ascending hairs in 2 rows either side of the midline, but always ±uniform on lateral faces, never clearly aligned into distinct rows on the lateral faces; membranous-chartaceous upper part united to (0.5–)1.0–2.1 mm above bitextured line, glabrous, with 9 nerves in 3 groups of 3 obscure nerves radiating into lobes and awns; mid-lobe (10–)11–28 mm long (including awn), narrow-triangular and 0.4–0.5 mm wide at base gradually narrowing into an awn, subequal or slightly narrower than lateral lobes; lateral lobes (7–)10–21 mm long (including awn), narrow-triangular at base gradually narrowing into an awn, margins with a very narrow or obsolete membranous wing; reverse face of lemma with a transverse thickened callus of tissue across the bitexture line. *Callus* of basal floret 0.8–1.7 mm long, straight, attached very obliquely, sharply acute and pungent in face view, sharply acute in profile, white-bearded all over or the midline entirely glabrous or glabrous in upper part only, with the longest hairs 0.2–0.7 mm long. *Upper lemmas* similar to but smaller than lowest lemma, and often with longer callus to 2.0 mm long. *Palea* of basal floret distinctly shorter to slightly longer than lemma body, 3.0–4.5 mm long, 0.7–1.0 mm wide, narrowly oblanceolate, 2-keeled, glabrous, when immature not bitextured, but at maturity usually prominently bitextured, but sometimes weakly or obscurely bitextured, and then with a small membranous apex, lower part 2.0–3.3 mm long and indurated, upper part 0.5–1.0 mm long and translucent-membranous or translucent-sub-chartaceous, with a ±abrupt to somewhat diffuse transverse junction between them, apex truncate, notched, erose or less often muticous, fragile-membranous and becoming erose; keels raised but not winged or sometimes with a short ambiguous wing to 0.1 mm wide formed from the lower margin of the membranous part at the angle of the junction between indurated and membranous part, margin densely scabrous; flaps *c.* 0.10–0.25 mm wide, ±equal over most of length, narrower than 1/2 width of the palea body and not overlapping, entire. Upper *paleas* similar but smaller than palea of basal floret, or sometimes entirely chartaceous, not bitextured, lacking a clear membranous apex. *Lodicules* 0.5–0.9 mm long; apex truncate, level or oblique, undulate or not, glabrous. *Anthers* 3, 2.0–3.8 mm long, exserted at maturity. *Style*s 2, 1.8–2.8 mm long. *Caryopsis* not seen. (Figures 2, 6)

Note that this description is compiled from specimens referred here to *T. schinzii s. str.*, excluding *T. avenoides,* but includes *T. helmsii sensu* Lazarides (1997) and Lazarides *et al.* (2005). Measurements indicated with an asterisk (*) are from a single outlier specimen with small spikelets, *P.K. Latz* 830.

Diagnostic features. Foliage resinous. Leaf sheaths glabrous on surfaces and margins. Leaves epistomatous, lacking stomatal grooves on the lateral margins of the abaxial surface. Glumes narrowly lanceolate, (12.0–)14.0–26.0 mm long, 1.5–2.4 mm. Lemmas 0.80–1.25 mm wide *in situ*, bitextured
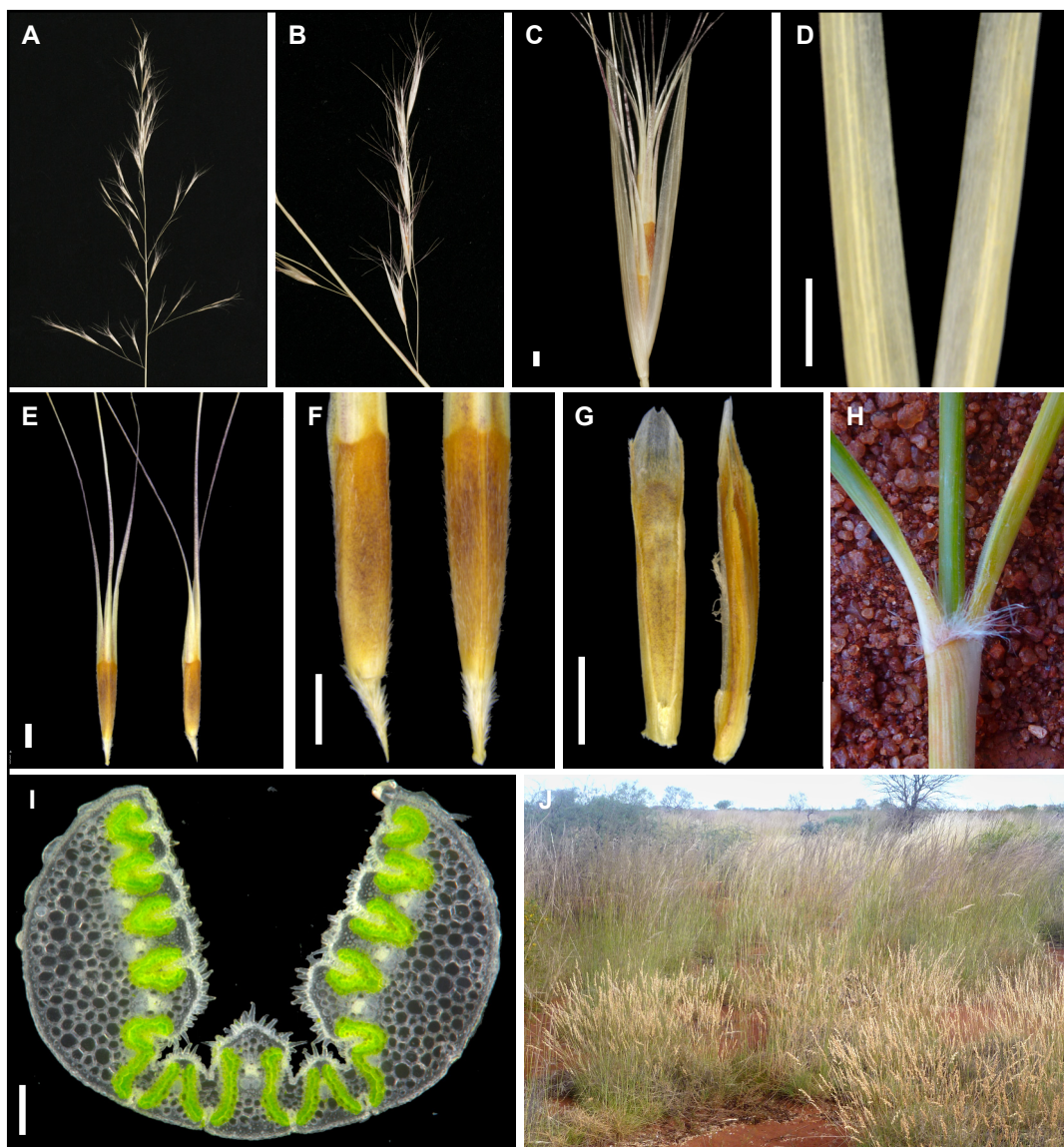
Figure 6. *Triodia schinzii*. A – inflorescence showing typical form; B – basal branches of inflorescence showing typical spikelet density; C – spikelet, showing glumes exceeding the combined florets (excluding awns); D – close-up of glumes showing multiple nerves; E – basal lemma showing relative awn and body lengths; F – lemma body in face and side view, showing appressed hairs on the indurated lower part, and a sharp transverse line demarcating the upper membranous part (lemma bitextured), and note the callus which is long-pungent, longer and sharper than that of *T. degreyensis* (*cf.* Figure 3); G – palea in face and side view, showing well-differentiated (bitextured) texture, and lack of indumentum; H – orifice of leaves showing orifice hairs, glabrous sheath faces and margins; I – leaf blade in section, showing epistomatous leaf anatomy and four abaxial stomatal grooves; J – flowering plants *in situ* (taller, finer plants in mid-ground; smaller plants in the foreground with straw-coloured inflorescences are *T. basedowii*, which commonly co-occurs with *T. schinzii*) showing habit on red sand plain. Scale bars = 1 mm (C–G); 0.2 mm (I). Images from *M.D. Barrett & W. Lewandrowski* MDB 3917 (A–G, J), *M.D. Barrett & B.M. Anderson* MDB 4072 (I), *M.D. Barrett, B.M. Anderson & P. Jobson* MDB 4517. Images by M.D. Barrett; images A, C, E, F, G and I modified from SᴘɪKᴇʏ (Barrett *et al*. 2017), used with permission.

with upper membranous part sharply demarcated from lower indurated part by a transverse line, indurated part appressed-hairy all over, lobes awned, callus 0.8–1.7 mm long. Palea usually bitextured, glabrous or rarely hairy, keels not winged (or at most with a short, narrow part-wing).

Selected specimens examined (of T. schinzii s. str.*).* NORTHERN TERRITORY: 8 km East of Docker River, 15 Dec. 2000, *D.E. Albrecht* 9668 (NT); On Docker River Rd, approximately 19.4 km E of Docker River, 10 Oct. 2014, *B.M. Anderson & P. Jobson* BMA 86 (PERTH); 45 km from Aileron towards Alice Springs, 2 Oct. 2004, *M.D. Crisp* 9773 (CANB, DNA); 22 miles E of Utopia Stn, 13 May 1955, *M. Lazarides* 5276 (PERTH); 40km ESE Barrow Creek, 15 May 1996, *P.K. Latz* 14845 (MEL, NT); Winnecke Hills Soak, 40 km SW of Lajamanu, 1 May 2004, *C.P. Mangion & D.L. Lewis* 114 (PERTH). SOUTH AUSTRALIA: 3 km NE Timber Camp Bore; Perdika Desert, 23 Mar. 1999, *P.K. Latz* 15859 (AD *n.v.*, CANB, NT). WESTERN AUSTRALIA: 5 km S of Capricorn Roadhouse, 8 Mar. 2012, *M.D. Barrett & W. Lewandrowski* MDB 3917 (PERTH); Coondiner Pool, 17 Mar. 2013, *M.D. Barrett & B.M. Anderson* MDB 4072 (PERTH, 2 sheets); 78 km NW of Marble Bar, 19 Mar. 2013, *M.D. Barrett & B.M. Anderson* MDB 4097 (PERTH); Ganthaume Point, Broome, 16 Apr. 2013, *M.D. Barrett & B.M. Anderson* MDB 4375 (DNA, PERTH, 2 sheets); 28 km SSW of Tunnel Creek Station, 9 May 2003, *D.J. Edinger & G. Marsh* DJE 3506 (PERTH); 3 km WNW of Mt Florrie, 73 km E of Warburton, Central Ranges, 28 Apr. 2001, *D.J. Edinger; B.& B. Backhouse & G. March* DJE 2312 (PERTH); 27 km SSW of Warburton, 10 May 2001, *D.J. Edinger, B. & B. Backhouse & G. Marsh* DJE 2465 (PERTH); Mindy North Mining Tenement, Newman, 23 April 2007, *T. Edwards* MN 51-01 (PERTH); Great Sandy Desert, 10 May 1979, *A.S. George* ASG 15684 (PERTH); Tobin Lake, 5 May 1979, *A.S. George* 15620 (DNA, PERTH, 2 sheets); Telfer, 3 May 2007, *P. Golos & K. Dixon* 4 (PERTH); Bungabiddy Creek, Lake Gregory, 12 June 2006, *T. Handasyde* TH 3028 (PERTH); Broome, 15 Mar. 1987, *K.F. Kenneally* 9856 (PERTH); 50 miles E of Docker River Settlement, 25 Oct. 1970, *P.K. Latz* 830 (CANB, DNA, PERTH); 3 km NW of Docker River Settlement, 24 Aug. 2007, *P.K. Latz* 22930 (NT); Rudall River, 9 Sep. 1971, *B.R. Maslin* 2195 (PERTH); 42 km E of Newman, 25 June 2007, *R. McIntyre* JB 2-22 (PERTH); 28.2 km from Weelarrana Homestead near Newman, 20 June 1996, *A.A. Mitchell* PRP 1153 (PERTH); 16.3 km from Sylvania Station Homestead near Newman, 24 June 1996, *A.A. Mitchell* PRP 1192 (PERTH); 25 km NNW of Muccan Station Homestead near Shay Gap, 20 Aug. 1997, *A.A. Mitchell* PRP 1825 (CANB, PERTH, 2 sheets); 5 km N on the Gary Hwy from the Gunbarrel Hwy, 9 June 2007, *L.S.J. Sweedman* 7081 (PERTH); Broome, 28 Aug. 2007, *Woodman Environmental Consulting* POB 03-19 (PERTH).

Specimens examined referred to T. helmsii *by M. Lazarides* (see also types cited above): NORTHERN TERRITORY: Petermann Ranges, 22 Sep. 1978, *A.C. Beauglehole* 60786 (DNA); 5 miles E of Docker River, 28 Sep. 1970, *C.R. Dunlop* 1916 (CANB, DNA). WESTERN AUSTRALIA: Petermann Ranges, 22 Sep. 1978, *A.C. Beauglehole* 60601 (CANB, DNA, MEL); Neale Junction, 10 Oct. 1966, *A.S. George* 8387 (PERTH).

Phenology. Fertile collections are mostly between March and September.

Distribution and habitat. The habitat of *T. schinzii s. str.* reported by Lazarides (1997), (excluding *T. helmsii*) is 'plains, dunes, sandhills, swales and pindan in deep, red sands, sandy loams, clayey sands and sandy red earths; also on shallow stony soils, alluvial creek levees, coastal pindan and beach sands' and 'associated with sandstone, laterite, limestone and slates'. It should also be noted that the second part of Lazarides' (1997) habitat description of *T. schinzii* [after 'also'] probably refers to marginal or underlying geology, and the presence of rocks in the substrate are here regarded as incidental marginal habitat rather than a typical habitat, since the vast majority of plants occur on sandy substrate, only rarely sand amongst rocks (M.D.Barrett, pers. obs.). Grigg *et al*. (2008) and Grigg (2009) reported

T. schinzii at Nifty in the Great Sandy desert rooting up to 2 m deep, and occurring only on sand, compared to *T. basedowii* rooting 0.2–1.0 m, on interdunes in sandy or gravelly soil).

Conservation status. Not considered at risk.

Etymology. The epithet *schinzii* honours Hans Schinz (1858–1941), Swiss explorer and botanist.

Notes. The descriptions of *T. schinzii* in Lazarides (1997), Sharp and Simon (2002) and Lazarides *et al*. (2005) include both *T. avenoides* and *T. schinzii* as treated here. The description of *T. helmsii* in Lazarides (1997) and Lazarides *et al*. (2005) is within the variation of *T. schinzii* described here, even excluding specimens previously attributed to *T. helmsii*.

Discrimination of *T. schinzii* from other species with epistomatous leaves and awned bitextured lemmas is discussed under *T. avenoides*.

The vernacular name Feathertop Spinifex has been applied to *T. schinzii* (Lazarides 1970; Sharp & Simon 2002; Barrett *et al*. 2017).

Triodia veniciae M.D. Barrett, *Nuytsia* 30: 222–227, Figure 1 (2019).

Since the treatment of this species in Barrett *et al*. (2017) and Barrett (2019), a slightly greater range of basal lemma mid-lobe (including awnlet) has been detected, the range now being 1.8–4.5 mm long (M.D. Barrett, pers. obs.; S. Coultas & C. van der Bergh, *in litt*., 21 May 2020). Additional images of vegetative parts and leaf section, not illustrated when the species was described (Barrett 2019) are shown in Figure 7. During surveys for this species in 2017, most populations located were growing on sparsely vegetated shale slopes, and were long unburnt. A single population (unvouchered, a few km north of *M.D. Barrett* 5412) had been burnt about 2–3 years prior, and observations on the fire response could be made. Most clumps had been burnt to stumps shortly above ground level, but were resprouting (Figure 7A). Small numbers of seedlings were also observed, while no seedlings were observed in any of 13 unburnt populations. *Triodia veniciae* is therefore, at least under some conditions, predominantly resprouting and germinates episodically after fire. Fire intensity would affect the survival rate, while seedling germination and recruitment is likely rainfall-dependent.
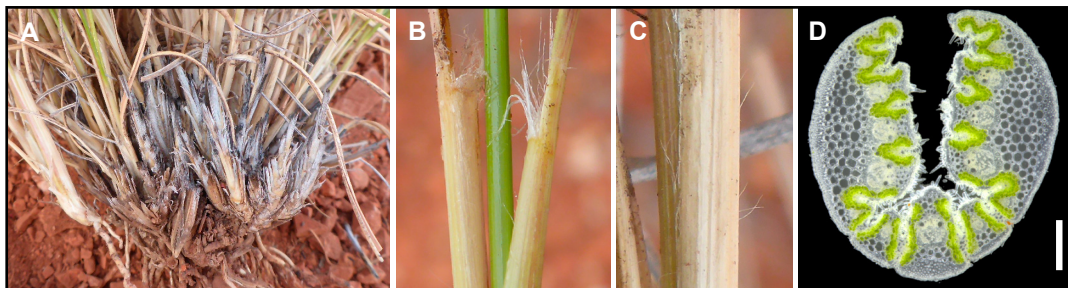

Figure 7. *Triodia veniciae*. A – base of plant burnt 2–3 years previously, showing burnt and killed culm bases on the margins, and culms that have re-sprouted post-fire in the central part; B – orifice of leaves, showing copious resin, embedding the leaf sheath hairs; C – leaf sheath indumentum, showing sparse pilose hairs that are usually present at least sparsely; D – leaf section, showing four abaxial stomatal grooves. Scale bar = 0.2 mm (D). Images from *M.D. Barrett* 5412 (B and C), and *M.D. Barrett* 5414 (D); image A is from an un-vouchered location a few km north of the location of *M.D. Barrett* 5412. Images by M.D. Barrett; images B and D modified from SᴘɪKᴇʏ (Barrett *et al*. 2017), used with permission.

Conclusions

All four species newly described here are tightly associated with specific geological substrates, highlighting an important role of niche specialisation in determining species range and intrinsic rarity in many Pilbara *Triodia*. With the species described here, the Pilbara *Triodia* flora is nearing completion, with only a single phrase-named species, *T.* sp. Mt Ella (M.T. Trudgen MET 12739), remaining without a formal name, though a full description is in Barrett and Trudgen (2018). In addition, no detailed description exists for a rare *T. longiceps* × *T. wiseana* hybrid, although features relevant to its identification are covered in Barrett *et al.* (2017). With the species described here, a total of 29 species and one hybrid are now known from the Pilbara bioregion and its immediate surrounds, more than doubling the 14 species listed from the Pilbara in the Flora of Australia treatment (Lazarides *et al*. 2005). Note that this accounting excludes three species reported by Lazarides *et al.* (2005): *T. acutispicula*, *T. bynoei* and *T. pascoeana*, which were erroneously mapped from the Pilbara based on misidentified specimens of *T. schinzii*, *T. melvillei* and *T. angusta*, respectively. If adjacent regions are included (Pilbara and Carnarvon, and western parts of Great Sandy Desert and Little Sandy Desert IBRA regions), then 14 species are endemic to this greater-Pilbara region, an endemism of 48%. Ongoing revision of some species complexes (e.g. *T. brizoides*, *T. spicata*. and *T. wiseana*) will likely further increase the endemism in the Pilbara and surrounds.

Acknowledgements

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