

***Austrostipa* (Poaceae) in Western Australia: new species, new records, keys, and character notes**

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Abstract

Williams A.R., *Austrostipa* (Poaceae) in Western Australia: new species, new records, keys, and character notes. *Nuytsia* 33: 39–101 (2022). *Austrostipa* S.W.L.Jacobs & J.Everett is a monophyletic genus of temperate Australian native grasses that occur throughout the southern part of the continent and in New Zealand. Eight new species from Western Australia are described and illustrated here, plus two newly recorded species that are range extensions from their previously known habitats in South Australia, bringing the total number of species recorded in this state to forty-four. Detailed character notes and a key to the species and the accepted subgenera are provided. The new species are: *A. anaiwaniorum* A.R. Williams, *A. burgesiana* A.R. Williams, *A. everettiana* A.R. Williams, *A. frankliniae* A.R. Williams, *A. heteranthera* A.R. Williams, *A. koordana* A.R. Williams, *A. nunaginensis* A.R. Williams and *A. turbinata* A.R. Williams. One former species (*A. nullanulla* J.Everett & S.W.L.Jacobs) has been reduced to synonymy with *A. vickeryana* J.Everett & S.W.L.Jacobs. The two species with range extensions are *A. echinata* (Vickery, S.W.L.Jacobs & J.Everett) S.W.L.Jacobs & J.Everett, which has been found at several sites around Esperance, and *A. mundula* (J.M.Black) S.W.L.Jacobs & J.Everett, which has been found in numerous small isolated coastal pockets around the south-west and up as far as Yanchep north of Perth. Five of the new species appear to be rare and isolated, including the newly discovered populations of *A. echinata* and *A. mundula*, and warrant conservation priority.

Introduction

Spear grasses in the genus *Stipa* L. occur in temperate, subtropical, and tropical mountain grasslands worldwide (Plants of the World Online). Jacobs and Everett (1996) found the Australian species to be monophyletic, based upon a combined study of molecular and morphological characters, and separated them into a new genus *Austrostipa* S.W.L.Jacobs & J.Everett. Similar conclusions were drawn by Jacobs *et al.* (2000), Romaschenko *et al.* (2010) and Bustam (2010), but more recent studies by Winterfeld *et al.* (2015) and Tkach *et al.* (2021) have not supported monophyly. *Austrostipa* is a strictly temperate genus in Australia and New Zealand. In Western Australia (WA) its species occur mostly in the south-west, from Shark Bay in the mid-north across to the Nullarbor Plain along the southern part of the border with South Australia.

The genus was treated by Everett *et al.* (2009) in volume 42A of the *Flora of Australia*, but this treatment was a summary extract from the more detailed revision of the Australian species (then *Stipa*) by Vickery *et al.* (1986) plus one new WA species (*A. geoffreyi* S.W.L.Jacobs & J.Everett) described in Jacobs

and Everett (1996). Jessop *et al.* (2006) in their *Grasses of South Australia* likewise extracted their information from Vickery *et al.* (1986) for their *Austrostipa* chapter, but they also included helpful notes from their own observations. Williams (2011) described two new rare WA species from the Swan Coastal Plain. Eight other new WA species have since been identified in collections held at PERTH and are described and illustrated here, while several character descriptions and clarifications are included that have not been published previously. A combined key to all WA subgenera and their species is provided. Herbarium abbreviations follow *Index Herbariorum* (Thiers 2014).

Methods

All specimens within the genus in the PERTH herbarium were examined morphologically in the period 2001–2003, and I continued to carry out specialist study of the collection through to 2019. Specimens that were significantly different from the published descriptions were given phrase names and all taxa were compared using the query facilities in the Intkey interface to a DELTA database (T.D. Macfarlane unpubl.) constructed from Vickery *et al.* (1986) and updated by me to reflect additions from newer collections since that time. Digital images were prepared using proprietary software Corel PhotoPaint, Helicon Focus and BeFunky, while vector illustrations and composite images were prepared using CorelDraw. IBRA 7 bioregions were taken from DSEWPC (2013).

Most of the new species described here were found to be very distinctive once the material had been adequately studied, but in two cases (the Ravensthorpe Ranges collections now known as *Austrostipa heteranthera* A.R. Williams and *A. turbinata* A.R. Williams, and the question of separate species status in *A. vickeryana* J. Everett & S.W.L. Jacobs and *A. nullanulla* J. Everett & S.W.L. Jacobs) multivariate numerical analyses were required to achieve clarity. In both cases the PAST statistical package (version 4.03, Hammer *et al.* 2001) was used, together with the Box-Cox character transformations (Box & Cox 1964) to mitigate biases in the data caused by different measurement scales and to transform each variable to an approximately Normal distribution. This allowed the data to be explored with a wide range of analytical methods. The standardised list of characters used is given in Table 1, measurements were all based on dried and usually mounted herbarium specimens, and the relevant analytical methods are listed under the appropriate sections, with details of results given in figure legends.

Important Characters

Vickery *et al.* (1986) devoted several pages to character definitions and illustrations, and Jacobs *et al.* (1996) published images and definitions of some lemma apex characters that distinguish native Australian *Stipa* from the introduced weedy species of *Nassella* E. Desv. Tkach *et al.* (2021) presented a collection of SEM images of lemma surface cells in Australasian *Stipeae* spp. which provide clarity in terminology. Some new characters were discovered in this present study, and several existing characters required clearer definition, so these are described here before the taxonomic treatment.

Habit development

The grass habit differs from most other herbs in that the apical meristem remains vestigial at the base of the plant during the early stages of vegetative growth. The first visible shoots are a series of concentric leaf sheaths that develop around, but extend above, the basal meristem, and when the meristem later elongates to form the culm, it elevates the leaf nodes (together with their sheaths and emerging leaf blades) in sequence on successively elongating internodes. One potentially useful

character arising from this developmental sequence in mature plants is whether the nodes either remain ‘enclosed’ within the preceding leaf sheath or emerge above it and become ‘exposed’ to view.

If the growing season is long enough, new lateral shoots (tillers) can arise from the base and develop in a similar manner. Each new shoot is accompanied by an adventitious root system. Some shoots can grow horizontally and produce new shoots and adventitious roots at each node to form an underground rhizome, but above-ground stolons do not occur in *Austrostipa*; and, as in all grasses, tap-roots do not form so all roots are adventitious.

Most *Austrostipa* species are perennial, in which case at least some of the vegetative growth must persist to protect the basal meristem from desiccation during the long dry season, typically from October to May in south-west WA. This is usually accomplished by culm bases persisting after flowering. In some cases, however, the dead stems can disintegrate down to soil level during the winter wet season and new stems emerge from underground in spring. Both species that have been placed in *A.* subg. *Longiaristatae* S.W.L.Jacobs & J.Everett (*A. compressa* (R.Br.) S.W.L.Jacobs & J.Everett and *A. macalpinei* (Reader) S.W.L.Jacobs & J.Everett) are exclusively annual species in WA and grow from seed each year, often only after fire, but all the new species described here appear to be perennials.

Vickery *et al.* (1986) separated the extravaginal branching condition from rhizomatous forms but did not explain the terminology they used to distinguish rhizomatous states; they also used the term ‘innovations’ for what others have called tillers. Clearer definitions relevant to present needs are provided by Briske (1991):

‘The spatial arrangement of tillers within the grass plant ... is a major determinant of architectural variation within the grass growth form (e.g., bunchgrasses versus sodgrasses). ... **Intravaginal tiller development** within the subtending leaf sheath results in a compact spatial arrangement of tillers defining the **bunchgrass** (caespitose or tussock) growth form. Contrastingly, **extravaginal tiller development** proceeds laterally through the subtending leaf sheath contributing to greater inter-tiller distance and tiller angles within the plant. Extravaginal tiller development is a prerequisite to the formation of the **sodgrass** (creeping or spreading) growth form which may be further accentuated by the development of rhizomes and stolons [emphases in original].’

Thus, a rhizome is an extension of an extravaginal branch, but an extravaginal branch does not necessarily produce a rhizome.

The term ‘sodgrass’ is somewhat misleading in much of mainland Australia where climate and habitat prevent the development of a year-round turf-like growth in perennial grasses. In virtually all places where *Austrostipa* occurs in WA, the plants are found as discrete tussocks, some with the ‘bunchgrass’ structure and some with the ‘sodgrass’ structure, because the growing season is too short, and the habitat is too variable to support the development of larger perennial swards.

Normally the aerial parts of a grass plant grow straight up when they are free to do so. When an extravaginal branch with sufficient internode length is present, new tillers are free to grow straight upwards without interference from adjacent shoots on the preceding node, so a rhizome develops. If conditions allow continued growth in this way a dense erect sward will result. However, if the extravaginal branch is too short, each new shoot must emerge at an angle until it is free of interference from adjacent shoots, after which it may bend at the first node towards vertical, thereby creating a

‘geniculate culm’. This produces a more open or spreading tussock pattern, like the usual condition with intravaginal branching.

In the intermediate case when a short rhizome is present, the angle at which new shoots emerge can be complicated by the behaviour of the culm and sheaths on the adjacent shoots. If the sheaths grow high and clasp tightly to their culms there will be little interference and a dense erect sward of tightly packed culms and tillers will result. But the presence of a short rhizome can become obscured if the culm bases are swollen, or if adjoining sheaths grow initially as multiple short cataphylls, or if they expand and/or draw back early from their culms. In all these cases, there may be sufficient interference between shoots to spread out the tussock structure. Spreading may also be exacerbated in old perennial tussocks when persistent culms or sheath bases from previous seasons remain intact and/or become infiltrated with soil or plant debris.

Four of the species included here (*Austrostipa heteranthera*, *A. turbinata*, *A. everettiana* A.R. Williams and *A. mundula* (J.M.Black) S.W.L.Jacobs & J.Everett) display the sodgrass habit, while all the species that share the nearest morphological similarity to them (*A. flavescens* (Labill.) S.W.L.Jacobs & J.Everett, *A. puberula* (Steud.) S.W.L.Jacobs & J.Everett and *A. eremophila* (Reader) S.W.L.Jacobs & J.Everett) have a fairly open tussock structure with one or more geniculate culms. The leaf sheaths in these latter species are generally short at first, sometimes producing several cataphylls, and they quickly peel back from the culms. The leaf blades emerge at an angle to the sheath, the flowering culms are conspicuously broader than the more mature tillers, and sometimes the flowering culms have a swollen base. A specimen of *A. flavescens* that displays all these features is shown in Figure 1A together with a specimen of *A. puberula* collected from the Mt Holland site (Figure 1B). In contrast, the new taxa produced densely packed tussocks consisting of erect shoots, clearly indicating the presence of a short rhizome. The leaf sheaths clasp tightly around their culms, the blades arise erectly from the sheaths, and it is difficult to distinguish between tillers, flowering culms, sheaths and leaf blades, as illustrated in Figure 1C, 1D & 1E for *A. heteranthera*, *A. turbinata* and *A. everettiana* respectively. In *A. mundula* (Figure 1F) the sheaths clasp tightly to the culms and the leaf blades arise erectly from the sheaths but in such a way that they usually produce a continuous arc across the whole blade, the sclerophyllous tissue stiffly maintaining the smooth curvature. This unique feature is quite outstanding in both the holotype of *A. mundula* and in the WA specimens assigned to this name.

Habit development was scored in multivariate analyses as a single variable where 0 = densely packed erect culms, and 1 = open structured tussocks.

Panicle structure

In most *Austrostipa* species the panicle has a conical shape, with the lower branches being the longest and the upper branches tapering towards a single apex. The internodes within the panicle axis are usually short enough for the lower branches to overlap them in the juvenile unopened state, and usually in the mature state as well (although sometimes the lowest node in the panicle can be depauperate, bearing one or more aborted spikelets on very short and undeveloped branches). Most panicles also carry dozens of spikelets. In four of the new species, however, there are only few spikelets, and on two of them (*A. koordana* A.R. Williams and *A. burgesiana* A.R. Williams), the lower nodes have their spikelets crowded together on very short branches that do not overlap the long panicle internodes. Figure 2 illustrates a range of panicle structures in WA species, which provides a context within which to evaluate the distinctiveness of the new species.

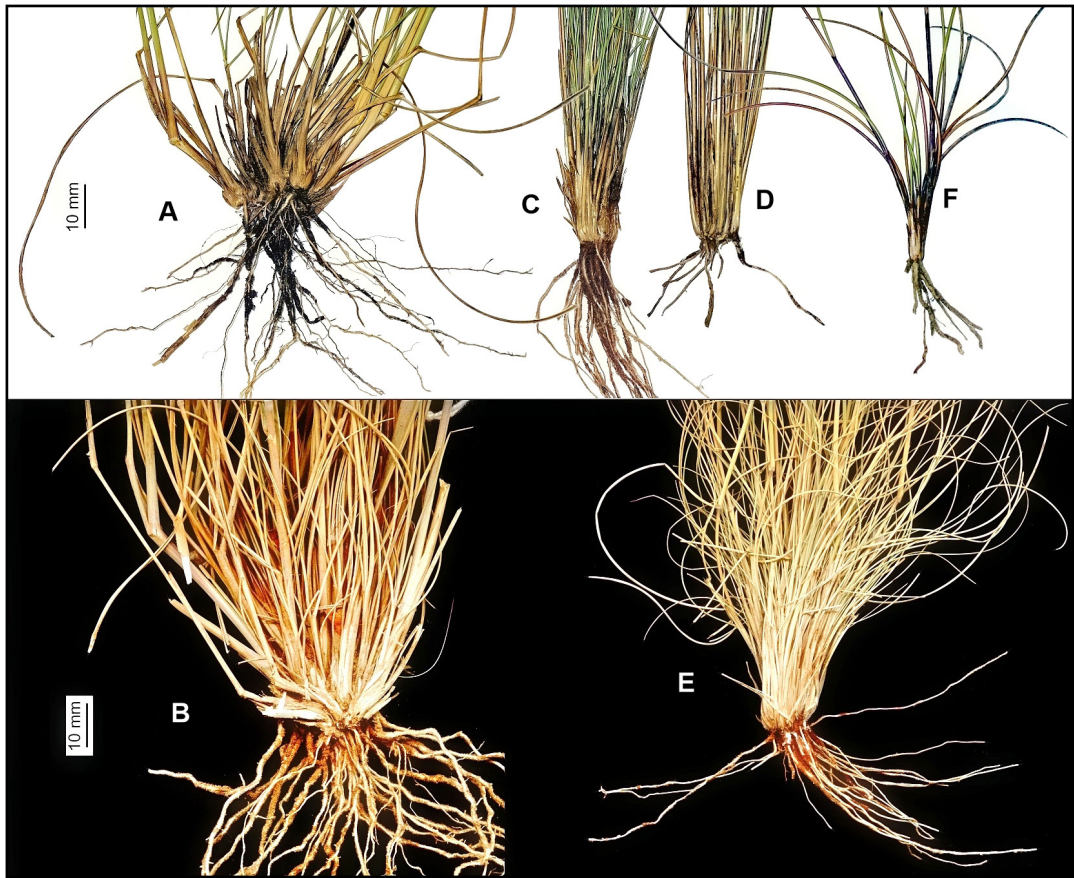


Figure 1. Tussock base variations in some new species of *Austrostipa* compared with related existing species. A & B – tussock structure open, with broad, geniculate flowering culms in A – *A. flavescens* and B – *A. puberula*; C– F – tussocks dense, with narrow and erect flowering culms in C – *A. heteranthera*, D – *A. turbinata*, E – *A. everettiana* and F – *A. mundula*. Scanned images by the author from T.E.H. Aplin 6463 (A); A. Dooley AD433 (B); A. Markey & J. Allen 6264 (C); S. Kern & R. Jasper LCH18459 (D); A. Dooley AD428 (E); G.J. Keighery & J.J. Alford 644 (F).

Austrostipa puberula has a somewhat reduced but otherwise standard panicle shape (Figure 2A), *A. pycnostachya* has many spikelets crowded together on short branches (Figure 2B), *A. trichophylla* Benth. has few spikelets on short branches distributed evenly along the panicle axis (Figure 2C), *A. geoffreyi* has many spikelets crowded on short branches but with longer basal internodes (Figure 2D) and *A. platychaeta* has few spikelets at the ends of evenly spaced long open branches (Figure 2E). *Austrostipa turbinata* (Figure 2F) is similar to *A. heteranthera* in having a much-reduced panicle with few spikelets. Both *A. burgesiana* and *A. koordana* (Figures 2G and 2H) have few spikelets on short branches but with long basal internodes. *Austrostipa elegantissima* (Figure 2I) has few spikelets at the end of long, evenly spaced, widely spreading, and unusually hairy branches; the florets remain attached to the panicle at maturity and the whole panicle acts as a single diaspore breaking off and blowing away in the wind.

It is sometimes difficult to count the actual number of spikelets on mounted specimens, so a simplified binary scale was initially used to reflect this condition: 0 = few (≤ 20); 1 = many (≥ 20). However, in the multivariate analyses the relevant species had sufficiently similar panicle branching patterns that panicle length could be used as a suitable correlate for spikelet number.

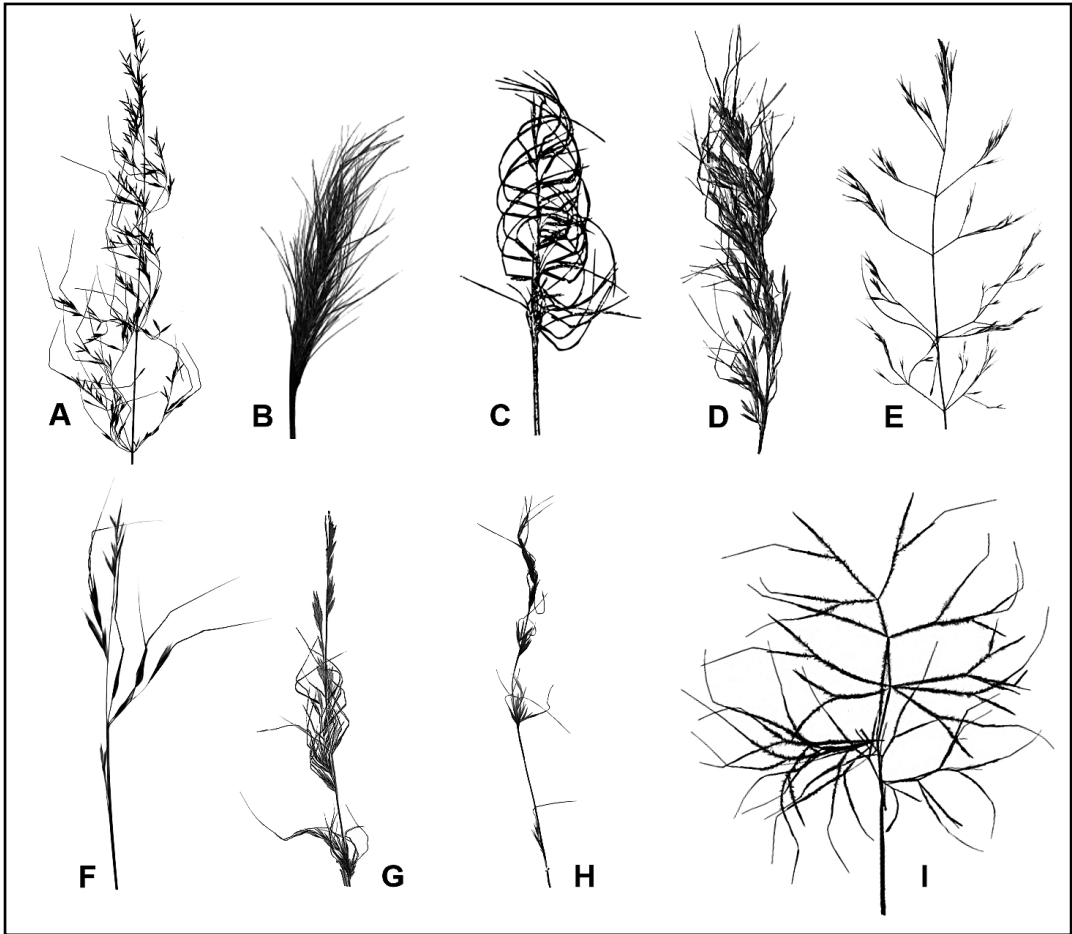


Figure 2. Panicle shape variations in *Austrostipa* (not to scale). Images were scanned from dried and pressed specimens — in life the branches are whorled around the central panicle axis. Distinctive characteristics are noted in the text. A – *A. puberula*; B – *A. pycnostachya*; C – *A. trichophylla*; D – *A. geoffreyi*; E – *A. platychaeta*; F – *A. turbinata* (*A. heteranthera* is similar); G – *A. burgesiana*; H – *A. koordana*; I – *A. elegantissima*. Images prepared by the author based on *A. Dooley* AD 433 (A); *M.N. Lyons & S.D. Lyons* 3401 (B); *K.R. Newbey* 6457 (C); *A.S. George* 10466 (D); *G.J. Keighery* 4371 (E); *A. Markey & J. Allen* 6263 (F); *A.A. Mitchell & P.J. Waddell* 10499 (G); *Anonymous* s.n. PERTH 08730202 (H); *R. Spellenberg & N. Zucker* RS 9469 (I).

Floret development

The progress of *Austrostipa* floret development and its different stages of maturation, especially anther development and the induration of the lemma and palea, was discovered to be of special significance in the identification of some of the new species. These findings also contradicted some parts of the genus description and key characters given in recent literature, notably the chapter on *Austrostipa* in the *Flora of Australia* (Everett *et al.* 2009).

Austrostipa floral anatomy is largely similar to that of grasses in general and is distinctive mainly because the single terminal awn on the lemma and the sharp callus at the base of the lemma turn the mature floret into a stiff and robust ‘miniature spear’ that in some species at least easily penetrates human clothing and animal hair.

Crucial differences begin to appear after the ‘boot’ stage when the plants’ physiology switches priority from vegetative production to seed production. Some species can be identified only when fully mature, but this is a difficult stage to catch because very soon after the floret matures it dehisces from the rachilla and falls away.

Important stages in *Austrostipa* floral development are illustrated in Figure 3. As shown in Figure 3A, a typical early-stage floret of *A. puberula* (with lemma and palea removed) has a bifid style with two lacinate stigmas and three immature anthers, of which the large green anterior one [left] develops before the two posterior ones [either side of the carpel in the image]; below these are the anterior [left] and posterior [right] lodicules. Mature lodicule number (2 or 3), size, and shape can have taxonomic value in some species, but the lodicules often adhere to the inner surfaces of the lemma and palea and are thus difficult to find when dissecting fully mature florets, so they have not been used as key characters in this study.

At anthesis, a freshly collected spikelet of *A. puberula* (Figure 3B) has all anthers equal-sized. The lodicules have swollen up and forced the lemma and palea to open, exposing the stigmas (white) and three undehisced anthers (green tinged with red). The anther filaments have elongated to ensure that when the anthers dehisce the pollen can disperse in the wind. Figures 3C and 3D (*A. juncifolia* and *A. eremophila* respectively) show two dried specimens that were collected at anthesis — the filaments have contracted due to drying but the enlarged yet undehisced anthers are now too big to fit back inside the floret.

Cleistogamy is illustrated in Figure 3E for *A. puberula*; only a single point mutation (Nair *et al.* 2010) is required to block lodicule development so that the lemma & palea remain closed. All three anthers have developed to sexual maturity without significant pigmentation, and all are shorter than those in Figure 3B (compare scale bars); they have dehisced inside the closed floret and the pollen granules (visible in the image) have probably already self-fertilised the ovary.

An aberrant anther syndrome found in three of the new species is described and reported here for the first time. A spikelet of one of the species, *A. heteranthera*, is illustrated at sexual maturity (Figure 3F). The large anterior anther has matured and dehisced inside the floret (pollen grains can be seen still clinging to the anther), resulting in self-fertilisation, while the posterior anthers have remained undeveloped as staminodes. Anthers of the other two species, *A. heteranthera* and *A. turbinata*, are illustrated in Figures 3G and 3H.

Austrostipa species generally have three opaquely pigmented anthers, all approximately the same size, and usually ≥ 2 mm long. Those in *A. juncifolia* and *A. eremophila* (Figures 3C and 3D) are typical and illustrate the dramatic difference between the aberrant and normal anther conditions. Clifford (1987) noted that the aberrant anther syndrome can occur in some species of non-Australian *Stipa* where only the anterior stamen matures, leaving the other two (posterior) stamens undeveloped and shorter, but this character had not previously been reported in *Austrostipa*.

For the multivariate analyses, anther colour was scored as 0 = colourless and/or translucent, 1 = opaquely pigmented, and anther length (mm) was scored twice — once for the longest (anterior) and once for the shortest (posterior) pair.



Figure 3. Floral development in *Austrostipa*. A – contents of a normally-developing floret of *A. puberula* at early ‘boot’ stage with the lemma and palea removed; B – A normally-developed chasmogamous spikelet of *A. puberula* at early anthesis where all organs have developed fully but have not yet sexually matured; C – dried floret of *A. juncifolia* which was collected at anthesis showing the mature but undehisced anthers still inside; D – dried floret of *A. eremophila* collected likewise at anthesis; E – the contents of a cleistogamous floret from *A. puberula*; F – aberrant anther syndrome at sexual maturity, as found in three of the new species; G – vector illustrations of re-hydrated anthers from a dried specimen of *A. heteranthera*; H – vector illustrations of re-hydrated anthers from a dried specimen of *A. turbinata*. Images A, B, E and F were prepared by the author from photographs supplied by Elizabeth Sandiford who collected and dissected fresh material from around Ravensthorpe in October 2013; EMS 145 (A); EMS 26 (B); EMS 219 (E); EMS 190 (F). Vector drawings were based on *A. Markey & J. Allen* 6267 (G) and *A. Markey & J. Allen* 6263 (H). Floret scans C and D were taken from *R.D. Royce* 6063 and *A.S. George* 8478 respectively. Scale bars are 1 mm in A, E and G, H; and 5 mm for B, C and D.

Floret induration

As a general principle, plants grow via cell divisions in specialized meristem regions. Parent meristem cells divide into two halves, each of which then elongates in a direction orthogonal to the plane of division to restore their previous size. As new cells move out of the meristem region, they elongate further until they reach their adult size and, finally, they differentiate into their adult form (which depends upon their position within the plant). The cell walls in the developing *Austrostipa* floret

are flexible enough to enable this growth to occur by having their cellulose fibres elongate through the polymerization of new monomers into their growing regions during the elongation phase. Once maturity is reached, however, the cellulose walls harden to provide a rigid structure that protects the seed during dispersal.

However, hardened cellulose walls only produce things like chaff, leaves, and grass stalks, while the mature *Austrostipa* floret is as hard as the hardwood in a forest tree! Not surprisingly perhaps, the cause is the same in both cases. Rigidity in the mature *Austrostipa* 'spear' is achieved via progressive lignification of the cellulose cell walls (Barossy *et al.* 2015) which thereby also prevents any further cell growth, and its rigid spear-like structure provides specifically directed assistance to its dispersal function. The freely-falling mature floret is easily displaced and carried away via contact with animals; its barbed point strengthens its hold on such animal vectors; when it falls to the ground the weighted point aids in reaching towards and penetrating the soil; when damp conditions arise, the twisted column absorbs moisture and expands, causing it to unwind, and this twisting action 'drills' the pointed diaspore into the ground and assists in promoting germination. Genuiculate and twisted awns like these are more successful in dispersal and burial in soil than straight awns (Cavanagh *et al.* 2019).

Observations during this study indicated that there is a standard sequence of tissue lignification during floret maturation and understanding this sequence is a useful aid to identification. The base of the floret (above the stipe) hardens first around its outer margins to provide strong points of attachment for the lemma and palea, but the inner region retains functional vascular tissue to allow the free flow of nutrients and moisture to promote development of the sex organs and the caryopsis on the inside. Then the outer surfaces of the lemma and palea harden before their inner surfaces, and this provides protection from desiccation while the caryopsis matures and expands to its full size. Last of all the caryopsis swells and hardens at maturity. When the floret is fully mature the vascular bundles in the stipe are sealed off at a sharp angle, a layer of spongy mesophyll develops in the abscission zone, the vascular supply vessels in the rachilla are sealed off, and only a small amount of force is then required to break the spongy tissue and release the mature floret from within the glumes. The sharp angle of abscission results in a sharp point, called the callus, on the end of the 'spear.' Only in the group that has been named *A.* subg. *Petaurista* S.W.L.Jacobs & J.Everett do the florets remain firmly attached to the panicle, which breaks off at maturity from its subtending culm and the whole panicle becomes the dispersal unit (diaspore).

Important stages in floret and awn induration are illustrated in Figure 4. Figure 4A shows an abundantly flowering panicle where the awns are all approximately straight and easily recognizable in the field. Figure 4B shows a typical young green *Austrostipa* floret (without hairs) showing the lemma, palea, stipe, collar, and three-cornered (triquetrous) awn. Figure 4C shows two typical mature lemmas with twisted awn columns (in *A. nunaginensis* and *A. blackii*). Figures 4D and 4E show a mature chasmogamous floret of *A. eremophila* (with hairs scraped off), showing the exposed palea (now known to be the dominant mature condition within the genus) and the position at the base of the lemma (circled) where lignification begins (4D), and the cross-section shows the lemma and its relation to the palea (4E). Figures 4F and 4G illustrate a cleistogamous floret of *A. vickeryana* (without hairs), showing how the lemma completely encloses the palea (4G); the position at the base of the lemma where lignification begins (circled) shows that early growth of the lemma begins with diverging margins which subsequently converge again to cover the palea (4F). It is worth noting here that the chasmogamy/cleistogamy distinction in *Austrostipa* is caused by the function or failure, respectively, of the lodicules and not by the exposure or closure of the lemma around the palea.

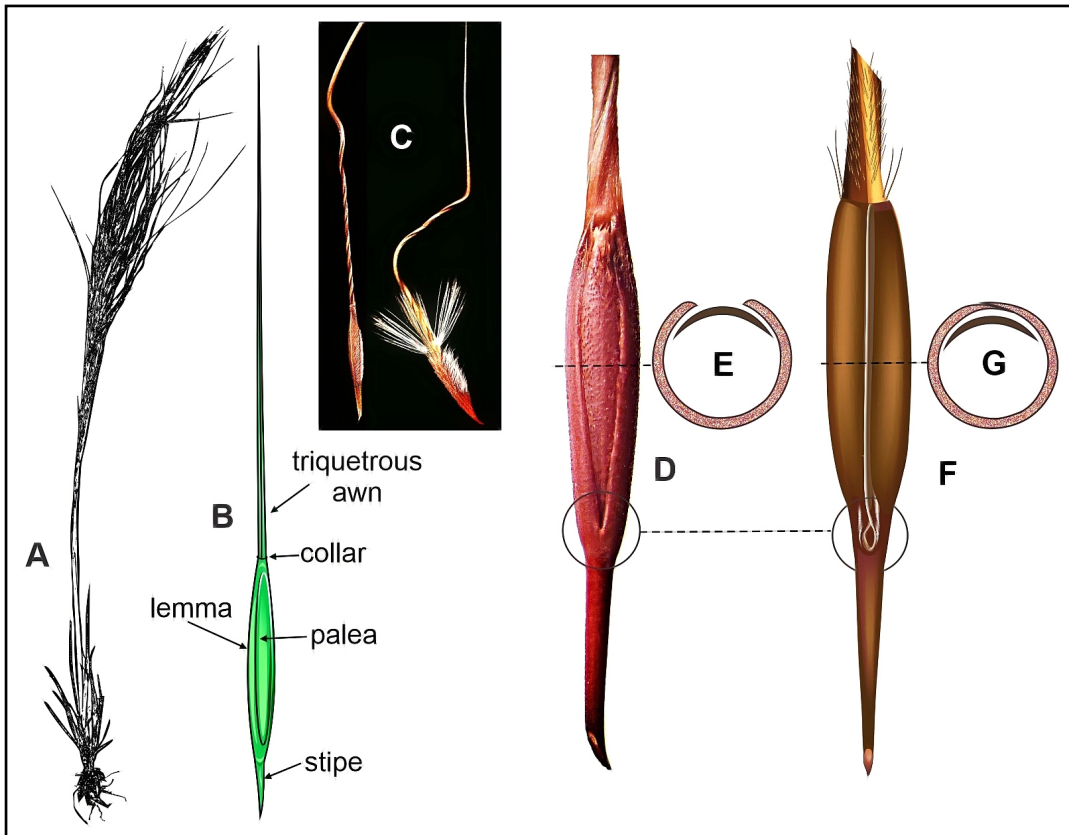


Figure 4. Important stages in floret and awn induration. A – immature green *Austrostipa* plant (vector outline of *A. compressa*); B – schematic diagram of a generic immature green *Austrostipa* floret; C – two mature florets showing brown colours resulting from lignification and twisting of the awn column; D – photograph of a typical mature chasmogamous floret (*A. eremophila*), scraped clean of hairs, showing the exposed palea and the lemma margin opening at the base (circled); E – schematic cross-section of the lemma and palea; note the obtuse edge of the lemma margin; F – vector drawing of a cleistogamous floret (*A. vickeryana* without hairs); the palea is entirely enclosed within the overlapping lemma margins, which are initially open at the base and subsequently closed (circled); G – schematic cross-section of the floret showing the tapered lemma margins fully enclosing the palea. Illustrations and photographs by the author from N. Hoyle 977 (A), M.E. Trudgen MET 21176 (C, left), T.J. Read 5147 (C, right), T.E.H. Aplin 1662 (D, E), W. O'Sullivan WOS303 (F, G).

A matter of practical consequence for identification to species level is that in the south-west of WA the peak wildflower season is in September, a time of year when *Austrostipa* plants are still quite immature. Such immature plants are often collected, however, because the panicle with its collection of ‘spears’ is distinctive even when green and the awns are still straight. When such specimens are dried the awns usually twist along the column and curl along the bristle (if relevant) into their mature shapes, and the question arises as to whether these immature specimens are at all useful for identification purposes, or whether they give universally misleading results.

Because elongation of newly divided cells is mostly parallel to the long axis of the floret, and because hairs generally elongate outwards from the epidermis in similar manner, it seems safe to suggest (and consistent with my experience) that the length of the lemma and awn, and the length of hairs, may be reasonably reliable guides to the mature state by the time the panicle emerges from within the flag-leaf sheath. In contrast, however, the condition of the lemma and its relation to the palea can be entirely misleading in this immature state — such determinations can only be made on mature material collected late in the growing season (usually November or December) just before seed-fall.

In most species and collections of *Austrostipa* at PERTH, and in loan material from other Australian herbaria, the lemma margins overlap and completely enclose the palea, and this is used as a defining character of the genus in the *Flora of Australia* (Everett *et al.* 2009). In contrast, however, an outstanding feature in one of the new species (*A. everettiana*) was that the lemma indumentum was sparse enough (in the recently collected, pressed, and dried specimen which I examined) to clearly reveal that the lemma margins were drawn back to expose the palea, a defining character previously found only in *Austrostipa lanata* (Vickery, S.W.L.Jacobs & J.Everett) S.W.L.Jacobs & J.Everett. But when I re-examined this new material several months later the exposed paleas had disappeared because the lemma margins had closed in around them. Further drying of the material in the controlled conditions of the Herbarium had apparently created the overlapping lemma condition as an artefact of two compounding factors: (1) the initial collection of *A. everettiana* was immature, even though lignification of the outer lemma and palea surfaces had begun; and (2) the reproductive components inside the floret continued to dry and shrivel for about a year after collection. Consequently, when mature specimens were collected late in the following growing season the exposed palea condition remained a constant feature because the hardened caryopsis now completely filled the floret interior.

In many other species, in contrast, the lemma indumentum is so dense that it obscures the lemma margins in relation to the palea. A survey was therefore carried out on selected immature and mature florets from all subgenera, and the hairs were scraped away with the side of a sharp scalpel blade to expose the lemma margins. This revealed a consistent pattern — in at least some species within all groups (except *Petaurista*) the lemma margins were drawn back to expose the palea in mature specimens, but they entirely enclosed the palea in immature specimens. In particular, the four subgenera listed in the *Austrostipa* key in the *Flora of Australia* (Everett *et al.* 2009) as having overlapping lemma margins (*Eremophilae* S.W.L.Jacobs & J.Everett, *Lancea* S.W.L.Jacobs & J.Everett, *Longiaristatae* and *Ceres* S.W.L.Jacobs & J.Everett) all displayed non-overlapping lemma margins in mature specimens (except for the newly described *Austrostipa turbinata* in *Eremophilae*).

This discovery requires two corrections to the *Austrostipa* chapter in the *Flora of Australia* (Everett *et al.* 2009). First, overlapping lemma margins should be removed from being one of the defining characters of the genus. Second, the subgenus key Couplet 9 on p.16 is no longer correct because it makes a contrast between ‘lemma margins not overlapping’ which separates *A. subg. Aulax* S.W.L.Jacobs & J.Everett, and the alternative ‘lemma margins overlapping’ which separates *Ceres*, *Longiaristatae*, *Lancea* and *Eremophilae*, all four of which are represented in the PERTH collection and most species in them contradict this description.

The geometry of the lemma margins involved in palea exposure is of an entirely different kind to the temporary divergence of the lemma and palea during anthesis — which is due to the swelling of the lodicules to expose the sex organs to fertilisation. Nor is it a late-appearing divergence produced by the swelling of the maturing caryopsis which could theoretically force the lemma margins apart. The circled regions in Figures 4D and 4F illustrate this point. In Figure 4D the lemma margin curvature that creates the obovate opening to expose the palea begins smoothly from the saddle-shaped opening at the top of the callus. In Figure 4F there is a similar saddle-shaped opening at the top of the callus, but the lemma margins then curve back again to create a complete covering for the palea. This geometry suggests that palea exposure is perhaps the more primitive feature.

These results show that there is a chronic difficulty in studying herbarium specimens of *Austrostipa* because a large proportion of them have immature florets. This is not the result of inadequate collection expertise or methodology but rather of the fact that *Austrostipa* florets generally fall from their spikelets very soon after the caryopsis matures. An immature plant that still has its distinctive spear-shaped

florets intact is easy to see in the field and clearly differentiates it from most other grass genera, but after the mature florets have fallen the plants become very much less conspicuous, and because they are now also incomplete (i.e., lacking their florets) they are much less likely to be collected as voucher specimens.

Lemma surface texture and indumentum

Lemma surface texture and indumentum are important characters for distinguishing species and some illustrations and clarifications of terminology are required. Vickery *et al.* (1986) described the lemma surface throughout the genus as varying from ‘quite smooth’—for which their exemplar was *Austrostipa lanata*, illustrated with an SEM image—to ‘almost crystalline or granular’ which they illustrated in two other species ([*A.*] *ramosissima* (Trin.) S.W.L.Jacobs & J.Everett, and [*A.*] *pubescens* (R.Br.) S.W.L.Jacobs & J.Everett), where they described the surface features as ‘tubercles.’ They chose the latter term as the basis for the name of their *A.* subg. *Tuberculatae* S.W.L.Jacobs & J.Everett, which contains species having these lemma surface features (Jacobs & Everett 1996). Their key characters for this subgenus were listed as ‘Lemma glabrous only in the top half, the glabrous portion rough, tuberculate or ‘crystalline’ (with individual small bumps or ridges of translucent silica).’

Jessop *et al.* (2006) published drawings that included the lemma shoulder region in *A. oligostachya* (Hughes) S.W.L.Jacobs & J.Everett and *A. pubinodis* (Trin. & Rupr.) S.W.L.Jacobs & J.Everett, two species within subg. *Tuberculatae*, showing smoothly rounded bumps in the former species (their Figure 50) and bulbous-based scabrous hooks in the latter (their Figure 51).

Bustam (2010) used six micro-morphological characteristics of the lemma in her study of the subgenus structure within *Austrostipa*, and these included what she described as ‘hooks’ and ‘silica bodies’ that presumably refer to the same features illustrated in Vickery *et al.* (1986) and Jessop *et al.* (2006). Bustam (2010) included three species from subg. *Tuberculatae* in her study but found that micro-morphological characters could not be matched to subgenus structure in general; however, they are usually consistent in florets across panicles and clearly distinguish between individual species, and obviously they set species in subg. *Tuberculatae* apart from all others.

Tkach *et al.* (2021) recently presented a collection of SEM images of lemma surface cells in Australasian *Stipeae* spp. which are of assistance in clarifying what earlier authors have described in words. They distinguished five different surface features: long cells (which make up most of the lemma surface), silica cells, cork cells, hooks (tubercles with a curved apical hair) and macro-hairs.

In my studies of specimens at PERTH I found that there are usually some visible features of the cellular sub-structure of the lemma surface at 40× magnification even in species with ‘smooth’ lemma surfaces such as *Austrostipa lanata* and *A. vickeryana*, and sometimes these mature and lignified surfaces can be described as ‘shiny’ or even ‘glossy’. However, there is nothing else like the newly described *A. burgesiana*, which has smoothly rounded bumps all over the sparsely haired main body of the lemma, some further excrescences around these bumps, tuberculate hairs, and tuberculate scabrous hooks in the otherwise glabrous shoulder region, so it clearly belongs in subg. *Tuberculatae* (Jacobs & Everett 1996) which has no other representatives in WA. The ‘translucent silica’ associated with all these surface features in subg. *Tuberculatae* is laid down on top of the lignified floret cells, as is evidenced by the damage caused by scraping the surface with a scalpel blade, so it must have been excreted from the surface cells either before or during the process of lignification. Furthermore, the ‘glossy’ surface in this case is almost mirror-like in reflecting strong light, and the translucent surface

coating of silica visibly sits on top of the lignified cellular surface. Based on Tkach *et al.* (2021) it seems likely that this glossy silica covering is produced by the ‘silica cells’ that are scattered amongst the lignified ‘long cells’.

Figure 5 illustrates important features of the lemma surface, with special attention also given to the differentiation in the indumentum between callus and lemma, as well as special features of the shoulder and neck regions of the lemma. Points to note in each case are given in the figure legend.

The technique of removing hairs from the lemma surface by scraping with the side of a sharp scalpel blade can reveal important properties of the indumentum. Normal lemma hairs can be removed entirely at their base, leaving the lignified lemma surface smooth and undamaged. The dislodged hairs

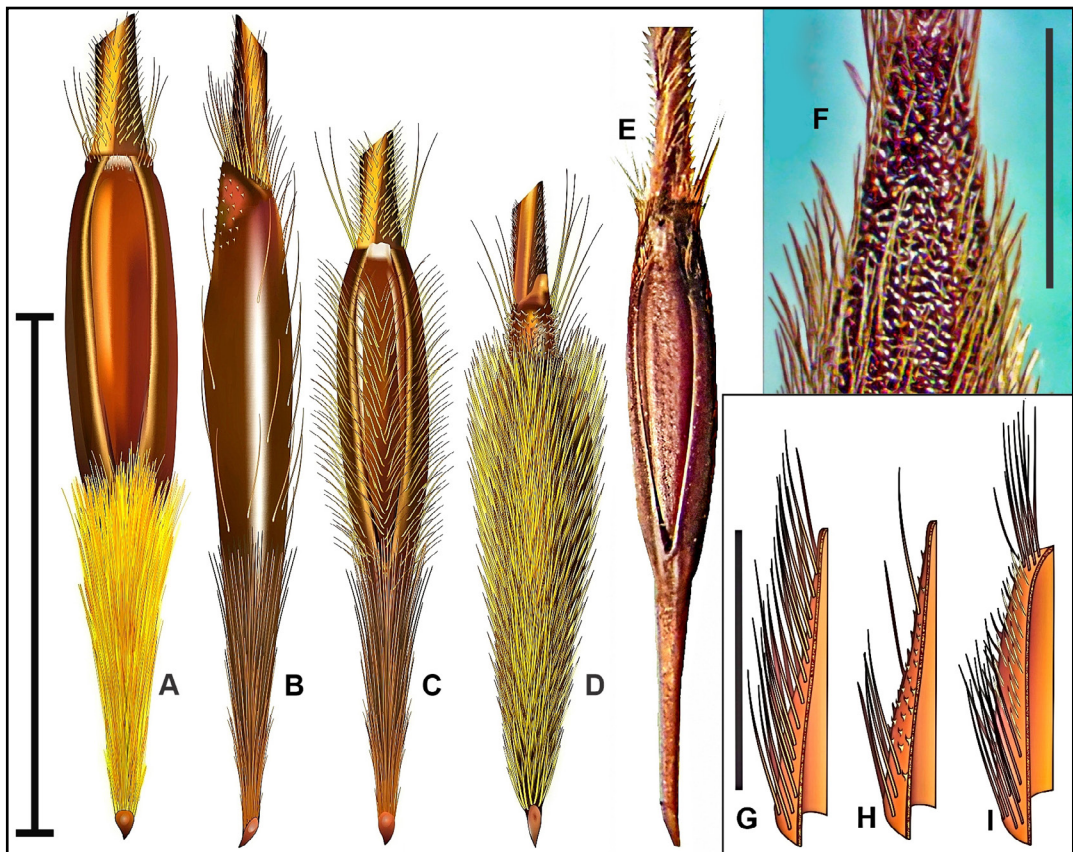


Figure 5. Lemma surface, indumentum, and shoulder ornament variations in *Austrostipa*. A – lemma and palea entirely glabrous (*A. lanata*, adaxial view) with hairy callus; B – lemma sparsely indumented with mostly non-overlapping hairs and scabrous shoulder region (*A. vickeryana*, lateral view); C – lemma and palea with overlapping hairs sparse enough to reveal underlying detail (*A. everettiana*); D – lemma and palea covered with hairs so dense that underlying detail is obscured, lemma and callus hairs are not differentiated, and shoulder region has a ‘shorn’ patch of hairs (*A. puberula*); E – photo of typical lemma and palea scraped clean of hairs showing smooth matte brown lignified surfaces undamaged by scraping (*A. everettiana*); F – tuberculate lemma surface where the glossy tubercles are fragile and shatter on scraping (*A. burgesiana*); G – schematic lemma shoulder section with continuous covering of even-length hairs; H – lemma shoulder section with scabrous patch that includes some normal-length hairs; I – lemma shoulder with clearly-defined patch of short ‘shaved’ hairs. Scale bar for florets is 5 mm, and for shoulder ornaments is 1 mm. Illustrations and images by the author based on *D.W. Goodall* 2705 (A); *W. O’Sullivan* WOS 303 (B); *A. Dooley* AD428 (C, E); *A.S. George* 10494 (D, I); *A.A. Mitchell & P.J. Waddell* 10499 (F); *A.M. Markey & J. Allen* 6267 (G); *K.R. Newbey* 11429 (H).

are essentially all the same, with no thickening at the base, nor any fragments of bulbous bases still adhering to them. In contrast, when the same scraping technique is applied to the lemma surface in subg. *Tuberculatae* it dramatically disrupts the tubercle bases. The lemma surface is left with ruptured tubercle bases all over the scraped surfaces, and the dislodged hairs are not all the same because at least some of them retain various amounts of tubercle fragments at their bases (see also Figure 18).

The same scraping technique can be used to distinguish between scabrous trichomes and the ‘shorn patch’ of hairs on the lemma shoulder in subg. *Eremophilae*. Normal lemma hairs grow up through the epidermis and are smoothly removed by the scalpel blade, leaving only the cut stub on an otherwise undamaged lemma surface, but scabrous trichomes are made of silica and have a broad thorn-like base attaching them to the lemma surface and the scraping technique disrupts these bases and leaves a scarred surface afterward.

Lemma surface indumentum especially requires clarification in distinguishing between the subgenera *Eremophilae* and *Lancea*, where the distinguishing feature is the presence or absence (respectively) of a short patch of ‘shorn’ hairs on the shoulder of the lemma. The definitions given in Vickery *et al.* (1986) and Jessop *et al.* (2006) are ambiguous and have two potentially different interpretations. In subg. *Eremophilae*, for example, the ‘shorn patch’ of shoulder hairs is said to be distinguished by an abrupt change in hair length, but it can also be ‘glabrous to scabrous’ in *A. puberula*. The glabrous state is potentially indistinguishable from a patch where hairs are merely ‘sparse’ as described for *A. mundula* and *A. flavescens* in subg. *Lancea* and the ‘scabrous’ and ‘shorn’ conditions could be difficult to distinguish from hairs that were merely ‘short’ compared to other parts of the lemma. Jessop *et al.* (2006) cited difficulty in separating subgenera *Eremophilae* and *Lancea* on their published descriptions, and in separating *A. eremophila* from *A. puberula* in size, and *A. eremophila* from *A. flavescens* regarding the lemma shoulder condition.

After an extensive examination of WA specimens in both subgenera, a distinctive separation between the two was formulated as follows:

- In subg. *Lancea*, the standard condition of the lemma is an even covering all over of long hairs (Figure 5G, note that *Austrostipa crinita* (Gaudich.) S.W.L.Jacobs & J.Everett has hairs of increasing length in the shoulder region which thereby create a ‘false coma’). In some species, and perhaps then only in some florets within a panicle, there may be a sparse patch near the lemma apex which exposes the lemma surface, and this is sometimes scabrous, where trichomes are usually ≤ 0.1 mm long, but it intergrades to at least some degree amongst the long hairs (Figure 5H).
- In subg. *Eremophilae*, every floret in the panicle bears a clearly defined ‘shaved’ or ‘short patch’ of hairs in the shoulder region below the apex. The short hairs are not sparse but of similar density to the surrounding longer hairs, and there is an abrupt and clear transition from long to short hairs around the edges of the patch (Figure 5I). This patch of hairs does not usually encircle the whole shoulder region but generally occupies only a limited dorsal portion on the abaxial side.

Some distinctive specimens of *A. eremophila* from the Nullarbor Plain have some unusual hairs that are inflated above their normal-sized bases, both in the ‘shaved’ shoulder region and in their coma. In the ‘shaved’ shoulder region some of these hairs look like tiny balloons, taking on the shape of a prolate spheroid because they are so short, and in some specimens, they lack pigment and are opaquely

white in contrast to the dark brown hairs on other parts of the lemma. And because they are attached to the lemma only by a standard-sized base they readily ‘pop’ off and fly away when scraped with the flat side of a scalpel blade. The hairs of the coma are also inflated to a similar diameter as those in the shaved region, but they are much longer and have the normal brown pigmentation and are translucent. The body hairs of the lemma in these specimens are otherwise typical of the genus, although unusually dark brown and distinctively shorter than in specimens found elsewhere. Furthermore, the lemma surface over the whole of the ‘shaved’ patch has a distinctive loss of pigmentation and appears whitish rather than dark brown. I chose not to recognize these characteristics as constituting a distinct taxon because I came across both specimens and individual florets that had intergrading characteristics. These specimens as a group are, however, worthy of further study.

Allocation of specimens into subgenera *Eremophilae* and *Lancea* can be difficult on other grounds, as Jessop *et al.* (2006) noted for some of their specimens from South Australia, so the multivariate study data on relevant members of both subgenera were combined, and the shoulder ornament states were scored as 0 = even or sparse hair covering, and 1 = distinctive shorn patch. Lemma hair differentiation was also scored as 0 = absent (e.g., no visible difference between the callus and lemma surface above it), and 1 = present (visible difference in hair presence, length, or orientation above the callus).

Cleistogamy

While Vickery *et al.* (1986) did not record the occurrence of the aberrant anther development syndrome and its consequent different-sized anthers, they did note that cleistogamous spikelets were commonly observed alongside chasmogamous spikelets within a single panicle, and that the cleistogamous spikelets usually had smaller anthers. *Austrostipa puberula* is usually cleistogamous, having three dwarfed and colourless anthers that are all fertile, while its near relative *A. eremophila* is chasmogamous and has three large, and fully fertile, pigmented anthers. Cleistogamy, colour loss, and aberrant anther maturation are probably independent developmental events, but they coincide in two of the new species (*A. turbinata* and *A. frankliniae* A.R. Williams).

Perennial grasses are usually chasmogamous, which maximizes their ability to spread their wind-borne pollen. Groves and Whalley (2002: 164) highlighted the role of cleistogamy as follows: ‘Self-fertilization retards gene flow between populations and facilitates spatial differentiation. ... Cleistogamy is, therefore, a mechanism for ensuring self-fertilization and the resulting high degree of structuring of genotypic frequency, increasing the frequency of genotypes adapted to local environments.’ The joint occurrence of cleistogamy, colour loss, and aberrant anther development suggests a unique adaptation to a particular local environment and thus a limited geographical range, which both of these species display.

One practical consequence of cleistogamy is that the anthers always remain inside the floret. As the spikelet matures, the anthers therefore become squashed up inside the lemma apex by the expanding caryopsis. In my experience, no cleistogamous floret has ever contained the squashed remnants of originally long and pigmented anthers; any squashed anthers have always been unpigmented (white in the dried condition, becoming translucent when rehydrated).

Since cleistogamy is the more unusual outcome in this combination of features it was scored as: 0 = absent; 1 = present; and non-overlapping lemma margins were not included as a separate character in multivariate analyses.

Sclerophyllous leaves

The Hughes (1921) revision of Australian *Stipa* included a study of leaf cross-section anatomy. While it was not found to reflect the perceived phylogenetic structure of the genus at the time, it did ‘add frequently to the distinctiveness of the species.’ One distinctive leaf type of interest in this study is the ‘sclerophyllous’ leaf. Hughes described it as having ‘a continuous sclerenchymatic hypoderma on both sides and strong percurrent girders, mesophyll much reduced.’ Morphologically it appears tightly rolled or folded, and the external (abaxial) surface is hard, rounded, stiff, smooth, and usually glabrous. In my experience, it only attains the fully indurate state at maturity, with some dried specimens containing younger leaves that have shrivelled, or (rarely) the blades may have been pushed outwards at the collar region by transiently swollen auricles. At maturity however, these auricles are resorbed, the ‘percurrent girders’ strengthened, and the leaf blades are back in the vertical position with the sheaths and blades permanently re-aligned, erect, hard, smooth and rounded.

Vickery *et al.* (1986) did not continue Hughes’ usage of this character, nor has it appeared in subsequent literature on *Austrostipa*, although it has important value in non-Australian *Stipa* as referenced here under the treatment of *A.* subg. *Lanterna* S.W.L.Jacobs & J.Everett. I also found it to be an extremely distinctive leaf type in the PERTH collections. It occurs in all species within *A.* subg. *Lobatae* S.W.L.Jacobs & J.Everett, and in all specimens of *A. pycnostachya* (Benth.) S.W.L.Jacobs & J.Everett, an endemic WA species in *A.* subg. *Falcatae* S.W.L.Jacobs & J.Everett. In the present study it occurs in both new species from the Ravensthorpe Ranges (*A. heteranthera*, *A. turbinata*), in the new record of *A. echinata*, and in *A. mundula* with its distinctively curved leaves. Vickery *et al.* (1986) distinguished *A. mundula* from *A. exilis* in having erect versus flexuose leaves, respectively, but this distinction is invalid because they failed to recognize leaf sclerophylly as a distinctive character, and they failed to recognize the smoothly curved single arc in the sclerophyllous leaves on the type specimen of *A. mundula* as a distinctive characteristic. The flexuose (wavy) leaf condition in *A. exilis* is due to its lack of sclerophyll so it is not restricted to the single-arc smooth curve seen in *A. mundula*.

Leaf sclerophylly was scored as 0 = absent, 1 = present in erect form, 2 = present in curved form, the latter distinction being justified on the grounds that linear sclerophyllous growth is mechanically simpler to achieve than smoothly integrated curved growth as observed in *A. mundula*.

Table 1. List of the 30 characters used in the multivariate study, with their scoring methods.

Character	Units or States
Habit	0 = densely packed erect culms; 1 = open tussock
Culm height (including inflorescence)	mm
Culm width above the base	mm
Basal leaf sheath width	mm
Leaf blade length	mm
Leaf blade width (dry specimens)	mm
Leaf blade abaxial indumentum	0 = absent, sparse, or rare; 1 = well developed & common
Leaf blade sclerophylly	0 = absent; 1 = present, erect; 2 = present, curved
Panicle length	mm
Lower glume length	mm
Upper glume length	mm

Character	Units or States
Lemma length	mm
Lemma hair density	1= sparse, exposing the palea; 2= dense, concealing the palea and lemma surface
Lemma hair colour at maturity	0 = white; 1 = various shades of brown
Lemma hair length	0 = undifferentiated; 1 = differentiated at callus
Lemma shoulder characteristics	0 = sparse or evenly indumented; 1 = distinctly 'shaved'
Palea margins	0 = matte; 1 = glossy
Cleistogamy	0 = absent; 1 = present
Callus length	mm
Awn length	mm
Column length	mm
Column length to 1st bend	mm
Column width above the base	mm
Column hair length	mm
Longest anther length	mm
Shortest anther length	mm
Short anther fertile	0 = no; 1 = yes
Anther colour	0 = not pigmented; 1 = opaquely pigmented
Long anther penicillation	0 = none; 1 = few to many
Caryopsis length	mm

Taxonomy

Jacobs and Everett (1996) divided the genus into thirteen subgenera, eleven of which contain WA species. Several attempts have been made to critically assess this subgenus structure using molecular sequences, chromosome numbers, and micro- as well as macro-morphological data. Bustam (2010) concluded that her molecular and micro-morphological data did not 'contain enough information for analyses at subgeneric level.' Syme *et al.* (2012) suggested from analyses of nuclear ribosomal ITS sequences that subg. *Eremophilae* should perhaps be included in subg. *Austrostipa*. Another study by Syme (2012) showed strong phylogenetic support for recognizing subgenera *Austrostipa*, *Falcatae*, and *Lobatae*, and strong support for joining *Bambusina* and *Petaurista*, while other subgenera including *Eremophilae* had mixed phylogenetic origins (*Lancea* was not represented).

Winterfeld *et al.* (2015) used cytogenetic data mapped onto molecular phylogenetic trees based on nuclear ITS and chloroplast 3' *trnK* DNA sequence data and found widespread polyploidy and hybrid speciation as well as evidence of paraphyly in the genus. They found four 'strongly supported' lineages within *Austrostipa*: Clade 1 (subg. *Lobatae*), Clade 2 (subg. *Falcatae*), Clade 3 (subg. *Arbuscula*, *Bambusina*, and *Petaurista*), and Clade 4 (subg. *Austrostipa*, *Ceres*, *Lancea*, *Tuberculatae*). They concluded, however, that the cytogenetics of *Austrostipa* is evolutionarily still unstable and much more work is required.

Tkach *et al.* (2021) used molecular phylogenetics, micromorphology and cytogenetic data and likewise found clear evidence of hybrid speciation and polyploidy within *Austrostipa*. Their analyses did not clearly support the monophyly of the genus and they tentatively suggested the inclusion of subgenera *Ceres*, *Eremophilae*, *Lancea*, *Lanterna*, and *Tuberculatae* into an expanded *Austrostipa* subgenus with the following qualification: ‘This suggestion, however, should not be interpreted as attempt to supersede traditional morphology-based by molecular phylogenetic taxonomic concepts. It is rather a contribution to obtain monophyletic taxa, which can serve as reliable units addressing questions about character evolution and/or biogeography in *Austrostipa*, which have been barely touched upon to date.’ They also erected a new monospecific subgenus on their evidence (*Austrostipa* subg. *Paucispiculatae* Röser, Tkach & M.Nobis), with the type species *A. muelleri* (Tate) S.W.L.Jacobs & J.Everett. This species does not occur in WA.

The crucial issue in alpha taxonomy, which is the concern of this present study, is to know which morphological characters provide the best indicators of historical diversification, so hypotheses about historical diversification can legitimately be used to suggest which might be such morphological indicators. If we accept the four ‘strongly supported’ clades of Winterfeld *et al.* (2015) and include subg. *Eremophilae* and *Lanterna* in Clade 4 as suggested by Tkach *et al.* (2021) then we could reduce the number of subgenera in WA to five as follows:

ARBUSCULA (*Arbuscula*, *Bambusina*, *Petaurista*) – this group highlights the combination of branching culms and robustly rhizomatous root systems.

AUSTROSTIPA (*Austrostipa*, *Ceres*, *Eremophilae*, *Lancea*, *Lanterna*, *Tuberculatae*) – this group brings together the perennial, caespitose, herbaceous habits, with twice bent awn columns, and mostly non-saline habitats.

FALCATAE – this group highlights the role of awn shape differences (falcate versus twice bent).

LOBATAE – this group highlights the move to saline habitats (endemic to south-west WA only) and the associated development of a rush-like habit in culms, leaves, and tillers.

LONGIARISTATAE – this group highlights the annual versus perennial habit.

Would such an arrangement add anything of substance to our understanding of the genus? It is simpler, and thus easier to comprehend as a possible reflection of the historical diversification of the genus, and it does suggest ways in which future studies might be able to find causal links, or at least correlations between, the molecular/chromosomal data and the morphological data. However, all authors acknowledged uncertainty in their conclusions, significant methodological criticism exists (e.g. Alvarez & Wendel 2003; Krawczyk *et al.* 2017), and this annotated list is nothing more than my personal *post hoc* attempt to rationalize their results. Much more research is yet required to produce a definitive result. Nevertheless, as an interim guide for the benefit of future research I have included a key to these newly suggested subgenera below, and the main key to the species is arranged according to the same subgenus structure.

In the case of the separation of *A. anaiwaniorum* A.R. Williams from *A. tenuifolia* (Stued.) S.W.L.Jacobs & J.Everett, a re-circumscription of *A. tenuifolia* is given. New and revised descriptions of both *A. vickeryana* and *A. lanata* are given because many new collections have become available since

the original descriptions were formulated and because of the reduction of *A. nullanulla* to synonymy with *A. vickeryana*.

Key to a revised subgenus structure among *Austrostipa* in WA

1. Culms of mature plants usually branched at the nodes; nodes and auricles usually glabrous, ligules > 1 mm long, glabrous; nodes exerted well above the lower leaf sheaths; mature root system robustly rhizomatous; panicle branches glabrous, scabrous, or conspicuously hairy and may be strongly divergent from the panicle axis; awns straight or once bent at maturity, or weakly falcate (if strongly falcate then the bristle is conspicuously flattened)..... subg. **ARBUSCULA**
- 1: Culms of mature plants unbranched at the nodes; auricles often hairy, ligules < 1 mm long (except *A. pycnostachya*); nodes glabrous to densely sericeous, often concealed by the leaf sheath from a lower node; mature root system caespitose; panicle branches glabrous or scabrous, not strongly divergent from the panicle axis; awns twice bent or falcate at maturity
2. Awn column straight, bristle clearly falcate; lemma hairs white at maturity (reddish-brown in *A. frankliniae*) 2. subg. **FALCATAE**
- 2: Awn column twice bent, bristle straight; lemma hairs white, or turning brown at maturity
3. Plants annual; tussocks of a single flowering culm which has a long, broad, flag leaf fully sheathing the base of the much longer inflorescence, together with a basal tuft of short, narrow tillers; awns unusually long, mostly > 100 mm, (often appears only after fire) subg. **LONGIARISTATAE**
- 3: Plants perennial; tussocks with one or more flowering culms, which are usually much longer than the inflorescence; awns clearly twice bent & usually < 70 mm long
4. Plants salt-tolerant, found around salt lakes or in salinized seasonally flooded areas; tussocks with long, erect, terete leaves, similar to and difficult to distinguish from the flowering culms; the most common species (*A. juncifolia*) has long, translucent, hairy lemma lobes subg. **LOBATAE**
- 4: Plants not salt-tolerant; tussocks usually with a basal tuft of leaves that are easily distinguished from the erect flowering culms; lemma lobes short or absent 1. subg. **AUSTROSTIPA**

Key to the species and subgenera of *Austrostipa* in Western Australia

* indicates species that are keyed twice.

1. Culms of mature plants usually branched at the nodes; nodes and auricles usually glabrous, ligules > 1 mm long, glabrous; nodes exerted well above the lower leaf sheaths; mature root system robustly rhizomatous; panicle branches glabrous, scabrous, or conspicuously hairy and sometimes strongly divergent from the panicle axis; awns straight or once bent at maturity, or weakly falcate (if strongly falcate then the bristle is conspicuously flattened)..... subg. **ARBUSCULA**
2. Florets, with straight or weakly bent awns, remaining attached to the glumes at maturity, the widely divergent panicle branches creating an orb-like structure which breaks off from the culm at maturity so the whole panicle acts as the dispersal unit and blows around in the wind; panicle branches

- conspicuously hairy, the hairs erect and 0.3–3.0 mm long; lemmas glabrous, scabrid, and minutely tuberculate, with a short and angled callus
3. Pedicel hairs 1–3 mm long; culms and leaves mostly glabrous; occurs widely across the Southwest and into the arid zone **A. elegantissima**
 - 3: Pedicel hairs 0.3–1.0 mm long; lower culms and leaves densely pubescent; restricted to arid parts of the Southwest **A. tuckeri**
 - 2: Florets disarticulating from the glumes at maturity, the awns usually falcate; panicle branches glabrous or scabrous with hairs ≤ 0.3 mm long; lemmas densely hairy, callus weakly bent
 4. Lemmas 3–4 mm long awns 14–30 mm long, lower glume 4–5.5 mm long (restricted to the Nullarbor Plain on skeletal sandy soils)..... **A. nullaborensis**
 - 4: Lemmas 4.5–6.5 mm long, awns 30–90 mm long, lower glume 6–15 mm long
 5. Awn bristle strongly curved and distinctly flattened, wider than the column which is scabrous **A. platychaeta**
 - 5: Awn bristle slightly curved or straight, not flattened, and no wider than the column which is usually pubescent **A. acrociliata**
 - 1: Culms of mature plants unbranched at the nodes; auricles often hairy, ligules < 1 mm long (except *A. pycnostachya*); nodes glabrous to densely sericeous, often concealed by the leaf sheath from a lower node; mature root system caespitose; panicle branches glabrous or scabrous, not strongly divergent from the panicle axis; awns twice bent or falcate at maturity
 6. Awn column straight, bristle clearly falcate; lemma hairs white at maturity (reddish-brown in *A. frankliniae*) subg. **FALCATAE**
 7. Culm bases, nodes, sheaths, and leaf blades densely hairy
 8. Lemma hairs white; leaves straight, curved or flexuose but not curled into circles; culm bases not swollen, hairs straight
 9. Leaves coarse, stiff, erect, or gently curved; column pubescent, hairs 0.3–1.5 mm long..... **A. drummondii**
 - 9: Leaves flexuose; column scaberulous, hairs < 0.3 mm long..... **12. A. nunaginensis**
 - 8: Lemma hairs brown; leaf blades stiffly curled backwards into circular patterns; culm bases swollen and densely covered in long crinkled hairs..... **11. A. frankliniae**
 - 7: Culm bases, nodes, sheaths and leaves mostly glabrous or sparsely hairy
 10. Culms from a short rhizome; nodes hairy; ligules 3–7 mm long; leaf blades narrow, terete, smooth, erect, and glabrous; panicle dense, compact and spike-like, up to 140 mm long, 10 mm wide, enclosed by sheath; column hairs 0.02–0.05 mm long **A. pycnostachya**
 - 10: Culms from a tussock; nodes usually glabrous; ligules usually < 1 mm long; leaf blades not simultaneously terete, smooth, erect and glabrous; panicle somewhat spreading, not spike-like, 250–400 mm long; column hairs usually > 0.05 mm long
 11. Spikelets large in most parts: lower glume 14–20 mm long, upper glume 11.5–18 mm long; floret 7–8 mm long; awn 70–100 mm long, sturdy (0.3–0.4 mm wide near the base), bristle strongly falcate

12. Auricles small or absent; ligule densely hairy abaxially; awn column weakly twice bent **13. *A. tenuifolia***
- 12: Auricles prominent, with a dense line of long broad hairs underneath; ligule glabrous; awn column straight,..... **10. *A. anaiwaniorum***
- 11: Spikelets small in most parts: lower glume 8–14 mm long, upper glume 6–12.5 mm long; floret 4–6.5(–7) mm long; awn 38–90 mm long, delicate (usually 0.2–0.3 mm wide near the base), bristle gently falcate
13. Leaf blades very fine 0.3–0.6(1.2) mm wide, inrolled, ribbed; nodes exserted, glabrous
14. Tussock open at base, culms at angles to one another, not erect; leaf sheaths green, loose around the culm, softly pilose; blades with dense, erect, long (≥ 0.5 mm) spreading hairs; column ≤ 10 mm to the first bend, pubescent with hairs ≥ 0.25 mm long..... ***A. trichophylla***
- 14: Tussock densely packed, culms erect; leaf sheaths glabrous, long and tightly clasping the culms; blades glabrous, scabrous or shortly pubescent, hairs < 0.5 mm long; column 2.5–7 mm to the first bend, scabrous with hairs ≤ 0.2 mm long ***A. scabra***
- 13: Leaf blades 1–3 mm wide, often expanded and flexuose; nodes may be concealed by subtending leaf sheath, glabrous
15. Nodes of culm exposed; awn column scabrous or pubescent, hairs usually ≥ 0.2 mm long
16. Plants slender, culms compressible, ≤ 1 mm wide, tillering intravaginally; lemma surface finely granular, becoming coarser near the apex where the white hairs are sparse, awn column densely pubescent or villous with erect hairs 0.2–0.5 mm long ***A. variabilis***
- 16: Plants robust, culms not compressible, 1–2 mm wide, tillering extravaginally but caespitose; lemma surface smooth or slightly granular, entirely sericeous; awn column scabrous ***A. nodosa***
- 15: Nodes of culm concealed by subtending leaf sheaths; awn column minutely scabrous, hairs < 0.05 mm long ***A. nitida***
- 6: Awn column twice bent, bristle straight; lemma hairs white, or turning brown at maturity
17. Plants annual, often appearing only after fire; tussocks with a single flowering culm which has a long, broad, flag leaf fully sheathing the base of the much longer inflorescence, together with a basal tuft of short, narrow tillers; awns unusually long, mostly > 100 mm subg. **LONGIARISTATAE**
18. Leaf sheaths covered with distinctively large, broad, long, transparent hairs, sometimes only on the lower sheaths..... ***A. macalpinei***
- 18: Leaf sheaths glabrous or minutely scabrous, sometimes with a few distinctively large, broad, long, transparent hairs on some sheath margins only..... ***A. compressa***
- 17: Plants perennial; tussocks with one or more flowering culms, which are usually much longer than the inflorescence; awns clearly twice bent & usually < 70 mm long

19. Plants found around salt lakes or in salinized seasonally flooded areas; tussocks with long, erect, terete leaves, similar to and difficult to distinguish from the flowering culms; the most common species (*A. juncifolia*) has long, translucent, hairy lemma lobes subg. **LOBATAE**
- 20: Basal leaf sheaths 7–14 mm wide; ligule 2.5–12 mm long, smoothly integrated with the sheath so there are no sheath lobes; lemma lobes 1–3 mm long; growing around salt lakes or salinized soils in the southern Wheatbelt in Western Australia
21. Upper glumes 9–10 mm long; floret 6.5–9 mm long; callus 1.1–1.5 mm long; lemma lobes 1–2.5 mm long; awn 25–50 mm long; anthers penicillate; style glabrous (widespread in Southern Wheatbelt) **A. juncifolia**
- 21: Upper glumes 12–16 mm long; floret 9–12 mm long; callus 2–3 mm long; lemma lobes 2.5–3 mm long; awn 50–80 mm long; anthers not penicillate; style hispid with bristly hairs 0.2–0.4 mm long (known only from Lakes King, Grace, Tay and Chinocup) **A. geoffreyi**
- 20: Basal leaf sheaths 2–4 mm wide; ligule 0.0–1.0(–2) mm long, usually shorter than adjacent sheath lobes; lemma lobes 0.4–1.0 mm long; growing on the Swan Coastal Plain in seasonally flooded calcareous soils
22. Ligule broad between short sheath lobes; involucre a glabrous ridge of indurated tissue at the base of the panicle, not encircling the culm; upper glume 5-nerved in the lower part; lemma hairs white at maturity; anthers not penicillate, 3.2–3.3 mm long. **A. jacobsiana**
- 22: Ligule narrow to almost absent between long sheath lobes (2–6 mm); involucre a ring of hairs 0.3–1.3 mm long at the base of the panicle that almost encircle the culm; upper glume 3-nerved in the lower part; lemma hairs dark golden brown at maturity; anthers penicillate, 4.2–5 mm long **A. bronwenae**
- 19: Plants not found in saline habitats; tussocks usually with a basal tuft of leaves that are easily distinguished from the erect flowering culms; lemma lobes short or absent
23. Lemma hairs white at maturity
24. Awn column with conspicuously long hairs 0.5–5 mm long throughout its length, sometimes extending along one side of the bristle subg. **AUSTROSTIPA**
25. Awn column 17–30 mm to the first bend, the hairs 0.3–2.0 mm long, evenly distributed and not extending along the bristle; lemma 7–13 mm long
26. Lemma 8–13 mm long; column 20–30 mm to the first bend; awn 70–110 mm long; leaf blades and sheaths glabrous or scabrous; upper glume 6-nerved in the lower part..... **A. semibarbata**
- 26: Lemma 7–10 mm long; column 17–24 mm to the first bend; awn 50–70 mm long; leaf blades and sheaths hairy; upper glume 1–4-nerved in the lower part **A. campylachne**
- 25: Awn column 5–17 mm to the first bend, the hairs 0.5–5.0 mm long, often attached to only one side of the column making a spiral pattern which sometimes extends along one side of the bristle; lemma 4–11.5 mm long
27. Lemma 4–7.5 mm long; column 5–15 mm to the first bend, the hairs 0.5–5.0 mm long; awn 30–60 mm long; upper glume 10–16 mm long; culm base glabrous or scabrous **A. hemipogon**

- 27: Lemma 7.5–11.5 mm long; column 10–17 mm to the first bend, the hairs 0.6–3.0 mm long; awn 60–100 mm long; upper glume 15–20 mm long; culm base hairy **A. mollis**
- 24: Awn column hairs rarely exceeding 0.3 mm long, bristle scabrous
- 28: Lemma with a true coma of long hairs, 2–5 mm long, which all emerge from around the lemma apex, and at seed-fall the hairs diverge umbrella-like; inland plants **A. blackii**
- 28: Lemma *either* with a long false coma where the lemma hairs are distributed evenly but increase in length towards the apex and at seed-fall the hairs remaining appressed to the lemma; *or* with no coma, or a true coma ≤ 0.5 mm long
- 29: Floret with long white hairs in a false coma, 2–2.5 mm long; lemma hairs gradually increasing in length towards the apex; on the mid-west coast only, and nearby islands **A. crinita***
- 29: Floret *either* with no coma, or a true coma ≤ 0.5 mm, the hairs white or slightly coloured; lemma hairs evenly short, scabrous, or absent; in the south-west and southern coastal and inland regions
- 30: Foliage bluish, densely covered with short velvety hairs ≤ 0.1 mm long; coast and islands of the Great Australian Bight only **A. velutina***
- 30: Foliage green, either glabrous, scabrous, or with hairs up to 0.5 mm long and sparse enough to be seen individually, and generally of uneven lengths, not velvety; widespread in the agricultural region **4. A. exilis***
- 23: Lemma hairs various shades of brown at maturity
- 31: Lemma surface smooth and sometimes shiny but not glossy, entirely glabrous (except for the callus), or with few sparse hairs; the leaf sheath margins, auricles and ligules bearing very long (up to 9 mm) and crinkly-woolly hairs
- 32: Lower glume 15–26 mm long; ligules 0.4–1.5 mm long; lemma and palea usually entirely glabrous, palea fully or at least clearly exposed at maturity **7. A. lanata**
- 32: Lower glume 9–18 mm long; at least some ligules $\gg 2$ mm long; lemma and palea sparsely hairy (rarely both glabrous), palea fully and firmly enclosed by lemma throughout development **8. A. vickeryana**
- 31: Lemma surface mostly smooth (glossy and rough in *A. burgesiana*), usually evenly covered with hairs but sometimes with a distinctive patch in the shoulder region *either* glabrous, scabrous, or with sparse or evenly ‘shorn’ hairs; leaf sheath margins, auricles and ligules with straight hairs usually ≤ 1 mm
- 33: Lemma surface glossy and rough (tuberculate) due to silica bodies that shatter when scraped with the edge of a scalpel blade **9. A. burgesiana**
- 33: Lemma surface hard and mostly smooth, not overall tuberculate, not glossy, with hairs that may be cleanly removed with a scalpel blade without damaging the surface
- 34: Lemma hairs *either* dark brown at maturity with an evenly ‘shorn’ patch of short hairs on the shoulder region just below the apex or (in *A. plumigera*) pale brown and with long hairs (0.5–1 mm long) on both sides of the awn bristle

35. Flowering culms short and narrow, usually ≤ 1 mm wide and ≤ 60 cm tall, erect and densely packed, often indistinguishable from tillers; basal leaf sheaths similar in diameter to tiller and usually ≤ 1 mm wide; mature leaves narrow, indurate, and terete
36. Lemma hairs sparse enough to reveal the drawn-back lemma margins, which broadly expose the palea; at maturity, the palea margins brightly glossy **1. A. everettiana**
- 36: Lemma hairs dense enough to obscure the state of the lemma margins and the palea; at maturity, the palea margins not glossy **3. A. turbinata**
- 35: Flowering culms broader than tillers and usually ≥ 2 mm wide, 80–120 cm tall, spreading and/or geniculate, not densely packed; basal leaf sheaths loosely clasping (tightly clasping in *A. koordana*) or peeling away from the culm shortly above the base, larger than tiller sheaths; mature leaves not indurate or terete, either revolute or flat, usually with a distinct and enduring auricle and the blade arising at an angle to the culm
37. Bristle on the awn with long hairs (0.5–1.0 mm) on both sides **A. plumigera**
- 37: Bristle on the awn scabrous, with hairs < 0.2 mm on both sides
38. Anthers ≤ 2 mm long, unpigmented, all or only one fertile, and at maturity remaining compressed within the cleistogamous floret; lower glume 8–14 mm long
39. Anthers all fertile, equal lengths, 1–2 mm long; lemma surface smooth; callus 0.7–1.8 mm long; panicle regular in size & shape (pyramidal); leaf sheaths ≤ 100 mm long, not tightly stem-clasping; ligule inconspicuous **A. puberula**
- 39: Anterior anther ~ 1 mm long and fertile, posterior ones 0.4–0.5 mm long, sterile; lemma surface smoothly rugose; callus 2–2.6 mm long; panicle irregular (not pyramidal), sparse with long internodes (~ 80 mm) and few spikelets at the lower nodes clustered on branches very much shorter (~ 15 mm) than the internodes; leaf sheaths 200–300 mm long, tightly stem-clasping; ligule visible and densely pubescent with conspicuous white hairs **2. A. koordana**
- 38: Anthers ≥ 2.5 mm long, always pigmented and fertile; floret chasmogamous; lower glume 15–25 mm long **A. eremophila**
- 34: Lemma hairs variously pale brown through to dark brown at maturity, sometimes with a glabrous or scabrous bare patch in the shoulder region, sometimes with scattered longer hairs, but not having an evenly ‘shorn’ patch
40. Awn column with long hairs near the base, grading to short hairs where it meets the bristle; restricted to dongas (gilgais) on the Nullarbor Plain **A. dongicola**
- 40: Awn column with evenly distributed hair lengths throughout; mostly coastal plants, but also inland in the Wheatbelt region
41. Leaves rigidly erect and pungent-pointed; awn 90–110 mm long, column 30–35 mm long **A. echinata**
- 41: Leaves erect or flexuose, not pungent-pointed; awn 23–80 mm long, column ≥ 30 mm long
42. Floret with long white hairs in a false coma, 2–2.5 mm long; lemma hairs gradually increasing in length towards the apex; on the mid-west coast only, and nearby islands **A. crinita***

- 42: Floret either with no coma, or a short coma, the hairs white or coloured; lemma hairs evenly short, scabrous, or absent; in the south-west and southern coastal and inland regions
43. Foliage bluish, densely covered with short velvety hairs ≤ 0.1 mm long; coast and islands of the Great Australian Bight only..... **A. velutina***
- 43: Foliage green, either glabrous, scabrous, or with hairs up to 0.5 mm long and sparse enough to be seen individually, and generally of uneven lengths, not velvety; usually found further into the South-West region
44. Flowering culms short and narrow, usually ≤ 1 mm wide and ≤ 60 cm tall, often indistinguishable from innovations and erect and densely packed; basal leaf sheaths similar in diameter to tiller basal sheaths and usually ≤ 1 mm wide; mature leaves narrow and sometimes flexuous, or indurate and either terete and erect or stiffly curved
45. Leaf sheaths and blades usually hirsute with long hairs exceeding 0.5 mm and shorter hairs of various lengths between them, blades flexuous; lemma hairs white at maturity..... **4. A. exilis***
- 45: Leaf sheaths and blades glabrous or pubescent (hairs $\ll 0.5$ mm); lemma with brown hairs at maturity
46. Anthers translucent white when re-hydrated, of different sizes, one fertile and 0.8–1.1 mm long, two sterile and 0.4–0.6 mm long **5. A. heteranthera**
- 46: Anthers opaquely pigmented, all fertile and 3–4 mm long **6. A. mundula**
- 44: Flowering culms broader than innovations and usually ≥ 2 mm wide, spreading and/or geniculate, not densely packed, 80–120 cm tall; basal leaf sheaths loosely clasping or peeling away from the culm shortly above the base, larger than tiller sheaths; mature leaves not indurate or terete, either revolute or flat, usually with a distinct and enduring auricle and the blade arising at an angle to the culm..... **A. flavescens**

1. *Austrostipa* S.W.L.Jacobs & J.Everett subg. *Austrostipa*

A. *Eremophilae* group (previously *Austrostipa* subg. *Eremophilae* S.W.L.Jacobs & J.Everett)

A number of unusual specimens were collected during vegetation mapping (Craig *et al.* 2008) and floristic surveys (Kern *et al.* 2008; Markey *et al.* 2012) of the Ravensthorpe Ranges in the southern region of the Yilgarn Greenstone Belt (Bodorkos & Sandiford 2006) which did not fit descriptions for existing species recorded for WA but they did match *A. mundula* (*Lancea* group), using the text keys in Jessop *et al.* (2006) and Everett *et al.* (2009). This species had previously been recorded only in south-east South Australia and western Victoria. However, the new specimens differed from *A. mundula* in some major characters not used in the text keys. Two new interim taxa were identified amongst them and were entered into the WA plant census (<https://florabase.dpaw.wa.gov.au>) as *Austrostipa* sp. Ravensthorpe Range (A. Markey & J. Allen 6261) described here as *A. heteranthera*, and *Austrostipa* sp. Carlingup Road (S. Kern & R. Jasper LCH 18459) described here as *A. turbinata*.

While searching the PERTH collection for specimens of *A. flavescens* similar to the Ravensthorpe Ranges material, a number of specimens turned out to closely match *A. mundula* but with just two minor differences in non-key characters. These collections were from several isolated pockets around the south and west coast that had geographical disjunctions of up to 2,500 kilometres from their nearest relatives in South Australia, so they were entered into the WA plant census with the interim phrase name *Austrostipa mundula* subsp. *Torndirrup* (C.A. Hortin 1068) although this subspecies status was subsequently rejected (see below).

A floristic survey of the Forrestania Greenstone Belt in the Mt Holland area in October 2009 (Thompson & Allen 2013) yielded another unusual but immature specimen of *Austrostipa* that was entered into the WA plant census as *Austrostipa* sp. Mt Holland (W.A. Thompson & J. Allen 948). Further survey work in October 2012 relocated the population of about 50 scattered tussocks, from which mature specimens were collected. Extensive searching for other populations in nearby localities was carried out (Andrew Dooley field notes Oct. 2012). Several populations of *A. puberula* (*Eremophilae* group of subg. *Austrostipa*) were located nearby. Thompson and Allen (2013) found immature specimens of *Austrostipa* sp. Carlingup Road (S. Kern & R. Jasper LCH 18459) about 8 km to the north on the Forrestania Greenstone ridge but no additional populations of *A. sp.* Mt Holland. This taxon is in clear need of priority conservation because the Forrestania Greenstone Belt has no conserved areas within it (Thompson & Allen 2013) and it is being actively mined and explored for base and precious metals. *Austrostipa* sp. Mt Holland (W.A. Thompson & J. Allen 948) is described here as *A. everettiana*.

The two new Ravensthorpe Ranges taxa had floral characteristics distinctive of the *Lancea* and *Eremophilae* groups, and were uniformly small in all parts, yet not so small as to rule out falling within the extreme lower limits of other known species and subspecies. To investigate this possibility, all specimens of potentially related species (*A. flavescens* and *A. exilis* from *Lancea*, and *A. eremophila* and *A. puberula* from *Eremophilae*) in the PERTH collection were examined, plus representative loan specimens from AD of *A. mundula* (including the holotype), *A. eremophila*, *A. flavescens*, *A. exilis* plus several specimens with '*A. exilis?*' as the identification. A list of potentially important characters was compiled from published keys, together with two-way comparisons among each of the listed species using the DELTA dataset derived from Vickery *et al.* (1986) adjusted to reflect character data observed in PERTH collections and the final list of 30 characters used is presented in Table 1.

A number of multivariate analyses were then carried out using these 30 characters scored with averaged published values for each of the existing species, plus individual specimen values for the new species and *A. mundula* and *A. puberula* (the published species with characteristics most similar to the new taxa). An ordination plot of results is given in Figure 6 which clearly shows that the new species are quite distinct from existing species. In the cases of both *A. puberula* and *A. mundula*, all the specimens from WA grouped most closely with the averaged values from their published data.

Figure 6 shows that the variation between specimens is usually much less than the variation between taxa. *Austrostipa turbinata* and *A. heteranthera* are distinct from one another, *A. everettiana* is unique, and the WA collections of *A. mundula* group most closely with its averaged published range data.

The characters that distinguish the three new species in the *Eremophilae* group (*A. turbinata*, *A. koordana*, and *A. everettiana*) from likely relatives are given in Table 2.

Table 2. Differences between new and allied species in *Eremophilae* group of *Austrostipa* subg. *Austrostipa*.

Character	Species				
	<i>A. everettiana</i>	<i>A. puberula</i>	<i>A. eremophila</i>	<i>A. koordana</i>	<i>A. turbinata</i>
Culms	narrow, densely packed, erect	broad, in an open tussock, geniculate	broad, in an open tussock, geniculate	broad, in an open tussock, geniculate	narrow, densely packed, erect
Leaf sheaths	0.5–0.9 mm wide, glabrous margins	5–7 mm wide, woolly margins	4–8 mm wide, ciliate margins	3 mm wide, glabrous margins	1.0–1.3 mm wide, glabrous margins
Leaf blades	3.5–12 cm long, 0.3 mm wide	10–25 cm long, 1–2 mm wide	10–30 cm long, 1.5–4 mm wide	21–28 cm long, 0.7–1.2 mm wide	4–17 cm long, 0.3–0.6 mm wide
Panicle	6–10 cm long	15–30 cm long	15–30 cm long	22 cm long	9–16 cm long
Lower glumes	10–12 mm long	8–14 mm long	15–25 mm long	12–14 mm long	12–16 mm long
Lemma hair appearance	differing from callus	same as callus	differing from callus	same as callus	same as callus
Lemma indumentum	sparse, revealing the uncovered palea	dense, concealing the uncovered palea	dense, concealing the uncovered palea	dense, concealing the uncovered palea	dense, concealing the uncovered palea
Exposed palea margins	glossy, glabrous	dull, with hairs	dull, with hairs	dull, with hairs	dull, with hairs
Anthers	2–2.3 mm long, not penicillate	0.6–2 mm long, penicillate	2.5–4 mm long, penicillate	0.4–1.0 mm long, not penicillate	0.3–1.6 mm long, penicillate
Caryopsis	2.6–2.9 mm long	2–5 mm long	3.5–4.5 mm long	2.7–3 mm long (immature)	2.2–2.5 mm long

1. *Austrostipa everettiana* A.R. Williams, *sp. nov.*

Typus: Forrestania Greenstone Belt, Mt Holland area, Western Australia [precise locality withheld for conservation reasons], 27 October 2012, *A. Dooley* AD428 (*holo*: PERTH 08414297; *iso*: CANB).

Austrostipa sp. Mt Holland (W.A. Thompson & J. Allen 948), Western Australian Herbarium, in *Florabase*, <https://florabase.dpaw.wa.gov.au/> [accessed 12 July 2021].

Perennial *grass*, with densely packed, erect, narrow culms arising from a short rhizome; shoots intra- or extra-vaginal, 400–600 mm tall, with a basal tuft of leaves. *Culms* unbranched, not geniculate, glabrous; nodes two per culm, exserted, thickened, with abundant retrorse indumentum. *Leaf sheaths* tightly enveloping the culm, 0.7–0.9 mm wide at the base of the culm, 0.5–0.9 mm wide at the upper nodes, glabrous. *Ligules* 0.3–0.5 mm long, blunt; abaxial surface and margin sericeous with hairs 0.5–0.7 mm long; adaxial surface glabrous; sheath lobes absent. *Auricles* distinct and subtended by erect hairs 1.7–2.3 mm long. *Leaf blades* green at flowering time, flexuose, 35–120 mm long, *c.* 0.3 mm

wide in the inrolled or involute state; abaxial surface ribbed and scabrous; adaxial surface strongly ribbed and scaberulous with minute scattered trichomes. *Panicle* 60–100 mm long, exserted, narrowly contracted, 10–25 mm wide, not subtended by a marked involucl, the spikelets overlapping; lowest internodes 15–30 mm long, scaberulous, the hairs 0.01–0.03 mm long; minimum undivided branch length 4–6 mm, maximum undivided branch length 6–10 mm; branches with acutely angled edges, 20–25 mm long including glumes; pedicels angular, 2–12 mm long, scabrous on their edges, the hairs 0.05–0.2 mm long. *Spikelets* 10–12 mm long, 3–9 per node. *Glumes* subequal, acuminate, scabrous on nerves, straw-coloured; lower glume 3-nerved, 10–12 mm long; upper glume 5-nerved, 9–10 mm long. *Floret* turbinate, 4.3–6.0 mm long, sericeous with an even covering of initially white hairs that turn rich brown at maturity, 0.4–0.8 mm long, with a distinct ‘shorn’ patch of short hairs near the apex. *Lemma* hairs sparse enough during development to expose the palea, at maturity the glossy palea margins also visible; lemma lobes inconspicuous, 0.07–0.2 mm long; lemma margins drawn back to reveal the palea, which has glossy glabrous margins at maturity and a dorsal line of hairs equal in length to those on the lemma; *coma* distinct, 1.1–1.5 mm long. *Callus* 2.0–2.9 mm long, sericeous with rich brown hairs 0.5–0.7 mm long, the tip weakly bent. *Awn* 37–44 mm long, 0.35–0.45 mm wide near the base, twice bent; column 15–20 mm long, 7–11 mm to the first bend, scabrous with hairs 0.2–0.3 mm long; bristle straight, angular in cross section, no broader than the column, scaberulous with hairs *c.* 0.01 mm long. *Palea* subequal to the lemma. *Lodicules* not seen. *Anthers* 3, all fertile, brown, 2.0–2.2 mm long, not penicillate. *Style* glabrous. *Caryopsis* 2.6–2.9 mm long, 0.2 mm wide; embryo 0.7–1.0 mm long; hilum 1.5–2.0 mm long. (Figure 7A–C)

Diagnostic features. Extremely narrow erect culms in densely packed tussocks; twice-bent awn column with straight bristle; dark brown indumentum on mature floret with short patch of ‘shaved’ hairs on the shoulder region; immature lemma margins drawn back to fully expose the palea underneath, and mature florets clearly revealing the exposed palea to have a narrow band of dorsal hairs and glossy, glabrous margins.

Other specimens examined. WESTERN AUSTRALIA: [locality withheld for conservation reasons] 2 Oct. 2009, W.A. Thompson & J. Allen 948 (PERTH).

Phenology. Flowers September–October with fruit maturing in October–November.

Distribution and habitat. Only known from one location (Figure 7D) in the Southern Cross sub-bioregion of the Coolgardie bioregion, where it grows in low, open *Eucalyptus* woodland over a sparse shrubland of *Melaleuca*, *Acacia*, *Santalum* and *Allocasuarina* over *Trymalium* and *Styphelia*, in skeletal to shallow soils of red-brown clay-loam on a WNW facing hill slope with abundant coarse fragments of greenstone. Associated grass species included *Austrostipa variabilis*, *Rytidosperma* sp., *Vulpia myuros* f. *megalura* and *Pentameris airoides*.

Conservation status. Listed by Smith and Jones (2018) as Priority One under Conservation Codes for Western Australian Flora under the phrase name *Austrostipa* sp. Mt Holland (W.A. Thompson & J. Allen 948). Only known from a single population of about 50 scattered tussocks. Mining for gold and nickel and further exploration for these and other metals is currently underway in this geological formation. The only known population is not in a protected area. Researchers have been calling for conservation of the distinctive Forrestania Greenstone flora for over 20 years (Thompson & Allen 2013) and this new species of *Austrostipa* adds to the urgency of that case.

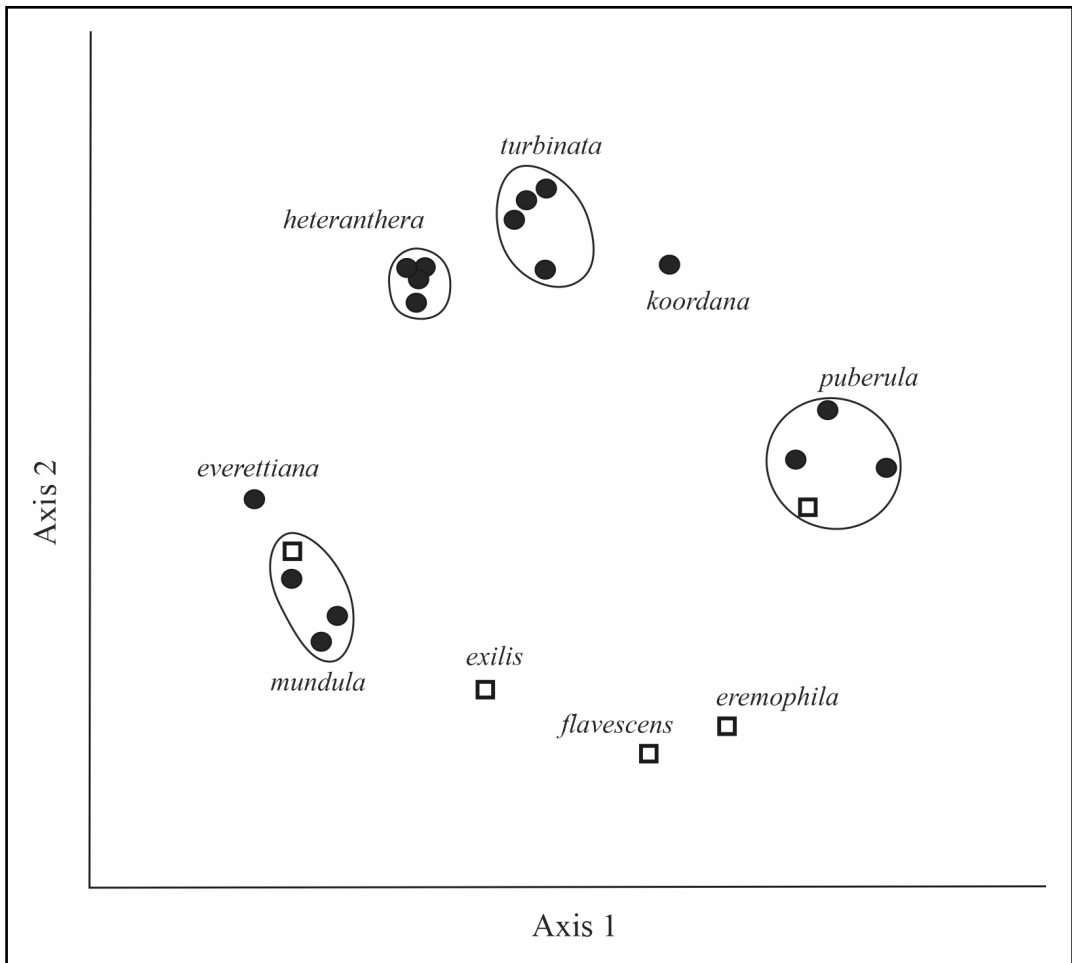


Figure 6. A nonmetric multidimensional scaling (NMDS) plot of new and potentially related previously named taxa in the *Eremophilae* and *Lancea* groups of *Austrostipa* subgenus *Austrostipa*, based on Box-Cox transformed data using the 30 characters listed in Table 1 (axes 1 and 2 of a 2-D plot, stress 0.11). Open squares represent existing taxa (*A. flavescens*, *A. eremophila*, *A. puberula*, *A. mundula* and *A. exilis*), where averaged published character range data were used and black filled circles represent individual specimen data. Ellipses represent high confidence ($\geq 96\%$) clusters as determined by UPGMA classification using correlation coefficients. Replicate specimens of three new species (*A. turbinata*, *A. heteranthera* and *A. everettiana*) are clearly separated from each other and from all other species included in the analyses. Replicate WA specimens of *A. mundula* clustered with the species description based on specimens from South Australia and Victoria. Replicate specimens of *A. puberula* from WA also clustered with its species description from the literature and were well separated from all others. *A. everettiana* and *A. koordana* are both confirmed as being separate species.

Etymology. Named after Joy Everett, formerly Senior Systematic Botanist at the Royal Botanic Gardens, Sydney, and Scientific Editor of their journal *Telopea*, who with Surrey Jacobs authored or co-authored most of the current primary taxonomic literature on the genus *Austrostipa*.

Affinities. The twice-bent awn column, dark brown mature lemma indumentum with a ‘shaved’ patch on the lemma shoulder and drawn back lemma margins exposing the palea places it in the *Eremophilae* group within subgenus *Austrostipa*. Differences between related taxa in this group are listed in Table 2.

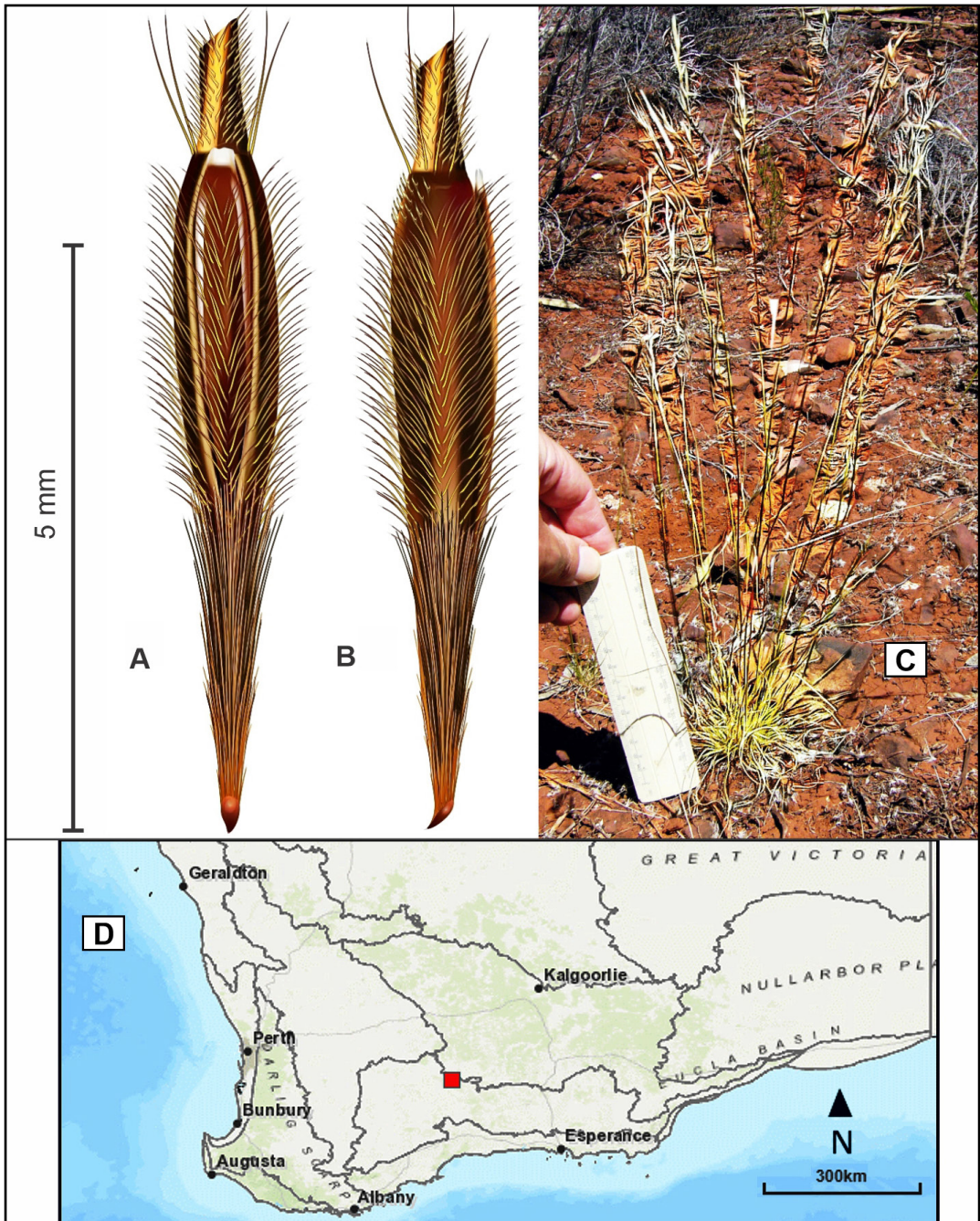


Figure 7. *Austrostipa everettiana*. A – adaxial view of floret showing how the glossy palea margins can be seen through the sparse indumentum; B – lateral view of floret showing the ‘shaved’ patch of short hair on the dorsal lemma shoulder region. C – *in-situ* view of mature tussock, ruler 15 cm long; artificially enhanced for clarity; D – location of the population (■). Vector drawings (A, B) by the author based on *A. Dooley* AD 428; site photo by Andrew Dooley (C).

2. *Austrostipa koordana* A.R. Williams, *sp. nov.*

Typus: Roadside near Koorda, Western Australia [precise locality withheld for conservation reasons], October 2015, *Anonymous s.n.* (*holo*: PERTH 08730202).

Austrostipa sp. Koorda (Anonymous s.n. PERTH 08730202), Western Australian Herbarium, in *Florabase*, <https://florabase.dpaw.wa.gov.au/> [accessed 12 July 2021].

Slender, erect, perennial *tussock grass*, branching extravaginally, *c.* 800 mm tall. *Culms* mostly glabrous, 1–2 mm wide above a densely hairy base (hairs *c.* 1 mm long); nodes 3 or 4, glabrous, enclosed by unusually long and tightly clasping leaf sheaths (200–300 mm long). *Basal leaf* sheaths 3 mm wide, glabrous; upper sheaths glabrous, 3 mm wide. *Ligules* 1.5 mm long, densely pubescent with conspicuous white hairs on margins and abaxially; adaxial surface glabrous. *Auricles* barely present, glabrous. *Leaf blades* 210–280 mm long, rolled, 0.7–1.2 mm wide; abaxial surface glabrous; adaxial surface scabrous. *Panicle* narrow, *c.* 20 mm wide, *c.* 220 mm long, involucre a glabrous ridge; spikelets few and densely clustered at the lower nodes on branches much too short (≤ 15 mm long) to overlap the unusually long internodes (80 mm long). *Spikelets* 12–14 mm long. *Glumes* minutely scabrous, and 3-nerved; lower glume 12–14 mm long, upper glume 11–12 mm long. *Lemmas* 5.8–6.6 mm long, light brown, smoothly rugose, with pale brown hairs, and a ‘shaved’ patch of scabrous hairs on the abaxial shoulder. *Callus* 2–2.6 mm long, sericeous with hairs 0.4–0.5 mm long. *Awn* column pubescent with hairs *c.* 0.4 mm long, twice bent, 7–10 mm to the first bend, and 3–5 mm to the second bend, 0.25–0.3 mm wide at the base; bristle 50–53 mm long, scabrous; total awn length 60–68 mm. *Palea* equal to the lemma. *Lodicules* two; abaxial lodicule spatulate, acute, 0.75 mm long; paleal lodicule 0.75 mm long, linear, obtuse. *Anthers* white (non-pigmented), dwarfed, only one fertile; anterior anther *c.* 1 mm long, fertile; posterior ones 0.4–0.5 mm long, sterile, compressed within cleistogamous lemma. *Caryopsis* 2.7–3 mm long (immature), embryo and hilum not discernible. (Figure 8A–D)

Diagnostic features. The following combination of characters is unique in the *Eremophilae* group in WA: long internodes (80 mm long) in the sparse panicle, with few spikelets clustered at the lower nodes on very short branches; aberrant anther development syndrome; smoothly rugose lemma surface (prominent in the recently dried specimen but much reduced after prolonged drying because the specimen was immature); long (200–300 mm) leaf sheaths that are tightly stem-clasping; and densely pubescent ligules with conspicuous white abaxial hairs.

Phenology. Flowers late spring with fruit maturing in early summer.

Distribution and habitat. Only known from a single roadside collection near Koorda in the Avon Wheatbelt bioregion (Figure 8E).

Conservation status. Listed by Smith and Jones (2018) as Priority One under Conservation Codes for Western Australian Flora under the phrase name *Austrostipa* sp. Koorda (Anonymous s.n. PERTH 08730202).

Etymology. Named after the geographical place name Koorda.

Affinities. Unlike any other members of the *Eremophilae* group (see *Diagnostic features*).

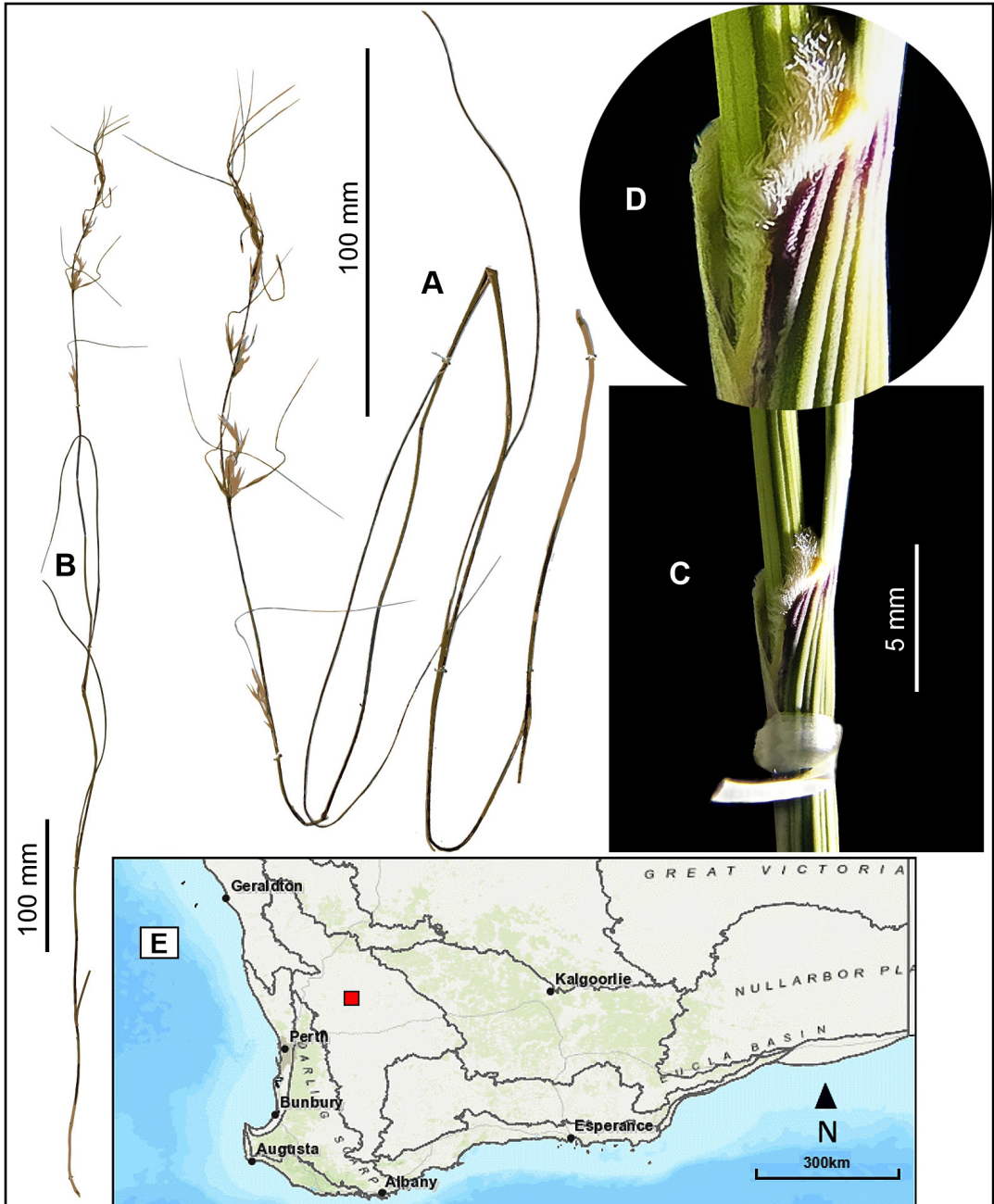


Figure 8. *Austrostipa koordana*. A – single flowering culm from herbarium sheet; B – the same specimen digitally straightened out; C – image of collar region showing conspicuously hairy ligule compared with the glabrous leaf, sheath, and culm, plus the tightly stem-clasping nature of the sheath; D – enlarged view of the collar region; E – location of the population (■). Images by the author from *Anonymous s.n.* PERTH 08730202.

3. *Austrostipa turbinata* A.R. Williams, *sp. nov.*

Typus: Ravensthorpe Range, Western Australia [precise locality withheld for conservation reasons], 6 December 2008, A. Markey & J. Allen 6262A (*holo*: PERTH 08415560; *iso*: CANB).

Austrostipa sp. Carlingup Road (S. Kern & R. Jasper LCH 18459), Western Australian Herbarium, in *Florabase*, <https://florabase.dpaw.wa.gov.au/> [accessed 12 July 2021].

Austrostipa aff. *eremophila* in Kern *et al.* (2008).

Perennial *tussock grass*, with densely packed, erect, narrow culms arising from a short rhizome; shoots intra- or extra-vaginal; 250–480 mm tall, without a basal tuft of leaves. *Culms* unbranched, not geniculate; upper culms glabrous or with part indumentum on internodes; nodes 2 or 3, exserted, thickened, sericeous. *Leaf sheaths* tightly enveloping the culm, 0.8–1.3 mm wide at the base of the culm, 0.2–1 mm wide at the upper nodes, glabrous or puberulous and/or with ciliate margins. *Ligules* 0.2–2.5 mm long, blunt; abaxial surface and margin scabrous to pubescent with hairs 0.03–0.2 mm long; adaxial surface glabrous; sheath lobes 0.2–1.2 mm long. *Auricular region* marked at flowering time, with erect hairs 0.1–1.5 mm long. *Leaf blades* green at flowering time, erect at maturity, 40–170 mm long, 0.3–0.6 mm wide, rolled when immature, folded at maturity, sclerophyllous; abaxial surface obscurely ribbed, glabrous and smooth or with short indumentum; adaxial surface strongly ribbed, finely pubescent with hairs 0.03–0.06 mm long. *Panicle* 70–170 mm long, exserted at maturity, contracted, 20–30 mm wide, spikelets sparse, sometimes subtended by a distinct involucrel (one odd specimen *c.* 33 mm long); lowest internode 27–58 cm, glabrous or finely scaberulous, the hairs 0.03–0.06 mm long; minimum undivided branch length 1–8 mm, maximum undivided branch length 7–28 mm; branches somewhat flattened with angled edges, 40–80 mm long overall (including glumes); pedicels likewise flattened, 1–7 mm long, scabrous on their angled edges, the hairs 0.1–0.15 mm long. *Spikelets* 12–16 mm long, 6–22 spikelets per node. *Glumes* unequal, acuminate, scabrous on nerves, straw-coloured; lower glume 3-nerved, 10–16 mm long; upper glume 5-nerved, 7–10 mm long. *Floret* turbinate, 5–6.5 mm long, sericeous with golden brown hairs at maturity, 0.7–0.8 mm long, with a ‘shorn’ patch below the lemma where the hairs are *c.* 0.1 mm long. *Lemma* lobes absent or minute; coma 0.8–1.3 mm long. *Callus* 1.5–2 mm long, sericeous with hairs 0.3–1.5 mm long, tip distinctly bent. *Awn* 45–63 mm long, 0.22–0.25 mm wide near the base, twice bent, column 17–24 mm long, 9–13 mm to the first bend, scabrous, with hairs 0.1–0.35 mm long, bristle angular, no broader than column, scabrous with hairs 0.03–0.10 mm long. *Palea* equal to and not completely enclosed by mature lemma, margins glabrous, dorsally pubescent. *Lodicules* 2; 0.6–1.1 mm long, 0.15–0.25 mm wide; obtuse to roundly acute. *Anthers* 3, only one fertile; anterior one fertile, 0.5–1.6 mm long, not penicillate or with one or two penicil hairs; posterior ones sterile, 0.25–0.6 mm long, sometimes with a single penicil hair per locule. *Style* glabrous. *Caryopsis* 2.2–3.6 mm long, *c.* 0.2 mm wide; embryo 0.6–1.0 mm long, hilum 1.7–2.5 mm long. (Figure 9A–C)

Diagnostic features. Lemma hairs dense enough to obscure the lemma margins and palea, dark brown at maturity with an evenly ‘shorn’ patch of short hairs on the shoulder region just below the apex; palea margins not glossy; flowering culms short and narrow, usually ≤ 1 mm wide and ≤ 60 cm tall, erect and densely packed, often indistinguishable from tillers; basal leaf sheaths similar in diameter to tiller and usually ≤ 1 mm wide; mature leaves narrow, indurate, and terete; panicle short and sparse with few spikelets.

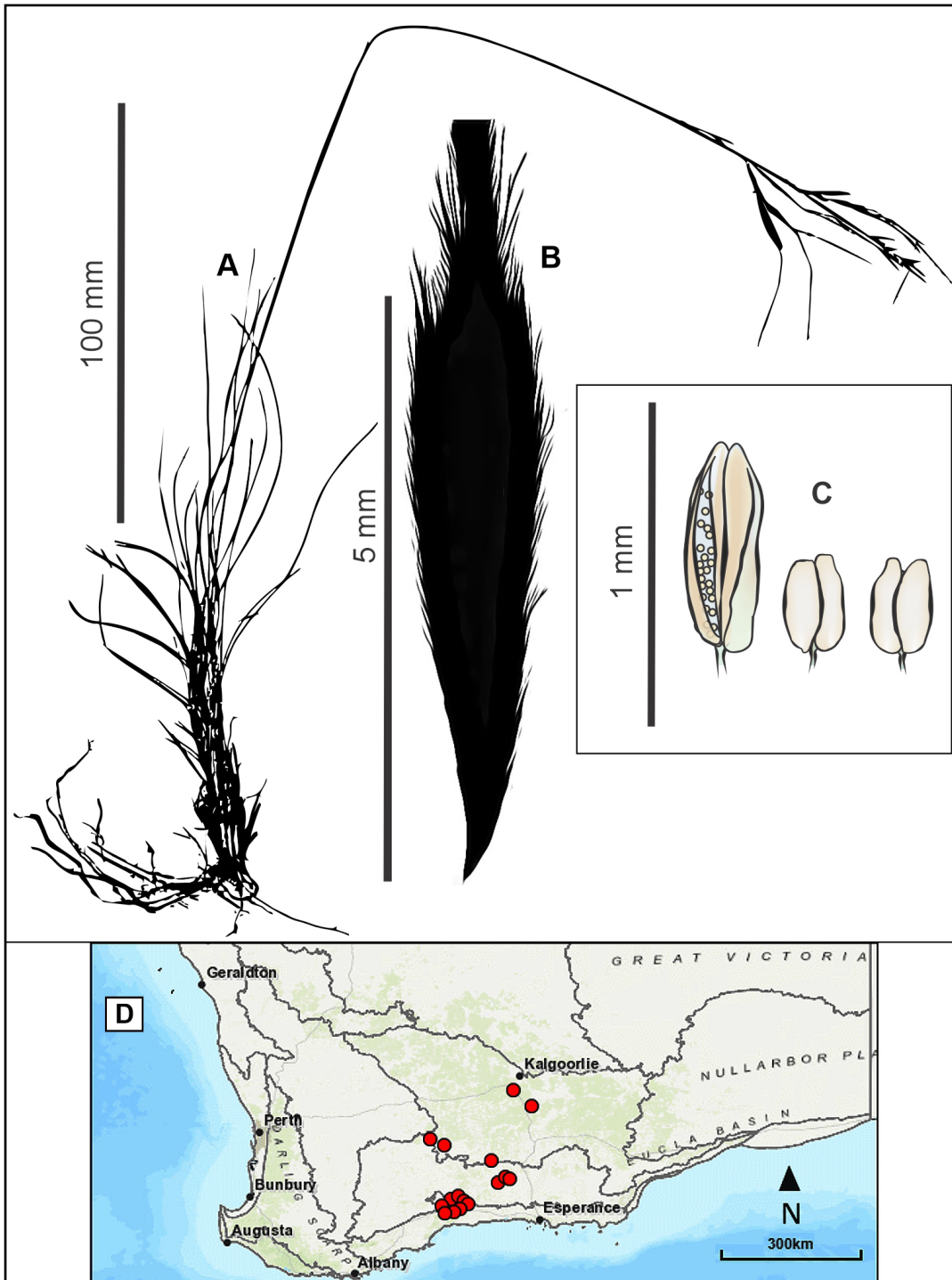


Figure 9. *Austrostipa turbinata*. A – vector outline of the small whole plant with its very small and sparse panicle; B – silhouette image of floret showing the turbinate shape and the short patch of 'shaved' hair in the shoulder region; C – vector drawings of rehydrated dwarfed and non-pigmented anthers, only one of which is fertile; D – distribution of *A. turbinata* (●). Illustrations by the author based on A. Markey & J. Allen 6268.

Distribution and habitat. Known from the Fitzgerald sub-bioregion of the Esperance Plains bioregion (Figure 9D) in the South-west Botanical Province and from South Australia. Occurs in *Eucalyptus* open forest, woodland and mallee shrubland, on loam or clay soils.

Phenology. Flowers September–October with fruit maturing in November–December.

Etymology. Named for the turbinate shape of the lemma, which is highlighted by the patch of short hairs near the apex and topped with an expanded coma.

Other specimens examined. WESTERN AUSTRALIA: [localities withheld for conservation reasons] 2 Oct. 1983, *M.A. Burgman & S. McNee* 2623 (PERTH); 11 Nov. 2013, *G.F. Craig* 9497–9502 (PERTH); 10 Sep. 2010, *S. Kern* SOK 926 (MEL, PERTH); 5 Oct. 2007, *S. Kern & R. Jasper* LCH 18459 (PERTH); 17 Nov. 2008, *A. Markey & J. Allen* 6267 (PERTH); 6 Dec. 2008, *A. Markey & J. Allen* 6268 (PERTH); 24 Nov. 1997, *W. O’Sullivan* WOS 307 (PERTH); 21 Oct. 2009, *W.A. Thompson & J. Allen* 2219 (PERTH); 1 Apr. 2000, *E. Tink* 475 (PERTH).

Conservation status. To be listed as Priority One under Conservation Codes for Western Australian Flora (Tanya Llorens pers. comm.). Restricted to greenstone ranges. Impaired anther development restricts reproductive success and cleistogamy restricts character variation; together, these factors reduce the prospects of it being found beyond specialized habitats and localised geographical ranges.

Affinities. Similar to *A. puberula* and *A. eremophila* in having a ‘shaved’ patch of short hairs on the lemma shoulder but differs in being smaller in all dimensions than both these species, and in having erect, narrow culms and leaves, tightly clasping leaf sheaths, and the aberrant anther development syndrome. Differs from *A. mundula* in having the aberrant anther development syndrome and a sericeous abaxial ligule surface. Differs from *A. heteranthera* in being cleistogamous, having a turbinate floret with a short patch of ‘shaved’ hairs on the shoulder region, and typically a short indumentum on the foliage.

B. *Lancea* group (previously *Austrostipa* subg. *Lancea* S.W.L.Jacobs & J.Everett)

One new species, *A. heteranthera*, is now included in the *Lancea* group of subg. *Austrostipa*, and two existing species previously known from South Australia, *A. mundula* and *A. echinata*, are now known to occur in very restricted habitats in WA as well. Furthermore, one previously priority listed species, *A. exilis*, has been found to occur commonly throughout the south-west region and has consequently been dropped from the conservation listings.

4. Notes on *Austrostipa exilis* (Vickery) S.W.L.Jacobs & J.Everett

When this study began there were only five collections of *Austrostipa exilis* at PERTH and it had been allocated Priority Two conservation status. There are now 42 collections, distributed throughout the Southwest Province and it has been dropped from the priority list. All but two of these collections have leaves as described by Vickery *et al.* (1986) ‘Leaf blades loosely convolute, flexuose, ... abaxial surface slightly ribbed, scaberulous **and** pubescent **and/or** hirsute [emphases added].’ The two unusual specimens collected in the Ravensthorpe Ranges area (a region well known for unusual specimens in a variety of taxa) had just scabrous leaves without any admixture of longer hairs.

Almost 90% of currently known *A. exilis* collections come from South Australia and most of these have the usual multiple layers of leaf hair types as described above (although Plate 3 in Jessop *et al.*

2006 illustrates three sections of culm, node, leaf sheath and blade, having just hirsute indumentum). However, Vickery *et al.* (1986) noted two odd specimens in SA that had more or less glabrous leaves, but they came from areas of overlap between the distributions of *A. mundula* and *A. exilis*, suggesting possible hybrid status. The reduced leaf indumentum was also common amongst the South Australian loan specimens of *A. exilis* that were sent to us where annotations on these specimens expressed doubt about their identity.

A curious collection of eight plants from the Booylgoo Range in inland WA was initially given the phrase name *Austrostipa* sp. Booylgoo Range (A. Markey & S. Dillon 4581) because in most of its characteristics it matched the falcate species *A. trichophylla*, which was growing nearby in isolated patches at the same survey site, but it had a twice-bent awn, not falcate, which put it out of subg. *Falcatae*. The otherwise closest match was *A. exilis*, but all other WA collections of this taxon at PERTH are located within the Southwest Province, which at its nearest point is at least 400 km from this survey site in the Murchison bioregion. This site is also 580 km inland from the nearest coastline, and where *A. exilis* occurs elsewhere throughout southern Australia (492 records at present) it is nowhere else found more than 260 km inland from the nearest coastline (Australia's Virtual Herbarium map, extracted 17 July 2017, noting that the given scale was incorrect at that time). Interestingly, the leaves on the Booylgoo Range specimens are not flexuose, but erect, and strongly nerved adaxially, which better fits the original description of the species by Vickery (1980). I have concluded for present purposes that this phrase-named taxon should be retained but noting that further study of the *A. exilis* complex across WA and SA is required.

In the above key, white lemma hairs at maturity are said to occur in *A. exilis* as this is the condition in all PERTH specimens. However, Vickery *et al.* (1986) and Everett *et al.* (2009) described the hairs as white or golden and Jessop *et al.* (2006) described them as whitish to golden-brown. Neither these colour variations, nor the 'black lemma' used by Vickery *et al.* (1986) in their key, have been observed in PERTH collections.

5. *Austrostipa heteranthera* A.R. Williams, *sp. nov.*

Typus: Overshot Hill, west of Ravensthorpe Range, Western Australia [precise locality withheld for conservation reasons], 17 November 2008, *A. Markey & J. Allen* 6260 (*holo*: PERTH 08415552; *iso*: CANB).

Austrostipa sp. Ravensthorpe Range (A. Markey & J. Allen 6261), Western Australian Herbarium, in *Florabase*, <https://florabase.dpaw.wa.gov.au/> [accessed 12 July 2021].

Perennial *tussock grass*, with densely packed, erect, narrow culms arising from a short rhizome; shoots intra- or extra-vaginal; 300–700 mm tall, without a basal tuft of leaves. *Culms* unbranched, not geniculate; upper culms glabrous or with part indumentum on internodes; nodes 2, exserted, thickened, sericeous. *Leaf sheaths* tightly enveloping the culm, 0.7–1.3 mm wide at the base of the culm, 0.6–1.2 mm wide at the upper nodes, glabrous or rarely with short indumentum or ciliate. *Ligules* 0.3–0.8 mm, blunt; abaxial surface and margin sericeous; adaxial surface glabrous; sheath lobes 0–1.2 mm long. *Auricular region* marked, with erect hairs 0.1–1.2 mm long. *Leaf blades* green at flowering time, erect, 35–150 mm long, 0.3–0.7 mm wide, rolled or involute; abaxial surface not ribbed, glabrous and smooth, rarely scabrous or pubescent; adaxial surface strongly ribbed, pubescent with an even covering of erect hairs 0.03–0.06 mm long. *Panicle* 60–210 mm long, exserted, contracted, 20–30 mm wide, spikelets sparse, not subtended by a marked involucl; lowest panicle internode 27–50 mm long, finely scaberulous, the hairs 0.01–0.03 mm long; minimum undivided branch length 1–7 mm,

maximum undivided branch length 6–17 mm; branches with acutely angled edges, 25–55 mm long overall including glumes; pedicels likewise angular, 2–12 mm long, scabrous on their edges, the hairs 0.05–0.2 mm long. *Spikelets* 4–12 per panicle node, 10–16 mm long. *Glumes* unequal, acuminate, scabrous on nerves, straw-coloured; lower glume 3-nerved, 10–16 mm long; upper glume 5-nerved, 6.5–10 mm long. *Floret* fusiform, 4.5–6.5 mm long, sericeous with an even covering of yellowish-brown hairs at maturity, 0.5–1.2 mm long, indumentum sometimes sparse near the apex with scabrous trichomes *c.* 0.03 mm long. *Lemma* lobes absent or minute; coma 0.8–1.3 mm long. *Callus* 1.5–2 mm long, sericeous with hairs 0.5–0.6 mm long, tip weakly bent. *Awn* 40–60 mm long, 0.22–0.3 mm wide near the base, twice bent, column 17–24 mm long, 8–13 mm to the first bend, scabrous, with hairs 0.05–0.3(–0.6) mm long, bristle straight, angular in cross section, no broader than the column, scabrous with hairs 0.07–0.15 mm long. *Palea* equal to and not enclosed by the mature lemma, margins glabrous, pubescent along and between dorsal nerves. *Lodicules* not found. *Anthers* 3, only one fertile; anterior one fertile, 0.75–1.1 mm long, not usually penicillate; posterior ones 0.3–0.7 mm long, usually having a single penicil hair per locule. *Style* glabrous. *Caryopsis* 2.7–4 mm long, *c.* 0.2 mm wide; embryo 0.7–1.1 mm long; hilum 1.8–2.5 mm long. (Figure 10A–C)

Diagnostic features. Flowering culms short and narrow, usually ≤ 1 mm wide and ≤ 600 mm tall, almost indistinguishable from innovations, erect and densely packed; basal leaf sheaths similar in diameter to tiller basal sheaths and usually ≤ 1 mm wide; mature leaves narrow, indurate and terete; leaf sheaths and blades glabrous or pubescent (hairs $\ll 0.5$ mm); lemma with brown hairs at maturity; anthers translucent white when re-hydrated, of different sizes, one fertile and 0.8–1.1 mm long, the other two sterile and 0.4–0.6 mm long.

Distribution and habitat. Occurs mainly in the Fitzgerald sub-bioregion of the Esperance Plains bioregion (Figure 10D). Forest, woodland, mallee shrubland and low heath. In loamy soils over ironstone or granite.

Phenology. Flowers October–November with fruit maturing in November–December.

Etymology. Named for the unusually dwarfed and unpigmented anthers of different lengths, only one of which is fertile, while the other two remain very short and sterile, i.e., they are staminodes (grasses generally have three long anthers of equal length).

Other specimens examined. WESTERN AUSTRALIA: [localities withheld for conservation reasons] 26 Sep. 1984, *M.A. Burgman* 3648 (PERTH); 11 Nov. 2013, *G.F. Craig* 9492–9496 (PERTH); 1 Nov. 2008, *A. Markey & J. Allen* 6261 (PERTH); 6 Dec. 2008, *A. Markey & J. Allen* 6262 (PERTH); 6 Dec. 2008, *A. Markey & J. Allen* 6263 (PERTH); 5 Dec. 2008, *A. Markey & J. Allen* 6264 (PERTH); 22 Nov. 2008, *A. Markey & J. Allen* 6265 (PERTH); 19 Nov. 2008, *A. Markey & J. Allen* 6266 (PERTH); 11 Dec. 2008, *A. Markey & J. Allen* 6272 (PERTH); 1 Nov. 2009, *W.A. Thompson & J. Allen* 2220 (PERTH); 22 Oct. 2009, *W.A. Thompson & J. Allen* 2221 (PERTH); 27 Oct. 2009, *W.A. Thompson & J. Allen* 2222 (MEL, PERTH); 27 Oct. 2009, *W.A. Thompson & J. Allen* 2223 (PERTH); 21 Oct. 2009, *W.A. Thompson & J. Allen* 2224 (PERTH).

Conservation status. Recently downgraded to Priority Two (Western Australian Herbarium 1998–) under Conservation codes for Western Australian Flora, under the phrase name *Austrostipa* sp. Ravensthorpe Range (*A. Markey & J. Allen* 6261). Restricted to Ravensthorpe Ranges. The reduction to a single functional anther in this taxon is likely to restrict reproductive success and this may limit it to specialized habitats and localised geographical ranges.

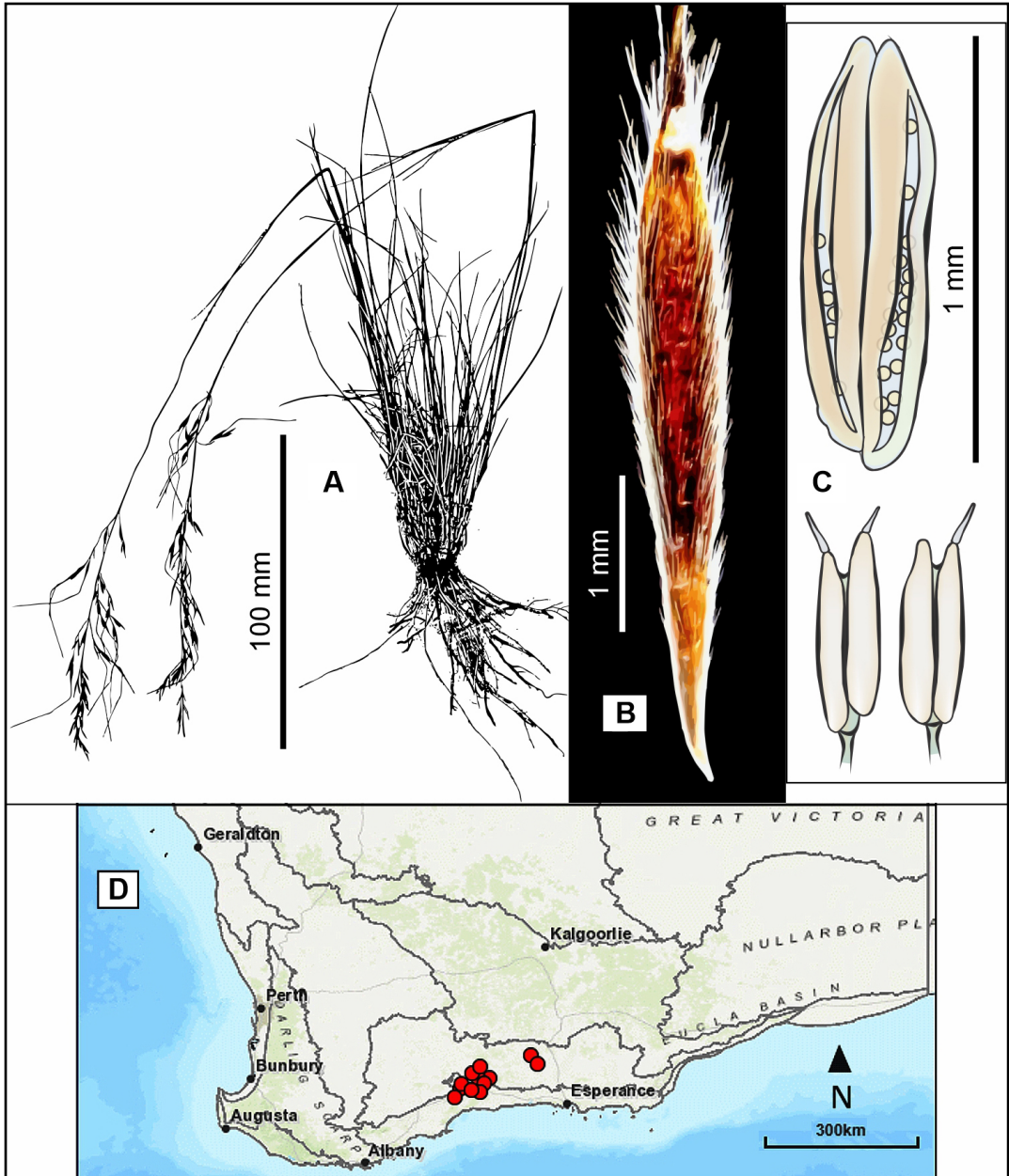


Figure 10. *Austrostipa heteranthera*. A – vector outline of mature whole plant; B – backlit image of a mature floret showing hair distribution in the shoulder region; C – vector drawings of rehydrated stamens, the anterior one (top) is fertile and the posterior two (below) are penicillate and sterile; D – distribution of *A. heteranthera* (●). Illustrations by the author based on A. Markey & J. Allen 6267.

Affinities. Differs from *A. mundula* and very small specimens of *A. flavescens* in its habit (erect, densely packed culms, sheaths, and leaves) and in having the aberrant anther development syndrome. Similar to *A. turbinata* in most characteristics but differs in having a fusiform lemma with an even covering of hairs (no 'shaved patch' as shoulder ornament), being chasmogamous rather than cleistogamous, and with glabrous leaves; it grows together with this species at Ravensthorpe Range survey site R216.

6. Notes on *Austrostipa mundula* (J.M.Black) S.W.L.Jacobs & J.Everett

The distribution of *A. mundula* is shown in Figure 11, with the previously known populations in South Australia and Victoria separately coloured (red) from the newly identified Western Australian collections (black). The species occurs in WA only in small isolated coastal populations from east of Esperance around to north of Perth. The four populations sampled in the Perth area (in 1902, 1960, 1963, and 1967) may correlate with the intensity of collection effort in that area so more collecting at other coastal locations may locate further populations. Two of the Perth populations are now extinct through urban development. The surviving population in the south is in a tiny reserve surrounded by industrial development, and the population in the north is in the urban growth region of Yanchep.

Only two characters were found to differ between the WA collections and the published description of *A. mundula*: WA collections had penicillate anthers, and hairs on the abaxial surface of the ligule. Examination of the type specimens of *A. mundula* revealed that there were some sparse hairs (sometimes only lower down) on the backs of the ligules, so that character can be eliminated from the published differences. The penicil difference, however, was confirmed to be real.

The WA collections of *A. mundula* have only one, or rarely two, fragile penicil hairs on each anther locule, while other existing members of the *Lancea* group are fully penicillate with several hairs per locule. The new species *A. heteranthera* and *A. turbinata* sometimes have a single penicil hair per locule and sometimes only on the staminodes. Does this single character justify subspecies status for the WA collections? I have chosen not to recognize subspecies status on this single character because the penicil hairs on WA *A. mundula* (and in *A. heteranthera* and *A. turbinata*) are mostly singular and unusually fragile and can be dislodged during dissection and sample preparation whereas other *Austrostipa* species usually have several penicil hairs that are quite robustly attached.

It is possible that in earlier (perhaps wetter) times, *A. mundula* may have extended right across southern WA, but then retreated during a subsequent drying phase to its currently isolated coastal positions. This scenario would be consistent with the phylogeographic review of Byrne (2008), who found widespread patterns of geographically isolated populations in many different biota of southern Australia, resulting from oscillating periods of expansion from, and contraction to, major refugia during Pleistocene climatic changes. Further studies that include molecular data could perhaps clarify the situation.

Loan specimens of *A. mundula* from South Australia (AD) included two leaf types (one form is uniformly curved in a single stiffened arc from the base, the other is straight and stiffly erect), but the type specimens are both of the former type with uniformly curved leaves in a single stiffened arc. Collections from WA likewise include specimens with either one or other of these leaf types. This difference should be taken into account in any further taxonomic work on this species.

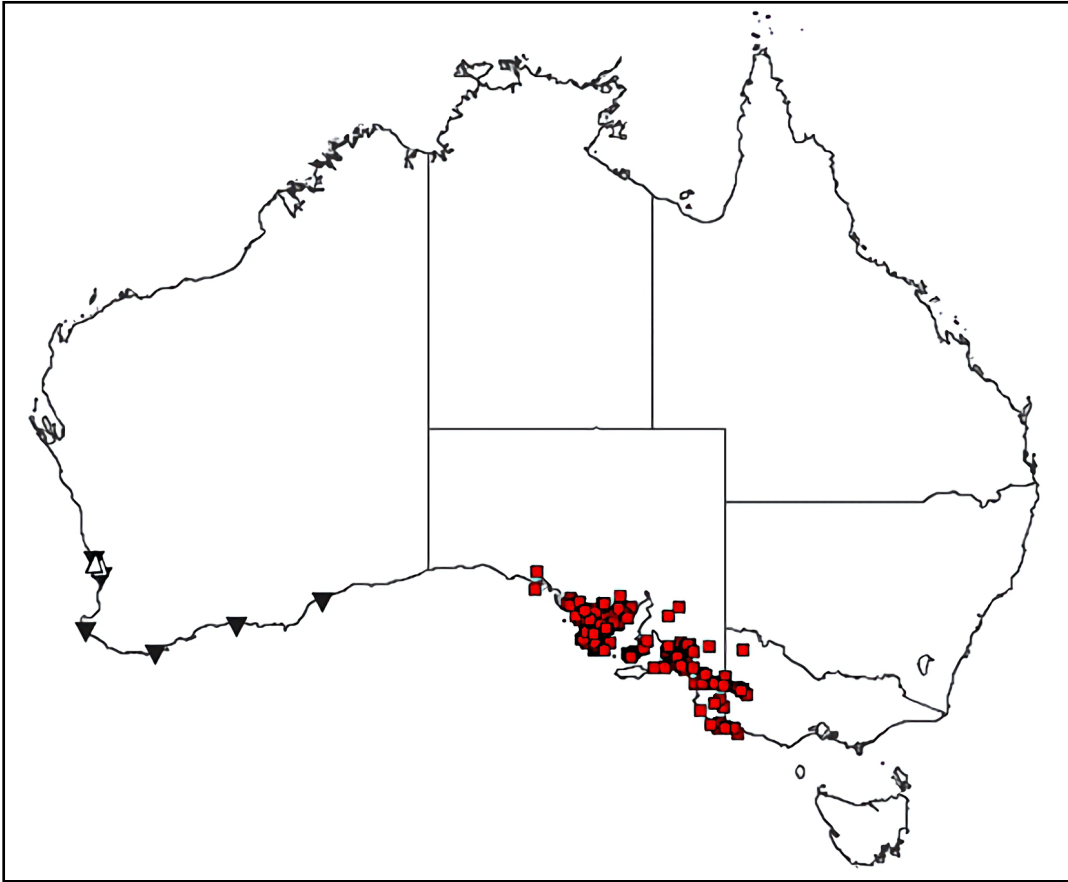


Figure 11. Distribution of *Austrostipa mundula* prior to this study (■) in southern South Australia and western Victoria, specimen data reproduced with permission from *Australasian Virtual Herbarium* (AVH 2012). Distribution of newly identified populations in Western Australia (▼) and earlier known populations now extinct (Δ).

C. *Lanterna* group (previously *Austrostipa* subg. *Lanterna* S.W.L.Jacobs & J.Everett)

Austrostipa subg. *Lanterna* was differentiated from its near relatives (which have twice-bent awns and dark brown lemmas and lemma hairs) in the *Flora of Australia* (Everett *et al.* 2009) as follows: ‘Lemma glabrous or almost so, with surface smooth and shining.’ The alternative couplet describes the surface of any glabrous portion of the lemma as being ‘rough (tuberculate or ‘crystalline’ with individual small bumps or ridges of translucent silica)’. The leaf sheath margins, auricles, and ligules in subg. *Lanterna*, now included within subg. *Austrostipa*, also bear highly distinctive very long and crinkly-woolly hairs, while species in other groups have shorter and usually straight hairs in these locations. From my observations, the species in the *Lanterna* group also appear to be exclusively cleistogamous, with dwarfed and non-pigmented anthers. This small group, according to Everett *et al.* 2009, consisted of just three species that occur in arid and semi-arid southern inland regions from eastern Western Australia to western Victoria and New South Wales.

Within this group *A. lanata* (Vickery, S.W.L.Jacobs & J.Everett) S.W.L.Jacobs & J.Everett is distinguishable because of its entirely glabrous lemma with its margins not concealing the entirely glabrous palea. The other two species, *A. vickeryana* (J.Everett & S.W.L.Jacobs) S.W.L.Jacobs &

J. Everett and *A. nullanulla* (J. Everett & S.W.L. Jacobs) S.W.L. Jacobs & J. Everett, were described as having a lemma with a sparse indumentum (rarely glabrous) which completely encloses the palea. The type specimens for each of these latter two species are clearly distinguishable from one another but only a few specimens of each species were available to the original authors, Everett and Jacobs (1983). As more specimens have accumulated since that time the differences noted in the protologues have begun to blur and overlap, suggesting that a new study was required, so a comprehensive survey was carried out across all available specimens (from PERTH, AD, MEL, and NSW) including type specimens.

Vickery *et al.* (1986) stated in the description of *A. vickeryana* that it ‘differs from *A. nullanulla* in having coarser, usually folded leaves (rolled in *A. nullanulla*), a less open inflorescence and longer lemma and awn.’ In their key, they chose lower glume length and awn length as the clearly distinguishing characters, and in a multiple-entry key the lemma length ranges were given as 6–7 and 5–6 mm respectively. I found no discernible differences in the leaf blades between these two species. Freitag (1985), in describing the large collection of Asian *Stipa* specimens available to him, distinguished two kinds of leaf blades — thin (in more moist environments) and thick (in drier environments). Under water stress both kinds of leaf blade typically roll or fold inwards (to become involute or conduplicate) and they reduce water loss by depositing extra sclerenchyma under the outer (abaxial) surface layer. This is not sufficient in thin blades to obscure their ribbed appearance on the outer (abaxial) surface, but in thick blades the extra sclerenchyma does obscure the ribs (vascular bundles) so that the abaxial surface becomes smooth and the rolled or folded blade becomes almost circular in cross section. Freitag (1985) described this latter condition as xeromorphic, however it had been described earlier by Hughes (1921) and termed sclerophyllous in Australian *Stipa*, so I retained that terminology here. Neither Vickery *et al.* (1986) nor Everett *et al.* (2009) recognized this leaf condition, even though both species typically occur in saline arid or semi-arid (i.e., xeric) habitats. All mature leaves on specimens that I examined were characteristically sclerophyllous, but younger leaves were more varied in appearance.

The inflorescences in both species were all contracted in mature plants, especially after floret disarticulation, but they were larger in larger plants, and broader when they were fully laden with fresh young florets, which is also when the panicle branches were most pliable and there was a larger mass for gravity to pull the branches downward and thus also outwards. I saw no evidence of pulvini in branch axils that might also have contributed to this effect. Leaf and panicle data were not included in the keys provided in Vickery *et al.* (1986) and Everett *et al.* (2009), suggesting that these authors did not consider their noted characters to be consistently reliable. Gonzalez *et al.* (2012) and Freitag (1985) studied character reliability in *Stipa s. str.* and they found that floral characters proved consistently more reliable than vegetative characters, so I focussed on the following floral characters that were listed as reliably diagnostic in the published keys: lower glume length, awn length, awn column length, column length to the first bend, column length from the first to second bend, bristle length, and lemma length.

Sixty-two fertile specimens were examined, of which 12 were identified as *A. vickeryana* and 50 as *A. nullanulla*. An UPGMA classification of specimens using Euclidean distance produced a group of 28 that included the two *A. vickeryana* type specimens, and a group of 34 specimens that included the two *A. nullanulla* type specimens. Several ordination methods all produced a continuum of variation with no discernible disjunctions between these two groups of specimens, as illustrated in Figure 12, and discriminant analysis likewise did not extract two significantly different groups. The two groups appear to simply distinguish specimens with smaller floral parts (*A. nullanulla*) from those with larger floral parts (*A. vickeryana*) as illustrated in Figure 12. Jessop *et al.* (2006) noted the same result of their studies, saying ‘The differences between [the two species] are entirely in measurements, such as glumes, lemma and awn lengths. A specimen from near Tallaringa Well (NW) is intermediate between

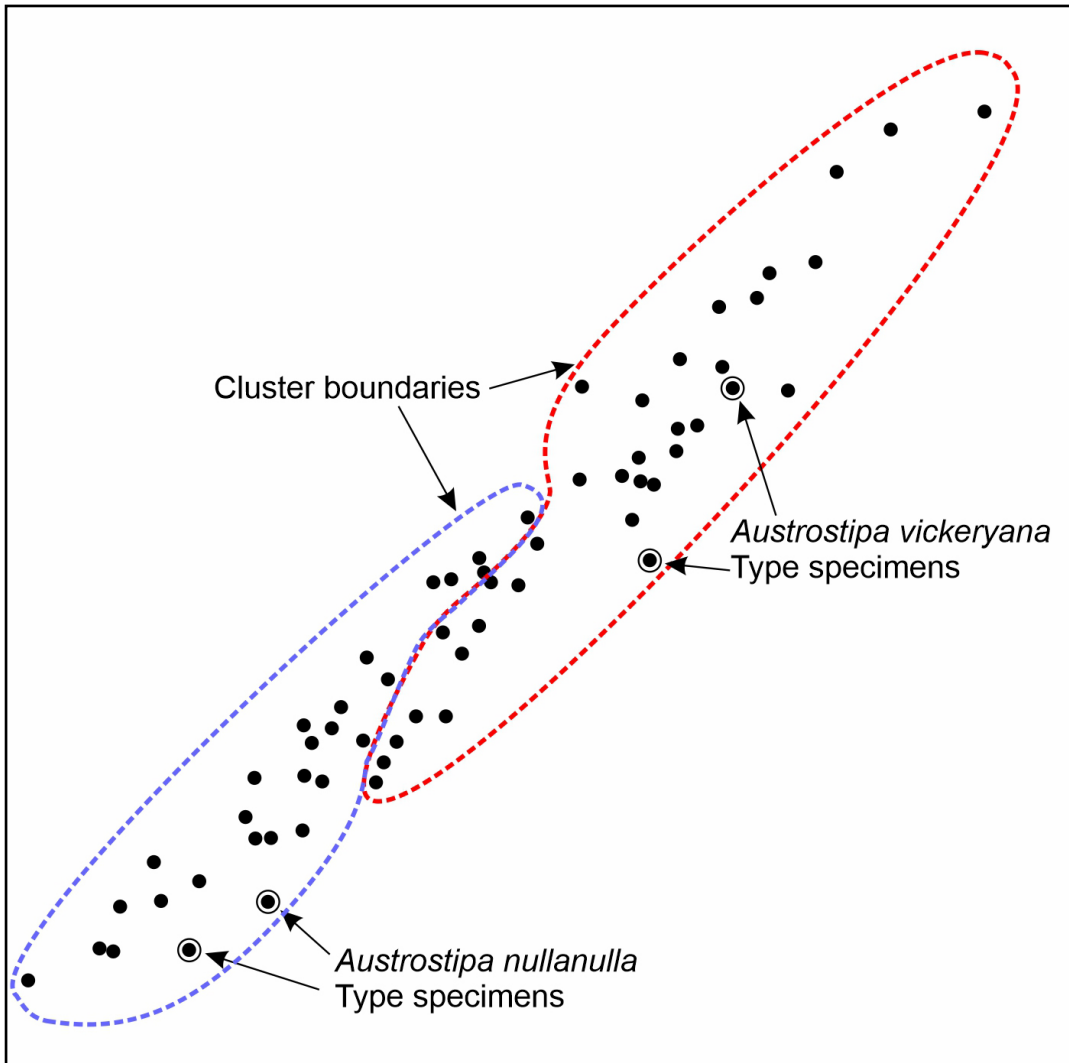


Figure 12. Overlapping character states in *Austrostipa vickeryana* and *A. nullanulla*. Non-metric multidimensional scaling plot of 62 specimens based on 7 floral characters, rotated 45° to reflect generally increasing floral character sizes from left to right (98% of the variance is represented in the long axis, with 1% in the narrow axis). Type specimens of *Austrostipa vickeryana* and *A. nullanulla* are circled and labelled. The dashed lines enclose the two groups identified in a UPGMA classification of Box-Cox normalized data. The type specimens were clearly distinct from one another originally, but if they had really represented two separate species then a disjunction should occur within the larger sample of specimens. There is no such disjunction, but rather a large overlapping region between the two groups, so the two names simply represent a trend from specimens with generally smaller floral parts on the left (*A. nullanulla*) to those with generally larger floral parts on the right (*A. vickeryana*) within a single-species complex.

these two species and cannot be identified.’ Accordingly, I have reduced *A. nullanulla* to become a synonym of *A. vickeryana*.

Molecular analyses by Jacobs *et al.* (2007) on the systematics of the tribe *Stipeae* included both *A. nullanulla* and *A. vickeryana*. They found that *A. nullanulla* separated at a terminal branch of the cladogram from *A. blackii* (these two species are strikingly different morphologically) and these two then joined *A. vickeryana* at the next branch point. Similar terminal triplet patterns were found in triplicate within-species specimens of *A. elegantissima*, *A. ramosissima*, and *A. scabra*, which

suggests that *A. nullanulla* and *A. vickeryana* differ only at a within-species level (the suggested connection between *A. nullanulla* and *A. blackii* is morphologically quite spurious). Furthermore, the same terminal triplet pattern also occurred on a nearby branch that joined *Achnatherum pinetorum*, *Austrostipa mollis* and *Nasella argentinensis*, indicating that the data were not providing any useful phylogenetic information at the species level at all. This study was based on nuclear ribosomal ITS sequences and a review by Alvarez and Wendel (2003) listed so many problems using ribosomal ITS sequences they concluded, ‘we recommend that ITS no longer be routinely utilized for phylogenetic analyses.’ It therefore seems premature to place any species-level taxonomic weight on this particular result in Jacobs *et al.* (2007).

Key to the species in *Lanterna* group

1. Lower glume 15–26 mm long; ligules 0.4–1.5 mm long; lemma and palea usually entirely glabrous, palea fully or at least clearly exposed at maturity **A. lanata**
- 1: Lower glume 9–18 mm long; at least some ligules >> 2 mm long; lemma and palea sparsely hairy (rarely both glabrous), palea fully and firmly enclosed by lemma throughout development..... **A. vickeryana**

7. *Austrostipa lanata* (Vickery, S.W.L.Jacobs & J.Everett) J.Everett & S.W.L.Jacobs, *Telopea* 6: 586 (1996). *Stipa lanata* Vickery, S.W.L.Jacobs & J.Everett, *Telopea* 3: 68 (1986). *Type*: north of Mundrabilla Homestead, Western Australia [precise locality withheld for conservation reasons], 31 July 1974, A.A. Mitchell 2 (*holo*: PERTH 00985961!).

Perennial *tussock grass*, 300–450 mm tall. *Culms* 1–2 mm wide near the base, terete, ribbed, glabrous to pubescent, especially below the nodes; nodes 1 or 2, glabrous to puberulous, exerted only in older, geniculate culms. *Leaf sheaths* broad, the upper sheaths inflated, innovations held tightly into bundles; ribs of lowermost sheaths long-woolly to hirsute, pubescent between the ribs, to glabrous with age on uppermost sheaths; outer margin glabrous to long-woolly ciliate, especially just below the ligule; inner margin glabrous. *Ligules* 0.4–1.5 mm long, truncate, densely ciliate. *Auricular region* with conspicuous long woolly hairs. *Leaf blades* expanded to loosely rolled, 100–200 mm long, 1.5–4 mm wide, abaxial surface unribbed to strongly ribbed, glabrous above to antrorsely hirsute on lower leaves; adaxial surface strongly ribbed, pubescent, the hairs short, more or less antrorse. *Panicle* 10–15 cm long, contracted, generally few-flowered, the base enclosed by the sheath except when mature; axis terete, pubescent, ribbed; branches terete, 10–40 mm long, hirsute to pubescent; pedicels angular, 4–15 mm long, hirsute to pubescent. *Spikelets* 15–26 mm long, slightly gaping at maturity after floret disarticulation. *Glumes* unequal, smooth, firm and often purple-coloured at the base, hyaline at the acuminate tips; lower glume 15–26 mm long, 3-nerved in lower part; upper glume 14–19 mm long, 5-nerved in lower part. *Floret* turbinate, 6–8 mm long, with a neck. *Lemma* deep brown at maturity, smooth, shiny, entirely glabrous (1 specimen had some hairs) except for a minutely scaberulous dorsal patch of antrorse hairs on the neck; lemma margins smoothly drawn back to expose the entirely glabrous palea (1 specimen had some hairs); coma present but sparse, in two tufts, 1–1.5 mm long. *Callus* prominent 3–4 mm long, straight, the hairs white or coppery to dark rusty brown at maturity. *Awn* 50–80 mm long, 0.4–0.5 mm wide near the base, twice bent; column 20–30 mm long, 8–15 mm to the first bend, densely pubescent, hairs 0.1–0.3 mm long; bristle antrorsely scabrous. *Palea* subequal to the lemma, obtuse, ciliate at the tip but otherwise glabrous and shiny. *Lodicules* 2–3; abaxial lodicules membranous, *c.* 1 mm long, oblong; paleal lodicule absent or acute, 0.5–0.8 mm long. *Anthers* unpigmented, dwarf, 0.3–0.4 mm long. *Style* glabrous. *Caryopsis* 4 mm long; embryo *c.* 30% the length, hilum *c.* 85% the length. (Figure 13D–G)

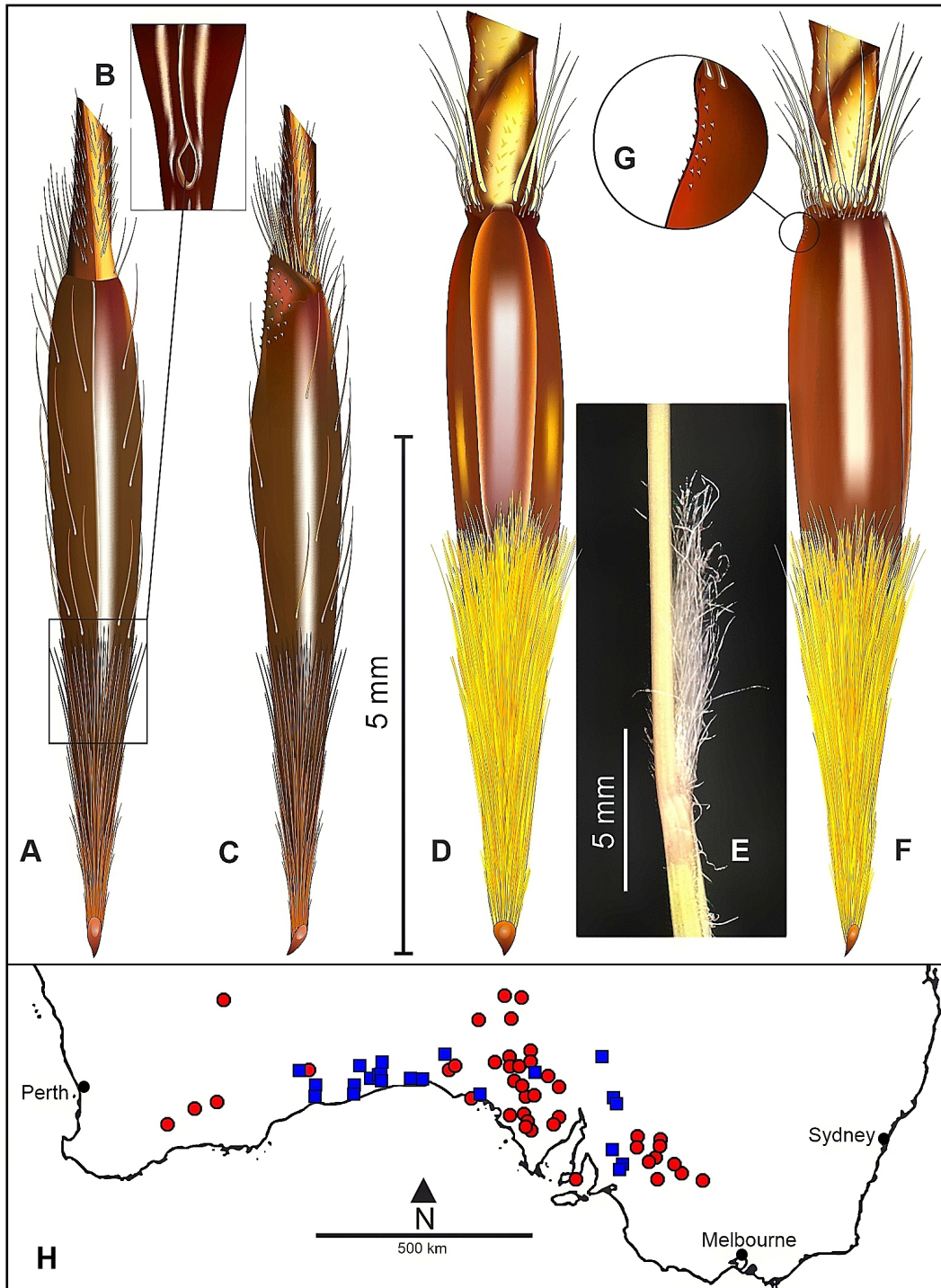


Figure 13. *Lanterna* group of *Austrostipa* subgenus *Austrostipa*. A–C *A. vickeryana*; A – floret, adaxial view, lemma margins overlapping; B – magnified lemma base with hairs removed, lemma margins diverge initially but then fold back and overlap; C – floret, lateral view; D–G *A. lanata*; D – floret, adaxial view; E – leaf sheath/blade collar region showing very long hairs on the ligule; F – floret lateral view; G – enlarged view of the scabrid neck region; H – distribution of *A. lanata* (■) and *A. vickeryana* (●), data from Australia’s Virtual Herbarium (AVH 2016). Illustrations by the author based on *W. O’Sullivan* WOS303 (A–C); *A.A. Mitchell* 2 (D, F); and *F.M. Hilton* 234 (E).

Diagnostic features. Differs from *A. vickeryana* in the lemma and palea being entirely glabrous, the lemma margins being drawn back to expose the palea throughout development, and ligules 0.5–1.5 mm long. Distinguished from other species with twice-bent awns and dark brown lemmas and lemma hairs by the smooth and shiny lemma and palea surfaces and the leaf sheath margins, auricles and ligules bearing very long and crinkly-woolly hairs.

Specimens examined. WESTERN AUSTRALIA: [localities withheld for conservation reasons] 22 June 1966, *D.W. Goodall* 2705 (PERTH); 30 Aug. 1930, *E.R.L. Johnson* 68 (PERTH); Aug. 1930, *M.B. Johnston s.n.* (PERTH); 6 Dec. 1993, *J. Landsberg & J.M. Stol* 86 (PERTH); 7 Dec 1993, *J. Landsberg & J.M. Stol* 88 (PERTH). SOUTH AUSTRALIA: Nov. 2005, *Anon. s.n.* (AD); 5 Oct. 1966, *A.C. Beaglehole* 20041 (AD, NSW); 27 Nov. 1980, *J. Everett* 160 & *S.W.L. Jacobs* (NSW); 28 Nov. 1980, *J. Everett* 165 & *S. Jacobs* (NSW); 16 Oct. 1952, *F.M. Hilton* 234 (AD); 10 Oct. 1986, *G.J. Keighery & J.J. Alford* 875 (NSW); 19 Oct. 1997, *D.E. Murfet* 2977 (AD).

Phenology. Flowers June to December, fruits mature late-spring to early summer.

Distribution and habitat. Inland south-eastern Western Australia in the Coolgardie, Mallee, Murchison and Nullarbor bioregions, to western and central South Australia (Figure 13H), on shallow calcareous soils.

Conservation status. Recently listed as Priority Three (Western Australian Herbarium 1998–) under Conservation Codes for Western Australian Flora. While it is rarely collected *A. lanata* occurs across a wide geographic range in Australia.

Etymology. From Latin meaning ‘woolly’, regarding the sheath orifice indumentum.

Affinities. Considered by the original authors to be most similar to *A. eremophila* (of the *Eremophilae*), but later separated into the *Lanterna* group by Jacobs and Everett (1996).

8. *Austrostipa vickeryana* (J.Everett & S.W.L.Jacobs) S.W.L.Jacobs & J.Everett, *Telopea* 6: 589 (1996); *Stipa vickeryana* J.Everett & S.W.L.Jacobs, *Telopea* 2: 397 (1983). *Type:* Ifould Lake, Nullarbor Plain, South Australia, 2 October 1975, *R.J. Chinnock* 2729 (*holo:* AD 97546275!; *iso:* NSW 300383!).

Austrostipa nullanulla (J.Everett & S.W.L.Jacobs) S.W.L.Jacobs & J.Everett, *Telopea* 6: 587 (1996); *Stipa nullanulla* J.Everett & S.W.L.Jacobs, *Telopea* 2: 397 (1983). *Type:* ‘Nulla Nulla’ 2 km south of gate at northern end of Bluff Paddock. 25 November 1980, *J. Everett* 133 & *S.W.L. Jacobs* (*holo:* NSW 300364!; *iso:* AD 98414080!).

Annual or perennial *tussockgrass*, 400–450 mm tall. *Culms* (1.5–)2–2.5 mm wide near the base, terete to flattened (slightly), mostly glabrous but may be pubescent below the nodes; culm basal region glabrous; nodes 1 or 2, glabrous, rarely exserted. *Leaf sheaths* loose, glabrous, scabrous, or pubescent on the lowermost sheath bases or between the nerves, margins with long woolly cilia. *Ligules* membranous, lacinate, 1–8(–13) mm long, margin densely ciliate with long woolly hairs to 9 mm on tips and back, especially on those of the lower sheaths. *Auricular region* with conspicuous hairs. *Leafblades* rolled or folded at maturity, 10–30 cm long, 1–4 mm wide; abaxial surface unribbed, glabrous or very sparsely scaberulous; adaxial surface strongly ribbed, pubescent, the hairs short, margins scabrous. *Panicle* 9–20 cm long, exserted or included (the base enclosed by the sheath), slightly spreading when loaded with florets, narrow after they have fallen; branches 4–60 cm long, scaberulous, scabrous or shortly

pubescent; pedicels similar, 3–15 cm long. *Spikelets* 9–18 mm long, slightly gaping (at maturity) or widely gaping (after floret disarticulation). *Glumes* unequal, finely acuminate, scaberulous (on the nerves) or glabrous (between the nerves) or pubescent (minutely, especially at the tip), basally firm and membranous at the tip; lower glume 9–18 mm long, 3-nerved in lower part; upper glume 8–14 mm long, 5–7-nerved in lower part. *Floret* fusiform to turbinate, 5–7.5 mm long, with a neck. *Lemma* deep brown, 5-nerved and tightly convolute at maturity, smooth and shiny, except for an antrorsely scabrous dorsal patch on the neck, glabrous to very sparsely clothed with light brown, or dark brown hairs, denser along the margins; coma present, sparse in front, 1–1.7 mm long, angled distinctively upwards at the sides to meet at the back; lemma lobes absent. *Callus* 2–3 mm long, straight, the sericeous hairs light brown to coppery colour. *Awn* 45–125 mm long (relatively slender for its length), 0.23–0.3 mm wide near the base, twice bent; column 14–32 mm long, 7–18 mm to the first bend, scabrous or pubescent, hairs 0.1–0.3 mm long; bristle antrorsely scabrous. *Palea* subequal to the lemma, obtuse, glabrous or with sparse coppery hairs along the centre or apex only. *Lodicules* 3; abaxial lodicules membranous, c. 1 mm long, spatulate; paleal lodicule present, much smaller than the abaxial lodicules. *Anthers* unpigmented, dwarfed, 0.6–0.7 mm long. *Style* glabrous. *Caryopsis* 2.5–3 mm long, embryo 25–35% the length; hilum 65–75% the length. (Figure 13A–C)

Diagnostic features. Differs from *A. lanata* in the palea being entirely enclosed by the lemma throughout development, the lemma and palea being usually sparsely hairy, or rarely both glabrous, and at least some ligules >> 2 mm long. Differs from other species with twice-bent awns and dark brown lemmas and lemma hairs by the smooth and shiny lemma and palea surfaces and the leaf sheath margins, auricles and ligules bearing very long and crinkly-woolly hairs.

Selected specimens examined. WESTERN AUSTRALIA: [localities withheld for conservation reasons] 29 Sep. 1992, *G.J. Keighery* 13122 (PERTH); 25 Oct. 2000, *M.N. Lyons & S.D. Lyons* 3409 (CANB *n.v.*, PERTH); 23 Nov. 1997, *W. O'Sullivan* WOS 301 (PERTH); 23 Nov. 1997, *W. O'Sullivan* WOS 303 (PERTH). SOUTH AUSTRALIA: N of Tarcoola – Bulgunnia, 15 Apr. 1998, *R.J. Bates* 50171 (AD); 28 Sep. 1998, *R.J. Bates* 51079 (AD); Island in *s. dat.*, *D.J. Duval* 1588 (AD); 9 Nov. 2005, *M.K. Jones* 112 (AD); 24 Oct. 1998, *D.E. Murfet* 3362 (AD); 28 Oct. 2010, *H.P. Vonow* BS721-403 (AD). NEW SOUTH WALES: 25 Nov. 1980, *J. Everett* 132 (NSW); 12 Dec. 1985, *S.W.L. Jacobs* 4625 (NSW); 9 Dec. 1986, *R.F. Parsons* 606 (NSW); 3 Dec. 1975, *R.J. Stanley* 1784 (NSW). VICTORIA: 17 Dec. 1986, *J.H. Browne* 409 (AD *n.v.*, CANB, HO *n.v.*, MEL *n.v.*, NSW *n.v.*); 21 Feb. 1991, *G. Burnell s.n.* (MEL); 23 Oct. 2007, *J.A. Jeanes* 1715 (AD *n.v.*, CANB *n.v.*, MEL); 4 Dec. 2007, *I.R.K. S[luiter]* 08/06 (MEL).

Phenology. Flowers from June to October, fruits mature from late spring to early summer.

Distribution and habitat. Inland saline areas of eastern Western Australia through to western New South Wales and Victoria (Figure 13H). Grows on low rises (Kopi dunes) around gypsum salt lakes.

Conservation status. Recently listed as Priority Three (Western Australian Herbarium 1998–) under Conservation Codes for Western Australian Flora. Widespread across southern inland parts of the continent but not common. Few localities are known for Western Australia.

Etymology. The epithet was chosen by the original authors to honour their eminent mentor Dr Joyce Vickery MBE, (1908–1979), pioneer female botanist, conservationist, and Australian grass specialist, forensic scientist, and journal editor at the New South Wales National Herbarium, Royal Botanic Gardens, Sydney (Hooker 2002). Having personally benefitted from Dr Vickery's expertise in my early career I also wished to honour her memory in this instance.

Affinities. Considered by the original authors to be most similar to *A. eremophila* (of the *Eremophilae* group), but later placed in the *Lanterna* group.

D. *Tuberculatae* group (previously *Austrostipa* subg. *Tuberculatae* S.W.L.Jacobs & J.Everett)

The glossy tuberculate lemma surface of *A. burgesiana* undoubtedly places it in the *Tuberculatae* group, but this group has no other representatives in WA. All other species occur on the eastern side of the continent, including eastern Tasmania, with the nearest known occurrence being about 2,000 km away east of Adelaide in South Australia.

9. *Austrostipa burgesiana* A.R. Williams, *sp. nov.*

Typus: ‘Mt Burgess’ Station [Mt Burges Station], Western Australia [precise locality withheld for conservation reasons], 3 December 2013, A.A. Mitchell & P.J. Waddell 10499 (*holo:* PERTH 08552363; *iso:* AD *n.v.*, BRI *n.v.*).

Austrostipa sp. Mount Burgess (A.A. Mitchell & P.J. Waddell 10499), Western Australian Herbarium, in *Florabase*, <https://florabase.dpaw.wa.gov.au/> [accessed 12 July 2021]

Robust, erect, perennial *tussock grass*, branching extravaginally, 800–1000 mm tall. *Culms* unbranched, not geniculate, glabrous, *c.* 2 mm wide at the base; nodes 4 or 5, glabrous, exserted. *Leaf sheaths:* basal ones *c.* 2.5 mm wide, hirsute; upper ones glabrous, *c.* 1.2 mm wide. *Ligules* 0.5–1.0 mm long, acute, densely ciliate on margins and abaxially; adaxial surface glabrous. *Auricles* present, with a small tuft of hairs, *c.* 0.3 mm long. *Leaf blades* 70–120 mm long, lower ones hirsute, upper ones glabrous, rolled, *c.* 0.3 mm wide. *Panicle* narrow, *c.* 20 mm wide, 150–250 mm long, involucre a glabrous ridge, spikelets few and densely clustered at the lower nodes, on branches too short (≤ 40 mm long) to overlap the internodes (*c.* 50 mm long); minimum undivided branch length 1 mm, maximum undivided branch length 7 mm; maximum branch length 40 mm long (including glumes) scabrous on the edges. *Spikelets* 13–18 per node, 10–11 mm long. *Glumes* subequal, acuminate, translucent, glabrous, prominently 3-nerved; upper glume 10–11 mm long, lower glume 9–10 mm long. *Floret* turbinate, 4.5–5.5 mm long (including the callus), sericeous with sparse brown hairs except for the glabrous shoulder region. *Lemma* dark brown, tuberculate all over, glabrous in the upper 0.5 mm exposing the tuberculate shoulder surface. *Callus* *c.* 1.3 mm long, sericeous with hairs *c.* 0.3 mm long. *Lemma* margins overlapping in the mature floret. *Awn* column plumose in the lower part (hairs *c.* 0.5 mm long) tapering to scabrous (*c.* 0.05 mm long) in the upper part, twice bent, 5–7 mm to the first bend, 6–7 mm to the second bend, *c.* 0.25 mm wide at the base; bristle 23–25 mm long, scabrous; total awn length 34–38 mm. *Palea* glabrous. *Lodicules* not seen. *Anthers* not seen (apparently shed during anthesis). *Style* glabrous. *Caryopsis* *c.* 2.7 mm long but immature; embryo and hilum underdeveloped and not yet visible. (Figure 14A–C & E)

Diagnostic features. Differs from all other WA species in its unique combination of the lemma surface being glossy and rough (tuberculate) due to silica bodies that shatter when scraped with the edge of a scalpel blade, its distinctively reduced panicle structure and its densely pubescent ligules bearing conspicuously white hairs.

Phenology. Flowers late spring with fruit maturing in early summer.

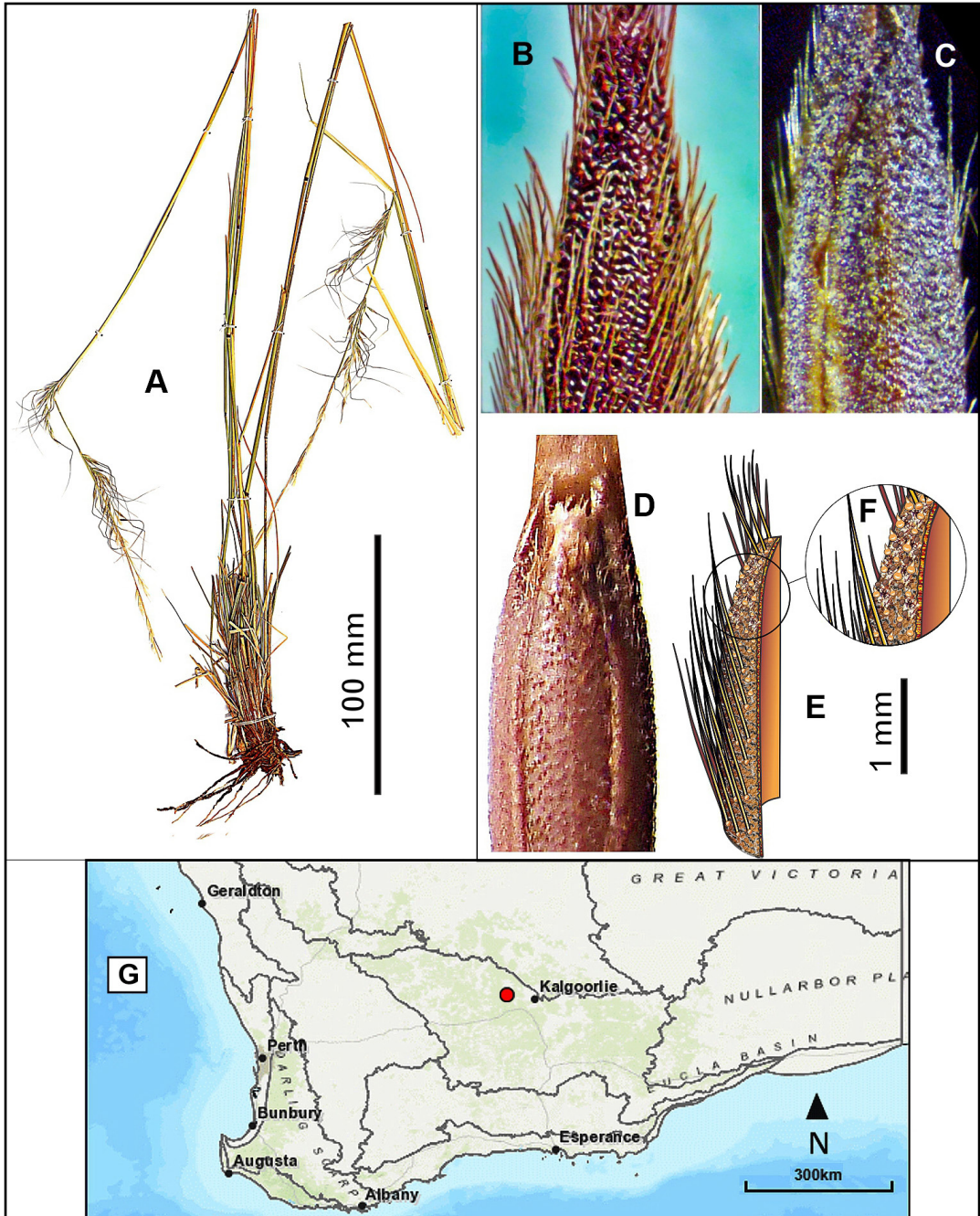


Figure 14. *Austrostipa burgesiana* and a single image of an *A. eremophila* floret. A – image of whole mature plant of *A. burgesiana*; B – image of floret shoulder region showing lemma surface entirely covered with glossy silica tubercles; C – same region of lemma surface after scraping with a scalpel blade, the fractured silica bodies creating the whitish colour showing that the entire surface has been damaged; D – upper lemma and palea surface of *A. eremophila* floret after being scraped with a scalpel blade in the same way showing that hairs have been shaved off leaving the lignified surface cells undamaged; E – schematic diagram of the lemma shoulder region of *A. burgesiana* with magnified section (F) showing a variety of different silica features that are not easily resolved with a light microscope; G – location of population (●). Items B–E are all at the same scale. Images and vector illustrations by the author based on A.A. Mitchell & P.J. Waddell 10499 (A–C, E), and T.E.H. Aplin 1662 (D).

Distribution and habitat. Only known from a single collection near Mt Burges Station homestead (Figure 14G), in the Southern Goldfields of the Coolgardie bioregion, where it was an infrequent component of a *Maireana pyramidata* shrubland on a flow line within a calcareous plain.

Conservation status. Recently listed as Priority One (Western Australian Herbarium 1998–) under Conservation Codes for Western Australian Flora under the phrase name *Austrostipa* sp. Mt Burges (A.A. Mitchell & P.J. Waddell 10499).

Etymology. This species is named for Mt Burges Station, where the only known specimen was collected, but is also an acknowledgment of my heritage. A 'burgess' in English, from medieval times, referred to a free citizen of a town or borough, sometimes a landowner with merchant and voting rights, or to a representative of such in local government or in the national parliament. The surname Burgess (or Burges) thus carries the sense of ordinary people being good citizens, including my maternal grandfather, Edward Burgess, and my mother Mavis.

Affinities. Key differences from other species within the *Tuberculatae* group include the following: lemma hairs not restricted to nerves (this excludes *A. oligostachya*); culms erect (this excludes *A. muelleri*); spikelets > 12 per inflorescence (this excludes *A. nivicola*); leaf blades intact at flowering (this excludes *A. aphylla*); glumes tapering to a fine acuminate tip (this excludes *A. rudis*, *A. pubescens* and *A. pubinodis*). The nearest match in the *Flora of Australia* key is to *A. aphylla* in that the leaf blades in both species are extremely narrow and rather short for such a robust plant (perhaps withering prior to falling?). However, *A. aphylla* only occurs in eastern Tasmania and it differs from *A. burgesiana* in numerous other features. The likely nearest related WA group, *Eremophilae*, can be distinguished on the following characters. The lemma surface in *Eremophilae* is smooth and dull brown, not glossy and tuberculate, and the upper 0.5 mm is not glabrous but bears a distinct patch of short hairs; mature lemma hairs in *Eremophilae* are a much darker rich brown colour. The panicle in *Eremophilae* is not contracted, with few spikelets on short branches clustered at the nodes; it is more symmetrically broad and more open with evenly distributed spikelets. Awn column hairs in *Eremophilae* are of even length throughout.

Notes. Tubercles and tuberculate hairs can be seen under a microscope but may be unfamiliar to those working with WA species of *Austrostipa*. A convenient technique for uniquely identifying them is to scrape the hairs off the lemma with the edge of a sharp scalpel blade. The tubercles readily shatter and at least some of the dislodged hairs will retain a fragment of the fractured tubercle at their base. However, the most obvious result is that the bared lemma surface is left covered with disrupted tubercles, which take on a whitish appearance due to reflection and refraction of light from the fractured silica, clearly distinct from the undisturbed dark brown lemma surface in the background (Figure 14C). When hairs are scraped off the mature lemmas of other WA species, they usually come off cleanly at the base, leaving the hard, lignified, lemma surface without any damage or discoloration, as in *A. eremophila* (Figure 14D).

2. *Austrostipa* subg. *Falcatae* S.W.L.Jacobs & J.Everett

Falcatae S.W.L.Jacobs & J.Everett is a large subgenus in *Austrostipa* that occurs right across southern Australia. The taxonomic history of some species within *Falcatae* has been complex and remains controversial, as noted below. Amongst published molecular studies relevant to subgenus structure within *Austrostipa* both Syme *et al.* (2012) and Syme (2012) managed to obtain a reasonably meaningful picture with ITS sequence comparisons, and both identified *Falcatae* as being monophyletic, with all eight taxa (out of 31 in the study) grouped together into a single clade. Winterfeld *et al.* (2015) used

cytogenetic data mapped onto molecular phylogenetic trees based on nuclear ITS and chloroplast 3' *trnK* DNA sequence data and likewise found *Falcatae* to be a distinctively monophyletic group.

Three new species are described and illustrated here: *Austrostipa nunaginisensis* (*A.* sp. Cairn Hill) known from seven sites in the northern wheatbelt (Greenough to Bruce Rock), *A. frankliniae* (*A.* sp. Dowerin) known from three populations in the east-central wheatbelt (Dowerin to Coolgardie), and *A. anaiwaniorum* (*A.* sp. Marchagee) quite widely collected but previously included under the name *A. tenuifolia*.

Vickery *et al.* (1986) recognised a lot of variation in the members of this subgenus, and their main points are still relevant, given below in quotes. *Austrostipa nitida*, the type species for the genus, 'is a very variable species. ... The auricles ... vary from glabrous to woolly, with no detectable pattern that we could correlate with variation in other characters. There is similar variation in other vegetative characters.' They cited 15 specimens that 'all have broad leaves and sheaths' and said 'Other such groups of specimens can be separated from [*A.*] *nitida* but we have been unable to detect any reliable pattern in the variability. Clearly this large species and its many forms would be worthy of further studies.' Hughes (1921) is cited as having confused *A. nitida* with *A. scabra*.

'The identity and circumscription of [*Austrostipa*] *falcata*, treated here as [*A.*] *scabra* subsp. *falcata*, have been a source of considerable confusion in Australian herbaria where many other species have been misdetermined under this name' — Hughes, Black and Bentham are cited. 'In foliage, appearance of the rootstock, glumes, indumentum and dimensions of the lemma and column, the two subspecies are much alike.' They identified the inflorescence shape and the ligule as the differentiating characters. However, they then admitted 'There are some intermediates between the subspecies that have the inflorescence type of one subspecies but the ligule type of the other' and cited 10 examples.

Regarding *Austrostipa tenuifolia* they said it 'is similar to *A. variabilis* but differs in the longer floret and awns and the longer, usually unequal glumes.' In their written descriptions, the awn lengths of these two species overlap and several specimens of *A. tenuifolia* in our collection that were determined by Vickery and/or Everett have florets in the 6–7 mm range, overlapping that of *A. variabilis*.

Regarding *A. variabilis* they said, 'The specific epithet has been applied to a range of species (nearly all of the *Falcatae*) by Australian collectors and authors in recent years, and their identifications and descriptions must be regarded with caution.' They then attempted to clarify the situation by stating that '*S. variabilis* is characterised by a floret 4.5–7 mm long and a densely pubescent column of the awn.' In their written descriptions we find that all but *A. tenuifolia* fit the floret size range (and, as mentioned previously, several specimens of *A. tenuifolia* in our collection determined by them have florets in the 6–7 mm range), and *A. trichophylla* and *A. tenuifolia* can both have "densely pubescent" and *A. nitida* can have 'pubescent' columns.

They made no specific comments on *A. trichophylla*, *A. nodosa*, or *A. drummondii* so we could infer that these species fit well within their descriptions. However, we have already seen that *A. trichophylla* overlaps with *A. variabilis*, and in their written descriptions *A. nodosa* and *A. drummondii* overlap at least some of the other species in virtually all characters used.

Jessop *et al.* (2006) found similar problems with character variability and offered the following advice with their key to the South Australian species. 'This key must be used with caution. Many species

overlap in their characters more than implied by Vickery, Jacobs and Everett and absolutely reliable characters are sometimes hard, if not impossible, to find.’ ‘Specimens apparently intermediate with *A. nitida* and *A. scabra* are particularly common. Less frequent problems occur with distinguishing it from *A. drummondii*, which is usually recognisable by its thick and often short leaves and characteristic indumentum. An isotype of *A. nitida* in AD has leaves which are closer to *A. scabra* in width than to *A. nitida*.’ ‘*A. nodosa* merges with both *A. nitida* and *A. scabra*. The often-exposed culm nodes, the sparse panicle and the leaf breadth provide characters for separating *A. nodosa*, but many specimens cannot be identified with certainty.’ Regarding the two subspecies of *A. scabra* ‘A large number of specimens cannot be placed with any certainty and users may prefer to ignore the subspecies. There is also a problem in distinguishing *A. scabra* from a number of other species ... especially *A. nitida*. The large number of very narrow, very straight leaves is immediately recognisable on many specimens, but intermediates do occur. It has been decided to treat specimens formerly identified as *A. variabilis* in this species. [They] were [originally] described from opposite ends of the continent and separated in their key by Vickery [*et al.*] (1986) on the length of the hairs on their columns. ... this character is not very reliable.’ Regarding *A. trichophylla* ‘[they] give the column hairs as usually 0.15–0.3 mm long, yet in their key it is allocated to the group with [column] hairs 0.25–0.8 (as opposed to [those with] 0.2 mm long or less). ... specimens identified by one of them show that the hairs may even be about 1 mm long.’

Jessop *et al.* (2006) recorded no difficulties with *A. tenuifolia*. However, I discovered that in our PERTH collections of *A. tenuifolia* there were two mutually exclusive kinds of collar regions (i.e. specimens either had one type or another, with no intermediates) as illustrated in Figure 15C compared with Figure 18C. Type specimens for *A. tenuifolia* were found to be all of the latter kind (as in Figure 18C) so I have segregated specimens with the alternative kind (Figure 15C) into a new species *A. anaiwaniorum*. The new species is quite abundant in WA and its geographic range is similar to that of *A. tenuifolia*, but it does not extend as far eastward, as illustrated in Figure 15D. Removal of *A. anaiwaniorum* from within *A. tenuifolia* required a revision of the description of *A. tenuifolia*, which is given below.

The descriptions of *A. tenuifolia* in Vickery *et al.* (1986) and in the *Flora of Australia* (Everett *et al.* 2009) both say that the abaxial surface of the ligule can be either hairy or glabrous, and the authors identified specimens of both kinds among the PERTH collection as being ‘*Stipa*’ *tenuifolia*. The key character used to separate this taxon from *A. blakei* in Vickery *et al.* (1986) was: ‘Auricles hirsute with a dense line of long white hairs,’ but this character is not present on any of their cited type specimens, which all lack an auricle. Their synonymy included six previously named taxa based on four Drummond collections from Western Australia and their discussion of synonymy was quite complex, indicating a fair amount of confusion amongst different workers at earlier times. Of particular interest to the present article is their lectotypification of *Drummond* 4: 391 as the type for *Stipa scabra* var. *occidentalis* Benth. (thus making it now an isotype specimen for *A. tenuifolia*) and their explicit rejection of *S. puberula* as a possible synonym. The present analysis indicates that *A. anaiwaniorum* does have some affinities with *A. puberula*.

I have not followed Jessop *et al.* (2006) in their inclusion of *A. variabilis* within *A. scabra*, because the distinction remains useful, if sometimes uncertain, within our PERTH collections. This may be relevant to a comment made by Vickery *et al.* (1986) that the holotype as well as the majority of their specimens came from WA and perhaps *A. variabilis* was ‘a recent introduction to South Australia’. However, the broader question remains as to how the pervasive variability across this

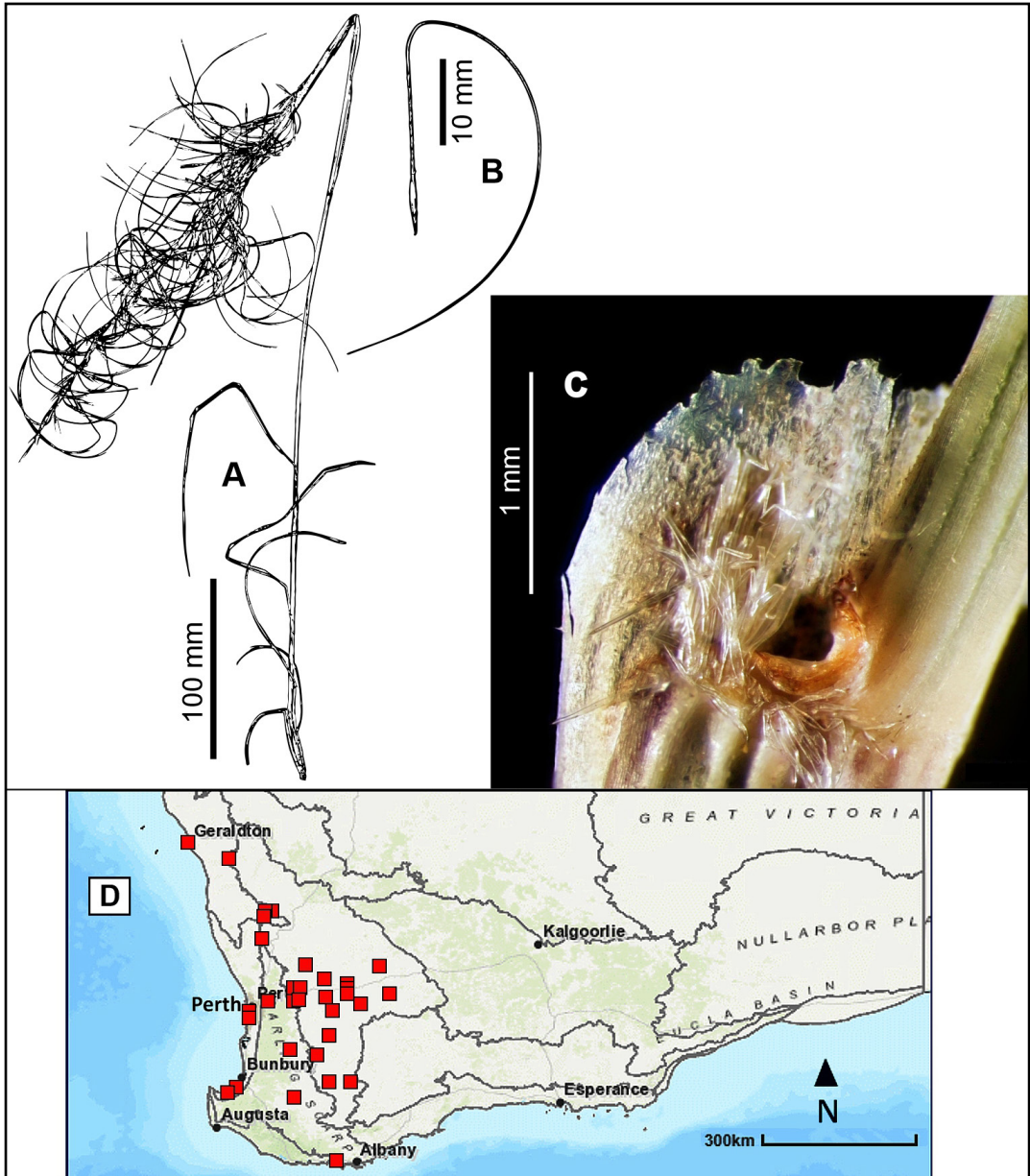


Figure 15. *Austrostipa anaiwaniorum*. A – vector outline of a single flowering culm; B – vector outline of typical floret with straight awn column and falcate bristle; C – image of collar region with glabrous ligule and leaf sheath margin, and the well-developed auricle with its distinctive line of large hairs running underneath it; D – distribution of *A. anaiwaniorum* (■). Illustrations by the author based on *A. Despeissis* s.n. PERTH 00481831 (A, B), and *U. Bell* 393 (C).

entire subgenus should be dealt with. I have found that the existing published species descriptions (except as described in this article for *A. tenuifolia*) are generally useful for practical purposes until more advanced methods of determination become available.

10. *Austrostipa anaiwaniorum* A.R. Williams, *sp. nov.*

Typus: near 156 mile peg on Geraldton Highway [now Midlands Road] (c. 4 miles south of Marchagee), Western Australia, 20 October 1970, B.R. Maslin 1407 (*holo*: PERTH 00481629).

Austrostipa sp. Marchagee (B.R. Maslin 1407), Western Australian Herbarium, in *Florabase*, <https://florabase.dpaw.wa.gov.au> [accessed 22 July 2021].

Perennial *tussock grass*, 600–1000 mm tall with a basal tuft of leaves. *Culms* terete, unbranched, 2–3 mm wide near the base, erect or geniculate at the base, shoots intra- or extra-vaginal, glabrous, scaberulous or puberulous; nodes 3–5, mostly enclosed, thickened, glabrous. *Leaf sheaths* loosely enveloping the culm, 2–5 mm wide at the base; lower ones glabrous or pubescent, margin glabrous or ciliate; upper ones 1–3 mm wide, glabrous, with glabrous margins. *Ligules* truncate or ovate, entire, coriaceous, 0.5–1 mm long, margin glabrous, entire; abaxial surface glabrous, continuous with the glabrous sheath margin. *Auricles* conspicuous, with an adjacent conspicuous horizontal line of hairs 1–2 mm long which sometimes encircles the collar. *Leaf blades* green at flowering time, in-rolled, erect, 75–200 mm long, 0.5–1 mm wide, margins glabrous; abaxial surface unribbed or ribbed, glabrous, scabrous or hirsute; adaxial surface strongly ribbed, hirsute with hairs c. 0.3 mm long. *Panicle* exserted, 300–400 mm long, 30–40 mm wide, spreading; axis terete, scabrous, usually compact with closely-spaced fascicles of few-flowered branches; branches 50–80 mm long, terete, scabrous; pedicels terete 15–25 mm long, scabrous or scaberulous. *Spikelets* 14–20 mm long, gaping, subequal or unequal, acuminate, either membranous or firm, purple-tinged. *Glumes* glabrous or scabrous; lower glume 14–20 mm long, 3–5-nerved in lower part; upper glume 12–17 mm long, 3–5-nerved in lower part, 3-nerved in upper part. *Floret* linear, 6.5–9 mm long, with a neck, granular surface becoming tuberculate below the apex, dark brown at maturity. *Lemma* hairs white, erect and spreading, sparse, glabrous below the apex; lemma lobes 1 or 2, 0.1–0.2 mm long; coma 0.6–0.8 mm long. *Callus* straight, 2.0–2.5 mm long, the hairs white or yellowish. *Awn* 70–100 mm long, 0.3–0.4 mm wide near the base; column straight, 13–16 mm long, pubescent or plumose with hairs 0.2–0.5 mm long; bristle falcate, scabrous with hairs 0.1–0.2 mm long, triangular in cross section, no broader than column. *Palea* subequal to the lemma, margins and tip membranous and glabrous. *Lodicules* 2 or 3; abaxial lodicules blunt, 0.8 mm long, paleal lodicule acute, 2 mm long. *Anthers* penicillate or not, 1.0–3.5 mm long. *Style* glabrous. *Caryopsis* 3.8–5 mm long; embryo 0.7–1.6 mm long; hilum 3–3.3 mm long. (Figure 15A–C)

Diagnostic features. Differs from *A. tenuifolia* in having a straight awn column and a collar region with a glabrous ligule and leaf sheath margin and a well-developed auricle with a distinctive line of large hairs running underneath it.

Other specimens examined. WESTERN AUSTRALIA: corner Eagle and Walker Streets, Mundaring, 2 Nov. 2000, *U. Bell* 331 (PERTH); Yarragil Valley, Mundaring, 3 Dec. 2001, *U. Bell* 393 (PERTH); NE corner of Yarragadee Road and Depot Hill Road, Yarragadee, 3 Sep. 2004, *U. Bell* 514 (PERTH); Reserve 27092, Bay Street–Drove Street, Katanning, 14 Nov. 2009, *U. Bell* 594 (PERTH); Reserve 27092, Bay Street–Drove Street, Katanning, 14 Nov. 2009, *U. Bell* 596 (PERTH); Bay/Drove Street Bush Res. 27092, Katanning, 16 Dec. 2011, *U. Bell* 618 (PERTH); Buller River, N of Geraldton, 2 Sep. 1947, *S.T. Blake* 18080 (BRI, K, NSW *n.v.*, PERTH); E of Lakes turnoff towards York, Wamby

Nature Reserve, 9 Oct. 1998, *R. Davis* 7249 (PERTH); NE of Dinninup, c. 55 km NE of Bridgetown, 28 Oct. 1998, *R. Davis* 8245 (PERTH); Oak Park Shire Reserve approx. 18 km NNE of the town of Goomalling, 18 Sep. 1999, *A.G. Guinness et al. s.n.* (PERTH); site 109, B. & W. Davey property, S of Youndegin-Kelkering Road, S of Cunderdin, 1 Oct. 2003, *M. Hislop & M. Griffiths* WW 109-17 (PERTH); Northern slopes of Mount Brown, Shire of York, 30 Sep. 2004, *M. Hislop & M. Griffiths* WW 145-26 (AD *n.v.*, PERTH); Bush remnant c. 25 km N of Cunderdin, 20 Oct. 1997, *B.J. Lepschi, T.R. Lally & W.H. Treasure* B JL 3580 (PERTH); Tronox Cooljarloo Minesite, 6 Oct. 2016, *B. Loudon* 92C-05-01 (PERTH); Lake Coomelberrup, 43 km ESE of Wagin, SAP wetlands site SPM014C, 11 Nov. 2000, *M.N. Lyons & S.D. Lyons* 3850 (PERTH); saline pan, 13.5 km ENE of Gunyidi, SAP wetlands site SPS158H, 5 Oct. 2000, *M.N. Lyons, S.D. Lyons* 3851 (PERTH); Salt River, 7.5 km S of Kellerberrin, SAP wetlands site SPS208C, 13 Oct. 2000, *M.N. Lyons & S.D. Lyons* 3855 (PERTH); Granite walk, Foxes Lair, 18 Oct. 2005, *P. Rose* 434 (PERTH); Lake Banganup, Jandakot, 2 Nov. 1974, *A.S. Weston* 9798 (CANB, PERTH); 15 km NNW of Kellerberrin, 23 Sep. 2008, *G. Wiehl* F 8022 (PERTH).

Phenology. Flowering from mid-winter to early spring. Fruiting from mid-spring to late summer.

Distribution and habitat. Occurs in the Geraldton Sandplains, Jarrah Forest, Avon Wheatbelt and Swan Coastal Plain bioregions (Figure 15D).

Conservation status. Widespread and common, similar in distribution and habitat to *A. tenuifolia*.

Etymology. The epithet is in recognition of the Northern Anaiwan people, original custodians of the land where I was born in northern New South Wales, where I grew up, and where I first studied and then practised as a botanist. The name is registered as item D64 in the AIATSIS language catalogue: <https://collection.aiatsis.gov.au/austlang/language/d64>.

Affinities. Previously included in *A. tenuifolia* which is similar in most floral and vegetative characters but has an entirely different collar region as illustrated in Figure 15C compared with Figure 18C and a different awn structure. *A. tenuifolia* has a dense mass of white hairs on the abaxial surface of the ligule, which is not continuous with a sheath margin, but in this species the abaxial surface of the ligule is glabrous, and it is continuous with a broad glabrous sheath margin. *A. tenuifolia* usually has no auricle and is glabrous in the region where the auricle could be, but this new species has a well-developed auricle and it has a dense line of hairs of an entirely different kind to those on the ligule of *A. tenuifolia*, being broader, longer, and transparent. The falcate awn in *A. tenuifolia* has an exaggerated terminal curve on the column which can sometimes make it look like the column is twice bent, but in *A. anaiwaniorum* the bristle is strictly falcate from the end of a straight column. There are also differences in basal sheath indumentum, culm indumentum below the nodes, and distinctive features of the panicle nodes.

11. *Austrostipa frankliniae* A.R. Williams, *sp. nov.*

Typus: Lake Champion Nature Reserve, Western Australia [precise locality withheld for conservation reasons], 7 October 2012, *A. Dooley* AD 427 (*holo:* PERTH 08449252).

Austrostipa sp. Dowerin (G. Wiehl F 8004), Western Australian Herbarium, in *Florabase*, <https://florabase.dpaw.wa.gov.au> [accessed 13 February 2012].

Perennial *tussock grass*, 250–400 mm tall with a basal tuft of leaves. *Culms* terete, unbranched, 3 mm wide near the bulbous base, not geniculate, glabrous; nodes 1–3, enclosed, thickened, glabrous. *Leaf sheaths* loosely enveloping the culm, 1.5–2 mm wide above the bulbous base; lower ones densely hirsute with crinkly hairs, margin glabrous; upper ones 1–1.5 mm wide, glabrous, margin hirsute around the mouth. *Ligules* 0.2–0.3 mm long, shape obscured by the abundance of abaxial hairs, continuous with the sheath margin. *Auricles* absent, but sheath apex with dense tuft of white hairs *c.* 1 mm long. *Leaf blades* partly green at flowering time, distinctively curved so that they make circular patterns, 120–160 mm long, 0.4 mm wide; abaxial surface unribbed, glabrous or minutely scaberulous; adaxial surface strongly ribbed, scabrous. *Panicle* enclosed, 100–250 mm long, 30–50 mm wide, contracted, axis terete, scabrous, sparse with few-flowered branches 40–80 mm long, terete, scabrous; pedicels terete, 3–40 mm long, scabrous or scaberulous. *Spikelets* 13–17 mm long, gaping, unequal, acuminate, membranous. *Glumes* glabrous; lower glume 13–17 mm long, 3-nerved in lower part; upper glume 11–13 mm long, 5-nerved in lower part. *Floret* lanceolate, 4.7–7.5 mm long, with a neck, brown at maturity, with finely granular and glossy surface. *Lemma* brown, with brown hairs, and a bare patch in the shoulder region revealing the glossy scabrid lemma surface (sometimes becoming tuberculate on the neck); lemma lobes 0.2–0.3 mm long; coma 0.6–0.8 mm long. *Callus* straight, 1.4–2.5 mm long, the hairs distinctively white, pale, or the same colour as the lemma. *Awn* 70–100 mm long, *c.* 0.4 mm wide near the base; column straight, 10–12 mm long, scabrous with hairs 0.1–0.2 mm long; bristle falcate, scabrous with hairs 0.1–0.2 mm long, triangular in cross section, no broader than column. *Palea* subequal to the lemma and enclosed by it. *Lodicules* 2 or 3; abaxial ones blunt, 0.5 mm long, paleal one acute 0.5 mm long. *Anthers* not penicillate, dwarfed and non-pigmented, only one fertile; anterior one sparsely fertile, 0.8–0.9 mm long; posterior ones sterile, 0.4–0.5 mm long. *Style* glabrous. *Caryopsis* 3.5–4 mm long; embryo 1–1.25 mm long; hilum 2.5–3 mm long. (Figure 16A–D)

Diagnostic features. This species is unique in three ways: (1) falcate awns with brown lemma hairs (all other members of this subgenus have white lemma hairs); (2) strongly curved leaf blades that create circular patterns (other species have straight, gently curved, or flexuose leaf blades); (3) the long crinkly hairs covering the densely hairy basal sheaths are also unique in this subgenus (but do occur in the *Lanterna* group of subsp. *Austrostipa*).

Other specimens examined. WESTERN AUSTRALIA: [localities withheld for conservation reasons] 26 Nov. 2011, *A. Dooley* AD 291 (PERTH); 7 Oct. 2012, *A. Dooley* AD 424 (PERTH); 7 Oct. 2012, *A. Dooley* AD 425 (PERTH); 7 Oct. 2012, *A. Dooley* AD 426 (PERTH); 7 Oct. 2012, *A. Dooley* AD 427 (PERTH); 11 Oct. 2011, *R. Meissner & R. Coppen* 3868 A (PERTH); 14 Oct. 2011, *R. Meissner & R. Coppen* 3870 (MEL, PERTH); 21 Oct. 2008, *G. Wiehl* F 8004 (PERTH).

Phenology. Flowering in spring. Fruiting late spring to early summer.

Distribution and habitat. Small populations have survived in reserves in the Avon Wheatbelt, Coolgardie and Yalgoo bioregions (Figure 16E).

Conservation status. *Austrostipa frankliniae* is listed by Smith and Jones (2018) as Priority Two under Conservation Codes for Western Australian Flora, under the name *A. sp.* Dowerin (*G. Wiehl* F 8004).

Etymology. Named in honour of Lady Jane Franklin (1791–1875), pioneer female naturalist and philanthropist, who founded the first botanic garden and natural history museum in Tasmania, and a society for the advancement of science that became the first Royal Society outside of Britain.

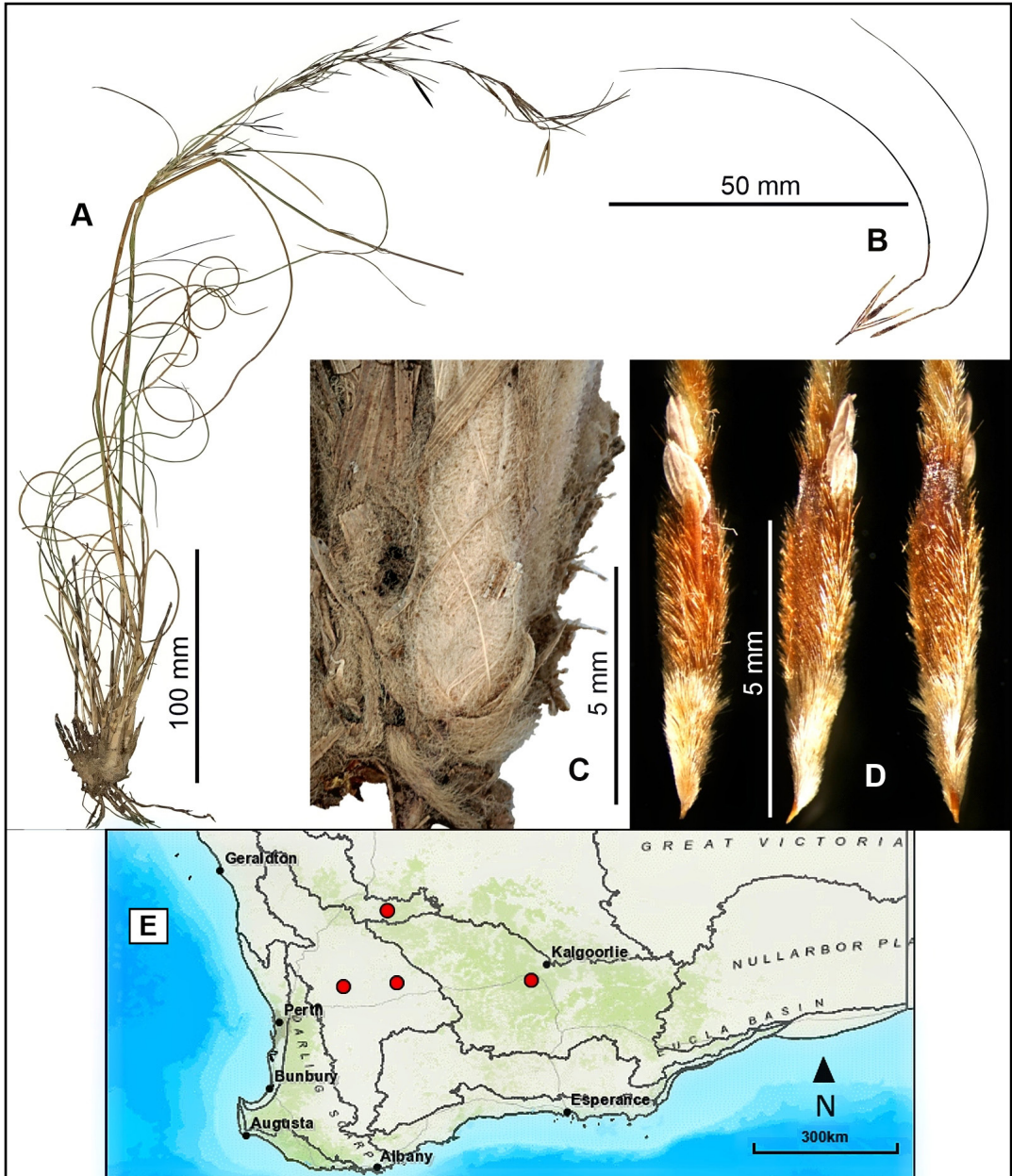


Figure 16. *Austrostipa frankliniae*. A – vector trace of mature whole plant showing its unique curly leaves; B – vector trace of spikelet and two florets; C – image of crinkly woolly culm bases; D – three different views of a single floret with its unique red-brown indumentum; E – distribution of *A. frankliniae* (●). Images by the author based on G. Wiehl F 8004.

Affinities. Molecular studies of *Austrostipa* (cited earlier) have consistently found that subg. *Falcatae* has a distinct monophyletic status, so the falcate awn of *A. frankliniae* is sufficient to place it in this subgenus; however, the three diagnostic features listed above set it apart from all other members of the subgenus.

12. *Austrostipa nunaginensis* A.R. Williams, *sp. nov.*

Typus: Warradarge [precise locality withheld for conservation reasons], Western Australia, 23 October 2011, *B. Morgan* BES 000102 (*holo:* PERTH 08460574).

Austrostipa sp. Cairn Hill (M.E. Trudgen 21176), Western Australian Herbarium, in *Florabase*, <https://florabase.dpaw.wa.gov.au> [accessed 12 July 2021].

Perennial *tussock grass*, 200–500 mm tall, with a basal tuft of leaves. *Culms* terete, unbranched, 1–2 mm wide near the base, geniculate, densely pubescent; nodes 3–5, enclosed early but becoming visible as sheath peels back, thickened, densely sericeous. *Leaf sheaths* loosely enveloping the culm, 2–5 mm wide at the base; lower leaf sheaths densely pubescent, margin ciliate; upper leaf sheaths 1–3 mm wide, glabrous, or pubescent. *Ligules* truncate or ovate, entire, coriaceous, 0.2–0.3 mm long, margin glabrous, entire; abaxial surface pubescent, continuous with the sheath margin. *Auricles* conspicuous, with hairs 1–2 mm long. *Leaf blades* green at flowering time, flexuose, 75–100 mm long, 0.5–1 mm wide, margins glabrous; abaxial surface ribbed, glabrous; adaxial surface strongly ribbed, hirsute with hairs 0.3 mm long. *Panicle* exserted, 100–200 mm long, 20–30 mm wide, spreading; axis terete, scabrous, usually sparse with moderately close fascicles of usually few-flowered branches; branches 30–80 mm long, angular, scabrous; pedicels flattened, 15–25 mm long, scabrous or scaberulous. *Spikelets* 11–13 mm long, gaping, subequal, acuminate, membranous, purple-tinged. *Glumes* glabrous or scabrous; lower glume 11–13 mm long, 3–5-nerved in lower part; upper glume, 10–12 mm long, 3–5-nerved in lower part, 3-nerved in upper part. *Floret* linear, 6.4–7.6 mm long, with a neck, surface finely granular but tuberculate below the apex, dark brown at maturity, the 3 main nerves slightly thickened at the apex. *Lemma* hairs white, erect and spreading, sparse, glabrous below the apex; lemma lobes absent or present, 0–0.2 mm long; coma 0.3–0.7 mm long. *Callus* straight, 2.0–2.5 mm long, the hairs white. *Awn* 70–80 mm long, 0.25–0.35 mm wide near the base; column straight, 11–14 mm long, scaberulous with hairs 0.02–0.03 mm long; bristle falcate, scabrous with hairs 0.1–0.2 mm long, triangular in cross section, no broader than column. *Palea* subequal to the lemma and enclosed by it, acute or obtuse, with a line of white hairs along the centre only, margins and tip membranous and glabrous. *Lodicules* 2 or 3; abaxial lodicules blunt, 0.8 mm long, paleal lodicule acute, 2 mm long. *Anthers* penicillate or not, 1.0–3.5 mm long. *Style* glabrous. *Caryopsis* 3.8–5 mm long; embryo 0.7–1.6 mm long; hilum 3–3.3 mm long. (Figure 17A–D)

Diagnostic features. The combination of minutely scaberulous awn column with densely hairy basal leaf sheaths and nodes with geniculate culms sets it apart from *A. nitida* and *A. scabra*.

Other specimens examined. WESTERN AUSTRALIA: [localities withheld for conservation reasons] Oct. 1913, *A. Baxter s.n.* (PERTH); 9 Oct. 2006, *K. Freeman* 23 (PERTH); 25 Sep. 2007, *C. Godden & K. Greenacre* SLU 97-08 (PERTH); 12 Oct. 2006, *C. Godden & G. Woodman* GI-10-06 (PERTH); Oct. 1970, *B. Greig* 17 (PERTH); 4 Nov. 2001, *M. Hislop* 2370 (PERTH); 14 Sep. 2001, *C. Howell* 560 (MEL, PERTH); 7 Nov. 2017, *B. Loudon* W3-11-01 (PERTH); 17 Oct. 2014, *B. Morgan & H. Ajduk* DHR 9-1 (PERTH); 19 Nov. 2012, *B. Morgan* BMor 1379 (PERTH); 23 Oct. 2000, *M.E. Trudgen* MET 21176 (PERTH).

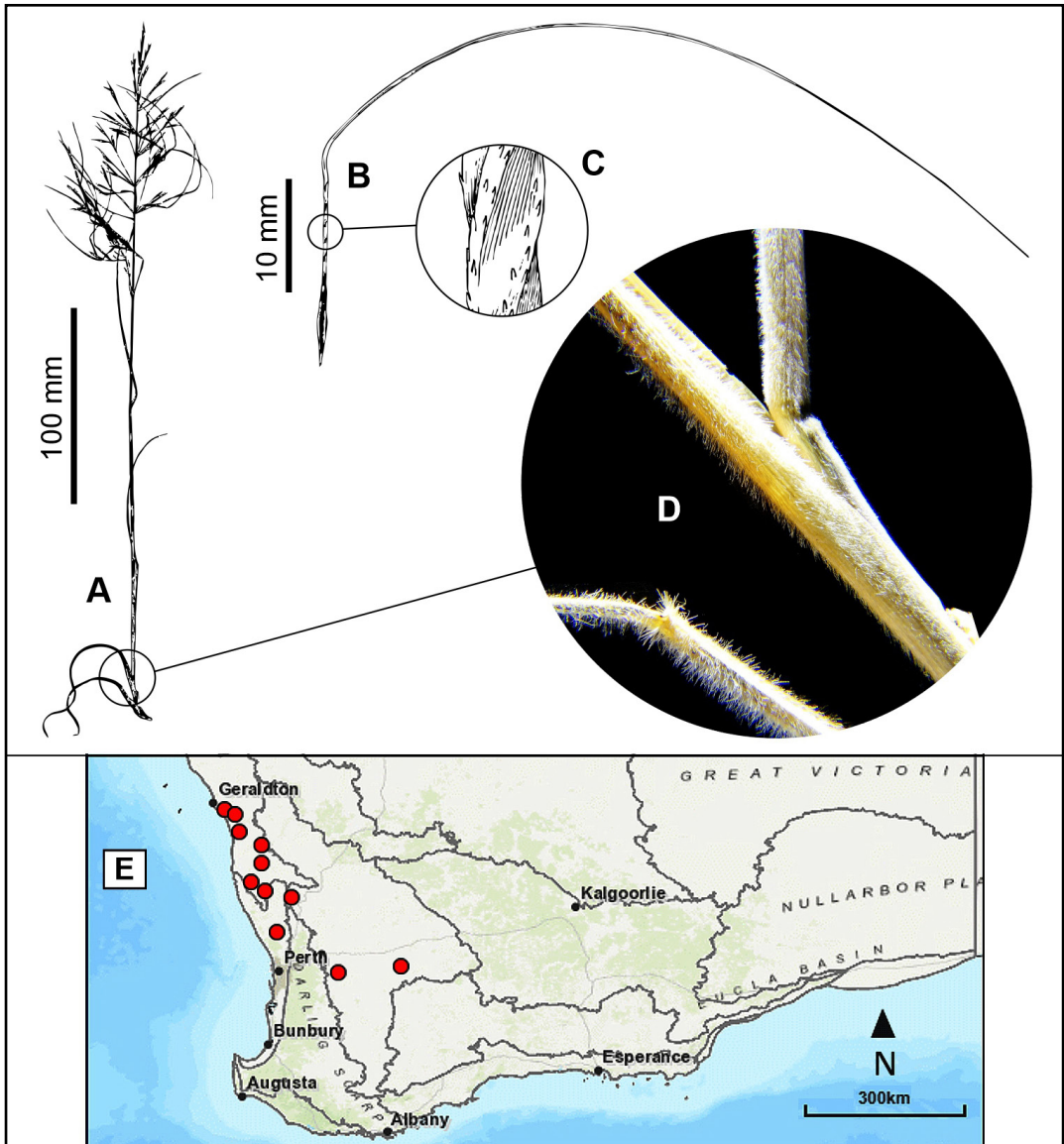


Figure 17. *Austrostipa nunaginensis*. A – vector outline of a mature single flowering culm; B – vector outline of a mature floret; C – vector illustration of a section of the distinctively scaberulous awn column; D – image of the densely hirsute culm base and leaf sheath; E – distribution of *A. nunaginensis* (●). Illustrations by the author based on *M.E. Trudgen* MET 21176.

Phenology. Flowering late spring, fruiting early summer.

Distribution and habitat. Occurs in the Geraldton Sandplains, Avon Wheatbelt and Swan Coastal Plain bioregions (Figure 17E).

Conservation status. *Austrostipa nunaginensis* is listed by Smith and Jones (2018) as Priority Three under Conservation Codes for Western Australian Flora, under the name *A. sp. Cairn Hill* (M.E. Trudgen 21176).

Etymology. The epithet is derived from the town of Nunagin (now called Bruce Rock), the location cited where it was first collected in 1913, the year that the town and the East Avon Road District were first gazetted.

Affinities. Similar to *A. nitida* and *A. scabra* but differs in having densely hairy basal leaf sheaths and nodes and geniculate culms.

13. *Austrostipa tenuifolia* (Steud.) S.W.L.Jacobs & J.Everett, *Telopea* 6: 589 (1996); *Stipa tenuifolia* Steud., *Syn. Pl. Glum.* 1: 128 (1854). *Type:* N. Holl [Western Australia], *Drummond* coll. IV. n. 391 (*holo:* P!; *iso:* K!, MEL 59997!).

Stipa scabra var. *occidentalis* Benth., *Fl. Austral.* 7: 571 (1878). *Type:* *Drummond* coll. IV. n. 391 (*lecto:* K!, *fide* J.W. Vickery, S.W.L. Jacobs & J. Everett, *Telopea* 3: 119 (1986)).

Perennial tussock grass, shoots conspicuously extravaginal, 600–1000 mm tall, with a basal tuft of leaves. *Culms* erect, or geniculate at the base, unbranched, 0.8–2.5 mm wide near the base; nodes 2 or 3, enclosed, thickened, glabrous, or indumented. *Leafsheaths* tightly enveloping the culm, ribbed, outer margin ciliate; basal ones pubescent or villous; upper ones glabrous. *Ligules* truncate, or ovate, entire, coriaceous, 0.8–4 mm long; abaxial surface densely pubescent with conspicuous white hairs. *Auricles* absent or inconspicuous. *Leafblades* green and purple-tinged at flowering time, erect, in-rolled, 0–30 cm long, 0.5–3 mm wide; abaxial surface unribbed, or slightly ribbed, scabrous, or hirsute; adaxial surface and margins scabrous. *Panicle* 250–350 mm long, exserted, usually sparse, occasionally denser, with moderately close fascicles of usually few-flowered branches, spreading, 50–70 mm wide; axis terete, scaberulous; branches terete, 50–100 mm long, scabrous; pedicels angular, 10–30 mm long, scabrous or scaberulous. *Spikelets* 13–24 mm long, gaping. *Glumes* subequal, or unequal, acuminate, membranous or firm, purple-tinged; lower glume 13–24 mm long, 3-nerved in lower part; upper glume 12–18 mm long, 5-nerved in lower part, 3-nerved in upper part. *Floret* linear, 6.5–9 mm long, with a neck. *Lemma* finely granular, sometimes tuberculate over the apex of the midvein; lemma hairs white, or sometimes brownish at maturity, sparse, sericeous, usually glabrous in the upper part, sometimes having a distinct collar of short hairs completely encircling the shoulder region; lemma lobes 1 or 2, 0–0.4 mm long; coma 0.6–1.5 mm long. *Callus* 2.1–3.1 mm long, straight, sericeous with hairs white or yellow. *Awn* 70–120 mm long, 0.25–0.45 mm wide near the base, falcate; column 10–22 mm long, 6–13 mm to the first bend, pubescent, or plumose, with hairs 0.15–1.3 mm long; bristle triangular, no broader than column, scabrous. *Palea* subequal to the lemma, or shorter than the lemma, not completely enclosed by lemma, with a line of white hairs along the centre only, the margins and tip membranous and glabrous. *Lodicules* 2, membranous, 1.4–1.8 mm long, spatulate. *Anthems* 2.5–3.5 mm long, penicillate. *Style* glabrous *Caryopsis* 3–5 mm long; embryo 30 % the length, hilum 80 % the length. (Figure 18A–C)

Other specimens examined. WESTERNAUSTRALIA: Shackleton, 30 Sep. 2002, *U. Bell* 421 (PERTH); Bruce Rock–Narrembeen Road, 12 km out of Narrembeen, 30 Sep. 2002, *U. Bell* 423 (AD n.v., PERTH); Brixton Street Wetlands, Kenwick, 16 Nov. 2011, *K.L. Brown & G. Paczkowska* KLB 897 (PERTH); between Jerramungup and Ravensthorpe at West River Crossing, 10 Nov. 1968, *E.M. Canning* WA/68 7552 (CANB); 6.1 km N along Yerina Springs road from junction of Port Gregory Road, 9 Sep. 2005, *R. Davis* 10925 (NSW n.v., PERTH); in quadrat KA9 beside State Barrier Fence NW of Karara homestead in Lochada Station, 19 Sep. 2009, *D.J. Edinger* 6940 (PERTH); NW corner of Ullaring Rock, c. 250 km W of Mulline–Davyhurst Road on ex Credo Station, 31 Aug. 2011, *N. Gibson & M.A. Langley* 4882 (CANB n.v., PERTH); Woodvale Nature Reserve, 25 km N of Perth, 21 Sep. 2007, *G.J. Keighery* 17219 (PERTH); Koodjee Nature Reserve, 5 km N of Gillingarra, 18 Oct. 2011, *G.J. & B.J. Keighery* 1763 (PERTH); Site No. 154, M & J Mailey property, W end of Noble Road, S of Gunyidi–Wubin

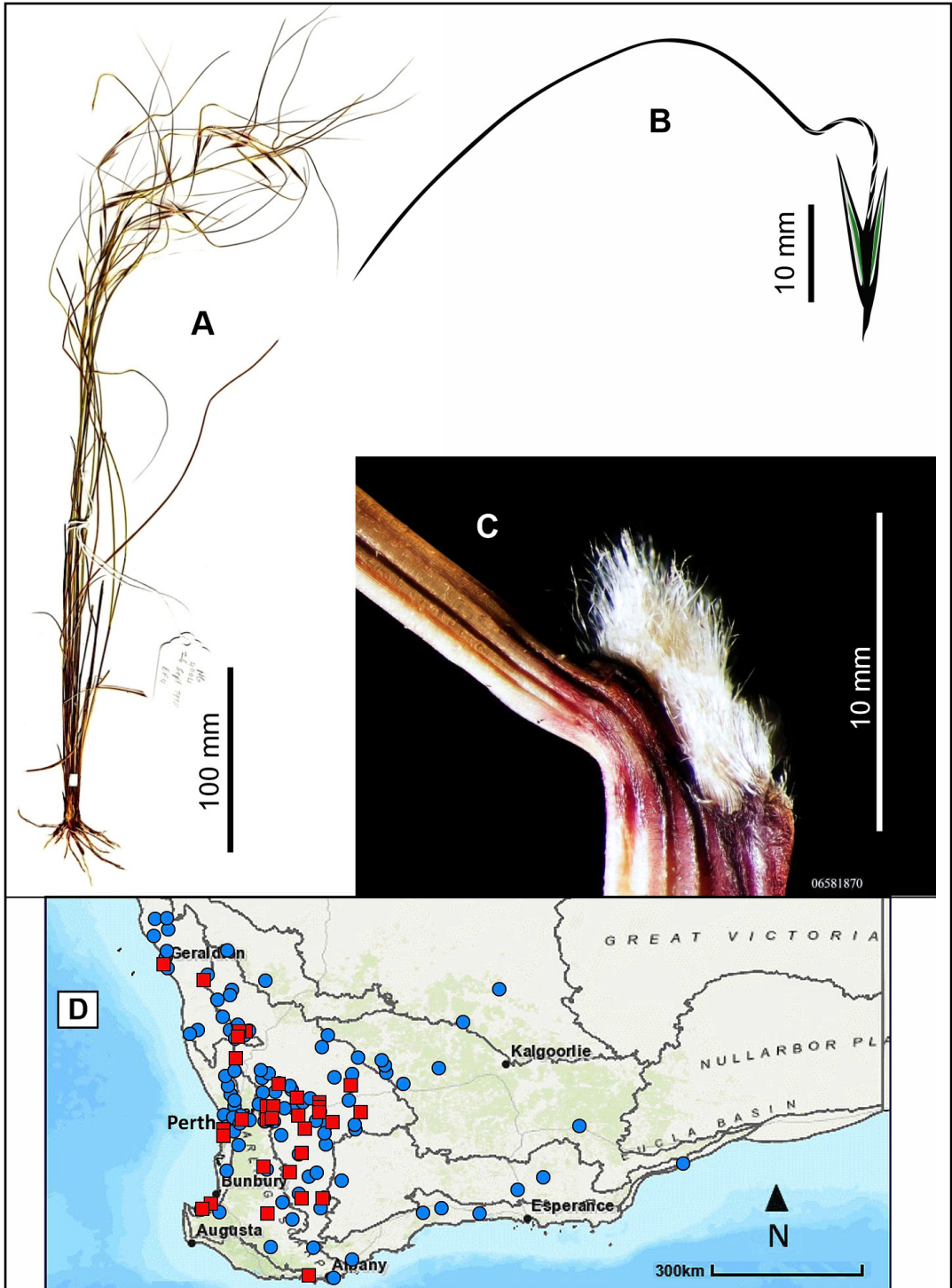


Figure 18. *Austrostipa tenuifolia*. A – image of a small whole mature plant on an herbarium sheet; B – schematic vector drawing of a single mature spikelet showing the awn column with its distinctively exaggerated apical curve just below the falcate bristle; C – lateral view of the collar region showing the distinctively dense and brightly pubescent abaxial surface of the ligule and absent auricle; D – distribution of *A. tenuifolia* (●), compared with *A. anaiwaniorum* (■). Illustrations by the author from *N. Gibson* 4004 (A), *Drummond* 4:391 (B), and *M. Hislop & M. Griffiths* WW 105.54 (C).

Road, NE of Watheroo, 22 Sep. 2005, *M. Hislop & M. Davis* WW 154-5 (PERTH); A. & C. Robinson property, W side of Robinson Road, E of Piawaning, 29 Sep. 2003, *M. Hislop & M. Griffiths* WW 105-54; Beverley Common Reserve, c. 4 km S of Beverley on W side of Great Southern Highway, 2 Oct. 2003, *M. Hislop & M. Griffiths* WW 111-33 (PERTH); Site 151, G. & V. Huckstep property, N side of Kuhl Road, S of Emu Proof Fence Road, N of Beacon, 21 Sep. 2005, *M. Hislop, R. Ovens & M. Griffiths* WW 151-18 (MEL, PERTH); near Highbury Hotel, 22 Oct. 1962, *D.N. Kraehenbuehl* 822 (AD, NSW); approx. 5 km SW of Beverley on Cropping Committee Hill, 13 Sep. 2003, *M. Ochtman* 711 (DNA *n.v.*, PERTH); Southern Bullfinch Greenstone Belt survey site BLFN07, c. 3.63 km SW of Mount Woodward, 4 Sep. 2009, *W.A. Thompson & J. Allen* 1693 (PERTH). SOUTH AUSTRALIA: Flora and Fauna Reserve, c. 85 km N of Port Lincoln, 11 Nov. 1960, *R.L. Specht* 2563 (AD).

Phenology. Flowers in winter and spring with fruit maturing in early summer; also responds to summer rain.

Distribution and habitat. Occurs in the Avon Wheatbelt, Coolgardie, Esperance Plains, Geraldton Sandplains, Jarrah Forest, Murchison, Swan Coastal Plain, Warren and Yalgoo bioregions of south-western Western Australia (Figure 18D), southern South Australia, and inland Victoria. Occurs widely in the landscape.

Conservation status. Widespread across southern inland parts of the continent.

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References

Alvarez, I. & Wendel, J.F. (2003). Ribosomal ITS sequences and plant phylogenetic inference. *Molecular Phylogenetics and*

Evolution 29: 417–434.

- AVH (2012, 2016). The Australasian Virtual Herbarium, Council of Heads of Australasian Herbaria, <<https://avh.chah.org.au>> [accessed 12 December 2012, 16 February 2016].
- Barroso, J., Serk, H., Granlundz, I. & Pesquet, E. (2015). The cell biology of lignification in higher plants. *Annals of Botany* 115: 1053–1074.
- Bodorkos, S. & Sandiford, M. (2006). Thermal and mechanical controls on the evolution of Archean crustal deformation: examples from Western Australia. In: Benn, K., Mareschal, J.-C. & Condie, K.C. (eds) *Archean Geodynamics and Environments. Geophysical Monograph Series* 164: 131–147.
- Box, G.E.P. & Cox, D.R. (1964). An analysis of transformations. *Journal of the Royal Statistical Society, Series B* 26(2): 211–252.
- Briske, D.D. (1991). Developmental morphology and physiology of Grasses. In: Heitschmidt, R.K. & Stuth, J.W. (eds) *Grazing Management: An Ecological Perspective*. pp. 85–108. (Timber Press: Oregon.)
- Bustam, B.M. (2010). Systematic studies of Australian stipoid grasses (*Austrostipa*) based on micro-morphological and molecular characteristics. *Biodiversitas* 11(1): 9–14.
- Byrne, M. (2008). Evidence for multiple refugia at different time scales during Pleistocene climatic oscillations in southern Australia inferred from phylogeography. *Quaternary Science Reviews* 27: 2576–2585.
- Cavanagh, A.M., Godfree, R.C. & Morgan, J.W. (2019). An awn typology for Australian native grasses (Poaceae). *Australian Journal of Botany* 67: 309–334. <https://doi.org/10.1071/BT18216>.
- Clifford, H.T. (1987). Spikelet and floral morphology. In: Soderstrom, T.R., Hilu, K.W., Campbell, C.S. & Barkworth, M.E. (eds) *Grass Systematics and Evolution*. pp. 21–30. (Smithsonian Institution Press: Washington.)
- Craig, G.F., Hickman, E.J., McQuoid, N., Newell, J., Rick, A.M. & Sandiford, E.M. (2008). *Vegetation of the Ravensthorpe Range, Western Australia: Mt Short to Kundip 1:10,000 scale*. Department of Environment and Conservation and South Coast Natural Resource Management Inc: Albany, Western Australia.)
- DSEWPC (2013). *Australia's Bioregions. Department of Sustainability, Environment, Water, Population and Communities, IBRA 7.1* <http://www.environment.gov.au/parks/nrs/science/bioregion-framework/ibra/index.html#ibra> [accessed 10 May 2013].
- Everett, J. & Jacobs, S.W.L. (1983). Studies in Australian *Stipa* (Poaceae). *Telopea* 2(4): 391–400.
- Everett, J., Jacobs, S.W.L. & Nairn, L. (2009). *Austrostipa*. In: *Flora of Australia*, Vol. 44A, Poaceae 2, pp.15–62. (ABRS/CSIRO Publishing: Melbourne.)
- Freitag, H. (1985). The genus *Stipa* (Gramineae) in southwest and south Asia. *Notes from the Royal Botanic Garden Edinburgh* 42(3): 355–489.
- Gonzalez, R., Aedo, C., Nickrent, D.L. & Garcia, M.A. (2012). A numerical taxonomic investigation of *Stipa* sect. *Smirnovia* and S. sect. *Subsmirnovia* (Poaceae). *Systematic Botany* 37(3): 665–670.
- Groves, R.H. & Whalley, R.D.B. (2002). Grass and grassland ecology in Australia. *Flora of Australia* 43: 157–182.
- Hammer, Ø., Harper, D.A.T., & Ryan, P.D. (2001). PAST: Paleontological Statistics Software Package for Education and Data Analysis. *Palaeontologia Electronica* 4(1): 9 pp. http://palaeo-electronica.org/2001_1/past/issue1_01.htm
- Hooker, C. (2002). Vickery, Joyce Winifred (1908–1979). <https://adb.anu.edu.au/biography/vickery-joyce-winfred-11926>
- Hughes, D.K. (1921). A revision of the Australian species of *Stipa*. *Bulletin of Miscellaneous Information* 1: 1–30.
- Jacobs, S.W.L. & Everett, J. (1996). *Austrostipa*, a new genus, and new names for Australasian species formerly included in *Stipa* (Gramineae). *Telopea* 6(4): 579–595.
- Jacobs, S.W.L., Everett, J. & Barkworth, M.E. (1996). Clarification of morphological terms used in the *Stipeae* (Gramineae), and a reassessment of *Nassella* in Australia. *Taxon* 44(1): 33–41.
- Jacobs, S.W.L., Everett, J., Barkworth, M.E., & Hsiao, C. (2000). Relationships within the Stipoid grasses (Gramineae). In: Jacobs, S.W.L. & Everett, J. (eds) *Grasses: Systematics and Evolution*. pp. 75–82. (CSIRO: Melbourne.)
- Jacobs, S.W.L., Bayer, R., Everett, J., Arriaga, M., Barkworth, M., Sabin-Badereau, A., Torres, A., Vazquez, F. & Bagnall, N. (2007). Systematics of the Tribe *Stipeae* (Gramineae) using molecular data. *Aliso* 23: 349–361.
- Jessop, J., Dashorst, R.M. & James, F.M. (2006). *Grasses of South Australia: An Illustrated Guide to the Native and Naturalised Species*. (Wakefield Press: Kent Town, South Australia.)
- Kern, S., Jasper, R., True, D., & Gibson, N. (2008). *Floristic survey of the Ravensthorpe Range*. (Western Botanical: Bassendean, W.A.).
- Krawczyk, K., Nobis, M., Nowak, A., Szczecińska, M. & Sawicki, J. (2017). Phylogenetic implications of nuclear rRNA IGS variation in *Stipa* L. (Poaceae). *Nature Scientific Reports* 7: 11506 | DOI:10.1038/s41598-017-11804-x
- Markey, A., Kern, S. & Gibson, N. (2012). Floristic Communities of the Ravensthorpe Range. *Conservation Science Western Australia* 8: 187–239.
- Nair, S.K. *et al.* (2010). Cleistogamous flowering in barley arises from the suppression of microRNA-guided HvAP2 mRNA

- cleavage. *Proceedings of the National Academy of Sciences* 107(1): 490–495.
- Plants of the World Online, Kew Science, <http://www.plantsoftheworldonline.org/taxon/urn:lsid:ipni.org:names:60437381-2> [accessed 19 May 2021].
- Romaschenko, K., Peterson, P.M., Soreng, R.J., Garcia-Jacas, N. & Susanna, A. (2010). Phylogenetics of *Stipeae* (Poaceae: Pooideae) based on plastid and nuclear DNA sequences. In: Seberg, O., Petersen, G., Barfod, A.S. & Davis, J.I. (eds) *Diversity, Phylogeny, and Evolution in the Monocotyledons*. pp. 511–537. (Aarhus University Press: Denmark.)
- Smith, M.G. & Jones, A. (2018). *Threatened and Priority Flora List, 16 January 2018*. Department of Biodiversity, Conservation and Attractions: Kensington, Western Australia.
- Syme, A.E., Murphy, D.J., Homes, G.D., Gardner, S., Fowler, R. & Cantrill, D.J. (2012). An expanded phylogenetic analysis of *Austrostipa* (Poaceae:Stipeae) to test infrageneric relationships. *Australian Systematic Botany* 25: 1–10.
- Syme, A.E. (2012). Diversification rates in the Australasian endemic grass *Austrostipa*: 15 million years of constant evolution. *Plant Systematics & Evolution* 298: 221–227.
- Thiers, B. (2014). *Index Herbariorum: A global directory of public herbaria and associated staff*. New York Botanical Garden's Virtual Herbarium. <http://sweetgum.nybg.org/ih/>
- Tkach N., Nobis, M., Schneider, J., Becher, H., Winterfeld, G., Jacobs, S.W.L. & Röser, M. (2021). Molecular phylogenetics and micromorphology of Australasian *Stipeae* (Poaceae, Subfamily Pooideae), and the interrelation of whole-genome Duplication and evolutionary radiations in this grass tribe. *Frontiers in Plant Science* 11: 630788. doi: 10.3389/fpls.2020.630788.
- Thompson, W.A. & Allen, J. (2013). Flora and vegetation of greenstone formations of the Yilgarn Craton: the northern Forrestania Greenstone Belt (Mount Holland area). *Conservation Science Western Australia* 8(3): 295–312.
- Vickery, J.W. (1980). Four new species of *Stipa* (Poaceae). *Telopea* 2(1): 11–15.
- Vickery, J.W., Jacobs, S.W.L. & Everett, J. (1986). Taxonomic studies in *Stipa* (Poaceae) in Australia. *Telopea* 3(1): 1–23.
- Western Australian Herbarium (1998–). *Florabase—the Western Australian Flora*. Department of Biodiversity, Conservation and Attractions. <https://florabase.dpaw.wa.gov.au/> [Accessed 12 July 2021].
- Williams, A.R. (2011). *Austrostipa* (Poaceae) subgenus *Lobatae* in Western Australia. *Telopea* 13(1–2): 177–192.
- Winterfeld, G., Schneider, J., Becher, H., Dickie, J. & Röser, M. (2015). Karyosystematics of the Australasian stipoid grass *Austrostipa* and related genera: chromosome sizes, ploidy, chromosome base numbers and phylogeny. *Australian Systematic Botany* 28(2–3): 145–159. <https://doi.org/10.1071/SB14029>.

