

Taxonomic reassessment of *Kelleria* (Thymelaeaceae) in Australia and recognition of a new endemic Victorian species

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Introduction

Prior to 1980, the dwarf, carpeting shrub, then known as *Drapetes tasmanicus* Hook.f. (Thymelaeaceae) was known only from alpine areas in Kosciuszko National Park, New South Wales, and similar habitats in Tasmania. The discovery in 1980 of a small population of apparently the same entity on the Bogong High Plains, Victoria, filled an apparent gap in the species' distribution. Heads's revision of the genus (1990a, b) resurrected *Kelleria* Endl. from *Drapetes* Banks, assigned the Australian species to *Kelleria*, and recognised the Kosciuszko and Tasmanian populations as *K. dieffenbachii* (Hook.) Endl. and treated the Victorian population as a distinct species, *K. laxa* (Cheeseman) Heads. Both species have long been known from New Zealand mountains. *Kelleria laxa* is distinguished, *inter alia*, but perhaps most significantly, from *K. dieffenbachii* by having vegetative buds in the flower heads that grow on after anthesis, whereas *K. dieffenbachii* lacks vegetative buds in the flower heads. Comparison of herbarium material of Australian and New Zealand representatives of *K. laxa* indicated sufficient differences to warrant closer scrutiny. A morphological analysis was undertaken to determine the variation in *K. dieffenbachii* and *K. laxa* from across their known ranges. A molecular analysis employing the nuclear ribosomal ITS and the chloroplast trnL-F DNA regions was also performed on a

Abstract

Victorian plants previously referred to *Kelleria laxa* (Cheeseman) Heads were found by multivariate analysis of morphological data to be distinct from New Zealand plants of that name. The Victorian plants are here named as *Kelleria bogongensis* Marks and their ecology and conservation status are discussed.

Key words: *Kelleria*, new species, Bogong High Plains

limited number of specimens (seven) representing the same taxa and geographic regions as the morphological analysis. Results of the molecular analysis showed no clear pattern and are not further discussed here, but the data are available from the authors on request.

Morphological study

A list of characters was compiled employing those characters that have been used in literature (e.g. Allan 1961; Heads 1990a, b) to distinguish *Kelleria laxa* and *K. dieffenbachii*, as well as characters that were observed

to differ across the ecological and geographic range of the species (Table 1). Ninety-six herbarium specimens from three Australian (CANB, HO, MEL) and two New Zealand (AK, CHR) herbaria (abbreviations follow Thiers, continually updated) were scored for these 26 characters, which included continuous, binary and multistate characters. Collection details are available from the authors on request.

Of the 96 specimens scored, nine were *K. laxa* from the Bogong High Plains, 26 were *K. laxa* from New Zealand, eight were *K. dieffenbachii* from New South Wales, 16 were *K. dieffenbachii* from Tasmania, and 37 were *K. dieffenbachii* from New Zealand (employing current identification status). The groups were inevitably of unequal sizes as very few collections have been made from the small populations in Victoria and New South Wales. Much larger samples were utilised for the New Zealand groups to adequately cover the more extensive geographic, ecological and morphological ranges of the species there.

Multivariate analysis was carried out with the PATN package (Belbin 1995), employing agglomerative hierarchical clustering (Unweighted Pair Group Method of Arithmetic averaging – UPGMA) to produce a dendrogram, Semi-Strong Hybrid Multidimensional Scaling to produce an ordination and Kruskal-Wallis values to indicate the importance of each character in the separation of major groups.

An initial analysis was carried out on the full data set of 96 collections scored for 26 characters. In a second analysis of 95 collections scored for 26 characters, an outlier (AK 58357) was omitted. Kruskal-Wallis values were calculated for the set of collections included in the second analysis. A third analysis assessed the effect of character 18 (presence of vegetative buds in the inflorescence), by omitting it from the data matrix, which thus comprised 96 collections scored for 25 characters.

Scanning Electron Micrographs were prepared from fresh material cultivated at the Royal Botanic Gardens Melbourne. Specimens were dissected then fixed in 2.5% glutaraldehyde in 0.1 M phosphate buffer, post-fixed in 1% OsO₄ then dehydrated through a series of acetone solutions. Specimens were critical-point dried in a Tousimis Samdri pvt-3 then mounted on stubs and sputter-coated with gold in an Edwards Sputter Coater S150B. Stubs were then viewed under a X1-30 Philips Scanning Electron Microscope.

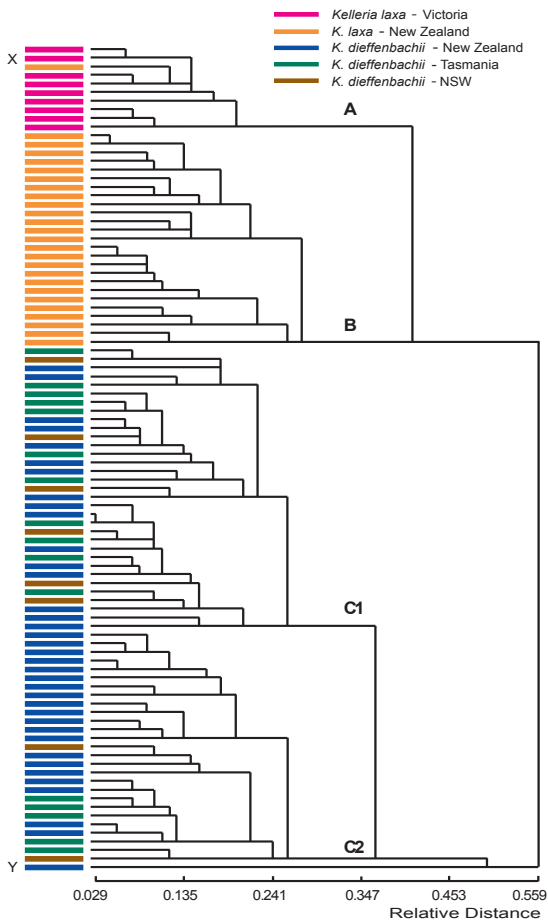
Table 1. Twenty-six morphological characters used to score specimens for multivariate analyses of Australian and New Zealand *Kelleria*

1.	Length of short shoot (mm)
2.	Length of leaf persistence on short shoot (mm)
3.	Leaves persistent on all of short shoot (0) or caducous (1)
4.	Leaves present on long shoot (0) or only on short shoot (1)
5.	Stem width of long shoot (mm)
6.	Stem hairs absent (0) sparse (1) moderately dense (2) or dense (3)
7.	Leaves per centimetre
8.	Leaf length (mm)
9.	Leaf width at midpoint (mm)
10.	Leaf width at base (mm)
11.	Average number of visible leaf veins
12.	Total length of perianth and hypanthium (mm)
13.	Hypanthium length (mm)
14.	Style length (mm)
15.	Filament length (mm)
16.	Gland scale diameter (mm)
17.	Hypanthium hairy on inside (0) or not (1)
18.	Vegetative buds in inflorescence (0) or inflorescence terminal (1)
19.	Seed length (mm)
20.	Seed width (mm)
21.	Average number of flowers in the inflorescence
22.	Gland scales 8 distinct (0) 8 closely paired (1) 4 notched (2) 4 round (3)
23.	Leaf length / leaf width at midpoint
24.	Leaf base width / leaf width at midpoint
25.	Total perianth and hypanthium length / hypanthium length
26.	Leaves per centimetre / leaf length

Results and further analysis

In the initial analysis, there were two main groups in the dendrogram (Fig. 1). One of these is divided further into two clear subgroups: one composed of specimens of *Kelleria laxa* from the Bogong High Plains (Group A, hereafter referred to as '*K. laxa* Bogong'), and one of *K. laxa* from New Zealand (Group B — '*K. laxa* NZ'). There is one aberrant specimen of *K. laxa* from the Lammerlaw Range, Otago, New Zealand (CHR 417905, labelled 'X' in Fig. 1) that clusters with the Victorian population. All specimens of *K. dieffenbachii* are placed in the second major group (Group C). The *K. dieffenbachii* specimens are divided into three subgroups, two of these large (C1 and C2), and the third a single outlier specimen,

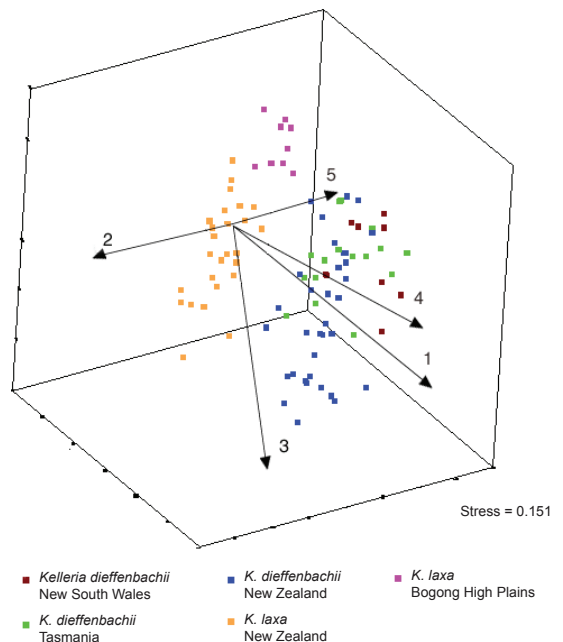
Figure 1. Dendrogram produced from analysis of 96 specimens of *Kelleria* scored for 26 characters. 'X' indicates specimen CHR 417905; 'Y' denotes AK 58357.



AK 58357, from Tongariro, North Island, New Zealand. These subgroups show no correlation with geographic distribution, as specimens from New South Wales, Tasmania and New Zealand are scattered throughout C1 and C2 (Fig. 1).

The outlier AK 58357 (labelled 'Y' in Fig. 1), a New Zealand specimen of *K. dieffenbachii*, compressed the spread of all other specimens in the initial ordination. It was a depauperate specimen, lacking flowers and seeds, so it was removed from the data set and the ordination re-run. The ordination pattern from the second analysis confirms the presence of three main groups, *K. laxa* Bogong, *K. laxa* NZ and *K. dieffenbachii* (Fig. 2). All *K. laxa* Bogong specimens formed a coherent group. The one New Zealand specimen (CHR 417905) that had grouped with the Bogong specimens in the initial dendrogram no longer groups with them and the significance of its placement in that group is equivocal.

Figure 2. Three-dimensional ordination of specimens scored in morphological study, omitting one outlier. Vectors of the five most important characters that correlate with the ordination pattern are shown. 1: presence of vegetative buds in inflorescence; 2: leaf width at midpoint; 3: total perianth length; 4: ratio of leaf base width to leaf mid-width; 5: leaves present on long shoot.



All *K. dieffenbachii* specimens form a group with New South Wales, Tasmanian and New Zealand specimens scattered throughout, however the lower end of the group contains only New Zealand specimens.

Vectors of the five most important characters that correlate with the ordination pattern (Fig. 2) indicate that the most critical differentiating character is the presence of vegetative buds in the inflorescence, which all *K. laxa* possess and all *K. dieffenbachii* lack. The second vector, leaf width at midpoint, distinguishes the *K. laxa* New Zealand group from the others. The hypanthium and perianth length vectors distinguish both the *K. dieffenbachii* group and the *K. laxa* NZ group from the Bogong group. There is a subgroup of *K. dieffenbachii* apparent in the dendrogram (Fig. 1, as part of C2) and also in the ordination (Fig. 2) that comprises only New Zealand specimens. This subgroup is particularly distinguished by flower size, which suggests the presence of larger flowers in this subgroup is what separates it from the other *K. dieffenbachii* specimens. The leaf base width/leaf mid-width vector, like the vegetative buds vector, separates *K. laxa* from *K. dieffenbachii*. The vector 'leaves present on the long shoot or not' also distinguishes *K. laxa* NZ from the *K. dieffenbachii* group.

Kruskal-Wallis values (Table 2) indicate that the most important character in separating the three major groups apparent in the dendrogram and ordination was the presence of vegetative buds in the inflorescence, followed by three leaf dimension characters and the number of leaf veins. Typical leaf shapes based on

mean values graphically summarise the differences in shape between the groups (Fig. 3). *Kelleria laxa* NZ has the largest leaves of all the groups and they are distinctly elliptic. Leaves of *K. dieffenbachii* are more linear and have on average three leaf veins compared to five. Leaves of *K. laxa* Bogong are the smallest of all the groups and are similar in shape and venation to *K. dieffenbachii* but are slightly more narrowed towards the base.

Figure 3. Average leaves of species of *Kelleria* in this study. Leaf proportions calculated from mean values for leaf length, width at base, width at midpoint and number of veins from all individuals included in the study for each species. **a.** *K. laxa* New Zealand; **b.** *K. laxa* Bogong High Plains; **c1 and c2.** *K. dieffenbachii*. Groups taken from multivariate analyses shown in Figs 1 and 2.

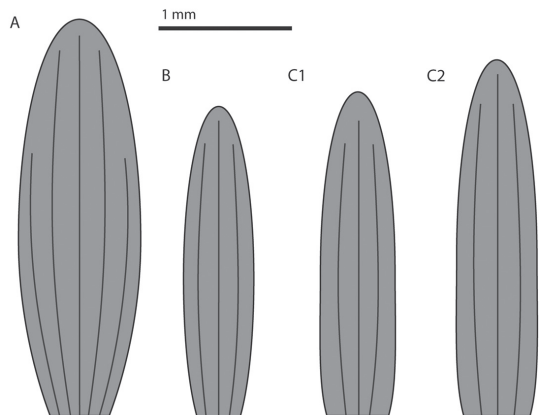


Table 2. Kruskal-Wallis values for the five most important characters for separating the three major groups identified in Fig. 1

Character	Kruskal-Wallis value	Group A "Bogong"	Group B <i>K. laxa</i> New Zealand	Group C <i>K. dieffenbachii</i>
		x ± sd (range)	x ± sd (range)	x ± sd (range)
18. Vegetative buds in inflorescence (0) or inflorescence terminal (1)	88.07	0 (buds present)	0 (buds present)	1 (buds absent)
24. Leaf base width / leaf width at midpoint	64.13	0.64 ± 0.084 (0.48 – 0.77)	0.50 ± 0.084 (0.35 – 0.67)	0.84 ± 0.11 (0.48 – 1.14)
9. Leaf width at midpoint (mm)	56.60	0.49 ± 0.055 (0.41 – 0.60)	0.86 ± 0.13 (0.70 – 1.20)	0.54 ± 0.073 (0.41 – 0.76)
23. Leaf length / leaf width at midpoint	43.56	4.5 ± 0.46 (4.0 – 5.2)	3.3 ± 0.50 (2.4 – 4.2)	4.5 ± 0.62 (3.2 – 6.2)
11. Average number of visible leaf veins	36.55	3.0 ± 0.00 (3 – 3)	4.0 ± 0.94 (3 – 5)	2.9 ± 0.57 (1 – 5)

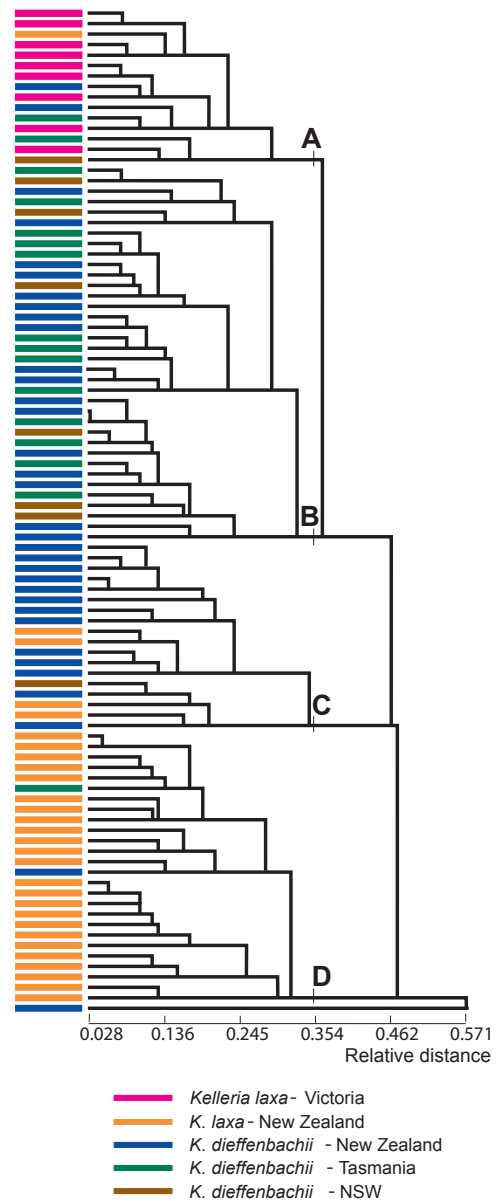
To test whether the binary character 'presence of vegetative buds in the inflorescence' (character 18) might have been masking the influence of some other characters, the agglomerative hierarchical analysis was re-run without this character. The groups in the dendrogram still mainly hold together (Fig. 4) with New Zealand *K. laxa* being most distantly separated from Bogong specimens rather than being nearest as in the initial classification. Group A comprises mostly Bogong specimens and Group B incorporates New South Wales, Tasmanian and New Zealand *K. dieffenbachii*. Group C is mostly New Zealand *K. dieffenbachii* and Group D is mostly New Zealand *K. laxa*. It is interesting to note that without this key character, the Bogong group is more closely linked to the *K. dieffenbachii* group that contains the other Australian specimens rather than to New Zealand plants of either species, and of these, it is most remotely linked to *K. laxa*.

Taxonomic implications

***Kelleria dieffenbachii*:** On morphological evidence *Kelleria dieffenbachii* was found to be a distinct taxon. All *K. dieffenbachii* specimens grouped together in the multivariate analyses and there was no significant separation of specimens from distinctly different geographic regions, i.e. Tasmania, New South Wales and New Zealand, that suggested distinct taxonomic recognition was warranted.

***Kelleria laxa*:** In the multivariate analyses, specimens were placed into two distinct groups – the Bogong group and the New Zealand group. Leaf size, leaf shape and flower size were important characters that separated them. The most important character shared by both groups in separating them from *K. dieffenbachii* was the presence of vegetative buds in the inflorescence. When this character was removed from the data set, the groups still largely held together, however the Bogong group aligned more closely with the *K. dieffenbachii* group in the classification. The presence of vegetative buds in the inflorescence changes the growth pattern and thus the architecture of the plant. *Kelleria dieffenbachii* plants have a clear long shoot/short shoot morphology where orthotropic short shoots, each bearing a terminal inflorescence, are borne on a plagiotropic runner that also produces adventitious roots. *Kelleria laxa* also has a long shoot/short shoot morphology, but one that is

Figure 4. Dendrogram produced as in Fig.1, but with character 18 removed



modified when the vegetative buds grow through the inflorescences. Heads (1990b) argued that the growth habit of *K. laxa* is of a form close to the boundary between monopodial and sympodial development. Vegetative buds are also produced in the inflorescence of the New Zealand species *K. lyallii*, *K. paludosa* and very occasionally *K. multiflora* (Heads 1990b).

There is a continuum of architectural modifications in *Kelleria* and *Drapetes* including suppression of

Key to *Kelleria* species investigated in this study

- 1 Vegetative buds in inflorescence absent, inflorescence terminal; ovary glabrous in Australian plants (glabrous or pilose in New Zealand) ***K. dieffenbachii***
- 1: Vegetative buds in inflorescence present; ovary pilose towards apex **2**
- 2 Leaves distinctly elliptic, mostly 5-nerved; leaves on short shoots 2.2–4.3 mm long, 0.5–1.2 mm wide; (2–)3–5 flowers per inflorescence; New Zealand ***K. laxa***
- 2: Leaves ± oblong, parallel sided for most of length, 1–3-nerved; leaves on short shoots 1.9–2.5 mm long, 0.4–0.6 mm wide; (1–)2(–3) flowers per inflorescence; mainland Australia ***K. bogongensis***

adventitious roots along the runner and suppression of the runner itself (Heads 1990b). In fact, the genus *Kelleria* displays a range of growth habits from cushions to loose mats or erect shrubs. The presence of vegetative buds in both New Zealand and Bogong *K. laxa* may be the result of parallel evolution, in which case *K. laxa*, as currently described, would be a polyphyletic taxon. Alternatively, this trait may have arisen once, in which case *K. laxa* Bogong and *K. laxa* New Zealand would be sister groups. A wider study of the entire genus should suggest which of these two explanations is more likely. Heads’s (1990b) diagram of phylogenetic affinities among species of *Kelleria* does not depict *K. laxa* and *K. dieffenbachii* as particularly closely related within the genus.

Based on the morphological evidence, which clearly separates *K. laxa* Bogong and *K. laxa* NZ, we propose that *K. laxa* Bogong be treated as a distinct species.

Taxonomy

***Kelleria bogongensis* Marks sp. nov.**

Type: AUSTRALIA, VICTORIA. Alpine National Park, Bogong High Plains, 0.5 km west of Mt Jim, January 1980, R. Adair 893 (holo: MEL 577528; iso: HO 38668).

Creeping, mat-forming, soft subshrub. Stems of short shoots to 0.8 mm diameter, sparsely pubescent, especially around leaf bases, or glabrous. Leaves glaucous to grey-green, oblong to very narrowly elliptic, slightly narrowed at base, those of short shoots 1.9–2.5 mm long, 0.4–0.6 mm wide, those of long shoots up to 4.0 mm long, 1- or 3-nerved, the lateral 2 nerves (when apparent) much finer than midrib, margins slightly incurved, sparsely ciliate distally, apex obtuse, with a tuft of straight, curved or flexuose hairs sometimes

extending slightly abaxially down midrib; leaves usually glabrescent with age. Bracts not differentiated from leaves, or slightly wider (to c. 0.7 mm wide). Inflorescence of 1–3 flowers (usually 2), with 1 or 2 central vegetative buds finally growing out. Flowers bisexual. Perianth 2.5–3 mm long, cream; hypanthium 1.3–2.2 mm long; tepals 4, triangular, 0.7–1.5 mm long, outer surface evenly covered with antrorse, simple hairs, usually with a few simple hairs on inner surface of tube; gland scales 8, inserted at summit of hypanthium, 0.07–0.1 mm diameter; stamens alternating with tepals, filaments 0.1–0.6 mm long; ovary narrowly ovoid, slightly shorter than hypanthium, sericeous toward apex; style 0.6–0.9 mm long, stigma papillose. Achene obliquely ovoid, 2.0–2.3 mm long, 1.0–1.1 mm wide, pilose toward apex, brown. Seed black, glossy; 1.9–2.2 mm long, 0.95–1.0 mm wide. (Figs 5, 6)

Other specimens examined: VICTORIA. Bogong High Plains, 1.0–1.5 km NNE of Mt Jim, 29.xii.1991, R.J. Adair s.n. (MEL); Bogong High Plains, 1.2 km due N of Mt Jim, 10.i.1992, N.G. Walsh 3287 (MEL); Bogong High Plains, 300 m NW from Mt Jim summit, 13.i.2000, N.G. Walsh 5173 (MEL); Bogong High Plains, c. 1.5 km N from Mt Jim, 3.iv.2006, N.G. Walsh 6419 & J.P. Walsh (K, MEL).

Distribution: Confined to a single population near Mt Jim, Bogong High Plains, north-eastern Victoria. On current knowledge, the population consists of eighteen patches, varying in size from c. 0.1 m² to c. 5 m², within an area of ca. 1.5 × 0.5 km.

Habitat: *Kelleria bogongensis* occurs in alpine grassland dominated by *Poa costiniana* Vick. on shallow organic loams overlaying basalt (Tertiary Older Volcanics). Plants form discontinuous mats on the edges of seasonally inundated pools, or between *Poa* tussocks, nearly always in association with *Argyrotegium nitidulum* (Hook.f.) J.M.Ward & Breitw. and *Lobelia surrepens* Hook.f.

Conservation status: Listed as Threatened under the Victorian Flora and Fauna Guarantee Act 1988 and considered to be Vulnerable under the Federal Environment Protection and Biodiversity Act 1999 (both as *Kelleria laxa*), and recognised as endangered in Victoria (Walsh & Stajsic 2007, as *K. laxa*). Applying IUCN (2001) criteria, it is assessed as Critically Endangered (CR) due to its extremely limited area of occupancy and susceptibility to habitat loss as a consequence of a warming climate. All populations are contained within the Alpine National Park.

Data collected in the course of this study (Marks, unpubl.) indicated that there was a significant decline in cover of *K. bogongensis* between 1993, when permanent study plots were established, and 2002. These dates encompassed a period of extended drought that culminated in the disastrous alpine fires of January 2003, which fortunately did not directly affect the *Kelleria* population. Prior to those fires, cattle grazed the Bogong High Plains over summer, potentially posing a further threat to the *Kelleria* population; but since 2003 cattle grazing has been withdrawn from the Alpine National Park. However, in recent years, there has

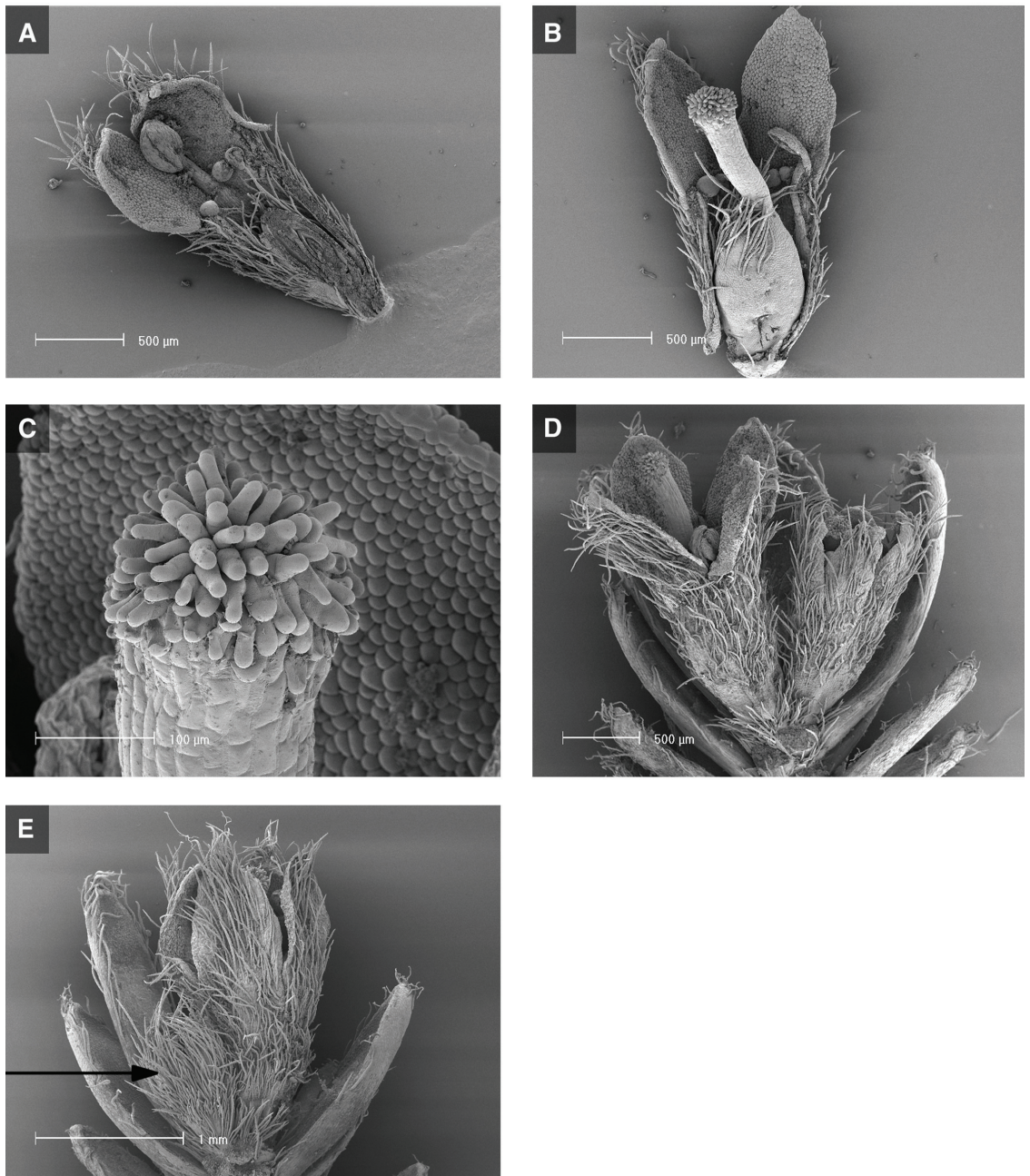
been a marked increase in the number of wild horses in the vicinity of Mt Jim where there is now a resident population in excess of 20 animals posing a significant threat through grazing/trampling pressures (NW pers. obs.).

Notes: *Kelleria bogongensis* differs from *K. laxa* with which it has been included, primarily in the shorter, 1–3-nerved leaves and mostly 2-flowered inflorescences. It differs further in the diameter of the stems of the long shoots being less than 0.8 mm (compared to greater than 0.8 mm in *K. laxa*), and the flowers having gland scales that are less than 0.1 mm in diameter, whereas those of *K. laxa* are greater than 0.1 mm in diameter. The size of all floral structures and length of short shoots are, on average, smaller in *K. bogongensis* than in *K. laxa*. In addition to the lack of vegetative buds in the inflorescence, *K. dieffenbachii* differs from *K. bogongensis* in having (1–)4(–6) flowers per inflorescence and coarser short shoot stems. The leaves of *K. dieffenbachii* do not narrow at the base like those of *K. bogongensis*. Plants of *K. bogongensis* and *K. dieffenbachii* (from Tasmania) grown in a glasshouse under identical conditions for eight months maintained their leaf shapes.

Figure 5. *Kelleria bogongensis*, field photograph, Bogong High Plains, Victoria



Figure 6. *Kelleria bogongensis*, scanning electron micrographs: **a.** longitudinal section through a young flower; **b.** section through an older flower showing ovary; **c.** papillose stigma; **d.** two flowers in an inflorescence, a third flower has been removed in the foreground; **e.** inflorescence with one flower removed in the foreground, arrow shows vegetative bud (from cultivated material of same collection as *Walsh 3287*)



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