

Alopecurus goekyigitiana (Poaceae, subtribe Alopecurinae sensu stricto), a new species from Turkey based on morphological and molecular investigation

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Abstract: *Alopecurus goekyigitiana*, a new species from the Taurus Mountains of Turkey, is described and illustrated. Phylogenetic analyses of DNA sequence data support its relationship within *Alopecurus* sect. *Colobachne* with *A. gerardi* (plastid), or with the complex of *A. davisii*, *A. lanatus*, and *A. vaginatus* (nuclear ribosomal spacers). The new species differs from the above taxa by various combinations of characters, in having slender rhizomes and a mat-forming habit, indumentum of lower sheaths sparsely sericeous, glabrescent, culm leaf blades absent or vestigial, basal blades filiform, a dorsal awn on the lemma that is vestigial or up to 2 mm long, erect (not geniculate), and the palea absent. Notes on its ecology and conservation status are presented. A distribution map for the new species and its closest allies in Turkey is provided.

Key words: Southwest Asia, DNA, endemic, foxtail, threat category

1. Introduction

The grass family (Poaceae Barnhart), with about 12,000 species and 763 genera, ranks as the second largest monocot family and the fifth largest plant family (Clayton and Renvoize, 1986; Caetano-Anolles, 2005; Perret et al., 2009; Soreng et al., 2015b).

In the checklist of the Poaceae of Turkey, Cabi and Doğan (2012) reported that Turkey hosts 146 grass genera including 547 species and 658 taxa. After the publication of the checklist of Poaceae, new grass taxa were recorded or described for the Turkish flora, such as *Sclerochloa woronowii* (Hack.) Tzvelev (Cabi et al., 2013); *Agropyron pinifolium* Nevski (Cabi et al., 2015a); *Bellardiachloa doganiana* Cabi & Soreng (Cabi et al., 2015b); *Pseudophleum anatolicum* Doğan, Behçet & A.Sinan (Doğan et al., 2015); *Poa pratensis* subsp. *irrigata* (Lindm.) H.Lindb.; and *Poa eigii* Feinbrun (Cabi and Soreng, 2016).

The genus *Alopecurus* L. (foxtail) is a member of the subfamily Pooideae tribe Poeae subtribe Alopecurinae, which in its narrowest sense comprises the genera *Alopecurus*, *Limnas* Trin., and perhaps *Cornucopiae* L. Currently this subtribe is placed in subtribe Poinae s.l. (Kellogg, 2015; Soreng et al., 2015b). *Alopecurus* contains

52 species (Kellogg, 2015) and is separated from other genera in the subtribe by its compact spike-like panicle or capitate inflorescences, spikelets disarticulating below the glumes, 1-flowered, rachilla extension absent, glumes strongly keeled and slightly longer than the floret body, connate in part, lemma with margins often connate at the base and awned from the back (awn usually geniculate and exerted, rarely absent), palea keeled, 1-veined, often reduced, or absent, flowers without lodicules, styles fused at base, and caryopsis, laterally compressed, with liquid or semiliquid endosperm, hilum ca. 1/3 the grain in length (Doğan, 1985, 1999; Boudko, 2014). Soreng et al. (2015a) provided the first broad molecular sampling of the species of *Alopecurus* primarily based on data from Boudko's (2014) master's thesis.

Cabi and Doğan (2012) reported 20 species and 10 infraspecies taxa in *Alopecurus* for Turkey. There are only 14 species reported in the Fl. Europaea account (Clarke, 1980), 20 in the former Soviet Union (Tzvelev, 1976), eight in the Flora of China account (Lu and Phillips, 2006), and 17 in Flora Iranica (Bor, 1970). Clearly, Turkey and the adjacent countries of the Irano-Turanian floristic region are a major center of diversity in the genus. However, up

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to now only five taxa are endemic to Turkey (*A. adanensis* Doğan, *A. anatolicus* Doğan, *A. lanatus* Sm., *A. gerardi* Vill. var. *cassius* (Boiss.) Doğan, and *A. utriculatus* Sol. subsp. *gaziantepicus* Doğan (Cabi and Doğan, 2012).

While collecting material of a new species of *Bellardiochloa* (described as *B. doganiana* Cabi & Soreng; Cabi et al., 2015b) from Konya, Bozkır region, Taurus Mts., Palaz Dağı, in 2014, we encountered an unusual species of *Alopecurus*. sect. *Colobachne* (P.Beauv.) Griseb. Initially we thought it might be new, but then thought it might be an odd form of *A. gerardi* Vill. When DNA data for the collection placed it with a separate complex of species, we revisited our initial hypothesis. Upon closer examination of these materials and herbarium specimens of putatively related taxa (Appendix), and going through the Flora of Turkey (*Alopecurus* treatment by Doğan, 1985) and other relevant floras, such as Flora Europaea (*Alopecurus* treatment by Clarke, 1980), Flora Orientalis (Boissier, 1884), Flora of Syria, Palestine, and Sinai (Post, 1933), Flora of Iraq (Bor, 1968), Flora Iranica (Bor, 1970), and Grasses of the Soviet Union (Tzvelev, 1976), we concluded that the specimens indeed belonged to a new species.

The objectives of the current paper are to describe a new *Alopecurus* species from Turkey, show its relationships with other species in the genus and interpret relationships among species of *Alopecurus*, and compare the new species' morphology to that of closely allied species.

2. Materials and methods

2.1. Morphological analysis

We compared our proposed new species with *Alopecurus* material (Appendix) housed at various European (E, G, K, P), North American (CAN, US), and Turkish (ANK, GAZI, ISTE, HUB, NAKU) herbaria. Herbarium acronyms follow Thiers (continuously updated). The gross morphology of the specimens was examined using a stereo binocular microscope. All authors of plant names follow Brummitt and Powell (1992).

2.2. Molecular analysis

A total of 27 samples were included in the molecular analysis: 24 *Alopecurus* (18 species) and three outgroup samples (Table 1). A representative sample across *Alopecurus* was chosen based on previous taxonomic (Doğan, 1997; 1999) and phylogenetic (Boudko, 2014; Soreng et al., 2015a) studies, with an emphasis on species in *A. sect. Colobachne* putatively related to our new species. Three genera [*Apera* Adans., *Bellardiochloa* Chiov., and *Gaudinopsis* (Boiss) Eig.] belonging to the nonhybrid sister clade of *Alopecurus* (Soreng et al., 2015a) were chosen as outgroups.

Three plastid (*matK*, *rpoB-trnC*, and *trnT-trnL-trnF* [TLF]) and two nuclear ribosomal DNA (nrDNA) markers (internal transcribed spacer [ITS] and external

transcribed spacer [ETS]) were sequenced. DNA extraction methods were described by Gillespie et al. (2008). Primers and amplification and sequencing protocols utilized were described in our previous studies (ITS and TLF, Gillespie et al., 2008; ETS, Gillespie et al., 2009, 2010; *matK* and *rpoB-trnC*, Soreng et al., 2015a). Sequences were assembled and edited using Geneious ver. 6.1.5 (Biomatters Ltd., <http://www.geneious.com>) and aligned using the MAFFT ver. 7.017 plugin (Katoh and Standley, 2013) followed by manual adjustment. The five alignments (ITS, ETS, *matK*, *rpoB-trnC*, and TLF) were concatenated in Geneious.

Maximum parsimony (MP) analyses were performed with PAUP* 4.0b10 (Swofford, 2002) on the separate and combined alignments using the heuristic search command with default settings, including tree-bisection reconnection (TBR) swapping and saving all multiple shortest trees (Multrees). Strict consensus trees were computed in PAUP and viewed in FigTree v1.4.0 (Rambaut, 2006–2014). Branch support was assessed using MP bootstrap analyses performed in PAUP with heuristic search strategy, default settings, and 5000 bootstrap replicates. Trees were inspected for conflicting topologies prior to performing analyses on combined alignments. No conflict was detected among the separate plastid trees (*matK*, *rpoB-trnC*, and TLF), or between ITS and ETS trees (with the exception of a minor difference in the position of *Alopecurus arundinaceus*). Analyses were performed on the combined plastid data and on the combined nrDNA data, but not on these two datasets combined since the plastid and nrDNA trees showed conflicting topology.

Optimal models of molecular evolution for individual markers were determined using the Akaike information criterion (AIC; Akaike, 1974) conducted through likelihood searches in jModeltest v2.1.4 with default settings (Darriba et al., 2012). Bayesian Markov chain Monte Carlo analyses were conducted in MrBayes v3.2.2 (Ronquist et al., 2012) on the partitioned nrDNA and plastid datasets. Models were set at GTR + Γ for ITS, ETS, *rpoB-trnC*, and TLF partitions, and at F81 + I for the *matK* partition based on the above AIC scores and the models allowed in MrBayes. For each dataset two independent runs of four-chained searches were performed for 10 million generations, sampling every 500 generations, with default parameters. A 25% burn-in was implemented prior to summarizing a maximum clade credibility tree and calculating Bayesian posterior probabilities (PP). Maximum likelihood (ML) trees are presented and the thick branches represent congruence with the parsimony tree.

3. Results

Alopecurus goekyigitiana Cabi & Soreng, **sp. nov.** (Figures 1 and 2)

Type:—TURKEY. C4 Konya, Bozkır, Karacahisar köyü, Palaz yaylası, steep slopes on northwest side of pass to

Table 1. Collections of *Alopecurus* and outgroup taxa used in the phylogenetic analysis, with voucher information, country of origin, and GenBank accession numbers for the five markers sequenced (nrDNA ITS and ETS; plastid *MatK*, *rpoB-trnC*, and *trnT-trnF*).

	Voucher	Country	ITS	ETS	<i>MatK</i>	<i>rpoB-trnC</i>	<i>trnT-L-F</i>
<i>Alopecurus aequalis</i> Sobol.	Peterson et al. 17115 US	Argentina	KM523749	KM523673	KM523821	KM523929	KM524037
<i>Alopecurus arundinaceus</i> Poir.	Gillespie et al. 10562 CAN	Turkey	KM523750	KM523674	KM523822	KM523930	KM524038
<i>Alopecurus davisi</i> Bor	Gillespie et al. 10459-1 CAN	Turkey	KM523751	KM523675	KM523823	KM523931	KM524039
<i>Alopecurus gerardi</i> Vill. var. <i>gerardi</i>	Gillespie et al. 10399-1 CAN	Turkey	KM523752	KM523676	KM523824	KM523932	KM524040
<i>Alopecurus gerardi</i> Vill. var. <i>gerardi</i>	Soreng et al. 7494 US	Greece	EU792344	GQ324238	—	—	EU792432
<i>Alopecurus gerardi</i> Vill. var. <i>gerardi</i>	Soreng et al. 7498 US	Greece	—	—	—	—	—
<i>Alopecurus gerardi</i> Vill. var. <i>gerardi</i>	Soreng 3827 US	Greece	—	—	—	—	—
<i>Alopecurus gerardi</i> Vill. var. <i>gerardi</i>	Soreng & Davis 4043 US	Turkey	—	—	—	—	—
<i>Alopecurus glacialis</i> K. Koch	Abdaladze et al. 429 MO	Georgia	KM523753	KM523677	KM523825	KM523933	KM524041
<i>Alopecurus hitchcockii</i> Parodi	Peterson et al. 16256 US	Peru	KM523755	KM523679	KM523827	KM523935	KM524043
<i>Alopecurus japonicus</i> Steud.	Tsugaru et al. 1495 MO	Japan	KM523756	KM523680	KM523828	KM523936	KM524044
<i>Alopecurus lanatus</i> Sm.	Gillespie et al. 10408-1 CAN	Turkey	KM523757	KM523681	KM523829	KM523937	KM524045
<i>Alopecurus lanatus</i> Sm.	Soreng & Davis 4042 US	Turkey	—	—	—	—	—
<i>Alopecurus magellanicus</i> Lam.	Peterson et al. 17217 US	Argentina	KM523758	KM523682	KM523830	KM523938	KM524046
<i>Alopecurus borealis</i> Trin.	Breitung 15736 US	Canada	KM523754	KM523678	KM523826	KM523934	KM524042
<i>Alopecurus myosuroides</i> Huds.	Gillespie et al. 10561 CAN	Turkey	KM523760	KM523684	KM523832	KM523940	KM524048
<i>Alopecurus myosuroides</i> Huds.	Gillespie et al. 10369 CAN	Turkey	KM523759	KM523683	KM523831	KM523939	KM524047
<i>Alopecurus ponticus</i> K.Koch	Soreng et al. 7961 US	Russia	KM523761	KM523685	KM523833	KM523941	KM524049
<i>Alopecurus pratensis</i> L.	Saarela & Sears 535 CAN	Canada	KM523762	KM523686	KM523834	KM523942	KM524050
<i>Alopecurus saccatus</i> Vasey	Howell 23254 US	USA	KM523763	KM523687	KM523835	KM523943	KM524051
<i>Alopecurus goekyigitiana</i> Cabi & Soreng	Soreng et al. 8856 US	Turkey	—	—	—	—	—
<i>Alopecurus stejnegeri</i> Vasey	Sladen 225 US	USA	KM523764	KM523688	KM523836	KM523944	KM524052
<i>Alopecurus textilis</i> Boiss.	Soreng 7962a US	Russia	KM523765	KM523689	KM523837	KM523945	KM524053
<i>Alopecurus vaginatus</i> (Willd.) Pall. ex Kunth	Gillespie et al. 10588-1 CAN	Turkey	KM523766	KM523690	KM523838	KM523946	KM524054
<i>Apera intermedia</i> Hack.	Gillespie et al. 10312 CAN	Turkey	KM523768	KM523692	KM523841	KM523950	KM524056
<i>Bellardiachloa carica</i> R.R.Mill	Gillespie et al. 10594-1 CAN	Turkey	KM523772	KM523696	KM523851	KM523961	KM524060
<i>Gaudinopsis macra</i> (Steven ex M.Bieb.) Eig	Gillespie et al. 10634 CAN	Turkey	KM523781	KM523705	KM523863	KM523976	KM524068

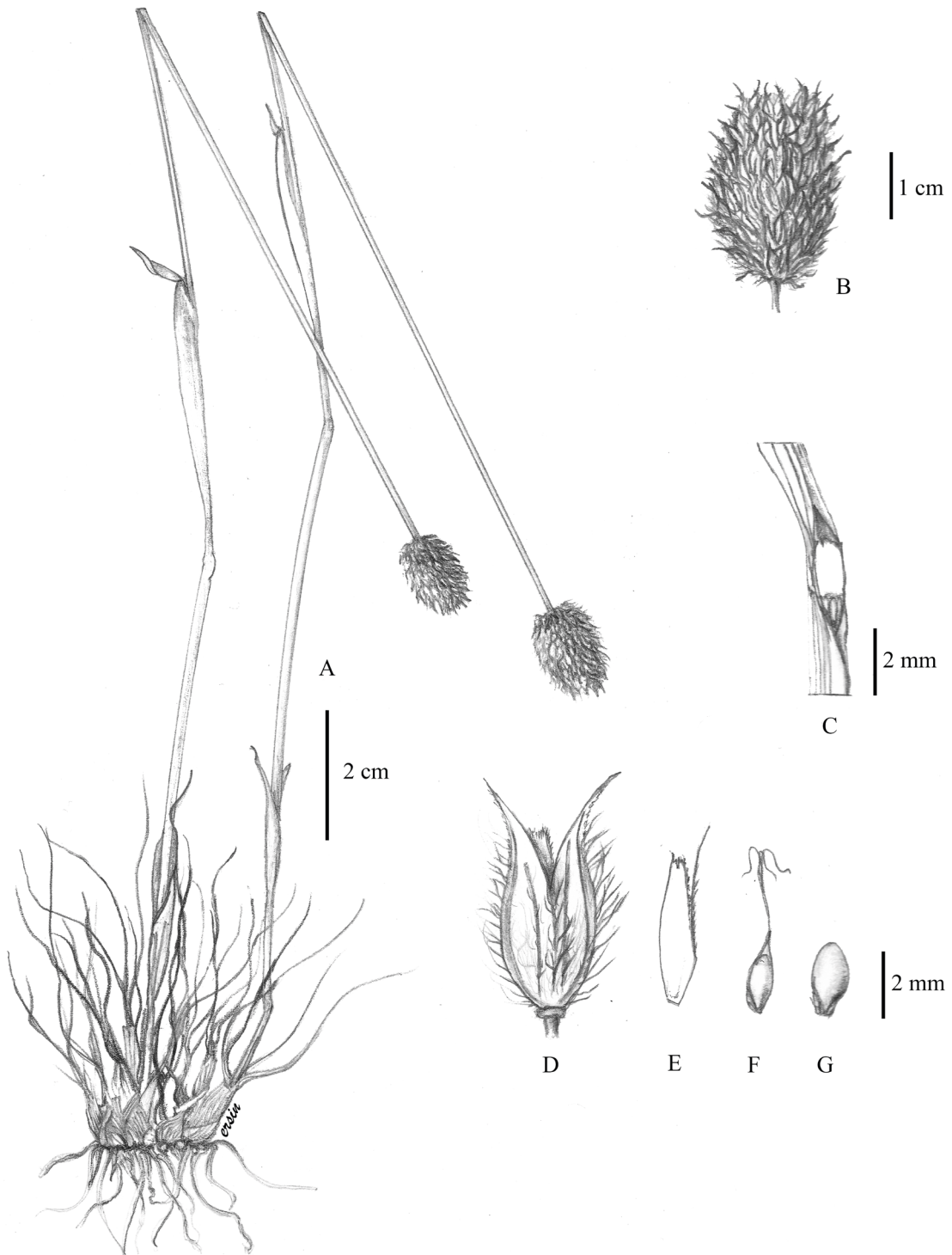


Figure 1. *Alopecurus goekyigitiana* (RJ Soreng et al. 8856). A- Habit ($\times 1$), B- panicle ($\times 2$), C- ligule ($\times 5$), D- spikelet ($\times 5$), E- lemma ($\times 5$), F- pistil ($\times 5$), G- caryopsis ($\times 5$) (illustrated by Ersin Karabacak).

Hacıobası yaylası, 2015 m, 37.04410°N, 32.09117°E, 25 July 2014, R.J. Soreng 8856, E.Cabi & B.Çingay (holotype US, isotypes ANK, CAN, E, G, HAOC, ISTE, K, KNYA, LE, NAKU, W).

3.1. Diagnosis

Alopecurus goekyigitiana differs from *A. gerardi*, *A. davisii*, and *A. lanatus* in having thin versus thick rhizomes, culm leaf blades absent or vestigial versus well developed, and forming extensive mats versus isolated tufts. It differs from

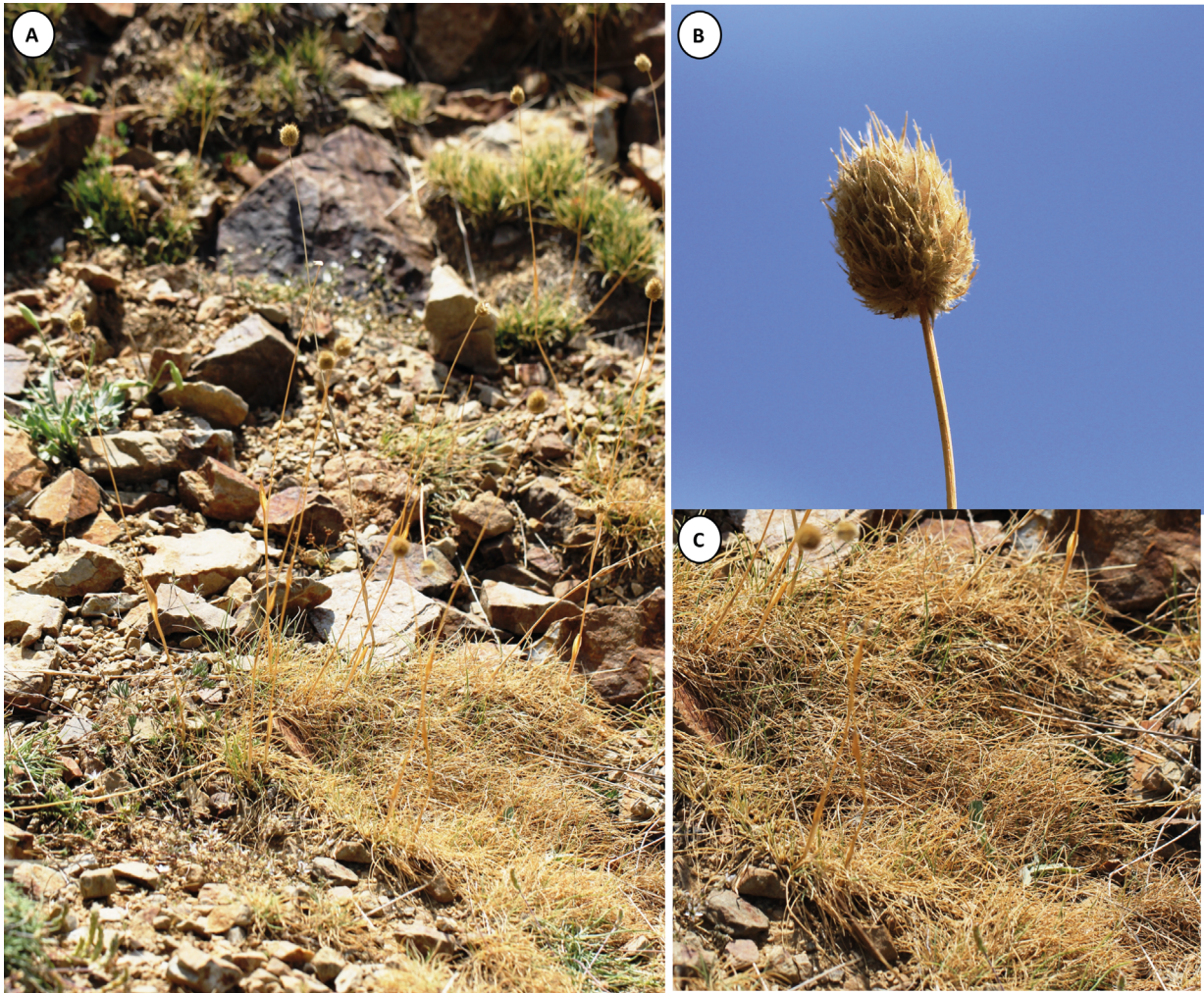


Figure 2. *Alopecurus goekyigitiana* at the type locality. A- Habit, B- inflorescence, C- mat-forming habit. Photos taken by Evren Cabi.

A. vaginatus in forming extensive mats versus tufts, an awn that is vestigial or up to 2 mm long, erect (not geniculate) versus 5–10.5 mm long and geniculate and twisted awn, and the palea absent versus present and well developed.

3.2. Etymology

The new *Alopecurus* species is named in honor of Ali Nihat Gökyiğit, founder and leading financial contributor of the Nezahat Gökyiğit Botanical Garden and ANG Foundation, for his continued contributions to the Illustrated Flora of Turkey and Turkish botany.

3.3. Description

Perennial, producing short slender rhizomes connecting mats up to 50 cm in diameter. Culms 15–43 cm tall, erect to geniculate at the nodes, glabrous, smooth, 1- or 2-noded, basal fascicles of sheaths slender (not stout). Leaves: sheaths of inner basal leaves sparsely sericeous, glabrescent, uppermost and subtending culm sheaths inflated, loose, glabrous; ligule 1–2 mm long, truncate to

obtuse, abaxially smooth, glabrous, margins of the lateral lobes and apex aculeate; blades mostly basal, of basal leaves filiform 3–4 cm × 0.7–0.9 mm, narrowly but abruptly naviculate, abaxially smooth, glabrous, adaxially sparsely scabrous, slightly scabrid on margins, pale grayish green, of culm leaves absent or vestigial to 1 cm long × 2.4 mm wide, linear. Panicle 0.6–1.2 × 0.7–0.9 cm, subspherical or globose. Spikelets 2.5–3.8 mm long excluding awns, awns up to 5 mm long; glumes lanceolate, 2.5–3.8 mm long, slightly connate at base, with aristate point to 1–2 mm, covered with cilia on lateral surfaces cilia mostly in lines, proximally white to distally gold-tinged, cilia of keels 1–1.2 mm long; lemma about 3 mm long, broadly lanceolate, obliquely truncate at apex, with a fringe of short stiff hairs at apex, dorsally mucronate or awned; awn vestigial or up to 2 mm long, erect. Palea absent. Anthers 1 (seen, developed, others disarticulated), 1.5–2 mm long. Caryopsis: 1.8 mm long, 1.2 mm broad, 0.9 mm thick, firm, straw-colored, broadly elliptical in side view,

fusiform in ventral view, sulcus absent, the ventral side bowed outward, hilum 0.2 mm long, round or elliptical.

3.4. Molecular analysis

Bayesian ML clade credibility trees for the nrDNA and plastid analyses are shown in Figures 3 and 4, respectively. Maximum parsimony analyses resulted in very similar trees (MP bootstrap values [BS] are shown in Figures 3 and 4); only the position of *A. pratensis* L. as sister to the *A. aequalis* Sobol.–*A. stejnegeri* Vasey clade (BS = 65) in the nrDNA tree differed. Nuclear and plastid ML trees were incongruent; hence, analyses were not performed on the combined datasets.

3.5. Suggested conservational status

Alopecurus goekyigitiana is endemic to the central Taurus Mountains, C4 zone of Konya and Antalya provinces in Anatolia, Turkey (Figure 5). The estimated extent of occurrence based on four known localities, all within 50 km of each other, is not more than 100 km². We have no evidence on trends of or actual size of the populations. Over the area examined at the type locality (ca. 50 m along the road and up to 30 m away from the road) individual mats of the species were frequent (perhaps 50 mats seen). High grazing pressure may have a significant impact on the populations of this species but the natural steep terrain of the region and high altitude habitat of this grass may

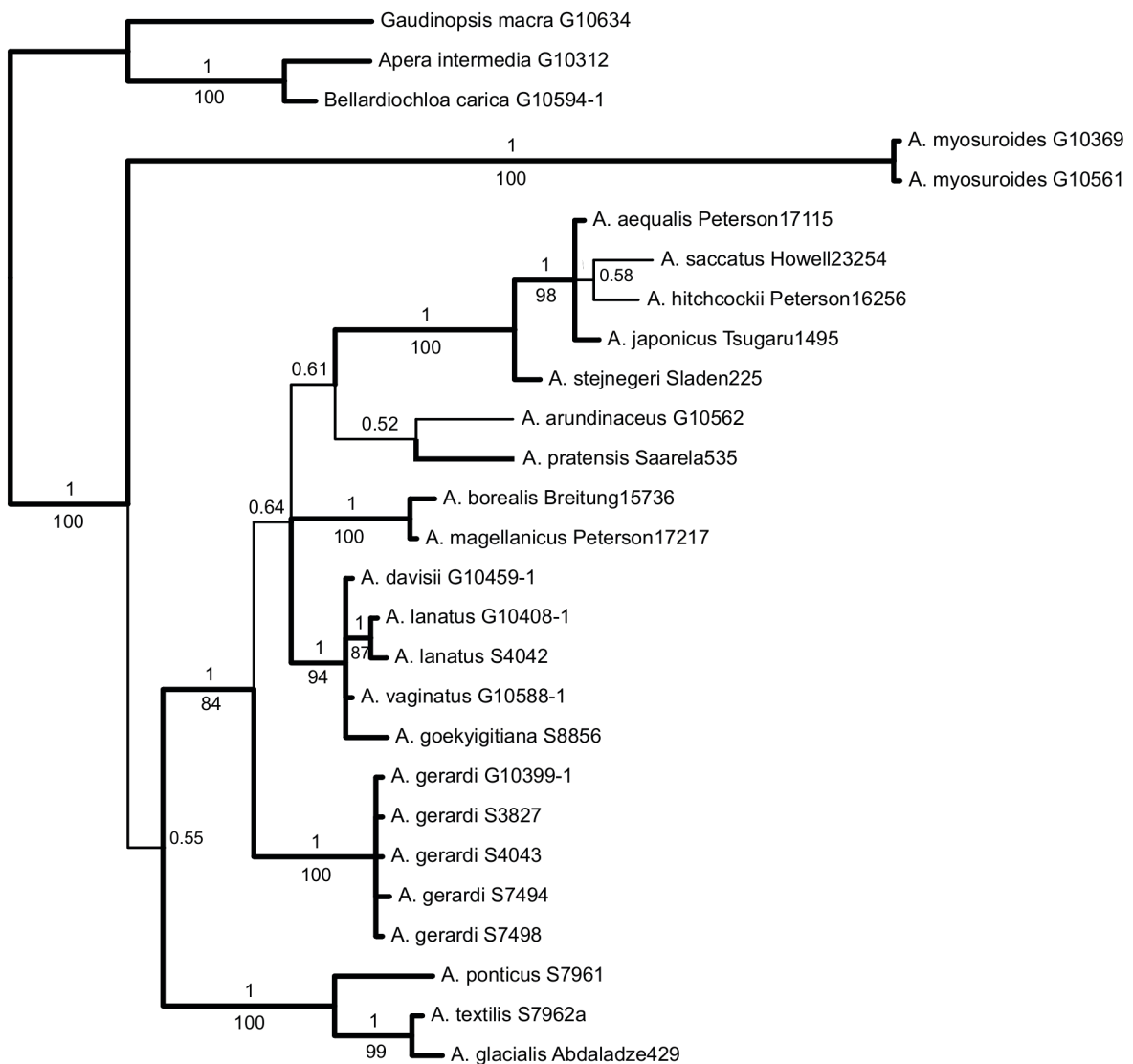


Figure 3. Bayesian ML clade credibility tree of *Alopecurus* and outgroups based on nuclear ribosomal ITS and ETS sequences; Bayesian posterior probabilities are shown above branches, maximum parsimony bootstrap values below branches. Thick branches represent congruence with the parsimony tree.

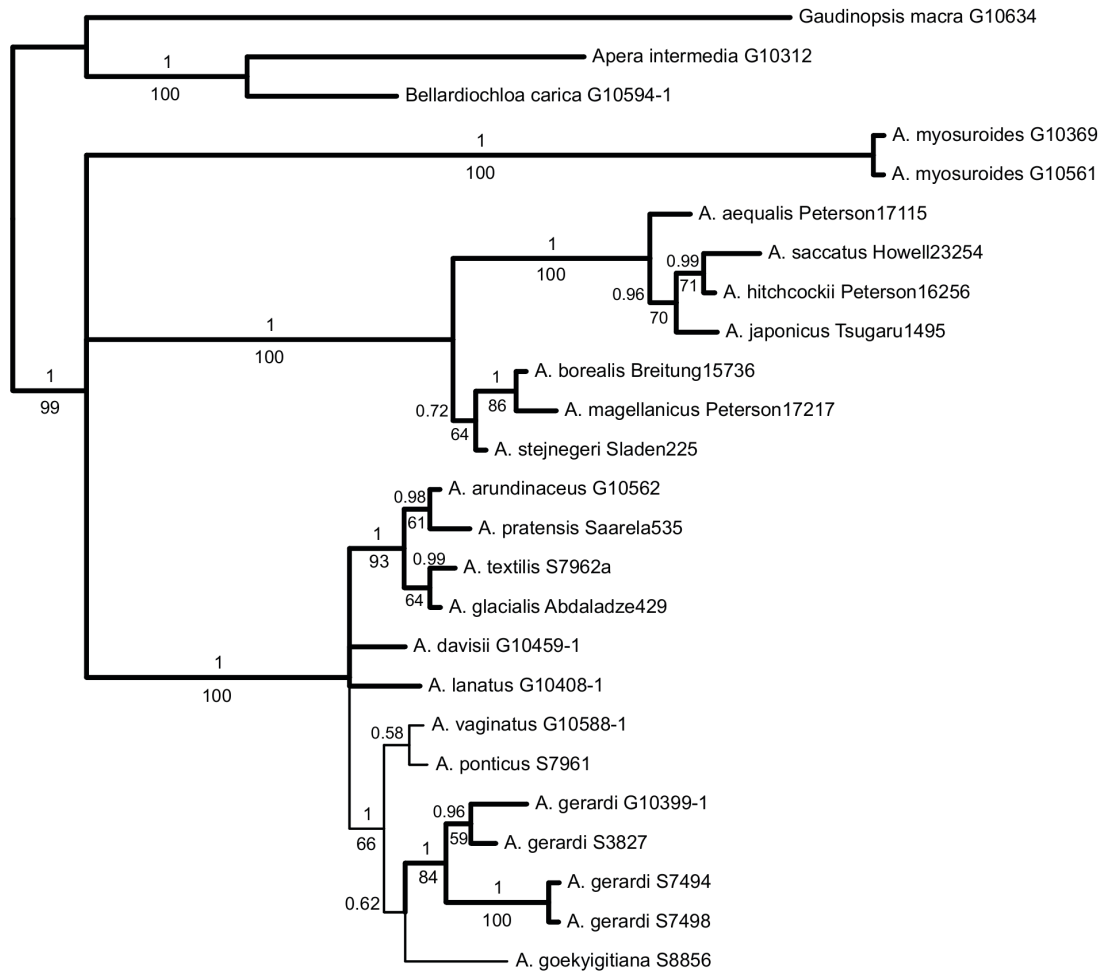


Figure 4. Bayesian ML clade credibility tree of *Alopecurus* and outgroups based on plastid *matK*, *rpoB-trnC*, and *TLF* sequences; Bayesian posterior probabilities are shown above branches, maximum parsimony bootstrap values below branches. Thick branches represent congruence with the parsimony tree.

confer some protection. Considering IUCN criteria A3 and B2 (IUCN, 2013), we recommend that the threat category of *A. goekyigitiana* be Endangered (EN).

3.6. Distribution and ecology

Apparently endemic to the Taurus Mountains, Palaz Dağları (mountain range), running along the shared eastern Antalya and southwestern Konya regional border in Turkey (Figure 5). High *Astragalus* steppe to low subalpine, on limestone and mixed sedimentary rocks, 2000–2300 m.

4. Discussion

The genus *Alopecurus* is often divided into sections (Tzvelev, 1976; Clarke, 1980; Doğan, 1985, 1997, 1999), including *Alopecurium* Dumort. (type *A. geniculatus* L.), *Alopecurus* s.s. (type *A. pratensis* L.), *Colobachne* (type *A. vaginatus* [Willd.] P. Beauv.), and *Pseudophalaris* Tzvelev (type *A. myosuroides* Huds.). The new species clearly

fits *Alopecurus* sect. *Colobachne* in having a strongly perennial, short rhizomatous habit, short ovoid to globose inflorescences, leaf blades often much reduced in length up the culm, glume apices gradually attenuated to a cusp, margins fused over 1/10–1/6 the length, lemma margins fused for less than 1/4 the length, palea present or rarely absent. The plants exhibit very short lemma awns, filiform basal leaves, and quite small ball-shaped inflorescences. The plants form mats, with tufts interconnected by short slender rhizomes. When keyed out in the Flora of Turkey account of *Alopecurus* (Doğan, 1985) it aligns near *A. gerardi* because it has short awns (not exerted), the glumes have aristate points 1–2 mm long, and there was a specimen cited under that taxon from the same vicinity (Çelik & Yurdakulol 10788). However, it still seemed odd that these collections had a mat-forming habit, slender rhizomes, filiform basal leaves, and short inflorescences. Closer examination of a series of specimens revealed the

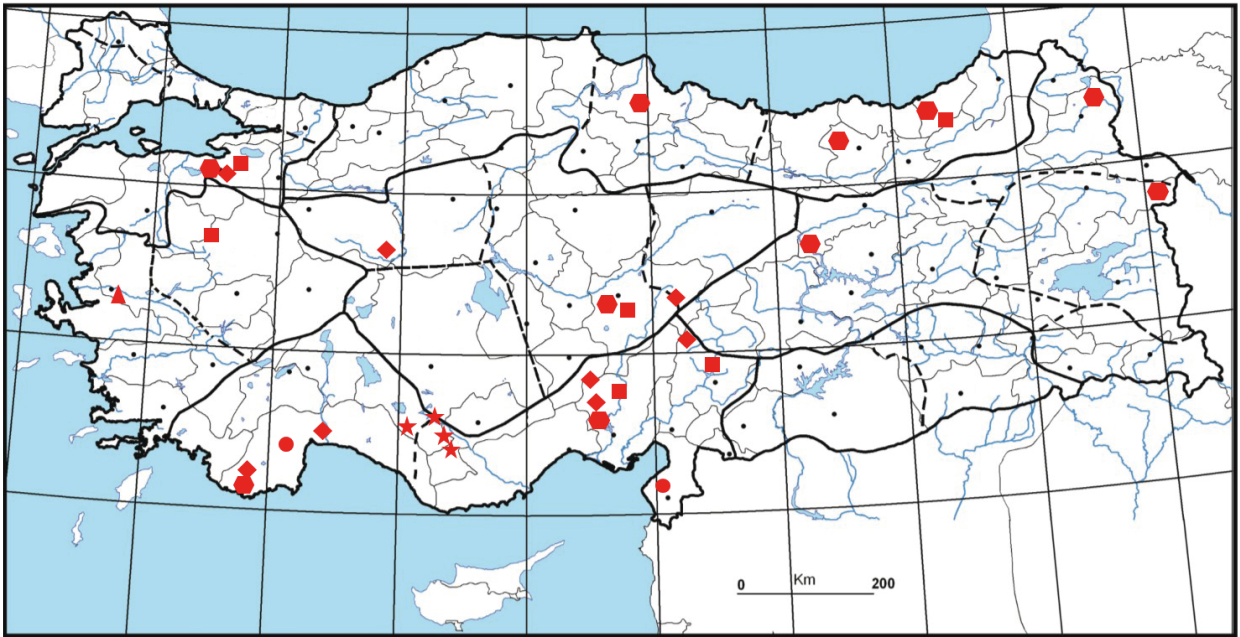


Figure 5. Distribution of *Alopecurus goekyigitiana* sp. nov. and its closest allies in sect. *Colobachne* in Turkey. (★) *A. goekyigitiana*; (■) *A. gerardi* var. *gerardi*, (●) var. *cassius*; (▲) *A. davisii*; (◆) *A. lanatus*; (●) *A. vaginatus*.

hairs of the glumes to be colored, the basal sheaths to be glabrescent (obscurely sericeous when young), and the palea to be absent, which along with other features convinced us that this was a new species.

The plastid tree resolved three strongly supported (PP = 1; BS = 100) main clades in *Alopecurus*: *A. myosuroides* Huds. (sect. *Pseudophalarus*); *A. aequalis* to *A. stejnegeri* (sects. *Alopecurium* and *Alopecurus* p.p.); and *A. arundinaceus* to *A. goekyigitiana* (sects. *Alopecurus* p.p. and *Colobachne*) (Figure 4).

The nuclear tree also resolved three moderately to strongly supported (PP = 1; BS = 84–100) main clades, but only the first one was the same as in the plastid tree: *A. myosuroides* (sect. *Pseudophalarus*); *A. aequalis* to *A. gerardi* (sects. *Alopecurium*, *Alopecurus*, and *Colobachne* p.p.); and *A. ponticus* K.Koch to *A. glacialis* K.Koch (*Colobachne* p.p.) (Figure 3). In both analyses sect. *Alopecurium* formed a strongly supported clade (PP = 1; BS = 98–100), but sects. *Alopecurus* and *Colobachne* did not resolve as monophyletic.

Alopecurus goekyigitiana resolved in a strongly supported clade with three sect. *Colobachne* species, *A. davisii*, *A. lanatus*, and *A. vaginatus*, in the nuclear tree (PP = 1, BS = 94), but relationships within this clade were not resolved (Figure 3). In the plastid tree it resolved in a clade with *A. vaginatus*, *A. ponticus*, and *A. gerardi*, strongly supported in the Bayesian analysis (PP = 1), but only weakly supported in the MP analysis (BS = 66) (Figure 4). Samples of *A. gerardi* form a moderately to strongly

supported clade (PP = 1, BS = 84–100) in both plastid and nuclear trees; while nuclear sequences are almost identical, plastids show considerable divergence.

The first published molecular phylogenetic study including a substantial breadth of sampling in *Alopecurus* included 17 species in a larger study focused on the origin of the *Dupontia* clade (Soreng et al. 2015a); it included a subset of samples of *Alopecurus* from Boudko's thesis (2014). In the present study we included the same 17 species (*A. glaucus* Less. redetermined as *A. borealis* Trin.) along with our new collection and additional samples of *A. gerardi*. Among the clades identified it is possible to resolve the traditional sections *Alopecurium* [type: *A. geniculatus*] and *Pseudophalaris* [type: *A. myosuroides*]. However, it is also evident that reticulation has played a role in the evolution of the other lineages detected. Possibly sect. *Alopecurus* s.s. (*Alopecurus arundinaceus* Poir. and *A. pratensis* L. [type]) is reticulate between *Colobachne* (type: *A. vaginatus* (Willd.) Kunth) and some unidentified ancestor. The *A. magellanicus* complex (sect. *Alopecurus* s.l.) is probably of a similar origin. Reticulation is presumably the reason for *A. stejnegeri* resolving as sister to species of the sect. *Alopecurium* clade in the nrDNA tree (Figure 3) rather than with the *A. magellanicus* and *A. borealis* (sect. *Alopecurus* s.l.) clade as in our plastid tree (Figure 4). Clearly, the taxonomy of the genus is complex and in need of further study.

It is also apparent from our phylogenetic analyses that our putative new species is allied with the *Alopecurus*

Table 2. Morphological characters separating *Alopecurus goekyigitiana* sp. nov., *A. gerardi*, *A. lanatus*, *A. davisii*, and *A. vaginatus*.

Characters/Taxa	<i>Alopecurus goekyigitiana</i> sp. nov.	<i>A. gerardi</i>	<i>A. lanatus</i>	<i>A. davisii</i>	<i>A. vaginatus</i>
Habit	Mat-forming perennial with slender rhizomes	Caespitose perennial with a very stout decumbent base	Caespitose perennial with a stout suberect base	Caespitose perennial with a stout, gradually thickened suberect base	Caespitose perennial with slender rhizomes, turf forming
Culm height	15–41 cm	6–45 cm	3.5–30 cm	7–38 cm	18–30 cm
Leaf sheaths vestiture	Lower sheaths sericeous (glabrescent), uppermost and subtending culm sheaths inflated	Lower sheaths glabrous, uppermost ones slightly inflated	Sheaths tomentose, uppermost ones inflated and white tomentose	Basal sheaths villous, upper sheaths glabrous and inflated	Sheaths glabrous, uppermost ones slightly inflated
Leaf blades	Culm leaves absent or vestigial, blades of basal leaves filiform 3–4 cm × 0.7–0.9 mm	Culm leaves fully developed, 1–7 cm × 1–4.2 mm	Culm leaves fully developed, 1–5.5 cm × 2–3 mm	Culm leaves fully developed, linear convolute, 1–5 cm × 1–3 mm	Culm leaves almost absent, blades of basal leaves filiform, flat, or convolute; 1–15 cm × 1–2 mm
Panicle	Panicle 0.6–1.2 × 0.7–0.9 cm, subspherical	Panicle 1–2.2 × 0.7–1 cm, ovoid to rectangular	Panicle 0.8–1.5 × 0.8–1.5 cm, capitate; ovate, or globose	Panicle 0.9–2 cm × 0.7–1 cm, ovate, rather dense	Panicle 1.4–2.5 × 0.7–1.3 cm, spiciform, or glomerate; oblong, or ovate, or globose
Lemma	Lemma 2–3 mm, broadly lanceolate, obliquely truncate at apex; dorsally awned; awn vestigial or up to 0.5 mm, not geniculate, not twisted	Lemma 3–4 mm, broadly lanceolate, obliquely truncate at apex; dorsally awned; awn 0.8–6 mm, geniculate and twisted or not, sometimes absent	Lemma 2.4–3.5 mm, oblong, truncate at apex; dorsally awned; awn 6.5–11 mm long overall; geniculate and twisted in lower half	Lemma 3.5–4 mm, obliquely truncate at apex, dorsally awned; awn 7–10 mm, geniculate; twisted in lower half	Lemma 3–4.5 mm, oblong; truncate at apex; dorsally awned; awn 5–10.5 mm, geniculate and twisted in lower half
Presence of palea	Absent	Present	Absent	Absent	Present
Palea length	n/a	2.5–3.5 mm	n/a	n/a	2.5–3.7 mm
Palea shape	n/a	1-veined, 1-keeled, linear, acuminate, ciliate in upper 1/2 of keel	n/a	n/a	1-veined; 1-keeled, glabrous

vaginatus complex of sect. *Colobachne* s.s., but its genotype is distinct from any of the other species sampled. Our phylogenetic analysis of nrDNA (Figure 3) shows that the grouping of *A. lanatus*, *A. davisii*, *A. vaginatus*, and our new species is strongly supported. *Alopecurus gerardi* samples form a strongly supported and divergent clade, which has less than 50% bootstrap support (PP = 0.64) as the sister of the clade that includes the above species and species of sections *Alopecurus* s.s., *Alopecurus* s.l., and *Alopecurium*. In the plastid DNA analysis there is strong support for the clade that includes these species (100% BS, PP = 1) and sect. *Alopecurus* s.s., while there is very poor to minimal support for any relationships among the sect. *Colobachne* species listed above (66% to >50% BS, PP 0.66 to >0.5).

Our DNA sequence data support placement of the new species within *Alopecurus* sect. *Colobachne*, specifically near *A. gerardi* Vill. (plastid), or near the complex of *A. davisii*, *A. lanatus*, and *A. vaginatus* (nuclear ribosomal

spacers). The new species differs from the above taxa in some important characters. Table 2 presents the salient morphological features separating the species of *Alopecurus* sect. *Colobachne*, including *A. goekyigitiana*.

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Appendix. Examined specimens.

Alopecurus goekyigitiana: **C3** Antalya: Gündoğmuş Palaz Dağları, Geyik Dağı, NE side, ca. 20 km ENE of Gündoğmuş above Topataş yaylası, 36.884444°N 32.195555°E, 2215–2345 m, alpine, limestone cliffs and steep exposed rocky gravelly slopes, growing with *Poa psychrophila* Boiss. & Heldr., *P. pseudobulbosa* Bor., *P. thessala* Boiss. & Orph., *P. sterilis* M.Bieb., *Pseudoroegneria* sp., *Festuca* sp., *Bellardiochloa doganiana* Cabi & Soreng, *Trisetum* sp., *Koeleria* sp., *Vicia* sp., *Marrubium* sp., *Veronica* sp., 25 Jul 2014, R. J. Soreng 8869, E. Cabi & B. Çıngay (NAKU, US); above Alanya, Alanya to Sarıveliler road, before Gökbel around Ovacık Yayla, calcareous rocky slopes, screes, 2079–2100 m, 13 Jul 2014, Cabi & Celeb St5_001 (NAKU); **C4** Konya: Bozkır, Üçpınar to Üçyazı, 2000 m, R. Çetık, G. Yurdakul 472 (ANK 1140).

A. gerardi var. *gerardi*: **A2(A)** Bursa: Uludağ., Büyük Hotel, 1780 m, A. Baytop (ISTE 36866); Keşiş dağı [Uludağ], June 1855, s.n. (E00398059); Bithynia, in regione alpina montis Olympi [Uludağ], 31 May 1899, J. Bornmüller 5626, (E E00398055); nahe Bursa am Nordhang des Ulu dağı nahe dem Gipfel, 22 Jun 1973, F. Holtz, & P. Hänel 00.338 (E E00398054); slopes between hotel and main ridge leading to summit of Uludağ., 19 Jun 1956, H. E. Moore 7277 (E E00398052); Uludağ, 9 Jul 1993, R. J. Soreng & J. I. Davis 4043 (US); Uludağ, 17 Jun 2011, L. J. Gillespie, E. Cabi, R. J. Soreng & K. Boudko 10399 (CAN, US). **A8** Rize: Cimil, 1866, B. Balansa. **B2** Kütahya: d. Simav. Ak Da., Kıcır to Akdağ, slopes and summit of Akdağ, open rocky slopes with some *Juniperus*, 1900–2100 m, 19 Jun 1965, Coode & Jones 2714 (E E00398056!). **B5** Kayseri: Bakır Dağ., nr Akoluk Y. above Kısge, 2000 m, P. H. Davis, J. G. Dodds & R. Çetık 19520 (ANK, E E00398057). **C5**

Adana: d. Karsanti, Torosan Dağı, 2090 m, Çelik & Yurdakulol 10788 (ANK). **C6** Maraş: Berit Dağı, 2440 m, 10 Aug 1865, H. C. Haussknecht (ANK).

Alopecurus lanatus: **B3** Akşehir: Sultan Dağları, Kızıltepe, 2200 m, 26.06.1985, Y. Akman 13871 (ANK); **B2** Bursa: Uludağ, Wolff 473 (ANK); Bursa: Uludağ. Alpine zone, above cliffs near summit, calcareous flats and gentle slopes in alpine zone, 40°06'59"N × 29°09'34"E, 2220 m, with *Juniperus* sp., *Carex* sp., L. J. Gillespie, E. Cabi, R. J. Soreng & K. Boudko 10408 (CAN, US); **C3** Antalya: Kemer, Tahtalı *Cedrus libani* Ormanı ve alpinik step, 1000–2200 m, 06.06.1979, H. Peşmen & A. Güner 4291 (Det. M. Doğan 1979) (ANK); Turkey: Antalya, Elmali, Bey Dağları, N side, saddle between Kızlar Sivrisi and Aktepe. Alpine, in windswept saddle, and adjacent dry slopes, around boulders and rock outcrops, limestone. 36°35'42"N, 30°06'43"E, 2691 m, with *Festuca pinifolia*, *Festuca* spp., *Draba* (white flw), *Astragalus*, *Marrubium* (leaves white pubescent). R. J. Soreng, E. Cabi & N. L. Soreng 8215 (NAKU, US); **B6** Maraş: Göksun, Binboğa Dağı, Işık Dağı, Kanlı yayla, 2800 m, P.H. Davis, R. Çetık 19995 (ANK). *A. davisii*: **B1** İzmir: Kemalpaşa, Nif Dağı, 1500 m, 15.04.1992, A. Yıldız (Det. E. Yurdakul) (ANK); Nif Dağı. Mountain summit, on ridge below fire tower. *Festuca* dominant alpine zone. 38°24'10"N × 27°21'14"E, 1460 m, L. J. Gillespie, E. Cabi, R. J. Soreng & K. Boudko 10459 (CAN, US, NAKU).

A. vaginatus: Muğla: Girdev Dağı. Summit area, accessed from pass along Seki-Girdev Gölü road. Summit area. 36°47'15"N × 29°37'49"E, elevation: 2570 m, L. J. Gillespie, E. Cabi, R. J. Soreng & K. Boudko 10588; **B7** Elazığ, Horozlu Dağı, north slopes, 1750 m, 17 May 1980, H. Evren 91 (ANK).