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Festuca giraldoi (Loliinae, Poaceae), a new species from Argentina, with a revision of the taxonomic concept and identity of *Festuca lilloi*

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Abstract *Festuca* is a genus of the Poaceae family with about 140 species in South America. Little information is available about *Festuca* species growing in the Eastern Sierras Pampeanas in Argentina, a region with a significant degree of endemism. The taxonomic delimitation of some species of this region is imprecise. One such taxon is *Festuca lilloi*, which has not only been recognized as a native species of the Peruvian Andes or endemic to the Western Sierras Pampeanas (northern Argentina), but also as a dominant floristic element in the Eastern Sierras Pampeanas (central Argentina). In spite of its ubiquity, there is very little information on variation in its morphology, anatomy and ecology across the Sierras Pampeanas and in adjacent areas. Recent fieldwork has resulted in the finding of a new species of *Festuca* that was erroneously assigned to *Festuca lilloi*. Morphological and anatomical differences between *F. lilloi* and the close species are evaluated, as are the species' ecological preferences. The delimitation of the new species, named here as *Festuca giraldoi,* follows the morphological species concept. A detailed description of the morphology, leaf anatomy and epidermal micromorphology (leaf and lemma) is provided for the new species.

Keywords Grasslands · Lemma epidermis · Systematic · SEM · Taxonomic revision

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Introduction

The genus *Festuca* L. (Loliinae, Poaceae) is represented by 140 taxa in South America (Stančík 2003a; Darbyshire et al. 2003; Stančík and Peterson 2007). The greatest taxonomic diversity of this genus is found in the Andean mountains region, with only two native species, *F. fimbriata* (Parodi) Türpe and *F. ulochaeta* Nees ex Steud., confined to the lowland forests of south-eastern Brazil and north-eastern Argentina, respectively (Stančík 2003a; Stančík and Peterson 2007; Catalán and Müller 2012; Ospina et al. 2015). However, very little information is available about species that occur in small mountain ranges associated with the Andes (e.g. Sylvester et al. 2017) or places with a significant degree of endemism, as is the case of the Eastern Sierras Pampeanas in Argentina.

A large number of new *Festuca* species are described from South America based on morphological evidence (e.g. Renvoize 1998; Stančík 2001, 2003a,b, 2004;

Müller 2006; Stančík and Peterson 2002, 2007). Phylogenetic studies (ITS, *trn*T-L and *trn*L-F) have revealed that *Festuca*, as traditionally circumscribed, is not a natural genus, but a large paraphyletic assemblage of distinctly related lineages with *Lolium* L., *Vulpia* C. C. Gmel. and several other genera falling within it (Catalán 2006; Catalán et al. 2007; Inda et al. 2008; Minaya et al. 2017). In this sense, one practical strategy has been to apply evidence from diverse sources to support the recognition of species (Wiens and Servedio 2000).

Morphometric analyses have recently been applied to clarify the taxonomy within *Festuca* (e.g. Foggi et al. 2006; Torrecilla et al. 2013; Ospina et al. 2013, 2016). The major problem linked to the delimitation of *Festuca* species in South America has been to distinguish between the species concept and the species criteria (as proposed by Wiens and Servedio 2000). Even the taxonomic identity and the geographic distribution of some *Festuca* species are controversial between taxonomic revisions and floristic catalogues, the reason being that they have been carried out within political boundaries (e.g. Parodi 1953; Türpe 1969; Tovar 1972; Nicora 1978; Matthei 1982; Renvoize 1998; Stančík 2003a; Zuloaga et al. 1994, 2008; Catalán and Müller 2012; Ospina et al. 2015).

One such taxon is *Festuca lilloi* Hack., which was described by Hackel (1914) as an endemic species from the Sierras Calchaquíes of the Eastern Sierras Pampeanas (northern Argentina). This taxon was considered a variety of *F. setifolia* Steud. ex Lechl., *F. setifolia* var. *lilloi* (Hack.) St.-Yves (Saint-Yves 1927), a native species from the Peruvian Andes. Later, *Festuca lilloi* was cited for Argentina and Peru, but the variety *F. setifolia* var. *lilloi* was synonymized under *F. lilloi* by Türpe (1969). Türpe also proposed '*Festuca lilloi* Hack. var. *breviaristata*' as a new variety from Tucumán (northern Argentina), and this author associated this new taxon with the species *Festuca setifolia*. Alexeev in 1984 raised Türpe's variety to the species level using the name *Festuca tucumanica* (as a replaced name). On the other hand, *Festuca lilloi* and *Festuca tucumanica* were recognized as two endemic species of northern Argentina (Zuloaga et al. 1994, 2008; Darbyshire et al. 2003), but the first taxon was also cited for the Peruvian and Bolivian Andes (Tovar 1972; Darbyshire et al. 2003; Renvoize 1998). Furthermore, Müller (2006) suggests that *Festuca setifolia* (from Peru) does not belong to the '*F. lilloi* group' (*F. lilloi*, *F. samensis* Joch. Müll., *F. tucumanica* and other specimens without an identity assigned). However, the geographic distribution of *F. lilloi* was expanded to the Córdoba province (central Argentina, Eastern Sierras Pampeanas) because Catalán and Müller (2012) proposed that *F. tucumanica* is a synonym of *F. lilloi*.

Both species were recognized as dominant elements in plant associations of the highland grasslands and *Polylepis* forests of central Argentina (Cabido et al. 1981, 1989, 1998, 2010; Cabido and Acosta 1985a,b, 1986a,b). Many herbarium collections by Kurtz in 1885, Burkart in 1910–1940, and recent collections from the Sierras de Córdoba were assigned to *F. lilloi*, which are not in agreement with the diagnostic characters cited by Hackel (1914) for this last taxon, but recent fieldworks in the Sierras Grandes of Córdoba (Argentina) confirm the discovery of a new species of *Festuca*.

In this paper we describe the new species and clarify the identity and taxonomic concept of *F. lilloi*. Our study is based on herbarium specimens and new collections. Traditional and new relevant morphoanatomical characters were explored, including a phenetic analysis.

Material and methods

All data for morphoanatomical analyses were based on herbarium specimens from B, BAA, BM, CORD, G, GOET, HSB, K, LIL, LP, LPB, MVFA, NY, P, S, SI, US and W (Thiers 2018). Protologues and types specimens (or digital scan images from Global Plants on JSTOR, http://plants.jstor.org) were checked for all names. All accepted species names and their synonyms were represented in our phenetic analyses. A total of 64 specimens were selected for the phenetic analyses and listed in Table 1 (54 general collections and 10 type specimens); each specimen was recognized as an OTU – operational taxonomic unit (Sokal and Sneath 1963; Sneath and Sokal 1973). Only well-preserved specimens bearing both well-developed leaves and inflorescences were considered in our analyses. The geographic distributions of all species are presented in the Fig. 1. Complementarily, recent collections of the new species were obtained by the second author within the framework of the project 'Altitudinal variation of plant species richness at Sierras Grandes (Córdoba, Argentina)' and Dr Leopoldo Iannone during a field trip focused on the study of the 'Diversity of endophytes belonging to the genus *Epichloë* (Clavicipitaceae, Ascomycetes) in native grasses of Argentina'.

Table 1 List of the plant materials used in this study

Taxon	Country	Locality	Altitude [m a.s.l.]	Voucher specimens records
F. fiebrigii	Argentina	Catamarca-El Alto, Cuesta del Portezuelo	no data	*H.H. Bartlett 19606* (SI), Feb 5, 1943
		Catamarca-Andalgalá, El Candado	no data	*P. Joergensen 1655* (SI), 1915
		Córdoba-Rio Cuarto between La Punilla and Achiras	942	*F. Biganzoli et al. 2116* (SI), Nov 29,2008
		Jujuy-Tumbaya, Volcán, 1–2 km from the city, around the lagoon	2,400	*O. Morrone et al. 4359* (SI) Apr 25, 2003
		Jujuy-Tumbaya, ranch of Dr.Grondona	2,800	*N. Deginani et al. 384* (SI), Feb 5, 1995
		La Rioja-Vinchina, Valle Hermoso between El Corral and La Punilla	3,250	*J. Hunziker y O. Caso 4274* (SI), Mar 9, 1950
		Salta-Rosario de Lerma, road 51 between Salta and S.A. de los Cobres	1,740	*A.M. Cialdella et al. 371* (SI), Feb 16,2002
		Salta-Chicoana, road 33 between S.F. de Escoipe and Escoipe	no data	*F.O. Zuloaga et al. 9412*(SI), Feb 15, 2007
		San Luis-Cnel. Pringles, road 10 between Intihuasi and diversion to Las Chacras	1,479	*F. Biganzoli et al. 2053* (SI)
		San Luis-Gral. Pedernera, El Morro, near Guanaco.	no data	*R.E. Scappini et al. 1821* (SI), Dec 19, 1995
		San Luis-CnelPringles, La Carolina	no data	*A. Burkart 10790* (SI), Nov. 8, 1940
		San Juan-Valle Fértil, Sierra de Elizondo hillsides	1,600	*M.E. Múlgura et al. 816* (SI), Dec 16, 1987
		San Juan-Valle Fértil, Sierra de Elizondo, hills and surroundings	1,700	*M.E. Múlgura et al. 874* (SI), Dec 17, 1987
		Tucumán-Infiernillo, banks of the course	2,850	*A. KrapovickasandC.L.Cristobal*(SI), Aug 30, 1971
		Tucumán-Tafí, road 307 fromTafí del Valle to Amaicha del Valle	2,970	*A.M. Cialdella et al. 154* (SI), Feb 10, 2002
	Bolivia	Chuquisaca-Oropeza, 5 km E of Potolo on road to Chaunaca	no data	*J.R.I. Wood 11898* (LPB), Mar 22, 1997
		Cochabamba-Ayopaya, 27 km from Independencia to Kami	no data	*S.G. Beck and R.Seidel 14621, 14624* (LPB), May 11, 1998
		La Paz-Pedro Domingo Murillo, Hillsides W of Jupania	3,100	*S. Renvoize 4496* (SI), Feb 12, 1987
		Tarija-Burdet O'Connor, from Tarija to Entre Rios	no data	*J.R.I. Wood and D.J. Goyder 15837* (LPB)
		Tarija-unknown province, between Tarija and Iscayachi, Sama range	2,560	*F.O. Zuloaga et al. 10414* (SI), Feb 25, 2008
		no data	no data	*C. Rojas 1590* (LPB)
F. hieronymi	Argentina	Córdoba-Calamuchita, Pampa de Achala	no data	*A. Burkart 7228* (SI) [two sheets], Dec 29, 1935
		Córdoba-Calamuchita, Pampa de Achala	no data	*A. Burkart 10118* (SI), Jan 13, 1940
		Córdoba-Calamuchita, Pampa de Achala	no data	*A. Burkart 10170* (SI), Jan 15, 1940
		Córdoba-Calamuchita, Pampa de Achala	no data	*A.R. Millán 791* (SI), Aug 3, 1926
		Córdoba-Calamuchita, Estancia El Catre	1,700	*A.R. Reichart s.n.* (SI), Dec, 1988
		Córdoba-Colón, Sierras Chicas, onroadfromAscochinga to La Cumbre	no data	*M.L. Giardelli 596* (SI), Nov 13, 1936
		Córdoba-Colón, Ascochinga	no data	*M.L. Giardelli 1042* (SI), Dec 21, 1938
		Córdoba-Colón, Sierras Chicas near Rio Ceballos onroad to El Cuadrado	no data	*A.T. Hunziker 9476*, Aug 16, 1951

Table 1 (continued)

Taxon	Country	Locality	Altitude [m a.s.l.]	Voucher specimens records
		Córdoba-Colón, La Cascada	no data	*E. Nicora 1131* (SI) [two sheets], Nov 13, 1936
		Córdoba-Colón, Ascochinga	no data	*E. Nicora 1770*(SI), Jan 30, 1938
		Córdoba-Juárez Celman, Villa Reducción, onhills	700	*A. Burkart 7257* (SI), Jul 28, 1935
		Córdoba-Punilla, Copina	no data	*A. Burkart 10123* (SI), Dic 13, 1940
		Córdoba-Pocho, mountains between Los Gigantes and Taninga	no data	*A. Burkart 20790* (SI [two sheets], LIL), Dic 5, 1958
F. lilloi	Argentina	Tucumán-Chicligasta, Estancia Las Pavas	3,400	*S. Venturi 11138* (LIL), Mar 13, 1924
		Tucumán-Chicligasta, Estancia Santa Rosa, Puesto La Cueva	3,800	*S. Venturi 3209* (SI), Mar 16, 1924
		Tucumán-Tafí del Valle, La Queñoa, summits of San José	3,000	*Díaz 9580* (LIL) [two sheets], Mar, 1933
		Tucumán-Tafí del Valle, Peñas Azules, Sierras Calchaquíes	3,400	*A. Burkart 5298* (SI), Jan 29, 1933
		Tucumán-Tafí del Valle, in alderforest	2,300	*Hueck 5* (SI, LIL), Jan 18, 1950
		Tucumán-Tafí del Valle, summit of Malamala	no data	*M. Lillo 3508* (LIL) [two sheets], Apr 6, 1904
		Tucumán-Tafí del Valle, El Infiernillo	3,100	*A. Türpe 417* (LIL), May, 1959
		Tucumán-Tafí Viejo, slope of Anfama	2,600	*M. Lillo 3992* (LIL), Feb 12, 1905
		Tucumán-Trancas, road to Lara	3,247	*A.C. Slanis et al. 4403–2009* (SI), Mar 27, 2009
		Tucumán-Trancas, 25 km road from Hualinchay to Tolombón	3,160	*F.O. Zuloaga et al. 10063* (SI), Feb 15, 2008
		Salta-Cafayate, Cerro del Cajón	3,900	*D. Rodriguez 1326* (SI), Jan 27, 1914
F. giraldoi	Argentina	Córdoba-San Alberto, Sierras Grandes-Pampa de Achala	1,967	*P.I. Picca and M. Apellániz 2040* (paratype, SI), Feb 12, 2011
		Córdoba-San Alberto, Sierras Grandes-Pampa de Achala	1,967	*P.I. Picca and M. Apellániz2045* (paratype, SI), Feb 13, 2011
		Córdoba-San Alberto, Sierras Grandes-Pampa de Achala	1,967	*P.I. Picca and M. Apellániz 2051* (type, SI), Feb 15, 2011
		Córdoba-Calamuchita, Pampa de Achala	no data	*A. Burkart 10168* (paratype, SI), Jan 15, 1910
		Córdoba-Calamuchita, Pampa de Achala	no data	*A. Burkart 10173* (paratype, SI), Jan 15, 1910
		Córdoba-Punilla, Pampa de Achala.	no data	*A. Burkart 10202* (paratype, SI), Jan, 1940
		Córdoba-Punilla, entre Tanti y Los Gigantes	1,600–1,700	*L. Iannoneand and M.C. Cargo 113* (paratype, SI), Jan 11 2013
		Córdoba-Punilla, entre Los Gigantes y Taninga	1,550–1,750	*L. Iannoneand and M.C. Cargo 115* (paratype, SI), Jan 11 2013
		Códoba-Santa Maria, entre estancia San Miguel y Cuesta del Corral	no data	*F. Kurtz 2960* (paratype, CORD), Dec 15, 1885

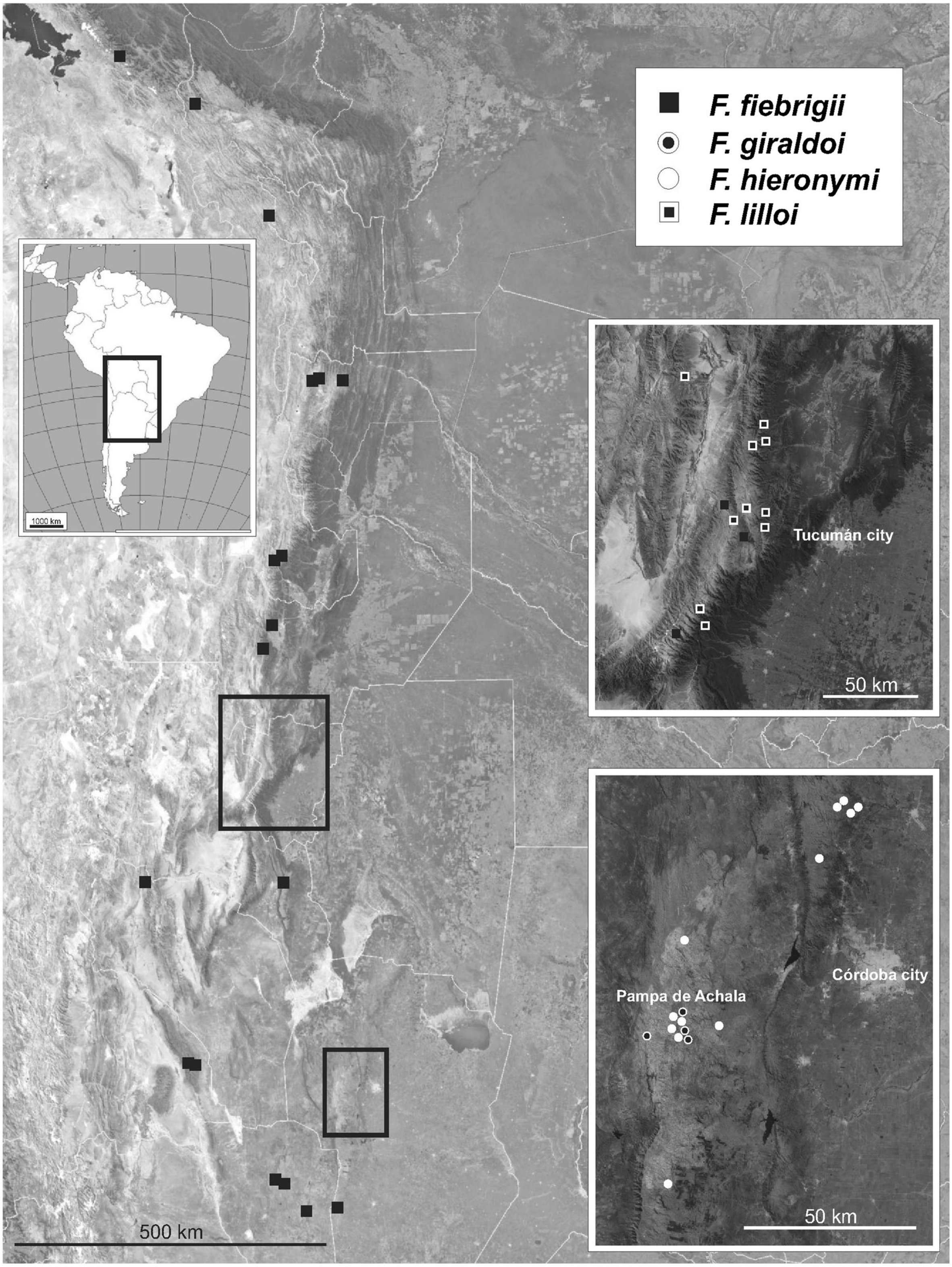


Fig. 1 Distribution of *Festuca hieronymi*, *F. fiebrigii*, *F. lilloi,* and *F. giraldoi* J.C. Ospina and P.I. Picca, according to the results of the present study. Dots indicate specimens from Table 1

We observed macromorphological characters in all specimens under a Wild Heerbrugg M5-26799 stereo microscope. Twelve characters (seven vegetative and five reproductive) were selected for our phenetic cluster analysis (Table 2). The morphological characteristics were described following the terminology used by Lawrence (1955) and Aranda and Forceck (1990). Foliar anatomy attributes were observed in cross sections from the middle area of the blade. Transversal cuts were obtained following the methodology used by Metcalfe (1960). The transversal cuts were fixed using a semi-permanent mounting medium (Ruzin 1999). A total of four informative characters were retained (Table 2). The anatomical observation and photos were taken under a Nikon SMZ 800 microscope with a mounted camera controlled by Nikon NIS elements software (Fig. 2). The anatomical description characteristics of the new species were described following the terminology used by Ellis (1976). Foliar epidermis micromorphology attributes were observed on both the adaxial and the abaxial surface. A total of five characters were selected (Table 2). Lemma epidermis micromorphology was observed on the abaxial surface from the basal anthecium of a well-developed spikelet. A total of three characters were retained (Table 2). All samples were coated with gold (40%) and palladium (60%) for scanning electron microscopy (SEM) and images were obtained under a TEM Philips EM 301 instrument (Figs. 3, 4). Epidermal features were described following the terminology of Ellis (1979).

Dataset characteristics were obtained and a phenetic analysis was carried out based on 24 characters (Table 2). The dataset contained both morphological and anatomical characters for the 64 OUTs. Correlation

Table 2 Morphoanatomical characters used in the phenetic cluster analysis

Type character	Character name	Character type
Macromorphology	Number of nodes in floriferous culms	units-discrete
	Type of leaf-sheath	qualitative-double state
	Ligule length	mm-continuous
	Type of ligule apex	qualitative-multistate
	Blade width	mm-continuous
	Blade length	cm-continuous
	Type of blade apex	qualitative-multistate
	Pungent apex development	qualitative-double state
	Panicle length	cm-continuous
	Spikelet length	mm-continuous
	Number of florets per spikelet	units-discrete
	Type of lemma apex	qualitative-multistate
	Shape of the leaves in outline	qualitative-multistate
Foliar anatomy	Number of vascular bundles between midrib and margin	units-discrete
	Relative position of the vascular bundles	qualitative-double state
	Vascular bundles localization	qualitative-double state
Foliar epidermis micromorphology	Type of epidermis morphology	qualitative-multistate
	Papillae development	qualitative-double state
	Shape of the anticlinal cell walls in the abaxial surface	qualitative-multistate
	Macro-hairs development in abaxial surface	qualitative-double state
	Prickles development in abaxial surface	qualitative-double state
Lemma epidermis micromorphology	*Shape of the anticlinal cell walls on the adaxial surface	qualitative-multistate
	*Macro-hairs development on adaxial surface	qualitative-double state
	*Prickles development on adaxial surface	qualitative-double state

Characters explored for the first time are marked with an asterisk (*)

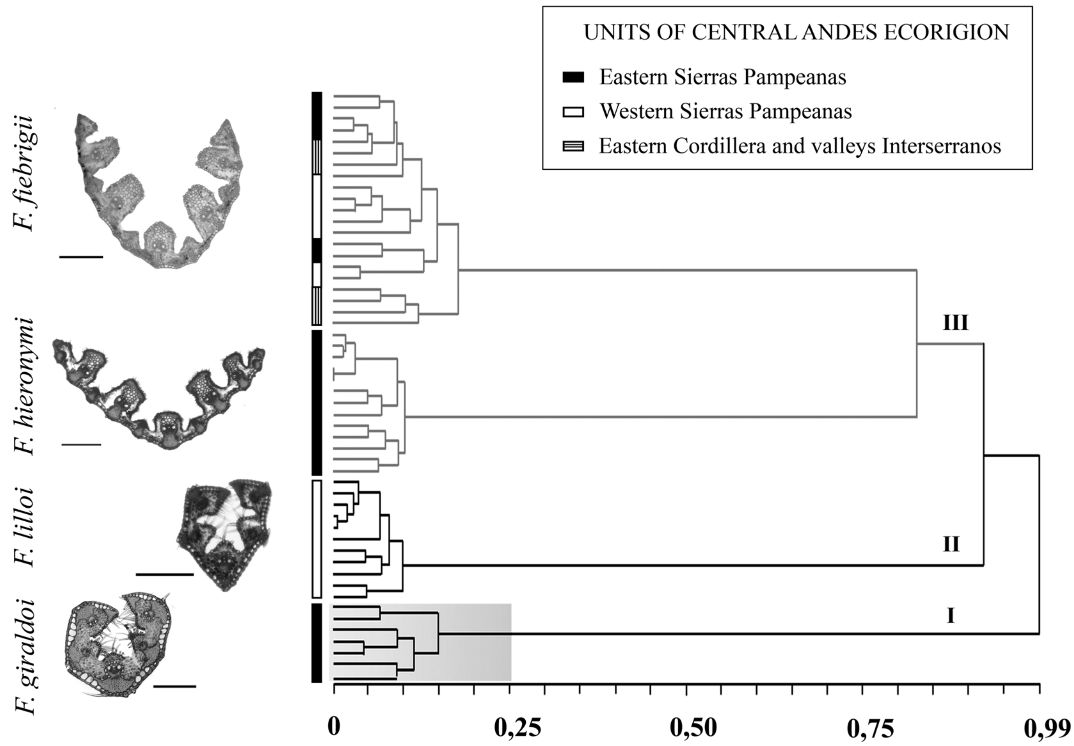


Fig. 2 Dendrogram derived from the Ward's cluster analysis of specimens of *Festuca hieronymi*, *F. fiebrigii*, *F. lilloi* and *F. giraldoi*. Shading differentiates the three main clusters (A, B, C). Grey shade indicates the specimens of the new species. Representative characteristics of leaf-blade anatomy characteristics are shown for each of the clusters

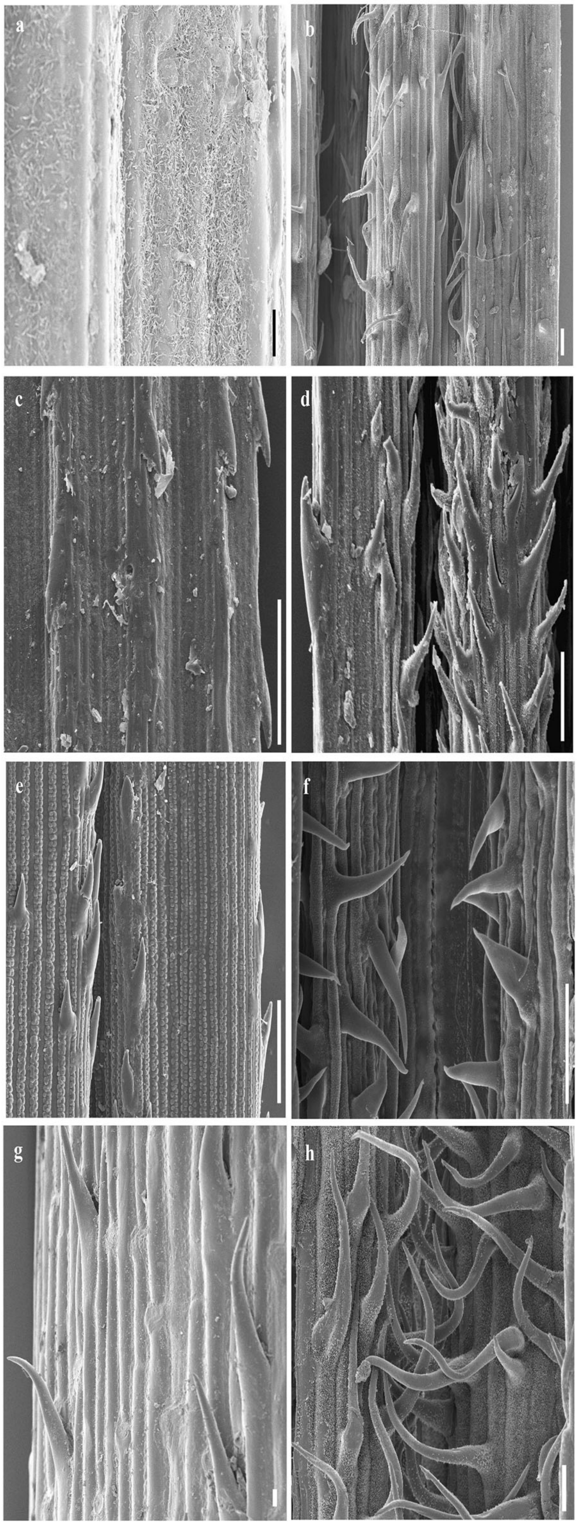
coefficients among characters were computed to reveal highly correlated characters (Escobar et al. 2011). The dataset had no missing data. Variables describing quantitative characters were standardized by subtracting their mean and dividing the result by the standard derivation; semi-quantitative characters were log-transformed (Sneath and Sokal 1973; Marhold 2011). The phenetic analyses used Ward's cluster method (minimization of the increase of the error sum of squares) with the Gower distance coefficient (Gower 1971). The co-phenetic correlation coefficient (*r*) was estimated to measure the distortion between the original matrix and the obtained phenogram (Sneath and Sokal 1973; Sebola and Balkwill 2009; Ospina et al. 2013, 2016). Statistical analyses were carried out using NTSYS-pc v. 2.21c (Rohlf 2009).

The species under study were all delimited on the basis of non-overlapping patterns of morphological variation as the primary criterion for inferring species boundaries. Phenetic clustering analyses were employed for this purpose, and the OTUs formed hierarchical non-overlapping groups strictly according to the degree of similarity (Sokal and Corvello 1970; de Queiroz and Good 1997; de Queiroz 2007).

The characterization of habitat and ecological preferences follows the ecoregions proposed by Pereyra (2003) based on geological, edaphic, climatic, landscape and vegetation aspects. Additionally, we used the work of Köppen (1923) and Drobe et al. (2011), who studied the geodynamic evolution of the Pampean Sierras, as well as information available in phytogeographical works (Cabrera 1957; Cabrera and Willink 1973) or catalogues specialized in grasses (Nicora and Rúgolo de Agrasar 1987).

Results

We used 30 characters in the initial cluster analyses; however, six of the characters showed correlations (ligules extended in auricles laterally, shape of the lobes of the auricles, presence or absence of ribs or furrows on the abaxial surface, presence or absence of prickles on the abaxial surface of anthecium, shape of the abaxial surface of the anthecium, and shape of the anticlinal horizontal walls on the abaxial surface of the anthecium). Therefore, 24 variables Ward's cluster



◀ **Fig. 3** SEM images of leaf blade epidermis (all pictures orientated to distal apex). **a** – Adaxial leaf-blade in *F. hieronymi*; **b** – abaxial leaf-blade in *F. hieronymi*; **c** – adaxial leaf-blade in *F. fiebrigii*; **d** – abaxial leaf-blade in *F. fiebrigii*; **e** – adaxial leaf-blade in *F. lilloi*; **f** – abaxial leaf-blade in *F. lilloi*; **g** – adaxial leaf-blade in *F. giraldoi*; **h** – abaxial leaf-blade in *F. giraldoi* [a–b From *Burkart 7228* (SI), c–d from *Morrone et al. 4359* (SI), e–f from *Burkart 5298* (LIL), g–h from *P. Piccaand M. Apellaniz 2051* (SI)]. Scale bar = 1 mm in a, c, e and g; scale bar = 1 μm in b, d, f and h

analyses aimed to test the validity of the current species delimitation (Table 2). The distribution of all the 24 variables departed from the normal distribution.

Four characters with taxonomic value were identified and explored for the first time in the species under study. These characters are marked with asterisks (*) in Table 2. These potential diagnostic characters were used in the morphoanatomical comparison between *Festuca lilloi* and its closest related species from the Sierras Pampeanas of Argentina (Table 3).

Ward's phenetic cluster analyses resulted in a dendrogram (Fig. 2) that divided all OTUs into three main groups: cluster I comprising only specimens of the new species, cluster II comprising all specimens of *F. lilloi,* and cluster III comprising two subgroups referred to as specimens of *F. hieronymi* and *F. fiebrigii*. Our phenetic Ward's cluster analyses showed low values of distortion (r = 0.98), indicating a complete success of separation without any misidentified specimens.

All specimens of *Festuca fiebrigii* and *F. hieronymi* were similar in leaf anatomy (Fig. 2, Table 3), having an expanded to rolled and flattened shape outline, differentiated costal and intercostal zones on the abaxial surface, and 5–6(–7) vascular bundles present between the midrib and the margin of the blade, situated close to the abaxial surface and at the same level. Both these species were differentiated from *F. lilloi* and all specimens of the new species in our leaf anatomy analysis (Fig. 2, Table 3) by: outline 'U-shaped' and rounded with angled arms, the costal and intercostal zones not differentiated on the abaxial surface, and 2–3 vascular bundles present between the midrib and the margin of the blade, all located in the centre of the blade at the same level. The observed anatomical differences confirm that these taxa are not closely related (as cited by Türpe 1969). The SEM observation revealed that attributes of the epidermal lemma were important diagnostic characters for separating *F. lilloi* and determining the new species proposed herein (Figs. 3, 4).

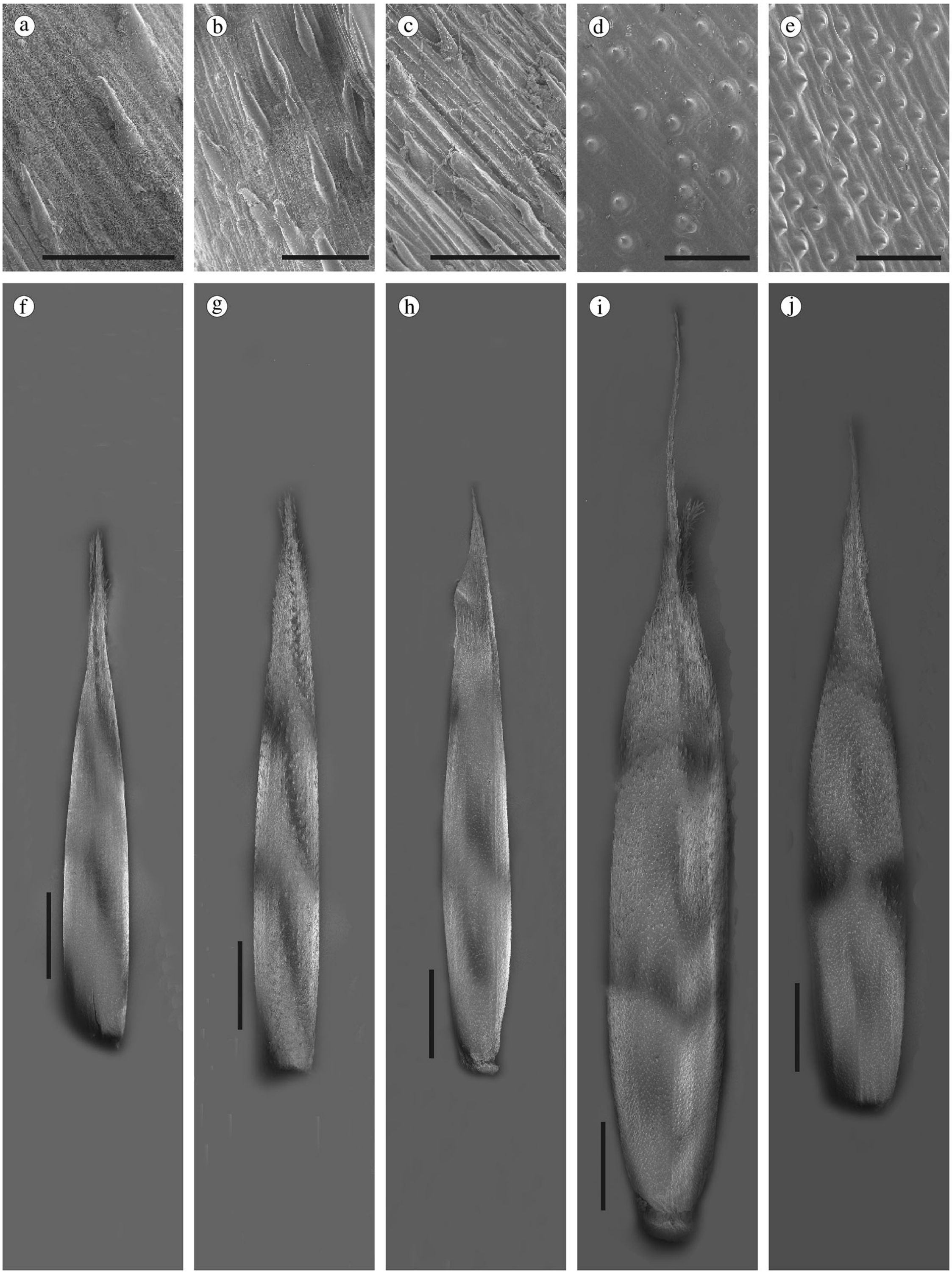


Fig. 4 SEM images of abaxial lemma epidermis and details of the medial zone of basal anthecium (all pictures orientated to distal apex). **a–f** – *Festuca hieronymi*; **b–g** – *Festuca fiebrigii*; **c–h** – *Festuca lilloi*; **d–i** and **e–j** – *Festuca giraldoi* [a–f from *Burkart 7228* (SI), b–g from *Morrone et al. 4359* (SI), c–h from *Burkart 5298* (LIL), d–i from *Burkart 10173* (SI), e–j from *P. Picca and M. Apellaniz 2051* (SI)]. Scale bar = 1 mm for all images

Table 3 Morphoanatomical comparison of *Festuca lilloi* with its closest relatives species

Characters	*F. lilloi*	*F. giraldoi*	*F. hieronymi*	*F. fiebrigii*
Morphological				
Number of nodes per floriferous culms	3–4	1–2	Without or 1	4–5
Blades	< 15 cm long, permanently folded, convolutes	< 15 cm long, permanently folded, convolutes	> 20 cm long, expanded and rolled in dry	> 20 cm long, expanded and rolled in dry
Ligular zone	Not differentiated	Differentiated	Differentiated	Not differentiated
Ligules	2.5–2.8 mm	3–3.5 mm	0.5–1 mm	0.8–2 mm
Apex of the ligules	Emarginate with lobes acute	Obtuse	Truncate	Obtuse
Auricules	Present	Absent	Present	Present
Panicles	< 15 cm long, erect, branches patent, without rudiments of aborted branches	< 16 cm long, contracted, branches ascendant, with rudiments of aborted	Panicles > 25 cm long, lax, branches erect, without rudiments of aborted branches	Panicles > 25 cm long, erect, branches erect, without rudiments of aborted branches
Spikelet length (mm).	6–7(–7.5)	19–23	7–8	10.5–12.5
Floret per spikelet (unit)	3–4	5–6	3–4	6–8
Lemma form	Acute	Narrowly lanceolate	Acute to acuminate	Narrowly obtuse
Apex of the lemma	Not awned	Awned, awn 2–3 mm long	Not awned	Sometimes mucronate, but not awned
Anatomical				
Shape outline of leaf cross-section	Rounded	Regularly angled	Expanded to rolled	Expanded to rolled
Number of vascular bundles between midrib and margin of the blade (unit)	1–2	3	5–6(–7)	5–6
Location of the vascular bundles	Centre of the blade	Close to the abaxial surface	Close to the abaxial surface	Close to the abaxial surface
Abaxialblade epidermis ornamentation				
Adaxial blade epidermis ornamentation				
Abaxial lemma epidermis ornamentation	Pricklets	Papillae	Microhairs	Microhairs
Epicuticular waxes	Absent	Absent	Rods	Rods
Horizontal walls	Straight	Deeply undulating in a 'Ω-shape' and very thick	Straight	Straight

Specimens from northern Argentina (Western Sierras Pampeanas of Tucumán) can be considered a separate species from *F. giraldoi* of central Argentina (Eastern Sierras Pampeanas of Córdoba) because the two groups are geographically separate (Fig. 1) and a result of unlinked geodynamic evolution (Drobe et al. 2011). In addition, the Eastern Sierras Pampeanas have a more humid climate than the Western ones. The dominant climatic type is steppe semiarid (Bs) with transitions between the wet mesothermal (Cf) and wet temperate (Cw), see Köppen 1923 and Pereyra 2003. Likewise, the characteristic vegetation of these mountains consists of xerophilous forests in the lower zones and open grasslands and patches of *Polylepis australis* above 1,500 m a.s.l. (Pereyra 2003).

New taxon

Festuca giraldoi J.C. Ospina and P.I. Picca, **sp. nov.** (Fig. 5)

Type: ARGENTINA. Córdoba Province, San Alberto Department, Sierras Grandes-Pampa de Achala, 1,967 m a.s.l., 31° 36′ 38.196″ S – 64°54′40.608″ W, 15 February 2011, *P. Picca and M. Apellaniz 2051* (holotype: SI 202281!; isotype: BAB!).

Plants (50–)60–90 cm tall (infertile culms), caespitose. *Floriferous culms* (95–)115–130 cm tall, erect, 2-nodes. *Leaf sheaths* scabrous at apex, not shiny, papyraceous, closed along their entire length, ligular zone not differentiated. *Auricles of the leaf sheaths* absent. *Pulvinus of the leaf sheaths* absent. *Ligules* 3–3.5 mm long, apex obtuse, margin membranaceous-ciliate, extended in auricles laterally. *Blades* 35–65 cm × 1.5–2 mm, erects to decumbent, convoluted, not rigid, apex shortly awned, not pungent; abaxial surface sparsely pilose; adaxial surface pilose. *Panicles* 9–16 cm long, linear, contracted, greenish to pale; branches ascendant, scabrous, with rudiments of aborted branches in axils of branches arranged in a rachis. *Spikelets* 19–23 mm long, with 5–6 florets, greenish to pale, rachilla scabrous, glabrous. *Glumes* subequal, scarcely scabrous dorsally and at apex, glabrous, nerves inconspicuous; lower glume 5–5.5 × 0.3–0.5(–0.7) mm, linear, apex shortly acuminate, 1-nerved; upper glume 5.5–6.3 × 0.8–1.2 mm, oblong-elliptic, apex acute and shortly acuminate, 3-nerved. *Lemma of the basal florets* 8–11 mm long (without awn), narrowly lanceolate, densely scabrous, with spherical papillae, apex awned, awn 2–3 mm long, nerves inconspicuous, 5-nervous. *Paleas* equal or shorter than lemmas, scarcely and shortly pilose at apex on keels. Anthers 4.5–5 mm long. Lodicules 1.5–2 mm long, lobed, margin fimbriated, glabrous. *Ovaries* densely hairs at apex. *Caryopsis* 2.5–3.5 mm long.

Distribution and ecology Known only from the Pampa de Achála and surrounding mountains, Córdoba province, central Argentina. *Festuca giraldoi* grows as a dominant element in the grass matrix characteristic of the ecosystems that develop at elevations around 2,000 m a.s.l., together with *Plantago myosuros* Lam. (Plantaginaceae); *Aristida laevis* (Nees) Kunth, *Jarava juncoides* (Speg.) Pañail., *Deyeuxia colorata* Beetle, *Schizachyrium spicatum* (Spreng.) Herter, *Paspalum quadrifarium* Lam., *Koeleria kurtzii* Hack. ex Kurtz, *Bulbostylis juncoides* (Vahl) Kük. exOsten (Poaceae); *Carex boliviensis*Van Heurck and Müll. Arg., *Carex distenta* Hack. ex Kurtz (Cyperaceae); *Juncus pallescens* var. *achalensis* (Barros) Novara (Juncaeae), *Neobartsia crenoloba* (Wedd.) Uribe-Convers and Tank (Orobanchaeae); *Berberis* sp. (Berberidaceae); *Blechnum laevigatum*Cav. (Blechnaceae); *Botrychium australe* R.Br. (Ophioglossaceae); *Dichondra* aff. *Microcalix* (Convolvulaceae); *Conyza primulifolia* (Lam.) Cuatrec. and Lourteig., *Stevia satureifolia* (Lam.) Cav., *Acmella decumbens* (Sm.) R.K. Jansen var. *affinis* (Asteraceae); *Pfaffia gnaphaloides* (L. f.) Mart. (Amaranthaceae) and *Lachemilla pinnata* (Ruiz and Pav.) Rothm (Rosaceae).

Etymology We are pleased to dedicate this new species to our colleague and friend Diego Giraldo-Cañas, Professor of the Universidad Nacional de Colombia, an outstanding botanist and agrostologist, and respected explorer of the flora of Argentina.

Paratypes ARGENTINA. Córdoba: San Alberto, Sierras Grandes-Pampa de Achala, 1967 m, 12 Feb 2011, *P.I. Picca and M. Apellániz 2040* (type, SI); Sierras Grandes-Pampa de Achala, 1967 m, 13 Feb 2011, *P.I. Picca and M. Apellániz 2045* (paratype, SI). Calamuchita, Pampa de Achala, 15 Jan 1910, *A. Burkart 10168, 10173* (paratype, SI). Punilla, Pampa de Achala, Jan 1940, *A. Burkart 10202* (paratype, SI); entre Tanti y Los Gigantes 1,600–1,700 m a.s.l., 11 Jan 2013, *L. Iannoneand* and *M.C. Cargo 113* (paratype, SI); entre Los Gigantes y Taninga 1,550–1,750 m a.s.l.,

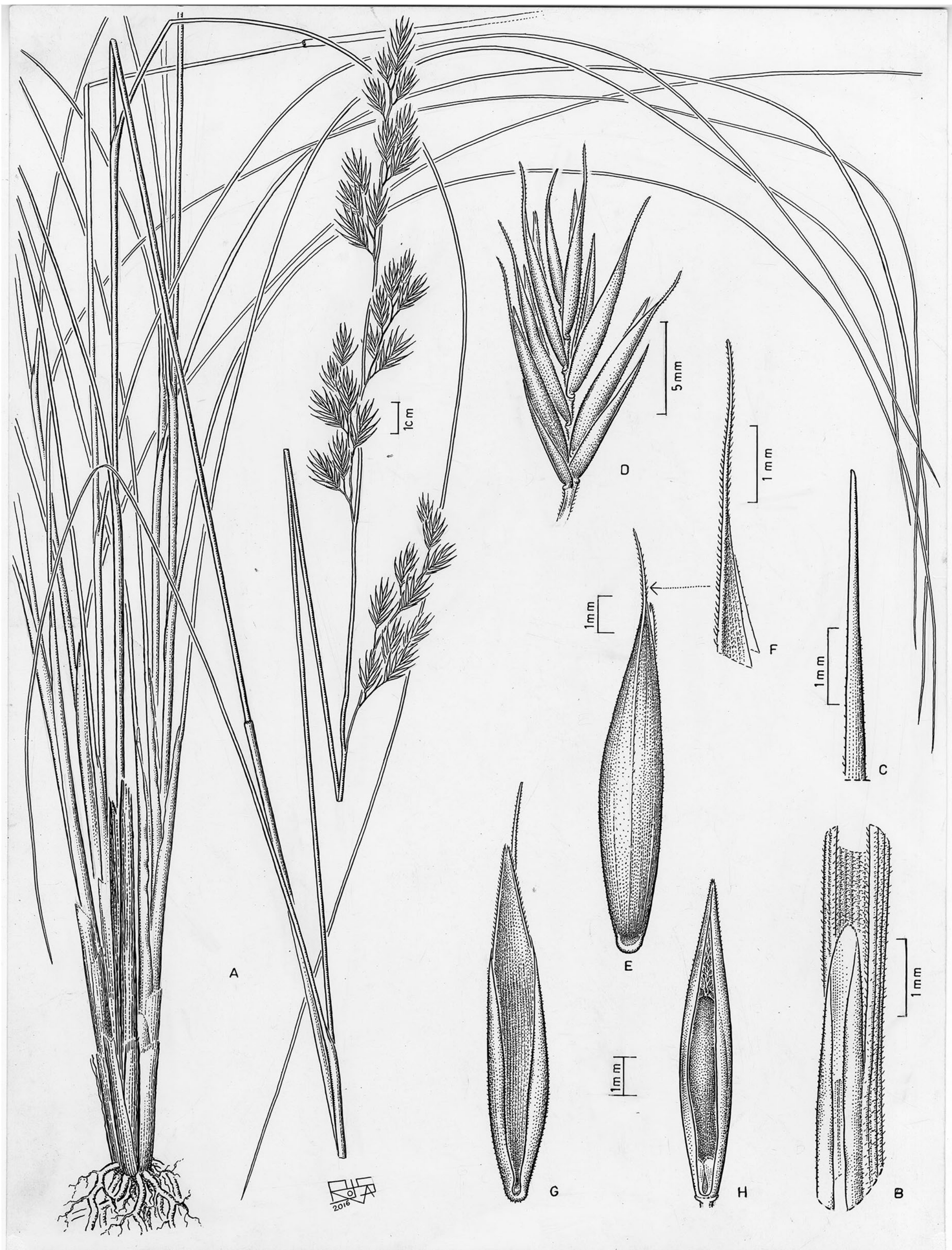


Fig. 5 *Festuca giraldoi* J.C. Ospina and P.I. Picca. **a** – Habit and inflorescence; **b** – ligular zone; **c** – apex of blades; **d** – spikelet; **e** – glumes; **f** – floret dorsal view; **g** – floret ventral view; **h** – anther; **i** – ovary and lodicules [from *P. Picca and M. Apellaniz 2051* (SI)]

11 January 2013, *L. Iannoneand and M.C. Cargo 115* (paratype, SI). Santa Maria, entre estancia San Miguel y Cuesta del Corral, 15 Dec 1885, *F. Kurtz 2960* (paratype, CORD).

Comments The new species is morphologically similar to *F. lilloi*, but the latter is easily recognized by its ligular zone not differentiated and its distinctly lanceolate-acute to subulate glume shape (vs ligular zone differentiated and glumes linear in the new species); the ligular apex of *F. lilloi* is denticulate or emarginate with lobes acute (vs entire and obtuse in the new species). The main morphological features separating the new species from *F. fiebrigii* are its floriferous culms with 1–2 nodes (vs 4–5, in *F. fiebrigii*) and its lemma apex with an awn 2–3 mm long (vs without an awn). Finally, the ligular features distinguishing the new species from *F. hieronymi* are its blade apex obtuse (vs truncate) and longer ligules of 3–3.5 mm (vs 0.5–1 mm). We therefore found these taxa to be clearly distinguishable, contrary to Türpe (1969), Tovar (1972), Renvoize (1998), Müller (2006), and Catalán and Müller (2012).

The foliar anatomy of *Festuca giraldoi* is characterized by a 'U-shaped' outline that is rounded with angled arms, with 2–3 vascular bundles present between the midrib and margin of the blade, all located in the centre of the blade at the same level, all located in the centre of the blade at the same level, the central rib is located in the central area of the blade, with associated sclerenchyma layers on both surfaces. Abaxial surface with straight edges forming angles associated with the vascular bundles, ribs angular, composed of a sclerenchyma block and found opposite to all vascular bundles, prickles present in the costal zone, macro-hairs absent. Adaxial surface markedly irregular, with rounded ribs situated opposite to all vascular bundles, lacking a sclerenchyma block, prickles present and scarce in the intercostal and margin zones, macro-hairs present and densely covering all the surface (Fig. 3).

The leaf epidermal micromorphology in *Festuca giraldoi* is characterized by an abaxial surface with intercostal and costal zone having rectangular long cells, arranged in rows with one short cell between each successive long cell, anticlinal horizontal walls deeply undulating in a 'Ω-shape', anticlinal vertical walls very thick at right angles to the horizontal walls containing silicified short cells that have a rounded shape, and prickles and stomata absent. Adaxial surface intercostal and costal zone with rectangular long cells, arranged in rows with one macro-hair, anticlinal horizontal walls smooth, anticlinal vertical walls angled, short cells absent, stomata flat-topped with horizontal walls of subsidiary cells rounded, stomata present only in the intercostal zone, prickles present only on the blade margin, and macro-hairs curved and abundant in both zones (Fig. 3e–f).

The epidermal micromorphology of *Festuca giraldoi* is characterized by a lemma with an intercostal zone with rectangular cells on the adaxial surface, arranged in rows with one short cell between each successive long cell, anticlinal horizontal walls deeply undulating in a 'Ω-shape' and very thick anticlinal vertical walls at right angles to the horizontal walls containing silicified short cells that have a rounded shape.

Discussion

Our present study found that some species of *Festuca* from the Eastern Sierras Pampeanas of central Argentina (Córdoba province) are quite similar in their morphology to species from the Western Sierras Pampeanas of Argentina (Tucumán province). In our opinion, this situation has led to confusion in the identification of herbarium or field material analysed by Cabido et al. (1981, 1989, 1998, 2010) and Cabido and Acosta (1985a, b, 1986a, b). In our phenetic cluster analysis based on morpho-anatomy and epidermal traits (Figs. 2, 3, 4; Table 3), 64 OTUs were clearly separated into four groups corresponding to *F. fiebrigii*, *F. hieronymi*, *F. lilloi* and a hitherto unknown taxon, described here as *Festuca giraldoi*. Our phenetic analysis demonstrates that at least two distinct systematic units may be recognized (*F. lilloi* and *F. giraldoi*) and that *Festuca lilloi* is not related to other taxa (*F. fiebrigii*, *F. hieronymi*) as stated in previous taxonomic works.

The first classification of the genus *Festuca* distinguished two artificial groups called 'fine-leaved' (or setaceous-leaved) and 'broad-leaved' (or flat-leaved) on the basis of leaf morphoanatomical characteristics (Hackel 1882). This classification was used by numerous other authors (Saint-Yves 1927; Türpe 1969; Tovar 1972; Matthei 1982; Clayton and Renvoize 1986; Renvoize 1998; Müller and Catalán 2006). Although the existence of these two artificial groups was confirmed by recent molecular phylogenies (Torrecilla and Catalán 2002; Catalán et al. 2004; Catalán 2006; Inda et al. 2008), the leaf morpho-anatomical patterns of numerous *Festuca* taxa form an intermediate phylogenetic clade between the two characteristics, and some broad-leaved taxa are located within the fine-leaved group. Analogous morphological similarity was found between *F. lilloi* and *F. giraldoi* (fine-leaf) and *F. fiebrigii* and *F. hieronymi.*

More recent studies, by contrast, have used epidermal evidence on the leaf and lemma to address specific questions surrounding *Festuca* species (Hackel 1882; Türpe 1969; Tovar 1972; Zarinkamar and Jouyandeh 2011; Ortúñez and Cano-Ruiz 2013). Our results corroborate the utility of foliar epidermal characters in the taxonomic determination of groups of specific specimens, since these have a constancy in epidermal characters which permits the identification of each of the four species recognized in our phenetic cluster analyses (Figs. 2, 3, 4; Table 3). These characters are very useful for the separation of *F. lilloi* from the homogeneous and well-defined species such as *F. giraldoi* (described herein; Figs. 2, 3, 4), which allows to classify these species as two different taxonomic units. From our results (Figs. 2, 3, 4; Table 3). Evidently, the individuals of *Festuca lilloi* sampled exhibited homogeneous morphology (Figs. 2, 3, 4, Table 3), rejecting their splitting into numerous taxa in previous taxonomic works.

The specimens of *F. setifolia* from the Western Sierras Pampeanas (Tucumán) can be considered a separate species from *F. giraldoi* of central Argentina (Eastern Sierras Pampeanas of Córdoba) because the two groups are geographically separate (Fig. 1) and morphoanatomically distinct (Table 3). In addition, the geodynamic evolution differs between the Western Sierras Pampeanas, Tucumán and the Eastern Sierras Pampeanas, Córdoba (Drobe et al. 2011). Compared to the Western Sierras Pampeanas, the Eastern Sierras Pampeanas are an older (Precambrian–Lower Cambrian vs Cambrian–Ordovician), lower-altitude mountain system (up to 3,000 m a.s.l. vs 5,000 m a.s.l.) with a humid climate and more developed, nutrient-rich soils (Pereyra 2003).

Our phenetic analyses of morphoanatomical (including epidermal) characters and habitat preferences of four species of *Festuca* occurring in central Argentina allow us to conclude that (1) every *Festuca* species considered in this study presents unique leaf anatomy attributes and that (2) our investigation of morphoanatomical characters in different specimens of *F. giraldoi* (collected at different times) shows that its variability of its species-specific traits is significantly different from that of other, related species (see Türpe 1969; Tovar 1972; Renvoize 1998; Müller 2006; Catalán and Müller 2012).

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Compliance with ethical standards

Competing interests and declarations The authors declare that they have no competing interests and that their investigations comply with the current laws of Argentina.

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