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**Native plants for ecological restoration in Italy:
taxonomy and species selection**

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*“For everyone who lacks the means to scream
To anyone who’s been locked out of their dreams”*

The Ghost Inside - Overlooked

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1 ABSTRACT

Grasslands represent one of the most widespread and ecologically significant terrestrial biomes, covering roughly 30-40% of Earth's land surface and providing a variety of vital ecosystem services. Among their dominant species, perennial grasses are particularly important for ecosystem, consisting often in the keystone and dominant species of these habitats, and partaking a critical role in the correct functioning of the vast majority of these ecosystemic services. Because of their undiscussed importance, perennial grasses have been the main focus when talking ecological restoration and protection of grasslands.

Within the grass family (Poaceae), *Festuca* L. is a globally distributed and ecologically diverse genus, with fine-leaved taxa (*Festuca* sect. *Festuca*) playing central roles in the composition of Eurasian steppes, alpine meadows, and semi-natural grasslands of Europe. Despite their ecological importance, the taxonomy of *Festuca* remains one of the most challenging in the grass family, with morphological convergence, polyploidy, hybridization, and incomplete lineage sorting leading to long-standing uncertainty in species delimitation. These taxonomic criticalities are not to be overlooked as they go far beyond the disciplines of taxonomy and systematic botany. In fact, this type of knowledge is fundamental to many other seemingly unrelated disciplines, as reliable species identification is fundamental to ecological restoration, conservation planning, and biodiversity monitoring.

This PhD project focuses on the *Festuca stricta-valesiaca* complex, a particularly intricate group of fine-leaved fescues distributed across Eurasia, focusing on the taxa that naturally occurs in the Alps and Apennines. Taxa within this complex have been variously interpreted as species, subspecies, or hybrids, and their boundaries remain controversial. The aim of the study is to integrate morphological, cytogenetic, and molecular approaches to achieve a clearer understanding of taxa boundaries, evolutionary relationships, and nomenclatural stability within the group, for further application in ecological restoration projects.

To this end, 987 individuals from 66 populations were collected across the Alps and Apennines, supplemented by herbarium research and historical type material consultation in different European herbaria. Morphological variation was quantified using 32 characters from vegetative, reproductive, and anatomical traits, with analyses conducted through ordination and canonical discriminant methods. Flow cytometry was employed on fresh and recent herbarium material to assess ploidy levels and cytotype variation across populations. Finally, for a limited number of individuals, genomic data were generated using ddRAD sequencing, allowing phylogenetic inference of relationships within the complex and between taxa.

The analyses revealed clear differentiation between taxa with lower ploidy (*F. valesiaca*, *F. sp. nova*) and the more complex group of polyploid taxa (hexaploids, octaploids, decaploids), which showed in some cases morphological overlap but also evidence of reproductive isolation. Several diagnostic morphological characters, particularly leaf cross-section anatomy, scabridity, spikelets elements size and pubescence, were confirmed as useful for discrimination, though many boundaries remain blurred by gradual variation and shared traits. Flow cytometry confirmed known ploidy levels but also identified unexpected cytotypes in the Apennines, suggesting overlooked diversity or some polyploidization events. Phylogenomic analyses showed promising early results and laid a solid base for a more complete study of the group in the future.

2 INTRODUCTION

2.1 Ecological restoration

Restoration ecology, or ecosystems restoration, is a modern concept that may refer both to a discipline and a practice stemming from the integration of many other disciplines such as ecology, conservation biology, landscape engineering and many others. Different definitions can be found in contemporary literature (Society for Ecological Restoration International 2004; van Andel & Aronson 2012; NBFC 2025) but they all converge on the following key concept: restoration ecology is the study and intentional process of restoring, as close as possible to their original state, degraded, damaged, or destroyed ecosystems.

Ingrained in the early visions of few individuals in the nineteenth and twentieth centuries, restoration ecology has experienced remarkable growth in recent decades. Although it remained relatively modest in scale until Bradshaw's pioneering work (1983), at the end of XX century has gained unprecedented levels of attention. Particularly, in the decades following the establishment of the Society for Ecological Restoration (SER) in the late 1980s, the field has drawn increasing interest not only from scientists but as well as from medias and governance. Today, the discipline is widely recognized as the proactive tool for excellence in conservation and biodiversity management (Bradshaw 1983, 1987, 2002; Jordan et al. 1988; Hobbs & Norton 1996; Choi 2004; Temperton et al. 2004; Harris et al. 2006) and a “hope for the future” (Dobson, Bradshaw & Baker 1997).

Politics and legislation are also major key components (Aronson 2010) and are becoming an extremely important aspect of restoration. Therefore, to achieve actual effectiveness one must consider not only the biological and physical aspects of the matter, but also the socio-economic and political matrix in which the restoration project is planned, financed and executed (Blignaut et al. 2007; Aronson 2010; van Andel & Aronson 2012).

This uprising in attention and popularity, not only towards ecological restoration but to sustainability and Nature-Based Solutions (NBSs), led to the investment on behalf of numerous governances in these themes. A great example is the UN Decade on Ecosystem Restoration, a call to all the member states of the UN, aimed to halt the degradation of ecosystems and restore them to achieve global goals. The UN Decade runs from 2021 through 2030, which is also the deadline identified for the Sustainable Development Goals in order to counteract climate change and stop the collapse of biodiversity beyond catastrophic levels (UN 2019). Another great example is the National Biodiversity Future Center (NBFC), the first national level research centre, funded by the European Union (NextgenEU), dedicated to biodiversity and its safeguarding, born from the coordination of different institutions between other research centres, universities and enterprises towards common sustainability goals (NBFC 2023).

The following PhD project finds its roots in the conjunction between the National Biodiversity Future Centre and the University of Pavia, focusing on the themes promoted by the UN Decade of Ecosystem Restoration with the final aim to fill in gaps in knowledge to crucially improve ecosystem restoration.

2.2 The importance of taxonomy and its applications

A successful ecological restoration intervention can be determined on the basis of nine attributes according to the SER (2004). The first two particularly emphasize on the composition of biological communities and are written as follows:

- 1 “The restored ecosystem contains a characteristic assemblage of the species that occur in the reference ecosystem and that provide appropriate community structure.”
- 2 “The restored ecosystem consists of indigenous species to the greatest practicable extent.”

It is therefore implied that, before making any kind of intervention, there should be a good understanding of the naturally occurring species. However, this is not always the case and misuse of species happens often with consequences on the rendition of the ecological restoration efforts (Medeiros et al. 2022). What comes across is that taxonomy, the ability to identify and classify organisms, is fundamental to conserving them. Without accurate taxonomic resolution, our understanding of biodiversity, ecosystem function, and the effect of environmental change is severely compromised (Mace 2004).

Taxonomy cements itself as a cornerstone of ecological research and conservation practice, yet it demands a high level of expertise and care to be used effectively. Misidentification or superficial classification without sound taxonomic knowledge undermines the integrity of ecological data and reflects a lack of scientific rigor (Woodcock 2002).

Historically, conservation efforts often prioritized charismatic species or broad vegetation types. However, with the emergence of biodiversity as a key concept, the focus of the matter shifted to ecosystem-based approaches. These strategies demand a more refined taxonomic framework to classify ecosystems, assess successional stages, understand habitat requirements, and conserve entire species communities.

A lack of sufficient taxonomic infrastructure can delay or prevent species detection and accurate identification in the ecosystems, leading to ineffective or misguided conservation and management responses (Douglas et al. 2009). Therefore, investment in taxonomic training, research, and infrastructure is critical not only for biodiversity science, but also for timely and effective conservation action.

2.3 Grasses and Grasslands: relevance, ecosystem services and endangerment

Grasslands are ecosystems primarily dominated by grasses and other graminoid plants, typically occurring in open rolling landscapes. While narrowly defined as areas where grasses are the dominant vegetation (Sanderson et al. 2009), the term "grassland" can also broadly encompass ecosystems with a mix of grasses and varying amounts of woody vegetation. This includes savannas, South America's cerrados, tundras, alpine meadows and certain desert or shrub-steppe regions where grasses coexist with shrubs or succulents. The composition of grasslands can thus range widely, reflecting different balances between grasses and woody species (Blair et al. 2014). Grasslands, intended in their broader definition, occur all over the globe with the only exception of Antarctica (though some grasses are found there) and occupy about 30–40% of Earth's terrestrial surface, covering more land than any other single biome type (O'Mara 2012; Blair et al. 2014; Bardgett et al. 2021; Parente et al. 2024). These ecosystems support some of the Earth's most extensive and diverse wildlife communities and are vital at both local and global scales, as they contribute significantly to a series of beneficial processes such as carbon sequestration, biodiversity maintenance, food production, etc.

As a matter of fact, grasses, especially the perennial species, contribute to a diverse number of ecosystem services of great importance (Ojija 2024). Perennial grasses significantly enhance soil biodiversity and activity by providing stable habitats for soil fauna (Lavelle et al. 2006; Tilman et al. 2006; Smith et al. 2008; Bardgett & Van Der Putten 2014; Ikoyi et al. 2023) and continuous inputs of organic compounds through their root systems. These roots exude a series of compounds such as sugars, amino acids, and organic acids that nourish a diverse community of soil organisms (Smith et al. 2008). The resulting increase in macro- and microbial diversity contributes to vital soil functions such as organic matter decomposition, nitrogen fixation, soil-borne disease suppression (De Deyn et al. 2003; Bardgett & Van Der Putten 2014; Mng'ong'o et al. 2023), and nutrient cycling (De Deyn et al. 2003; Mathieu et al. 2009), thus supporting soil fertility, and ecosystem resilience (Lavelle et al. 2006).

Beyond supporting soil biota, perennial grasses foster plant-soil symbiotic relationships (Smith et al. 2008; Giles et al. 2023), notably with nitrogen-fixing bacteria that convert atmospheric nitrogen into plant-available forms (De Deyn et al. 2003; Mng'ong'o et al. 2023). Their extensive and persistent root systems also contribute to carbon sequestration by storing carbon deep in the soil and within root biomass (Conant et al. 2001; Carlier et al. 2009). These processes play a key role in mitigating climate change by reducing atmospheric CO₂ concentrations and enhancing ecosystem adaptability to climatic variability (Conant et al. 2001; Lal 2004; DeLuca & Zabinski 2011; Wang et al. 2022). Extended roots also contribute to the soil structural stability and mitigation of erosion phenomena.

Perennial grasses are also valuable in controlling invasive alien plants (IAPs) (Maron & Marler 2008; Mganga et al. 2021). Their competitive growth, deep rooting systems, and rapid establishment enable them to outcompete IAPs for resources and suppress their spread through canopy shading (Blumenthal et al. 2005; Mganga et al. 2021) and soil stabilization. By improving soil health and supporting native plant communities, perennial grasses enhance ecosystem resistance to invasion. Restoration efforts using native perennial grass species have successfully reclaimed habitats degraded by IAPs, reestablishing ecological balance and promoting biodiversity (Blumenthal et al. 2005; Quinn & Holt 2009; Schuster et al. 2018; Schantz et al. 2019; Munishi & Ngondya 2022; Gannon et al. 2024).

In Europe, grasslands, and especially semi-natural grasslands, are among the most biodiverse ecosystems providing crucial habitats for a wide variety of native species and playing a key role in overall ecosystem functioning (Wilson et al. 2012; Dengler et al. 2014; Lindborg et al. 2023). Semi-natural grasslands in temperate Europe surpass tropical rainforests in vascular plant richness at smaller scales and support twice as many endemic vascular plants, largely due to moderate natural and anthropogenic disturbances such as grazing, mowing, fire, and drought (Pärtel et al. 2005). Despite their relevance, these habitats are severely threatened by land-use changes, including abandonment, afforestation, and shifting from traditional to modern agricultural practices (Johansen et al. 2019; Prangel et al. 2023).

Historically, the maintenance of semi-natural grasslands has depended on low-intensity human activities like grazing and mowing, which prevented woody plant invasion and preserved biodiversity (Pärtel et al. 2005; Johansen et al. 2019). Restoration of degraded grasslands is essential, not only to recover biodiversity, but also to sustain the provision of critical ecosystem services (Rey Benayas et al. 2009; Mace et al. 2012; Prangel et al. 2024).

Despite their high ecological value, grasslands remain underprotected, and among the most endangered ecosystems globally (Shipley et al. 2024). These ecosystems are recognized as the most transformed terrestrial biome, yet they receive the least formal protection among the world's 14 major biomes, with only 4% receiving formal protection (Henwood 2010). For example, the North American

tallgrass prairies have undergone extensive alteration due to agricultural conversion, habitat fragmentation, and land-use change (Hoekstra et al. 2005). This critical conservation gap underscores the urgent need for increased protection and restoration efforts to halt ongoing biodiversity and habitat loss.

2.4 *Festuca* L.: taxonomical history and criticalities

Following Ardenghi 2016 with the integration of more recent works, the history of taxonomical studies in *Festuca* can be traced as follows.

The genus *Festuca* L. (Poaceae) was first described by Linnaeus in 1753 (Linnaeus 1753). However, his original concept was much broader than today's understanding, encompassing species now assigned to different infrafamilial taxa. Examples include *Danthonia decumbens* (L.) DC. (= *Festuca decumbens* L.), *Glyceria fluitans* (L.) R.Br. (= *Festuca fluitans* L.), and *Rostraria cristata* (L.) Tzvelev (= *Festuca cristata* L.). Over the centuries, the boundaries of *Festuca* became more precise and defined, leading to the emergence of new genera.

One of the first agrostologists to recognize the lack of homogeneity in Linnaeus' classification was Palisot de Beauvois (1812) with the description of the genus *Schedonorus* P.Beauv. to accommodate species characterized by broad leaf blades. This distinction established the traditional separation between "broad-leaved fescues" and "fine-leaved fescues," the latter being defined by conduplicate leaf blades on the tillers. The fine-leaved group is considered the "authentic" *Festuca*, as evidenced by the designation of the fine-leaved *Festuca ovina* L. as the type species of the genus (Nash 1913; Jarvis et al. 1987; Jarvis 2007). Later taxonomic novelties were proposed by Grisebach (1852) and Janka (1860), who introduced the genera *Leucopoa* Griseb. and *Amphigenes* Janka, respectively (Müller & Catalán 2006). Around the same time, Willkomm (1861) described *Festuca* sect. *Eskia* Willk., comprising species with prominent ligules, and lemmas and paleas characterized by scarious margins.

Towards the end of the 19th century, Eduard Hackel published *Monographia Festucarum Europaeorum* (Hackel 1882), a landmark study on *Festuca* s.l., focusing on taxa native to Europe and neighbouring regions. Hackel significantly restructured the systematics of *Festuca* s.l., introducing methodological innovations that remain relevant today, such as the use of leaf cross sections and their anatomical organization as diagnostic characters. He rejected earlier segregated genera, favouring a broader circumscription similar to that of Linnaeus. However, acknowledging the genus's high variability, he introduced an infrageneric classification system divided into six sections (Hackel 1881, 1882). This structure, at least in part, is still in use today. Hackel placed most fine-leaved taxa in sect. *Ovinae* (Fr. ex Andersson) Hack., nom. inval., and distributed broad-leaved taxa among sections *Bovinae* (Fr. ex Andersson) Hack. (= *Schedonorus*), *Montanae* Hack., *Scariosae* Hack. (= sect. *Eskia* p.p.), *Subbulbosae* Nyman ex Hack., and *Variae* Hack. (= *Amphigenes* = sect. *Eskia* p.p.).

In the second half of the 20th century, Alexeev (1977a) introduced a new infrageneric subdivision of *Festuca* at the subgenus level, recognizing four subgenera: *Festuca*, *Drymanthele* Krecz. & Bobrov (= sect. *Montanae*), *Leucopoa* (Griseb.) Hack., and *Schedonorus* (P.Beauv.) Peterm., with *Festuca* including the fine-leaved taxa. Later, Holub (1984, 1998) elevated *Drymanthele* to genus rank under the new name of *Drymochloa* Holub, while Darbyshire (1993), opposing the trend of splitting, transferred *Schedonorus* taxa to *Lolium* L. based on biological affinities and the particularly high hybridization rates between *Schedonorus* and *Lolium*.

Following recent phylogenetic studies (Gaut et al. 2000; Torrecilla & Catalán 2002; Torrecilla et al. 2003, 2004; Catalán et al. 2004, 2007; Catalán 2006; Inda et al. 2008; Soreng et al. 2015) a new division of *Festuca* s.l. is proposed, distinguishing its members into two major clades:

- 1 Fine-leaved fescues (highly supported clade), comprising of two lineages:
 - 1a *Festuca* s.s. and several annual taxa previously assigned to other genera (*Ctenopsis* De Not., *Micropyrum* (Gaudin) Link, *Narduroides* Rouy, *Psilurus* Trin., *Vulpia* C.C.Gmel., and *Wangenheimia* F.Dietr.), along with two perennial taxa (*Dielsiochloa* Pilg. And *Hellerochloa* Rauschert).
 - 1b *Festuca* sects. *Eskia* Willk., *Pseudatropis* Krivot. (separated from *Eskia* by Krivotulenko 1960), and *Dimorphae* Catalán & Joch.Müll.
- 2 Broad-leaved fescues (poorly supported clade), consisting of multiple lineages with unclear relationships:
 - 2a *Schedonorus*, *Lolium*, and the monotypic *Micropyropsis* Romero Zarco & Cabezudo.
 - 2b *Festuca* sect. *Subbulbosae*.
 - 2c *Leucopoa* p.p.
 - 2d *Drymochloa*, *Festuca* sects. *Scariosae* and *Pseudoscariosae* Krivot. (the latter separated from by Krivotulenko, 1960).
 - 2e *Festuca* sect. *Lojaconoa* Catalán & Joch.Müll. (≡ *Subbulbosae* p.p.).
 - 2f *Leucopoa* p.p. (≡ *Amphigenes*) and *Festuca* sect. *Subulatae* Tzvelev.

Since the 2010s, researchers have sought to align taxonomic and nomenclatural treatments with the phylogenetic framework. The genera within the "fine-leaved fescues" clade (1a + 1b) have been consolidated under *Festuca* (Kellogg 2015; Soreng et al. 2015), except for sect. *Dimorphae* (*Festuca carpatica* F.Dietr., *F. dimorpha* Guss., *F. laxa* Host), which some authors (Foggi et al. 2005, 2010; Foggi & Müller 2009b) consider part of *Leucopoa*, despite molecular evidence suggesting otherwise. Within the "broad-leaved fescues" clade, most lineages have been treated as separate genera, though discrepancies between phylogenetic and taxonomic data persist: *Lolium* (2a), *Patzkea* G.H.Loos (2b + 2e), *Leucopoa* (2c + 2f), and *Drymochloa* (2d) (Darbyshire 1993; Foggi et al. 2005, 2010; Foggi & Müller 2009b; Loos 2010; Soreng et al. 2015).

Since the pivotal work of Hackel in the late 19th century, which laid the foundation for understanding *Festuca* in Europe, there has been substantial progress in the classification and taxonomy of this genus throughout the Euro-Mediterranean area. Significant contributions have come from various botanists, particularly from the French school of biosystematics, such as Saint-Yves, Bidault, Auquier, and Kerguélen, whose regional studies and methodological insights were later synthesized by Markgraf-Dannenberg in her influential treatment for *Flora Europaea*. Her work helped highlight key taxonomic issues and spurred further research on the group.

From the late 1980s onward, research on *Festuca* and its related groups has largely concentrated on individual species groups and sections, integrating advanced techniques such as karyological analysis, ploidy level determination, and genetic studies. Recent breakthroughs have refined the taxonomy of *Festuca* sensu stricto, thanks to studies on specific species and groups, such as sections *Festuca* (Fuente & Ortúñez 1998) and *Eskia* (Foggi et al. 2007; Torrecilla et al. 2013), and species including *F. inops* (Foggi et al. 2006), *F. marginata* (Ardenghi et al. 2024), *F. pallens* (Šmarda & Kočí 2003; Šmarda et al. 2007), *F. robustifolia* (Foggi & Signorini 2001), and aggregates like *F. trichophylla* (Al-Bermani et al. 1992), *F. violacea* (Foggi et al. 1999), *F. valesiaca* (Arndt 2008), and *F. alpina* (Foggi et al. 2012a). National-level works, including monographs and checklists for France (Kerguélen & Plonka 1989; Portal 1999; Foggi & Tison 2014), the Iberian Peninsula (Cebolla Lozano & Ponce 2003; Devesa et al. 2013), Italy (Foggi & Rossi 1996), and the broader Euro-Mediterranean region (Foggi & Müller 2009a), have also enriched local floristic knowledge.

Karyology, especially in terms of chromosome counting and ploidy analysis, continues to be a crucial tool for clarifying species boundaries, particularly in taxa with limited morphological differentiation (Auquier & Kerguélen 1977; Kerguélen & Plonka 1989; Šmarda 2006). As hybridization and polyploidy have been shown to play a central role in the evolution of *Festuca* (Malik & Thomas 1966), such data have proven vital in interpreting relationships within the group. Two contrasting approaches to systematic classification have emerged: one treats polyploid complexes as separate species or subspecies (e.g., de la Fuente García et al. 1997; Foggi et al. 1999; Arndt 2008), while the other merges taxa with identical ploidy levels into single taxonomical units (e.g., Foggi et al. 2006). When ploidy is consistent, but morphological or ecological differences are evident, recognizing subspecies allows researchers to retain important information on local variability (e.g., Foggi et al. 2012a).

Following the tradition initiated in France by Litardière (1949, 1950), contemporary researchers have published data on chromosome numbers and karyomorphology for previously unstudied taxa (e.g., Fuente et al. 2001; Šmarda & Kočí 2003; Fiorini et al. 2008; Ardenghi et al. 2016). As of the last treatment of *Festuca* for the flora of Italy (Foggi et al. 2017), most of the chromosome numbers are known for a majority of the taxa thanks to the recent endeavours of researchers (76 out of 83 of the reported taxa).

Despite methodological advances, classical nomenclatural work remains essential for interpreting the vast and varied body of historical literature on *Festuca*. Typification, the formal process of linking a name to a physical reference specimen or illustration (Art. 7.2 of the ICN: Editorial Committee of the Madrid Code 2025), remains fundamental to resolving historical ambiguities and ensuring the stability of names. Examining protologues (original descriptions and associated elements, Art. 8A.4 of the ICN) in this context can also yield insights valuable for subsequent research stages. Knowing the original locality of a taxon (its *locus classicus*) is particularly helpful for associating and define unequivocally new systematic data with established names, a practice referred to as "biosystematic typification" as defined by Auquier & Kerguélen (1977).

Over the last several decades, many scholars have focused on resolving typification issues within the genus (e.g., Fuente & Sanchez-Mata 1986; Jarvis et al. 1987; Reveal et al. 1991; Foggi & Signorini 1997; Signorini & Foggi 1997; Foggi et al. 2004, 2006, 2012b; Šmarda et al. 2009; Ardenghi et al. 2013), although significant work remains to address the complex and fragmented nomenclatural history of *Festuca* s.l. One of the ongoing goals in modern taxonomy is to align phylogenetic insights with correct and stable naming practices. The International Code of Nomenclature for algae, fungi, and plants (ICN)

provides tools for achieving this, such as the publication of new name combinations and the conservation or rejection of problematic names.

Although there has been substantial recent work on this topic (e.g., Darbyshire 1993; Soreng et al. 2001; Foggi et al. 2005; Danihelka et al. 2009; Foggi et al. 2010; Loos 2010), the classification of several *Festuca* sections and allied genera remains inconsistent with molecular findings.

As currently intended, the genus *Festuca* includes more than 500 species, mainly distributed in temperate and cool environments all around the globe, with a centre of diversity located in the Euro-Mediterranean region (Watson & Dallwitz 1992+; Clayton et al. 2006+; Euro+Med 2006+; Darbyshire & Pavlick 2007; Inda et al. 2008; Foggi & Tison 2014; Kellogg 2015; Soreng et al. 2015). The group, believed to be monophyletic (Kellogg 2015) until recent phylogenetic studies (Kriuchkova et al. 2023, Mucko et al. 2024), lacks any obvious morphological synapomorphies. Darbyshire & Pavlick (2007) described patterns of transverse leaf-sectional anatomy of putative diagnostic value for the whole genus, however comparable data are still not available for the other merged genera (Kellogg 2015). The perennial taxa traditionally referred to as “fine-leaved fescues” represent the principal group of this genus, amounting to about 450 species (Foggi & Tison 2014; Kellogg 2015). They are conventionally arranged in four main sections, distinguished on the basis of macro-morphological (emergence of new tillers, growth habit, ligule length) and anatomical (pattern of sclerenchyma in transverse tiller leaf section) characters:

- 1 *Festuca* sect. *Festuca* L. (incl. *F. ovina*, *F. stricta* Host, and *F. circummediterranea* Patzke groups) distinguished by tiller leaf sheaths white to grayish, fused only at the base or for a lesser portion of their length. Leaf cross-sections with an elliptic outline or developed up to form an elongated V shape. Sclerenchyma in various configurations depending on the subgroups.
- 2 *Festuca* sect. *Aulaxyper* Dumort. [incl. *F. rubra* L., *F. trichophylla* (Ducros ex Gaudin) K.Richt., and *F. violacea* Schleich. ex Gaudin groups] characterised by plane culm leaves. Mixed sterile shoots tillering (both intra- and extravaginal). Leaf sheaths brown-reddish, fused for most of their length if not completely. Ligula short rarely expanded in two auriculas. Leaf cross section in a polygonal outline with discrete sclerenchyma strands at its vertexes, rarely decurring towards each other.
- 3 *Festuca* sect. *Eskia* Willk. characterised by wide scarious margins and apices on the glumes and lemmas. Ligula oblong, well-developed, rarely expanded in two lateral auriculas. Caryopsis non-adherent to the palea, hilum as long as the caryopsis. Intravaginal tillering. Leaves conduplicate, dimorphic (external short; internal elongated), with pungent apices. Sclerenchyma trabeculae and cataphylls absent (Torrecilla et al. 2003).
- 4 *Festuca* sect. *Dimorphae* Catalán & Joch.Müll. Morphologically analogue to *Festuca* sect. *Eskia* but distinguished by phylogenomic evidence (Müller & Catalán 2006).

This arrangement in part corresponds to the classification system originally introduced by Hackel (1881, 1882) and is still used today, with special regards to the Euro-Mediterranean representatives of the genus (e.g., Foggi & Rossi 1996; Torrecilla et al. 2004; Devesa et al. 2013; Foggi & Tison 2014). Additionally, each section may be subdivided in groups (or aggregates) of small species on the basis of shared morphological, anatomical, karyological, and ecological features (e.g., Foggi et al. 2017).

2.5 The *Festuca stricta-valesiaca* complex

Considered as a sub-aggregate of the broader *Festuca ovina* group by many authors (e.g., Conert 1994; Foggi et al. 2017; Kerguélen & Plonka 1989; Portal 1999), the *Festuca stricta-valesiaca* complex is a group of morphologically cryptic polyploids that can be distinguished from the others for the following characteristics:

- 1- Leaf cross-sections presenting the sclerenchyma organized in three separate strands at margins and keel, often accompanied by accessory strands in between the main strands. These are decurrent, elongating towards each other and even rarely forming a complete ring (only exception being *Festuca stricta* subsp. *stricta*, which sclerenchyma often forms regular rings and is more rarely interrupted).
- 2- Tiller leaves barbed, ± scabrid to the touch, at least in the distal portion.
- 3- Lemmas always presenting a well-developed awn.
- 4- Abaxial surface of the leaves with at least three ribs separated by four furrows.

The group can be furtherly distinguished in two series described by Pawlus (1985) based on the following morphological features:

- 1- Series *Valesiaca* M.Pawlus: tiller leaves 0,2-0,8 mm in diameter. Cross sections with three major sclerenchyma strands at margin and keel, rarely presenting 2 additional minor strands between them. Vascular bundles 5, rarely 7. Ridges of the abaxial page 3, triangular in shape. The following taxa are stated as belonging to the series: *F. valesiaca*, *F. stricta* subsp. *sulcata* (sub. *F. rupicola*) and *F. valesiaca* subsp. *parviflora* (sub. *F. pseudovina*).
- 2- Series *Trachyphyllae* M.Pawlus: tiller leaves up to 1,5 mm in diameter. Cross sections with a sclerenchyma ring often interrupted and of irregular thickness. Vascular bundles 7-9, rarely 5. Abaxial face with 3-7 ridges. The following taxa are stated as belonging to the series: *F. stricta* subsp. *stricta* (sub. *F. stricta*), *F. stricta* subsp. *trachyphylla* (sub. *F. trachyphylla*), *F. makutrensis* and *F. duvalii*.

Arndt 2005 provides an exhaustive report of the group species focusing on their differentiation, distribution and ploidy.

Festuca valesiaca Schleich. ex Gaudin is the only diploid taxon in the complex ($2n=2x=14$). The name was validly published for the lower Valais (“circa Branson”) in 1811 but it first appeared (as a nomen nudum) in *exsiccata* lists of Schelicher and Thomas as early as 1806 (Moret 1999). The lectotype however was designated only in 2009 (Šmarda et al. 2009) from a single herbarium sheet (Herbarium Gaudin, LAU!) with four different specimens mounted and two original labels. Three of the specimens and one of the labels correspond to the description given in the protologue while the fourth plant can be identified as *Festuca trichophylla*. *F. valesiaca* currently presents three subspecies: *F. valesiaca* subsp. *valesiaca*, *F. valesiaca* subsp. *parviflora* (Hack.) R.Tracey and *F. valesiaca* subsp. *hypsohylla* (St.-Yves) Tzvelev.

- *F. valesiaca* subsp. *parviflora*: According to Conert (1994) can be easily identified from the broadly lanceolate lemmas and generally smaller size (stems, spikelets and awns are all generally shorter compared to *F. valesiaca* subsp. *valesiaca*), although Tracey (1977,1980)

instead recognizes a fluid transition between the two subspecies. It is Indigenous of the Pannonian region, extending to Central Asian, with a distribution that recalls that of many Eurasian steppic taxa. It has also been reported as an alien species for eastern Alps capable of moving along railways and roadsides while dispersed by traffic (Englmaier & Wilhalm 2018).

- *F. valesiaca* subsp. *hypsochila*: This subspecies distinguishes itself from the nominal subspecies by its brownish spikelets and occurs in Asia, ranging from the Caucasus region to North-eastern China (Tzvelev 1976; Alexeev 1977b).

Several tetraploid taxa ($2n=4x=28$) have been described as part of the *F. valesiaca* complex such as *F. brunnescens* (Tzvelev) Galusko, *F. duvalii* (St.-Yves) Markgr.-Dann., *F. dalmatica* (Hack.) K. Richt., *F. illyrica* Markgr.-Dann., *F. majovskyi* Holub, *F. makutrensis* Zapal., *F. pseudodalmatica* Krajina ex Domin and *F. wagneri* (Degen, Thaisz & Flatt) Degen. These tetraploids are currently a group of difficult assessment, as a detailed study has yet to be conducted on these taxa and information presented in literature regarding their systematic, distribution and cytology has been inconsistent and at some points even contradictory. A great example is the unclear morphological differentiation and distribution of *F. pseudodalmatica*, *F. dalmatica*, and *F. wagneri* in the Pannonian region, as key morphological characters strongly overlap between these species. Other taxa present similar controversies as well, raising questions about the clear definition (and therefore legitimacy) of the tetraploid taxa described so far for the complex.

Hexaploids taxa of the *F. valesiaca* complex are currently classified under the name *Festuca stricta* Host (1802), *Festuca brevipila* Tracey (1977) and *Festuca ticinensis* (Markgr.-Dann.) Markgr.-Dann (1978). Five subspecies currently fall under *F. stricta*.

- *F. stricta* subsp. *stricta* Host.: According to Pils (1984), the type subspecies is only distributed in the Lower Austrian Alps. The data for *Festuca stricta* subsp. *stricta* by Markgraf-Dannenberg (1980) and Dalla Torre & Sarnthein (1906) for South Tyrol were attributed by Pils (1984) to confusion with *Festuca bauzanina* subsp. *bauzanina*, which can also occasionally form complete sclerenchyma rings.
- *F. stricta* subsp. *sulcata* (Hack.) Patzke ex Pils (= *F. rupicola* Heuff.): is a widely distributed continental taxon which reaches westward up to the Swiss canton of St. Gallen and the Italian province of Lecco and extend eastwards through the Eurasian steppe (Alexeev 1978, 1983). *F. stricta* subsp. *sulcata*, and subsp. *trachyphylla* form morphologically transitional forms in the areas where they occur together, as pointed out by various authors (Markgraf-Dannenberg 1938, 1981; Patzke 1960, Pils 1984).
- *F. stricta* subsp. *trachyphylla* (Hack.) Patzke ex Pils ($\equiv$ *Festuca trachyphylla* (Hack.) R.P. Murray): Another commonly found hexaploid taxon widespread in Central Europe. Exact morphology and distribution lack clear boundaries due to the wide use and distribution of commercial varieties of this taxon (Foggi et al. 2017). Controversial are the delimitation with two other hexaploid taxa, *F. brevipila* Tracey (1977) and *F. ticinensis* (Markgr.-Dann.) Markgr.-Dann (1978), due to strongly overlapping morphological features and the same number of chromosomes (Wilkinson & Stace 1988; Arndt 2005).
- *F. stricta* subsp. *carnuntina* (Tracey) Pils: Described in 1977 from the Hainburg Mountains (Lower Austria), appears as a morphological in-between of *F. stricta* subsp. *stricta* and *F. stricta* subsp. *sulcata*. It presents a leaf cross-section with thickened sclerenchyma like the first subspecies organized however in discontinued strands like the latter.

- *F. stricta* subsp. *saxatilis* (Schur) Foggi & Signorini: Described in 1866, It's distributed near the Black Sea in eastern Balkans and Caucasus. It's morphologically similar to *F. stricta* subsp. *sulcata* but distinguished by the smooth leaves and palea according to Beldie (1972) and Markgraf-Dannenberg (1978).

Festuca ticinensis (Markgr.-Dann.) Markgr.-Dann is another hexaploid taxon described by Markgraf-Dannenberg in (1976) which occurs along the Ticino river basin, from higher Canton of Ticino to the Prealps around Lake Como and Lake Maggiore. As mentioned before, this taxon is morphologically indistinguishable from *F. stricta* subsp. *trachyphylla*, even sharing the same ploidy level ($2n=6x=42$).

Octaploids taxa ($2n=8x=56$) of the *F. valesiaca* complex have so far been described exclusively for the Alps under the name *F. bauzanina* subsp. *bauzanina* (Pils) S.Arndt and *F. bauzanina* subsp. *rhaetica* S.Arndt. They are recognizable and distinguished by their leaf cross section anatomy.

A single decaploid species ($2n=10x=70$) belonging to the *valesiaca* complex, *Festuca guinochetii* (Bidault) S. Arndt, has also been described for the area near S. Antonio, Bormio by Bidault in 1976. Its morphology and anatomy are barely recognizable from those of the octaploids taxa belonging to *F. bauzanina* but for few details.

Of all the aforementioned taxa, 10 naturally occur in the designated area of study: *F. valesiaca*, *F. pseudodalmatica*, *F. stricta* subsp. *stricta*, *F. stricta* subsp. *sulcata*, *F. stricta* subsp. *trachyphylla*, *F. brevipila*, *F. ticinensis*, *F. bauzanina* subsp. *bauzanina*, *F. bauzanina* subsp. *rhaetica* and *F. guinochetii* (Fig. 1).

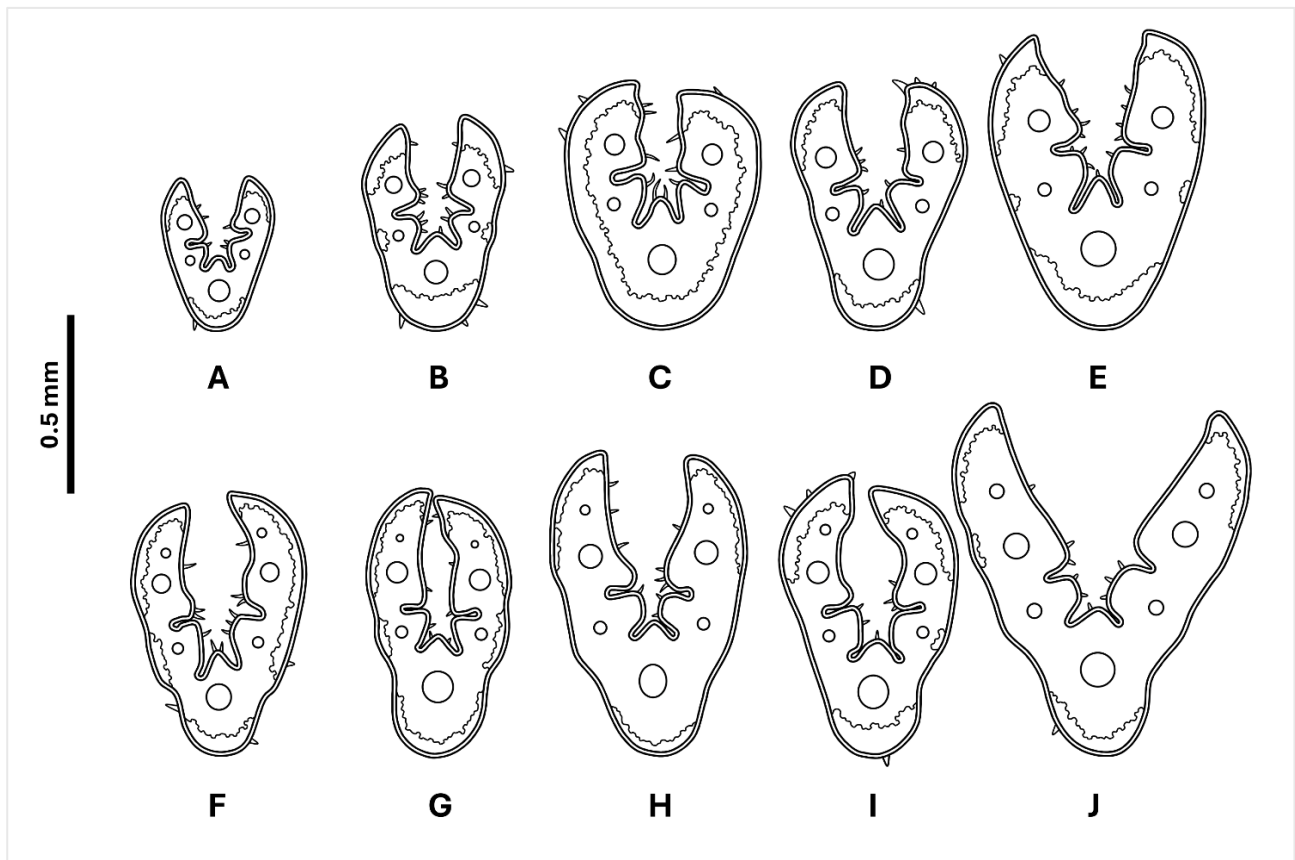


Figure 1: Leaf cross-sections for each taxon of the *stricta-valesiaca* complex occurring in the area of study. A: *F. valesiaca*; B: *F. pseudodalmatica*; C: *F. stricta* subsp. *stricta*; D: *F. stricta* subsp. *sulcata*; E: *F. bauzanina* subsp. *bauzanina*; F: *F. stricta* subsp. *trachyphylla*; G: *F. brevipila*; H: *F. ticinensis*; I: *F. bauzanina* subsp. *rhaetica*; J: *F. guinochetii*.

2.6 Aim of the PhD project

Given the premises on the crucial importance of taxonomy and the urgency in restoring ecosystems, the following work attempts at improving the current taxonomical knowledge and indirectly any effort toward ecological restoration. Many critical groups worth studying can be found within flowering plants, but because of their difficulty working just on a handful of species require a significant investment of time and resources. Wild grasses (Poaceae) are often regarded as one of the most difficult and diverse groups of Angiosperms and studies regarding their systematics are still leading to new findings even after decades of investigations. Yet, the challenge they pose should not warn away researchers. Grasses are the founding species of many grasslands, arguably the most important biomes after the rainforests and offer a variety of ecosystem services crucial to the wellbeing of the ecosystems they occupy.

Among the most important genera of grasses, *Festuca* L. is regarded as one of the most difficult and diverse. It occurs on every continent except Antarctica and different taxa are often cornerstone species of many grasses dominated habitats.

However, fine-leaved fescues have been already proven to be valuable tools in sustainable turfs and management of green urban areas, thanks to their drought and heat-tolerance (Robbins et al. 2016), weed suppression capabilities (Breuillin-Sessoms et al. 2021), and overall performance (Braun et al. 2020, Szabó-Szöllösi et al. 2024), racing their use in numerous ecological restoration projects. Examples of ecological restoration projects where fine-leaved fescues were involved include “Grassland restoration and marsh protection in Egyek-Pusztakócs” (LIFE04NAT/HU/000119; Lengyel et al. 2012, 2020), “LIFE FOR SEEDS” (LIFE20 NAT/SI/000253) and “LIFE Drylands” (LIFE18 NAT/IT/000803; Assini et al. 2024)

This study aims to further investigate a group of fescues taxa often referred as the *stricta-valesiaca* complex. Species of this group are original of the Eurasians steppes and subalpine meadows and are currently gaining popularity in the ecological restoration scene due to their performance and characteristics.

3 MATERIALS AND METHODS

3.1 Area of study and sampling design

The *a priori* area of study, as indicated by the project title, is Italy. However, being this study conducted on plant species, the term was adapted into a biogeographical sense. This led to include in the study area part of neighbouring countries where the Alps mountain range extended. Particularly, in the later sampling stage, plants were collected also from Switzerland and Austria alpine territories. On the other hand, Sicily and Sardinia were excluded from the area of study as no taxon from the *stricta-valesiaca* group is reported to inhabit these islands.

With this new extended definition of the area of study, extensive research was conducted on local and general floras (Markgraf-Dannenbergh 1980; Conert 1994; Foggi & Tison 2014; Ardenghi & Polani 2016; Foggi et al. 2017) to compile a list of expected taxa for the study. From these were excluded hybrids and alien taxa to the flora of Italy.

Occurrences for the selected taxa were collected from different sources, such as literature (e.g., Bidault 1967; Pils 1984; Rossi et al. 1998; Arndt 2005, 2008; Filibeck et al. 2020) herbaria (BOZ, BELL, FI, PAV, ROV; herbaria codes follow Thiers, continuously updated), and databases (GBIF), and then projected on a map of the study area. With this initial overview as a starting point, 66 locations were selected trying to also account for eventual record inaccuracies due to the difficulties in identifying *Festuca* taxa, the changes in the landscape since the records and other factors of uncertainty. When described in the original protologue and present in the area of study, *loci classici* of the taxon (or their closest modern equivalent) have been included in the final list of target locations following the concept of “biosystematic typification” (Auquier & Kerguelen 1977).

The sampling has been designed to include at least 15 individuals of each morphotype per population, to focus on the plants variability within the area and reduce the risk of incurring in biases that may occur when sampling fewer individuals. Exceptions occurred in smaller populations with fewer and more scattered individuals, where the number of samples collected was deemed as enough to not cause any decline in the population (especially in the case of endemics and lesser known taxa). In these cases, herbarium material from PAV and MSNM was used to integrate the collections.

3.2 Nomenclature and type materials

After defining the target taxa extensive bibliographical research has been conducted to unravel their nomenclatural history. A collection of names and their related synonyms, new combinations, basionyms and type material has been compiled as a first step of this project. Additionally, when possible, various material (including types) has been consulted and thoroughly studied either in presence, by travelling to the designated herbaria (BRNU, BELL, FI, G, MSNM, PAV, PRC, ROV, W, WU, Z, ZT; herbaria codes follow Thiers, continuously updated), or via high quality digital scans. This allowed the building of a general understanding of the taxa as intended by their authors and their variation. However, since most herbaria did not allow the detachment of leaves to perform cross-section (as it would damage in most cases historical material, even if only in minor part), most of the material studied from this phase was not included in the morphometrical analysis. Historical herbaria material was excluded from the ploidy analysis for the same reason, even though FCM has been proven as a reliable method to infer ploidy in herbarium material depending on its condition (Suda & Trávníček 2006).

3.3 Flow cytometry (FCM)

Flow cytometry (FCM) is a technique that has emerged as the preferred method for estimating DNA content (genome size) in vascular plants due to its rapid data acquisition, ease of sample preparation, and ability to analyze large numbers of nuclei with high accuracy (Pellicer & Leitch 2014; Bourge et al. 2018). This technique has become widely adopted across different fields related or involving botany such as plant cell biology, systematics, evolution, genetics, and biotechnology. A significant advancement in plant FCM is the demonstrated ability to reliably estimate DNA ploidy levels in dehydrated herbarium specimens using standard DAPI staining (Suda & Trávníček 2006). This innovation greatly enhances the versatility of FCM, enabling researchers (particularly plant taxonomists, biosystematists, and ecologists) to determine cytotype from non-fresh material with a simple and accessible protocol, thereby facilitating cytogenetic investigations under field or historical sample conditions.

Ploidy levels were investigated for 1 to 9 individuals per sampled population using flow cytometry with DAPI staining (FCM). Young, well-preserved leaf tissues were selected from both fresh specimens and herbarium samples (less than one year old) to have a good representation of each sampled population and its morphotypes. Leaf tissues were chopped together with an internal reference standard (*Lycopersicum esculentum* ‘Stupické polní tyčkové rané’) in a Petri dish containing 0.5 mL of Otto I buffer (0.1 M citric acid, 0.5% Tween 20, Otto 1990) using a razor blade. The resulting nuclear suspension was passed through a 50 µm nylon mesh filter, after which 1 mL of Otto II buffer (0.4 M Na₂HPO₄·12H₂O) with 2 µg/mL DAPI was added. Ploidy levels were then inferred via calculation using the following formula:

$$2C \text{ DNA sample} = \frac{\text{mean fluorescence sample peak}}{\text{mean fluorescence standard peak}} \times 2C \text{ DNA diploid } \textit{Festuca sect. Festuca}$$

Basic genome size for the *Festuca valesiaca* complex necessary to calculate the ploidy of the samples was studied and quantified in Šmarda et al. 2008.

Flow cytometric measurements were carried out using a CyFlow ML cytometer (Partec GmbH, Germany), fitted with a 365 nm UV LED (Sysmex Partec GmbH), at the Department of Botany and Zoology, Masaryk University, Brno, Czech Republic.

3.4 Morphometry

A total of 32 morphological traits were selected to investigate the different taxa morphologies, focusing on those recognized as diagnostic for fine-leaved fescue species. Measurements followed the methodological framework outlined here below, which follows standards and terminologies of previous relevant taxonomical studies on *Festuca* (Hackel 1882; Saint-Yves 1913; Ellis 1976; Wilkinson & Stace 1991; Foggi et al. 1999; Ardenghi et al. 2024; Bednarska et al. 2024). The characters are divided among three major groups (habit, spikelet and leaf cross-section) and are here described here in detail, along with their code and variable type (QD = quantitative discrete, QC = quantitative continuous, BI = binary, CO = ordinal):

- Habit morphology:
 - Culm length (Clm_L; QC): Length of the culm measured from the base of the inflorescence to the last visible node.
 - Tiller leaf blade length (LfB_L; QC): Length of the leaf blade of the sterile tillers measured from the collar to the apex.

- Panicle length (Pan_L; QC): Length of the inflorescence measured from its base to the insertion point of the last spikelet (at the base of the glumes).
- Scabridity degree of the panicle (Pan_Sk; CO): measurement of the panicle's rachis and branches roughness (1 = smooth, 2 = slightly scabrous, 3 = scabrous, 4 = strongly scabrous).
- Pubescence at the base of the panicle (Pan_Pb; CO): measurement of the pubescence on the culm observed at the base of the panicle (1 = glabrous, 2 = slightly pubescent, 3 = pubescent, 4 = highly pubescent).
- Culm leaf blade length (CLf_L; QC): Length of the uppermost leaf blade of the fertile shoots measured from the collar to the apex.
- Sheath to node distance (Sh_Nd; QC): Distance between the sheath and the node. Measured from the collar of the uppermost culm leaf to the first node encountered downward.
- Inferior branch of the panicle length (InfBr_L; QC): Length of the lower branch of the panicle measured from its insertion to the base of the terminal spikelet (base of the glumes).
- Pubescence of the young tillers sheaths (TilSh_Pb; CO): measure of the pubescence of the young leaf sheaths of the tillers (1 = glabrous, 2 = slightly pubescent, 3 = pubescent, 4 = highly pubescent).
- Pruinosity of nodes (Nd_Pr; BI): Presence of a waxy layer on the nodes (0 = non-pruinose, 1 = pruinose).
- Scabridity of the tiller leaf blades (Sk_Deg; CO): measurement of the tiller leaf blades roughness (1 = smooth, 2 = slightly scabrous, 3 = scabrous, 4 = strongly scabrous).
- Spikelet morphology:
 - Spikelets length (Sp_L; QC): length of the spikelet measured from the base of the glumes to the apex of the fourth floret (awn excluded). Spikelets with an undeveloped fourth floret or fewer than four florets can be measured up to the third floret, with an added increment equal to the distance between the apices of the second and third florets (as in Foggi et al. 1999).
 - Lower glume length (LGL_L; QC): length of the lower glume measured from base to apex.
 - Upper glume length (UGL_L; QC): length of the upper glume measured from base to apex.
 - Upper glume half width (UGL_hW; QC): half width of the upper glume measured at its widest point.
 - Lemma length (Lm_L; QC): length of the lemma of the second floret (from the base of the spikelet) measured from base to apex (excluding awn).
 - Lemma half width (Lm_hW; QC): half width of the lemma of the second floret measured at its widest point.
 - Awn length (A_L; QC): length of the longest awn on the spikelet.
 - Glume pubescence (GL_Pb; CO): measurement of the pubescence of the glumes (1 = glabrous, 2 = slightly pubescent, 3 = pubescent, 4 = highly pubescent).
 - Lemma pubescence (Lm_Pb; CO): measurement of the pubescence of the lemma (1 = glabrous, 2 = slightly pubescent, 3 = pubescent, 4 = highly pubescent).
 - Shininess of spikelets (Sp_Sh; CO): Presence of wax on spikelets (0 = visibly pruinose and opaque, 1 = pruinosity hard to directly observe and slightly opaque, 2 = reflective of the light).
- Leaf cross section morphology

- Organization of the sclerenchyma (Sc_Org; CO): description of the sclerenchyma arrangement pattern (1=discrete strands, 2= decurrent strands, 3= decurrent with sparse accessory strands, 4=interrupted ring, 5=continuous ring).
- Epidermal undulations (Ep_Und; BI): Presence of small undulations in between epidermal (0 = absent, 1 = present).
- Number of vascular bundles (VB_N; QD): Number of vascular bundles.
- Number of lateral ribs (R_N): Number of ribs on the abaxial surface (excluding the central one opposite the keel).
- Keel to mid-rib distance (KIMR; QC): Distance between the keel and the apex of the central opposite rib.
- Keel to longest margin distance (Klmg; QC): Distance between the keel and the apex of the most extended margin.
- Leaf section shape (Shp; CO): Shape of the leaf section as a proxy to measure the arms development compared to the thickness (1 = U-shaped, 2 = V-shaped, 3 = Y-shaped).
- Longest hair (LH; QC): Length of the longest hair of the indumentum on the abaxial surface of the section.
- Thickness of central sclerenchyma strand (Sc_CT; CO): Thickness of the sclerenchyma at the keel (1 = thin, 2 = medium, 3 = thick, 4 = very thick).
- Thickness of marginal sclerenchyma strand (Sc_MT; CO): Thickness of the sclerenchyma at the margins (1 = thin, 2 = medium, 3 = thick).
- Indumentum of outer epidermis (Ep_Ind; CO): Presence of trichomes on the outer surface of the section (0 = no trichomes, 1 = single trichome, 2 = multiple trichomes).

To account for intraindividual variability, the highest recorded value was used for the habit variables while the average (or mode for ordinal and binary coded variables) of three replicate measurements was used for spikelets and leaves cross-sections.

Spikelets, florets, and other small-scale structures were examined using an Evident Olympus SZ61TR stereomicroscope along with an Evident Olympus EP50 Camera for measurements. Leaf cross sections were studied with a Carl Zeiss Axiostar Plus microscope at 40× to 100× magnification and equipped with a ToupTek USB3.0 eyepiece camera (model S3CMOS05000KPA). Cross sections morphological data were recorded and measured using Toupview software (version 4.11.19728.20211022).

3.5 Multivariate Analysis

Normality of distribution for each quantitative trait was assessed within the taxa using the Shapiro-Wilk test. Although some traits displayed deviations from normality in certain taxa, the analyses proceeded without data transformation. This decision was based on evidence that the selected multivariate methods are reported to be quite robust to the violation of normality (Klecka 1980). Additionally, transforming only selected traits by taxon would compromise comparability and obscure true morphological differences among taxa, while transforming them globally would weaken the perceived variability. To detect redundancies and characters collinearity, pairwise correlations were examined using Spearman's rank coefficient, with a threshold of 0.95.

After the initial processing of the data, patterns of morphological variation were explored using Principal Coordinates Analysis (PCoA) based on Gower's distance matrix (Gower 1971). Gower's distance was preferred over other methods due to the capability of managing different variable types at the same time. This was followed by a jackknife-validated Canonical Discriminant Analysis (CDA) as per

Krzanowski (1990), which included the groupings revealed by the PCoA. Traits that showed no variation within groups were removed from the CDA dataset, reducing the number of characters used, to meet the assumptions of discriminant analysis and avoid any kind of bias or distortion in the final results.

All statistical computations were carried out in R (R Core Team 2025) using RStudio version 2024.4.2.764 (Posit Team 2025) with the MorphoTools2 package (Šlenker et al. 2022).

This procedure has not only been applied to the complete dataset, but also to subsets to look further in detail at the morphological variation between:

- Taxa belonging to the same infrageneric ranks (series)
- Taxa sharing the same ploidy level
- Taxa debated to be synonymous or of doubtful legitimacy

Performing PCoAs and DAs on different groupings of different subsets helped identifying different morphologies and their diagnostic characters more precisely, leading to the definition of clearer boundaries between taxa.

3.6 ddRADseq

Sample DNA was extracted from silica gel-dried leaf material and herbarium specimens of the target species included in the morphometric analyses and ploidy investigations. DNA integrity was verified by 1.5% agarose gel electrophoresis, and concentrations were quantified using a Qubit 2 Fluorometer with the 1X dsDNA HS Assay Kit (Thermo Fisher Scientific). Library preparation followed a modified version of the double-digest RADseq (ddRAD) protocol adapted from Sochor et al. (2024).

Each sample, consisting of 100 ng of genomic DNA, was digested using the restriction enzymes SbfI-HF and MseI in rCutSmart buffer (New England Biolabs) for 3 hours at 37 °C, followed by enzyme inactivation at 80 °C for 20 minutes. Ligation of the corresponding P1 and P2 adapters was carried out overnight at 16 °C using T4 DNA ligase (New England Biolabs), with subsequent heat inactivation at 65 °C for 10 minutes. Unique barcodes were incorporated in the P1 adapters to identify individual samples. Following restriction, DNA concentrations were again assessed with the Qubit fluorometer, and equimolar amounts of digested DNA were pooled into a single library. The pooled material was then purified using 1.2× SPRI magnetic beads and used as a template for PCR enrichment. PCR amplification was performed in four replicates, each 20 µl in volume for 18 cycles, using Phusion HF PCR Mastermix (New England Biolabs) with Illumina-compatible primers P1-i5 (5'-AATGATACGGCGACCACCGA-3') and P2-i7 (5'-CAAGCAGAAGACGGCATACGA-3'). Amplified libraries were then size-selected using SPRI magnetic beads with dual-sided selection (0.5× and 0.9× ratios) in accordance with the protocol provided by the manufacturer. The final ddRAD library was sequenced at the CEITEC genomics core facility (Brno, Czech Republic) on an Illumina NextSeq platform using a 300-cycle mid-output configuration, generating approximately 30 million paired-end reads. Sequence data were demultiplexed and processed using iPyRAD v0.9.97 assembling data *de novo* (Eaton & Overcast 2020). Reads were trimmed for low-quality bases whose score was below Q20. Phred quality score cutoff was set to 33. The read depth for base calling and majority-rule consensus was set to a minimum of 6 and allowed a maximum of 10,000 reads per sample, along with a minimum read length of 35 bp. A clustering threshold of 90% sequence similarity was applied, allowing a single base mismatch in barcodes. The number of consensus sequences allowed was set to a maximum of 6 alleles to accommodate both diploid and hexaploid individuals. Further assembly parameters included allowing 46% of missing data, a maximum of 5% uncalled bases, 5% heterozygosity, and a minimum of 7 samples sharing data at a

given locus (min_samples_locus 7). Additional locus-level thresholds included a maximum of 20% SNPs, 8 indels, and 20% heterozygous sites per locus (max_SNPs_locus 0.2; max_Indels_locus 8; max_shared_Hs_locus 0.2).

Phylogenetic inference based on the assembled loci was conducted using RAxML v.8.2.12 (Stamatakis 2014), applying the GTRCAT substitution model and performing a bootstrap analysis with 1,000 replicates to obtain a maximum likelihood tree. The resulting phylogenetic tree was visualized using FigTree v.1.4.4 (Rambaut 2015).

4 RESULTS

4.1 Sampling

During field seasons, 946 different individuals have been collected from 55 populations across the Alps and Apennines, including the *loci classici* or the closest modern equivalent. Localities were chosen after an investigation of different records, most of which were unverified. Additionally, 41 individuals from other 10 localities were implemented from herbarium material, raising the total count to 987 specimens from 65 populations (Fig. 2; see Suppl. Mat. 3).

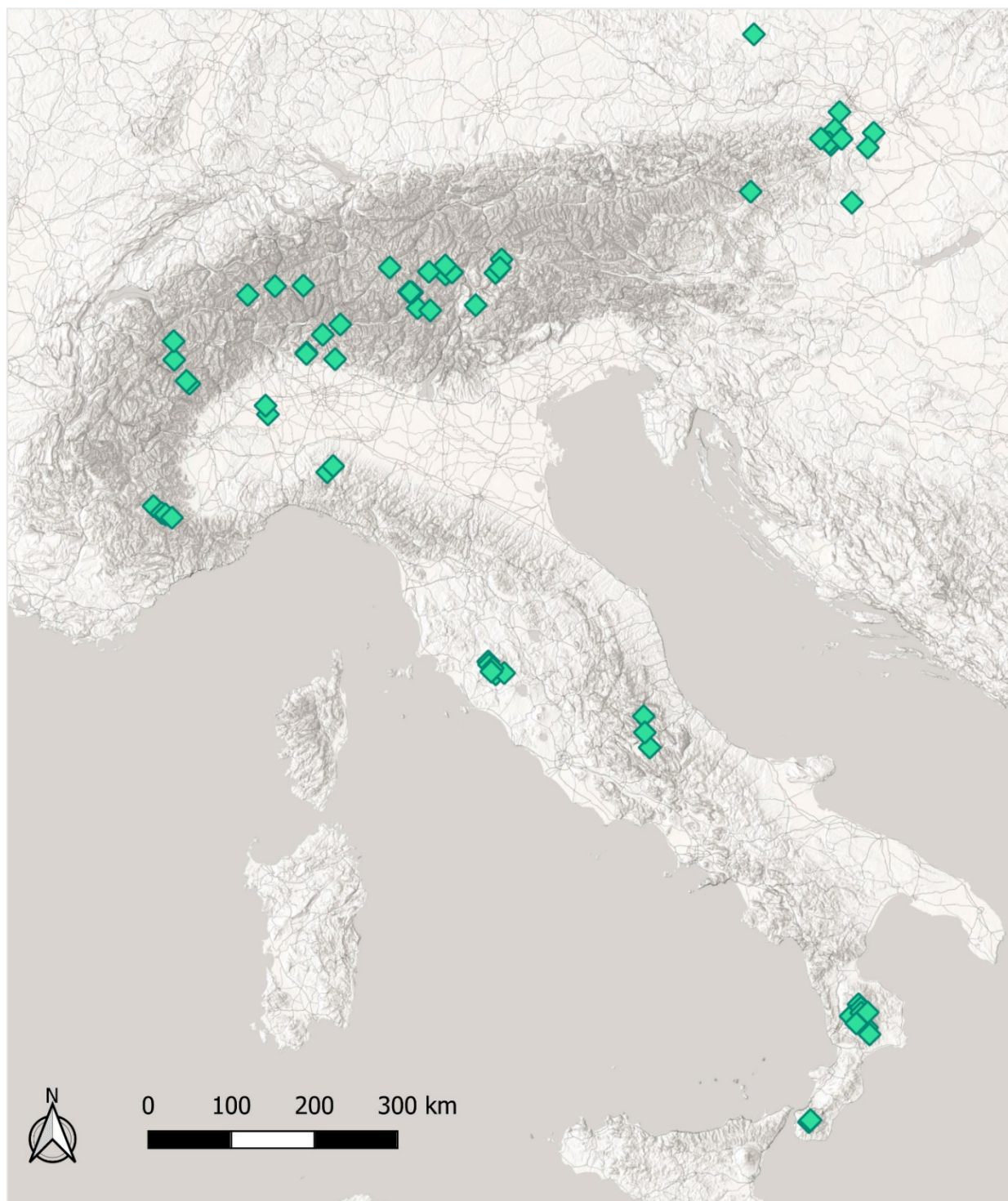


Figure 2: Distribution map of all the sampled material.

However, of the 987 samples:

- 94 were taxa outside of the target group (e.g., *F. laevigata*), collected due to the high difficulty of fescue's identification in the field and erroneous records.
- 109 samples were of two undescribed taxa with ambiguous morphology that could be mistaken as part of the *stricta-valesiaca* complex. Ultimately the first one appears to be closely related to taxa of the ser. *Ovinae*, while the second has been described as part of the *F. marginata* group (Pallanza et al. 2025).
- 90 were individuals of *F. marginata* subsp. *marginata* collected as part of an effort to describe one of the undescribed taxa mentioned in the previous bullet point.
- 112 presented some kind of damage that made it impossible for all characters to be collected (tufts burnt or grazed, shattered spikelets, etc.). Namely, collections from the Trentino Alto-Adige area showed poor spikelet conservation due to them being collected later in the season. But a second collection was conducted to enforce the effectively available samples from this area.

Finally, from the previous samples, 225 plants were chosen as representative of the same 55 populations to be studied via Flow Cytometry (FCM; see Suppl. Mat. 3).

4.2 Nomenclature and type materials

Over 244 names associated with the target taxa have been collected from over 116 different publications. A comprehensive list has been compiled (see Suppl. Mat. 1), associating each name with their original publication, as well as the herbaria conserving the type material when indicated. For basionyms published prior to 1990 (when it became mandatory to indicate the herbaria preserving the type specimens) whose type material couldn't be found, an indication of where the type might be conserved has been reported. When possible, type materials have also been consulted either digitally, via different platforms that offered high quality images of the herbarium sheets (GBIF, JACQ), or personally, when a visit could be arranged (BRNU, G, Z, ZT, W).

4.3 Flow cytometry (FCM)

A total of 225 different plants has been investigated via FCM (1-15 individuals per population depending on the population size and morphological variability). With various exceptions, inferred ploidy was in general concordance with the known ploidy of the assigned taxon in the Alpine area (see Suppl. Mat. 4). Populations freshly sampled in the Apennines on the other hand resulted in unexpected ploidies.

Main discrepancies in the Alps population resulted in:

- A population of few individuals occurring nearby the locus classicus of *F. ticinensis* ("Switzerland, Ticino, Mendrisio: on Mt. Generoso, following the road from S. Nicolao and going upward toward the peak, after the railway bridge near the road margin") turned out to be octaploid instead of hexaploid suggesting its identification as *F. bauzanina* subsp. *rhaetica*.
- A population reported as *F. bauzanina* subsp. *bauzanina* ("Italy, Trentino-Alto Adige, Castelbello: along the road to San Martino al Monte settlement, siliceous rocky grassland (occasionally pastured) surrounded by *Quercus pubescens* forest") was instead a mixture of hexaploids and diploids, with the identification likely referring to the hexaploid plants (reassigned as *F. stricta*

subsp. *sulcata*). Only one plant (MP00577) resulted, with unclear peak as an octaploid-decaploid.

- A single decaploid specimen (311-4) occurring within the population considered to be today's closest to the original locus classicus *F. bauzanina* subsp. *bauzanina* ("Italy, Trentino-Alto Adige, Staben-Stava: about 500 m ENE of the church (bridge) in the village, S exp. siliceous dry rocky grasslands and shrubs (*Fraxinus ornus*, *Zelkova*, *Ulmus minor*) along the road to Juval castle"). However, none of the dried specimen collected and analyzed from that location was morphologically assimilable to *F. guinochetii*. It is to be assessed if this is some sort of genetic aberration or if *F. guinochetii* actually occurs within the area with few sparse and rare individuals.
- An heptaploid *F. bauzanina* subsp. *rhaetica* (316-1) from the locus classicus population. Bidault (1967) reported heptaploids from this area but later investigations failed to find any (Arndt 2008). According to Arndt (2008), heptaploids in this area are casual hybrids of *F. bauzanina* subsp. *rhaetica* × *F. stricta* subsp. *trachyphylla*. However, no plant sampled resulted hexaploid and with one of the parental species missing it's difficult to confirm whether 316-1 is of hybridogenous origin.

Other lesser discrepancies, such as unclear peaks (7-8x, 8-10x, etc.) are assumed to be due to the degradation of plant material, which occurred during massive collections where plants may not have dried properly in the press.

For what concerns the Apennines, all freshly sampled populations except for the *F. valesiaca* population ("Italy, Abruzzo, Pescina: in the steppe at the beginning of the trail that goes from Pescina towards the Mt. Faito peak. Circa 600 m SE from the northern outskirts of the village.") resulted in an inferred ploidy completely different from those expected. The two populations reported as *F. stricta* subsp. *sulcata* in Abruzzo are tetraploid instead of hexaploid and showcased a morphology that was more related to the ser. *Trachyphyllae* taxa than to *F. stricta* subsp. *sulcata* and other ser. *Valesiaceae* species. Populations of supposedly *F. stricta* subsp. *trachyphylla* also showed ploidy discrepancies as the two sampled populations growing on ophiolitic substrates in the northern Apennines resulted to be octaploids.

4.4 Morphometry

Before any analysis, some samples were excluded from the dataset for their extremely different morphology, which was not typical of any taxa of the *stricta-valesiaca* complex. Namely the hexaploid populations from the Sila plateau and the octaploids from the northern Apennines. The hexaploid populations from the Sila turned out to be an undescribed taxon from the *F. marginata* group despite their unusual leaf cross-section anatomy and ploidy could create confusion with *F. stricta* subsp. *trachyphylla* (Pallanza et al. 2025). The octaploids from the northern Apennines were considered to be *F. stricta* subsp. *trachyphylla* as well, but with high probability they are also an undescribed taxon morphologically more suitable to be part of the ser. *Ovinae* than the ser. *Trachyphyllae* or ser. *Valesiaceae*.

Also, while the original concept of Pawlus of the ser. *Trachyphyllae* included *F. stricta* subsp. *stricta* due to its leaves cross-sections presenting a continuous sclerenchyma ring, other features were more typical of the ser. *Valesiaceae* (number of vascular bundles, number of ridges and number furrows on the adaxial surface). Additionally, unusual forms where the sclerenchyma ring would get in interrupted discrete strands, were more reminiscing of *F. stricta* subsp. *sulcata*, and had nothing in common with

taxa of the ser. *Trachyphyllae*. For these reasons *F. stricta* subsp. *stricta* was preemptively treated as part of the ser. *Valesiaceae* in this morphological study.

Overall species complex morphology

The first two components of the exploratory PCoA cover 31.71% of the dataset variability (Fig. 3). At first glance two main clusters of taxa can be identified: the low ploidy species (the diploid *F. valesiaca* and the tetraploids, *F. pseudodalmatica* and *F. sp. nova*) and the taxa with higher ploidy levels (The hexaploids *F. stricta* subsp. *stricta*, *F. stricta* subsp. *sulcata*, *F. stricta* subsp. *trachyphylla*, *F. brevipila* and *F. ticinensis*, the octaploids *F. bauzanina* subsp. *bauzanina* and *F. bauzanina* subsp. *rhaetica*, and the decaploid *F. guinochetii*).

Within the lower ploidies cluster a clear separation can be observed between *F. valesiaca* and *F. sp. nova*, determined by leaf anatomy differences, such as the number of vascular bundles, the leaf cross section shape and the sclerenchyma thickness. The few available samples of *F. pseudodalmatica* strongly overlap with the *F. valesiaca* cluster in the area facing the higher ploidy cluster. This is due to the high overall similarities between *F. valesiaca* and *F. pseudodalmatica* but the latter having larger spikelets and leaves due to the higher ploidy level.

In the higher ploidies cluster, a succession of taxa is observable, which follows the morphological separation made by Pawlus (1985) in ser. *Valesiaceae* (*F. stricta* subsp. *stricta*, *F. stricta* subsp. *sulcata* and *F. bauzanina* subsp. *bauzanina*) and ser. *Trachyphyllae* (*F. stricta* subsp. *trachyphylla*, *F. bauzanina* subsp. *rhaetica*, *F. brevipila*, *F. guinochetii* and *F. ticinensis*). In the *Valesiaceae* side of the cluster, the most distinct and marginal is the hexaploid *F. stricta* subsp. *stricta*. The taxon distinguishes itself from the others for the much more densely pubescent lemmas, base of the panicle and tiller leaves sheaths, the frequent tendency to form more frequently a complete sclerenchyma ring, the rounder outline of the cross-section and the more scabrid leaves. Its position in the scatterplot also confirms the chosen relocation from the ser. *Trachyphyllae* to the ser. *Valesiaceae* based on early observations.

F. stricta subsp. *sulcata* and *F. bauzanina* subsp. *bauzanina* completely overlap with each other and fall between the *F. stricta* subsp. *stricta* sub-cluster and the taxa of the ser. *Trachyphyllae*. These taxa can be quite variable, generally presenting three discrete sclerenchyma strands but occasionally presenting two more additional minor strands and more rarely forming a complete ring. The main morphological difference between the two taxa is restricted to the frequency with which the sclerenchyma strands fuse into a complete ring, which more commonly occurs in *F. bauzanina* subsp. *bauzanina* rather than *F. stricta* subsp. *sulcata*. However, it's still not enough to make a clear distinction without the aid of FCM. No clear boundaries are visible between the high ploidy taxa of the ser. *Trachyphyllae* at this stage with the only exception of *F. guinochetii* which appears significantly larger than any other taxon in the series.

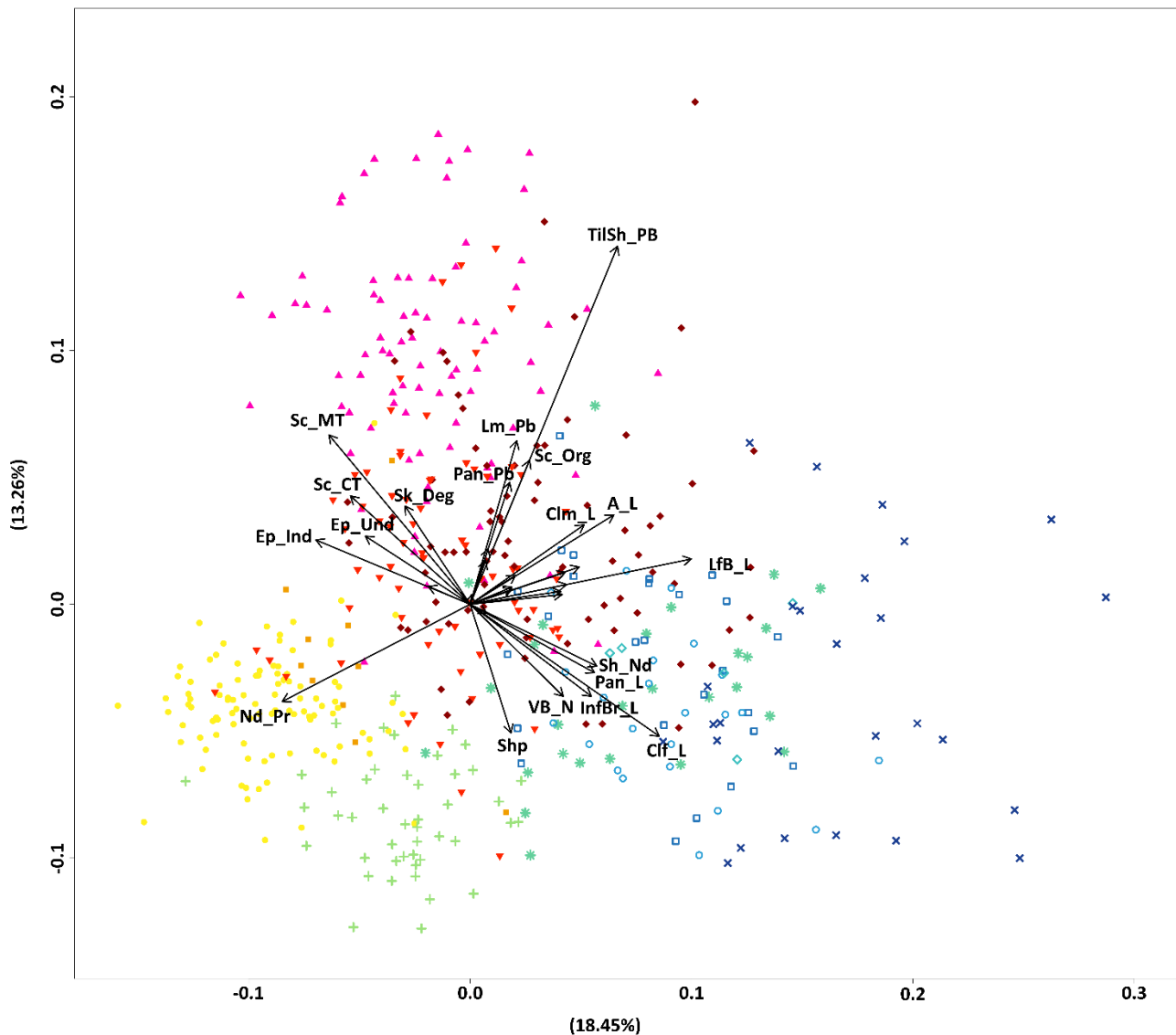


Figure 3: Biplot for the exploratory PCoA. Taxa are represented according to the following symbology: ● = *F. valesiaca*; ■ = *F. pseudodalmatica*; ▲ = *F. stricta* subsp. *stricta*; ▼ = *F. stricta* subsp. *sulcata*; ◆ = *F. bauzanina* subsp. *bauzanina*; + = *F. sp. nova*; * = *F. stricta* subsp. *trachyphylla*; ◇ = *F. brevipila*; ○ = *F. ticinensis*; □ = *F. bauzanina* subsp. *rhaetica*; × = *F. guinochetii*.

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The PCoA for the ser. *Valesiaceae* subset accounts for 34.83% of the variability by its first two axes (Fig. 4). Three main clusters can be easily recognized: the first consisting of the low ploidy taxa (*F. valesiaca* and *F. pseudodalmatica*), the second representing *F. stricta* subsp. *stricta* and the third composed by *F. bauzanina* subsp. *bauzanina* and *F. stricta* subsp. *sulcata*. Again, *F. stricta* subsp. *stricta* is strongly characterized by a denser pubescence of the tiller leaves sheaths and lemmas, and the sclerenchyma forming a complete ring but for rare exceptions. The lower ploidy cluster is characterized by being visibly more pruinose, especially near the nodes, and secondly by the overall smaller size of the cross-sections and floral elements. A gradient of the taxa sharing overall morphology but different ploidy levels can be observed starting from *F. valesiaca* ($2n=2x=14$). The few samples of *F. pseudodalmatica* ($2n=4x=28$) follow this pattern along with *F. stricta* subsp. *sulcata* ($2n=6x=42$) and *F. bauzanina* subsp. *bauzanina* ($2n=8x=56$). However, because ploidy and size don't follow a strictly linear correlation, differences between *F. stricta* subsp. *sulcata* and *F. bauzanina* subsp. *bauzanina* are rather weak compared to

those among other taxa and result in the two clusters overlapping for a great part of their area. Finally, *F. bauzanina* subsp. *bauzanina* and *F. stricta* subsp. *sulcata* also appear as larger plants, with longer culms, panicles and leaves compared to *F. stricta* subsp. *stricta*, despite the latter being a hexaploid taxon.

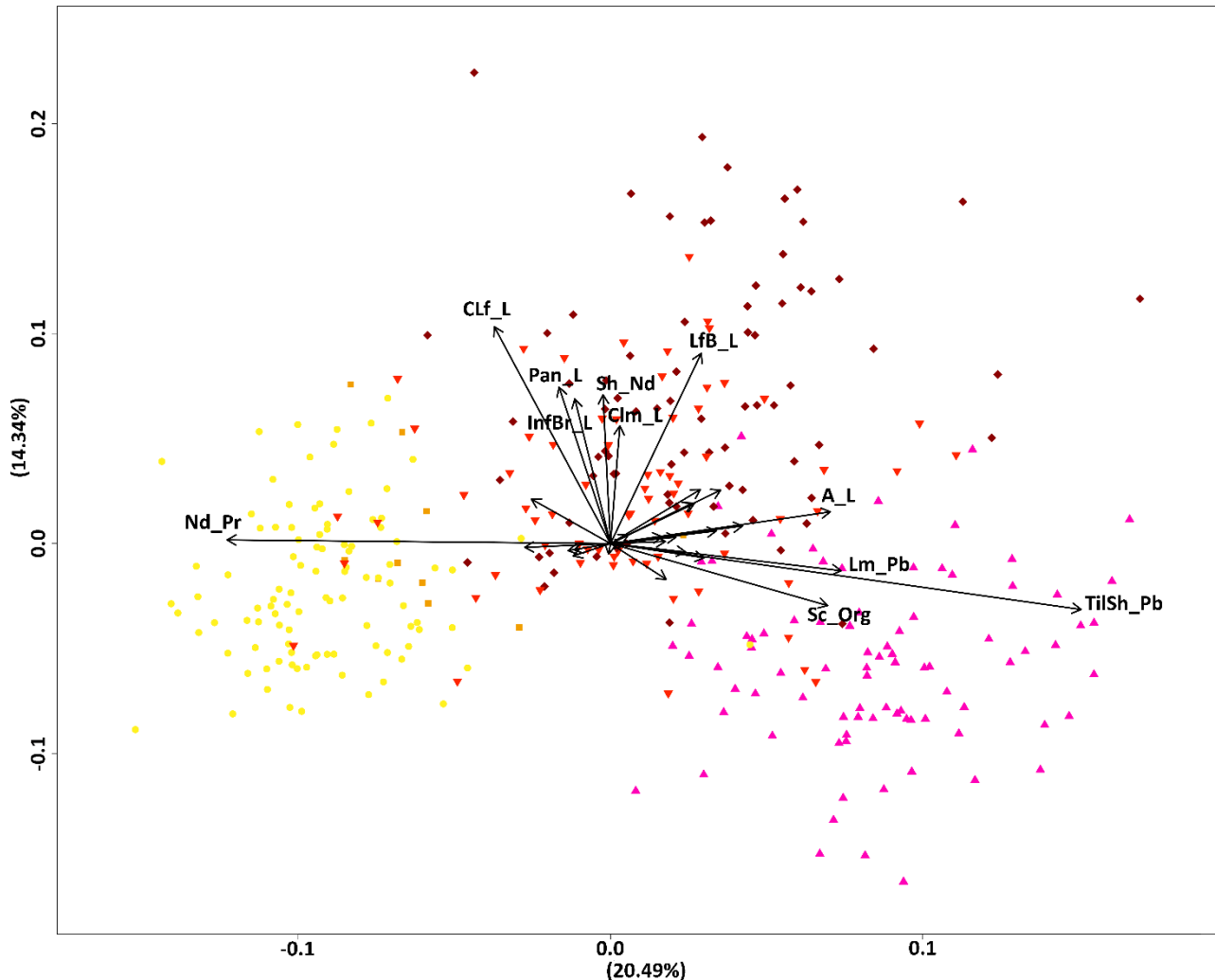


Figure 4: Biplot for the PCoA performed on the ser. *Valesiaceae* subset. Taxa are represented according to the following symbology: ● = *F. valesiaca*; ■ = *F. pseudodalmatica*; ▲ = *F. stricta* subsp. *stricta*; ▼ = *F. stricta* subsp. *sulcata*; ◆ = *F. bauzanina* subsp. *bauzanina*.

Ser. *Trachyphyllae* M.Pawlus

The ser. *Trachyphyllae* PCoA first two components cover 39.86% of the dataset variability (Fig. 5). The scatterplot shows two main clusters, the more compact *F. sp. nova* cluster and the high ploidy taxa cluster, which loosely follow a gradient reflecting the incrementing ploidy of the different taxa. *F. sp. nova* is clearly distinguished by the overall smaller spikelets, awns and leaf cross-sections, but particularly by the strongly scabrid leaves, which are also observable as a high density of teeth in the abaxial indumentum of the leaf cross-section. The other taxa follow a gradient dictated by their habitus: the higher the ploidy the taller and larger the plant (culms, leaves, panicles). However, among these *F. stricta* subsp. *trachyphylla* seems to be characterized by denser and more frequent pubescence of tiller leaves sheaths, lemmas and panicle compared to other taxa, as well as the tendency of the sclerenchyma to be thinner and more frequently developing in a complete or shortly interrupted ring. *F.*

ticinensis and *F. brevipila*, which are considered to be somewhat dubious taxa due to the strikingly similar morphology and the shared ploidy level with *F. stricta* subsp. *trachyphylla*, appear to fall on one end of the latter's cluster and fail to neatly separate themselves on any morphological basis. *F. bauzanina* subsp. *rhaetica* and *F. guinochetii* perfectly follow along the gradient dictated by ploidy and plant size.

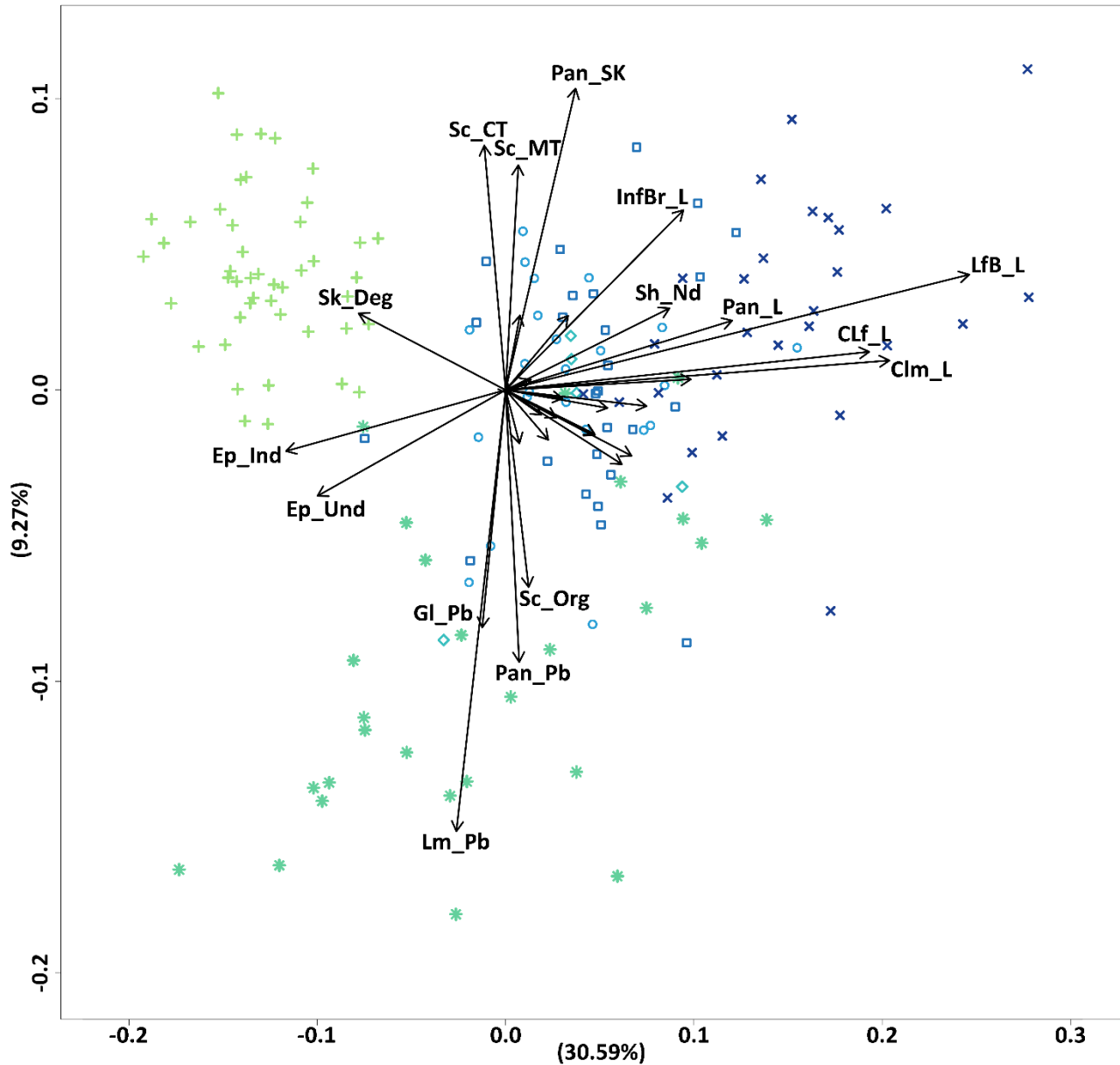


Figure 5: Biplot for the PCoA performed on the ser. *Trachyphyllae* subset. Taxa are represented according to the following symbology: + = *F. sp. nova*; * = *F. stricta* subsp. *trachyphylla*; ◇ = *F. brevipila*; ○ = *F. ticinensis*; □ = *F. bauzanina* subsp. *rhaetica*; × = *F. guinochetii*.

To further investigate the status of the hexaploid taxa, a second PCoA was performed (Fig. 6). Again, no significant clustering occurs among *F. stricta* subsp. *trachyphylla*, *F. ticinensis* and *F. brevipila*, while the hexaploid taxa of ser. *Valesiaca*, kept as a clear outgroup in this instance, are still perfectly distinguishable.

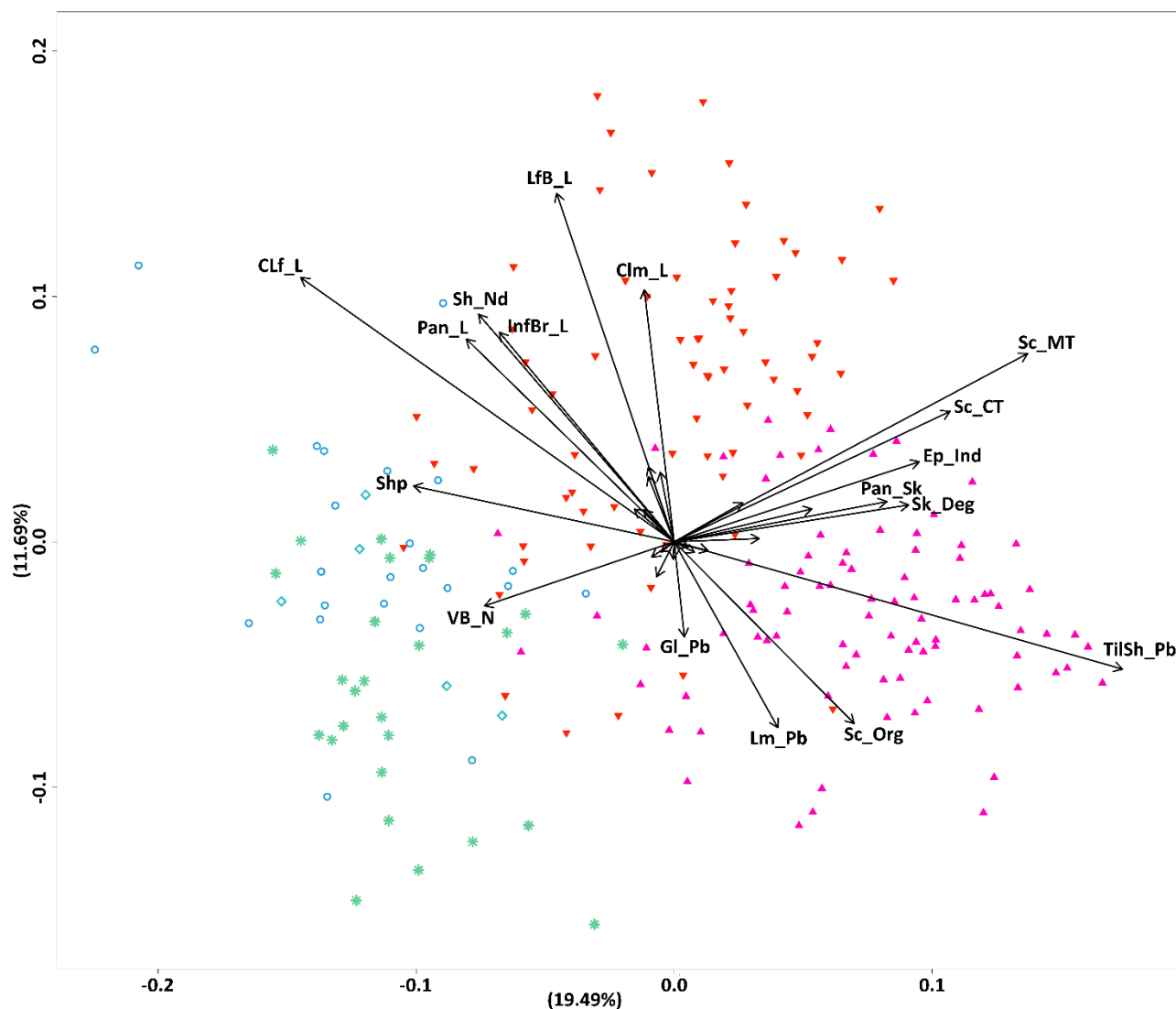


Figure 6: Biplot for the PCoA performed on the hexaploid taxa subset. Taxa are represented according to the following symbology: ▲ = *F. stricta* subsp. *stricta*; ▼ = *F. stricta* subsp. *sulcata*; * = *F. stricta* subsp. *trachyphylla*; ◆ = *F. brevipila*; ○ = *F. ticinensis*.

4.5 Groups testing and assessment

For each explorative PCoA, a jackknifed discriminant analysis (CDA) was run to test the grouping hypotheses made on the basis of the clusters individuated and their related significant characters.

Overall species complex morphology

Following the exploratory PCoA, four main clusters were individuated: the low ploidy *Valesiaceae* (*F. valesiaca* and *F. pseudodalmatica*), the high ploidy *Valesiaceae* (*F. stricta* subsp. *stricta*, *F. stricta* subsp. *sulcata*, and *F. bauzanina* subsp. *bauzanina*) the low ploidy *Trachyphyllae* (comprising only *F. sp. nova*) and the high ploidy *Trachyphyllae* (*F. stricta* subsp. *trachyphylla*, *F. bauzanina* subsp. *rhaetica* and *F. guinochetii*).

The CDA based on the four clusters individuated when exploring the morphology of all taxa together (Fig. 7) shows good separation among these groups. Size (quantitative characters related culms, leaves, panicles, spikelets and florets) appear as a strong indicator of higher ploidies as expected. The morphological separation between taxa of ser. *Trachyphyllae* and ser. *Valesiaceae* also resulted clear and

well defined. Individuals classified as ser. *Trachyphyllae* are characterized by a more elongated shape of the leaf cross-section and a higher number of vascular bundles while ser. *Valesiaceae* present rougher, more scabrid leaves and a sclerenchyma that develops in thicker strands composed by a higher number of cells layers. Leaves cross-sections from ser. *Trachyphyllae* also may present more than three ridges (one central and two or more lateral) but since ser. *Valesiaceae* always presents three with no variations within all the 345 individuals, the character had to be removed to avoid distortions and violations of the assumptions for the CDA. Finally, characters related to pruinosity are more marked in lower ploidies taxa of ser. *Valesiaceae*.

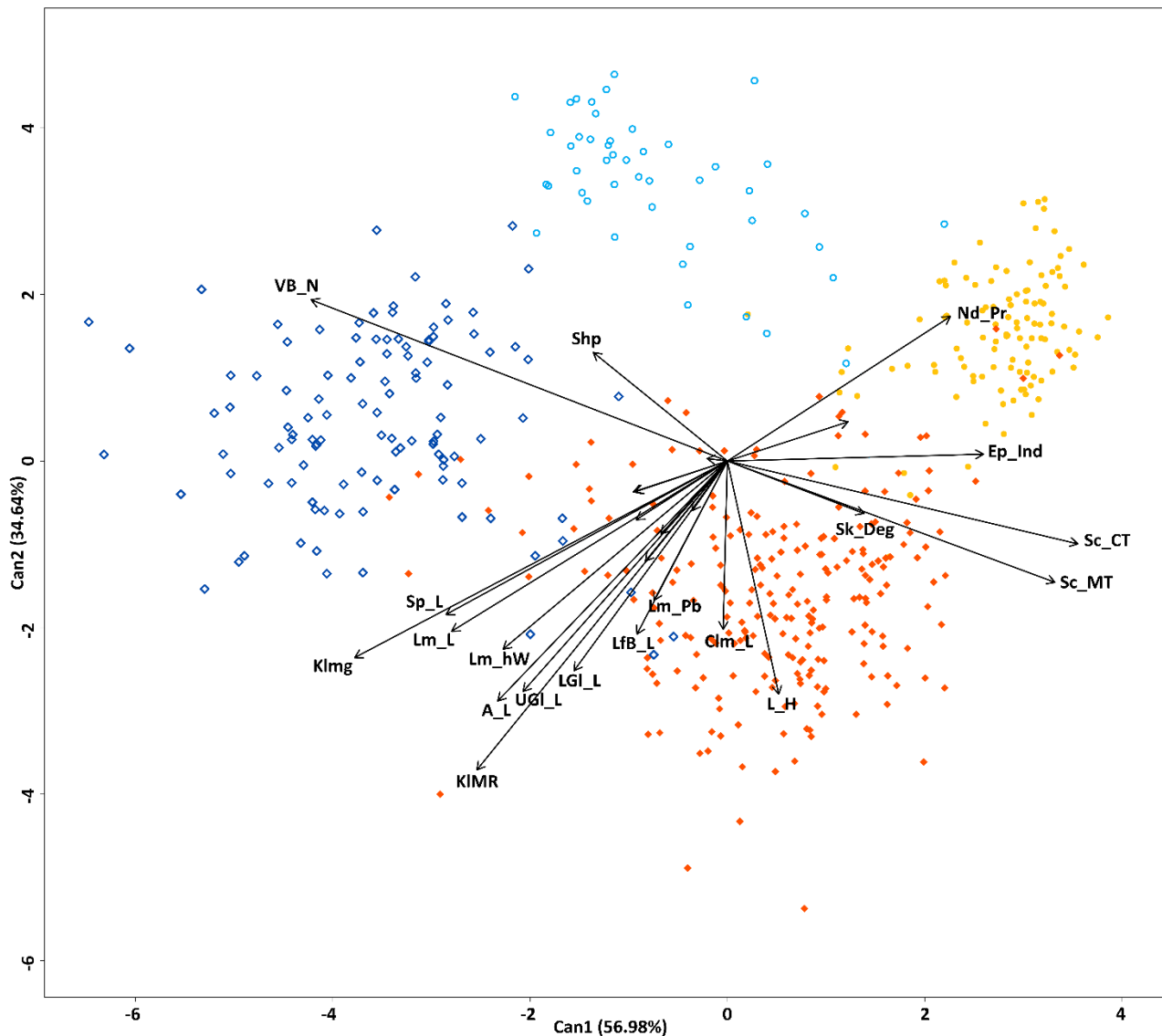


Figure 7: Biplot for the DA performed. Taxa are represented according to the following symbology: ● = Low ploidy *Valesiaceae* (*F. valesiaca* and *F. pseudodalmatica*); ◆ = High ploidy *Valesiaceae* (*F. stricta* subsp. *stricta*, *F. stricta* subsp. *sulcata*, and *F. bauzanina* subsp. *bauzanina*); ○ = Low ploidy *Trachyphyllae* (*F. sp. nova*); ◆ = High ploidy *Trachyphyllae* (*F. stricta* subsp. *trachyphylla*, *F. bauzanina* subsp. *rhaetica* and *F. guinochetii*). Low ploidy are taxa with $2n \leq 4x$ and high ploidy with $2n \geq 6x$.

Discriminatory functions based on these characters and visualized in the scatterplot showed a high percentage rate of correct classification as shown in the confusion matrix (Tab. 1).

Taxon	N	as.Val_L	as.Val_H	as.Tra_L	as.Tra_H	Correct	correct (%)
Val_L	111	107	3	1	0	107	96.40
Val_H	234	15	204	2	13	204	87.18
Tra_L	46	2	0	44	0	44	95.65
Tra_H	109	0	5	3	101	101	92.66
Total	500	124	212	50	114	456	91.20

Table 1: Confusion matrix for the DA performed. Taxa have been grouped according to the trends observed in the first PCoA. Groups are coded as follow, where low ploidy are taxa with $2n \leq 4x$ and high ploidy with $2n \geq 6x$: Val_L = Low ploidy *Valesiaceae*; Val_H = High ploidy *Valesiaceae*; Tra_L = Low ploidy *Trachyphyllae*; Tra_H = High ploidy *Trachyphyllae*.

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Despite the large overlap of *F. stricta* subsp. *sulcata* and *F. bauzanina* subsp. *bauzanina* clusters in the PCoA scatterplot, the taxa have been also kept separated for the DA due to their different ploidy.

The DA analysis performed on the taxa of the ser. *Valesiaceae* (Fig. 8) shows three main clusters which can be identified in *F. stricta* subsp. *stricta*, *F. valesiaca* and a third group consisting of *F. stricta* subsp. *sulcata* and *F. bauzanina* subsp. *bauzanina*. The few individuals of *F. pseudodalmatica* fall between the last two clusters, leaning more on the *F. stricta* subsp. *sulcata* and *F. bauzanina* subsp. *bauzanina* one. Again, *F. stricta* subsp. *stricta* is easily defined by the overall much denser pubescence of the plant when compared to other taxa, and the frequency with which the sclerenchyma forms a complete thickened ring. Visible pruinescence, smaller spikelets and thinner leaves are again the major characters characterizing *F. valesiaca*. The remaining taxa follow the morphological trend of distinguishing themselves, like *F. valesiaca*, from *F. stricta* subsp. *stricta* for being generally glabrous or very sparsely pubescent, and having the sclerenchyma organized in discrete strands rather than confluent into a ring. A morphological gradient mainly dictated by quantitative variables related to spikelets and leaves cross-sections can be identified, starting with *F. pseudodalmatica* close to the *F. valesiaca* cluster and going all the way to *F. bauzanina* subsp. *bauzanina* following the ploidy levels of the taxa involved.

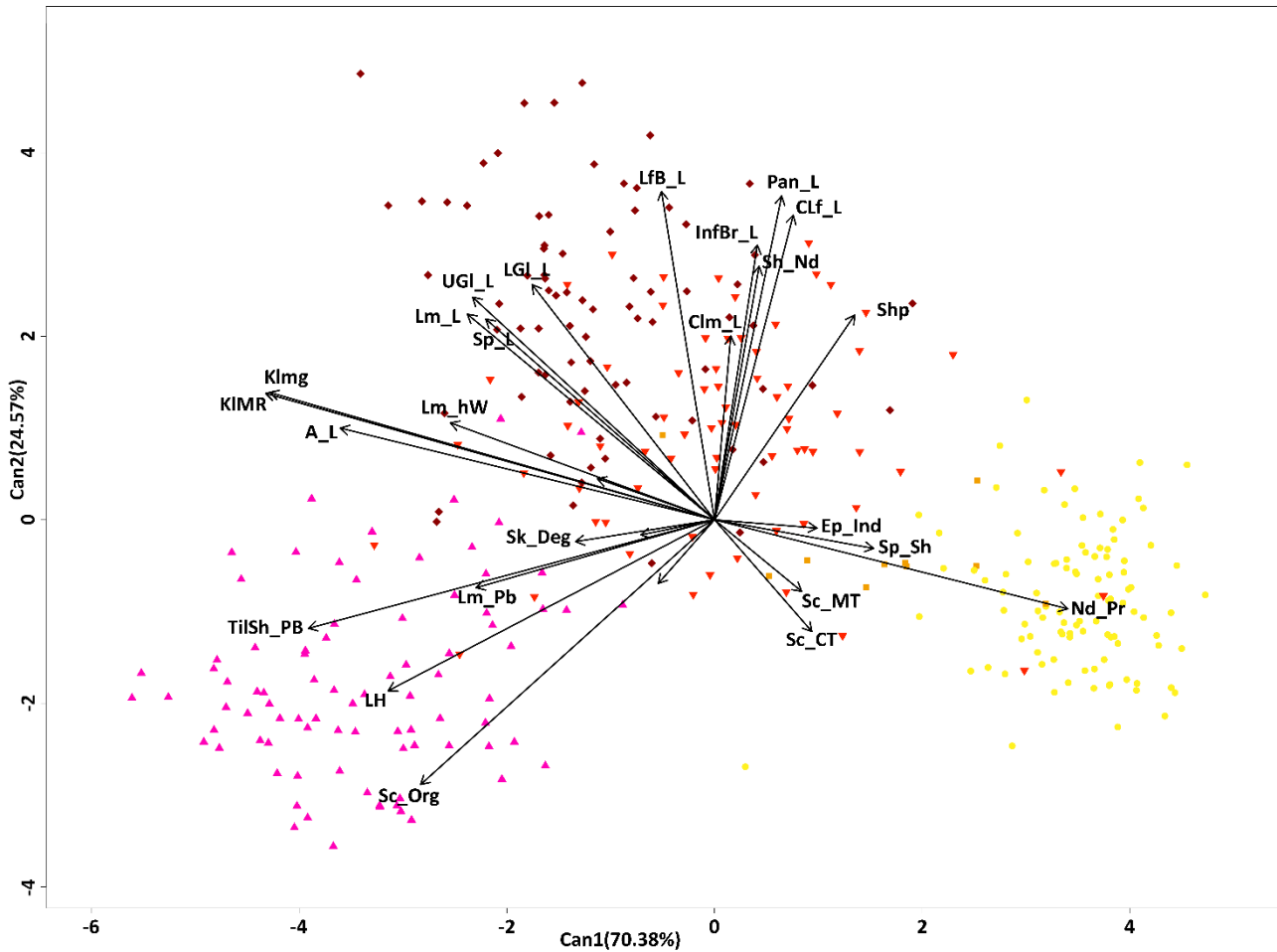


Figure 8: Biplot for the DA performed on the ser. *Valesiacaе* subset. Taxa are represented according to the following symbology: ● = *F. valesiaca*; ■ = *F. pseudodalmatica*; ▲ = *F. stricta* subsp. *stricta*; ▼ = *F. stricta* subsp. *sulcata*; ◆ = *F. bauzanina* subsp. *bauzanina*.

The situation observed in the scatterplot perfectly matches the discriminatory capabilities of the functions. As a matter of fact, from the confusion matrix (Tab. 2) we can extrapolate that, while *F. stricta* subsp. *stricta* and *F. valesiaca* individuals were correctly reassigned for the great part, the other taxa of ser. *Valesiacaе* largely overlap with a correct identification rate that goes from 57.75% to 73.08%.

Taxon	N	as.F_val	as.F_psd	as.F_str	as.F_sul	as.F_bau	correct	correct (%)
F_val	101	93	6	0	2	0	93	92.08
F_psd	10	2	6	0	2	0	6	60.00
F_str	85	0	0	76	4	5	76	89.41
F_sul	71	5	11	3	41	11	41	57.75
F_bau	78	0	2	2	17	57	57	73.08
Total	345	100	25	81	66	73	273	79.13

Table 2: Confusion matrix for the DA performed on the ser. *Valesiacaе* subset. Taxa are coded as follows: F_val = *F. valesiaca*; F_psd = *F. pseudodalmatica*; F_str = *F. stricta* subsp. *stricta*; F_sul = *F. stricta* subsp. *sulcata*; F_bau = *F. bauzanina* subsp. *bauzanina*.

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The DA performed on the ser. *Trachyphyllae* (Fig. 9) subset shows excellent discrimination between the *F. sp. nova* cluster and the other taxa. Besides the clearly smaller size due to the species being the only tetraploid in the Italian taxa of the series, *F. sp. nova* also sets itself aside for the strongly scabrid leaves, rich in barbs, that can easily be observed even in the cross-section.

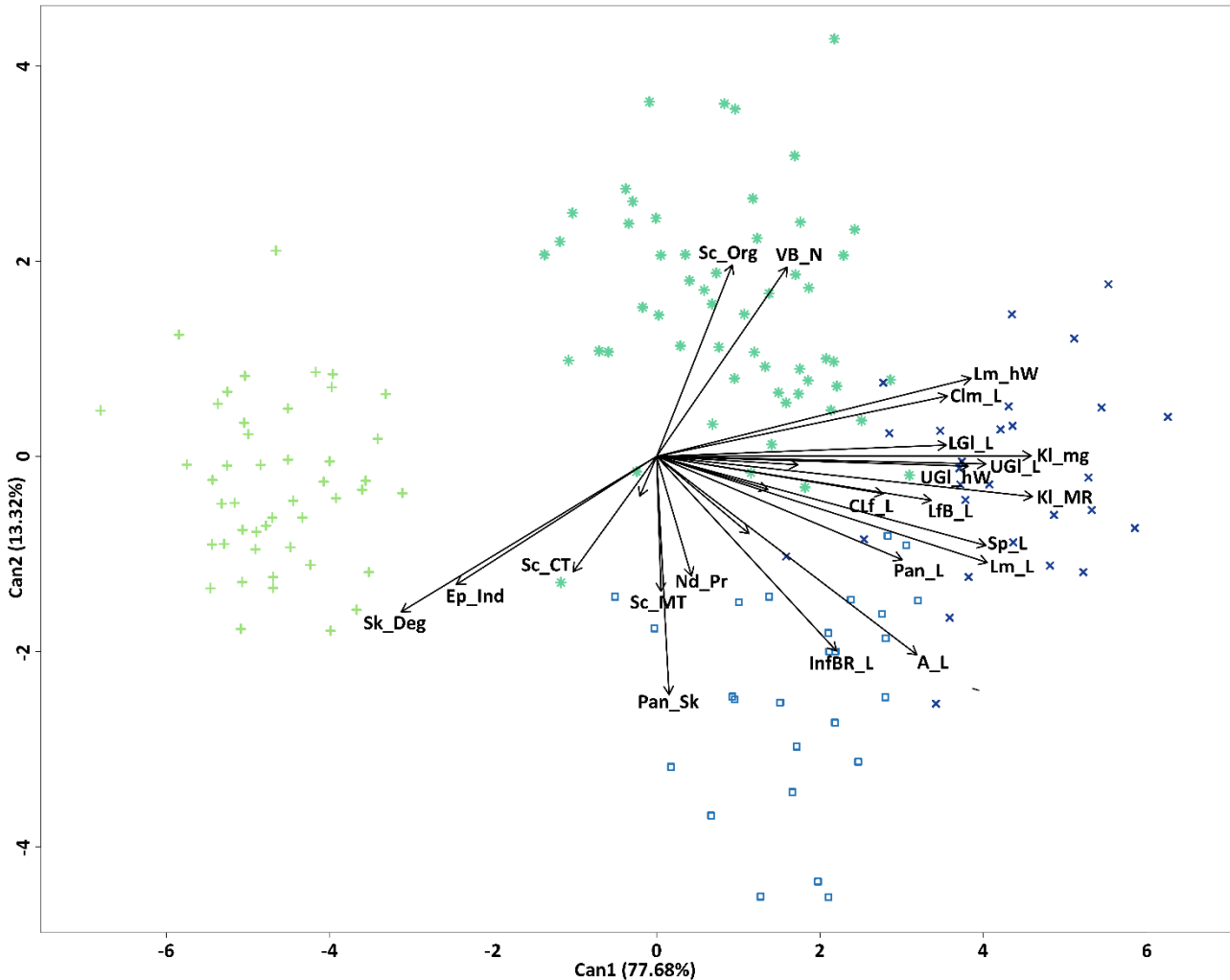


Figure 9: Biplot for the DA performed on the updated ser. *Trachyphyllae* subset. Taxa are represented according to the following symbology: $+$ = *F. sp. nova*; $*$ = *F. stricta* subsp. *trachyphylla*; $\square$ = *F. bauzanina* subsp. *rhaetica*; $\times$ = *F. guinochetii*. *F. brevipila* and *F. ticinensis* have been reassigned to *F. stricta* subsp. *trachyphylla* due to the results observed in the dedicated PCoAs.

Higher ploidy taxa follow a gradient for what concerns quantitative characters going from *F. stricta* subsp. *trachyphylla* (which now includes also *F. brevipila* and *F. ticinensis*, given the poor morphological and karyological differentiation), through *F. bauzanina* subsp. *rhaetica* and finishing with *F. guinochetii*. However, the clusters do not follow a strict linear direction but are rather influenced by other qualitative characters, moving the groups from one side or the other of the general line that is described by the quantitative characters. Namely, *F. bauzanina* subsp. *rhaetica* appears to be rougher in the apical part of the culm, below the panicle, and generally more pruinose, while *F. stricta* subsp. *trachyphylla* tends to have a more developed sclerenchyma and a higher number of vascular bundles in the leaf cross-section.

The overall discriminatory capacity of the functions shows excellent results as reported in the confusion matrix (Tab. 3), showing a high rate of correctly classified samples for each taxon.

Taxon	N	as.F_nov	as.F_tra	as.F_rha	as.F_gui	correct	correct (%)
F_nov	46	46	0	0	0	46	100.00
F_tra	55	1	46	5	3	46	83.64
F_rha	26	0	1	25	0	25	96.15
F_gui	28	0	0	1	27	27	96.43
Total	155	47	47	31	30	144	92.90

Table 3: Confusion matrix for the DA performed on the *ser*. Trachyphyllae subset. Taxa are coded as follows: F_nov = *F. sp. nova*; F_tra = *F. stricta* subsp. *trachyphylla*; F_rha = *F. bauzanina* subsp. *rhaetica*; F_gui = *F. guinochetii*.

4.6 ddRADseq

Although ddRADseq is a possibility that emerged and could be explored only in the final year of the project, early results for 14 samples and a preliminary phylogenomic tree are available as part of a research paper published during the PhD. These results helped assess the phylogenetic position of an undescribed taxon (*Festuca silana* Ardenghi, Pallanza & Foggi) and therefore include taxa (but not all the ones considered in the PhD) from the *stricta-valesiaca* complex and *F. marginata* subsp. *marginata*.

From the selected samples, a total of 67,353 loci were initially called, which was reduced to 2,713 loci after applying filtering criteria. The primary factor contributing to this reduction was the requirement that a locus had to be present in at least seven of the 13 samples. Following an initial round of analyses, one sample (F14) exhibiting low sequencing coverage was excluded based on quality assessment, and all analyses were subsequently repeated without it. The number of retained loci per sample ranged from 1,526 to 2,096. The resulting phylogenetic tree (Fig. 10) confirmed the phylogenomic position of the undescribed taxon as part of the *F. marginata* group, with most nodes receiving high bootstrap support.

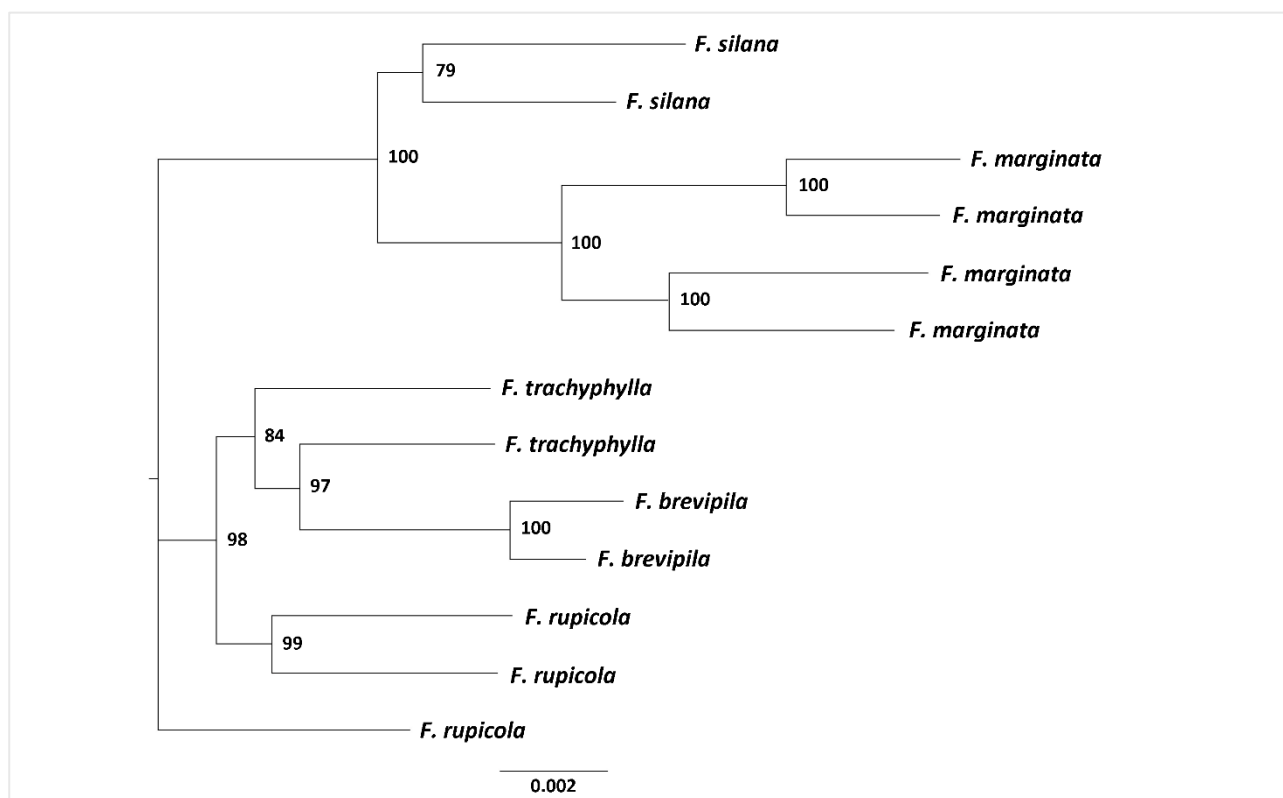


Figure 10: Phylogenetic tree of thirteen *Festuca* individuals, constructed using RAxML based on 2,713 loci and maximum likelihood estimation. The numbers in the nodes represent bootstrap values (%) from 1,000 replicates.

5 DISCUSSION

Taxonomical and nomenclatural history

What emerged from the bibliographical research is a very fragmented and dissonant taxonomical history for the *stricta-valesiaca* complex. With over 251 names coming from many different authors just for Europe, especially with most of them describing lower taxonomical ranks (see Suppl. Mat. 1), It's clear that there's a lot to consider when trying to envision the full picture. The lack of strict nomenclatural rules (if any at all for the oldest publications) combined with numerous and scattered authors all around Eurasia led to an inevitable inflation of taxa names and combinations. A pivotal role has also been played by transitional forms, high variability of widely distributed taxa and by the overall complexity of the *stricta-valesiaca* complex itself. Many names appear in publications of limited accessibility, due to the scarce availability and even for the language, as in earlier times most authors published under their mother tongue. Proving the redundancy of these names is, however, quite a strenuous work. While some typification works have already been done (Wilkinson & Stace 1988; Foggi & Signorini 2003; Šmarda et al. 2009), a significant part of the original materials associated with the names is still to be searched in different herbaria, as the strict requirement for a holotype was established by the ICBN only in 1990. Without a designated type to compare to the currently accepted species types, verifying the taxonomical status of a name becomes impossible and only shallow suppositions can be made on the protologue alone. For these reasons, bringing order to the current amass of names would require a proper and dedicated nomenclatural work with most of the effort directed in individuating the missing original materials, likely scattered among those herbaria that still lack freely accessible digitalized catalogues of their collections.

Integrative taxonomy of the complex

Overall, the combination of morphological and karyological features together supports most of the *a priori* taxa taken in exam, although some grey areas can be found. As previously reported by some authors, transitional morphologies can be observed within different polyploids of the same morphological series (Pils 1984, Arndt 2008) and within same ploidies taxa of the different morphological groups (Kozłowska 1925). This is probably due to the relatively recent origin of the taxa, which managed to separate themselves reproductively through polyploidization phenomena, but have yet to significantly diverge morphologically (Pils 1984). The only morphological variation observable within series is in size difference, rather than organization and morphological features (with the only exception being of *F. stricta* for the ser. *Valesiaca*). This is because of the influence of genome size, and thus ploidy levels, on overall features size in fescues, both macro- and microscopic (Rewicz et al. 2018). However, this difference in dimension becomes finer and finer as the ploidy levels of the compared taxa grow (see Suppl. Mat 5) making identification between higher ploidies individuals more challenging. This has been particularly clear with the difficulties of the DA functions in separating *F. pseudodalmatica* ($2n=4x=28$), *F. rupicola* ($2n=6x=42$) and *F. bauzanina* subsp. *bauzanina* ($2n=8x=56$) from each other, because of the shared morphology but different ploidy levels. The same gradient on the quantitative characteristics occurs in the taxa of the ser. *Trachyphyllae* as well, but some key qualitative features help separate the different taxa in more discrete groups as seen in the morphometric analyses (e.g., *F. rhaetica* being visibly more pruinous).

Of the original taxa considered in the study, *F. brevipila* and *F. ticinensis* were the one that showed no significant morphological or karyological differentiation from an already existing taxon, *F. trachyphylla* (which would be the name with the highest priority among these three). *F. brevipila* was described by

Tracey (1977) as differentiating from *F. trachyphylla* by “its shorter stems and leaves, the very short hairs on the upper leaf surface, the strong variability of the lengths of even adjacent stomatal openings, the shorter panicle, and the relatively small number of spikelets per panicle”. These differences were not observed on the samples collected (see Suppl. Mat. 5) and neither in previous studies that concerned the two taxa (Wilkinson & Stace 1988). As for *F. ticinensis*, in the original description Markgraf-Dannenberg (1976) does not provide any kind of diagnosis, and the holotype, stated to be preserved at the Zurich herbarium (Z) in the protologue, is missing from both the type collections and the Markgraf-Dannenberg uncatalogued private material, rendering difficult to make a final statement on the matter. However, the samples here analyzed came from localities based on specimens determined by Markgraf-Dannenberg herself, and just like for *F. brevipila*, no significant differentiation can be observed from *F. trachyphylla* (see Suppl. Mat. 5). With no morphological and karyological distinction among the three taxa there’s no reason to think that these are in fact three separate species, but rather a single widely distributed and morphologically variable taxon. Considering this, both at specific (here proposed) and subspecific rank, the *trachyphylla* epithet is the oldest and the one with the highest priority. However, few things should be noted regarding *F. trachyphylla*. Among the other names of the *F. stricta-valesiaca* complex, *F. trachyphylla* has been for long one of difficult definition, due to its high morphological variability and difficulties related to its identification. This is also reflected in our current knowledge about its distribution due to it being commonly reported as *F. duriuscula* sensu Auct. (Foggi et al. 2017), despite the name being a synonym of *F. rubra* (Euro+Med 2006). The situation is also furtherly complicated by the presence of numerous commercial varieties sold under the name of “hard fescue” for many uses (Foggi et al. 2017). These cultivars may have become extensively naturalized in areas where *F. trachyphylla* was not native (Hubbard 1984; Ruemmele et al. 2003) reasonably thanks to their high affinity for synanthropic conditions, altering the perception of what was the natural range of this species. Cross breeding between natural and cultivated individuals is also another plausible outcome to additionally complicate the situation, this time from a morphological point of view. This, combined with the already complicated natural situation of the group, highlights how much work is needed to properly fill in the gaps and build a complete view of the matter that can act as a solid foundation of transferable knowledge to other disciplines.

In the prospect of this PhD, these knowledge chasms regarding the current situation have been exposed particularly for the Apennines, where the situation was far more obscure than expected. As a matter of fact, the sampling done in the three Apennines macro-areas (northern, central and southern) based on records of *F. trachyphylla* and *F. rupicola* revealed three taxa that could not be properly classified with the use of keys to the Italian flora:

- Records of *F. trachyphylla* (Ardenghi & Polani 2016) from ophiolitic substrates in the northern Apennines display morphological characteristics between the ser. *Trachyphyllae* and species of *F. ovina* s.l. (such as *F. apuanica* and *F. robustifolia*). Particularly, the habit and leaf cross section anatomy are similar to those of *F. robustifolia* and other higher polyploids of the *F. ovina* s.l group, but the bluish scabrid leaves and densely pubescent sheaths are leaning into the *F. trachyphylla* morphology. Later, FCM revealed that these are all octaploids populations, further complicating the matter as *F. robustifolia* and *F. apuanica* are decaploids and *F. trachyphylla* an hexaploid. At the time of writing, these fescues cannot be assigned to any taxon recorded for the flora of Italy, as current identification keys fail to assign a name that can match both the ploidy and the morphological characteristics of these plants.

- The populations reported as *F. rupicola* from the valleys of Abruzzo in the central Apennines turned out to be morphologically distinct tetraploids, that may soon be described as a new species. They differ from any other member of the *stricta-valesiaca* complex found in Italy, and given the premises, a confrontation with other European taxa not concerning this thesis is being carried on. If no matching name can still be found after this extended analysis, these tetraploids may be described anew in an original research paper.
- Finally, in the southern Apennines, populations of hexaploids reported as *F. trachyphylla* from the Sila plateau (Calabria) were presenting unusual morphological features that clearly distinguished them from true *F. trachyphylla*, despite the similarities observed in leaves cross-sections. Morphometric and flow cytometry analysis, as well as evolutive relationships verified via ddRADseq have then proven that these plants are more closely related to taxa of the *F. marginata* group rather than to other hexaploids of the *stricta-valesiaca* complex (Pallanza et al. 2025, see Suppl. Mat. 6).

The only records which were confirmed by the morphological and flow cytometry analyses were the *F. valesiaca* populations reported by Filibeck et al. in 2020. On these premises, it is plausible that most records for the Apennines need to be accurately revised, as even good floristics researchers can easily end up mistaken when identifying taxa of these critical groups. Overall, what can be concluded by these different instances is that, compared to the Alps, where we had generations of agrostologists recording and studying fescues (e.g., Hackel, Host, Saint-Yves, Markgraf-Dannenberg, Pils, etc.), in the Apennines there is still a lot of work to do, with just few studies covering few species groups (Foggi et al. 1999, 2003, 2012) or limited areas (Foggi & Rossi 1996).

The taxonomic treatment proposed above, while complete from a morphological and karyological point of view, has its own limits. Specifically, focusing on implementing the phylogenomic data obtained via ddRADseq, would lead to a better grasp of the different taxa history and their evolutive relationships, possibly changing the picture designed by morphology and ploidy. For instance, understanding if the morphological differentiation between ser. *Valesiaca* and ser. *Trachyphyllae* is subsequent or precedent the insurgence of the different ploidy levels in the group could lead to the shifting of some taxa ranks and new nomenclatural combinations. The current available samples seem to indicate that the series designated by Pawlus in 1985 on morphological basis are paraphyletic, with *F. rupicola* and *F. trachyphylla* appearing as more closely related between them than *F. stricta*, which seems to be one of the earliest diverging taxa in the group. This could lead to the idea that in the group polyploidization occurs before morphological differentiation, acting as a first step in the speciation process. However, the limited sampling pool is currently weak to support any sound hypothesis, and other taxa should be included to better observe the inferred relationships among the different polyploids and rule out any bias.

Prospects on ecological restoration

The SER (2004) clearly states how a successful operation of restoration ecology must get as close as possible to the original community that inhabited the site of intervention. Although guidelines recommend the use of local seeds when approaching the ecological restoration of a designated area, convenience and cost efficiency often leads to the choice of commercially mass-produced varieties. However, introduction of non-native plants has a series of concerns and undesired side effects such as genetic pollution (Linhart and Grant 1996; Broadhurst et al. 2008), poor ecological adaptation (Montalvo & Ellstrand 2000; Wilkinson 2001; Bischoff et al. 2006; Broadhurst et al. 2008; Vander Mijnsbrugge

et al. 2010) and worse performance (Pizza et al. 2021). On the other hand, plants introduced may also be too competitive compared to native ones, damaging the local community as a whole rather than restoring it (Hagen et al. 2014). In the context of this study, these criticalities are aggravated by the taxonomical complexity of the group, its uncertain distribution and evolutive history. However, the *stricta-valesiaca* complex remains a keystone of steppe and xeric grasslands composition in Eurasia and for this very reason complications regarding the group and its application in restoration ecology should not be overlooked. The naturalization of *F. trachyphylla* beyond its native range and its wide use in the form of commercial varieties is maybe the clearest representation of how the lack of a proper taxonomical foundation led to a situation which perfectly encapsulates the undesired side effects of improper ecological restoration previously discussed.

Ideally, when approaching restoration ecology, complete floristic and vegetational surveys should be carried out for the neighbouring communities, along with the examination of previously conducted studies when available as to trace the best historical image of the original community. Species of the *stricta-valesiaca* can, in this instance, be identified with no doubts with the combination of morphology and karyology, with the latter being nowadays more accessible thanks to the reduced costs and tempistics of FCM. Investigations should also take in consideration that, despite these taxa occurring in different ecological niches a types of dry grasslands vegetation (Hroudová-Pučelíková 1972; Kozłowska 1925), they might coexist inside landscapes where the geomorphology of the site allows for the development of different microhabitats. As a matter of fact, these species are typically abundant in different vegetations of the *Festucetalia valesiacae* order but are not restricted to its specific communities or lower syntaxa, being found also in *Berberidion vulgaris* scrubs or in clearings of different thermophilous forests (Fig. 11, 12).

Ideally, seeds of the identified taxa should then be collected from the neighbouring populations to avoid possible undesired effects as described above. Naturally, taxa endemic to restricted areas should only be used in areas comprised within their natural range of distribution to avoid possible phenomena of invasion. The perfect approach considers all of these matters.

With this considered the use of the different taxa in restoration should be considered as follows:

- *F. valesiaca*: Ideal for grasslands with shallow soils, poor in nutrients, from low altitudes up to sub-alpine slopes. May be used as part of a mixture with other taxa of the complex depending on the original phytocenosis of reference (e.g., *F. pseudodalmatica*, *F. stricta*, *F. rupicola*, *F. trachyphylla*, *F. bauzanina*). Due to its distribution, it's highly recommended for sites in the Alps, from the Valais up to the easternmost edge of the mountain range in Austria. In the Apennines is to be considered carefully due to its few scattered occurrences and suggested only if the sites are close by extant natural populations.
- *F. pseudodalmatica*: Suggested only for sites in the easternmost edge of the Alps where its distribution range stretches naturally. On terrain with dry and sunny conditions or in transitional vegetation between grassland-shrubland and dry forests. Might be used in a mixture with *F. valesiaca* and *F. rupicola* depending on the taxa composition of the reference community.
- *F. stricta*: Indicated for dry meadows and open pine forests on rocky calcareous soils in sites occurring in Lower Austria, Burgenland and Styria. Might co-occur with *F. rupicola*, *F. trachyphylla* and *F. valesiaca* depending on the conditions and topography.
- *F. rupicola*: To be used in sites with steppic, sunny and dry conditions, with a better tolerance for mesophilic conditions compared to *F. valesiaca*. Might be used along with other species of the complex. Records include part of the Western Alps and Apennines, but given the results

reported in this thesis, application of this species is discouraged for sites outside of the Central and Eastern Alps.

- *F. trachyphylla*: Widespread and commonly found in several types of dry grasslands. However, due to it being introduced species in several areas, its use in restoration is rather controversial despite being already popular and heavily used in many projects already. Until clarity is made on where this taxon is native and where it's introduced by anthropic activities, its involvement in ecological restoration is to be arguably discouraged.
- *F. bauzanina*: Suggested for xerophilic grasslands and shrublands of Südtirol. Its distribution, like other cryptic alpine endemics of this complex, is esteemed on few verified records and might extend to other areas of the Alps. However, use of this species is still recommended for those sites that occur in locations where nearby populations have been studied morphologically and karyologically.
- *F. rhaetica*: On siliceous dry rocky slopes in the Rhaetian Alps. Use in restoration is suggested only for sites in the proximity of its locus classicus as, like with the other alpine endemics of this complex, its distribution is poorly known.
- *F. guinochetii*: Suggested mostly for the localities in the vicinity of Bormio and its locus classicus. Other verified records include the Gavia Pass and Grisons, but since it's not known how isolated these occurrences are and if there are other populations present nearby or between them, the use of this taxon should be considered with extreme care.

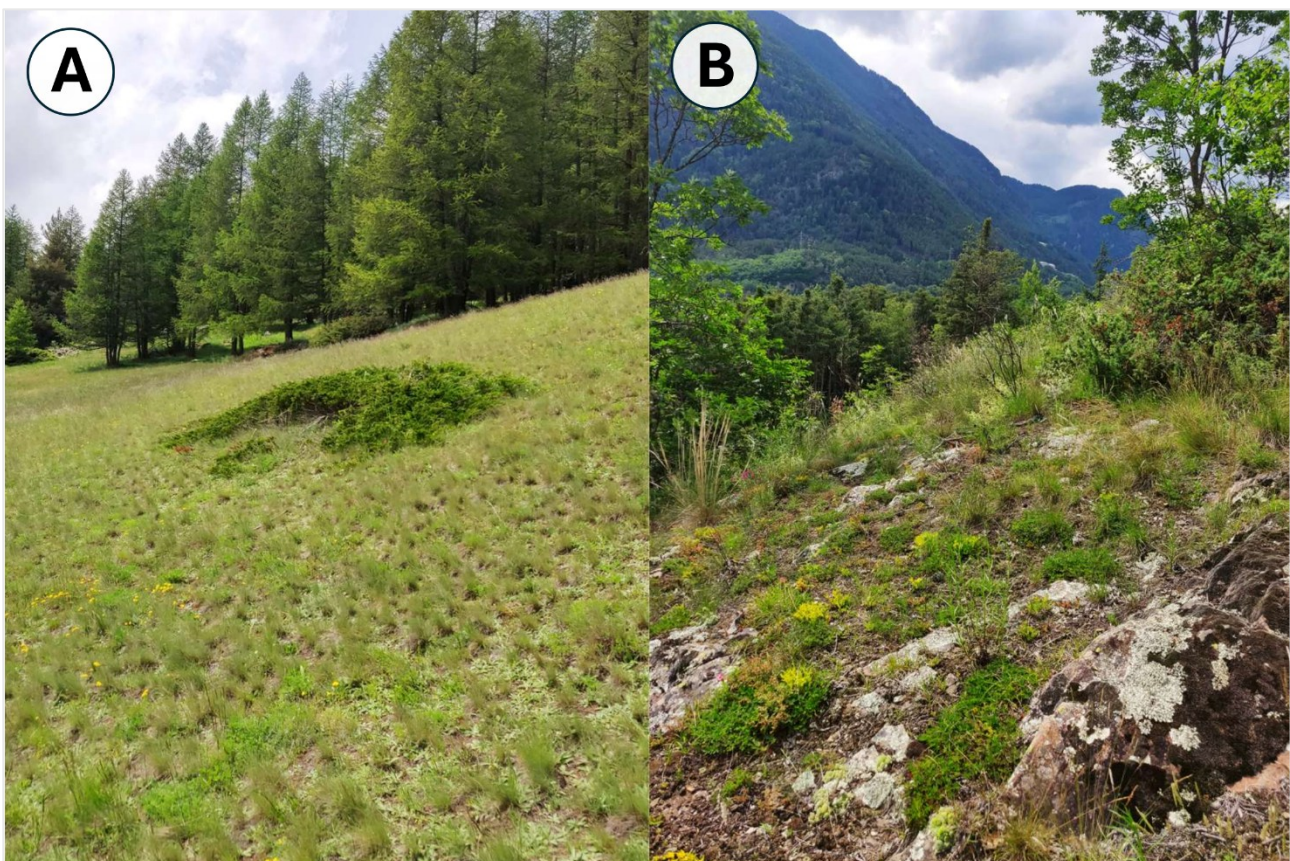


Figure 11: different landscapes with a predominance of the *Festuca stricta-valesiaca* species. A: South-exposed slopes bordering a mixed conifers forest, covered in *F. valesiaca* (Mt. Tsaplana, Italy); B: Siliceous outcrop with sparse *F. bauzanina* in a deciduous forest glade (Aica, Italy).

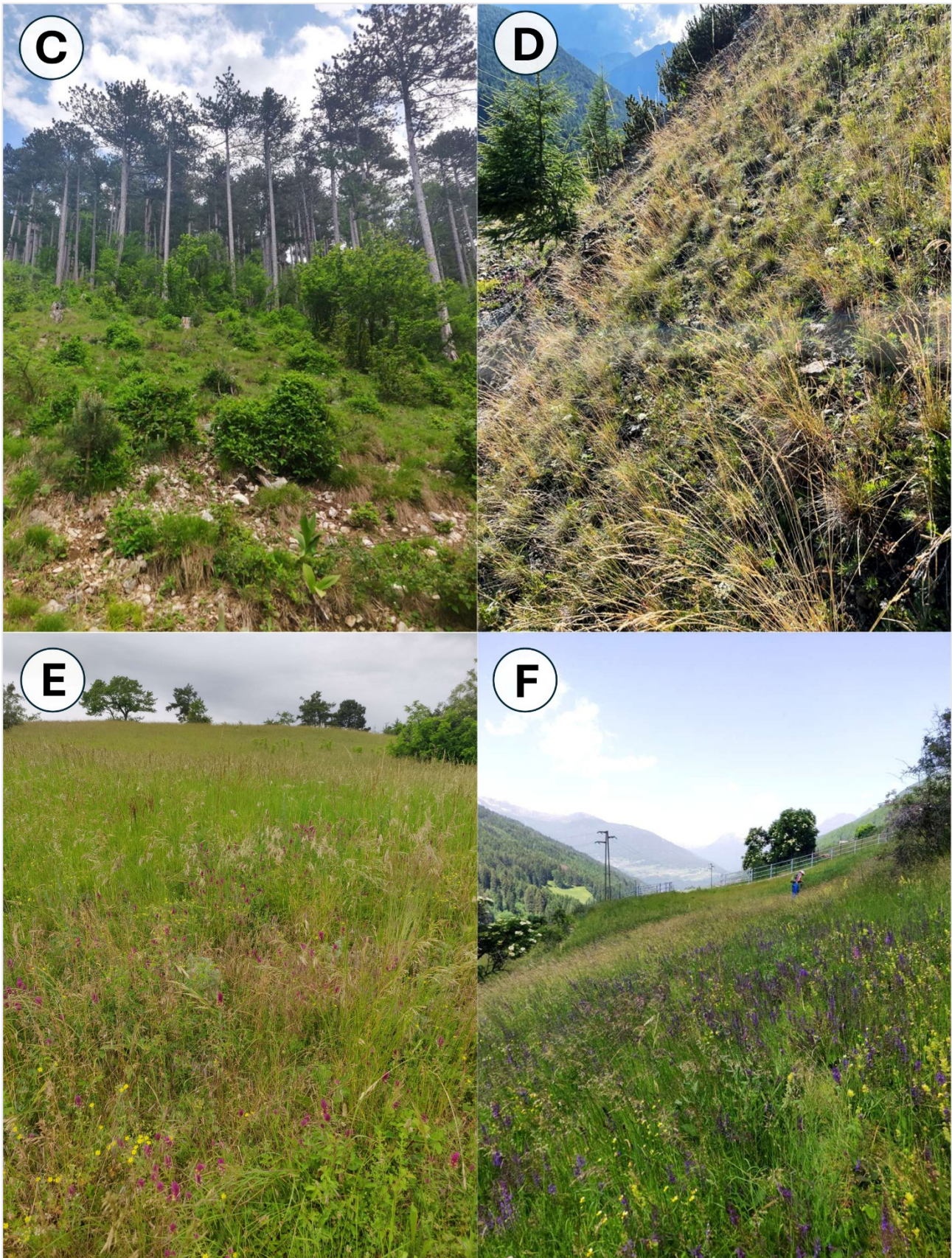


Figure 12: different landscapes with a predominance of the *Festuca stricta-valesiaca* species. C: Glades and ecotone zones within a *Pinus nigra* forest inhabited by *F. stricta* and *F. rupicola* (Reichental, Austria); D: Scree slopes covered in *F. rhaetica* (East of Zerne, Switzerland); E: Mesophilic meadow with *F. pseudodalmatica* and *F. rupicola* (Rechnitz, Austria); F: Pasture dominated by *F. guinochetii* (S. Antonio di Bormio, Italy).

6 CONCLUSIONS

This project aimed to resolve the taxonomy of the *Festuca stricta-valesiaca* complex in Italy, one of arguably the most important species complex among fescues, due to their keystone role in many xeric grasslands and its rising popularity within the ecological restoration scene.

The integrated approach used to investigate the species complex further highlights the criticality of the group due to its likely recent divergence, which is observable in the transitional nature of the different taxa morphologies despite the reproductive barrier insured via polyploidy. Important floristic gaps also emerged in the Apennines, where the names of the most common and widespread taxa of the group have been mistakenly applied to morphologically and karyologically distinct specimens yet to be described, furtherly proving the shallow understanding of the complex.

Complexity is not an excuse to overlook diversity, and much work is still to be done with the necessity of time and resources that go past the limitations of a doctoral course. As a matter of fact, this study resolved some ambiguities on one hand but exposed further problematics on the other. These start from the nomenclatural history, which results entangled and oversaturated due to the constant description of new names and recombination of old ones. Most of these names are without their designated types which are to be searched among the historical material of authors and collectors in different European herbaria. Expanding on the phylogenomic aspect is also crucial to further push the results of this work, in order to have a clear idea of the evolutive history of the group throughout the distributional range. Genetics would not only clarify the mechanics and their occurrence beyond the evolution of this group but also help consolidating boundaries among taxa and understand how diversity is distributed across the distribution range of the complex.

Additionally, contributing to systematic, this research also comes with important applications. Accurate delimitation and identification of introduced species are indispensable for ecological restoration, conservation planning, and biodiversity monitoring. Misidentifications can undermine restoration efforts by introducing maladapted or non-native taxa, thereby compromising ecosystem recovery. The taxonomic treatment and identification tools proposed in this thesis contribute to greater reliability in the use of fescues species in restoration projects, aiding the use of correct native taxa as expected by most guidelines for a successful intervention. By clarifying systematics and making it a reliable tool, this work reinforces the role of taxonomy as a founding discipline in restoration ecology and many other disciplines involving botany.

In conclusion, this thesis provides a first foundation for future taxonomical and biosystematic works on *Festuca* and demonstrates the value of integrative taxonomy in addressing complex plant groups. It acts as a bridge between systematic research and applied disciplines, offering advancements that can become powerful practical tools to guide the conservation and restoration of damaged ecosystems such as grasslands.

7 PROPOSED TAXONOMIC TREATMENT

What follows are the proposed taxonomical treatment of the group and the relative identification key for the taxa based on the data collected during the PhD. However, it is important to address something when it comes to identifying these taxa. What have been defined as “transitional forms” among the different taxa occurs along the morphological boundaries of each taxon, resulting in a fading between different forms rather than clean and discrete morphotypes. However, a morphological gradient is no excuse to ignore the reproductive barriers that insurged with polyploidy and simplify matters just for the sake of it. For this reason, identifying *Festuca* species can be a real challenge. Therefore it is recommended that, when identifying fescues, infraspecific variability is accounted for by observing different individuals from the same population. Intraspecific and intraindividual variability are also a key factor to be accounted for, due to the phenotypic plasticity that may occur in response to environmental stressors. These can be overcome by simply repeating the measurements on the same individuals, ruling out biases caused by these variations. This way, any unusual characteristic is contextualized and any bias related to “transitional forms” buffered.

The proposed treatment below rejects *F. brevipila* and *F. ticinensis* as valid taxa due to the lack of both a karyological and morphological distinction from *F. trachyphylla*, which is the oldest name for the now unified taxon. All remaining taxa are elevated at specific level following two criteria:

- Morphologically similar taxa within series (eg. *F. pseudodalmatica*, *F. rupicola* and *F. bauzanina*) are still treated as separate entities due to the presence of different ploidies that act as a reproductive barrier
- Taxa with the same ploidy distinguish themselves in the two series with a remarkable morphological separation that may be more noticeable than the one that occurs within subspecies. Also, subspecific taxa usually present an allopatric distribution, which is not the case of the polyploids of the *stricta-valesiaca* complex.

The identification key is followed by taxa descriptions, presenting ranges covering the 5% and 95% percentiles of the systematically measured characters, with the minimum and maximum values measured between brackets. Non-diagnostic characters have been given instead indicative ranges as to have nevertheless a complete and detailed description of each taxon.

7.1 Key to the species

1A– Leaves cross section with commonly with 5 vascular bundles. Adaxial surface always with 3 ridges and 4 furrows (ser. *Valesiaceae*).

2A– Sclerenchyma generally in 3 discrete strands located at the margins and keel, occasionally with two additional strands in-between the principal ones. Tiller leaves soft–flexible. Spikelets and tiller leaves sheaths glabrous to slightly pubescent.

3A– Plants often visibly pruinose, especially at the nodes.

4A– Spikelets (4.93) 5.54 – 7.28 (7.99) mm long, lemmas (3.33) 3.72 – 4.88 (5.46) mm long, awns (0.85) 1.26 – 2.32 (3.58) mm long. Tiller leaf blades hairlike, (0.3) 0.44 – 0.55 (0.62) mm in diameter. Diploid plants ($2n=2x=14$) widespread throughout Alps, rare and scattered in the Apennines. _____ ***F. valesiaca***

4B– Spikelets (6.53) 6.55 – 8.02 (8.46) mm long, lemmas (4.1) 4.22 – 5.44 (5.77) mm long, awns (2.06) 2.08 – 2.6 mm long. Tiller leaf blades (0.51) 0.52 – 0.66 (0.71) mm in diameter. Tetraploid plants ($2n=4x=28$) found in the easternmost edge of the Austrian Alps. _____ ***F. pseudodalmatica***

3B– Plants rarely pruinose at the eye.

5A– Spikelets (6.17) 6.44 – 8.55 (8.95) mm long, lemmas (4.06) 4.32 – 5.70 (6.01) mm long, awns (1.53) 2.04 – 3.26 (3.59) mm long. Tiller leaf blades (0.50) 0.54 – 0.76 (0.82) mm in diameter. Sclerenchyma in three discrete strands, almost never forming a complete ring. Hexaploid plants ($2n=6x=42$) found commonly in the central-eastern Alps, rarer scattered records in the western Alps and Apennines. _____ ***F. rupicola***

5B– Spikelets (6.05) 6.54 – 8.95 (9.58) mm long, lemmas (3.87) 4.43 – 6.06 (6.33) mm long, awns (1.51) 1.87 – 3.64 (4.57) mm long. Tiller leaf blades (0.55) 0.62 – 0.91 (0.96) mm in diameter. Sclerenchyma occasionally decurrent into forming a broken or complete ring. Octaploid plants ($2n=8x=56$) found in the Südtirolean Alps. _____ ***F. bauzanina***

2B– Sclerenchyma in a complete and thickened ring, rarely broken on its sides into multiple strands. Tiller leaves rigid. Spikelets and tiller leaves sheaths pubescent to densely pubescent. Hexaploid plants ($2n=6x=42$) endemic to the eastern Austrian Alps. _____ ***F. stricta***

1B– Leaves cross section commonly with 7 or more vascular bundles. Adaxial surface with 3-7 ridges and 4-8 furrows (ser. *Trachyphyllae*).

6A– Tiller leaf sheaths always glabrous. Spikelets < 7 mm long. Tiller leaf blades < 0.6 mm in diameter. Tetraploid plants ($2n=4x=28$) recorded only for the L'Aquila province, central Apennines. _____ ***F. sp. nova***

6B– Tiller leaf sheaths variable, but commonly puberule or pubescent. Spikelets > 7 mm long. Tiller leaf blades > 0.6 mm in diameter.

7A– Spikelets highly variable, puberule to densely pubescent, glabrous only in rare occasions. Sclerenchyma strands often fused into forming an interrupted or complete ring. Hexaploid plants ($2n=6x=42$) widely distributed, commonly found in both natural and synanthropic conditions. _____ ***F. trachyphylla***

7B– Spikelets generally glabrous, puberule in rare cases. Accessory sclerenchyma strands well developed, but rarely fusing with each other into forming an interrupted or complete ring. Polyploids endemic to central Alps.

8A– Spikelets (6.83) 7.35 – 8.83 (9.28) mm long, lemmas (4.58) 4.82 – 5.89 (6.06) mm long, awns (2.55) 2.93 – 3.79 (4.7) mm long. Tiller leaf blades (0.69) 0.73 – 0.95 (1.00) mm in diameter. Octaploid plants ($2n=8x=56$) inhabiting dry grasslands on steep slopes in the Rhaetian Alps. _____ ***F. rhaetica***

8B– Spikelets (7.52) 7.57 – 9.64 (9.69) mm long, lemmas (5.16) 5.20 – 6.56 (6.74) mm long, awns (1.9) 2.26 – 3.62 (3.95) mm long. Tiller leaf blades (0.87) 0.89 – 1.19 (1.22) mm in

diameter. Decaploid plants ($2n=10x=70$) found in mesophilous meadows and pastures of the central Alps. _____ ***F. guinochetii***

7.2 *Festuca valesiaca* Schleich. ex Gaudin in Agrost. Helv. 1: 242 (1811)Typus

LAU! Herb. Gaudin. Lectotype designated by Šmarda et al. (2009), complete of nomenclatural notes and copies of the original material.

Description

Perennial herb, caespitose, without runners; tillers intravaginal, arising within the lowest leaf sheaths. Plants forming dark green to glaucous-bluish tufts, often pruinose at the nodes, leaf sheaths and leaf blades. Culms erect, cylindrical, scabrid below the panicle, otherwise smooth to the touch, with 1–2 visible nodes, located in its lower part. culm height (20.8) 25.4 – 60.2 (67.8) cm, diameter circa 0.3–0.9 mm.

Leaves: Cauline leaves arising from the nodes, sheathing the culm for (4.6) 5.9 – 13.5 (17.6) cm. Cauline leaf blades (2.2) 2.8 – 8.7 (10.6) cm long, conduplicate. Cauline leaves ligules membranous, truncate, subnull, with two small auricles. Basal leaf sheaths open to the base, pale, rarely striate with faint red, the oldest ones decaying and of an ashen grey colour, glabrous. Basal leaves ligules membranous, truncate, subnull, with two lateral auricles present. Basal leaf blades conduplicate, erect, flexible, ((9.3) 12.6 – 28.4 (35.6) cm long, (0.3) 0.44 – 0.55 (0.62) mm in diameter, dark green or glaucous-bluish, rough to strongly scabrid due to the presence of several teeth on the abaxial surface, sometimes pruinose. Leaf cross-section V-shaped, occasionally U-shaped, with 5 vascular bundles. Adaxial surface characterized by 3 ribs, and 4 furrows with bulliform cells. Sclerenchyma usually in 3 main thickened strands (2 marginal, 1 at the keel), sometimes with additional abaxial strands opposing the smaller vascular bundles. In exceptionally rare occasions forming an incomplete to complete ring. Adaxial surface covered in a sparse indumentum of 20 – 40 µm long hairs. Abaxial epidermis with visible undulations between each cell and with few teeth.

Inflorescence: Panicles (3.5) 4.5 – 8.4 (10.1) cm long, loose and spreading at anthesis, otherwise contracted, light green turning to straw-colored at maturity, with 9 – 33 spikelets. Branches scabrid, 1 – 2 per node, the lower ones branched themselves.

Spikelets: Laterally compressed, lanceolate to elliptic, (4.93) 5.54 – 7.28 (7.99) mm long, with 3–7 florets. Glumes unequal, membranous, glabrous or with few sparse short hair in their apical part; lower glume 1-veined, lanceolate to subulate, (1.52) 2.02 – 3.07 (3.41) mm long; upper glume 3-veined, elliptic to lanceolate, acuminate, (2.45) 2.81 – 4.01 (4.3) mm long. Lemmas 5-veined, (3.33) 3.72 – 4.88 (5.46) mm long, glabrous or with sparse short hair in their distal part and along the margins, presenting an apical awn (0.85) 1.26 – 2.32 (3.58) mm long. Palea 2-veined, almost as long as the lemma, subulate-lanceolate, briefly bifid at the apex, with 2 shortly ciliated keels. Stigmas 2, plumose. Anthers 3, nutant. Caryopsis adherent to the palea.

Cytology: Chromosome number $2n = 2x = 14$.

Distribution and Ecology: Alps; Rare and scattered along the Northern Appennine, from Piedmont to Emilia Romagna, with its Eastmost recorded population by Rossi et al. 1998 on the Pietra di Bismantova formation. Populations have also been recently recorded in Abruzzo (Filibeck et al. 2020). Frequently found in xeric and steppic conditions, with strong light exposure with a preference for shallow soils and steep terrain (Hroudová-Pučelíková 1972). From low dry grasslands up to rocky hills and alpine slopes. Outside the area of study, the taxon extends eastward, reaching the steppes of central Asia.

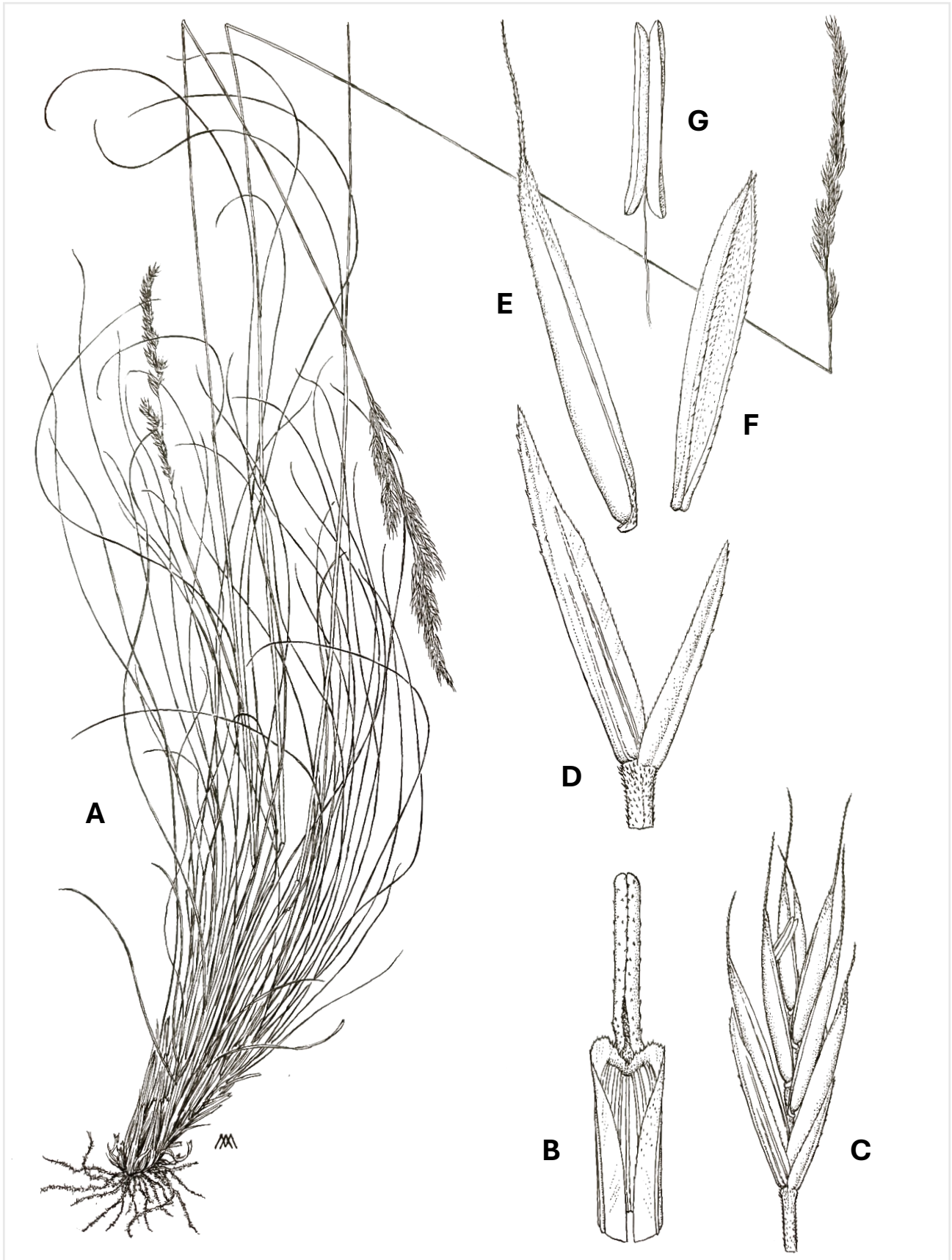


Figure 13: Illustration of *F. valesiaca*. A: overall species appearance; B: tiller leaves sheath and ligula; C: spikelet; D: glumes; E: lemma; F: palea; G: stamen. Artwork by Anne Eldredge Maury.

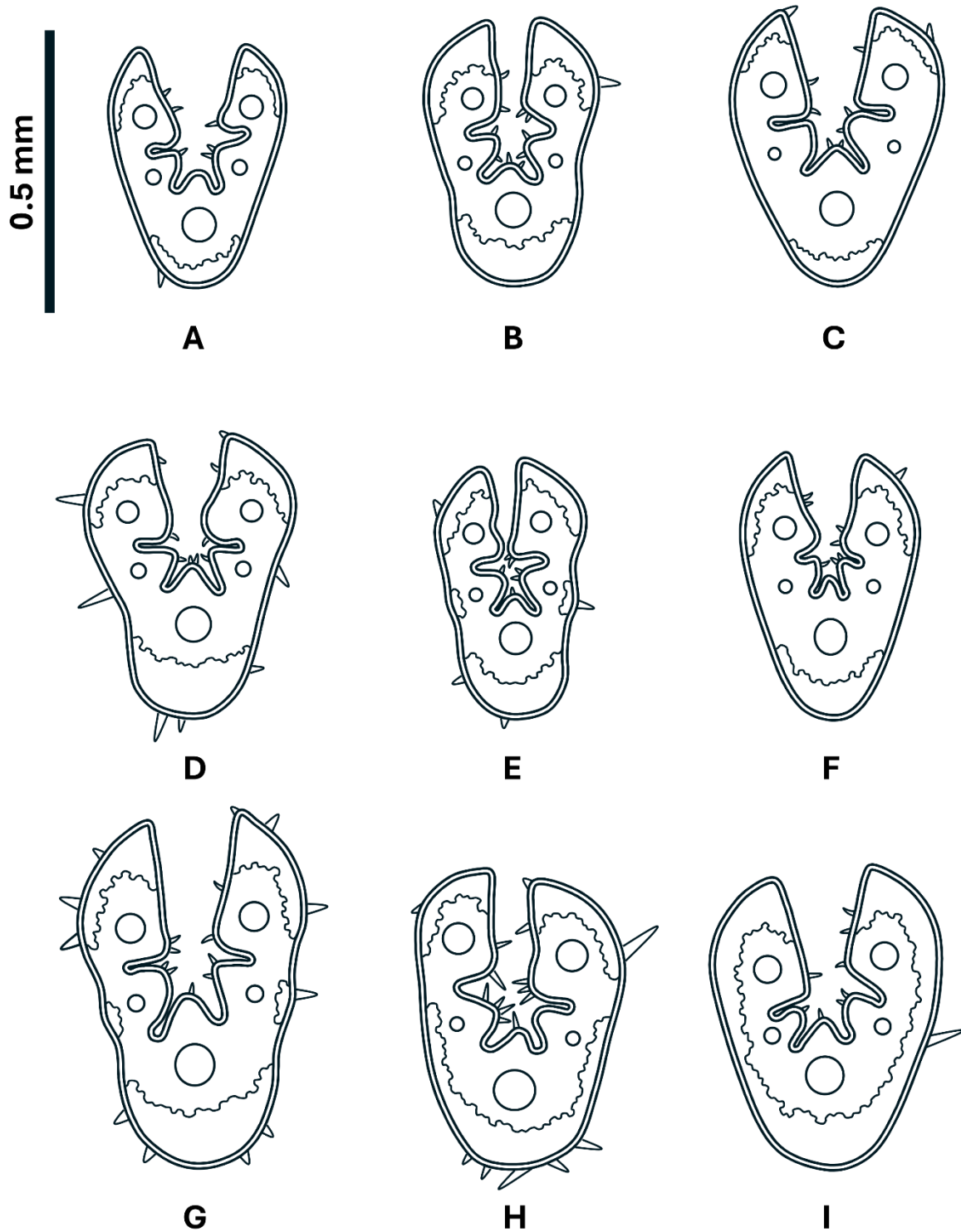
***Festuca valesiaca* Schelich. Ex Gaudin**

Figure 14: Morphological variability across leaves cross-sections of *F. valesiaca*. A: Lectotype preserved at the LAU herbarium; B – D: Pescina, Central Apennines; E: Tanas, eastern Rhaetian Alps; F: Chandonne, Valais; G: Niederwald, Valais; H: Rechnitz, foothills of the Styrian Prealps; I: Castebello, Ötztal Alps.

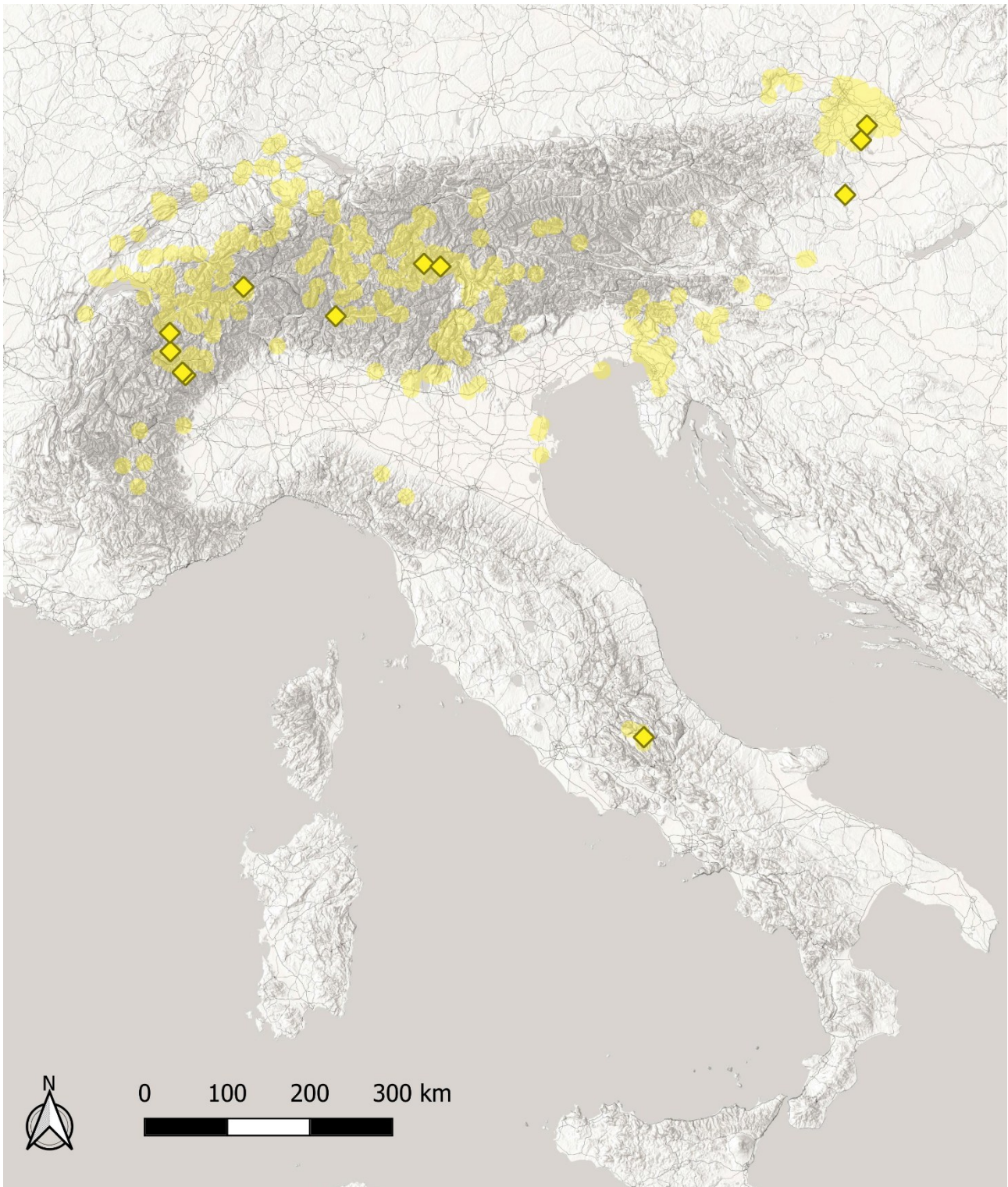


Figure 15: Range of distribution for *F. valesiaca* in the area of study. Data are portrayed as follows: ◆ = verified populations studied for this PhD; ● = records present in literature, databases and herbaria.

7.3 *Festuca sp. Nova*

Typus

The type has yet to be designated as a research paper formally describing this new taxon is currently under work.

Description

Perennial herb, densely caespitose. Tillers intravaginal, arising within the lowest leaf sheaths. Plants forming dark green to glaucous-bluish tufts, often pruinose at the nodes, leaf sheaths and leaf blades. Culms erect, cylindrical, scabrid below the panicle, otherwise smooth to the touch, with 1 – 2 nodes, located in its lower part. culm height (8.8) 12.8 – 32.3 (35.9) cm, diameter circa 0.3 – 0.9 mm.

Leaves: Cauline leaves arising from the nodes, sheathing the culm for (5.4) 6.5 – 12.6 (16.0) cm. Cauline leaf blades (1.5) 2 – 4.5 (5.2) cm long, conduplicate. Ligules membranous, truncate, with two small auricles. Basal leaf sheaths open to the base, pale, rarely striate with faint red, the oldest ones decaying and of an ashen grey colour, glabrous. Ligules membranous, truncate, often fringed, with two lateral auricles present. Basal leaf blades conduplicate, erect, flexible, (6.8) 7.4 – 21.8 (26.5) cm long, (0.48) 0.51 – 0.67 mm in diameter, dark green or glaucous-bluish, rough to strongly scabrid due to the presence of several teeth on the abaxial surface, sometimes pruinose. Leaf cross-section V-shaped, with (5) 7 vascular bundles. Adaxial surface characterized by 3 ribs, and 4 furrows with bulliform cells. Sclerenchyma usually in 3 main strands (2 marginal, 1 at the keel), often with 1–2 additional strands on each side, opposed to the vascular bundles or irregularly confluent with the main strands. In exceptionally rare occasions forming a complete ring. Adaxial surface covered in a sparse indumentum of 10 – 30 µm long hairs. Abaxial epidermis with visible undulations between each cell and with frequent teeth.

Inflorescence: Panicles (1.2) 3.32 – 7.33 (8.9) cm long, loose and spreading at anthesis, otherwise contracted, light greenish to straw colored at maturity, with 9 – 33 spikelets. Branches scabrid, 1 – 2 per node.

Spikelets: Laterally compressed, lanceolate to elliptic, (4.7) 5.9 – 7.3 (7.56) mm long, with 3 – 5 florets. Glumes unequal, lanceolate to elliptic, membranous with toothed or hairy margins; lower glume 1-nerved, (1.92) 1.97 – 2.90 (2.97) mm long; upper glume 3-nerved, (2.57) 2.73 – 3.93 (4.33) mm long. Lemmas 5-veined, (3.84) 3.94 – 4.80 (4.89) mm long, glabrous, margins glabrous, scarious, presenting an apical awn (1.43) 1.52 – 2.48 (2.71) mm long. Palea almost as long as the lemma, lanceolate, bifid at apex, with 2 shortly ciliated keels. Stigmas 2, plumose. Anthers 3, nutant. Caryopsis adherent to the palea.

Cytology: Chromosome number $2n = 4x = 28$.

Distribution and Ecology: The taxon is currently known from the localities of Barisciano and Prati del Sirente, Abruzzo. It inhabits xeric meadows and pastures of calcareous substrates along with other species typically found in dry and sunny conditions.

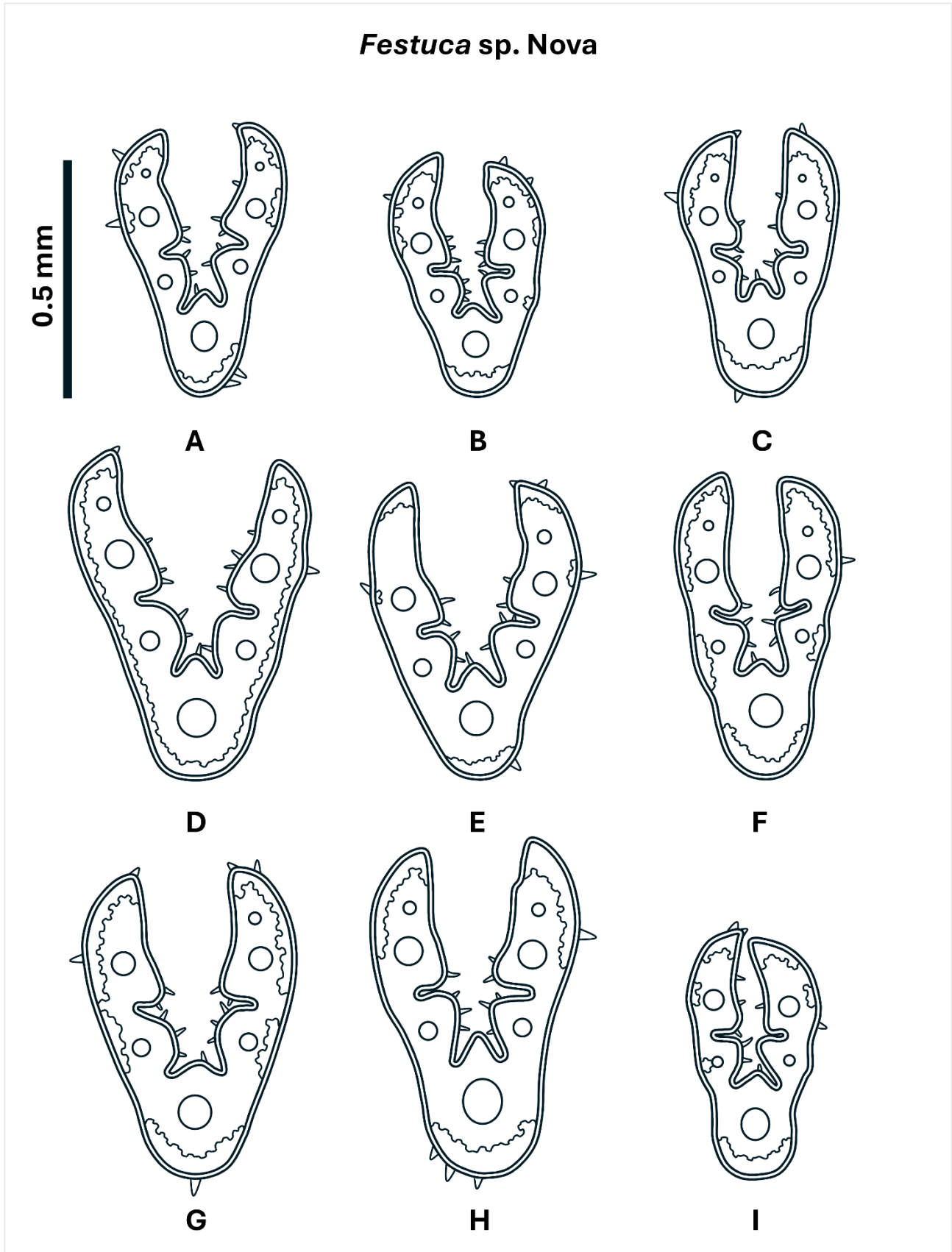


Figure 16: Morphological variability across leaves cross-sections of *F. sp. nova*. A – D: Prati del Sirente, Abruzzo, Central Apennines; E – I: Barisciano, Abruzzo, Central Apennines.



Figure 17: Known populations for *F. sp. nova* in Italy. Being firstly recognized by this PhD project, no other distribution data are currently available

7.4 *Festuca pseudodalmatica* Krajina ex Domin in Acta Bot. Bohem. 8: 61 (1929)Typus

PRC 451022! Lectotype designated by Šmarda et al. (2009), complete with nomenclatural notes.

Description

Perennial herb, densely caespitose, without runners; tillers intravaginal, arising within the lowest leaf sheaths. Plants forming dark green to glaucous-bluish tufts, often pruinose at the nodes, leaf sheaths and leaf blades. Culms erect, cylindrical, smooth to the touch, with 1 – 2 nodes, located in its lower part. culm height (29.1) 34.59 – 54.35 (54.8) cm, diameter circa 0.4 – 1.0 mm.

Leaves: Cauline leaves arising from the nodes, sheathing the culm for 7.8 – 12.9 (14.2) cm. Cauline leaf blades (3.1) 3.3 – 6.6 (7) cm long, conduplicate. Ligules membranous, truncate, with two small auricles. Basal leaf sheaths open to the base, pale, rarely striate with faint red, the oldest ones decaying and of an ashen grey colour, glabrous. Ligules membranous, truncate, often fringed, with two lateral auricles present. Basal leaf blades conduplicate, erect, flexible, (7.7) 10.9 – 25.1 (25.3) cm long, (0.51) 0.52 – 0.66 (0.71) mm in diameter, dark green or glaucous-bluish, rough to strongly scabrid due to the presence of several teeth on the abaxial surface, sometimes pruinose. Leaf cross-section V-shaped to U-shaped, with 5 vascular bundles. Adaxial surface characterized by 3 ribs, and 4 furrows with bulliform cells. Sclerenchyma usually in 3 main thickened strands (2 marginal, 1 at the keel), sometimes with 2 additional strands opposed to the vascular bundles. Adaxial surface covered in a sparse indumentum of 20 – 30 µm long hairs. Abaxial epidermis with visible undulations between each cell and with frequent teeth.

Inflorescence: Panicles (5.1) 5.5 – 8.7 (9.2) cm long, loose and spreading at anthesis, otherwise contracted, light greenish to straw colored at maturity, with 14 – 33 spikelets. Branches scabrid, 1 – 2 per node.

Spikelets: Laterally compressed, lanceolate to elliptic, (6.53) 6.55 – 8.02 (8.46) mm long, with 4 – 6 florets. Glumes unequal, lanceolate to elliptic, membranous with toothed or hairy margins; lower glume 1-veined, (2.39) 2.46 – 3.11 (3.17) mm long; upper glume 3-veined, (3.38) 3.47 – 4.21 (4.26) mm long. Lemmas 5-veined, (4.1) 4.22 – 5.44 (5.77) mm long, glabrous or distally puberule, margins glabrous, scarious to rarely ciliate, presenting an apical awn (2.06) 2.08 – 2.6 mm long. Palea 2-veined, almost as long as the lemma, lanceolate, bifid at apex, with 2 shortly ciliated keels. Stigmas 2, plumose. Anthers 3, nutant. Caryopsis adherent to the palea.

Cytology: Chromosome number $2n = 4x = 28$.

Distribution and Ecology: Commonly found in Eastern Europe, extending from the edge of the Alps in Austria up to Central Russia. Typically found in grasslands on rocky terrains and slopes, in sunny and xerophilic conditions, rarely also in the margins and glades of dry *Quercus* and *Picea* forests.

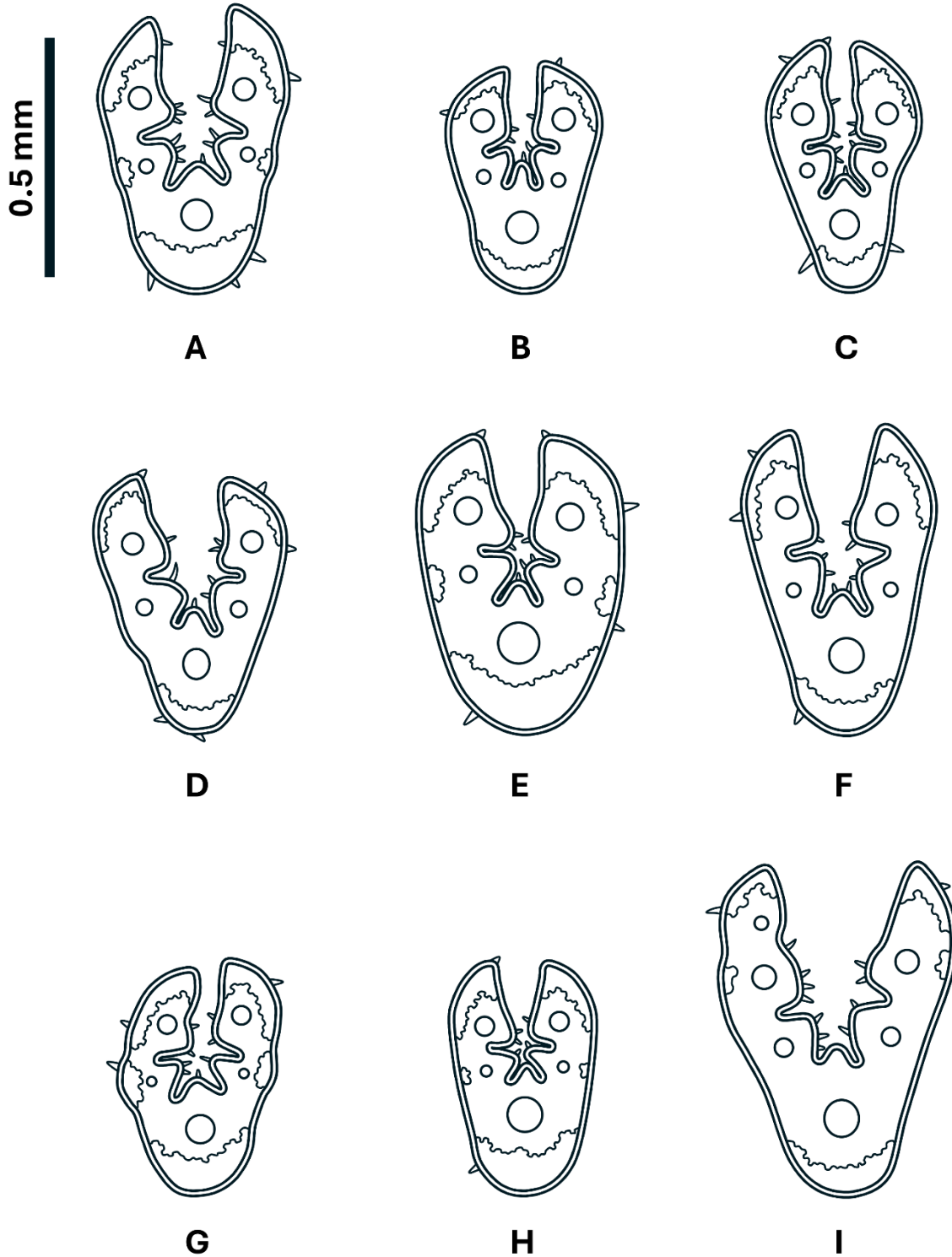
***Festuca pseudodalmatica* Krajina ex Domin**

Figure 18: Morphological variability across leaves cross-sections of *F. pseudodalmatica*. A – I: Rechnitz, foothills of the Styrian Prealps.



Figure 19: Range of distribution for *F. pseudodalmatica* in the area of study. The species is widely distributed outside the area of study, but only briefly reaches it only in the easternmost part of the Austrian Alps. Data are portrayed as follows: ◆ = verified populations studied for this PhD; ● = records present in literature, databases and herbaria.

7.5 *Festuca stricta* Host in Icon. descr. gram. austriac. 2: 62 (1802)Typus

W0353208! Lectotype designate by B. Foggi, M. A. Signorini & E. Vitek.

Description

Perennial herb, densely caespitose, without runners; tillers intravaginal, arising within the lowest leaf sheaths. Plants forming dark to greyish-green tufts, often pruinose at the nodes, leaf sheaths and leaf blades. Culms erect, cylindrical, occasionally scabrid below the panicle, otherwise smooth to the touch, with 1 – rarely 2 nodes, located in its lower part. culm height (21.6) 26.3 – 50.4 (58.3) cm, diameter circa 0.4 – 1.0 mm.

Leaves: Cauline leaves arising from the nodes, sheathing the culm for (3.6) 5.3 – 10.3 (11.3) cm. Cauline leaf blades (1.1) 1.4 – 5.3 (7) cm long, conduplicate. Ligules membranous, truncate, with two small auricles. Basal leaf sheaths open to the base, pale, rarely striate with faint red, the oldest ones decaying and of an ashen grey colour, hairy to densely pubescent. Ligules membranous, truncate, often fringed, with two lateral auricles present. Basal leaf blades conduplicate, erect, flexible, (10.6) 11.4 – 27.6 (42.9) cm long, (0.58) 0.64 – 0.90 (1.25) mm in diameter, dark green or greyish, rough to strongly scabrid on most of its length, due to the presence of several teeth on the abaxial surface, sometimes pruinose. Leaf cross-section U to V-shaped, with 5 (7) vascular bundles. Adaxial surface characterized by 3 ribs, and 4 furrows with bulliform cells. Sclerenchyma usually forming a complete and thickened ring, rarely interrupted in 3 main strands (2 marginal, 1 at the keel) and 3 additional strands, one on each side opposed to the vascular bundles. Adaxial surface covered in a dense indumentum of (20) 30 – 70 (90) µm long hairs. Abaxial epidermis with visible undulations between each cell and with frequent teeth.

Inflorescence: Panicles (2.6) 3.2 – 7.2 (8.9) cm long, loose and spreading at anthesis, otherwise contracted, light greenish to straw colored-bronzed at maturity, with 7 – 32 spikelets. Branches scabrid, 1 – 2 per node.

Spikelets: Laterally compressed, lanceolate to elliptic, (5.20) 6.40 – 8.36 (8.96) mm long, with 3 – 6 florets. Glumes unequal, lanceolate to elliptic, membranous with toothed or hairy margins; lower glume 1-veined, (1.95) 2.19 – 3.51 (3.82) mm long; upper glume 3-veined, (2.81) 3.30 – 4.84 (5.2) mm long. Lemmas 5-veined, (3.99) 4.13 – 5.63 (5.95) mm long, rarely glabrous, more commonly puberule to densely hairy, margins glabrous to ciliate, scarious, presenting an apical awn (1.9) 2.20 – 3.78 (4.08) mm long. Palea 2-veined, almost as long as the lemma, lanceolate, bifid at apex, with 2 shortly ciliated keels. Stigmas 2, plumose. Anthers 3, nutant. Caryopsis adherent to the palea.

Cytology: Chromosome number $2n = 6x = 42$.

Distribution and Ecology: Rare, from the eastern edge of the Alps in Austria extending to Bosnia and Romania. Found on xerophilic calcareous sites with shallow rocky soils, either as part of grasslands or open *Pinus nigra* forests.

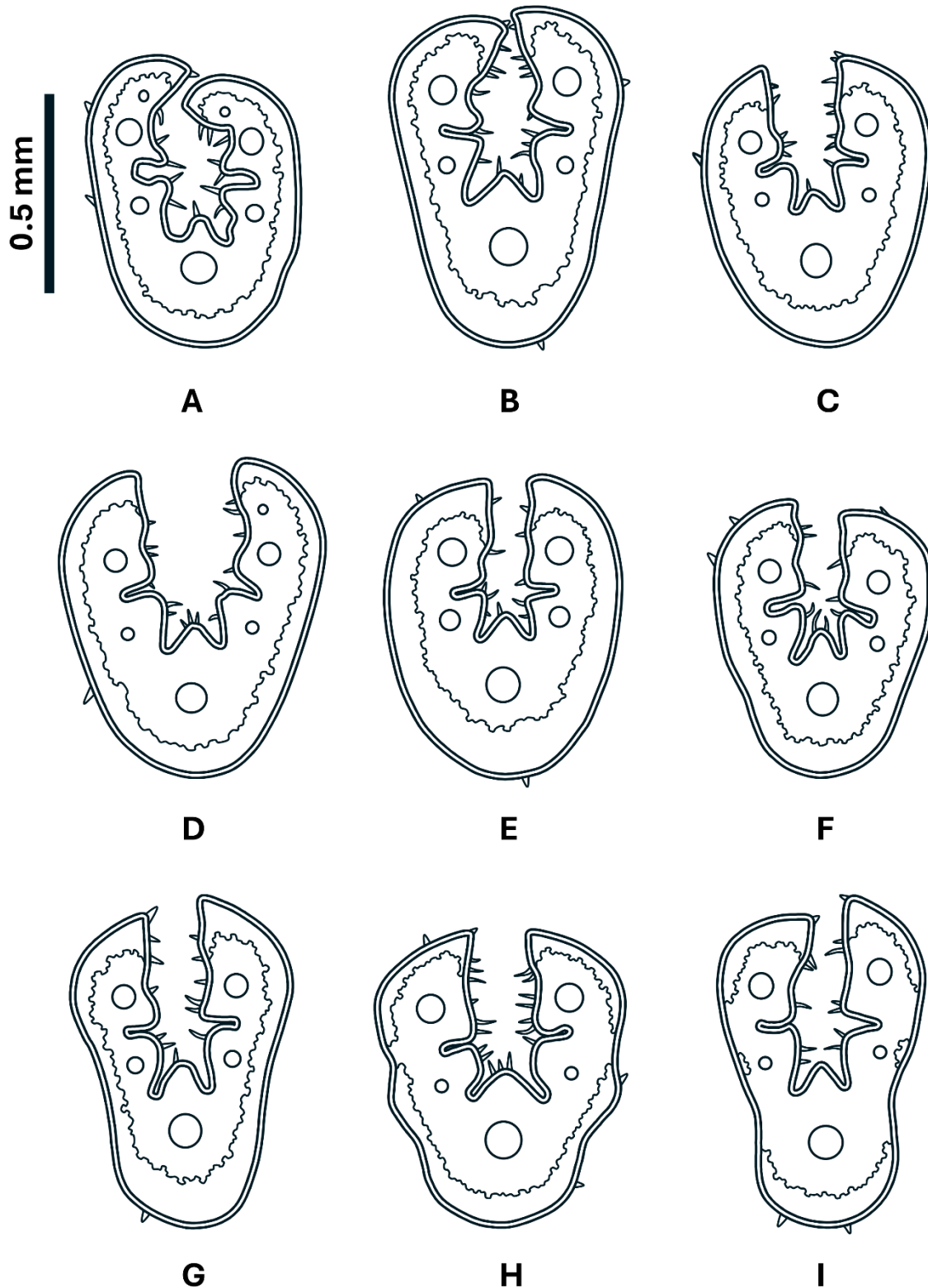
***Festuca stricta* Host**

Figure 20: Morphological variability across leaves cross-sections of *F. stricta*. A: Lectotype preserved at the W herbarium; A: Reichental, Eastern Alps, Upper Austria; B,C: Perchtoldsdorf, Eastern Alps, Lower Austria; D,E: Breitenbrunn, Eastern Alps, Burgenland; G: St. Margarethen, Eastern Alps, Burgenland; H: Sollenau, eastern Alps, Lower Austria; I: Reichental, Eastern Alps, Upper Austria.



Figure 21: Range of distribution for *F. stricta* in the area of study. Data are portrayed as follows: ◆ = verified populations studied for this PhD; ● = records present in literature, databases and herbaria.

7.6 *Festuca rupicola* Heuff. in Verh. K.K. Zool.-Bot. Ges. Wien 8: 233 (1858)Typus

F. rupicola name is originally described for the area around Mt. Domogled, Băile Herculane (Romania). However, neither the protologue nor subsequent literature specify where the original material is preserved and is possibly to be searched and designated from Heuffel's collections. The type for the widely accepted heterotypic synonym *F. sulcata* (which is of less priority when considered as species level) is preserved at the W herbarium (W0353201!).

Description

Perennial herb, densely caespitose, without runners; tillers intravaginal, arising within the lowest leaf sheaths. Plants forming dark green to glaucous-bluish tufts, often pruinose at the nodes, leaf sheaths and leaf blades. Culms erect, cylindrical, scabrid below the panicle, otherwise smooth to the touch, with 1 – 2 nodes, located in its lower part. culm height (24.9) 31.05 – 64.8 (69.8) cm, diameter circa 0.3 – 1.0 mm.

Leaves: Cauline leaves arising from the nodes, sheathing the culm for (5.3) 6.4 – 15.5 (17.2) cm. Cauline leaf blades (1.5) 2.7 – 9.8 (16.9) cm long, conduplicate. Ligules membranous, truncate, with two small auricles. Basal leaf sheaths open to the base, pale, rarely striate with faint red, the oldest ones decaying and of an ashen grey colour, glabrous to pubescent. Ligules membranous, truncate, often fringed, with two lateral auricles present. Basal leaf blades conduplicate, erect, flexible, (9.4) 14.6 – 39.4 (49.3) cm long, (0.50) 0.54 – 0.76 (0.82) mm in diameter, dark green or glaucous-bluish, rough to strongly scabrid due to the presence of several teeth on the abaxial surface, sometimes pruinose. Leaf cross-section V-shaped, with 5 (7) vascular bundles. Adaxial surface characterized by 3 ribs, and 4 furrows with bulliform cells. Sclerenchyma usually in 3 main strands (2 marginal, 1 at the keel), sometimes thickened, rarely with 1 additional strand on each side, opposed to the vascular bundles. In exceptionally rare occasions confluent into forming an interrupted or complete ring. Adaxial surface covered in a sparse indumentum of 20 – 50 (80) µm long hairs. Abaxial epidermis with visible undulations between each cell and with frequent teeth.

Inflorescence: Panicles (3.9) 4.1 – 9.9 (10.5) cm long, loose and spreading at anthesis, contracted before and after, light greenish to straw colored at maturity, with 7 – 49 spikelets. Branches scabrid, 1 – 2 per node, the lower ones branched themselves.

Spikelets: Laterally compressed, lanceolate to elliptic, (6.17) 6.44 – 8.55 (8.95) mm long, with 4 – 8 florets. Glumes unequal, lanceolate to elliptic, membranous with toothed or hairy margins; lower glume 1-veined, (2.1) 2.27 – 3.90 (4.12) mm long; upper glume 3-veined, (3.33) 3.37 – 5.17 (5.91) mm long. Lemmas 5-veined, (4.06) 4.32 – 5.70 (6.01) mm long, glabrous or hairy distally, margins scarious, glabrous to ciliate, presenting an apical awn (1.53) 2.04 – 3.26 (3.59) mm long. Palea 2-veined almost as long as the lemma, lanceolate, bifid at apex, with 2 shortly ciliated keels. Stigmas 2, plumose. Anthers 3, nutant. Caryopsis adherent to the palea.

Cytology: Chromosome number $2n = 6x = 42$.

Distribution and Ecology: Widely distributed, from Central-eastern Europe up to Central Asia. Typical of xerophilous grasslands and continental steppes, with a preference for more evolved soils. Also more rarely found in shrublands and open forests as it's more tolerant to shade compared to other species of the complex.

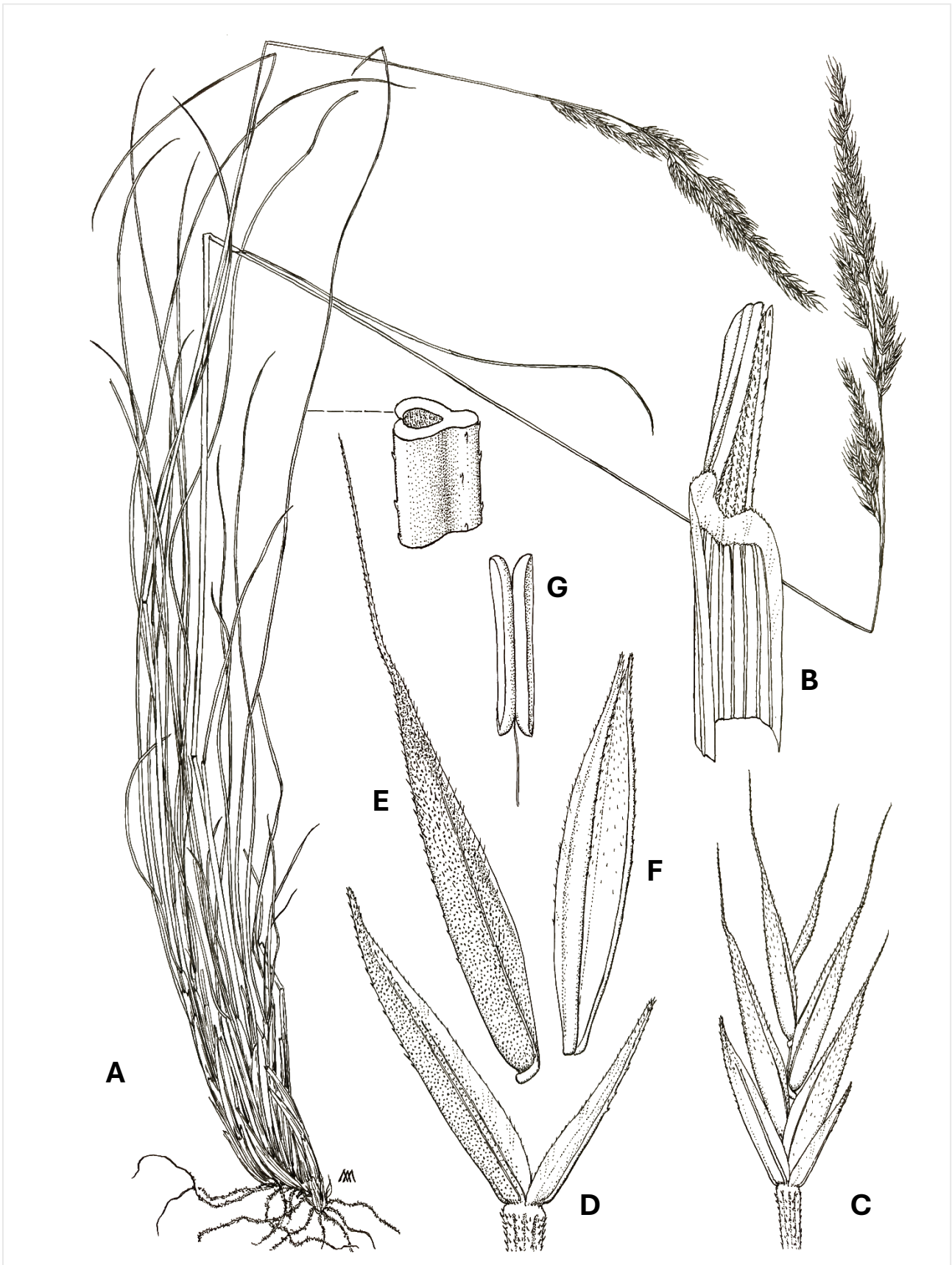


Figure 22: Illustration of *F. rupicola*. A: overall species appearance and tiller leaf section; B: tiller leaves sheath and ligula; C: spikelet; D: glumes; E: lemma; F: palea; G: stamen. Artwork by Anne Eldredge Maury.

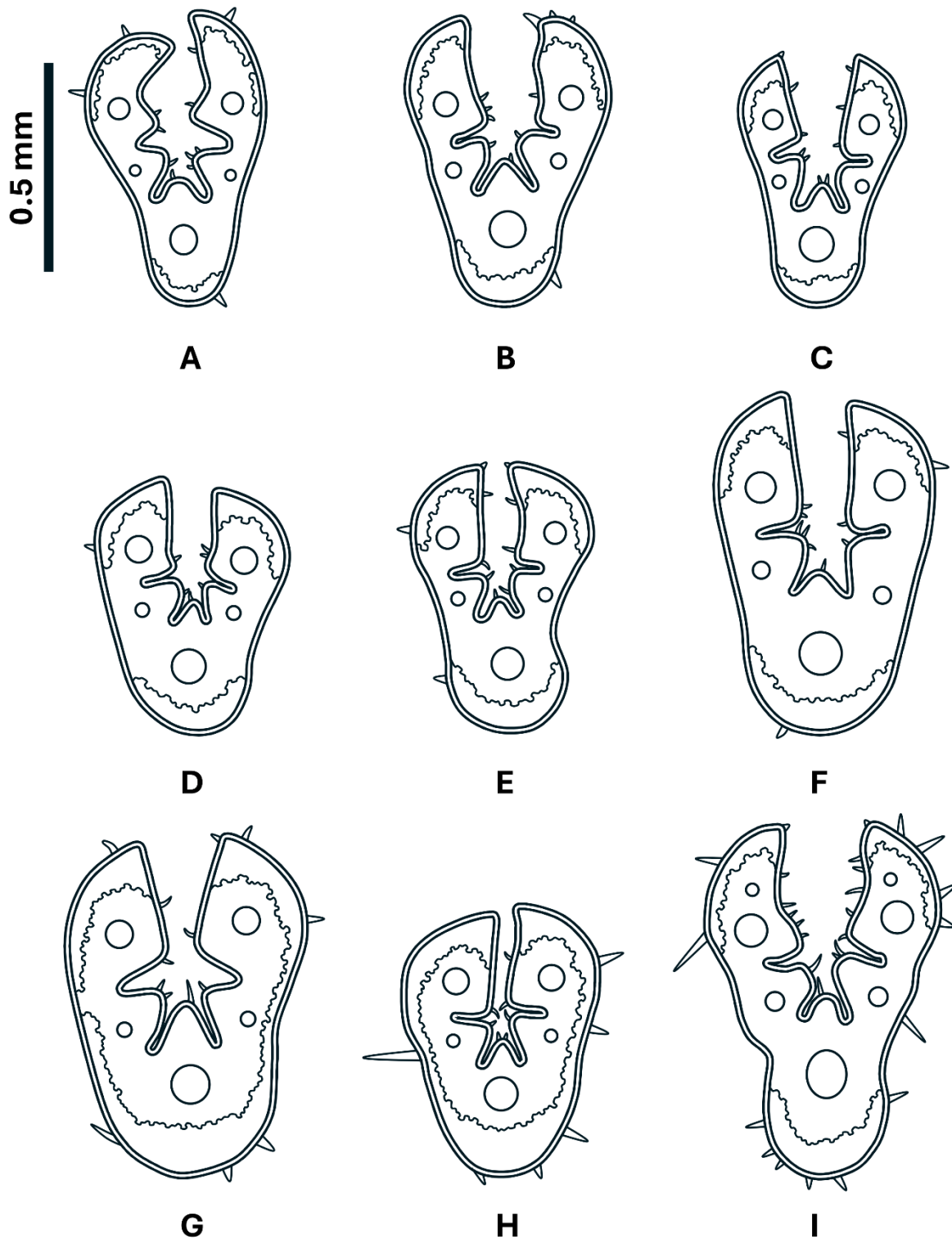
***Festuca rupicola* Heuff.**

Figure 23: Morphological variability across leaves cross-sections of *F. rupicola*. A: Lectotype for *F. sulcata* (= *F. rupicola*) preserved at the W herbarium; B: Sankt Peter Freienstein, Styria, eastern Alps; C, I: Tanas, Laas, Sarntal Alps; D: Dreistetten, Eastern Alps, Lower Austria; E: Reichental, Eastern Alps, Upper Austria; F: Mt. Barro, Galbate, Lugano Prealps; G,H: Castelbello, Sarntal Alps.

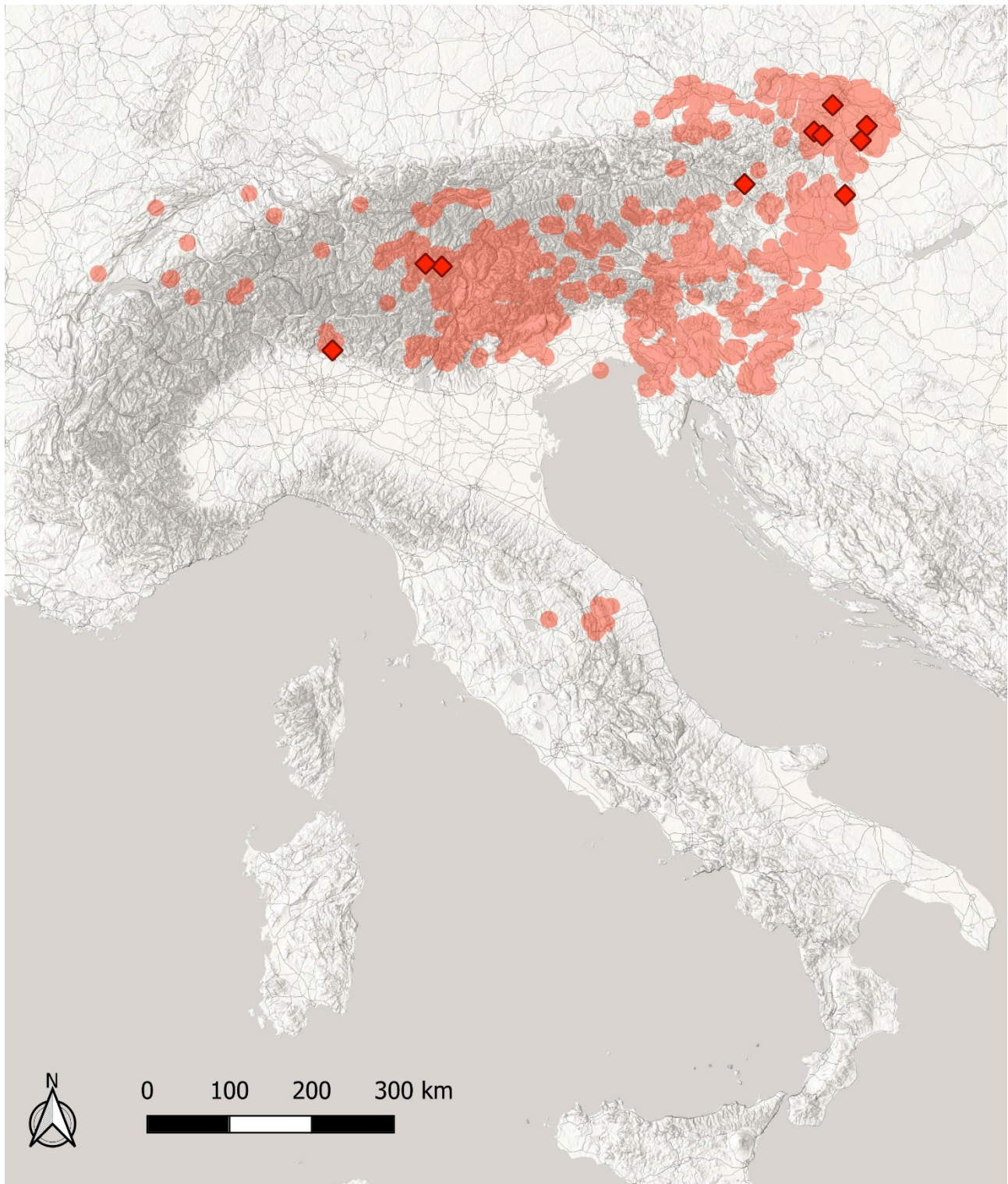


Figure 24: Range of distribution for *F. rupicola* in the area of study. Data are portrayed as follows: ◆ = verified populations studied for this PhD; ● = records present in literature, databases and herbaria.

7.7 *Festuca trachyphylla* (Hack.) R.P. Murray in The Flora of Somerset:318 (1896)Typus

W0353200!; W0040166! Lectotype designated by Wilkinson & Stace (1988).

Description

Perennial herb, densely caespitose, without runners; tillers intravaginal, arising within the lowest leaf sheaths. Plants forming dark green to glaucous-bluish tufts, often pruinose at the nodes, leaf sheaths and leaf blades. Culms erect, cylindrical, scabrid below the panicle, otherwise smooth to the touch, with 1 – 2 nodes, located in its lower part. culm height (17.3) 21.8 – 67.2 (73.1) cm, diameter circa 0.4 – 1.3 mm.

Leaves: Cauline leaves arising from the nodes, sheathing the culm for (4.1) 5.4 – 14.4 (26.4) cm. Cauline leaf blades (2.1) 2.3 – 11.7 (28.7) cm long, conduplicate. Ligules membranous, truncate, with two small auricles. Basal leaf sheaths open to the base, pale, rarely striate with faint red, the oldest ones decaying and of an ashen grey colour, puberule to densely hairy, rarely glabrous. Ligules membranous, truncate, often fringed, with two lateral auricles present. Basal leaf blades conduplicate, erect, flexible, (3.5) 7.7 – 49.4 (53.6) cm long, (0.64) 0.66 – 0.97 (1.09) mm in diameter, dark green or glaucous-bluish, rough to strongly scabrid due to the presence of several teeth on the abaxial surface, sometimes pruinose. Leaf cross-section V-shaped, with (5) 7 vascular bundles. Adaxial surface characterized by 3 ribs, and 4 furrows with bulliform cells. Sclerenchyma usually in 3 main strands (2 marginal, 1 at the keel), often with 1–2 additional strands on each side, opposed to the vascular bundles or irregularly confluent with the main strands. In exceptionally rare occasions forming a complete ring. Adaxial surface covered in a sparse indumentum of 10 – 40 (50) µm long hairs. Abaxial epidermis with visible undulations between each cell and with frequent teeth.

Inflorescence: Panicles (3.1) 4.2 – 9.2 (11.5) cm long, loose and spreading at anthesis, contracted before and after, light greenish to straw colored at maturity, with 6 – 45 spikelets. Branches scabrid, 1 – 2 per node.

Spikelets: Laterally compressed, lanceolate to elliptic, (6.64) 6.90 – 8.58 (8.83) mm long, with 3 – 7 florets. Glumes unequal, lanceolate to elliptic, membranous with toothed or hairy margins; lower glume 1-nerved, (2.17) 2.42 – 3.63 (4.21) mm long; upper glume 3-nerved, (3.05) 3.51 – 4.89 (5.03) mm long. Lemmas 5-veined, (4.11) 4.43 – 5.76 (6.28) mm long, glabrous to pubescent, margins scarious, glabrous to ciliate, presenting an apical awn (0.60) 1.85 – 3.55 (4.00) mm long. Palea almost as long as the lemma, lanceolate, bifid at apex, with 2 shortly ciliated keels. Stigmas 2, plumose. Anthers 3, nutant. Caryopsis adherent to the palea.

Cytology: Chromosome number $2n = 6x = 42$.

Distribution and Ecology: Native of Central Europe, now widespread in all the continent from France to eastern and Northern Europe. Originally of xeric grasslands but now common also in anthropic environments.

Notes: Due to its capabilities to grow in synanthropic conditions and the wide use of commercial varieties, it remains difficult to understand what the natural geographical and morphological boundaries of this taxon are (Foggi et al. 2017). A proper study involving phylogenomics of both cultivated and wild plants from all types of habitats could shed some light on the matter, revealing relationships between different morphotypes and populations of different localities.

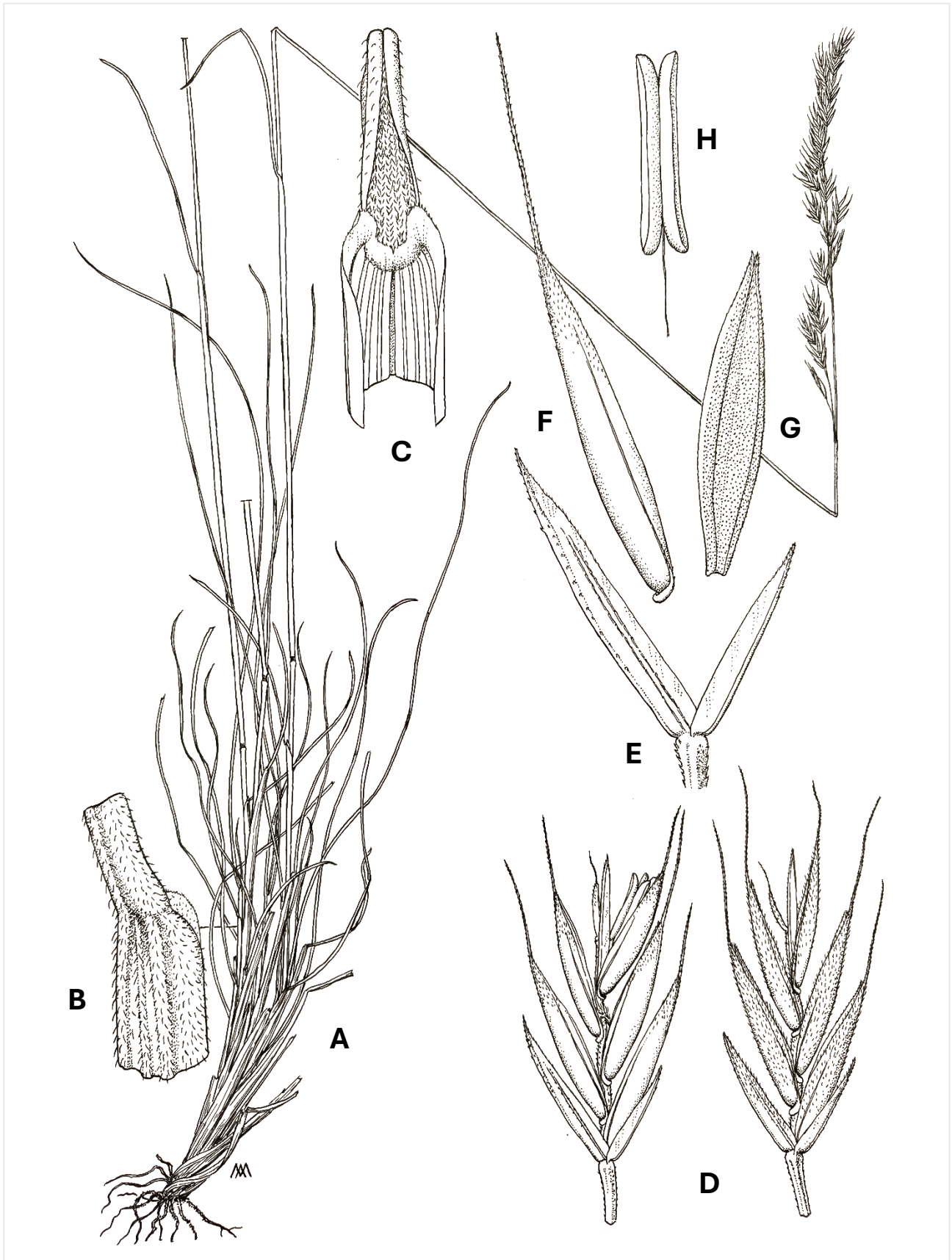


Figure 25: Illustration of *F. trachyphylla*. A: overall species appearance; B: tiller leaves sheath; C: ligula; D: spikelets variability; E: glumes; F: lemma; G: palea; H: stamen. Artwork by Anne Eldredge Maury.

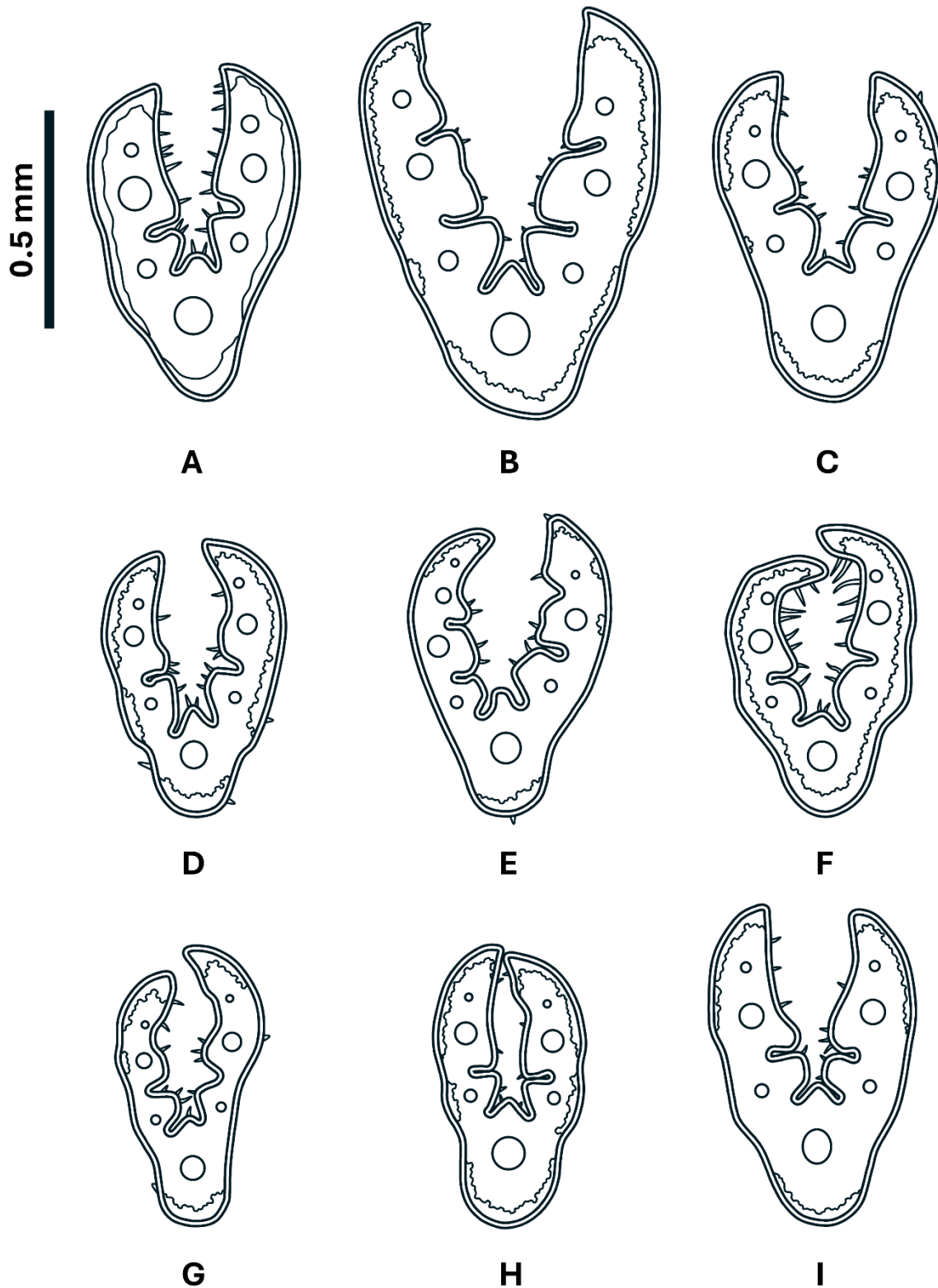
***Festuca trachyphylla* (Hack.) R.P. Murray**

Figure 26: Morphological variability across leaves cross-sections of *F. trachyphylla*. A: Drawing on the lectotype preserved at the W herbarium; B, C: Bad Vöslau-Gainfarn, Eastern Alps, Lower Austria; D – F: Mt. Amiata group, Tuscan Apennine. G: Villata, Lombardy; H: Amaliendorf, Lower Austria; I: Fontana, Valle Leventina, Canton Ticino.

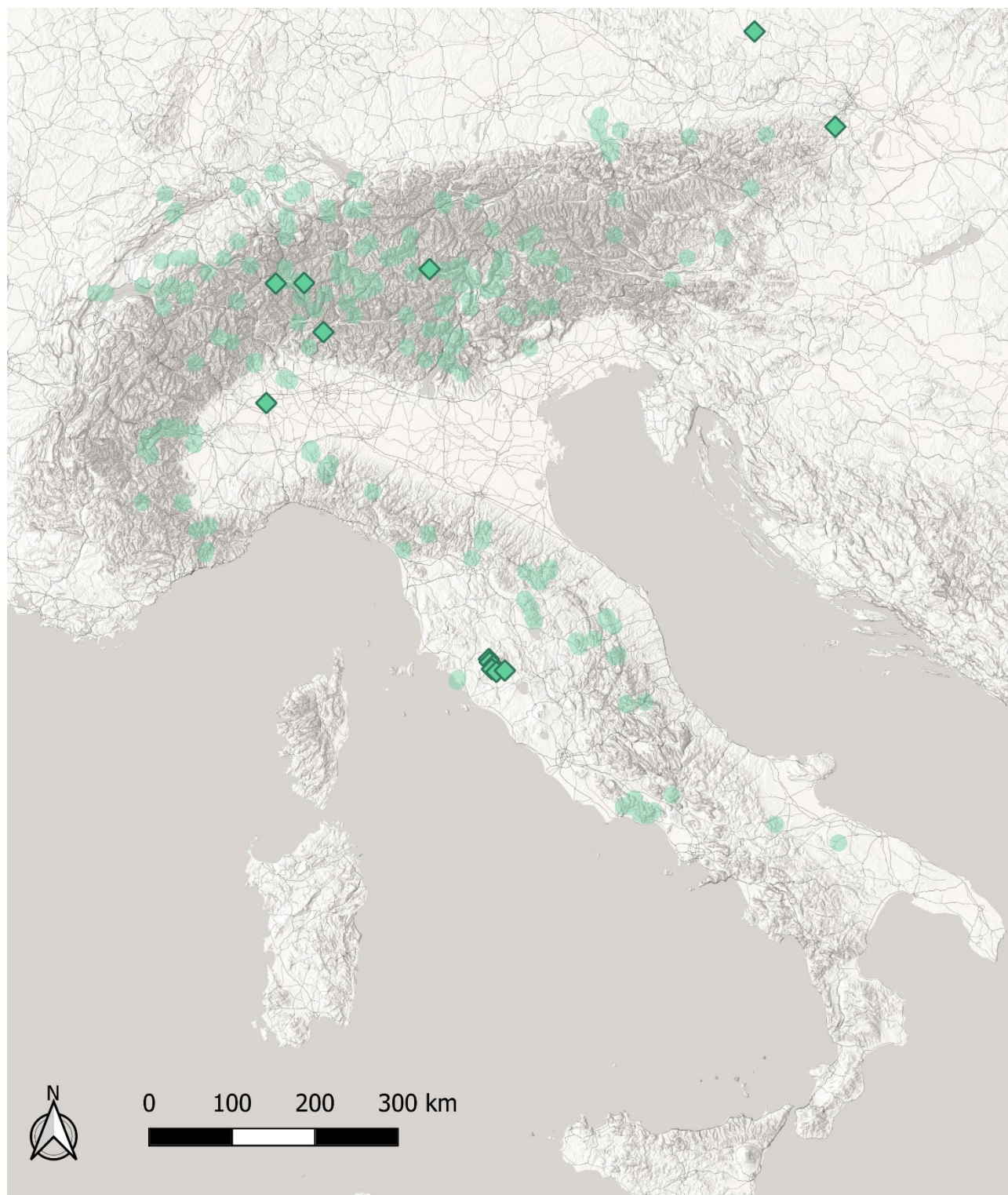


Figure 27: Range of distribution for *F. trachyphylla* in the area of study. Data are portrayed as follows: ◆ = verified populations studied for this PhD; ● = records present in literature, databases and herbaria.

7.8 *Festuca bauzanina* (Pils) S.Arndt in Pl. Syst. Evol. 271(3-4): 135 (2008)Typus

WU0079182! Holotype.

Description

Perennial herb, densely caespitose, without runners; tillers intravaginal, arising within the lowest leaf sheaths. Plants forming dark green to glaucous-bluish tufts, often pruinose at the nodes, leaf sheaths and leaf blades. Culms erect, cylindrical, slightly scabrid below the panicle, otherwise smooth to the touch, with 1 – 2 nodes, located in its lower part. culm height (21.6) 32.3 – 66.2 (71.1) cm, diameter circa 0.4 – 1.2 mm.

Leaves: Cauline leaves arising from the nodes, sheathing the culm for (5.1) 6.8 – 16.6 (17.8) cm. Cauline leaf blades (1.8) 3.6 – 14.4 (21.2) cm long, conduplicate. Ligules membranous, truncate, with two small auricles. Basal leaf sheaths open to the base, the younger pale, then turning to an ashen grey as they decay, puberule to densely pubescent. Ligules membranous, truncate, often fringed, with two lateral auricles present. Basal leaf blades conduplicate, erect, flexible, (13.7) 17.18 – 50.15 (62.6) cm long, (0.55) 0.62 – 0.91 (0.96) mm in diameter, dark green or glaucous-bluish, rough to strongly scabrid due to the presence of several teeth on the abaxial surface, sometimes pruinose. Leaf cross-section V-shaped, with 5 (7) vascular bundles. Adaxial surface characterized by 3 ribs, and 4 furrows with bulliform cells. Sclerenchyma usually in 3 main strands (2 marginal, 1 at the keel), often with 1 additional strand on each side, opposed to the vascular bundles or confluent with the main strands. In some occasions forming a complete ring. Adaxial surface covered in a sparse indumentum of 20 – 50 (60) µm long hairs. Abaxial epidermis with visible undulations between each cell and with frequent teeth.

Inflorescence: Panicles (5.4) 5.6 – 12.4 (16.0) cm long, loose and spreading at anthesis, contracted before and after, light greenish to straw colored at maturity, with 9 – 47 spikelets. Branches scabrid, 1 – 2 per node.

Spikelets: Laterally compressed, lanceolate to elliptic, (6.05) 6.54 – 8.95 (9.58) mm long, with 3 – 7 florets. Glumes unequal, lanceolate, herbaceous, glabrous or distally puberule in few occasions, with scarious margins; lower glume 1-nerved, (2.13) 2.58 – 4.07 (4.98) mm long; upper glume 3-nerved, (2.50) 3.60 – 5.49 (6.70) mm long. Lemmas 5-veined, (3.87) 4.43 – 6.06 (6.33) mm long, glabrous to distally pubescent, margins glabrous or sometimes ciliate, presenting an apical awn (1.51) 1.87 – 3.64 (4.57) mm long. Palea almost as long as the lemma, lanceolate, bifid at apex, with 2 shortly ciliated keels. Stigmas 2, plumose. Anthers 3, nutant. Caryopsis adherent to the palea.

Cytology: Chromosome number $2n = 8x = 56$.

Distribution and Ecology: Typical of xerophilous meadows. Also found in more sciaphilous and mesophilic conditions of transitional habitats such as margins of montane woodlands and shrublands. Trentino up to Bozen and extending to Valtelline. Alpine endemic.

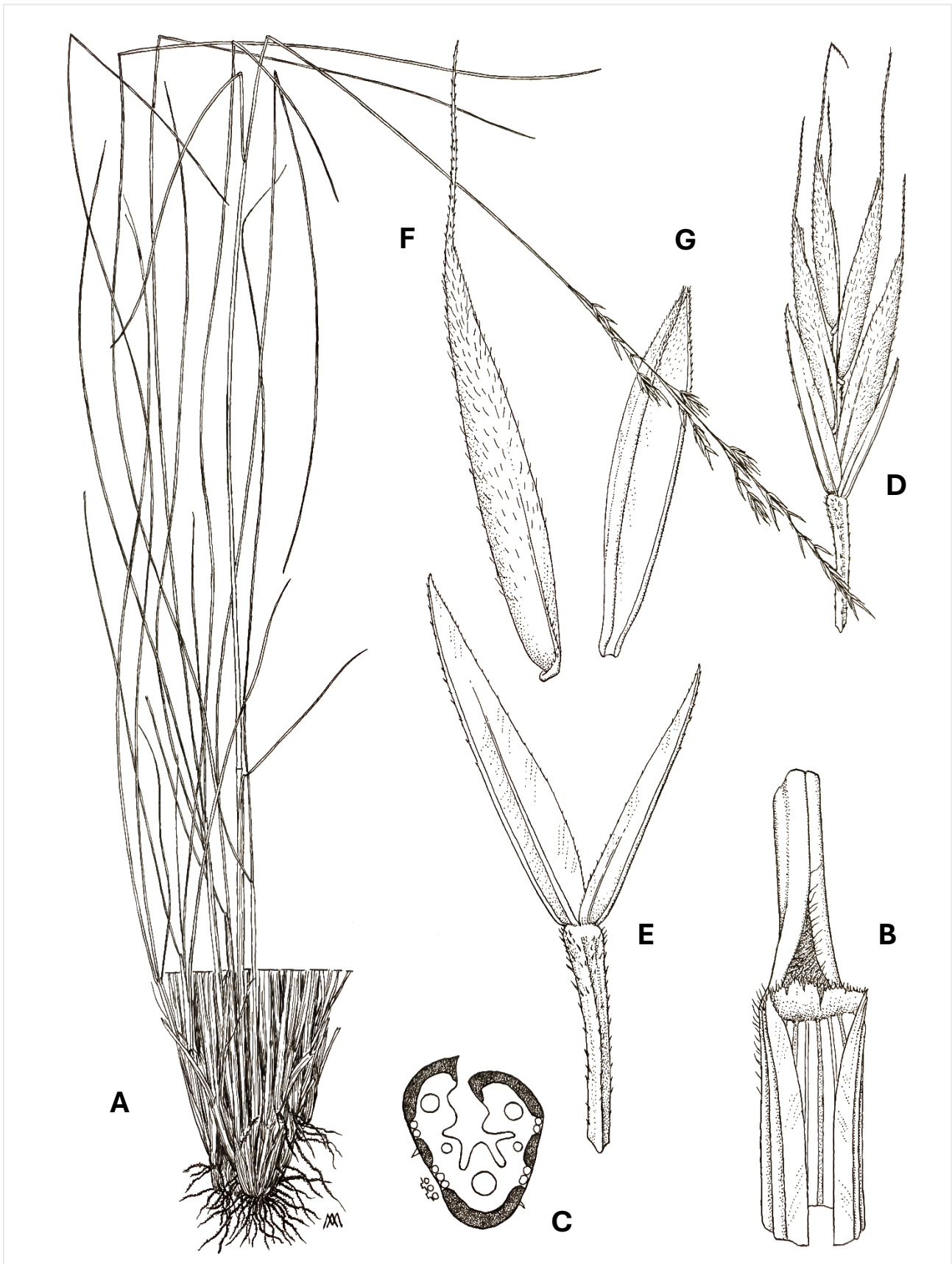


Figure 28: Illustration of *F. bauzanina*. A: overall species appearance; B: tiller leaves sheath and ligula; C: leaf cross-section; D: spikelet; E: glumes; F: lemma; G: palea. Artwork by Anne Eldredge Maury.

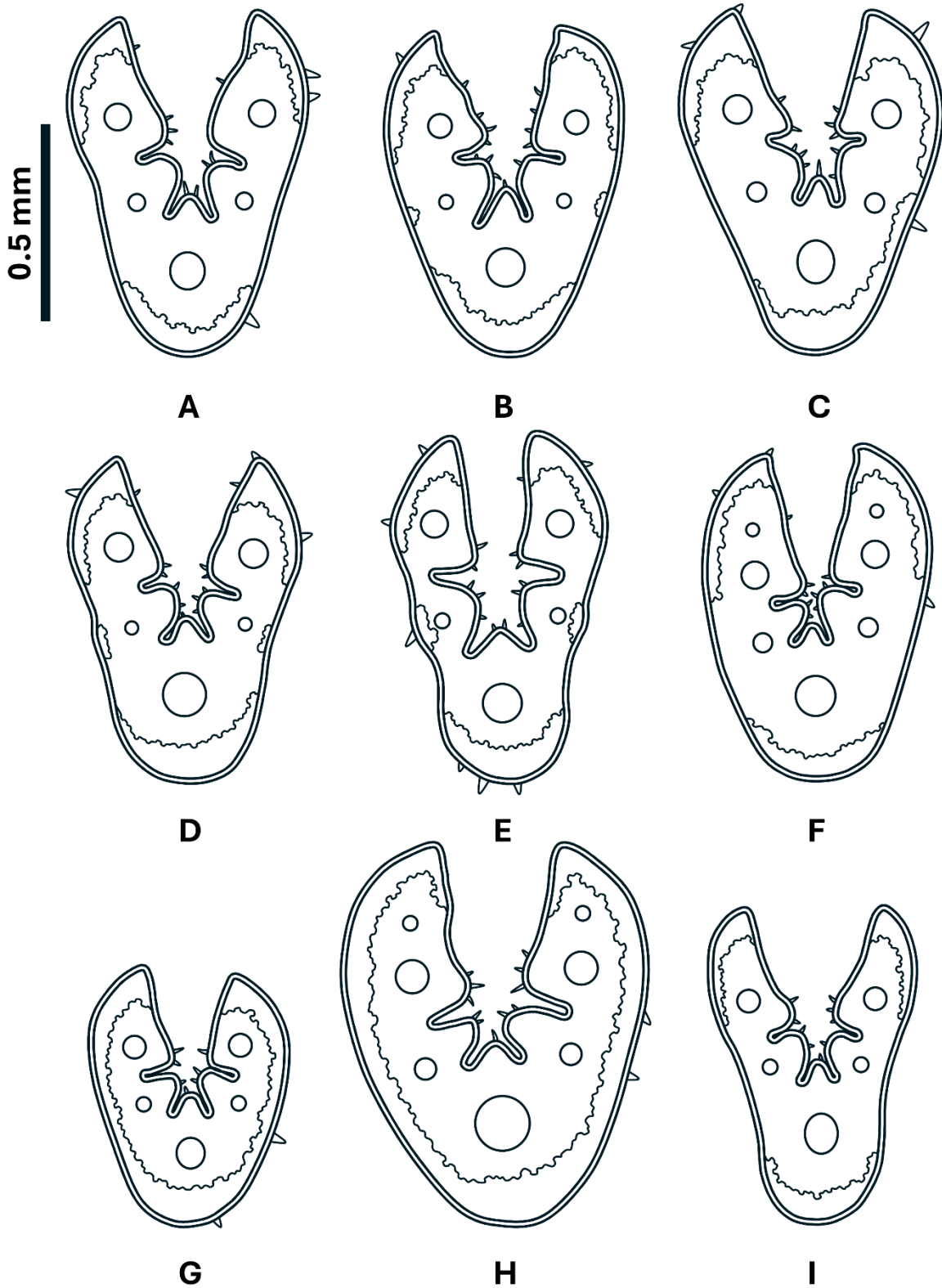
***Festuca bauzanina* (Pils) S.Arndt**

Figure 29: Morphological variability across leaves cross-sections of *F. bauzanina*. A – C: Aica, Natz-Schabs, Sarntal Alps; D – F: Sabiona Abbey, Klausen, Sarntal Alps; G – H: Juval, Naturns, Ötztal Alps; I: Castelfeder, Auer, Dolomites.



Figure 30: Range of distribution for *F. bauzanina* in Italy. Data are portrayed as follows: ◆ = verified populations studied for this PhD; ● = records present in literature, databases and herbaria.

7.9 *Festuca rhaetica* (S.Arndt) Landolt in Fl. Indicativa 269 (2010)Typus

JE00009519!; JE00009520! Holotype

Description

Perennial herb, densely caespitose, without runners; tillers intravaginal, arising within the lowest leaf sheaths. Plants forming dark green to glaucous-bluish tufts, sometimes pruinose at the nodes, leaf sheaths and leaf blades. Culms erect, cylindrical, scabrid below the panicle, otherwise smooth to the touch, with 1–2 nodes, located in its lower part. culm height (23.4) 26.0 – 60.7 (69.7) cm, diameter circa 0.4–1.3 mm.

Leaves: Cauline leaves arising from the nodes, sheathing the culm for (3.8) 4.1 – 14.6 (15.5) cm. Cauline leaf blades (1.6) 4.3 – 11.0 (12.9) cm long, conduplicate. Ligules membranous, truncate with two small auricles. Basal leaf sheaths open to the base, the younger pale, then turning to an ashen grey as they decay, pubescent or glabrous. Ligules membranous, truncate, often fringed, with two lateral auricles present. Basal leaf blades conduplicate, erect, flexible, (16.0) 16.1 – 40.4 (46.5) cm long, (0.69) 0.73 – 0.95 (1.00) mm in diameter, dark green or glaucous-bluish, rough to strongly scabrid due to the presence of several teeth on the abaxial surface, often pruinose. Leaf cross-section V-shaped, with (5) 7 vascular bundles. Adaxial surface characterized by 3 ribs, and 4 furrows with bulliform cells. Sclerenchyma usually in 3 main strands (2 marginal, 1 at the keel), often with 1 additional strand on each side, opposed to the vascular bundles or irregularly confluent with the main strands, in rare occasions forming a complete ring. Adaxial surface covered in a sparse indumentum of 20 – 40 µm long hairs. Abaxial epidermis with visible undulations between each cell and with frequent teeth.

Inflorescence: Panicles (5.1) 5.9 – 10.4 (11.6) cm long, loose and spreading at anthesis, contracted before and after, light greenish to straw-coloured at maturity, with 10 – 40 spikelets. Branches scabrid, 1 – 2 per node.

Spikelets: Laterally compressed, lanceolate, (6.83) 7.35 – 8.83 (9.28) mm long, with 3 – 6 florets. Glumes unequal, lanceolate, herbaceous, glabrous or distally puberule, with scarious margins; lower glume 1-nerved, (2.29) 2.39 – 3.63 (3.89) mm long; upper glume 3-nerved, (3.51) 3.59 – 4.84 (4.94) mm long. Lemmas 5-veined, (4.58) 4.82 – 5.89 (6.06) mm long, glabrous or distally pubescent, margins glabrous to ciliate, presenting an apical awn (2.55) 2.93 – 3.79 (4.7) mm long. Palea almost as long as the lemma, lanceolate, bifid at apex, with 2 shortly ciliated keels. Stigmas 2, plumose. Anthers 3, nutant. Caryopsis adherent to the palea.

Cytology: Chromosome number $2n = 8x = 56$.

Distribution and Ecology: On south exposed calcareous meadows, prevalently in xerophilous habitats. Southern and Eastern Rhaetian Alps but possibly extending to the Lugano Prealps. Central-Alpine endemic.

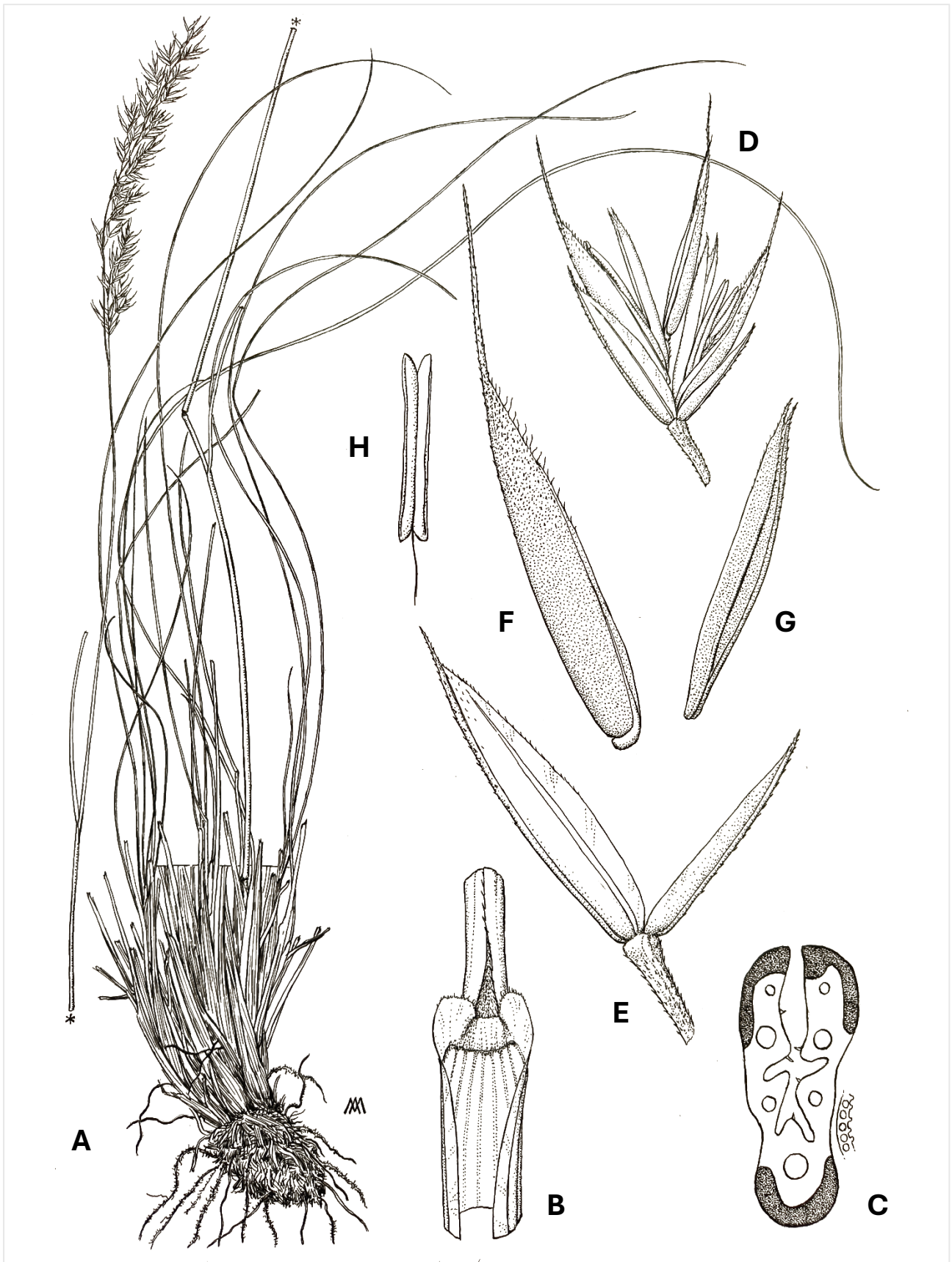


Figure 31: Illustration of *F. rhaetica*. A: overall species appearance; B: tiller leaves sheath and ligula; C: leaf cross-section; D: spikelet; E: glumes; F: lemma; G: palea; H: stamen. Artwork by Anne Eldredge Maury.

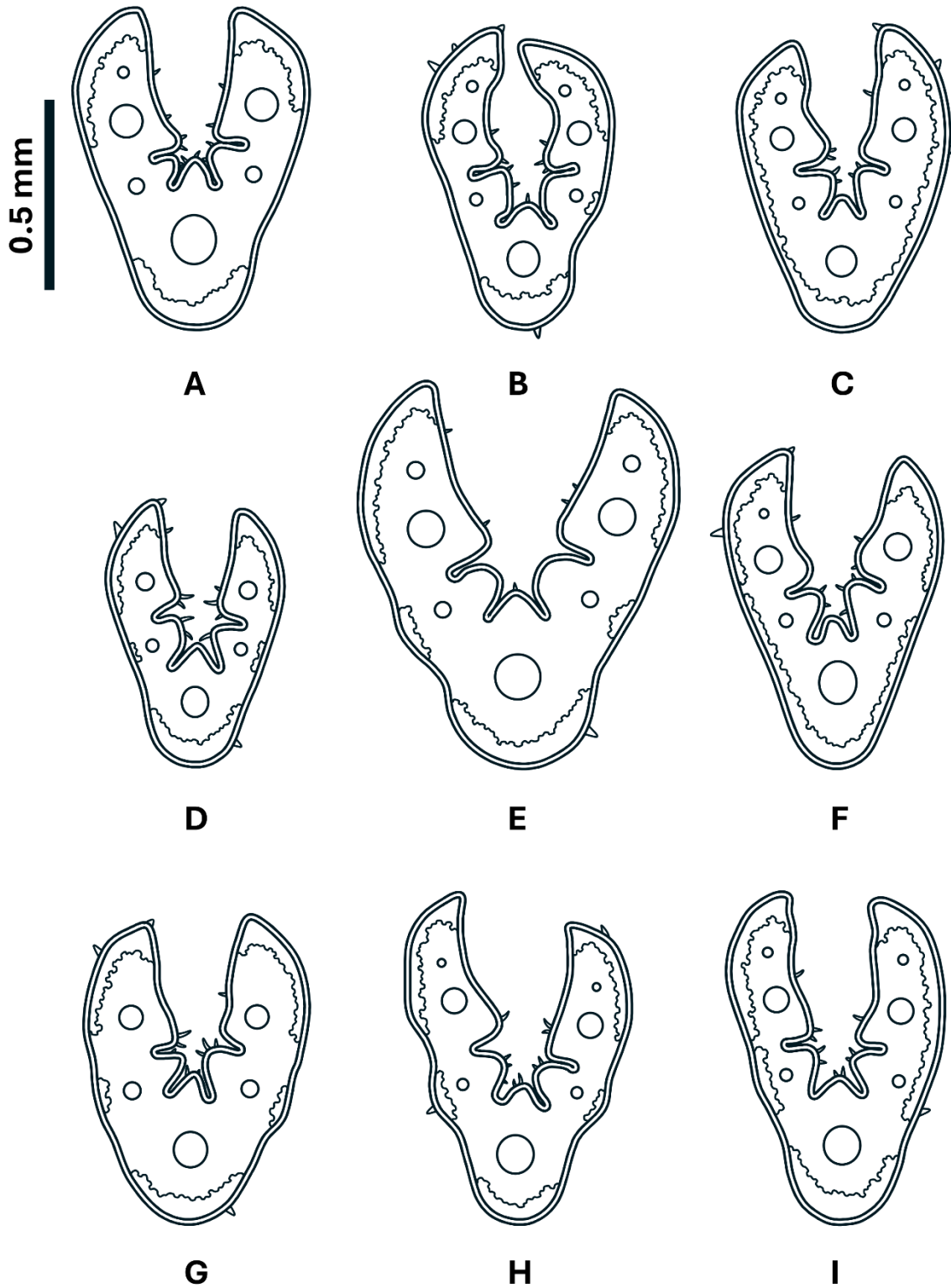
***Festuca rhaetica* (S.Arndt) Landolt**

Figure 32: Morphological variability across leaves cross-sections of *F. rhaetica*. A – G: 2km E of Zernez, Grisons, Western Rhaetian Alps; H – I: Mt. Generoso, Lugano Prealps, Canton Ticino.



Figure 33: Range of distribution for *F. rhaetica* in Italy. Data are portrayed as follows: ◆ = verified populations studied for this PhD; ● = records present in literature, databases and herbaria.

7.10 *Festuca guinochetii* (Bidault) S.Arndt in Pl. Syst. Evol. 271(3-4): 136 (2008)Typus

Herb. Bidault; “probably lost” according to Arndt (2008)

Description

Perennial herb, densely caespitose, without runners; tillers intravaginal, arising within the lowest leaf sheaths. Plants forming dark green to glaucous-bluish tufts, often pruinose at the nodes, leaf sheaths and leaf blades. Culms erect, cylindrical, scabrid below the panicle, otherwise smooth to the touch, with 1 – 3 nodes, located in its lower part. culm height (29.3) 32.5 – 73.5 (77.2) cm, diameter circa 0.5 – 1.2 mm.

Leaves: Cauline leaves arising from the nodes, sheathing the culm for (7.7) 8.28 – 17.02 (19.1) cm. Cauline leaf blades (4.1) 4.9 – 14.1 (18.5) cm long, conduplicate. Ligules membranous, truncate, with two small auricles. Basal leaf sheaths open to the base, pale, rarely striate with faint red, the oldest ones decaying and of an ashen grey colour, visibly pubescent or on few occasions glabrous. Ligules membranous, truncate, often fringed, with two lateral auricles present. Basal leaf blades conduplicate, erect, flexible, (21.4) 23.1 – 43.4 (47.2) cm long, (0.87) 0.89 – 1.19 (1.22) mm in diameter, green to glaucous-bluish, slightly scabrid to rough due to the presence of several teeth on the abaxial surface, rarely pruinose. Leaf cross-section V-shaped, with 7 – 9 vascular bundles. Adaxial surface characterized by 3 (5) ribs, and 4 (6) furrows with bulliform cells. Sclerenchyma usually in 3 main strands (2 marginal, 1 at the keel), often with 2 additional strands on each side, opposed to the vascular bundles or irregularly confluent with the main strands into occasionally forming a complete ring. Adaxial surface covered in a sparse indumentum of 20 – 40 (50) µm long hairs. Abaxial epidermis with faint undulations between each cell and with frequent teeth.

Inflorescence: Panicles (5.5) 5.9– 12.8 (14.6) cm long, loose and spreading at anthesis, contracted before and after, light greenish to straw-coloured at maturity, with 13 – 45 spikelets. Branches scabrid, 1–2 per node.

Spikelets: Laterally compressed, lanceolate, (7.52) 7.57 – 9.64 (9.69) mm long, with 3 – 7 florets. Glumes unequal, lanceolate, herbaceous, glabrous or distally puberule, with scarious margins; lower glume 1-nerved, (2.63) 2.85 – 4.34 (5.08) mm long; upper glume 3-nerved, (3.83) 3.97 – 5.73 (6.00) mm long. Lemmas 5-veined, (5.16) 5.20 – 6.56 (6.74) mm long, glabrous or distally puberule, margins glabrous, presenting an apical awn (1.9) 2.26 – 3.62 (3.95) mm long. Palea almost as long as the lemma, lanceolate, bifid at apex, with 2 shortly ciliated keels. Stigmas 2, plumose. Anthers 3, nutant. Caryopsis adherent to the palea.

Cytology: Chromosome number $2n = 10x = 70$.

Distribution and Ecology: Central Alps, in the area between the Provinces of Sondrio, Bolzano and Trento. Recorded also from few localities in Grisons, Switzerland. Found in habitats ranging from secondary mesophilous grasslands to alpine slopes and rocky habitats.

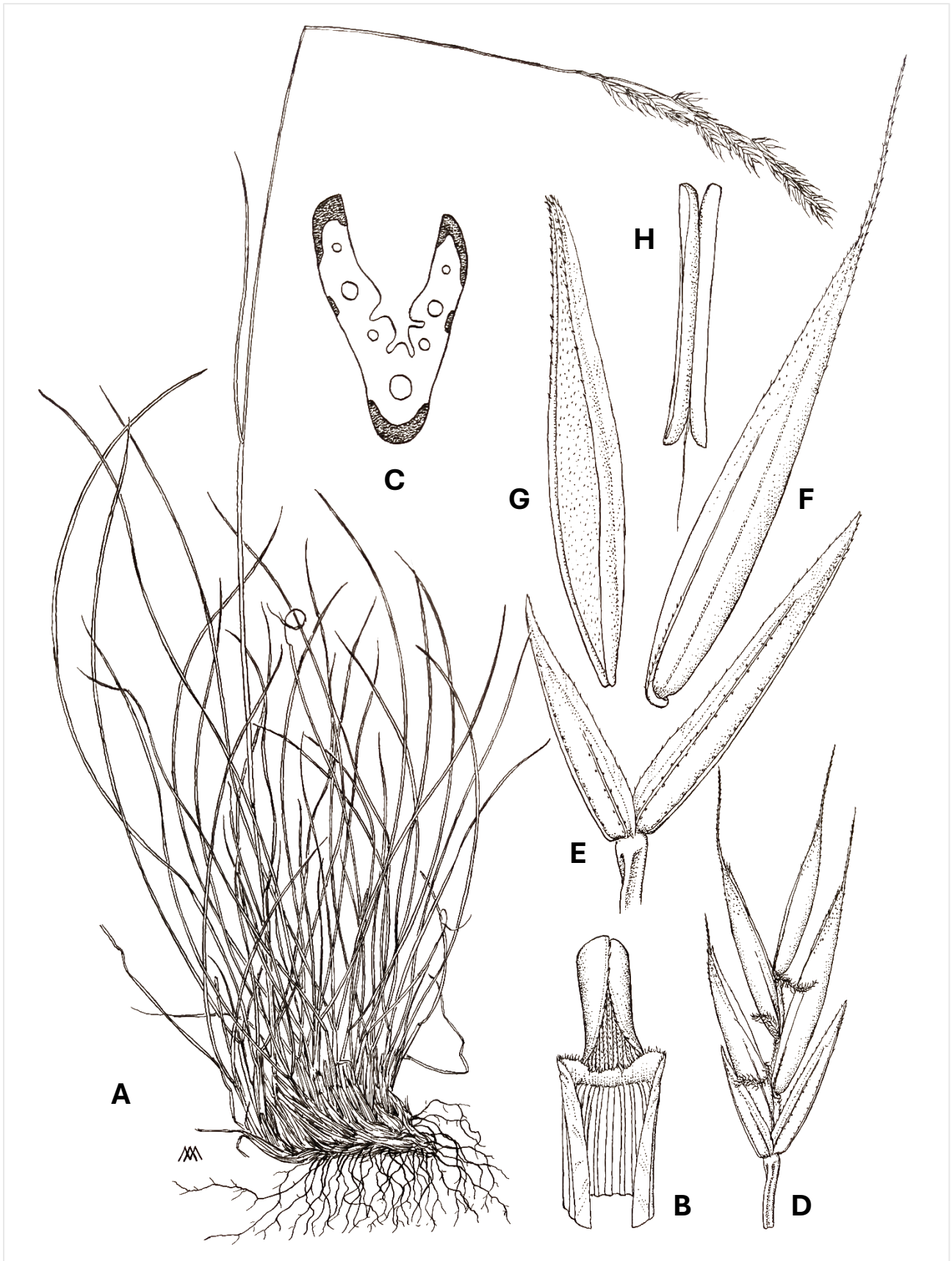


Figure 34: Illustration of *F. guinochetii*. A: overall species appearance; B: tiller leaves sheath and ligula; C: leaf cross-section; D: spikelet; E: glumes; F: lemma; G: palea; H: stamen. Artwork by Anne Eldredge Maury.

***Festuca guinochetii* (Bidault) S.Arndt**

0.5 mm

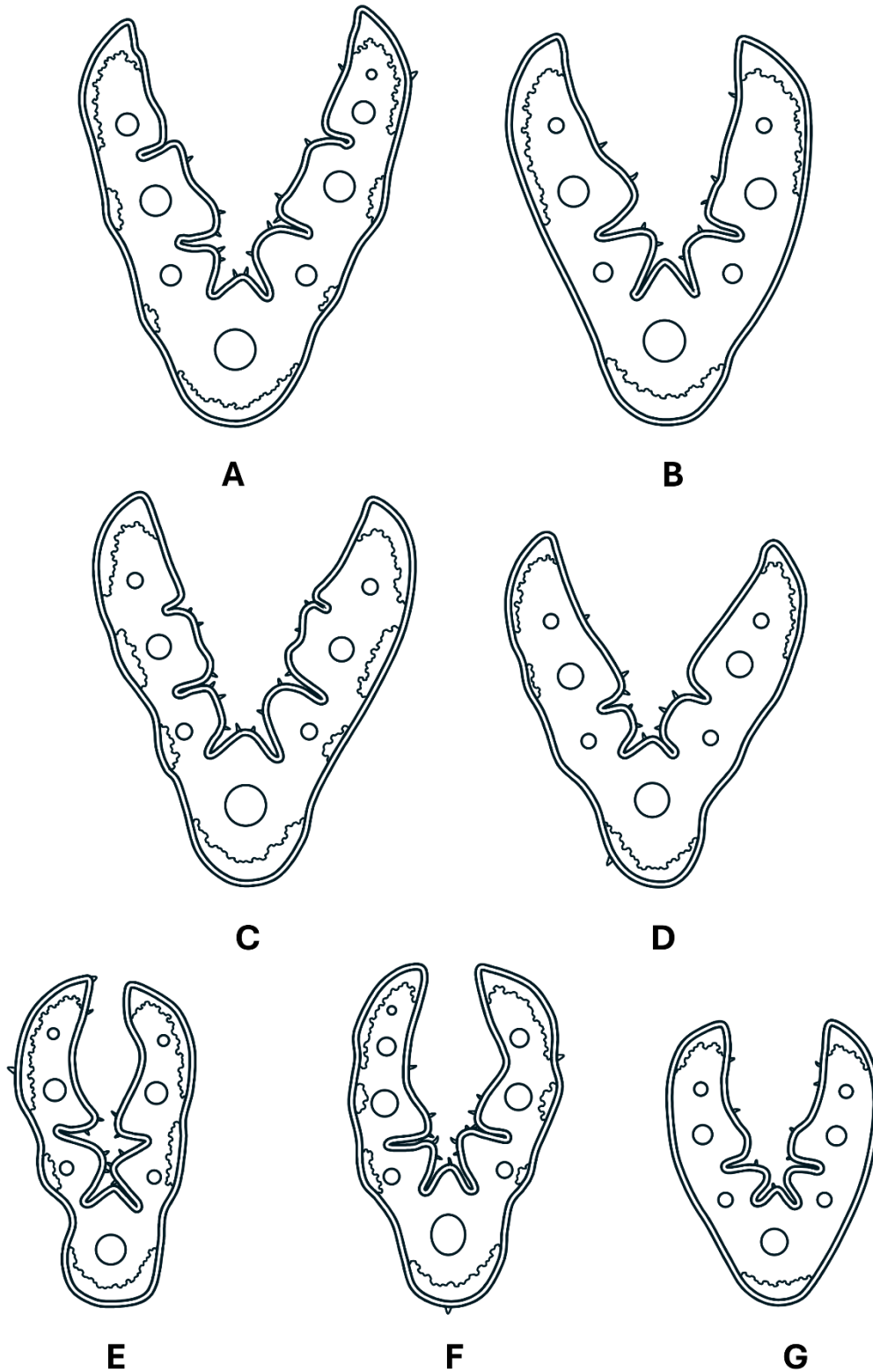


Figure 35: Morphological variability across leaves cross-sections of *F. guinochetii*. A, C, E: S. Antonio di Bormio, Ortler Alps; B, F: Bormio, Ortler Alps; D, G: Gavia Pass, Southern Rhaetian Alps.



Figure 36: Range of distribution for *F. guinochetii* in Italy. Data are portrayed as follows: ◆ = verified populations studied for this PhD; ● = records present in literature, databases and herbaria.

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9 SUPPLEMENTARY MATERIALS

The following supplementary materials are provided in the following pages as an integral part of this PhD thesis:

- Supplementary Materials 1 – Nomenclatural data: A table reporting the names, synonyms, protologues and type collocation for each of the taxa names considered at the beginning of the PhD.
- Supplementary Materials 2 – Retrieved type material: Digital copies of the available types of the taxa names considered at the beginning of the PhD.
- Supplementary Materials 3 – Fieldwork collections: A table reporting for each taxon the locality of collection, the number of individuals sampled, the number of individuals analysed with morphometrics and FCM, as well as the herbarium of origin for the extra material analyzed. A second table following the same layout is provided for the taxa outside the target species of the *stricta-valesiaca* complex.
- Supplementary Materials 4 – FCM data: A table reporting for each taxon (following the preliminary field identification) the locality of collection and results for the sample analysed with FCM. A second table following the same layout is provided for the taxa outside the target species of the *stricta-valesiaca* complex.
- Supplementary Materials 5 – Morphological data: Boxplots for the main morphological variables are provided for the ser. *Valesiaca*e and ser. *Trachyphyllae* taxa.
- Supplementary Materials 6 – ISI publications: A list of the ISI publications produced during the PhD is provided
- Supplementary Materials 7 – Congresses Posters: A list and the full posters presented at congresses during the PhD are provided.
- Supplementary Materials 8 – Congresses Abstracts: A list and the full abstracts presented to the scientific committees for oral presentations at congresses during the PhD are provided.

9.1 Nomenclatural data

The following table presents the early nomenclatural data collected for each taxon of the *stricta-valesiaca* complex. Synonyms are reported under every name that resulted accepted at the moment of the preliminary screening, along with the bibliographical reference to the protologue. Subspecies occurring outside the area of study but belonging to the target species that instead are found naturally in the Italian peninsula and Alps have also been included.

TAXON	PROTOLOGUE
<i>Festuca valesiaca</i> Schleich ex Gaudin	Agrost. Helv. 1: 242 (1811)
<i>Festuca communis</i> var. <i>valesiaca</i> (Schleich. ex Gaudin) Petif	Enum. Pl. Fl. Palat.: 12 (1830)
<i>Festuca duriuscula</i> subsp. <i>valesiaca</i> (Schleich. ex Gaudin) P.Fourn.	Quatre Fl. France: 79 (1934)
<i>Festuca duriuscula</i> var. <i>valesiaca</i> (Schleich. ex Gaudin) Bluff & Fingerh.	Comp. Fl. German. 1: 140 (1825)
<i>Festuca duriuscula</i> var. <i>valesiaca</i> Mutel	Fl. Franç. Herbor. 4: 101 (1837)
<i>Festuca duriuscula</i> subsp. <i>valesiaca</i> (Schleich. ex Gaudin) Celak.	Prodr. Fl. Bohmen 4: 722 (1881)
<i>Festuca ovina</i> subsp. <i>valesiaca</i> (Gaudin) Rouy	Fl. France 14: 211 (1913)
<i>Festuca ovina</i> var. <i>valesiaca</i> (Schleich. ex Gaudin) Link	Hort. Reg. Bot. Berol. 2: 267 (1833)
<i>Festuca ovina</i> var. <i>valesiaca</i> (Schleich. ex Gaudin) W.D.J.Koch	Syn. Fl. Germ. Helv.: 812 (1837)
<i>Festuca ovina</i> f. <i>valesiaca</i> (Schleich ex Gaudin) Asch.	Fl. Prov. Brandenburg: 856 (1864)
<i>Festuca ovina</i> subsp. <i>sulcata</i> var. <i>valesiaca</i> (Schleich. ex Gaudin) Hack.	Bot. Centralbl. 8: 405 (1881)
<i>Festuca ovina</i> subsp. <i>valesiaca</i> (Schleich. ex Gaudin) Kozłowska	Bull. Intern. Acad. Polon. Sci. Lettr., Cl. Sc. Math. Nat. Sér. B 1925: 336 (1925)
<i>Festuca ovina</i> var. <i>valesiaca</i> (Schleich. ex Gaudin) Arcangeli	Comp. Fl. Ital. 2: 59 (1894)
<i>Festuca pallens</i> var. <i>valesiaca</i> (Schleich. ex Gaudin) Opiz	Seznam: 44 (1852)
<i>Festuca sulcata</i> subsp. <i>valesiaca</i> (Schleich. ex Gaudin) Nyman	Consp. Fl. Europ.: 828 (1882)

<i>Festuca sulcata</i> var. <i>valesiaca</i> (Schleich. ex Gaudin) Hervier	Rech. Fl. Loire 1: 54 (1885)
<i>Festuca sulcata</i> var. <i>valesiaca</i> (Schleich. ex Gaudin) Markgr.-Dann.	Verh. Bot. Ver. Prov. Brandenb. 77: 92 (1937)
<i>Festuca sulcata</i> var. <i>valesiaca</i> P.Fourn.	Fl. Compl. Plaine Franç.: 587 (1928)
<i>Festuca biformis</i> J.Vetter	Verh. K. K. Zool.-Bot. Ges. Wien 65: 150 (1915)
<i>Festuca calcigena</i> J.Vetter	Verh. K. K. Zool.-Bot. Ges. Wien 67: 177 (1917)
<i>Festuca diluta</i> J.Vetter	Verh. K. K. Zool.-Bot. Ges. Wien 67: 173 (1917)
<i>Festuca duriuscula</i> var. <i>hirsuta</i> Gaudin	Fl. Helv. 1: 282 (1828)
<i>Festuca firma</i> J.Vetter	Verh. K. K. Zool.-Bot. Ges. Wien 67: 172 (1917)
<i>Festuca glauca</i> var. <i>filiformis</i> Kirschl.	Prodr. Fl. Alsace: 204 (1836)
<i>Festuca glauca</i> var. <i>pannonica</i> (Wulfen) Soó	Acta Bot. Acad. Sci. Hung. 2: 194 (1955)
<i>Festuca interjecta</i> J.Vetter	Verh. K. K. Zool.-Bot. Ges. Wien 67: 175 (1917)
<i>Festuca kirghisorum</i> (Tzvelev) E.B.Alexeev	Novosti Sist. Vyssh. Rast. 15: 65 (1979)
<i>Festuca kirghisorum</i> Katsch.	Fl. Kirgiz. SSR II: 151 (1950), sine descr. lat.
<i>Festuca sulcata</i> subf. <i>subrupicola</i> Nyár.	Rev. Roumaine Biol., Sér. Bot. 9: 163 (1964)
<i>Festuca meredisensis</i> f. <i>subrupicola</i> (Nyár.) Soó	Acta Bot. Acad. Sci. Hung. 17(1-2): 116 (1972)
<i>Festuca meredisensis</i> Nyár.	Bulet. Grăd. Muz. Bot. Cluj 8: 103 (1928)
<i>Festuca ovina</i> subsp. <i>sulcata</i> var. <i>pseudovina</i> subvar. <i>tenuissima</i> Hack.	Monogr. Festuc. Eur.: 103 (1882)
<i>Festuca ovina</i> subvar. <i>hirsuta</i> (Gaudin) Hack.	Monogr. Festuc. Eur.: 105 (1882), nom. illeg.
<i>Festuca ovina</i> var. <i>hirsuta</i> (Gaudin) Link	Hort. Reg. Bot. Berol. 2: 267 (1833), nom. illeg.
<i>Festuca pannonica</i> Wulfen ex Host	Icon. Descr. Gram. Austriac. 4: 36 (1809)
<i>Festuca ovina</i> var. <i>pannonica</i> (Wulfen) Alef.	Landw. Fl.: 354 (1866)
<i>Festuca pallens</i> subsp. <i>pannonica</i> (Wulfen ex Host) Soó	Acta Bot. Acad. Sci. Hung. 18(3-4): 371 (1973)
<i>Festuca pseudovina</i> subsp. <i>tenuissima</i> (Hack.) K. Richt.	Pl. Eur. 1: 95 (1890)
<i>Festuca ronnigeri</i> J.Vetter	Verh. K. K. Zool.-Bot. Ges. Wien 72: 115 (1922)
<i>Festuca rupicola</i> f. <i>hirsuta</i> (Gaudin) Beldie	Fl. Republ. Socialist. România 12: 551 (1972), nom. illeg.
<i>Festuca rupicola</i> subsp. <i>kirghisorum</i> Tzvelev	Bot. Žurn. 56(9): 1255 (1971)

<i>Festuca rupicola</i> var. <i>hirsuta</i> (Gaudin) Tzvelev	Botanika (Minsk) 29: 129 (2010), nom. Inval.
<i>Festuca rupicola</i> var. <i>hirsuta</i> (Gaudin) Tzvelev	Novosti Sist. Vyssh. Rast. 9: 40 (1972)
<i>Festuca saxicola</i> J.Vetter	Verh. K. K. Zool.-Bot. Ges. Wien 67: 178 (1917)
<i>Festuca squamulosa</i> Ovcz. & Shibkova	Izv. Otd. Estestv. Nauk 17: 49 (1957)
<i>Festuca valesiaca</i> f. <i>arida</i> Reverd.	Sist. Zametki Mater. Gerb. Krylova Tomsk. Gosud. Univ. Kuybysheva 3-4: 5 (1928)
<i>Festuca valesiaca</i> var. <i>banatica</i> (Degen) Beldie	Fl. Republ. Socialist. România 12: 546 (1972)
<i>Festuca valesiaca</i> var. <i>pseudovalesiaca</i> Blocki ex Zapł.	Consp. Fl. Galic. Crit. 1: 63 (1906)
<i>Festuca valesiaca</i> f. <i>banatica</i> Degen	Sched. Gram. Hung.: 385 (1914)
<i>Festuca valesiaca</i> f. <i>craiovensis</i> (Buia & Nyár.) Beldie	Fl. Republ. Socialist. România 12: 547 (1972)
<i>Festuca valesiaca</i> f. <i>crassifolia</i> Reverd.	Sist. Zametki Mater. Gerb. Krylova Tomsk. Gosud. Univ. Kuybysheva 3-4: 5 (1928)
<i>Festuca valesiaca</i> f. <i>densiuscula</i> Reverd.	Sist. Zametki Mater. Gerb. Krylova Tomsk. Gosud. Univ. Kuybysheva 3-4: 5 (1928)
<i>Festuca valesiaca</i> f. <i>hirtula</i> (Nyar.) Beldie	Fl. Republ. Socialist. România 12: 547 (1972)
<i>Festuca valesiaca</i> f. <i>longifolia</i> (Rav. ex Nyár.) Beldie	Fl. Republ. Socialist. România 12: 547 (1972)
<i>Festuca valesiaca</i> f. <i>viridis</i> (Nyar.) Beldie	Fl. Republ. Socialist. România 12: 547 (1972)
<i>Festuca craiovensis</i> Buia & A.Nyár.	Rev. Roumaine Biol., Sér. Bot. 9: 161 (1964)
<i>Festuca valesiaca</i> subf. <i>hirtula</i> A.Nyár.	Rev. Roumaine Biol., Sér. Bot. 9: 154 (1964)
<i>Festuca valesiaca</i> subf. <i>longifolia</i> Rav. ex Nyár.	Rev. Roumaine Biol., Sér. Bot. 9: 154 (1964)
<i>Festuca valesiaca</i> subf. <i>viridis</i> A.Nyár.	Rev. Roumaine Biol., Sér. Bot. 9: 155 (1964)
<i>Festuca valesiaca</i> subsp. <i>kirghisorum</i> (Katsch. ex Tzvelev) Tzvelev	Zlaki SSSR: 410 (1976)
<i>Festuca valesiaca</i> var. <i>hirsuta</i> (Link) E.B.Alexeev	Byull. Moskovsk. Obshch. Isp. Prir., Otd. Biol. 78(3): 109 (1973)
<i>Festuca vallesiaca</i> var. <i>strictifolia</i> (Opiz) Krajina	Acta Bot. Bohem. 4: 210 (1930)
<i>Sesleria vallesiaca</i> P.Beauv. ex Steud.	Nomencl. Bot. 1: 339, 772 (1821), pro syn.
<i>Festuca valesiaca</i> subsp. <i>hypsochila</i> (St.-Yves) Tzvelev	Bot. Žurn. 56(9): 1255 (1971)
<i>Festuca ovina</i> var. <i>hypsochila</i> St.-Yves	Candollea 5: 111 (1932)

<i>Festuca kryloviana</i> var. <i>musbelica</i> Reverd.	Sist. Zametki Mater. Gerb. Krylova Tomsk. Gosud. Univ. Kuybysheva 2: 4 (1927)
<i>Festuca valesiaca</i> subsp. <i>musbelica</i> (Reverd.) Tzvelev	Bot. Žurn. 56(9): 1255 (1971)
<i>Festuca musbelica</i> (Reverd.) Ikonn.	Opred. Vyssh. Rast. Badakhshana 75 (1979)
<i>Festuca oreophila</i> Markgr.-Dann.	Willdenowia 11: 208 (1981)
<i>Festuca valesiaca</i> subsp. <i>parviflora</i> (Hack.) Tracey	Pl. Syst. Evol. 128: 291 (1977)
<i>Festuca</i> x <i>boghisensis</i> Prodan	Bul. Ști. Acad. Republ. Populare Romîne, Sect. Biol. Ști. Agric. Ser. Bot. 9: 289 (1957), sine descr.
<i>Festuca compressa</i> Kit.	Linnaea 32: 311 (1864), nom. illeg.
<i>Festuca duriuscula</i> subsp. <i>parviflora</i> Hack.	Term. Füz. 2: 288 (1878)
<i>Festuca duriuscula</i> var. <i>tenuis</i> Hack.	Term. Füz. 2: 288 (1878)
<i>Festuca ovina</i> subsp. <i>sulcata</i> var. <i>pseudovina</i> Hack. (Hack.)	Bot. Centralbl. 8: 405 (1881)
<i>Festuca ovina</i> subsp. <i>pseudovina</i> (Hack. ex Wieseb.) Kozłowska	Bull. Intern. Acad. Polon. Sci. Lettr., Cl. Sc. Math. Nat. Sér. B 1925: 340 (1926)
<i>Festuca ovina</i> subsp. <i>sulcata</i> var. <i>valesiaca</i> subvar. <i>pseudovina</i> (Hack. ex Wieseb.) St.-Yves	Bull. Soc. Bot. France 71: 36 (1924)
<i>Festuca ovina</i> subsp. <i>valesiaca</i> rasse <i>pseudovina</i> (Hack. ex Wiesb Asch. & Graebn.	Syn. Mitteleurop. Fl. 2(1): 480 (1900)
<i>Festuca ovina</i> var. <i>pseudovina</i> (Hack. ex Wiesb.) Hack.	Monogr. Festuc. Eur.: 102 (1882)
<i>Festuca valesiaca</i> subsp. <i>pseudovina</i> (Hack. ex Wiesb.) Hegi	Ill. Fl. Mitt.-Eur. 1: 334 (1906)
<i>Festuca valesiaca</i> subsp. <i>pseudovina</i> (Hack. ex Wiesb.) Simonkai	Enum. Fl. Transsilv.: 588 (1887)
<i>Festuca valesiaca</i> var. <i>pseudovina</i> (Hack. ex Wiesb.) Schinz & R.Keller	Fl. Schweiz, ed. 2: 59 (1905)
<i>Festuca ovina</i> var. <i>dura</i> Hack.	Monogr. Festuc. Eur.: 111 (1882)
<i>Festuca pseudovina</i> f. <i>capillifolia</i> Reverd.	Sist. Zametki Mater. Gerb. Krylova Tomsk. Gosud. Univ. Kuybysheva 3-4: 6 (1928)
<i>Festuca pseudovina</i> f. <i>ciliata</i> Reverd.	Sist. Zametki Mater. Gerb. Krylova Tomsk. Gosud. Univ. Kuybysheva 3-4: 6 (1928)
<i>Festuca pseudovina</i> f. <i>compacta</i> Reverd.	Sist. Zametki Mater. Gerb. Krylova Tomsk. Gosud. Univ. Kuybysheva 3-4: 6 (1928)

<i>Festuca pseudovina</i> f. <i>gracilior</i> Reverd.	Sist. Zametki Mater. Gerb. Krylova Tomsk. Gosud. Univ. Kuybysheva 3-4: 6 (1928)
<i>Festuca pseudovina</i> f. <i>hirtiflora</i> Borbás	Magyar Homokp. Növ.: 70 (1886)
<i>Festuca pseudovina</i> f. <i>rutila</i> (Hack. ex Jáv.) Soó	Acta Bot. Acad. Sci. Hung. 18(3-4): 373 (1973)
<i>Festuca pseudovina</i> f. <i>salina</i> (A.Kern. ex Hack.) Soó	Acta Bot. Acad. Sci. Hung. 18(3-4): 373 (1973)
<i>Festuca pseudovina</i> f. <i>subpruinosa</i> Borbás	Magyar Homokp. Növ.: 70 (1886)
<i>Festuca pseudovina</i> Hack. ex Wiesb.	Oesterr. Bot. Z. 30: 126 (1880)
<i>Festuca pseudovina</i> subf. <i>barbulata</i> Nyár.	Rev. Roumaine Biol., Sér. Bot. 9: 159 (1964)
<i>Festuca pseudovina</i> f. <i>angustiflora</i> (Hack.) Reverd.	Sist. Zametki Mater. Gerb. Krylova Tomsk. Gosud. Univ. Kuybysheva 3-4: 6 (1928)
<i>Festuca pseudovina</i> var. <i>minutiflora</i> Reverd.	Sist. Zametki Mater. Gerb. Krylova Tomsk. Gosud. Univ. Kuybysheva 3-4: 6 (1928)
<i>Festuca pseudovina</i> var. <i>rutila</i> Hack. ex Jáv.	Magyar Fl.: 100 (1924)
<i>Festuca pseudovina</i> var. <i>salina</i> (A.Kern. ex Hack.) Soó	Acta Bot. Acad. Sci. Hung. 18(3-4): 373 (1973)
<i>Festuca pulchra</i> Schur	Enum. Pl. Transsilv.: 785 (1866)
<i>Festuca racemosa</i> Kit.	Linnaea 32: 313 (1864), nom. nud.
<i>Festuca valesiaca</i> subsp. <i>pseudovina</i> (Hack. ex Wiesb.) Hegi	Ill. Fl. Mitt.-Eur. 1: 334 (1906)
<i>Festuca valesiaca</i> subsp. <i>pseudovina</i> var. <i>parviflora</i> (Hack.) Asch. & Graebn.	Ill. Fl. Mitt.-Eur. 1: 334 (1906)
<i>Festuca valesiaca</i> var. <i>tenuis</i> (Hack.) Krajina	Acta Bot. Bohem. 9: 210 (1930)
<i>Festuca pseudovina</i> subsp. <i>angustiflora</i> (Hack.) K. Richt.	Pl. Eur. 1: 95 (1890)
<i>Festuca reptans</i> J.Vetter	Verh. K. K. Zool.-Bot. Ges. Wien 65: 153 (1915)
<i>Festuca valesiaca</i> f. <i>krajinae</i> Soó	Acta Bot. Acad. Sci. Hung. 17(1-2): 116 (1972)

<i>Festuca pseudodalmatica</i> Krajina ex Domin	Acta Bot. Bohem. 8: 61 (1929)
<i>Festuca dalmatica</i> var. <i>pseudodalmatica</i> (Krajina ex Domin) Beldie	Fl. Republ. Socialist. România 12: 548 (1972)
<i>Festuca karadagensis</i> Hadac & Chrtek	Folia Geobot. Phytotax. 4: 212 (1969)
<i>Festuca pseudodalmatica</i> f. <i>angulosa</i> (Nyár. & L.Popov) Soó	Acta Bot. Acad. Sci. Hung. 17(1-2): 116 (1972)

<i>Festuca valesiaca</i> f. <i>angulosa</i> Nyár. & L.Popov	Rev. Roumaine Biol., Sér. Bot. 9: 154 (1964)
<i>Festuca valesiaca</i> subsp. <i>pseudodalmatica</i> (Krajina) Soó	Mezoseg FL.: 11 (1969)
<i>Festuca valesiaca</i> var. <i>pseudodalmatica</i> (Krajina ex Domin) Nyár.	Rev. Roumaine Biol., Sér. Bot. 9: 154 (1964)
<i>Festuca dalmatica</i> subsp. <i>pseudodalmatica</i> (Krajina ex Domin) Soó	Acta Bot. Acad. Sci. Hung. 4: 199 (1957)

<i>Festuca stricta</i> Host	Icon. Descr. Gram. Austriac 2: 62 (1802)
<i>Festuca duriuscula</i> var. <i>stricta</i> (Host) Schur	Enum. Pl. Transsilv.: 787 (1866)
<i>Festuca ovina</i> var. <i>stricta</i> (Host) Link	Hort. Reg. Bot. Berol. 2: 266 (1833)
<i>Festuca ovina</i> subsp. <i>sulcata</i> var. <i>stricta</i> (Host) Hack.	Bot. Centralbl. 8: 405 (1881)
<i>Festuca ovina</i> subsp. <i>sulcata</i> var. <i>sulcata</i> subvar. <i>stricta</i> (Host) Markgr.-Dann.	Ber. Bayer. Bot. Ges. 28: 204 (1950)
<i>Festuca ovina</i> subsp. <i>valesiaca</i> proles <i>stricta</i> (Host) Asch. & Graebn.	Syn. Mitteleurop. Fl. 2(1): 480 (1900)
<i>Festuca valesiaca</i> subsp. <i>stricta</i> (Host) Hegi	Ill. Fl. Mitt.-Eur. 1: 334 (1906)
<i>Festuca duvalii</i> var. <i>multinervis</i> Stohr	Wiss. Z. Martin-Luther-Univ. Halle-Wittenberg, Math.-Naturwiss. Reihe 9: 399 (1960)
<i>Festuca stricta</i> var. <i>multinervis</i> (Stohr) Kerguélen & Plonka	Bull. Soc. Bot. Centre-Ouest, n.s. 1988 19: 20 (1988)
<i>Festuca trachyphylla</i> var. <i>multinervis</i> (Stohr) Stohr ex Auquier	Nouv. Fl. Belg., Grand-Duché Luxemb., Nord France: 749 (1973)
<i>Festuca brevipila</i> var. <i>multinervis</i> (Stohr) Dengler	Kieler Not. Pflanzenk. Schleswig-Holstein Hamburg 24: 5 (1996)
<i>Festuca stricta</i> f. <i>braunii</i> Soó	Acta Bot. Acad. Sci. Hung. 17(1-2): 116 (1972)
<i>Festuca stricta</i> Schleich. ex Gaudin	Alpina III: 59 (1808)
<i>Festuca intermedia</i> Roem. & Schult.	Syst. Veg., ed. 15 bis 2: 715 (1817), nom. superfl.
<i>Festuca stricta</i> subsp. <i>carnuntina</i> (Tracey) Pils	Phyton 24(1): 54 (1984)
<i>Festuca carnuntina</i> Tracey	Pl. Syst. Evol. 128: 289 (1977)
<i>Festuca stricta</i> subsp. <i>sulcata</i> (Hack.) Pils	Phyton 24(1): 49 (1984)
<i>Festuca ovina</i> var. <i>sulcata</i> Hack.	Bot. Centralbl. 8: 405 (1881)
<i>Festuca ovina</i> subsp. <i>sulcata</i> (Hack.) Hack.	Bot. Centralbl. 8: 405 (1881)

<i>Festuca ovina</i> var. <i>sulcata</i> (Hack.) Arcang.	Comp. Fl. Ital. 2: 59 (1894)
<i>Festuca ovina</i> var. <i>sulcata</i> (Hack.) Hack.	Nachtr. Fl. Nieder-Oesterr.: 26 (1882)
<i>Festuca ovina</i> var. <i>sulcata</i> (Hack.) Rouy	Fl. France 14: 211 (1913)
<i>Festuca rupicola</i> var. <i>sulcata</i> (Hack.) Soó	Erdélyi Mezőség Fl.: 11 (1949)
<i>Festuca stricta</i> subsp. <i>sulcata</i> (Hack.) Patzke	Oesterr. Bot. Z. 108: 506 (1961), nom. amb.
<i>Festuca stricta</i> subsp. <i>sulcata</i> (Hack.) Patzke ex Joch.Müll.	Hausknechtia 7: 67 (1999)
<i>Festuca sulcata</i> (Hack.) Beck	Fl. Nieder-Österreich 1: 103 (1890)
<i>Festuca sulcata</i> (Hack.) Nyman	Consp. Fl. Europ.: 828 (1882)
<i>Festuca valesiaca</i> subsp. <i>sulcata</i> (Hack.) Asch. & Graebn	Syn. Mitteleurop. Fl. 2(1): 478 (1900)
<i>Festuca valesiaca</i> subsp. <i>sulcata</i> (Hack.) Hegi	Ill. Fl. Mitt.-Eur. 1: 333 (1906)
<i>Festuca valesiaca</i> var. <i>sulcata</i> (Hack.) Cadevall	Fl. Catal. 6: 254 (1936)
<i>Festuca vallesiaca</i> subsp. <i>sulcata</i> (Hack.) Schinz & R.Keller	Fl. Schweiz, ed. 2: 59 (1905)
<i>Festuca</i> × <i>subspicata</i> A.Nyár.	Rev. Roumaine Biol., Sér. Bot. 9: 172 (1964), designat. typiomissa
<i>Festuca rupicola</i> f. <i>submutica</i> Beldie	Fl. Republ. Socialist. România 12: 555 (1972)
<i>Festuca anceps</i> Kit.	Linnaea 32: 314 (1864)
<i>Festuca duernsteinensis</i> J.Vetter	Verh. K. K. Zool.-Bot. Ges. Wien 72: 116 (1922)
<i>Festuca duriuscula</i> f. <i>inaequata</i> Kit. ex Hack.	Term. Füz. 2: 284 (1878)
<i>Festuca rupicola</i> f. <i>inaequata</i> (Kit. ex Hack.) Soó	Acta Bot. Acad. Sci. Hung. 17(1-2): 117 (1972)
<i>Festuca duriuscula</i> f. <i>pauciflora</i> Heuff.	Verh. K. K. Zool.-Bot. Ges. Wien 8: 196 (1858)
<i>Festuca rupicola</i> f. <i>pauciflora</i> (Heuff.) Soó	Acta Bot. Acad. Sci. Hung. 17(1-2): 117 (1972)
<i>Festuca ganeschinii</i> Drobow	Trudy Bot. Muz. Imp. Akad. Nauk 14: 175 (1915)
<i>Festuca glaberrima</i> Schur	Enum. Pl. Transsilv.: 791 (1866)
<i>Festuca rupicola</i> f. <i>glaberrima</i> (Schur) Beldie	Fl. Republ. Socialist. România 12: 555 (1972)
<i>Festuca granitica</i> J.Vetter	Verh. K. K. Zool.-Bot. Ges. Wien 67: 179 (1917)
<i>Festuca megaphylla</i> Schur	Enum. Pl. Transsilv.: 789 (1866)
<i>Festuca ovina</i> subsp. <i>sulcata</i> var. <i>genuina</i> Hack.	Monogr. Festuc. Eur.: 104 (1882)
<i>Festuca ovina</i> subvar. <i>barbulata</i> Hack.	Monogr. Festuc. Eur.: 105 (1882)

<i>Festuca ovina</i> subvar. <i>hispida</i> Hack.	Monogr. Festuc. Eur.: 105 (1882)
<i>Festuca rupicola</i> var. <i>hispida</i> (Hack.) Soó	Acta Bot. Acad. Sci. Hung. 10: 376 (1964)
<i>Festuca rupicola</i> f. <i>hispida</i> (Hack.) Beldie	Fl. Republ. Socialist. România 12: 551 (1972)
<i>Festuca ovina</i> subvar. <i>sulcatiformis</i> Markgr.-Dann.	Ber. Bayer. Bot. Ges. 28: 208 (1950)
<i>Festuca ovina</i> var. <i>fissa</i> J.Vetter	Repert. Spec. Nov. Regni Veg. 48: 166 (1940)
<i>Festuca ovina</i> var. <i>juncifolia</i> J.Vetter	Repert. Spec. Nov. Regni Veg. 48: 166 (1940)
<i>Festuca colorata</i> Schur	Enum. Pl. Transsilv.: 788 (1866)
<i>Festuca pallens</i> subsp. <i>colorata</i> (Schur) Breistr.	Bull. Soc. Bot. France 121: 63 (1974)
<i>Festuca rupicola</i> subsp. <i>colorata</i> (Schur) Soó	Acta Bot. Acad. Sci. Hung. 23(3-4): 389 (1978)
<i>Festuca rupicola</i> f. <i>colorata</i> (Schur) Beldie	Fl. Republ. Socialist. România 12: 555 (1972)
<i>Festuca recognita</i> Reverd.	Sist. Zametki Mater. Gerb. Krylova Tomsk. Gosud. Univ. Kuybysheva 3-4: 7 (1928)
<i>Festuca recognita</i> f. <i>glabra</i> Reverd.	Sist. Zametki Mater. Gerb. Krylova Tomsk. Gosud. Univ. Kuybysheva 3-4: 7 (1928)
<i>Festuca recognita</i> f. <i>subglabrata</i> Reverd.	Sist. Zametki Mater. Gerb. Krylova Tomsk. Gosud. Univ. Kuybysheva 3-4: 7 (1928)
<i>Festuca rupicola</i> Heuff.	Verh. K. K. Zool.-Bot. Ges. Wien 8: 233 (1858)
<i>Festuca sulcata</i> var. <i>rupicola</i> (Heuff.) Nyman	Consp. Fl. Europ.: 829 (1882)
<i>Festuca sulcata</i> f. <i>almasului</i> A.Nyár. & Serb.	Rev. Roumaine Biol., Sér. Bot. 9: 163 (1964)
<i>Festuca rupicola</i> f. <i>almasului</i> (A.Nyár. & Serb.) Beldie	Fl. Republ. Socialist. România 12: 552 (1972)
<i>Festuca sulcata</i> f. <i>ciliata</i> Podp.	Spisy Přír. Fak. Masarykovy Univ. 12: 10 (1920)
<i>Festuca rupicola</i> f. <i>ciliata</i> (Podp.) Soó	Acta Bot. Acad. Sci. Hung. 17(1-2): 117 (1972)
<i>Festuca sulcata</i> f. <i>glaucantha-hirsuta</i> Weighart ex Podp.	Kvetena Moravy 6: 155 (1926)
<i>Festuca rupicola</i> f. <i>glaucantha-hirsuta</i> (Weighart ex Podp.) Soó	Acta Bot. Acad. Sci. Hung. 17(1-2): 117 (1972)
<i>Festuca sulcata</i> f. <i>hackelii</i> Zapał.	Consp. Fl. Gallic. Crit. 1: 75 (1906)
<i>Festuca rupicola</i> f. <i>hackelii</i> (Zapał.) Soó	Acta Bot. Acad. Sci. Hung. 17(1-2): 117 (1972)
<i>Festuca sulcata</i> var. <i>incurvata</i> Nyár.	Acta Univ. Szeged., Bot. 1: 32 (1942)
<i>Festuca rupicola</i> f. <i>incurvata</i> (Nyár.) Soó	Acta Bot. Acad. Sci. Hung. 17(1-2): 117 (1972)

<i>Festuca rupicola</i> f. <i>longifolia</i> (Nyár. & Prodan) Soó	Acta Bot. Acad. Sci. Hung. 17(1-2): 117 (1972)
<i>Festuca rupicola</i> f. <i>megaphylla</i> (Schur) Soó	Acta Bot. Acad. Sci. Hung. 17(1-2): 117 (1972)
<i>Festuca rupicola</i> f. <i>minor</i> Beldie	Fl. Republ. Socialist. România 12: 791 (1972)
<i>Festuca sulcata</i> f. <i>portensis</i> Nyár.	Rev. Roumaine Biol., Sér. Bot. 9: 162 (1964)
<i>Festuca rupicola</i> f. <i>portensis</i> (Nyár.) Soó	Acta Bot. Acad. Sci. Hung. 17(1-2): 117 (1972)
<i>Festuca sulcata</i> f. <i>prorepens</i> Rohlena	Acta Bot. Bohem. 2: 4 (1923)
<i>Festuca rupicola</i> f. <i>prorepens</i> (Rohlena) Soó	Acta Bot. Acad. Sci. Hung. 17(1-2): 111 (1972)
<i>Festuca sulcata</i> f. <i>pseudobulbosa</i> Nyár. & Soó	Székely. Fl., Suppl.: 12 (1943)
<i>Festuca rupicola</i> f. <i>pseudobulbosa</i> (Nyár. & Soó) Soó	Acta Bot. Acad. Sci. Hung. 17(1-2): 117 (1972)
<i>Festuca sulcata</i> f. <i>strictiflora</i> Nyár.	Bot. Közlem. 38: 131 (1941)
<i>Festuca rupicola</i> f. <i>strictiflora</i> (Nyár.) Beldie	Fl. Republ. Socialist. România 12: 551 (1972)
<i>Festuca</i> × <i>supinoides</i> A.Nyár.	Rev. Roumaine Biol., Sér. Bot. 9: 171, designat. typiommisa
<i>Festuca rupicola</i> f. <i>supinoides</i> (A.Nyár.) Beldie	Fl. Republ. Socialist. România 12: 555 (1972)
<i>Festuca sulcata</i> f. <i>tricostata</i> Nyár.	Rev. Roumaine Biol., Sér. Bot. 9: 163 (1964)
<i>Festuca rupicola</i> f. <i>tricostata</i> (Nyár.) Soó	Acta Bot. Acad. Sci. Hung. 17(1-2): 117 (1972)
<i>Festuca sulcata</i> var. <i>coziae</i> Nyár.	Rev. Roumaine Biol., Sér. Bot. 9: 163 (1964)
<i>Festuca rupicola</i> var. <i>coziae</i> (A.Nyár.) Beldie	Fl. Republ. Socialist. România 12: 552 (1972)
<i>Festuca rupicola</i> var. <i>dacica</i> Beldie	Fl. Republ. Socialist. România 12: 790 (1972)
<i>Festuca rupicola</i> var. <i>retezatensis</i> Beldie	Fl. Republ. Socialist. România 12: 791 (1972)
<i>Festuca rupicola</i> var. <i>rodnensis</i> Beldie	Fl. Republ. Socialist. România 12: 791 (1972)
<i>Festuca sulcata</i> var. <i>longifolia</i> Nyár. & Prodan	Fl. Român., ed. 2: 1235 (1939)
<i>Festuca sulcata</i> subf. <i>hirtiflora</i> Nyár.	Rev. Roumaine Biol., Sér. Bot. 9: 163 (1964)
<i>Festuca sulcatifrons</i> Nyár.	Rev. Roumaine Biol., Sér. Bot. 9: 171 (1964)
<i>Festuca triplicifolia</i> J.Vetter	Verh. K. K. Zool.-Bot. Ges. Wien 66: 126 (1917)
<i>Festuca vindobonensis</i> J.Vetter	Verh. K. K. Zool.-Bot. Ges. Wien 66: 129 (1917)
<i>Festuca rupicola</i> var. <i>sulcatiformis</i> (Markgr.-Dann.) Markgr.-Dann.	Catal. Fl. Austriae, Erg.-Heft.: 108 (1963)
<i>Festuca valesiaca</i> var. <i>sulcatiformis</i> (Markgr.-Dann.) Stohr	Wiss. Z. Martin-Luther-Univ. Halle-Wittenberg, Math.-Naturwiss. Reihe 9: 398 (1960)

<i>Festuca valesiaca</i> var. <i>ganeschirii</i> (Drobow) Tzvelev	Novosti Sist. Vyssh. Rast. 9: 42 (1972)
<i>Festuca stricta</i> subsp. <i>trachyphylla</i> (Hack.) Patzke ex Pils	Phyton 24(1): 58 (1984)
<i>Festuca trachyphylla</i> (Hack.) R.P. Murray	Fl. Somerset: 318 (1896)
<i>Festuca ovina</i> subvar. <i>trachyphylla</i> Hack.	Monogr. Festuc. Eur.: 91 (1882)
<i>Festuca cinerea</i> var. <i>trachyphylla</i> (Hack.) Stohr	Wiss. Z. Martin-Luther-Univ. Halle-Wittenberg, Math.-Naturwiss. Reihe 9: 395 (1960)
<i>Festuca duriuscula</i> subsp. <i>trachyphylla</i> (Hack.) K. Richt.	Pl. Eur. 1:94 (1890)
<i>Festuca duriuscula</i> var. <i>trachyphylla</i> (Hack.) Dalla Torre & Sarnth	Fl. Tirol 6: 254 (1906)
<i>Festuca duriuscula</i> var. <i>trachyphylla</i> (Hack.) Druce	Fl. Oxfordshire: 348 (1886)
<i>Festuca glauca</i> var. <i>trachyphylla</i> (Hack.) Rohlena	Vestn. Kral. České Spol. Náik, Trida Math.-Pir 1899 24: 4 (1899)
<i>Festuca longifolia</i> var. <i>trachyphylla</i> (Hack.) Howarth	J. Linn. Soc., Bot. 47: 35 (1925)
<i>Festuca ovina</i> f. <i>trachyphylla</i> (Hack.) Jansen	Fl. Neerl. 1(2): 47 (1951)
<i>Festuca ovina</i> subsp. <i>sulcata</i> var. <i>trachyphylla</i> (Hack.) Markgr.-Dann.	Ber. Bayer. Bot. Ges. 28: 204 (1950)
<i>Festuca ovina</i> var. <i>trachyphylla</i> (Hack.) Maire	Fl. Afrique N. 3: 126 (1955)
<i>Festuca ovina</i> var. <i>trachyphylla</i> (Hack.) Druce	List. Brit. PL.: 83 (1908)
<i>Festuca ovina</i> var. <i>trachyphylla</i> (Hack.) Hegi	Ill. Fl. Mitt.-Eur. 1: 332 (1906)
<i>Festuca ovina</i> var. <i>trachyphylla</i> (Hack.) Schinz & R.Keller	Fl. Schweiz, ed. 2: 59 (1905)
<i>Festuca rupicola</i> subsp. <i>trachyphylla</i> (Hack.) Markgr.-Dann.	Catal. Fl. Austriae, Erg.-Heft.: 108 (1963)
<i>Festuca stricta</i> subsp. <i>trachyphylla</i> (Hack.) Patzke ex Joch.Müll.	Hausknechtia 7: 67 (1999)
<i>Festuca stricta</i> subsp. <i>trachyphylla</i> (Hack.) Patzke	Oesterr. Bot. Z. 108: 506 (1961), nom. amb.
<i>Festuca trachyphylla</i> (Hack.) Krajina	Acta Bot. Bohem. 9: 190 (1930)
<i>Festuca duvalii</i> f. <i>barbulata</i> Auquier	Bull. Jard. Bot. Natl. Belg. 39: 114 (1969)

<i>Festuca trachyphylla</i> f. <i>barbulata</i> (Auquier) Auquier	Bull. Soc. Échange Pl. Vasc. Eur. Occid. Bassin Médit. 15: 139 (1974)
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<i>Festuca brevipila</i> Tracey	Pl. Syst. Evol. 128: 287 (1977)
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<i>Festuca ticinensis</i> (Markgr.-Dann.) Markgr.- Dann.	Bot. J. Linn. Soc. 76: 328 (1978)
<i>Festuca ovina</i> subsp. <i>ticinensis</i> Markgr.-Dann.	Veröff. Geobot. Inst. Rübel Zürich 57: 62 (1976)

<i>Festuca bauzanina</i> (Pils) S. Arndt	Pl. Syst. Evol. 271: 135 (2008)
<i>Festuca stricta</i> subsp. <i>bauzanina</i> Pils	Phyton 24(1): 61 (1984)
<i>Festuca rupicola</i> subsp. <i>bauzanina</i> (Pils) Kiem	Ber. Bayer. Bot. Ges. 58: 63 (1987)
<i>Festuca bauzanina</i> subsp. <i>rhaetica</i> S. Arndt	Pl. Syst. Evol. 271: 136 (2008)
<i>Festuca rhaetica</i> (S. Arndt) Landolt	Fl. Indicativa: 269 (2010)

<i>Festuca guinochetii</i> (Bidault) S. Arndt	Pl. Syst. Evol. 271: 136 (2008)
<i>Festuca ovina</i> var. <i>guinochetii</i> Bidault	Bull. Soc. Bot. France 114: 58 (1967)

9.2 Retrieved type material

High quality scans of the types associated with the names considered for the study at the beginning of this PhD project are reported in the pages below:

- *Festuca valesiaca* Schleich. ex Gaudin (LAU!)
- *Festuca pseudodalmatica* Krajina ex Domin (PRC451022!)
- *Festuca stricta* Host (W0353208!)
- *Festuca stricta* subsp. *sulcata* (Hack.) Patzke ex Joch.Müll. (W0353201!)
- *Festuca stricta* subsp. *trachyphylla* (Hack.) Patzke ex Pils (W0353200!; W0040166!)
- *Festuca brevipila* Tracey (W0061924!)
- *Festuca bauzanina* subsp. *bauzanina* (Pils) S.Arndt (WU0079182!)
- *Festuca bauzanina* subsp. *rhaetica* S. Arndt (JE00009519!; JE00009520!)

As explained in the “DISCUSSION” and “PROPOSED TAXONOMIC TREATMENT” chapters of this thesis, the holotype for *Festuca ticinensis* (Markgr.-Dann.) Markgr.-Dann. has been searched and never found in the Z+ZT herbaria (indicated in the protologue), while the holotype for *Festuca guinochetii* (Bidault) S.Arndt is considered to be lost according to Arndt (2008).

Festuca valesiaca Schleich. ex Gaudin



Festuca pseudodalmatica Krajina ex Domin



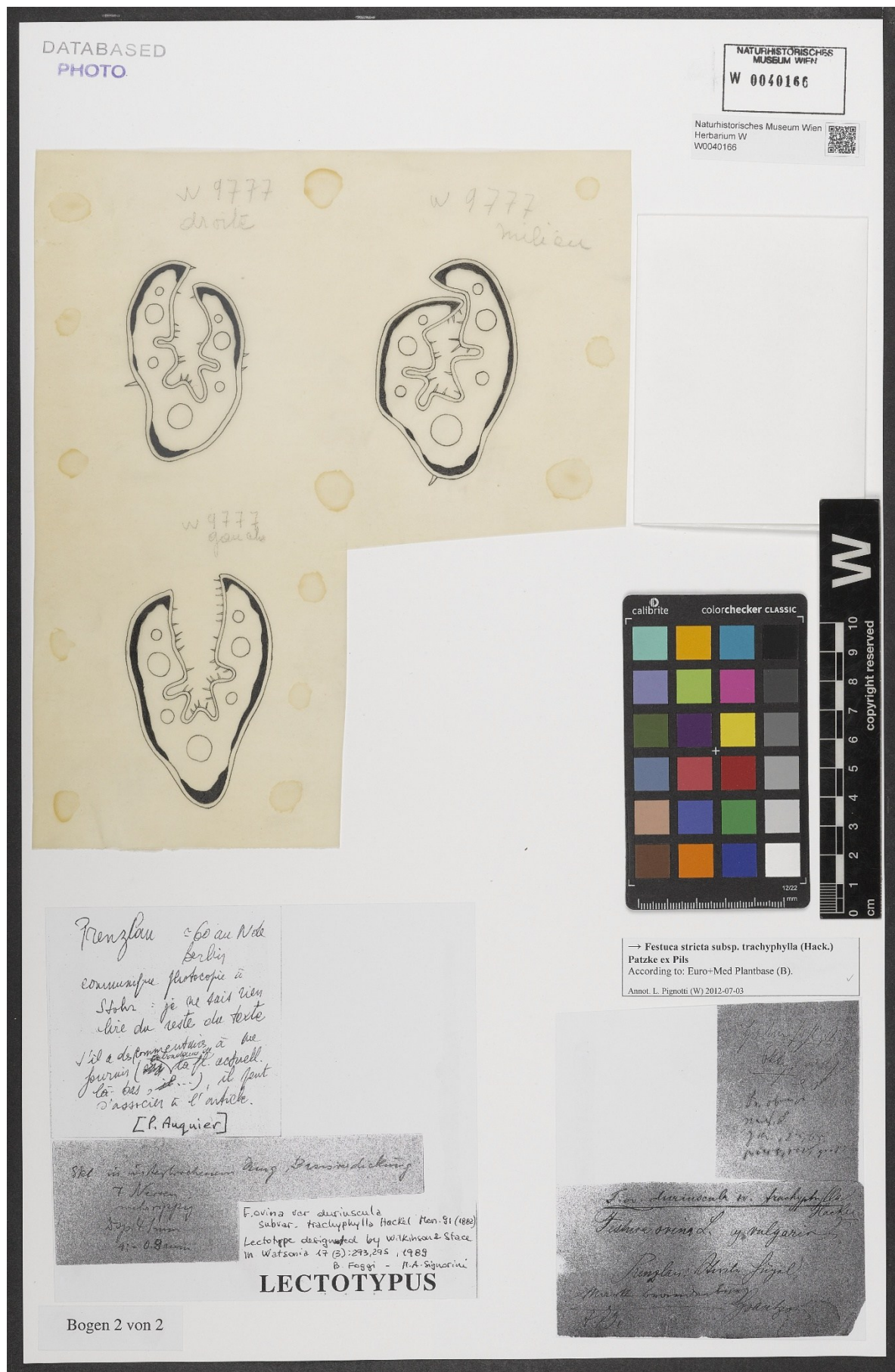
Festuca stricta Host



Festuca stricta subsp. *sulcata* (Hack.) Patzke ex Joch.Müll.



Festuca stricta subsp. *trachyphylla* Patzke ex Pils



Festuca brevipila Tracey



Festuca bauzanina subsp. *bauzanina* (Pils) S.Arndt



Festuca bauzanina subsp. *rhaetica* S. Arndt



Festuca bauzanina supsb. *rhaetica* S. Arndt



9.3 Fieldwork collections

Tables A and B are provided for the samples collected. Columns from left to right are reporting : Localities (★ representing the locus classicus or modern equivalent), number of samples collected, number of samples studied with multivariate morphometry, number of samples studied with FCM (* indicates samples whose ploidy was observed via chromosome count instead), herbarium of origin for samples integrating the collection.

Table A: taxa of the *stricta-valesiaca* complex

<i>Festuca valesiaca</i> Schleich. ex Gaudin				
Locality	N	Morphometry	FCM	Herbarium
Italy, Dubino (SO)	1	1	\	MSNM
Italy, Pescina (AQ)	14	14	2	\
Italy, Lillaz (AO)	18	16	2	\
Italy, Mt. Tsaplana (AO)	15	15	2	\
Italy, Saint-Rhémy en Bosses (AO)	15	15	3	\
Italy, Tanas (BZ)	2	2	1	\
Italy, Castelbello (BZ)	10	4	6	\
Switzerland, Chandonne (VS)★	14	14	3	\
Switzerland, Niederwald (VS)	13	13	3	\
Austria, Breitenbrunn (AT-112)	2	1	1	\
Austria, St. Margarethen (AT-112)	9	6	3	\
Austria, Rechnitz (AT-113)	1	0	1	\
<i>Festuca</i> sp. nova (2n = 4x = 28)				
Locality	N	Morphometry	FCM	Herbarium
Italy, Prati del Sirente (AQ)	26	26	4	\
Italy, Barisciano (AQ)	20	20	4	\
<i>Festuca pseudodalmatica</i> Krajina ex Domin				
Locality	N	Morphometry	FCM	Herbarium
Austria, Rechnitz (AT-113)	13	10	3	\
<i>Festuca stricta</i> subsp. <i>stricta</i> Host				
Locality	N	Morphometry	FCM	Herbarium
Austria, Reichental (AT-122)	20	15	5	\
Austria, Brunn and der Schneebergbahn (AT-122)	15	12	3	\
Austria, Sollenau (AT-122)	20	16	4	\
Austria, Bad Vöslau-Gainfarn (AT-122)	18	14	3	\
Austria, Perchtoldsdorf (AT-127)	16	13	3	\
Austria, Breitenbrunn (AT-112)	14	10	4	\
Austria, St. Margarethen (AT-112)	9	5	4	\
<i>Festuca stricta</i> subsp. <i>sulcata</i> (Hack.) Patzke ex Pils				
Locality	N	Morphometry	FCM	Herbarium
Austria, Reichental (AT-122)	8	7	1	\
Austria, Dreistetten (AT-122)	8	6	2	\
Austria, Perchtoldsdorf (AT-127)	4	1	3	\
Austria, Breitenbrunn (AT-112)	7	4	3	\
Austria, St. Margarethen (AT-112)	5	3	2	\
Austria, Rechnitz (AT-113)	2	0	2	\

Austria, Sankt Peter Freienstein (AT-223)	7	4	3	\
Italy, Castelbello (BZ)	63	30	15	\
Italy, Tanas (BZ)	13	10	2	\
Italy, Mt. Barro (LC)	6	6	0	MSNM
<i>Festuca stricta</i> subsp. <i>trachyphylla</i> (Hack.) R.P.Murray				
Locality	N	Morphometry	FCM	Herbarium
Austria, Bad Vöslau-Gainfarn (AT-122)	7	4	3	\
Italy, Monticello Amiata (GR)	1	1	*	PAV
Italy, Mt. Aquilaia (GR)	7	7	*	PAV
Italy, Mt. Labbro (GR)	6	6	*	PAV
Italy, Roccalbegna (GR)	1	1	*	PAV
Italy, Cellena (GR)	1	1	*	PAV
Italy, Mt. Civitella (GR)	3	3	*	PAV
Italy, Tanas (BZ)	1	1	0	\
Italy, Villata (VC)	5	3	\	PAV
<i>Festuca ticinensis</i> (Markgr.-Dann.) Markgr.-Dann.				
Locality	N	Morphometry	FCM	Herbarium
Switzerland, Fontana (TI)	4	4	2	\
Switzerland, Olivone (TI)	11	10	3	\
Italy, Mt. Grona (CO)	9	9	\	MSNM
Italy, Sesia river near Vercelli (VC)	1	\	\	MSNM
<i>Festuca brevipila</i> Tracey				
Locality	N	Morphometry	FCM	Herbarium
Austria, Amaliendorf (AT3) ★	8	5	6	\
<i>Festuca bauzanina</i> subsp. <i>bauzanina</i> (Pils) S. Arndt				
Locality	N	Morphometry	FCM	Herbarium
Italy, Juval (BZ) ★	21	17	7	\
Italy, Scezze (BZ)	10	\	3	\
Italy, Aica (BZ)	39	33	9	\
Italy, Sabiona Abbey (BZ)	31	22	12	\
Italy, Castelfeder (BZ)	7	6	1	\
Italy, Castelbello (BZ)	1	\	1	\
<i>Festuca bauzanina</i> subsp. <i>rhaetica</i> S. Arndt				
Locality	N	Morphometry	FCM	Herbarium
Switzerland, Zernezz (GR) ★	41	21	8	\
Switzerland, Mt. Generoso (TI)	5	5	3	\
<i>Festuca guinochetii</i> (Bidault) S.Arndt				
Locality	N	Morphometry	FCM	Herbarium
Italy, S. Antonio di Bormio (SO) ★	30	13	7	\
Italy, Bormio (SO)	13	9	4	\
Italy, S. Nicolò di Bormio (SO)	11	\	3	\
Italy, Passo del Gavia (BS)	10	6	4	\
Italy, Vermiglio (TN)	1	\	1	\
Italy, Juval (BZ)	1	\	1	\

Table B: other *Festuca* taxa

<i>Festuca</i> sp. nova (2n = 8x = 56)				
Locality	N	Morphometry	FCM	Herbarium
Italy, il Groppo (PV)	18	\	3	\
Italy, Sassi Neri (PC)	15	\	3	\
<i>Festuca laevigata</i> Gaudin				
Locality	N	Morphometry	FCM	Herbarium
Italy, Pescina (AQ)	15	\	2	2
Italy, Barisciano (AQ)	2	\	\	\
Italy, Vinadio (CN)	11	\	\	\
Italy, Sambuco (CN)	7	\	\	\
Italy, Pontebernardo (CN)	6	\	\	\
Italy, Colle della Maddalena (CN)	3	\	\	\
<i>Festuca luedii</i> (Markgr.-Dann.) Foggi, Gr. Rossi, Parolo et Wallossek				
Locality	N	Morphometry	FCM	Herbarium
Italy, Passo del Gavia (BS)	5	\	\	\
<i>Festuca ovina</i> s.l.				
Locality	N	Morphometry	FCM	Herbarium
Italy, Lillaz (AO)	2	\	\	\
Switzerland, Chandonne (VS)	1	\	\	\
<i>Festuca silana</i> Ardenghi, Pallanza & Foggi				
Locality	N	Morphometry	FCM	Herbarium
Italy, Vaccarizzo (CS)	15	\	3	\
Italy, Mt. Spineto (CZ)	2	\	\	\
Italy, Mt. Gariglione (CZ)	15	\	3	\
Italy, Carlomagno A (CS)	14	\	2	\
Italy, Carlomagno B (CS)	16	\	1	\
Italy, Ariamacina (CS)	14	\	3	\
<i>Festuca marginata</i> subsp. <i>marginata</i> (Hack.) K.Richt.				
Locality	N	Morphometry	FCM	Herbarium
Italy, Prati del Sirente (AQ)	1	\	1	\
Italy, Ariamacina (CS)	1	\	1	\
Italy, Torre Garga (CS)	16	\	3	\
Italy, Serro Sgarrone (RC)	15	\	3	\
Italy, Cardeto (RC)	15	\	1	\
Italy, Mt. Spineto (CZ)	13	\	5	\
Italy, Aprigliano (CS)	14	\	3	\
Italy, Parenti (CS)	15	\	3	\
<i>Festuca inops</i> De Not.				
Locality	N	Morphometry	FCM	Herbarium
Italy, Pescina (AQ)	6	\	3	\
<i>Festuca</i> cfr. <i>rubra</i>				
Locality	N	Morphometry	FCM	Herbarium
Italy, Maso Rivetta (BZ)	12	\	\	\
<i>Festuca heterophylla</i> Lam.				
Locality	N	Morphometry	FCM	Herbarium
Switzerland, S. Nicolao	17	\	\	\

Festuca amethystina L.				
Locality	N	Morphometry	FCM	Herbarium
Austria, Reichental (AT-122)	1	\	1	\
Festuca csikhegyensis Simonk.				
Locality	N	Morphometry	FCM	Herbarium
Austria, Sankt Peter Freienstein (AT-223)	6	\	6	\

9.4 FCM data

The table below contains all the data obtained via FCM study of the samples divided by preliminary identification of the taxa on the field. Columns from left to right report the following: sample unique identification code, locality of collection, mean peak of the standard, mean peak of the sample, standard's coefficient of variation, sample's coefficient of variation, sample to standard ratio, inferred ploidy of the sample. Records marked in red and with the “!!” annotation near their ID represent major discrepancies with the ploidy and the identification attributed to the sample. Records in orange and with the “!” annotation near their ID represent inconsistencies imputable to poor sample quality or aberrations.

<i>Festuca valesiaca</i> Schleich. ex Gaudin							
Sample ID	Locality	St mean	2n mean	St CV	2n CV	2n/St ratio	Ploidy
2150/7V	Austria, Breitenbrunn (AT-112)	199,25	291,9	2,64	2,16	1,464993726	2x
2152/1	Austria, St. Margarethen (AT-112)	213,29	306,69	3,19	2,97	1,437901449	2x
2152/2	Austria, St. Margarethen (AT-112)	223,19	314,44	3,75	2,95	1,408844482	2x
2152/3	Austria, St. Margarethen (AT-112)	217,75	309,68	3,54	2,98	1,422181401	2x
2154/4	Austria, Rechnitz (AT-113)	212,19	333,07	4,2	2,21	1,569678119	2x
MP00068	Italy, Pescina (AQ)	129,94	187,57	3,23	3,53	1,44351239	2x
MP00069	Italy, Pescina (AQ)	203,95	288,33	2,5	3	1,413728855	2x
MP00373	Switzerland, Niederwald (VS)	217,01	319,05	3,05	4,67	1,470208746	2x
MP00370	Switzerland, Niederwald (VS)	197,17	279,93	2,48	3,38	1,419739311	2x
MP00365	Switzerland, Niederwald (VS)	199,18	291,56	2,64	2,73	1,463801587	2x
MP00331	Italy, Saint-Rhémy en Bosses (AO)	199,8	275,5	2,62	3,11	1,378878879	2x
MP00332	Italy, Saint-Rhémy en Bosses (AO)	198,36	287,44	2,84	3,17	1,449082476	2x
MP00345	Italy, Saint-Rhémy en Bosses (AO)	201,47	270,09	2,39	3,6	1,340596615	2x
MP00346	Switzerland, Chandonne (VS)★	197,89	264,85	2,28	3,16	1,338369801	2x
MP00348	Switzerland, Chandonne (VS)★	155,33	208,11	4,41	3,98	1,339792699	2x
MP00353	Switzerland, Chandonne (VS)★	182,41	250,48	3,37	4,05	1,373170331	2x
MP00260	Italy, Lillaz (AO)	199,78	304,84	2,26	2,54	1,525878466	2x
MP00261	Italy, Lillaz (AO)	200,45	315	2,03	2,85	1,571464206	2x
MP00285	Italy, Mt. Tsaplana (AO)	194,68	300,69	3,24	2,86	1,544534621	2x
MP00291	Italy, Mt. Tsaplana (AO)	195,87	305,29	2,64	2,84	1,55863583	2x
MP00649	Italy, Tanas (BZ)	202,09	292,62	2,31	2,6	1,447968727	2x
312	Italy, Juval (BZ)	211,69	308,82	2,84	2,4	1,45883131	2x
313	Italy, Castelbello (BZ)	211,06	306,96	2,35	1,81	1,454373164	2x
314	Italy, Castelbello (BZ)	214,61	314,66	2,63	1,84	1,466194492	2x
315	Italy, Castelbello (BZ)	214,01	316,08	2,17	1,92	1,47694033	2x
317-1V !!	Italy, Castelbello (BZ)	207,18	874,04	3,57	1,93	4,218746983	6x
317-2V !!	Italy, Castelbello (BZ)	202,89	872,23	3,4	1,43	4,299029031	6x
317-3V	Italy, Castelbello (BZ)	205,25	297,14	3,77	2,79	1,447697929	2x
317-4V	Italy, Castelbello (BZ)	206,75	305,16	3,92	2,88	1,47598549	2x
317-5V	Italy, Castelbello (BZ)	202,28	297,58	3,4	2,07	1,471129128	2x
<i>Festuca pseudodalmatica</i> Krajina ex Domin							
Sample ID	Locality	St mean	2n mean	St CV	2n CV	2n/St ratio	Ploidy
2154/1	Austria, Rechnitz (AT-113)	215,7	624,77	3,38	1,78	2,896476588	4x
2154/2	Austria, Rechnitz (AT-113)	207,65	591,51	4,04	1,78	2,84859138	4x
2154/3	Austria, Rechnitz (AT-113)	211,77	627,98	3,58	2,1	2,965386976	4x
<i>Festuca stricta</i> subsp. <i>stricta</i> Host							

Sample ID	Locality	St mean	2n mean	St CV	2n CV	2n/St ratio	Ploidy
2143/1	Austria, Reichental (AT-122)	155,96	715,03	2,77	2,26	4,584701205	6x
2143/2	Austria, Reichental (AT-122)	157,59	702,82	3,25	2,97	4,459800749	6x
2143/3	Austria, Reichental (AT-122)	155,8	709,57	2,76	2,19	4,55436457	6x
2143/4	Austria, Reichental (AT-122)	157,42	714,2	3,46	2	4,536907636	6x
2143/5	Austria, Reichental (AT-122)	156,21	699,84	2,87	3,04	4,480122911	6x
2145/1	Austria, Brunn and der Schneebergbahn (AT-122)	152,6	676,42	2,81	3,76	4,432634338	6x
2145/2	Austria, Brunn and der Schneebergbahn (AT-122)	151,86	696,35	2,5	2,01	4,585473462	6x
2145/3	Austria, Brunn and der Schneebergbahn (AT-122)	148,07	682,84	3,52	2,88	4,61160262	6x
2146/1	Austria, Sollenau (AT-122)	154,53	692,64	2,69	3,56	4,482236459	6x
2146/2	Austria, Sollenau (AT-122)	156,51	700,06	2,76	2,21	4,472941026	6x
2146/3	Austria, Sollenau (AT-122)	157,09	694,93	2,98	2,49	4,423769813	6x
2146/4	Austria, Sollenau (AT-122)	156,99	708,16	2,23	1,71	4,510860564	6x
2148/1	Austria, Bad Vöslau-Gainfarn (AT-122)	156,36	696,85	2,56	1,96	4,456702481	6x
2148/2	Austria, Bad Vöslau-Gainfarn (AT-122)	155,12	700,44	2,42	2,1	4,515471893	6x
2148/3	Austria, Bad Vöslau-Gainfarn (AT-122)	156,12	698,47	2,73	2,17	4,47393031	6x
2149/1	Austria, Perchtoldsdorf (AT-127)	154,79	717,46	3,98	1,05	4,635053944	6x
2149/2	Austria, Perchtoldsdorf (AT-127)	156,77	703,93	2,35	1,85	4,490208586	6x
2149/3	Austria, Perchtoldsdorf (AT-127)	156,2	707,36	3,14	3,17	4,528553137	6x
2150/1	Austria, Breitenbrunn (AT-112)	153,11	683,19	2,39	2,31	4,462086082	6x
2150/2	Austria, Breitenbrunn (AT-112)	153,39	683,52	3,28	1,85	4,456092314	6x
2150/3	Austria, Breitenbrunn (AT-112)	154,86	688,73	2,47	2,3	4,447436394	6x
2151/1	Austria, St. Margarethen (AT-112)	180,13	762,63	4,1	1,95	4,233775607	6x
2151/2	Austria, St. Margarethen (AT-112)	184,64	803,9	3,58	1,64	4,353877816	6x
2151/3	Austria, St. Margarethen (AT-112)	175,15	755,64	3,04	1,5	4,314244933	6x
2151/4	Austria, St. Margarethen (AT-112)	185,81	774,97	4,11	2,35	4,170765836	6x
<i>Festuca stricta</i> subsp. <i>sulcata</i> (Hack.) Patzke ex Joch.Müll.							
Sample ID	Locality	St mean	2n mean	St CV	2n CV	2n/St ratio	Ploidy
2143/7R	Austria, Reichental (AT-122)	157,67	714,67	2,18	1,68	4,532694869	6x
2144/1	Austria, Dreistetten (AT-122)	152,4	694	2,72	2,21	4,553805774	6x
2144/2	Austria, Dreistetten (AT-122)	159,77	719,81	2	1,29	4,505288853	6x
2149/4R	Austria, Perchtoldsdorf (AT-127)	156,19	702,66	3,13	2,89	4,498751521	6x
2149/5R	Austria, Perchtoldsdorf (AT-127)	155,01	695,69	3,65	3,16	4,48803303	6x
2149/6R	Austria, Perchtoldsdorf (AT-127)	149,31	696,14	3,48	2,38	4,662380283	6x
2150/4R	Austria, Breitenbrunn (AT-112)	153,93	693,43	2,44	2,71	4,504839862	6x
2150/5R	Austria, Breitenbrunn (AT-112)	151,39	687,73	2,78	2,06	4,542770328	6x
2150/6R	Austria, Breitenbrunn (AT-112)	169,62	750,52	2,61	2,02	4,424714067	6x
2153/1	Austria, St. Margarethen (AT-112)	182,99	816,84	5,25	1,82	4,463850484	6x
2153/2	Austria, St. Margarethen (AT-112)	182,42	804,99	4,03	1,75	4,412838505	6x
2155/1	Austria, Rechnitz (AT-113)	174,04	734,86	3,61	1,89	4,222362675	6x
2155/2	Austria, Rechnitz (AT-113)	181,43	776,69	3,6	1,6	4,280934796	6x
2156/1	Austria, Sankt Peter Freienstein (AT-223)	177,71	768,42	2,46	1,43	4,324011029	6x
2156/2	Austria, Sankt Peter Freienstein (AT-223)	171,72	748,52	2,77	1,91	4,358956441	6x
2157/4R	Austria, Sankt Peter Freienstein (AT-223)	177,07	779,69	2,66	2,08	4,403286836	6x
2157/5R	Austria, Sankt Peter Freienstein (AT-223)	172,7	755,28	3,3	2,32	4,373364215	6x
MP00110 !!	Italy, Barisciano (AQ)	195,95	554,44	2,72	4,75	2,829497321	4x
MP00117 !!	Italy, Barisciano (AQ)	198,87	553,09	2,41	3,12	2,781163574	4x

MP00118 !!	Italy, Barisciano (AQ)	197,41	547,32	2,56	2,85	2,772503926	4x
MP00119 !!	Italy, Barisciano (AQ)	196,69	556,47	2,65	2,32	2,82917281	4x
MP00090 !!	Italy, Prati del Sirente (AQ)	185,28	568,26	2,9	2	3,067033679	4x
MP00091 !!	Italy, Prati del Sirente (AQ)	182,71	568,79	3,22	2,1	3,113075365	4x
MP00096 !!	Italy, Prati del Sirente (AQ)	185,08	571,72	3,17	2,42	3,089042576	4x
MP00098 !!	Italy, Prati del Sirente (AQ)	180,4	568,96	2,95	1,85	3,153880266	4x
MP00574	Italy, Castelbello (BZ)	171,18	723,02	2,35	2,26	4,223741091	6x
MP00580	Italy, Castelbello (BZ)	160,68	703,07	2,26	2,06	4,375591237	6x
MP00647	Italy, Tanas (BZ)	172,37	760,37	2,99	2,37	4,411266462	6x
MP00658	Italy, Tanas (BZ)	169,25	741,36	2,55	2,17	4,380265879	6x
317-10R	Italy, Castelbello (BZ)	201,02	858,59	2,29	2,41	4,271167048	6x
317-6R	Italy, Castelbello (BZ)	199,57	870,95	2,52	2,05	4,364132886	6x
317-7R	Italy, Castelbello (BZ)	201,54	862,37	3,64	1,41	4,278902451	6x
317-8R	Italy, Castelbello (BZ)	204,91	852,09	3,41	1,43	4,158362208	6x
317-9R	Italy, Castelbello (BZ)	200,77	863,96	2,92	1,72	4,303232555	6x
<i>Festuca stricta</i> subsp. <i>trachyphylla</i> (Hack.) Patzke ex Pils							
Sample ID	Locality	St mean	2n mean	St CV	2n CV	2n/St ratio	Ploidy
2147/1	Austria, Bad Vöslau-Gainfarn (AT-122)	152,93	673,42	3,4	3,12	4,40345256	6x
2147/2	Austria, Bad Vöslau-Gainfarn (AT-122)	154,35	679,83	2,46	2,38	4,40447036	6x
2147/3	Austria, Bad Vöslau-Gainfarn (AT-122)	154,97	675,95	2,47	1,63	4,361811964	6x
MP00004 !!	Italy, il Groppo (PV)	132,95	784,5	4,28	1,59	5,900714554	8x
MP00009 !!	Italy, il Groppo (PV)	130,67	750,5	3,16	3,77	5,743475932	8x
MP00011 !!	Italy, il Groppo (PV)	133,32	778,4	3,36	3,77	5,838583858	8x
MP00026 !!	Italy, Sassi Neri (PC)	139,99	886,91	2,68	1,81	6,335523966	8x
MP00030 !!	Italy, Sassi Neri (PC)	138,41	837,15	2,78	2,63	6,048334658	8x
MP00032 !!	Italy, Sassi Neri (PC)	138,05	839,06	2,39	2,77	6,077942774	8x
<i>Festuca ticinensis</i> (Markgr.-Dann.) Markgr.-Dann.							
Sample ID	Locality	St mean	2n mean	St CV	2n CV	2n/St ratio	Ploidy
MP00296 !!	Switzerland, Mt. Generoso (TI) ★	147,94	782,1	3,4	3,05	5,286602677	8x
MP00297 !!	Switzerland, Mt. Generoso (TI) ★	147,1	827,31	2,72	2,38	5,624133243	8x
MP00295 !!	Switzerland, Mt. Generoso (TI) ★	126,33	684,31	4,63	6,01	5,416844772	8x
MP00316	Switzerland, Fontana (TI)	173,01	750,23	3,27	3,33	4,33633894	6x
MP00327	Switzerland, Olivone (TI)	150,36	682,09	3,17	2,44	4,536379356	6x
MP00329	Switzerland, Olivone (TI)	153,83	715,11	2,46	2,3	4,648703114	6x
MP00330	Switzerland, Olivone (TI)	154,53	682,28	2,37	2,67	4,415194461	6x
MP00317	Switzerland, Fontana (TI)	155,44	708,07	3,26	3,31	4,555262481	6x
<i>Festuca brevipila</i> Tracey							
Sample ID	Locality	St mean	2n mean	St CV	2n CV	2n/St ratio	Ploidy
2142/1	Austria, Amaliendorf (AT3) ★	154,84	678,7	2,28	1,63	4,383234306	6x
2142/2	Austria, Amaliendorf (AT3) ★	157,45	689,58	2,41	1,46	4,379676088	6x
2142/3	Austria, Amaliendorf (AT3) ★	156,27	692,26	2,37	1,75	4,429896973	6x
2142/4	Austria, Amaliendorf (AT3) ★	156,48	691,08	2,28	1,76	4,416411043	6x
2142/6	Austria, Amaliendorf (AT3) ★	153,25	676,99	2,49	1,95	4,417553018	6x
2142/7	Austria, Amaliendorf (AT3) ★	155,13	683,4	2,29	1,52	4,405337459	6x
<i>Festuca bauzanina</i> subsp. <i>bauzanina</i> (Pils) S.Arndt							
Sample ID	Locality	St mean	2n mean	St CV	2n CV	2n/St ratio	Ploidy
MP00549	Italy, Juval (BZ) ★	147,63	809,65	3,34	1,63	5,484318905	8x

MP00549	Italy, Juval (BZ) ★	148,21	782,7	2,57	2,88	5,281020174	±8x
MP00549 !	Italy, Juval (BZ) ★	148,45	744,36	3,79	2,84	5,01421354	7-8x
MP00600	Italy, Sabiona Abbey (BZ)	148,89	833,48	3,71	1,99	5,597958224	8x
MP00601	Italy, Sabiona Abbey (BZ)	146,77	835,62	3,61	2,94	5,693397833	8x
MP00604	Italy, Sabiona Abbey (BZ)	142,18	787,68	2,95	3,11	5,540019693	8x
MP00577 !	Italy, Castelbello (BZ)	132,77	875,89	2,59	2,98	6,597047526	8-10x
309-1	Italy, Aica (BZ)	141,34	818,87	3,31	2,23	5,793618226	8x
309-2	Italy, Aica (BZ)	140,97	819,81	3,17	1,94	5,815492658	8x
309-3	Italy, Aica (BZ)	135,94	787,96	3,93	2,1	5,796380756	8x
309-4	Italy, Aica (BZ)	141,16	823,11	3,7	1,67	5,831042788	8x
309-5	Italy, Aica (BZ)	134,99	791,03	3,37	1,96	5,859915549	8x
309-6	Italy, Aica (BZ)	140,99	818,76	3,21	2,09	5,80722037	8x
310-1	Italy, Sabiona Abbey (BZ)	141,09	798,39	3,72	2,91	5,658728471	8x
310-2	Italy, Sabiona Abbey (BZ)	127,86	744,43	3,5	1,53	5,822227436	8x
310-3	Italy, Sabiona Abbey (BZ)	137,4	788,01	2,75	2,18	5,735152838	8x
310-4	Italy, Sabiona Abbey (BZ)	141,73	803,02	3,25	2,45	5,665843505	8x
310-5	Italy, Sabiona Abbey (BZ)	138,55	808,78	2,5	1,94	5,837459401	8x
310-6	Italy, Sabiona Abbey (BZ)	141,9	821,8	2,14	1,6	5,791402396	8x
310-7	Italy, Sabiona Abbey (BZ)	136,38	806,24	3,33	2,32	5,911717261	8x
310-8	Italy, Sabiona Abbey (BZ)	141,82	820,61	2,54	1,89	5,786278381	8x
310-9	Italy, Sabiona Abbey (BZ)	141,33	821,79	2,96	1,64	5,814689026	8x
311-1	Italy, Juval (BZ) ★	151,6	852,19	3,52	1,69	5,621306069	8x
311-2	Italy, Juval (BZ) ★	154,37	898,45	3,63	1,41	5,820107534	8x
311-3	Italy, Juval (BZ) ★	153,66	891,39	3,42	1,57	5,801054276	8x
311-4 !!	Italy, Juval (BZ) ★	127,96	900,73	3,98	1,72	7,03915286	10x
311-5	Italy, Juval (BZ) ★	136,38	807,5	3,82	1,8	5,920956152	8x
317-11B	Italy, Castelbello (BZ)	198,74	875,63	3,35	1,93	4,405907215	6x
317-12B	Italy, Castelbello (BZ)	201,7	867,51	3,3	1,92	4,300991572	6x
317-13B	Italy, Castelbello (BZ)	197,98	855,02	3,3	1,93	4,318719063	6x
317-14B	Italy, Castelbello (BZ)	200,77	858,51	3,02	1,55	4,276087065	6x
317-15B	Italy, Castelbello (BZ)	201,44	846,5	3,81	1,48	4,202243844	6x
317-16B	Italy, Castelbello (BZ)	199,69	846,82	3,44	1,63	4,240673043	6x
325	Italy, Castelbello (BZ)	148,63	866,97	3,19	1,63	5,833075422	8x
MP00584	Italy, Scezze (BZ)	143,06	790,71	2,87	2,15	5,527121487	8x
MP00587	Italy, Scezze (BZ)	139,19	831,14	3,83	3,29	5,971262303	8x
MP00590 !	Italy, Scezze (BZ)	127,26	658,4	2,77	3,94	5,173660223	7-8x
MP00534	Italy, Aica (BZ)	119,29	707,79	4,2	3,13	5,933355688	8x
MP00592 !	Italy, Aica (BZ)	155,6	781,48	2,68	3,36	5,022365039	7-8x
MP00597	Italy, Aica (BZ)	147,17	820,41	4,47	2,23	5,574573622	8x
<i>Festuca bauzanina</i> subsp. <i>rhaetica</i> S. Arndt							
Sample ID	Locality	St mean	2n mean	St CV	2n CV	2n/St ratio	Ploidy
MP00608	Switzerland, Zerne (GR) ★	146,88	796,02	2,81	2,47	5,419526144	8x
MP00607	Switzerland, Zerne (GR) ★	143,28	753,26	3,54	3,83	5,257258515	8x
MP00616	Switzerland, Zerne (GR) ★	137,99	781,32	3,75	3,92	5,662149431	8x
316-1 !	Switzerland, Zerne (GR) ★	150,77	761,54	3,86	1,72	5,051004842	±7x
316-2	Switzerland, Zerne (GR) ★	147,23	843,66	3,67	1,4	5,730218026	8x
316-3	Switzerland, Zerne (GR) ★	148,01	849,9	3,12	1,59	5,742179582	8x

316-4	Switzerland, Zerne (GR) ★	146,83	831,76	3,15	1,31	5,664782401	8x
316-5	Switzerland, Zerne (GR) ★	147	840,71	3,59	1,46	5,719115646	8x
<i>Festuca guinochetii</i> (Bidault) S.Arndt							
Sample ID	Locality	St mean	2n mean	St CV	2n CV	2n/St ratio	Ploidy
MP00622 !	Italy, S. Nicolò di Bormio (SO)	106,36	860,21	3,91	2,17	8,087720948	12x
MP00624	Italy, S. Nicolò di Bormio (SO)	123,27	882,81	2,69	3	7,161596495	±10x
MP00629 !	Italy, S. Nicolò di Bormio (SO)	132,97	890,66	3,01	2,33	6,698202602	8-10x
MP00634	Italy, S. Antonio di Bormio (SO) ★	121,93	884,52	4,42	1,73	7,254326253	±10x
MP00637	Italy, S. Antonio di Bormio (SO) ★	123,35	906,02	2,73	1,41	7,345115525	±10x
320-1	Italy, Bormio (SO)	127,91	911,63	2,77	1,67	7,127120632	10x
320-2	Italy, Bormio (SO)	103,24	774,14	2,29	1,46	7,498450213	10x
320-3	Italy, Bormio (SO)	126,88	910,41	3,37	1,53	7,175362547	10x
320-4	Italy, Bormio (SO)	127,18	919,16	2,66	1,73	7,227236987	10x
322-1	Italy, S. Antonio di Bormio (SO) ★	123,34	923,27	3,19	1,12	7,485568348	10x
322-2	Italy, S. Antonio di Bormio (SO) ★	125,93	896,16	2,8	1,68	7,116334472	10x
322-3	Italy, S. Antonio di Bormio (SO) ★	125,66	891,94	3,44	1,58	7,098042336	10x
322-4	Italy, S. Antonio di Bormio (SO) ★	124,76	881,95	3,16	2,01	7,069172812	10x
322-5	Italy, S. Antonio di Bormio (SO) ★	123,96	924,55	2,05	1,95	7,45845434	10x
323-1	Italy, Passo del Gavia (BS)	124,89	889,8	3,14	2,13	7,124669709	10x
323-2	Italy, Passo del Gavia (BS)	123,99	886,81	3,72	1,22	7,152270344	10x
323-3	Italy, Passo del Gavia (BS)	122,63	899,46	3,3	1,67	7,334746799	10x
323-4	Italy, Passo del Gavia (BS)	122,5	899,2	3,26	1,57	7,340408163	10x
324	Italy, Vermiglio (TN)	122,64	885,3	3,22	1,36	7,218688845	10x

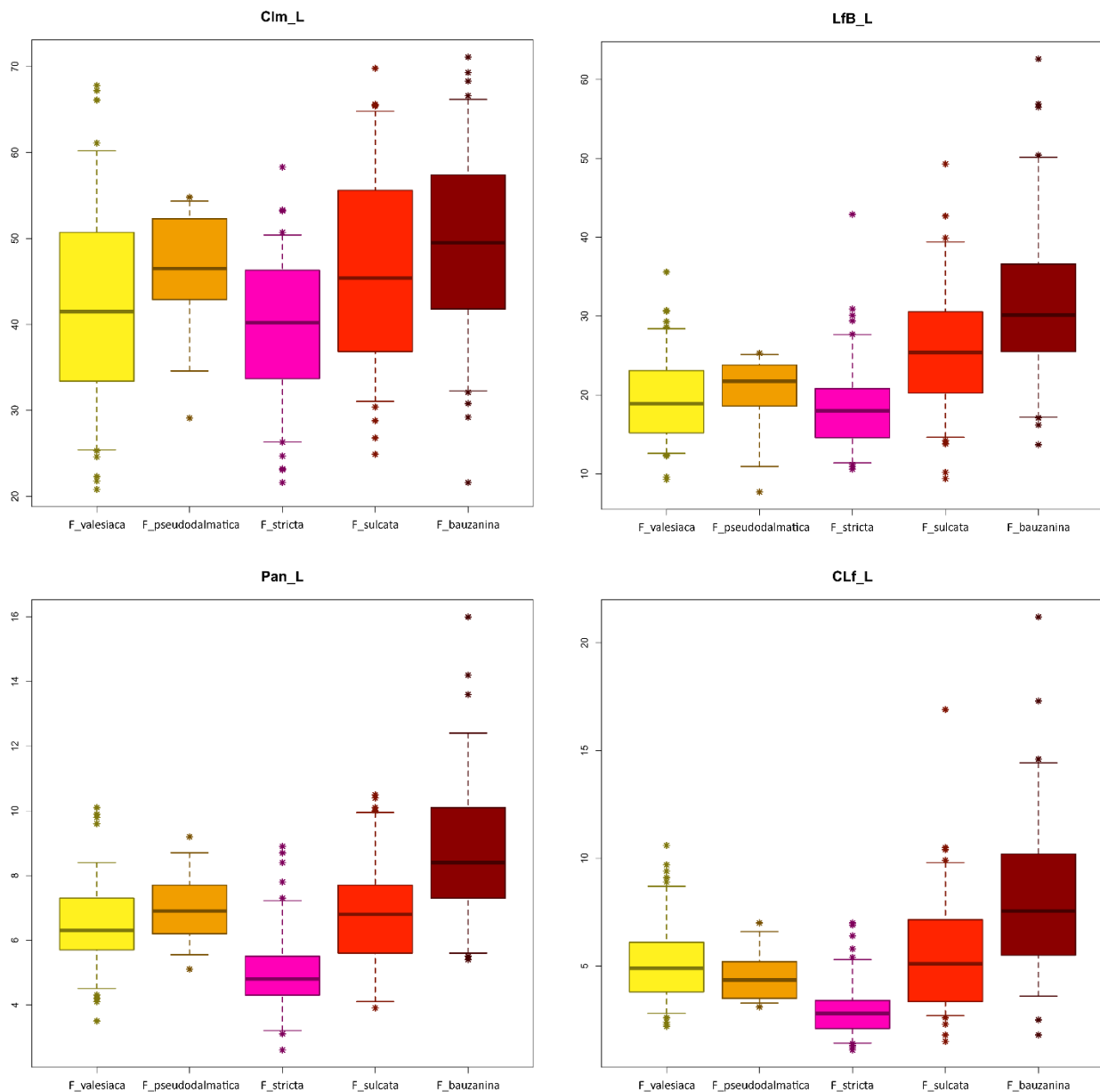
9.5 Morphological data

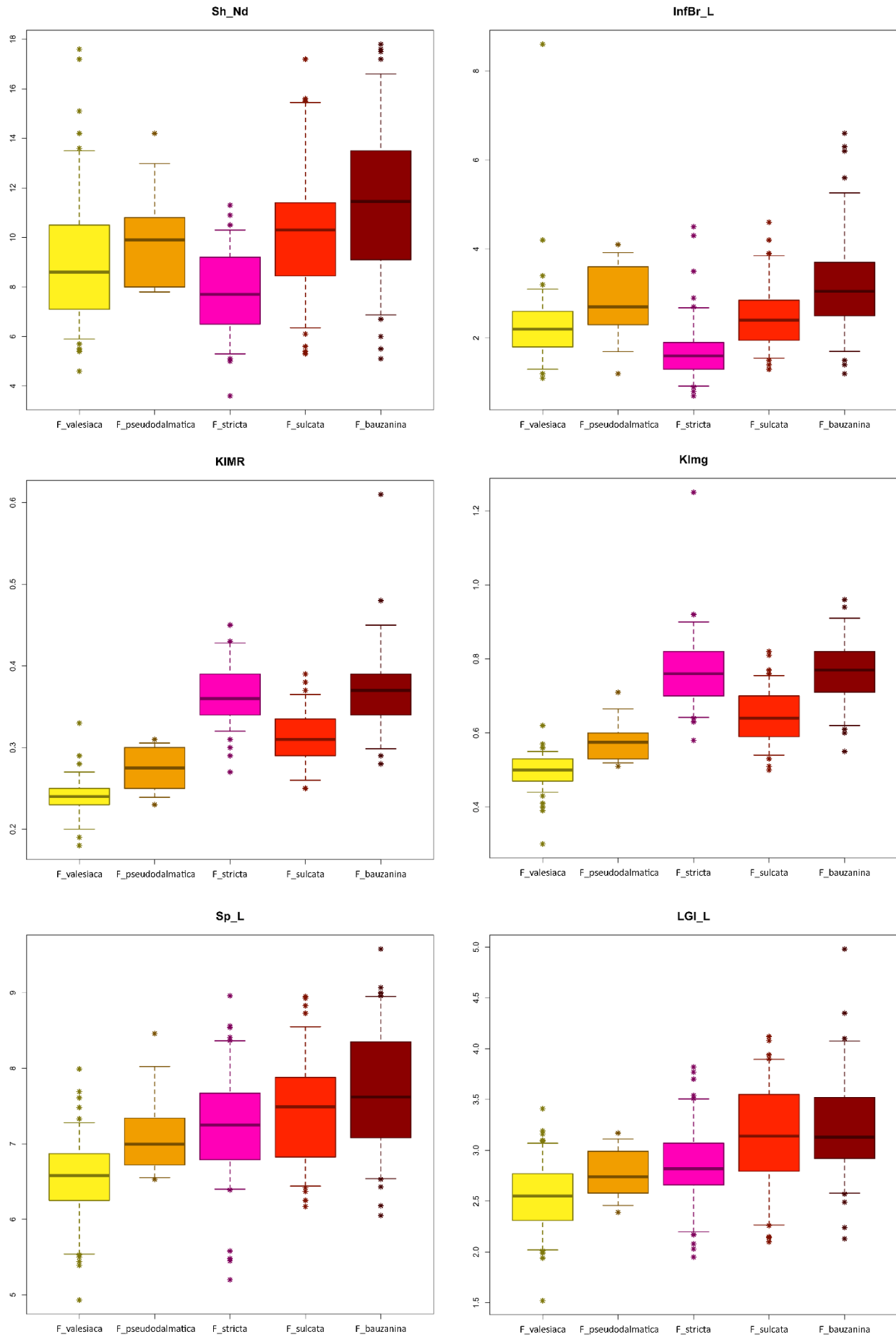
Ser. *Valesiaca*

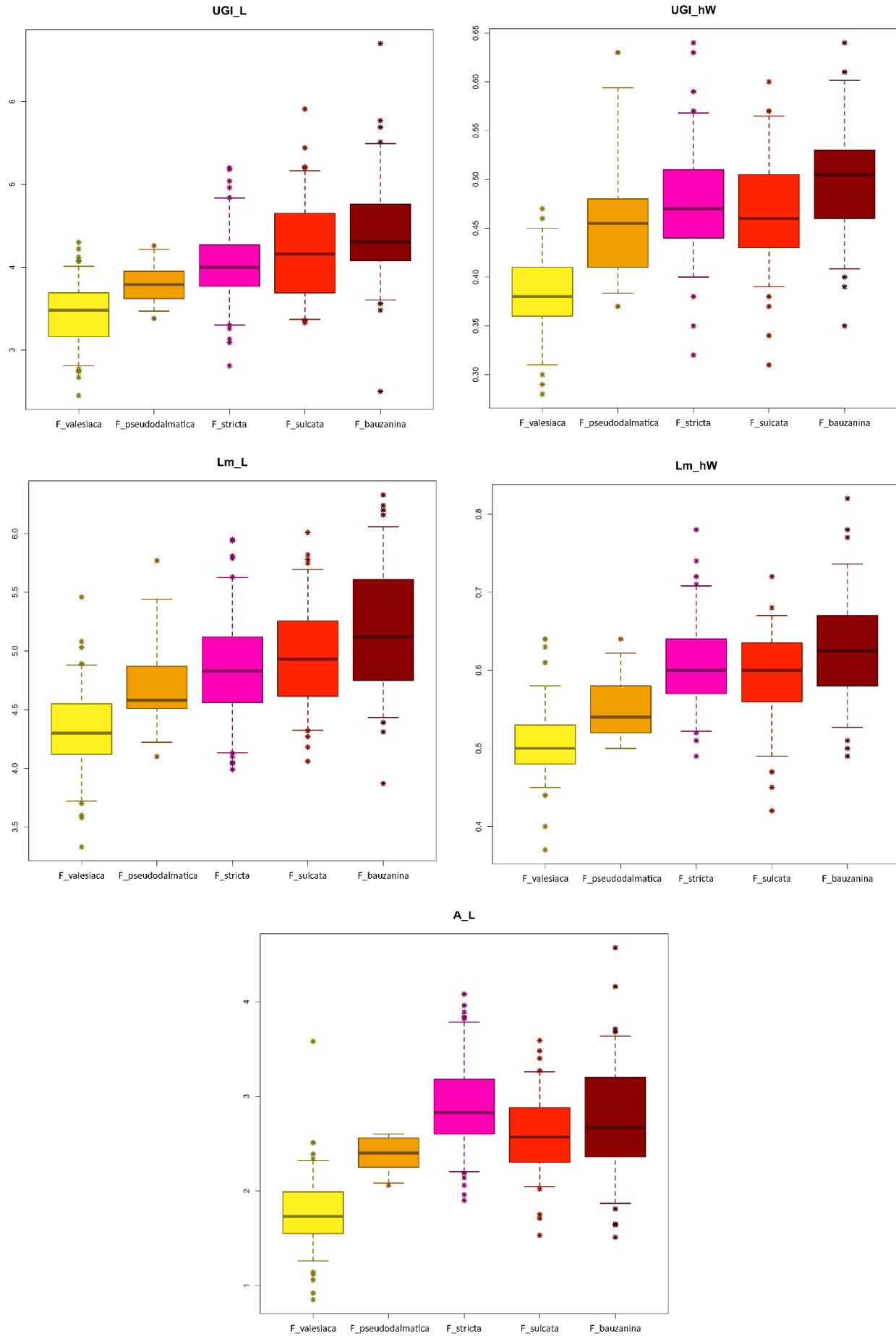
The following boxplots describe the variability for the main morphological characters of the taxa in the ser. *Valesiaca*. Characters follow the codes listed in the “MATERIALS AND METHODS” section of this thesis. Taxa are presented in order of increasing ploidy:

- $2n=2x=14$: *F. valesiaca*.
- $2n=4x=28$: *F. pseudodalmatica*.
- $2n=6x=42$: *F. stricta*, *F. rupicola* (= *F. stricta* subsp. *sulcata*).
- $2n=8x=56$: *F. bauzanina*.

Outliers have been kept to better highlight the full range of variability occurring across the different taxa.





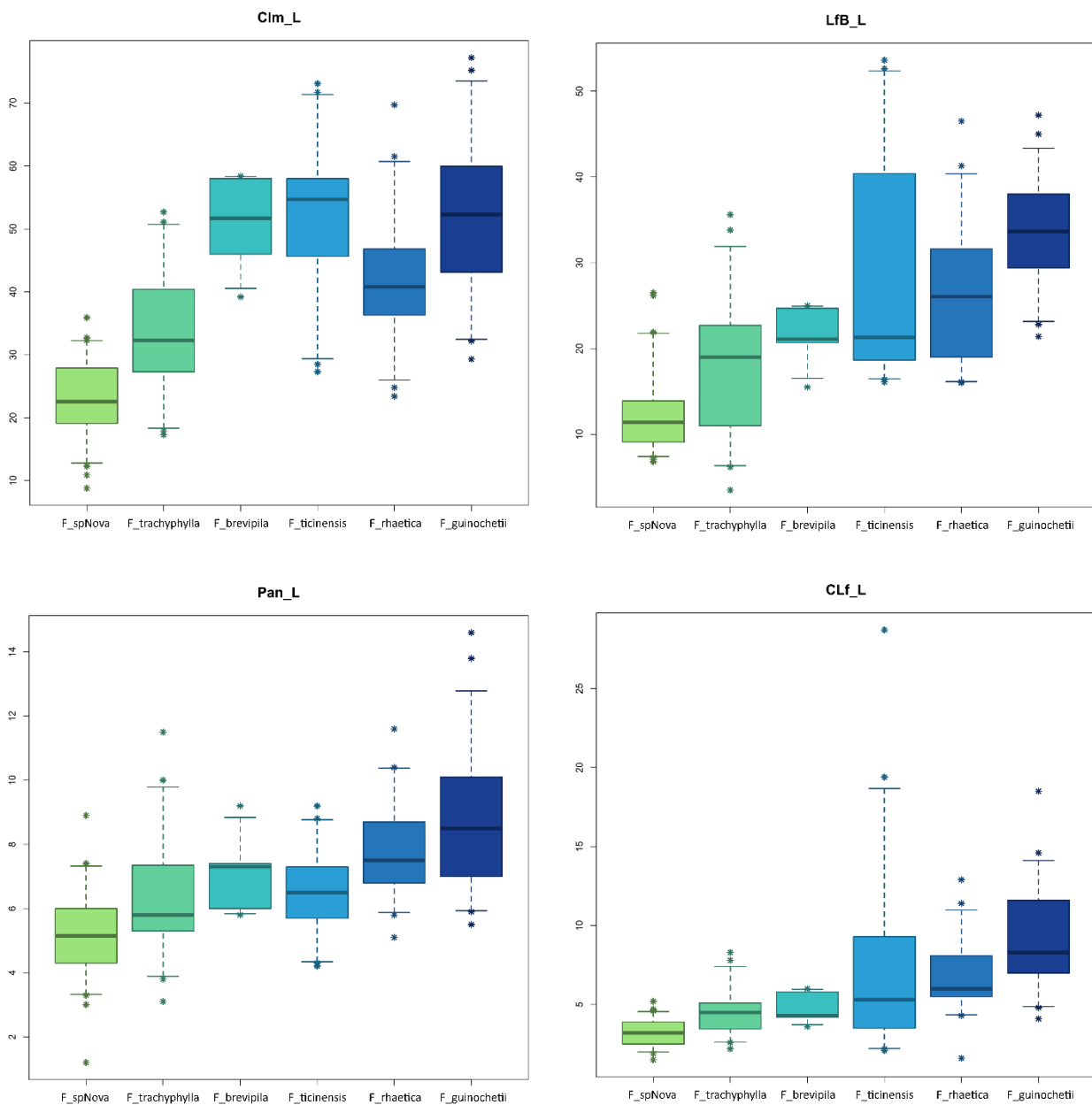


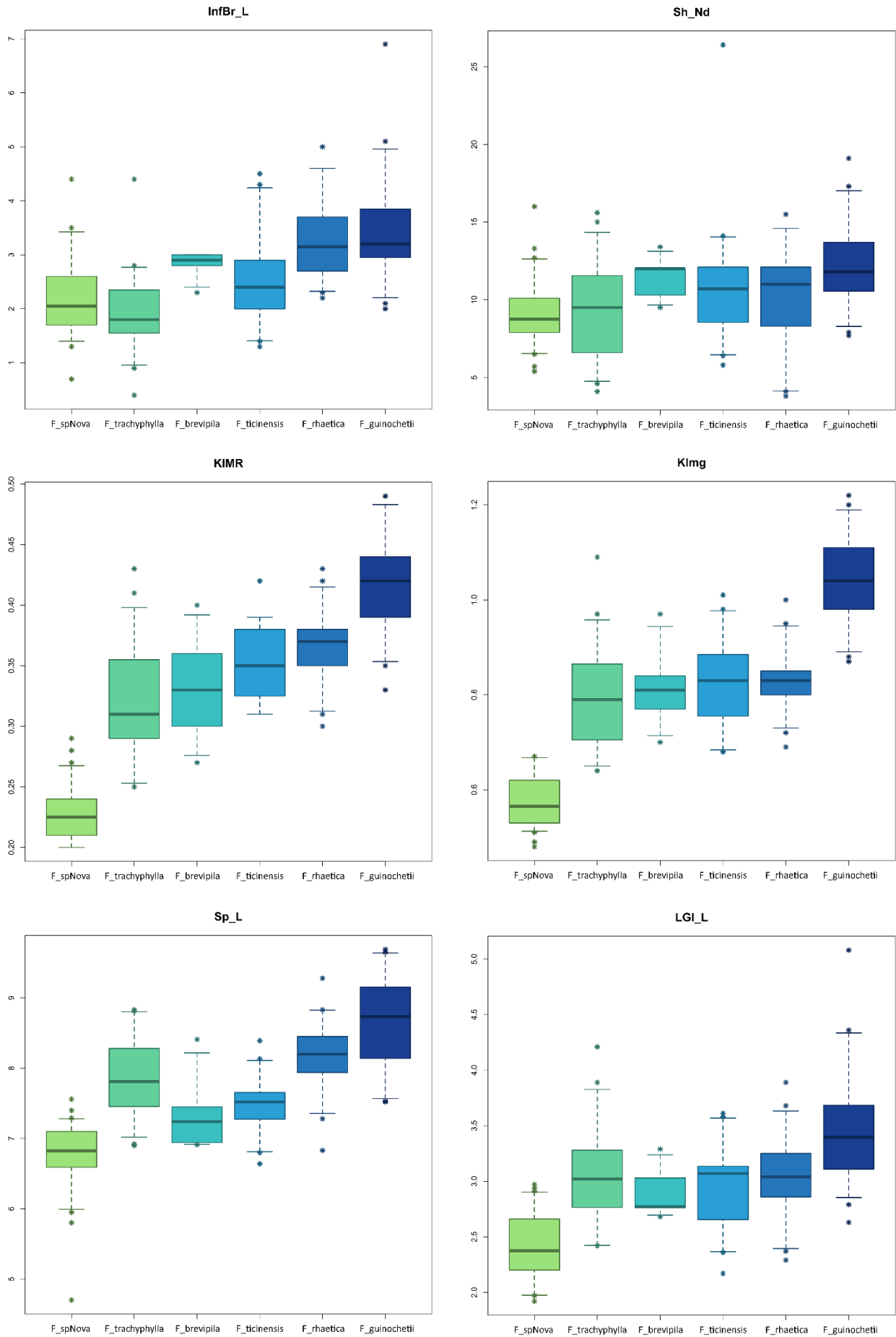
Ser. *Trachyphyllae*

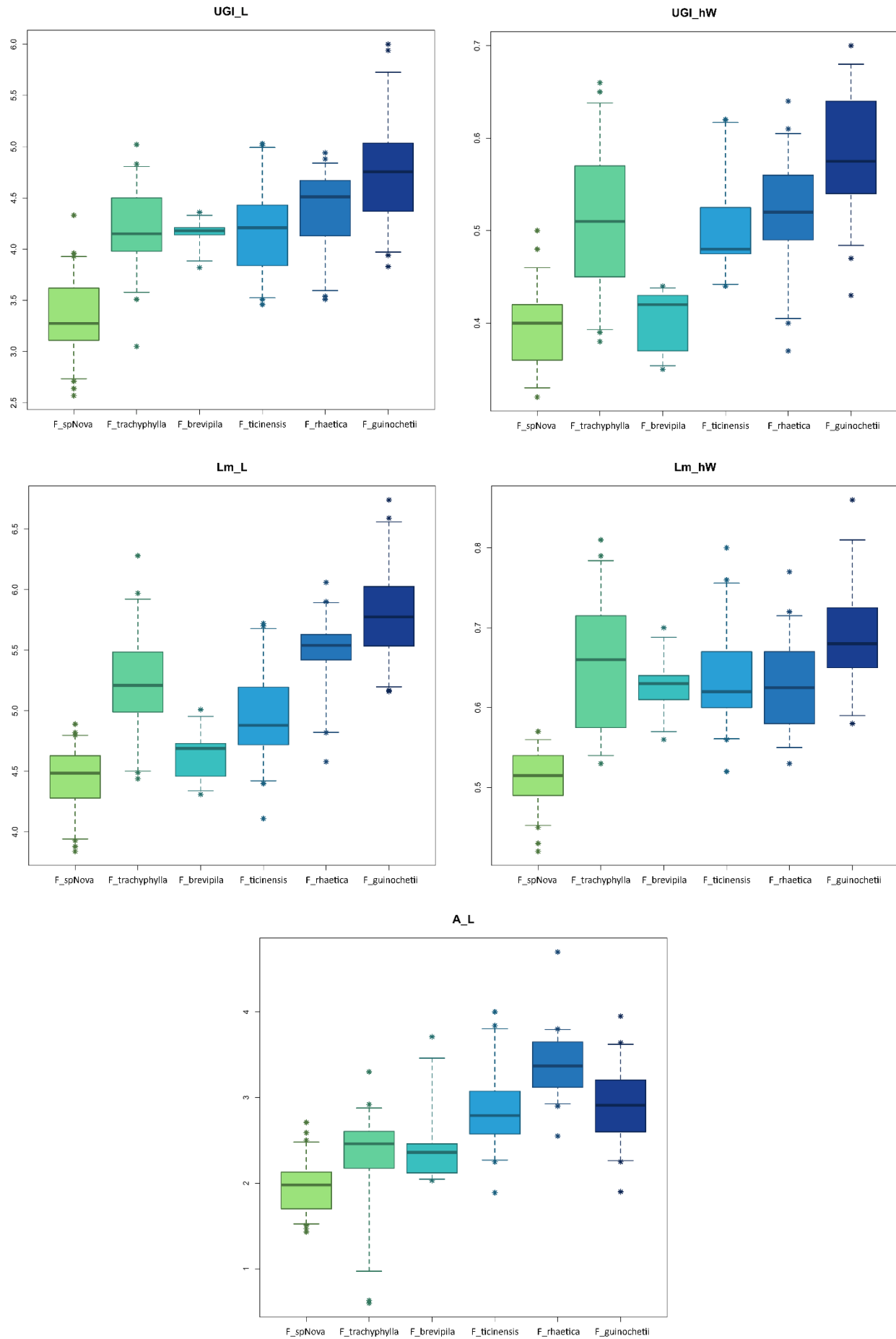
The following boxplots describe the variability for the main morphological characters of the taxa in the ser. *Trachyphyllae*. Characters follow the codes listed in the “MATERIALS AND METHODS” section of this thesis. Taxa are presented in order of increasing ploidy:

- $2n=4x=28$: *F. sp. nova*.
- $2n=6x=42$: *F. trachyphylla*, *F. brevipila*, *F. ticinensis*.
- $2n=8x=56$: *F. rhaetica*.
- $2n=10x=70$: *F. guinochetii*.

Outliers have been kept to better highlight the full range of variability occurring across the different taxa.







9.6 ISI publications

The following ISI publications have been produced during the course of the PhD:

- Pallanza M, Orsenigo S, Ardenghi NMG, Bernardo L, Šmarda P, Šarhanová P, Rossi G, Foggi B (2025) *Festuca silana* (Poaceae), a new species from the Sila plateau in Italy. *PhytoKeys* 255: 85-102. <https://doi.org/10.3897/phytokeys.255.146942>
- Fainelli F, Baldesi G, Pallanza M, Orsenigo S (2024) Extinct or Not? Confirming the “Extinct” Status of *Hieracium tolstoidii* (Asteraceae) with Integrated Taxonomic Investigation. *Diversity*, 16(9), 591. <https://doi.org/10.3390/d16090591>
- Bartolucci F, Domina G, Bertolli A, Boni R, Galasso G, Caporusso C, Del Guacchio E, Laface VLA, Forte L, Lonati M, Menini F, Mezza I, Napolitano F, Nota G, Pallanza M, Pazienza G, Pellegrino G, Prosser F, Santangelo A, Tomasi G, Torino L, Viciani D, Lastrucci L (2025) Notulae to the Italian native vascular flora: 19. *Italian Botanist* 19: 143-154. <https://doi.org/10.3897/italianbotanist.19.159733>

The research paper published as the main author describing *F. silana* is fully reported in the following pages as a direct output of the research carried during this PhD project.

Festuca silana (Poaceae), a new species from the Sila plateau in Italy

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Abstract

A new hexaploid species of fine-leaved fescue from *Festuca* sect. *Festuca* (*Festuca silana* Ardenghi, Pallanza & Foggi, **sp. nov.**) endemic to the Sila plateau is described. The new taxon shows morphological affinities with species of the *F. marginata* group from which it can be distinguished by higher ploidy, ecology, and leaf cross section anatomy. ddRADseq data suggests *F. silana* could be a local hexaploid descendant/derivate of the widespread diploid *F. marginata*. Its distribution is restricted to several localities in the Sila highlands of the Southern Apennines, Italy.

Key words: Calabria, endemic, fescue, flow cytometry, Italy, morphometry, new species, ploidy, RAD sequencing



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Introduction

Festuca L. (Poaceae, Loliinae) is one of the most species-rich genera of grasses (Poaceae), containing worldwide around 680 accepted species (Govaerts 2024). Within the *Festuca* genus, “fine-leaved fescues” represent the most important group, with approximately 450 species (Foggi and Tison 2014; Kellogg 2015). The taxonomy and systematics of *Festuca* has historically been regarded by botanists as difficult, due to the morphological convergence of unrelated taxa, phenotypic plasticity, complex nomenclature and a lack of clear universally accepted diagnostic features between taxa. The first solid foundation to modern taxonomic *Festuca* studies was posed by Eduard Hackel in his “*Monographia Festucarum Europaeorum*” (Hackel 1882). Hackel introduced novelties in the approach to identification and classification of fescues, including the study of the leaf cross-section, one of the main investigation tools still in use in modern festucology. Since then, many scholars have dedicated their efforts toward the taxonomy and systematics of *Festuca*, integrating the initial morphometrical approach with more modern techniques stemming from technological and scientific advances. These include analysis of the relative

genome size (Šmarda et al. 2008; Martínez-Sagarra et al. 2021), chromosome number (Šmarda and Kočí 2003; Ardenghi et al. 2016), DNA sequencing (Boeuf et al. 2022, Kriuchkova et al. 2023, Mucko et al. 2024) and electron microscopy (Ortúñez and Cano-Ruiz 2013). Although the implementations of these new methods emanate from improved floristic records and checklist (Roleček et al. 2019; Gudkova et al. 2023; Bednarska et al. 2024), to the conservation and applications of the taxa studied (Ardenghi et al. 2017), most recent works have focused on groups of species, using an integrated approach combining multivariate morphometry, ploidy level and genetics (Šmarda et al. 2007; Foggi et al. 2012; Ardenghi et al. 2024; Bednarska et al. 2024).

During an extensive sampling conducted across the European Mediterranean basin in 2014 by N.M.G. Ardenghi, an unusual taxon belonging to the fine-leaved fescues was collected in different localities of the Sila plateau (Italy). The entity was already known and reported by Sarfatti in the “Prodoromo della Flora della Sila” under *Festuca ovina* L. subsp. *laevis* Hack. var. *gallica* (Hack.) St.-Yves subvar. *costei* St.-Yves ($\equiv$ *Festuca costei* (St.-Yves) Markgr.-Dann.) based on the original identification by Markgraf-Dannenberg (Sarfatti 1959). However, this taxon has been overlooked until now. A preliminary study of morphology and leaf cross section anatomy of both fresh samples and herbaria specimens including the holotype for *F. costei*, led us to question the identification proposed by Markgraf-Dannenberg. In fact, these fescues differ from *F. costei* in a series of readily identifiable features, especially in the leaf cross-section (e.g. number of vascular bundles, development and organization of the sclerenchyma, etc.) and rather appear to be morphologically in between the *F. stricta* and the *F. marginata* groups. In particular, the Sila entity appears to have the typical cross sections of the former and the overall morphology of the latter.

Due to the unusual combination of leaf cross-section anatomy and general morphology, we initially thought it could be a taxon of the *F. stricta* group (i.e.: *F. stricta* Host, *F. rupicola* Heuff., *F. trachyphylla* (Hack.) R.P.Murray) which present similar patterns in the organization of the tiller leaves sclerenchyma. This is especially true for *F. trachyphylla*, which is also the only species from the stricta group to normally present 7 vascular bundles in the cross section, a shared characteristic with the Sila specimens. Nevertheless, the samples still share numerous morphological similarities (e.g. smooth leaf blades, glabrous spikelets, etc.) with *Festuca marginata* (Hack.) K. Richt., which occurs in similar types of habitats across Italy.

To better understand the relationships among these different taxa, we chose to apply an integrated approach combining classical morphometry, ploidy level analysis using flow cytometry and ddRADseq sequencing. The results from these combined analyses support that the taxon from the Sila plateau is a new endemic species.

Materials and methods

Materials

Overall, 177 individuals representing 25 populations of five different taxa (*F. marginata*, *F. rupicola*, *F. stricta*, *F. trachyphylla* and the proposed new species) ranging from the Alps to the Apennines and from fresh and herbarium

material (BRNU, FI, G, MSNM, PAV; Herbaria codes follow Thiers 2024, updated continuously) were morphologically studied (Suppl. material 1: tables S4, S5). Specimens were carefully selected to ensure a balanced representation of the different taxa. Fifty of the freshly collected individuals from the same populations were also analyzed using flow cytometry.

Morphometric analysis

We selected 35 morphological characters for the analysis (Table 1), choosing those considered as diagnostic for fine-leaved fescues.

Measurements were performed according to the standards described in Foggi 1999 (which complies with Hackel 1882; Saint-Yves 1913; Ellis 1976; Wilkinson and Stace 1991) with minor modifications. To account for intraindividual variation, we chose to either keep the highest recorded value for the sample or to use the mean value calculated from three different measurements depending on the morphological character. Characters concerning leaf cross sections follow a design similar to Bednarska et al. (2024). Spikelet, floret and other microscopic characters were observed under a Eurotek NB-50T stereomicroscope at magnifications of 8x–10x. Leaf cross sections were studied with a Carl Zeiss Axiostar Plus microscope at magnifications of 40x–100x. Both microscopes were coupled with a camera (ToupTek USB3.0 Eyepiece Camera S3CMOS05000KPA) and all observed characters were measured using Toupview ver. 4.11.19728.20211022 software.

Each quantitative character was tested for normality of distribution within taxa using the Shapiro-Wilk test. Some characters had non-normal distribution for some taxa, however, since the chosen analyses have been shown to be robust to violation of the normality of distribution assumption (Klecka 1980), we decided to continue without transforming the data. To further support this decision, it has to be clear that non-fitted variables would have to be transformed as a whole, independently from the taxon, leading to a weakened perception of the actual morphological variability among taxa. Characters were also tested for significant correlations (>0.95) via Spearman's non-parametric coefficient. High correlation was found only between characters related to the tiller leaves' scabridity (Sk_Deg, Sk_Ext, Ep_Ind). Among them, we decided to keep only the density of the abaxial epidermis indumentum as observed in the cross section (Ep_Ind) in the analyses as it was the least subjective to measure. We also decided not to include the culm length and tiller leaf blade length (Clm_L and LfB_L respectively) due to their high dependency on environmental factors such as grazing, trampling and wildfires. However, these characters were systematically measured in all samples and used in the morphological description of the new species. After preliminary data manipulation, 31 of the original characters were used to perform the analyses.

A PCoA utilizing Gower's distances (Gower 1971) was used to visualize the pattern of morphological variation among the studied taxa. Following the PCoA, a jackknifed canonical discriminant analysis (CDA) was performed (Krzanowski 1990), taking into account the morphological groups individuated with the PCoA and the ploidy levels inferred with flow cytometry. All characters invariant within the groups were excluded from the CDA dataset (bringing down the characters used to 25) as it is one of the fundamental assumptions to avoid any type of distortion in Discriminant Analyses.

Table 1. Morphological characters used in multivariate analyses and their coding. QD = quantitative discrete, QC = quantitative continuous, BI = binary, CO = ordinal.

Code	Character	Type
CIm_L	Culm length	QC
LfB_L	Tiller leaf blade length	QC
Pan_L	Panicle length	QC
Pan_Sk	Panicle scabridity	CO
Pan_Pb	Pubescence at the base of the panicle	CO
Clf_L	Culm leaf blade length	QC
Sh_Nd	Sheath to node distance	QC
InfBr_L	Inferior branch of the panicle length	QC
TilSh_Pb	Tiller sheaths pubescence	CO
Nd_Pr	Node pruinosity	BI
Sh_Pr	Tiller sheaths pruinosity	BI
Sh_Col	Tiller sheaths color	CO
Sk_Deg	Tiller leaves scabridity degree	CO
Sk_Ext	Percentage of tiller leaves scabrid surface	QC
Sc_Org	Sclerenchyma organization	CO
Sc_CT	Central sclerenchyma strand thickness	CO
Sc_MT	Marginal sclerenchyma strands thickness	CO
KIMR	Keel to middle rib distance	QC
KImg	Keel to margins distance	QC
VB_N	Number of vascular bundles	QD
R_N	Number of accessory ribs	QD
Shp	Leaf cross-section outline shape	CO
Ep_Und	Presence of epidermal undulations	BI
Ep_Ind	Richness of epidermal indumentum	CO
LH	Longest hair in the abaxial surface of the cross-section	QC
Sp_L	Spikelet length	QC
LGI_L	Lower glume length	QC
UGI_L	Upper glume length	QC
UGI_hW	Upper glume half-width	QC
Lm_L	Lemma length	QC
Lm_hW	Lemma half width	QC
A_L	Awn length	QC
GI_Pb	Glumes pubescence	CO
Lm_Pb	Lemma pubescence	CO
Sp_Sh	Spikelet shininess	CO

All statistical analyses were computed with R (R Core Team 2024) in RStudio 2024.4.2.764 (Posit team 2024) using the MorphoTools2 package (Šlenker et al. 2022).

Ploidy estimation

The ploidy level was measured in 50 samples (1–4 per population) using flow cytometry with DAPI dye. The youngest and most well-preserved leaves were selected from representative individuals of both fresh plants and herbarium vouchers (no older than one year). Samples were then co-chopped with the standard (*Lycopersicum esculentum* “Stupické polní tyčkové rané”) in a Petri dish containing 0.5 mL Otto I buffer (0.1M citric acid, 0.5% Tween 20; Otto

1990) using a razor blade. The nuclei suspension was then filtered through a 50 µm nylon mesh before 1 mL of Otto II buffer (0.4M Na₂HPO₄ · 12H₂O) supplemented with 2 µg/mL DAPI was added. Samples were analyzed with a CyFlow ML flow cytometer (Partec GmbH, Germany) equipped with a UV light-emitting diode (365 nm, Sysmex Partec GmbH) at the Department of Botany and Zoology, Masaryk University, Brno, Czech Republic. To confirm the ploidy level, chromosome counts were performed using the Fuelgen protocol. In brief, Squash preparations were made on root tips obtained from germinating seeds. The root tips were pre-treated with 0.4% colchicine for 3 hours and then fixed in Carnoy fixative solution for 1 hour. After hydrolysis in HCl 1N at 60 °C for 7–8 minutes, the tips were stained in leuco-basic fuchsin for 3 hours.

DNA extraction and ddRAD sequencing

Genomic DNA was extracted from silica gel-dried leaves or herbarium specimens from 14 samples of the same species included in the morphometric analyses (Suppl. material 1: table S7). DNA quality was assessed by 1.5% agarose gel electrophoresis, and concentration was measured using a Qubit 2 Fluorometer with the 1X dsDNA HS Assay Kit (Thermo Fisher Scientific).

The double digest restriction site-associated DNA (ddRAD) library preparation protocol was adapted from Sochor et al. (2024) with modifications. Briefly, 100 ng of genomic DNA was digested with SbfI-HF and MseI restriction enzymes in rCut-Smart buffer (New England Biolabs) at 37 °C for 3 hours, followed by enzyme inactivation at 80 °C for 20 minutes. Immediately afterwards, P1 and P2 adapters, corresponding to the restriction sites of the respective enzymes, were ligated using T4 DNA ligase (New England Biolabs) at 16 °C overnight, with subsequent heat inactivation at 65 °C for 10 minutes. The P1 adapter for each sample contained a unique barcode for individual identification. The DNA concentration of each restricted sample was measured using the Qubit fluorometer, and equimolar amounts of digested DNA from all samples were pooled. The pooled samples were purified with 1.2 × SPRI magnetic beads and used as a template for PCR enrichment. PCR amplification was performed in four 20 µl reactions (18 cycles each) using Phusion HF PCR Mastermix (New England Biolabs) and standard Illumina P1-i5 (5'-AATGATACGGCGACCACCGA-3') and P2-i7 (5'-CAAGCAGAAGACGGCATACGA-3') primers. The protocol for each step is available in the Suppl. material 1: table S6. The final amplified products were size-selected using SPRI magnetic beads, with left and right side selections at 0.5 × and 0.9 × ratios, following the manufacturer's protocol. The final ddRAD library was sequenced at the CEITEC facility (Brno, Czech Republic) on an Illumina NextSeq platform using a mid-output configuration with 300 cycles. Sequencing utilized a portion of the platform's capacity, generating approximately 30,000,000 paired-end reads.

Phylogenomic analysis

Paired-end reads generated by Illumina sequencing of the ddRAD library were demultiplexed and analyzed using iPyRAD v.0.9.97 (Eaton and Overcast 2020). Quality control parameters were configured as follows: trimming was performed for bases with a quality score below Q20, allowing up to five low-quality bases per read. The Phred Q score offset was set to 33. The minimum read depth for

base calling and majority-rule consensus was set to 6, with a maximum read depth per sample capped at 10,000. The sequence similarity threshold was specified as 0.90, permitting a maximum of one base mismatch in barcodes. Adapter sequences were strictly filtered out, and a minimum read length of 35 bp was required. Consensus sequence assembly was conducted with the following parameters: a maximum of six alleles per consensus sequence to accommodate diploid and polyploid species in the dataset; a maximum of 5% uncalled bases and 5% heterozygous sites per consensus sequence; and a minimum of seven samples sharing data at a given locus (allowing up to 46% missing data). Locus filtering parameters were set to allow a maximum of 20% SNPs per locus, up to eight indels per locus, and a maximum of 20% heterozygous sites per locus.

Phylogenomic relationships among individuals based on ddRAD data were inferred using RAxML v.8.2.12 (Stamatakis 2014). The GTRCAT substitution model was employed, and bootstrap analysis with 1,000 replicates was performed to construct a maximum likelihood tree. The resulting phylogeny was visualized using FigTree v.1.4.4 (Rambaut 2015).

Results

Morphometric analysis

The first two axes of the exploratory PCoA account for 45.23% of the variability. Three main clusters can be observed in the biplot (Fig. 1): species of *F. stricta* group, the Sila hexaploid and the diploid *F. marginata*. The hexaploid taxon from the Sila plateau appears morphologically as an in-between entity but still clearly distinct from the other two groups. In particular, the taxon seems to share with the species of the *F. stricta* group the tendency to develop decurrent to confluent sclerenchyma strands (Sc_Org), as well as presenting undulations between epidermal cells (Ep_Pap) and longer awns (A_L). However, these are the only similarities between the two groups, as the Sila specimens resemble more, on a superficial level, species of the *F. marginata* group. They lack numerous other features typical

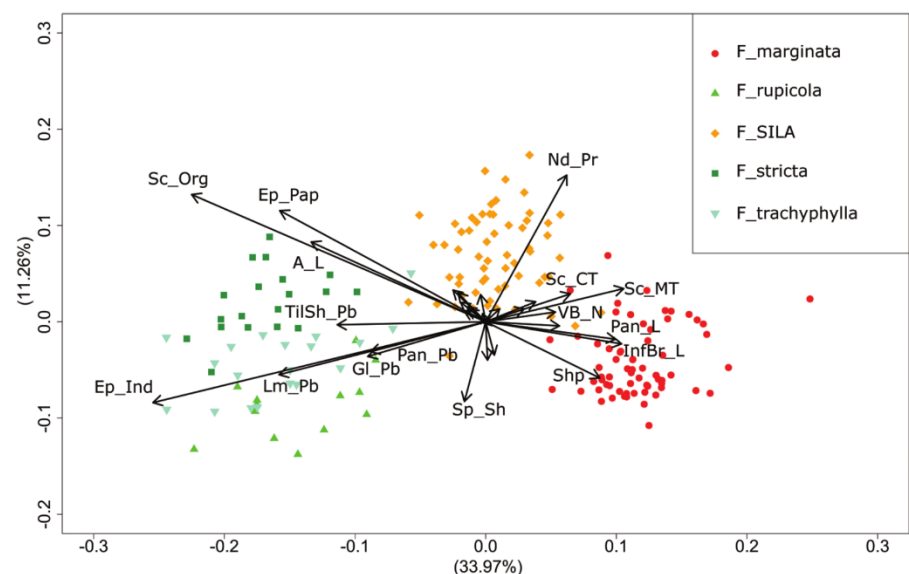


Figure 1. Biplot for the PCoA performed with Gower's distance.

of the *F. stricta* taxa, such as scabrid leaf blades due to the presence of barbs on the adaxial indumentum (Ep_Ind) and an overall pubescence observed in the panicle (Lm_Pb, Gl_PB, Pan_Pb) and tiller sheaths (TilSh_Pb). Compared to the new species, *F. marginata* tends to develop discrete thickened sclerenchyma strands (Sc_Org, Sc_MT, Sc_CT), a larger number of vascular bundles (VB_N), bigger panicles (Pan_L, InfBr_L) and leaves in a more elongated conduplicate “V” shape (Shp). Finally, the Sila taxon seems to be overall a more pruinous plant (Nd_Pr, Sp_Sh) compared to all the other species analyzed. Based on the clustering of the taxa in the biplot, we decided to merge the species from the *Festuca stricta* aggregate into a single group to avoid distortions in the following discriminant analysis.

The jackknifed CDA (Fig. 2) fully supports the grouping hypothesis indicated by the scatterplot of the PCoA with 97.74% classification success in 177 samples (Table 2). Again, the new species appears as a distinct morphological in-between entity of the other considered species.

Table 2. Confusion matrix for the DA performed on the three morphological groups individuated by the PCoA.

Taxon	N	<i>F. marginata</i>	<i>F. sila</i>	<i>F. stricta</i> group	correct	%
<i>F. marginata</i>	65	65	0	0	65	100.00
<i>F. silana</i>	61	3	58	0	58	95.08
<i>F. stricta</i> group	51	0	1	50	50	98.04
Total	177	68	59	50	173	97.74

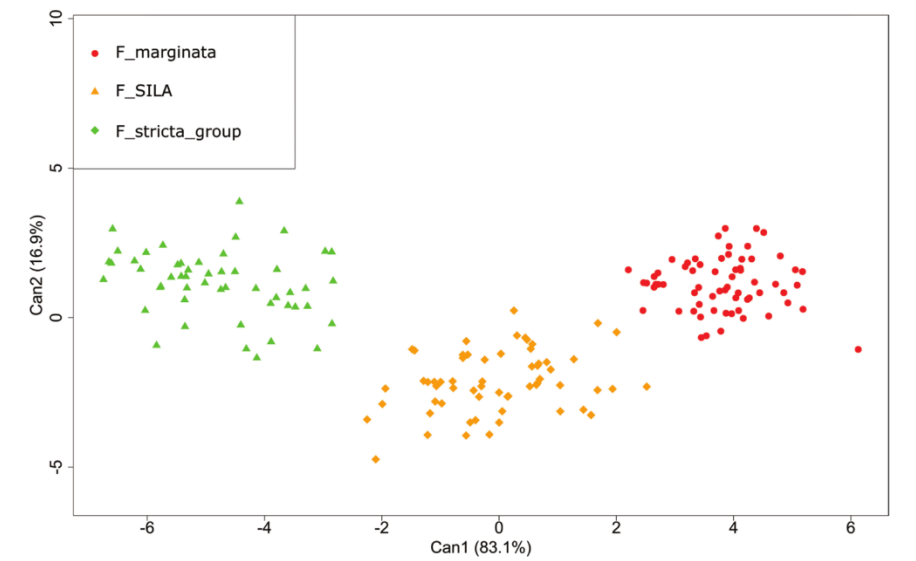


Figure 2. Scatterplot for the DA performed on the three morphological groups individuated by the PCoA.

Ploidy estimation

Overall, 50 of the freshly collected individuals were studied with flow cytometry. All 20 individuals of *F. stricta* s.l. (*F. stricta*, *F. trachyphylla* and *F. rupicola*) were hexaploid and all *F. marginata* samples were diploid (17 individuals) in accordance with previous works (Portal 1999; Arndt 2008, Šmarda et al. 2008; Ardenghi et al. 2016, 2024). All 13 individuals assumed as *F. silana* were hexaploid.

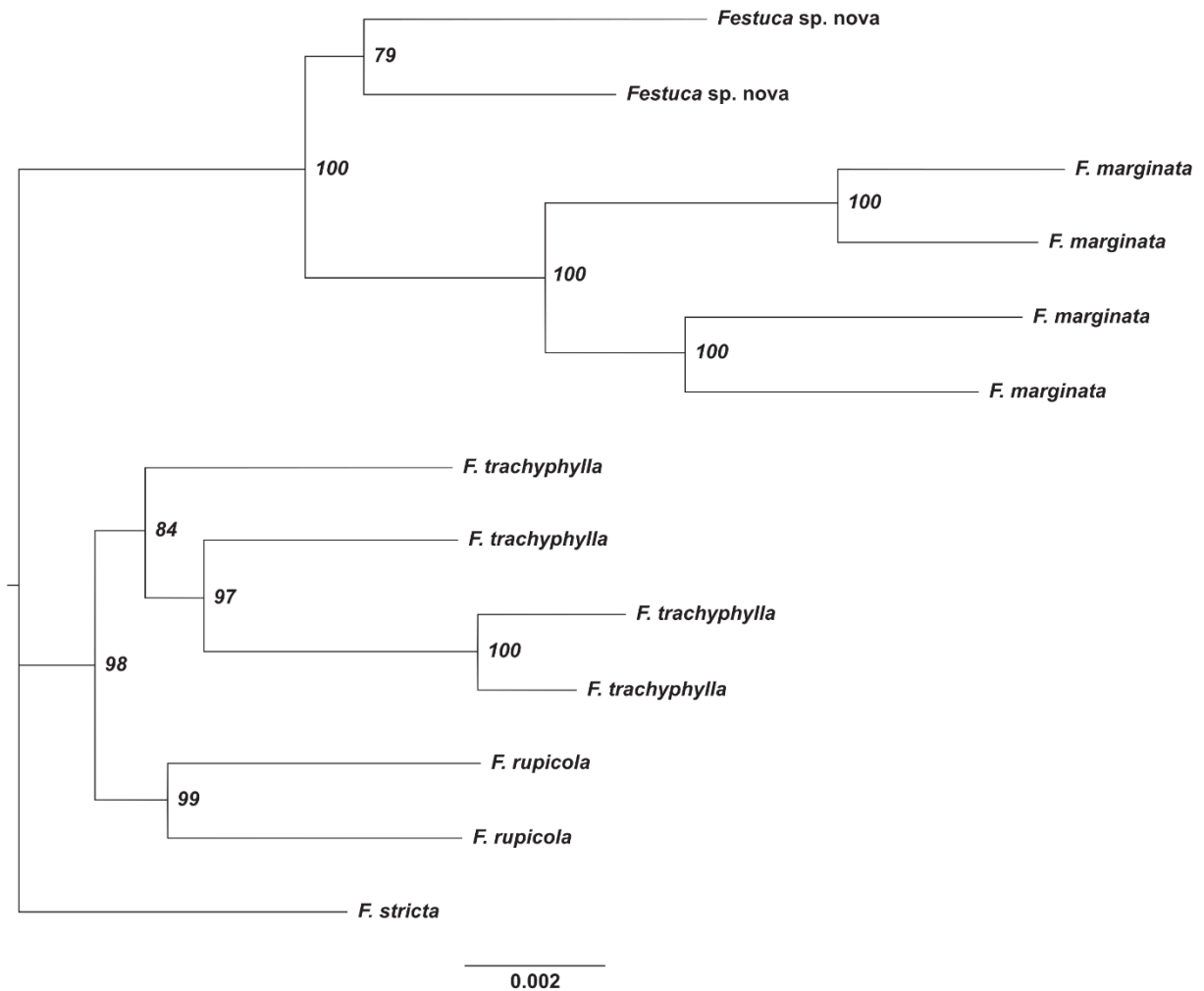


Figure 3. Phylogenetic tree of thirteen *Festuca* individuals, constructed using RAxML based on 2,713 loci and maximum likelihood estimation. The numbers in the nodes represent bootstrap values (%) from 1,000 replicates.

Phylogenomic analysis

A total of 67,353 loci were initially identified, which were reduced to 2,713 after filtering. The primary cause of this reduction was the requirement for a minimum of seven out of 13 samples to contain data for a given locus. Following the first analysis, one sample (F14) with low sequencing coverage was excluded based on quality assessment, and the analyses were repeated without this sample. The number of retained loci per sample ranged from 1,526 to 2,096. The resulting best tree effectively resolved each species, with high bootstrap support for most nodes (Fig. 3).

Taxonomic treatment

Festuca silana Ardenghi, Pallanza & Foggi, sp. nov

[urn:lsid:ipni.org:names:77360044-1](https://nomenclature.ipni.org/names/77360044-1)

Typus. ITALY • Sila piccola, Zagarise (Catanzaro), Latteria, Lato W del sentiero, Pendi-ci SW del M. Gariglione (WGS84: 39°07'29.4"N, 16°37'32.8"E), 1587 m, prateria me-so-xerofila con roccia granitica affiorante, assieme a *Patzkea paniculata*, 06.07.2014, N. Ardenghi & L. Bernardo. (**holotype:** PAV-150000!; **isotypes:** FI!, CLUI, WI, GI!).

ITALY • Sila grande, Spezzano della Sila (CS), Vaccarizzo, Sponda S del Lago Cecita (WGS84: 39°22'13.5"N, 16°30'40.1"E), 1150 m, prato arido con *Astragalus parnassi* subsp. *clabricus*, su sabbie granitiche con affioramenti rocciosi, 05.07.2023, M. Pallanza & L. Bernardo. (**paratypes**: PAV-150002!, PAV-150003!, FI!, CLUI!, WI!, G!).

ITALY • Sila grande, Casali del Manco (CS), Lago Ariamacina, Sponda N del lago (WGS84: 39°20'00.8"N, 16°32'39.0"E), 1327 m, prato arido con *Astragalus parnassi* subsp. *clabricus*, su sabbie granitiche, 05.07.2023, M. Pallanza & L. Bernardo. (**paratypes**: FI!, CLUI!, WI!, G!).

ITALY • Sila grande, San Giovanni in Fiore (CS), Carlomagno, A W della SP211 (WGS84: 39°16'58.1"N, 16°32'36.1"E), 1535 m, prato mesofilo a *Patzkea paniculata*, su substrato granitico con spesso strato di suolo, 05.07.2023, M. Pallanza & L. Bernardo. (**paratypes**: PAV-150001!, FI!, CLUI!, WI!, G!).

Description. Perennial herb, caespitose to densely caespitose, occasionally pruinose. Tiller shoots intravaginal. Culms (32.0–) 44.7–57.2 (–69.5) cm long and (0.52–) 0.77–1.04 (–1.29) mm in diameter, erect cylindrical, canaliculated, smooth to the touch, with 1 (–2) visible nodes, dark brown to black in color, located in its lower third. Cauline leaves 1 (–2), (1.6–) 2.6–4.0 (–5.3) cm long, sheathing the culm for (5.8–) 8.0–10.3 (–12.8) cm. Basal leaf sheath glabrous, on extremely rare occasions with few sparse hairs, open down to the base, yellowish in color, more rarely veined in red. Ligula 0.5–0.8 mm long, membranaceous, truncate, fringed, with two auricles at the sides. Basal leaf blade (7–) 11.8–21.6 (–31.7) cm long and (0.75–) 0.94–1.06 (–1.36) mm in diameter, smooth, somewhat rigid, conduplicate, bright to dark green. Cross section outline in an open U-V shape. Subepidermal sclerenchyma organized in 3 main strands located at the margins and keel of the leaf blade, thickened and often decurrent or accompanied by secondary strands opposing vascular bundles, forming an interrupted or irregular complete ring. Vascular bundles 7(–9). Ribs 2 (–4). Abaxial surface of the leaf blade covered with a dense indumentum of (0.03–) 0.04–0.07 (–0.13) mm long hairs. Adaxial surface smooth, with small undulations between epidermal cells. Panicle (4–) 6.4–8.6 (–12.5) cm long, cylindrical to pyramidal during anthesis, dense, with 7–27 spikelets; branches 1–5, simple, antrorsely scabrid; nodes 7–12. Spikelets (6.24–) 7.33–8.13 (–8.87) long, laterally flattened, elliptic, green, with (3–) 4–6 (–8) fertile florets. Glumes 2, unequal, lanceolate, glabrous or rarely with few sparse hairs on the margins and apex. Lower glume (2.21–) 2.55–3.12 (–3.90) mm long, with a single nerve. Upper glume (2.46–) 3.68–4.31 (–5.12) mm long, 3-nerved. Lemma (3.82–) 4.81–5.26 (–5.83) mm long, lanceolate, glabrous or more rarely with few sparse hairs near the apex, terminating in an apical awn (1.23–) 1.83–2.52 (–3.30) mm long. Palea 4.53–5.71 mm long, lanceolate, bifid, with 2 finely dentated keels. Anthers 3, (1.72–) 2–2.44 (–2.93) mm long, yellow to orange in color. Ovary glabrous. Stygmata 2, with a feather-like shape. Lodicules 2, bilobed, 0.83–1.06 mm long. Caryopsis 2.42–3.85 mm long, brown to dark orange at maturity, adherent to the palea (Fig. 4). Somatic chromosomes 42 (2n = 6x).

Eponym. The new species is named after the Sila plateau where it typically occurs.

Diagnosis. Differt a *Festuca costei* (St.-Yves ex Litard.) Markgr.-Dann. crassiore sclerenchyma in laminarum margine et carina, plerumque 7

(non (7–) 9–11) fasciculis vascularibus, densioribus et longioribus trichomatibus in abaxiale superficie, minutis undulationibus inter epidermidis cellulas, 42 (non 28) chromosomatibus.

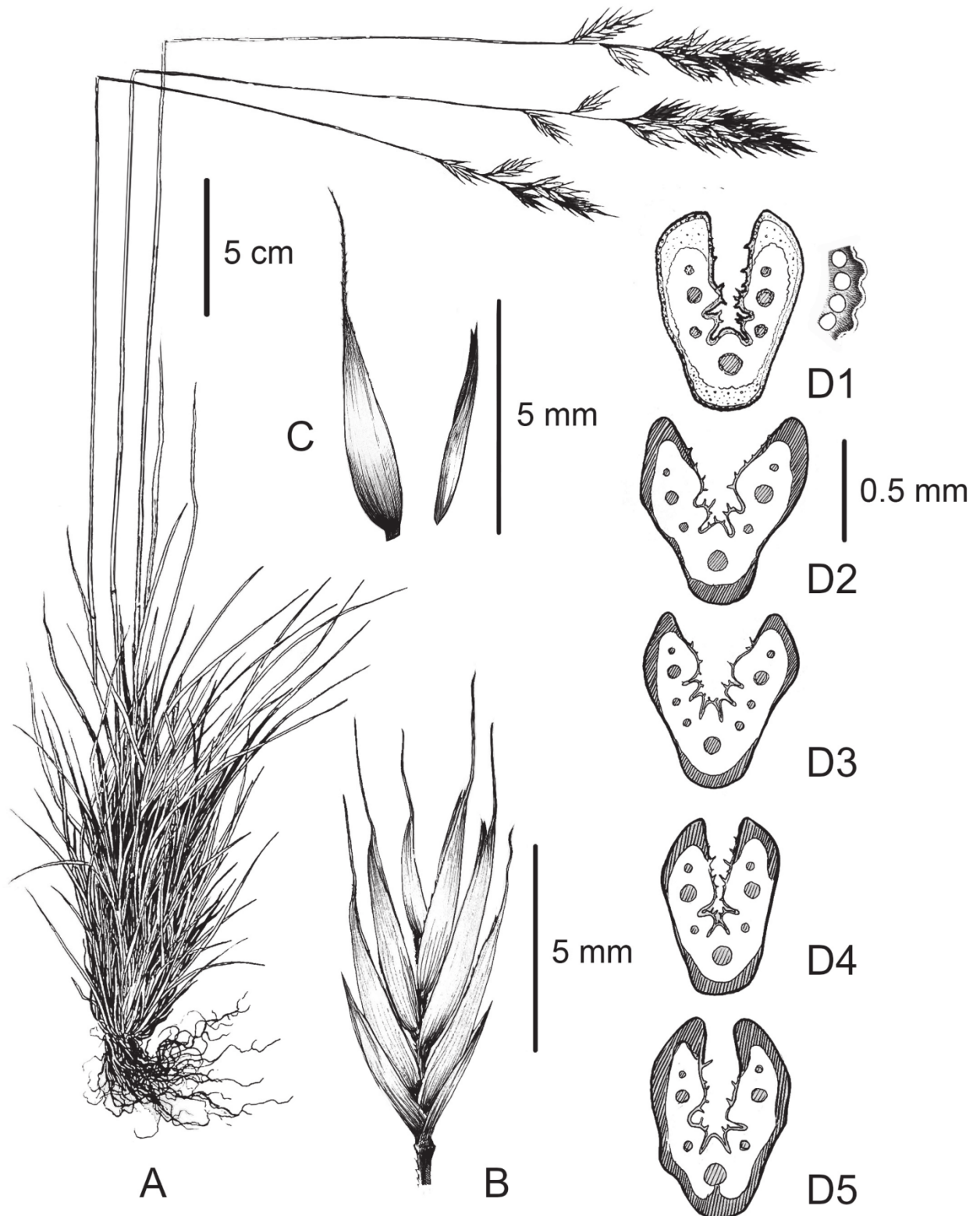


Figure 4. Illustration of *Festuca silana* Pallanza, Ardenghi & Foggi based on the specimens from the locus classicus **A** overall habitus and morphology of the species **B** detailed appearance of the spikelet **C** detailed view of lemma and palea **D1** leaf cross-section of the holotype **D2–D5** different leaves cross-sections showcasing intraspecific variability.

It differs from *Festuca costei* (St.-Yves ex Litard.) Markgr.-Dann. for the thicker sclerenchyma at margins and keel of the leaves, vascular bundles are rarely more than 7 (compared to the (7–) 9–11 in *F. costei*). Abaxial indumentum is more dense and with longer trichomes compared to *F. costei*. It also presents small undulations between epidermal cells. Somatic chromosomes $2n = 6x = 42$ instead of $2n = 4x = 28$ in *F. costei*.

Differt a *Festuca marginata* (Hack.) K.Richt. sclerenchyma plerumque decurrente vel completum anulum fingente potius quam in tribus discretis filis ordinato, fasciculis vascularibus raro plus quam 7 (non (7–) 9–11 ut solet in *F. marginata*), longioribus trichomatibus in densiore abaxiale superficie, longioribus aristis, undulationibus inter epidermidis cellulas, 42 chromosomatibus, non 14.

It differs from *Festuca marginata* (Hack.) K.Richt. in the sclerenchyma, usually decurrent or up to forming a complete ring instead of being organized in three discrete strands. Vascular bundles are rarely more than 7 (compared to the (7–) 9–11 in *F. marginata*). Abaxial indumentum is richer and with longer trichomes compared to *F. marginata*. Awns longer compared to *F. marginata*. Undulations are present in between epidermal cells. Somatic chromosomes $2n = 6x = 42$ instead of $2n = 2x = 14$ in *F. marginata*.

Differt a *Festuca trachyphylla* (Hack.) R.P.Murray sclerenchyma prope margines et carinam crassiore; foliis numquam scabris et colore viridi clariore (non glauco ut solet in *F. trachyphylla*); spiculis numquam pubescentibus; foliarum vaginis quam saepissime glabris (non pubescentibus ut solet in *F. trachyphylla*).

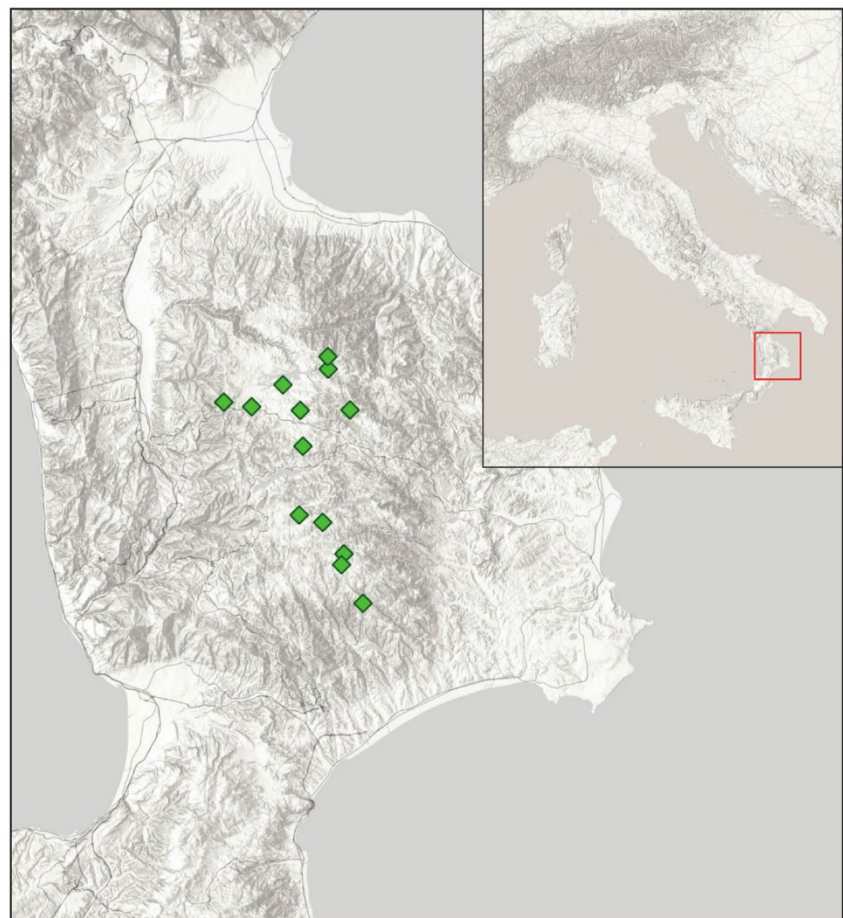


Figure 5. Map of the Sila and known stations of *F. silana* occurring within the plateau.

It differs from *Festuca trachyphylla* (Hack.) R.P.Murray in the sclerenchyma, thicker in the correspondence of margins and keel, the leaf blades never scabrid and of a brighter green color (opposed to the glaucous of *F. trachyphylla*). Spikelets are never pubescent. Leaf sheaths are glabrous except for extremely rare exceptions (opposed to the commonly pubescent in *F. trachyphylla*).

Distribution and ecology. The species is only known from the Sila highland, currently from 13 populations (Fig. 5). It mainly grows in grassland and pasture communities (*Anthemidetalia calabricae* Brullo, Scelsi & Spampinato, 2001) on granitic sands in xerophilic to mesophilic conditions at altitudes between 1100 m and 1600 m. *F. silana* typically occurs in grasslands of xerophile to mesophile conditions, along with other *Festuca* taxa such as *F. marginata* subsp. *marginata*, *F. trachyphylla*, *F. rubra* subsp. *commutata* and *F. cyrnea*.

Conservation status. Although the plant has a distribution limited to the Sila plateau, it is one of the dominant species in the grasslands that it inhabits and lacks any particular threat that could cause a decline in the population. Therefore, it had to be considered as Least Concern (LC) according to IUCN (2012).

Key to the studied species

- 1 Sclerenchyma strands decurrent sometimes with accessory strands or confluent in an irregular complete ring. Spikelets 7–8.5 mm. Awns usually > 2 mm long. Hexaploid plants **2**
 - Sclerenchyma in three discrete strands, never decurrent. Spikelets 6–7 mm. Awns short, generally < 2 mm. Diploid plants. ***F. marginata* subsp. *marginata***
- 2 Leaf scabrid, at least in the apical/upper part. Spikelets and leaf sheaths generally pubescent. Plants glaucous to dark green. **3**
 - Leaves completely glabrous/smooth, never scabrid. Spikelets glabrous. Leaf sheaths usually glabrous, only very rarely with sparse hair. Plant bright/fresh green. ***F. silana***
- 3 Tiller leaves with 5 (rarely 7) vascular bundles. Sclerenchyma of regular thickness throughout its length. Plants of natural areas. **4**
 - Tiller leaves with 7–9 (rarely 5) vascular bundles. Sclerenchyma irregularly thickened throughout its length. Plant typical of synantropic or disturbed habitats. ***F. trachyphylla***
- 4 Sclerenchyma generally forming a thick continuous ring, more rarely partly interrupted. Leaves strongly scabrid. ***F. stricta***
 - Sclerenchyma in three decurrent strands at the margins and keel, more rarely with accessory strands opposed to the vascular bundles. Leaves moderately to weakly scabrid. ***F. rupicola***

Discussion

Despite the superficial similarities with other taxa of the *Festuca marginata* group and *F. trachyphylla*, our findings fully support *F. silana* as a standalone species. Attempts to identify the samples of *F. silana* with current keys of the Italian flora led to *F. costei* due to the high importance of the sclerenchyma ring and the general appearance of plants resembling the *F. marginata* group. However, many morphological characters neglected by the keys

(such as the number of vascular bundles, the presence of undulations in-between epidermal cells, shorter arms of the leaf cross-section, etc.) easily emerge when looking at the specimens of the two taxa side by side. *F. costei* (= *F. arvernensis* Auquier, Kerguélen & Markgr.-Dann. subsp. *costei* (St.-Yves) Auquier & Kerguélen) has been described for the Massif Central in France and never reported for the Apennines. The separation between the two taxa was also confirmed by the ploidy inference via flow cytometry. *F. silana* is always hexaploid, thereby excluding any possibility of it being a particular morphotype of *F. costei*, which has been consistently reported as tetraploid (Auquier and Kerguélen 1977; Portal 1999; Šmarda et al. 2008). Additionally, although *F. costei* appears in the most recent checklists of the Italian vascular flora (Bartolucci et al. 2018, 2024), it has been reported for a single locality in the Maritime Alps (Piedmont, Italy; Foggi et al. 2017), but we could not trace any herbarium specimens supporting this data. Moreover, we visited the locality reported by Foggi et al. (2017) and could not find any individuals of this taxon here. Finally, biogeographical considerations were quite weak in supporting this determination and a disjunction between Massif Central – Southern Apennines is not very plausible. In light of these considerations, *F. costei* is not a component of the flora of Italy.

Despite the shared hexaploidy and similar leaf cross-sections' anatomy, fescues of the *F. stricta* group differ from *F. silana* in their commonly pubescent tiller leaves' sheaths and spikelets. Also, species of the *F. stricta* group commonly display some level of scabridity in the tiller leaf blades, which never occurs in *F. silana*. Finally, *F. silana* differs from *F. marginata* from the strong morphological distinction in leaf cross section anatomy, especially in sclerenchyma development and structure, as well as for the ploidy level (diploid vs hexaploid). The morphological differences can be attributed to the different ploidy levels, as it has been shown that an increase in ploidy level influences different morphological characters in fine-leaved fescues (Rewicz et al. 2018).

It is reasonable to think that *F. silana* may have originated from autopolyploidy of *F. marginata*, which is also present in the Sila plateau and sometimes even within the same localities. This hypothesis is supported by the ddRADseq sequencing results. It should be noted that the *F. marginata* group has recently been revised in Central-Southern Europe (Ardenghi et al. 2024) and all the previously described taxa have been reduced to two single diploid subspecies reflecting major differences in morphology and genome size between the populations in Greece (considered as *Festuca marginata* subsp. *heldreichii* (Hack.) Ardenghi & Foggi) and the remaining European populations (reported under *Festuca marginata* (Hack.) K. Richt. subsp. *marginata*). This newly discovered taxa from the Southern Apennines highlights the need for continued taxonomic research to broaden the understanding of plant diversity of critical groups such as *Festuca* in the Apennines.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

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Author contributions

Conceptualization: SO, MP, NMGA, PŠ, BF. Data curation: PŠ, LB, MP. Formal analysis: MP, PŠ, PŠ. Funding acquisition: GR, PŠ, SO. Investigation: PŠ, NMGA, LB, MP, BF. Methodology: LB, BF, NMGA, MP, PŠ, PŠ. Resources: BF, LB, PŠ. Supervision: GR, SO, BF. Writing - original draft: PŠ, SO, LB, BF, NMGA, GR, MP, PŠ. Writing - review and editing: PŠ, MP, GR, PŠ, NMGA, BF, LB, SO.

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Data availability

All of the data that support the findings of this study are available in the main text or Supplementary Information.

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Supplementary material 1

Occurrences, studied specimens, protocols

Authors: Mattia Pallanza, Orsenigo Simone, Petr Šmarda, Petra Šarhanová

Data type: xlsx

Explanation note: Excel file with a guide sheet describing the content of the different other sheets. A List of herbaria specimens studied as an exploratory part of the research, datasets for the PCoA and DA, Protocols and information on the samples used in the DNA extraction and ddRAD sequencing are available.

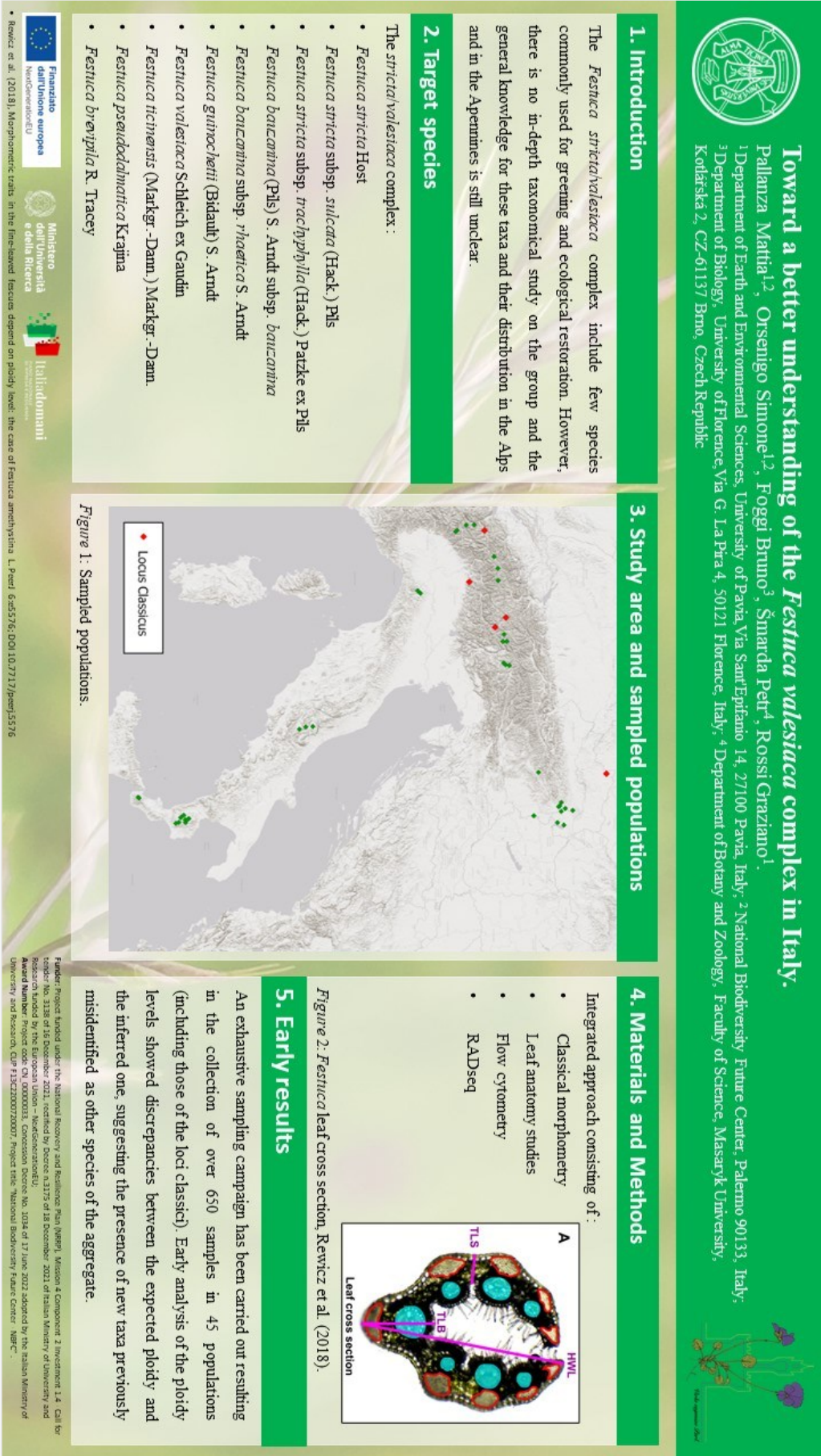
Copyright notice: This dataset is made available under the Open Database License (<http://opendatacommons.org/licenses/odbl/1.0/>). The Open Database License (ODbL) is a license agreement intended to allow users to freely share, modify, and use this Dataset while maintaining this same freedom for others, provided that the original source and author(s) are credited.

Link: <https://doi.org/10.3897/phytokeys.255.146942.suppl1>

9.7 Congresses posters

The following posters have been presented at congresses:

- Pallanza M, Orsenigo S, Foggi B, Šmarda P, Rossi G (2023) Toward a better understanding of the *Festuca valesiaca* complex in Italy. 118° Congresso della Società Botanica Italiana. 13-16 September 2023, Pisa.
- Pallanza M, Orsenigo S, Foggi B, Šmarda P, Rossi G (2024) The *Festuca stricta/valesiaca* complex in Italy: filling in the gaps with integrative taxonomy. XX International Botanical Congress. 21-27 July 2024, Madrid.
- Pallanza M, Orsenigo S, Foggi B, Šmarda P, Šarhanová P, Rossi G (2025) Uncovered *Festuca* diversity in the Italian peninsula: early results. Forum Nazionale della Biodiversità 2025. 19-21 May 2025, Milan.



The *Festuca stricta/valesiaca* complex in Italy: filling in the gaps with integrative taxonomy.

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1. INTRODUCTION

Integrative taxonomy combines data from multiple sources (e.g. morphology, genetics, ecology) to better understand diversity within critical groups of species. One such group are the fine leaved fescues (*Festuca* sect. *Festuca*), one of the most challenging to describe due to a high species diversity often only identified from difficult to observe characters.

In Italy, several authors have worked on disentangling the taxonomy and systematics of fine-leaved fescues in the last decades, however, the *stricta/valesiaca* complex has not yet been investigated.

Our aim is to revise the *stricta/valesiaca* for the Alps and Apennines and identify clear boundaries between the taxa using an integrative taxonomy-based approach. Morphological data processing is still ongoing, but early ploidy analysis performed on samples from 49 populations (Fig.1) shows severe gaps and misinformation in our current knowledge, especially in the Apennines.

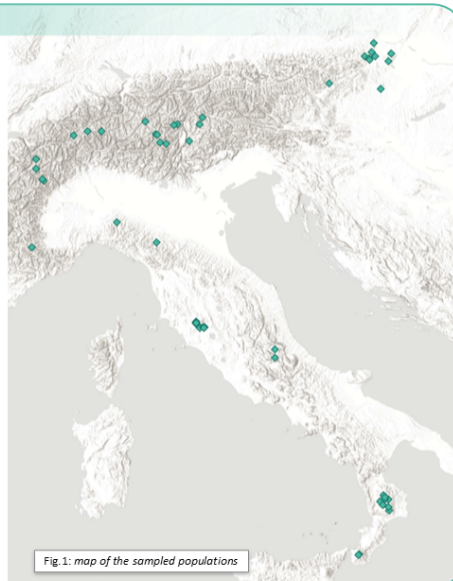


Fig.1: map of the sampled populations

2. TARGET TAXA

According to the latest checklists, there are 9 different *stricta/valesiaca* taxa within the study area:

- *Festuca stricta* Host subsp. *stricta*
- *Festuca stricta* subsp. *sulcata* (Hack.) Pils
- *Festuca stricta* subsp. *trachyphylla* (Hack.) Patzke ex Pils
- *Festuca bauzanina* (Pils) S. Arndt subsp. *bauzanina*
- *Festuca bauzanina* subsp. *rhætica* S. Arndt
- *Festuca guinochetii* (Bidault) S. Arndt
- *Festuca valesiaca* Schlecht ex Gaudin
- *Festuca ticinensis* (Markgr.-Dann.) Markgr.-Dann.
- *Festuca pseudodalmatica* Krajina ex Domin

3. METHODS

We selected an approach that integrated classic morphology with ploidy levels. After consultation with other authors, 35 diagnostic characters were selected. Currently, 49 populations have been sampled over the Alps and Apennines, totaling more than 800 samples.

4. EARLY RESULTS

Flow cytometry was performed for at least 3 individuals from each population, being careful not to miss coexisting taxa and hybrids. When combined with preliminary multivariate analysis of the morphology, some controversies were highlighted.



5. SILA HIGHLAND

Early morphological and ddRADSeq analyses performed on a hexaploid taxon previously reported as *F. stricta* subsp. *trachyphylla* shows that, despite similarities in leaf section anatomy, these plants are more aligned to the *F. marginata* group and perhaps represent a new, undescribed species.



6. GRAN SASSO MASSIF

Preliminary ploidy analysis performed on populations reported as *F. stricta* subsp. *sulcata* shows that these plants are tetraploid and not hexaploid as expected. This may be due to the unrecorded occurrence of some Balkan taxa in this group.



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Uncovered *Festuca* diversity in the Italian peninsula: early results

Pallanza Mattia^{1,2}, Foggi Bruno³, Šmarda Petr⁴, Šarhanová Petra⁴, Rossi Graziano¹, Orsenigo Simone^{1,2}

B125

GENERAL BACKGROUND

Festuca is one of the most diverse genera in the grass family (*Poaceae*) and recently gained popularity in the ecological restoration scene due to its key characteristics.

However, its complexity call for more in-depth taxonomical studies, especially because of this new success in ecosystems restoration. As a matter of fact, an improper use in the field of species without an appropriate understanding of their taxonomy and distribution may lead to setbacks and possibly even damage to the ecosystem.

Our study is currently aiming to fill in the gaps in knowledge regarding the *Festuca stricta/valesiaca* group, a complex of species that had major success in the restoration scene. Results so far have proved that there's a hidden diversity that has yet to be uncovered.



A NEW SPECIES IN THE SILA PLATEAU

Our investigations on the morphology, ploidy and phylogenomics of some populations found in the area of the Sila Plateau led to the discovery of a new taxon. *Festuca silana* Ardenghi, Pallanza & Foggi is a new species endemic to Calabria officially described and published in earlier 2025.



A NEW RECORD FOR THE CENTRAL APENNINES

Individuals collected from the central Apennines and previously identified as *F. rupicola* Heuff. were found to be tetraploids instead of hexaploids. The specimens are under study along with other european tetraploids species to understand whether this is a new record or a taxon new to science.



ALPINE ENDEMIC SPECIES

Due to *Festuca*'s taxonomical criticalities, many taxa, especially local ones, are still debated to be legitimate or not. Our ongoing studies are also evaluating the status of four taxa originally described as endemic of the Alps, some of which have been considered controversial.

**FORUM NAZIONALE
DELLA BIODIVERSITÀ 2025**

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19 • 21 Maggio 2025
Università degli Studi di Milano-Bicocca

9.8 Congresses abstracts

The following abstracts have been presented for oral presentations at congresses and are presented integrally in the following pages:

- Pallanza M, Ardenghi NMG, Bernardo L, Šmarda P, Šarhanová P, Orsenigo S, Rossi G, Foggi B (2024) Indagini su alcune popolazioni di *Festuca* L. (Poaceae) della Sila. Riunioni scientifiche dei gruppi Gruppo per la Floristica, Sistematica ed Evoluzione. 8-9 November 2024, Roma.
- Pallanza M, Ardenghi NMG, Bernardo L, Šmarda P, Šarhanová P, Orsenigo S, Rossi G, Foggi B (2025) A new species of *Festuca* L. (Poaceae) endemic to the Sila plateau in Italy. CYBO: Conference of Young Botanists 2025. 5-7 February 2025, Genoa.
- Pallanza M, Foggi B, Šmarda P, Šarhanová P, Rossi G, Orsenigo S (2025) The *Festuca valesiaca* complex in Italy: applying integrative taxonomy to a critical group. 120° Congresso della

Riunioni scientifiche dei gruppi Gruppo per la Floristica, Sistematica ed Evoluzione 8-9 novembre 2024, Roma

Indagini su alcune popolazioni di *Festuca* L. (Poaceae) della Sila.

M. Pallanza, N.M.G. Ardenghi, L. Bernardo, P. Šmarda, P. Šarhanová, S. Orsenigo, G. Rossi, B. Foggi

Durante una campagna di campionamento funzionale alla revisione del gruppo di *Festuca marginata* (Hack.) K.Richt. (= *F. circummediterranea* Patzke) nel Mediterraneo (Ardenghi et al. 2024), uno degli autori (N.M.G. Ardenghi) ha rinvenuto sull'altopiano della Sila un taxon appartenente al genere *Festuca* di difficile inquadramento tassonomico. In passato, erano già stati rinvenuti nell'area campioni con una morfologia simile, raccolti da Sarfatti (1959) e determinati come *Festuca ovina* L. subsp. *laevis* Hack. var. *gallica* (Hack.) St.-Yves subvar. *costei* St.-Yves ($\equiv$ *Festuca costei* (St.-Yves) Markgr.-Dann.) da Markgraf-Dannenberg (Sarfatti 1959). Gli individui si presentano con una morfologia peculiare, riconducibile ad altri membri del gruppo di *F. marginata* ma con una tendenza a formare occasionalmente un anello sclerenchimatico completo (Fig. 1), caratteristica comune al gruppo di *Festuca stricta* Host. Tuttavia, una preliminare conta cromosomica ha rivelato che il taxon è esaploide ($2n=6x=42$) diversamente da *F. marginata* che risulta sempre diploide ($2n=2x=14$) e *F. costei* che risulta tetraploide ($2n=4x=28$) (Auquier & Kerguelen 1977, Šmarda et al. 2008). La particolare combinazione di caratteri morfologici e l'inusuale livello di ploidia ci hanno stimolato ad affrontare il problema dell'identificazione e dell'inquadramento tassonomico tramite un approccio tassonomico integrato. Per meglio chiarire l'identità di questo taxon, abbiamo selezionato 4 ulteriori taxa di confronto sulla base di caratteristiche morfologiche e cariologiche comuni: *Festuca stricta* Host, *Festuca rupicola* Heuff., *Festuca trachyphylla* (Hack.) R.P.Murray e *Festuca marginata* (Hack.) K. Richt..

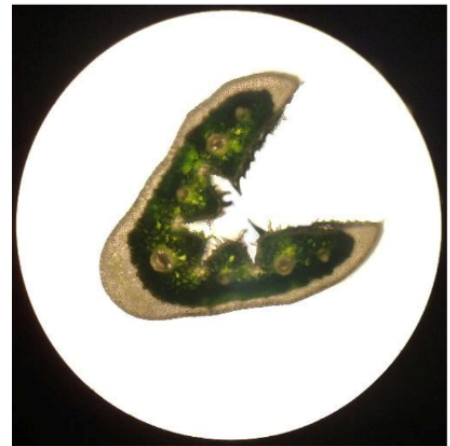


Fig. 1: Tipica sezione fogliare del taxon rinvenuto sulla Sila

158 individui sono stati campionati per un totale di 25 popolazioni distribuite tra Alpi e Appennini. Di questi 47 sono stati analizzati mediante citometria di flusso per stimarne la dimensione del genoma e dedurre i livelli di ploidia, mentre per le analisi morfometriche sono stati presi in esame ulteriori 19 campioni d'erbario conservati presso l'erbario FI.

I risultati della citometria di flusso confermano che il taxon della Sila è esaploide, così come anche le diverse specie appartenenti al complesso di *F. stricta*. Tutti i campioni di *F. marginata* sono risultati invece diploidi in accordo con quanto riportato in letteratura (Ardenghi et al. 2024).

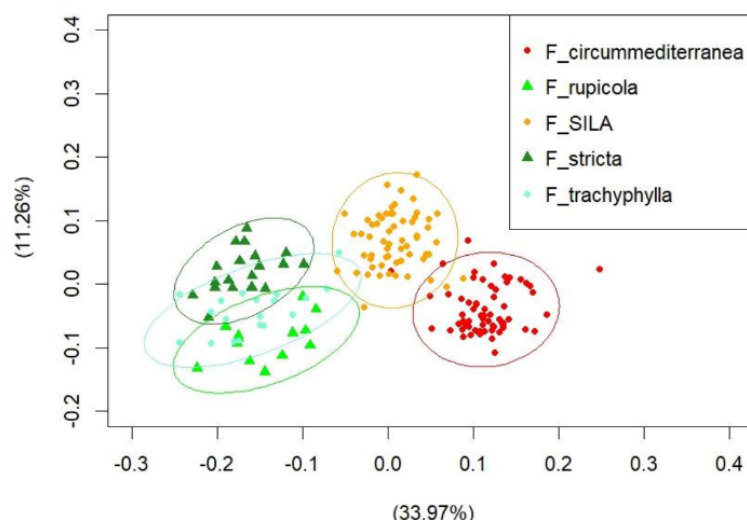


Fig. 2: Scatterplot della PCoA

Per quanto riguarda la morfometria, 35 caratteri morfologici (17 numerici continui, 15 categorici ordinali e 3 binari) sono stati selezionati come diagnostici sulla base di precedenti trattamenti (Portal 1999, Foggi et al. 2017) e studi di revisione tassonomica (Foggi et al. 1999, Foggi et al. 2012) sul genere *Festuca*. Una prima indagine esplorativa è stata effettuata tramite l'utilizzo di una Principal Coordinate Analysis (PCoA). Lo scatterplot prodotto ci ha permesso di designare tre principali gruppi morfologici: il primo composto da *F. stricta*, *F. rupicola* e *F. trachyphylla*, il secondo costituito da solo individui di *F. marginata* e il terzo di soli individui esaploidi della Sila, che formano un cluster ben distinto

collocato tra i due precedenti (Fig. 2). L'ipotesi basata sui gruppi designati dalla PCoA è stata poi testata tramite Discriminant Analysis (LDA) con ricampionamento jackknife.

I risultati fino ad ora ottenuti consentono di affermare che le popolazioni esaploidi della Sila appartengono ad un taxon a sé stante, diverso da *Festuca marginata*, ma che probabilmente si è originato a partire da questa specie per fenomeni di auto o allopoloidizzazione, come sembrerebbero suggerire i dati preliminari di analisi genomiche effettuate con la tecnica ddRADseq.

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TALK – A new species of *Festuca* L. (Poaceae) endemic to the Sila plateau in Italy.

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During a sampling campaign aimed at revising the *Festuca marginata* (Hack.) K.Richt. (= *F. circummediterranea* Patzke) group in the Mediterranean, a curious taxon belonging to the genus *Festuca* was found on the Sila plateau. Historically, specimens with similar morphology had been collected in the area by Sarfatti and identified as *Festuca ovina* L. subsp. *laevis* Hack. var. *gallica* (Hack.) St.-Yves subvar. *costei* St.-Yves ($\equiv$ *Festuca costei* (St.-Yves) Markgr.-Dann.) by Markgraf-Dannenberg. However, the specimens displayed quite an unique morphology resembling other members of the *F. marginata* group (to which *F. costei* belongs) but occasionally showed a complete sclerenchymatic ring with irregular thickness, a trait typically associated with the *Festuca stricta* Host group. Preliminary chromosome counts revealed that this taxon is hexaploid ($2n=6\times=42$), differing from the consistently diploid *F. marginata* ($2n=2\times=14$) and tetraploid *F. costei* ($2n=4\times=28$), confirming the inconsistencies that emerged from a preliminar morphological study. This distinctive combination of morphological traits and unusual ploidy level lead to further investigations using an integrated taxonomic approach. To clarify the identity of this taxon, four additional comparative taxa were selected based on shared morphological and karyological characteristics: *Festuca stricta* Host, *Festuca rupicola* Heuff., *Festuca trachyphylla* (Hack.) R.P.Murray, and *Festuca marginata* (Hack.) K. Richt. A total of 158 individuals from 25 populations across the Alps and Apennines were sampled. Of these, 47 were analyzed via flow cytometry to estimate genome size and infer ploidy levels. Additionally, morphometric analyses included 19 herbarium specimens housed at FI. Flow cytometry results confirmed that the Sila taxon is consistently hexaploid, as are other species within the *F. stricta* complex, while all *F. marginata* samples were diploid, as expected in accordance with literature. Morphometric analysis involved 35 diagnostic traits (17 continuous numerical, 15 ordinal categorical, and 3 binary) selected based on prior studies of the genus *Festuca*. An exploratory Principal Coordinate Analysis (PCoA) revealed three primary morphological groups: one comprising *F. stricta*, *F. rupicola*, and *F. trachyphylla*; another of *F. marginata* individuals; and a distinct cluster of hexaploid Sila individuals positioned between the other two groups. The groups identified via PCoA were subsequently tested using Linear Discriminant Analysis (LDA) with jackknife resampling. Additionally, ddRADseq analyses were carried out to better clarify the genetic relationships within the different taxa, revealing that despite the mixed morphological characters the new taxon from the Sila is more closely related to the *F. marginata* group rather than the *F. stricta* group. Overall, all performed analyses suggest that the hexaploid populations from Sila represent a distinct taxon separate from other similar fescues present in the Italian flora. It is likely that it originated through auto- or allopolyploidization events of other *F. marginata* group members present in the area, as suggested by the preliminary genomic analyses.

1.3 = The *Festuca valesiaca* complex in Italy: applying integrative taxonomy to a critical group.

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Festuca subgenus *Festuca*, commonly known as fine-leaved fescues, comprises a taxonomically challenging group of grasses that dominate a variety of xerophytic and alpine plant communities across Europe. These species are found usually in harsh habitats, such as xerophilic grasslands and subalpine prairies, where they often represent the cornerstone taxa of their communities. Due to convergent adaptations to drought and extreme temperatures, such as narrow leaves, dense tillering, and well-developed leaves sclerenchyma, taxa within this group often exhibit striking morphological similarity, rendering immediate taxa identification particularly difficult. As a result, fine-leaved fescues represent one of the most taxonomically problematic grass lineages in Southern Europe.

In Italy, multiple studies have addressed the taxonomy of this group over recent decades ^[1,2]; however, the *stricta/valesiaca* complex has remained largely unexamined. This complex includes nine naturally occurring taxa in the Italian Peninsula: *F. valesiaca* Schleich. ex Gaudin, *F. pseudodalmatica* Krajina, *F. stricta* Host, *F. trachyphylla* (Hack.) R.P.Murray, and *F. rupicola* Heuff., along with four endemics of the Alpine region: *F. bauzanina* (Pils) S.Arndt subsp. *bauzanina*, *F. bauzanina* subsp. *rhaetica* S.Arndt, *F. guinochetii* (Bidault) S. Arndt, and *F. ticinensis* (Markgr.-Dann.) Markgr.-Dann. Species of this group can be identified by the presence of three major sclerenchyma strands in the tiller leaf cross-section—diagnostic for species such as *F. valesiaca* and *F. rupicola*—which in some taxa may converge to form a partially closed (*F. trachyphylla*) or complete thickened (*F. stricta*) sclerenchyma ring (Fig. 1).

The present study aims to revise the *stricta/valesiaca* complex using an integrative taxonomic approach, combining morphological, anatomical, ploidy and phylogenomic data to further clarify uncertain species boundaries. Both preliminary molecular and morphological data reveal considerable gaps in the current knowledge of the group. Flow cytometry on freshly collected populations has identified significant discrepancies between observed and expected ploidy levels, while morphology shows different and defined clusters of individuals within populations that were considered to belong to the same species. This suggests recurrent misidentification across herbarium and field samples, particularly for what regards records from the Apennines, where multiple taxa appear to have been consistently confused or go unseen (e.g. the newly described *Festuca silana* Ardenghi, Pallanza & Foggi has gone unnoticed for decades ^[3]).

Our findings highlight the urgency of a comprehensive taxonomic reassessment of this group and underscore the importance of combining classical taxonomy with cytogenetic and molecular tools. Accurate identification of these taxa is essential for understanding their ecological roles, biogeographic patterns, and for informing conservation strategies in some of the most threatened habitats of Southern Europe.

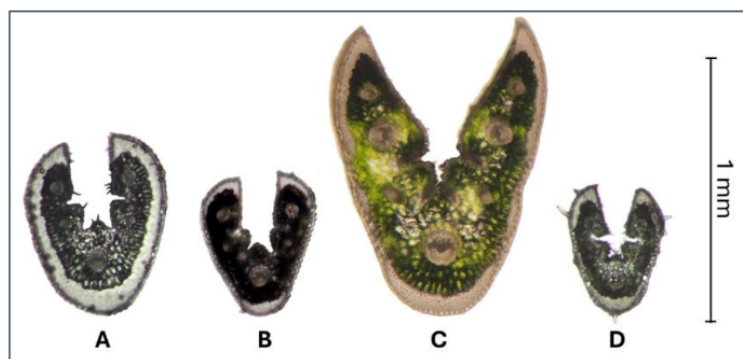


Fig. 1: Leaf cross-sections for different taxa of the stricta-valesiaca group: A – *F. stricta* Host; B – *F. rupicola* Heuff.; C – *F. guinochetii* (Bidault) S. Arndt; D – *F. valesiaca* Schleich. ex Gaudin

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10 TEACHING AND TUTORSHIPS

During the PhD I partake in the following teaching and tutoring activities:

Teaching and tutorship:

- Lecturer for the Systematic Botany course (bachelor's degree in environmental sciences and technologies) during the academic years 2023-2024, 2024-2025.
- Lecturer for the Systematic Botany pre-course (master's degree in Agrifood Sustainability) for the academic years 2023-2024, 2024-2025
- Tutor for the Botany course (bachelor's degree in biology) during the academic years 2022-2023, 2023-2024, 2024-2025.
- Tutor for the Systematic Botany course (bachelor's degree in environmental sciences and technologies) during the academic years 2022-2023, 2023-2024, 2024-2025.

Theses tutorship:

- Alessia Ruzzoli, Bachelor's degree (L32). "Approfondimento mediante approccio tassonomico integrato del genere *Festuca* (Poaceae) in Abruzzo". September 2024
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