A new association with *Patzkea paniculata* on serpentine substrates at low elevations in the western Alps (Italy)

Francesca Colozza¹*, Elisabetta Fenoglio¹*, Davide Barberis¹, Michele Lonati¹

¹ Department of Agriculture, Forest and Food Sciences. University of Torino. Largo Paolo Braccini 2, Grugliasco (TO), I-10095, Italy

Corresponding author: Davide Barberis (d.barberis@unito.it)

Subject editor: Simonetta Bagella ✦ Received 20 June 2022 ✦ Accepted 21 August 2022 ✦ Published 22 November 2022

Abstract

*Patzkea paniculata* usually dominates grassland communities in the subalpine and alpine belts. The analysis of a unique vegetation community found at low altitudes growing on serpentinitic substrates in the North-Western Alps (Italy) dominated by *P. paniculata*, is hereby presented. These communities are substantially different from already described alpine communities, framed in the alliance *Festucion variae* (class *Caricetea curvulae*, order *Festucetalia spadiceae*) and typical of higher elevations. Syntaxonomic and ecological investigations were performed to provide a correct phytosociological framework for these grasslands. The new association *Potentillo albae-Patzkeetum paniculatae* ass. nova is here described, with two different variants, one co-dominated by *Bromopsis erecta* and the second with co-dominance of *Molinia arundinacea*. It is a secondary grassland of arid environments attributable to the alliance *Bromion erecti* (class *Festuco valesiacae-Brometea erecti*), and characterized by the presence of numerous species, both rare and typical of serpentinitic substrates.

Keywords

*Bromion*, grasslands, phytosociology, *Potentilla alba*, *Molinia arundinacea*, Alps

Introduction

*Patzkea paniculata* is a gregarious grass species scattered in the main mountain ranges of southern Europe, as far as Morocco (Vittoz et al. 2005). *Patzkea paniculata* grasslands are found in rather restricted areas (Sburlino et al. 1996) and are characterized by high biodiversity (Garde 1996), indeed they are included in the habitat 6150 (Siliaceous alpine and boreal grasslands) according to European Natura 2000 habitat classification (Biondi et al. 2009).

Four associations are actually described in the Alps within the class *Caricetea curvulae* (Lonati and Siniscalco 2012): *Centaureo uniflorae-Festucetum spadiceae* Guinochet 1938, widespread from Ligurian to Graian Alps (south-western Alps), *Junipero nanae-Festucetum spadiceae* Négre 1950, limited in the Meje-Ecrins-Pelvoux Massif and in Valle d’Aosta (western Alps), *Polygalo chaenobuxi-Festucetum paniculatae* (Vittoz, Selldorf, Eggemberg & Mair) Lonati & Siniscalco 2006, in the Pennine and Lepontine Alps (western Alps), and *Hypochaerido uniflorae-Festucetum paniculatae* Hartl ex Theurillat 1989, in the eastern Alps.

These grasslands are apparently indifferent to the sub-strate, on soils with an acid to weakly acid reaction and prefer steep southern-facing slopes (Sburlino et al. 1996). The origin of these stands, mainly occurring in the upper mountain and subalpine belt, seems to be in most cases derived from the cutting down of the natural woody cover. Only in a few cases they can be considered of natural origin: at higher altitudes, where they constitute a stage of recolonisation after the glaciation (Négre 1950), as colonizing formations of stony ground (Barbero 1970), in the lower alpine belt (Guinochet 1938) and in areas subject to avalanche disturbance (Braun-Blanquet 1972).

*Patzkea paniculata* at low altitudes tend to be a subordinate species to other more competitive ones (Vittoz et al. 2005), and has been found at exceptionally low altitudes (500-800 m a.s.l.) in the outer Cottian Alps by Mon-
Based on the information by Mondino, several new coenosis dominated by *P. paniculata* were found in the colline and montane belts on shallow soils on serpentine substrates, which probably act as a selective agent on the flora (Mota et al. 2017). The aim of this work was to describe and characterize these low altitude *P. paniculata* dominated communities, contributing to the knowledge and phytosociological characterization of this species on Italian territory.

**Study area**

The investigated grasslands are located in the outer Cottian and Graian Alps of Piemonte Region (North-West Italy) at an altitude of 450–1200 m a.s.l. (Fig. 1). Some areas fall in protected areas: Zone of Special Conservation “Laghi di Avigliana” (IT1110007) and Natural Park of Monte San Giorgio.

The substrate is characterized by serpentinites (Piana et al. 2017a, 2017b), a metamorphic rock predominantly composed of magnesium and iron silicates, highly resistant to alteration (D’Amico et al. 2014). These characteristics affect the soil chemical and physical properties leading to stress or even toxicity in plant species that are not adapted to the substrate, indeed several endemic species exist on serpentinites (Kruckeberg 1984). The resistance to alteration of the parent rock and the steepness of the slopes determines the formation of shallow, scarcely evolved soils, subject to sheet erosion. Moreover, the centuries-long anthropic exploitation, especially through grazing, has favored the erosive processes leading to deterioration of the already poor soils (Mondino 1975, 1997).

Two weather stations represent the studied area (Avigliana and Lanzo). The average annual temperatures range from 11.2 °C to 12.2 °C (Table 1). Rainfall ranges from 871.1 mm to 1334.2 mm (Table 1; ARPA Piemonte 2021).

As reported in Figure 2, Avigliana, in the Cottian Alps, shows a drought period during summer. Contrarily, Lanzo does not show any drought period.

**Methods**

In spring 2021, 15 phytosociological surveys were carried out according to the phytosociological method in grasslands dominated by *P. paniculata*, using the abundance-dominance values proposed by Braun-Blanquet (1928) and Westhoff and Van der Maarel (1978). These relevés were localized in four sites, three were in the Cottian Alps and one in the Graian Alps. The localization of relevés is reported in Appendix I. While the minimum area for surveys on grassland ecosystems is 16 m$^2$ (Chytrý and Otýpková 2003), we used a slightly higher size, 25 m$^2$, to better detect the variability of our grasslands.

Abundance-dominance values were transformed into numerical values according to van der Maarel (1979), which were used to classify the 15 vegetation surveys by hierarchical cluster analysis (option for clustering: UPGMA; resemblance coefficient: Bray-Curtis coefficient). The results of the analysis were compared with the syntaxonomical classification (classes, orders, alliances and associations) indicated by Mucina et al. (2016), Biondi et al. (2014), Theurillat et al. (1995), Royer and Ferrez (2020), for the attribution of the characteristic and differential communities.

---

**Figure 1.** Map of the study area. Location of the study area inside the Piemonte Region and Italy. Distribution of the studied communities is defined by colored polygons; the blue area represents the Graian populations, while the red area represents the Cottian populations.
species. This allowed the attribution of the studied grasslands to the proper syntaxa. In the final table, the relative frequencies of occurrence of each species in the surveys indicated by I to V were calculated according to Poldini and Sburlino (2005) (I 0-20%, II 21-40%, III 41-60%, IV 61-80%, V 81-100%).

For each survey the ecological indicator values for temperature (T), continentality (K), light (L), moisture (F), reaction (R), nutrients (N), humus (H), aeration (D) from Landolt et al. (2010) were calculated with a mean weighted with the species cover percentages attributed to each classes according to Tasser and Tappeiner (2004) (+ = 0.3%; 1 = 2.8%; 2a = 10.0%; 2b = 20.5%; 3 = 38.0%). The weighted average values of the indices were used to perform a Principal Component Analysis, in order to highlight ecological differences between relevés.

All statistical analyses were performed using the software Past 4.04 (Hammer et al. 2001). The species nomenclature follows Bartolucci et al. (2018) and subsequent updates. The phytosociological nomenclature follows the Vegetation Prodrome of Italy (Biondi et al. 2014) and the rules of the fourth edition of the International Code of Phytosociological Nomenclature (Theurillat et al. 2020).

### Results

According to the 15 vegetation surveys, the stands examined have fallen into the class Festuco valesiacae-Bromea erecti Br.-Bl. & Tuxen ex Br.-Bl., 1949. This syntaxonomical classification has been identified on the basis of the presence of 18 characteristic and differential species of this class and its subordinate units (Table 2). Despite the dominance of *P. paniculata*, no other species characteristic of the class *Caricetea curvulae* Br.-Bl., 1948, order Festucetalia spadiceae Barbero, 1970 em. Grabherr 1993 and specifically of the alliance *Festucion varie* Guinochet, 1938 were present, confirming that these swards are different from typical *P. paniculata* grasslands located in the subalpine and alpine belt. Thus, the coenosis have been placed in the order *Brometalia erecti* Koch, 1926, suborder *Leucanthemo vulgaris-Bromenalia erecti* Biondi, Ballelli, Allegrezza & Zuccarello, 1995, alliance *Bromion erecti* Koch, 1926, due to the number and cover of characteristic species of these two subordinate syntaxa (Theurillat 1995, 2020; Royer and Ferrez 2020; Terzi 2016).

According to the floristic list identified by the phytosociological surveys (Table 2), it has not been possible to

---

**Table 1.** Average climatic values. Annual values of rainy days, rainfall and temperature for the period 1991-2020 in the weather stations of Avigliana, and Lanzo.

| Altitude (m a.s.l.) | Rainy days (n year⁻¹) | Annual precipitation (mm year⁻¹) | Average annual temperature (°C) |
|---------------------|-----------------------|---------------------------------|-------------------------------|
| Avigliana (Cottian Alps) | 340 | 73.3 | 871.1 | 12.2 |
| Lanzo (Graian Alps) | 580 | 87.0 | 1334.2 | 11.2 |

---

**Figure 2.** Climograph of the weather stations. a) Avigliana (Cottian Alps) and b) Lanzo (Graian Alps). The red line indicates monthly average temperature (°C). Precipitations (mm) are indicated by the blue solid line (20 mm = 10 °C). The intersection of the dashed blue line (30 mm = 10 °C) with the temperature line (red) indicates the drought period, according to Walter and Lieth (1960). The average values refer to the 30-year period from 1991 to 2020.
Table 2. Phytosociological table.

| Number | 1  | 2  | 3  | 4  | 5  | 6  | 7* | 8  | 9  | 10 | 11 | 12 | 13 | 14 | 15 |
|--------|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Code   | LAN10 | LAN11 | LAN12 | LAN13 | LAN14 | LAN15 | VAL01 | VAL02 | VAL03 | VAL04 | AVDP1 | AVDP2 | PO10 | PO11 | PO12 |
| Elevation (m a.s.l.) | 1172 | 1162 | 1113 | 1105 | 1122 | 1084 | 841 | 945 | 882 | 903 | 454 | 931 | 825 | 823 | 817 |
| Aspect (°N) | 175 | 195 | 180 | 200 | 150 | 180 | 300 | 320 | 315 | 220 | 300 | 0 | 40 | 135 | 100 |
| Slope (°) | 21 | 18 | 15 | 20 | 20 | 18 | 45 | 30 | 25 | 45 | 35 | 15 | 20 | 15 | 10 |
| Area (m²) | 25 | 23 | 25 | 23 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 |
| Vegetation cover (%) | 90 | 95 | 90 | 90 | 90 | 65 | 65 | 74 | 75 | 80 | 83 | 90 | 90 | 85 | 85 |

**Characteristic species of Potentilla albae-Patrzkeetum paniculatae ass. nova**

- *Carlina acaulis*
- *Trifolium montanum*
- *Vicia cracca*
- *Prunella grandiflora*
- *Euphorbia verrucosa*
- *Carthana acutis*
- *Carex montana*
- *Leontodon hispidus*
- *Plantago lanceolata*
- *Campanula glomerata*
- *Dactylis glomerata*
- *Campanula gaudinii*
- *Brachypodium rupestre*
- *Teucrium chamaedrys*
- *Potentilla verna*

**Characteristic species of Bromopsis erecta**

- *Hippocrepis comosa*
- *Carex caraphylla*
- *Helianthemum nummularium subsp. nummularium*
- *Knautia arvensis*
- *Stachys rectae*
- *Pentanema hirtum*
- *Pentanema angustifolia*
- *Pentanema minus*
- *Pentanema conocarpae*
- *Pentanema filipendulae*
- *Pentanema sanguineae*
- *Pentanema sileneae*
- *Pentanema veronicae*

**Characteristic species of Festuco valesiacae-Brometea erecti and subordinate unities**

- *Teucrium chamaedrys*
- *Hachypodium rupestre*
- *Centaraea scabiosa subsp. gaudini*
- *Dianthus gaudinii*
- *Dianthus seguierii*
- *Centaraea scabiosa*
- *Pulsatilla vulgaris*
- *Pulsatilla saxifragae*
- *Phleum phleoides*
- *Veronica spicata*
- *Euphorbia cyperi*
- *Filiendula vulgaris*

**Companion species**

- *Geranium sanguineum*
- *Hypericum perforatum*
- *Silene nutans*
- *Veronica angustifolia*
- *Thalictrum minus*
- *Teucrium scorodonum*
Table 2. Ingressive species of Rhamno catharticae–Prunetia spinose

| Plant species                      | Invasive species of Odontarrhena argentea | Invasive species of Cerastium arvense | Invasive species of Poa pratensis | Invasive species of Takhtajaniantha austriaca | Invasive species of Knautia mollis | Invasive species of Luzula campestris | Invasive species of Scrophularia canina | Invasive species of Genista germanica | Invasive species of Festuca rubra | Invasive species of Phyteuma italicum | Invasive species of Noccaea praecox | Invasive species of Avenella flexuosa | Invasive species of Carex ornithopoda | Invasive species of Gentiana pneumonanthe | Invasive species of Pulmonaria australis | Invasive species of Potentilla erecta | Invasive species of Leucanthemum heterophyllum | Invasive species of Pulmonaria australis | Invasive species of Gentiana pneumonanthe | Invasive species of Fumana procumbens | Invasive species of Carex orthotricha | Invasive species of Asplenellum flexuosum | Invasive species of Noccaea praecox | Invasive species of Phyteuma italicum | Invasive species of Festuca rubra | Invasive species of Genista germanica | Invasive species of Scrophularia canina | Invasive species of Luzula campestris | Invasive species of Muscari comosum | Invasive species of Knautia mollis | Invasive species of Pileum hisaratum | Invasive species of Takkhojahainthia austriaca | Invasive species of Pea pratensis | Invasive species of Cerastium arvense | Invasive species of Odontarrhena argentea | Invasive species of Pulsatilla montana |
|----------------------------------|--------------------------------------------|--------------------------------------|----------------------------------|----------------------------------------------|----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|
| Hieracium umbellatum agg.        | .                                          | .                                    |                                  | .                                            | .                                | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 |
| Trifolium rubens                 | .                                          | .                                    | .                                | .                                            | .                                | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 |
| Melampyrum cristatum            | .                                          | .                                    | .                                | .                                            | .                                | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 |
| Galium verum                    | .                                          | .                                    | .                                | .                                            | .                                | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 |
| Polygonum odoratum               | .                                          | .                                    | .                                | .                                            | .                                | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 |
| **Invasive species of Rhamno catharticae–Prunetia spinose** |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |
| Rosa canina                     | .                                          | .                                    | .                                | .                                            | .                                | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 |
| Rubus fruticosus aggr.           | .                                          | .                                    | .                                | .                                            | .                                | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 |
| Prunus spinosa                  | .                                          | .                                    | .                                | .                                            | .                                | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 |
| Crataegus monogyna               | .                                          | .                                    | .                                | .                                            | .                                | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 |
| Ligustrum vulgare                | .                                          | .                                    | .                                | .                                            | .                                | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 |
| Acer campestre                  | .                                          | .                                    | .                                | .                                            | .                                | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 |
| Rhamnus cathartica               | .                                          | .                                    | .                                | .                                            | .                                | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 | .                                 |
| **Other companion species**      |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |                                                     |
place the coenosis object of the study in an association already described. The present work proposes the new association Potentillo albae-Patzkeetum paniculatae ass. nova (holotypus: rel. n. 7, Table 2). Characteristic species of association are: P. paniculata, Potentilla alba, Vincetoxicum hirundinaria, Campanula bertolae, Oreoselinum nigrum, Pentanema hirtum, and Cervaria rivini.

The dendrogram resulting from the cluster analysis (Fig. 3) has divided the surveys into two groups, which, however, couldn’t be elevated to the rank of subassociation, due to the absence of differential species between the two groups. As shown in Table 2 the subgroup A, was characterized by the presence of Molinia arundinacea, with high cover values, comparable to those of P. paniculata. Thus, a variant (Poldini and Sburlino 2005) with M. arundinacea (group A) has been proposed within Potentillo albae-Patzkeetum paniculatae ass. nova. The other group, B, formed by the surveys 7-15, could for the same reason be considered a variant with Bromopsis erecta.

The Principal Component Analysis (PCA) has highlighted the ecological differences between the two defined groups, in which most of the variance (62.56%) could be explained by the first component. The Landolt indicator values (Landolt et al. 2010) that appear to be of greatest importance in differencing the groups were F and H, positively correlated with component 1, and K and D, negatively correlated with the same component (Fig. 4).

A high number of ingressive species of the classes Trifolio medii-Geranietea sanguinei Müller, 1962 and Rhamno catharticae-Prunetea spinosae Rivas Goday & Borja ex Tüxen, 1962, and their subordinate units, with 15 and 7 species, respectively, were observed.

Discussion

Physiognomy and structure

The communities are distributed in patches into a matrix of oak forests on serpentine rocks. These grasslands are rich in perennial herbaceous species, with P. paniculata as the dominant one even if never exceeds 50% cover in the surveys (Table 2).

Several shrub species tend to encroach these grasslands, primarily Rosa canina, Rubus fruticosus aggr. and Prunus spinosa.

Syntaxonomy

Clear ecological affinities exist between coenosis dominated by P. paniculata in the subalpine and alpine belts and those described in the present work: they are both located on south-facing steep slopes. In spite of the dominance of P. paniculata, comparable to the cover observed in the high-elevation stands usually attributed to the Festucion variæ alliance (order Festucetalia spadiceae, class Cariceta curvulae), the absence of other species characteristic of these syntaxa led to the exclusion of this attribution. The species that characterize the study area, indeed, make them clearly more similar to the arid grasslands of lower altitudes of the class Festuco valesiacae-Bromea erecti. In particular, these stands can be placed in the order Brometalia erecti, suborder Leucanthemo vulgar-
is-Bromenalia erecti, alliance Bromion erecti. At high elevations, the stands dominated by *P. paniculata* are typically placed in *Caricetalia curvulae*, but some exceptions exist e.g. in the Lucanian Apennines, where some *P. paniculata* dominated coenosis are placed in the class *Festuco valesiacae-Brometea erecti* and more precisely in the alliance *Phleo ambiguui-Bromion erecti* (Biondi, Ballelli, Allegrezza & Zucarell o ex Biondi & Gal denzi, 2012, of Scor zon re-Chrysopogonetalia). The uncommon ± 3.6 species in Group B). Additionally, some species are high plant diversity (36 ± 2.8 species in Group A and 40 ± 3.6 species in Group B). While high abundance of *P. paniculata* aggr., *Pr unella grandiflora* (Ngéré 1950; Vitt oz et al. 2005; Lon ati and Siniscalco 2006).

The coenosis described in the present study have a unique species composition compared to the other associations of the alliance *Bromion erecti*, primarily due to the high abundance of *P. paniculata*, a gregarious species that tends to be dominant when present (Pignatti et al. 2017-2019). Alongside it, *B. erecta* and *Brachypodium rupestre* are often present, in most cases with high cover values, and are characteristic of *Bromion erecti* and *Fes tuco valesiaca-Brometea erecti*, respectively. The presence of these two species, defined by Mondino et al. (2007) as initiators of *Bromion* communities, is considered consistent with membership of the alliance and its higher-ranking syntaxa.

### Diagnostic species

Among the characteristic species of the new association, *P. alba* grows in arid grasslands and deciduous scrublands, in hilly and mountainous areas. It can be found in the *Brometalia erecti* communities but is also frequent in the *Quercetalia pubescenti-petraeae* Klika, 1933 (Pignatti et al. 2017-2019). According to Oberdorfer (1983) it is also characteristic of the association *Potentillo albae-Querc etum petraeae* Libbert, 1933, described for Central Europe, and reported for the Piemonte Region (NW-Italy) on ultrabasic soils in the pre-Alpine belt (IPLA 2020). *Campanula bertolae* is endemic to the ophiolitic areas of the Western Piedmontese Alps (Pignatti et al. 2017-2019, Fenaroli et al. 2013). The remaining characteristic species, *V. hirundinaria*, *O. nig rum*, *P. hirtum*, and *C. rivini*, are invasive species from the class *Trifolio medi-Geranietae sanguinei*, giving a good representation of the patchy landscape of open and woody areas typical of these semi-natural grasslands.

Like most of the *Bromion* communities (Calaciura and Spinelli 2008), these *P. paniculata* grasslands show a high plant diversity (36 ± 2.8 species in Group A and 40 ± 3.6 species in Group B). Additionally, some species are interesting and worthy of conservation. The uncommon *Daphne cneorum* is usually found on serpentinite soils, while *Odontarrhena argentea* is considered endemic to serpentine (Mondino et al. 2007; D’Amico et al. 2014).

Other rare species found in the surveys are *Pulsatilla montana* and *Gentiana pneumonanthe* both protected at regional level and the latter also vulnerable according to the IUCN list.

### Synecology and synchorology

Between the two groups identified through the cluster analysis, Group A, characterized by the co-dominance of *M. arundinacea*, was observed in the Graian Alps, at an altitude between 1050 and 1200 m a.s.l. This variant has high values of freshness, due to the annual rainfall (Table 1, Fig. 2), and high humus content, probably linked to deeper soils. In addition to *M. arundinacea*, other species indicative of mesophilic conditions confirm the ecology of this variant: *Anemonoides nemorosa*, *Calluna vulgaris*, *G. pneumonanthe*, *Potentilla erecta*, *Serratula tinctoria*, etc. As indicated by Pignatti et al. (2017-2019), *M. arun dinacea* can also colonize grasslands belonging to *Bromo* and is considered a pyrophytic species (Stampelli et al. 1994). It is also considered a stress-tolerant competitor adapted to nutrient-poor soils (Taylor et al. 2001): this advantage in competition seems to be due to high clonal growth and adaptation to low phosphorus concentrations (El-Kahloun et al. 2006; Øien and Moen 2001; Güsew ell and Koerselman 2002). Indeed, as reported by Mota et al., (2017), low phosphorus concentration is a selective factor for vegetation evolution on serpentine rocks. In addition, early in the growing season, *M. arundinacea* can store nutrients inside its roots (Pfadenhauer and Twennhöven 1986; El-Kahloun et al. 2000). These characteristics could be the reasons for its strong competitiveness also on these limiting substrates.

The variant with *B. erecta* (group B) is localized in the Cottian Alps at a lower altitudinal range between 450 and 950 m a.s.l., characterized by a drier climate, highlighted by the summer drought period (Fig. 2). This variant was observed on shallow, poorly structured soils, on very steep slopes, as confirmed by the graph resulting from the PCA (Fig. 4). *Patzkea paniculata* and *B. erecta* are associated with a high cover also of *B. rupestre*. This variant differs from the previous one in the lack of *M. arundinacea* and of other mesophilic species.

### Syndynamics

*Potentillo albae-Patztkeetum paniculatae* ass. nova is dynamically linked to the vegetation of the downy oak forests (*Quercion pubescenti-petraeae*), forming an alternating woodlands/grasslands pattern. This balanced landscape is maintained by disturbances like grazing, that keep *P. paniculata* dominated grasslands open. Indeed, in a state of complete abandonment these communities could be limited to the driest and steepest rocky outcrops, where they could be identified as primary. Although the evolution of these secondary grasslands into scrublands and eventual-
Conclusions

The new association Potentillo albae-Patzcketum paniculatae ass. nova describes the P. paniculata coenosis of low altitudes on serpentine substrate in North-West Italy, in the Cottian and Graian Alps. These communities are original due to the lower altitudes than the associations previously described in the Alps, in the alpine and subalpine belts. Moreover, they fall within the phytosociological class Festucotalia/Brometea, order Brometalia erecti, alliance Bromion erecti in analogy with some coenoses described for the Lucanian Apennines (Sburlino et al. 1996). Two variants were identified, one with B. erecta and one with M. arundinacea, differentiated by pedo-climatic characteristics. These communities are included in the habitat 6210 in the Natura 2000 classification (Biondi et al. 2009) and host some rare species, particularly those endemic to serpentine. They are therefore worthy of conservation. This work contributes to the knowledge of the syntaxonomy of the western Italian Alps, where further research could be performed to report and describe similar coenoses.

Syntaxonomic scheme

FESTUCO VALESIACAE-BROMETEAE ERECTI Br.-Bl. & Tuxen ex Br.-Bl., 1949
BROMETALIA ERECTI Koch, 1926
LEUCANTHEMO VULGARIS-BROMENALIA ERECTI Biondi, Ballelli, Allegrezza & Zuccarello, 1995
Bromion erecti Koch, 1926
Potentillo albae-Patzcketum paniculatae ass. nova

Author contributions

ML conceived and designed the research; FC, EF, DB, ML performed the data collection, analyzed the data and edited the manuscript.

Funding

The authors have no funding to report.

Competing interests

The authors have declared that no competing interests exist.

Bibliography

ARPA Piemonte, Banca dati meteorologica: https://www.arpa.piemonte.it
Barbero M (1970) Les pelouses orophiles acidophiles des Alpes maritimes et ligures, leur classification phytosociologique: Nardetalia strictae, Festucetalia spadiceae et Caricetalia curvatae. Ann. Fac. Sci. Marseille 43B: 173–195
Bartolucci F, Peruzzi I, Galasso G, Albano A, Alessandrini A, Ardedghi NMG, et al. (2018) An updated checklist of the vascular flora native to Italy. Plant Biosystems 152(2): 179–303. https://doi.org/10.1080/11263504.2017.1419996
Biondi E, Blasi C, Burrascano S, Casavecchia S, Copir R, Del Vico E, Galdenzi D, Gigante D, Lasen C, Spampinato G, Venanzoni R, Zivkovic L (2009) Manuale Italiano di Interpretazione degli habitat della Direttiva 92/43/CEE. SBI, MATTM, DPN. [available online at http://vnr.unipg.it/habitat/index.jsp]
Biondi E, Blasi C, Allegrezza M, Anzellotti I, Azzella MM, Carli E, et al. (2014) Plant communities of Italy: The Vegetation Prodomo. Plant Biosystems 148(4): 728–814. https://doi.org/10.1080/11263504.2014.948527
Braun-Blanquet J (1928) Pflanzensoziologie. Grundzüge der Vegetationskunde. Springer, Berlin, DE. https://doi.org/10.1007/978-3-662-02056-2
Braun-Blanquet J (1972) L’alleanza del Festucion spadiceae des Alpes sud-occidentales. Bull. Soc. Bot. Fr. 119: 591–602. https://doi.org/10.1.010/00378941.1972.10839065
Calaciura B, Spinelli O (2008). Management of Natura 2000 habitats. 6210 Semi natural dry grassland and scrubland facies on calcareous substrates (Festuco-Brometalia) (*important orchid sites). European Commission.
Chytrý M, Otyjñíková Z (2003) Plot sizes used for phytosociological sampling of European vegetation. Journal of Vegetation Science 14(4): 563–570. https://doi.org/10.1111/j.1654-1103.2003.tb02183.x

Francesca Colozza et al.: Potentillo paniculatae ass. nova communities on serpentine
D’Amico ME, Bonifacio E, Zanini E (2014) Relationships between serpentine soils and vegetation in a xeric inner-Alpine environment. Plant Soil 376: 111–128. https://doi.org/10.1007/s11104-013-1971-q

El-Kahloun M, Boeye D, Verhagen B, van Haevebroek V (2000) A comparison of the nutrient status of Molinia caerulea and neighbouring vegetation in a rich fen. Belgian Journal of Botany 133: 91–102.

Fenaroli F, Pistarino A, Peruzzi L, Cellinese N (2013) Campanulatae (Campanulaceae), a new species for northern Italy. Phytotaxa 111 (1): 27–38. https://doi.org/10.11646/phytotaxa.111.1.2

Garde L (1996) Guide pastoral des espaces naturels du sud-est de la France (250 p). Louis-Jean, Gap: CERPAM/Méthodes et Communication.

Guinichert M (1938) Études sur la végétation de l’étage alpin dans le bassin supérieur de la Tinée (Alpes Maritimes). Thèse de doctorat es sciences, Grenoble. Boc Frères & Riou, Lyon.

Güsewell S, Koerselman W (2002) Variation in nitrogen and phosphorus concentrations of wetland plants. Perspectives in Plant Ecology, Evolution and Systematics 5: 37–61. https://doi.org/10.1016/S1383-8319(00)00022

Hammer Ø, Harper DAT, Ryan PD (2001) Past: Paleontological Statistics Software Package for Education and Data Analysis. Palaeoecologia Electronica, vol. 4, issue 1, art. 4: 9pp., 178kb. http://palaeco-electronica.org/2001_1/pastissue_01.htm

Kruckeberg AR (1984) California serpentine: flora, vegetation, geology, soils and management problems. University of California Press, Berkeley.

Landolt E, Baumlér B, Erhardt A, Hegg O, Klötli F, Lämmler W, Novis M, Rudmann-Maurer K, Schweingruber FH, Theurillat JP, Urmel E, Vust M, Wohlgemuth T (2010) Flora indicative. Ecological Indicator Values and Biological Attributes of the flora of Switzerland and the Alps. Haupt Verlag Ag, Berna.

Lonati M, Siniscalco C (2006) Le praterie a Festuca paniculata (L.) Sch. et Th. (Polygalo chamaebuxis-Festucetum paniculatae ass. nova) delle Alpi Pennine (Piemonte, Italia). Fitosociologia 43 (1): 55–66

Lonati M, Siniscalco C (2012) A redefinition of geographic boundaries between Festuca paniculata (L.) Schinz & Thell. associations in the western Alps. Acta Botanica Gallica: Botany letters 159 (1): 109–119. https://doi.org/10.1080/12558078.2012.671658

Mondino GP (1975) La vegetazione del piano collinare e montano del Pinerolese (Alpi Cozie, Piemonte). Allionia 20: 121.

Mondino GP (1997) Flora e vegetazione del Monte S. Giorgio (Piossasco-Torino), Riv. Piem. St. Nat. 18: 57–87.

Mondino GP (2007) Flora e Vegetazione del Piemonte. L’artistica Editrice, Savigliano (CN)

Mota JR, Garrido-Becerra JA, Merlo ME, Medina-Cazorla JM, Sánchez-Gómez P (2017) The Edaphism: Gypsum, Dolomite and Serpentine Flora and Vegetation. In: Loidi J. (eds) The Vegetation of the Iberian Peninsula. Plant and Vegetation, vol 13. Springer, Cham. https://doi.org/10.1007/978-3-319-54867-8_6

Mucina L, Bultmann H, Dierßen K, Theurillat JP, Raus T, Ćarni A, et al. (2016) Vegetation of Europe: hierarchical floristic classification system of vascular plant, bryophyte, lichen, and algal communities. Appl Veg Sci 19: 3-264. https://doi.org/10.1111/avsc.12257

Négrel R (1950) Contribution à l’étude phytosociologique de l’Oisans: la haute vallée du Vénéon (Massif Meije–Ecrins-Pelvoux). Phytoton 2: 23–50.

Oberdorfer E (1983) Pflanzensoziologische Excursionflora. E. Ulmer, Stuttgart.

Öien D-I, Moen A (2001) Nutrients limitation in boreal plant communities and species influenced by scything. Applied Vegetation Science 4: 197–206. https://doi.org/10.1111/j.1654-109X.2001.tb00488.x

Pfadenhauer J & Twenhouven FL (1986) Nährstoffökologie von Molinia caerulea und Carex acutiformis auf baumfreien Niedermoorflächen des Alpenvorlandes. Flora 178: 157–166. https://doi.org/10.1016/S0367-2530(71)31487-1

Piana F, Fioraso G, Andrea I, Mosca P, D’Atri AR, Barale L, Falletti P, Monegato G, Morelli M, Tallone S, Vigna B (2017a) Geology of Piemonte Region (NW Italy, Alps–Appennines junction zone). Journal of Maps 13(2): 395–405. https://doi.org/10.1007/s11104-017-1361218

Piana F, Barale L, Compagnoni R, D’Atri AR, Fioraso G, Irace A, Mosca P, Tallone S, Monegato G, Morelli M, (2017b) Geological Map of Piemonte region at 1: 250,000 scale, Explanatory Notes. Memorie dell’Accademia delle Scienze di Torino, Serie V, Cl. Sci. Fis. 41:2–148, ISSN: 1120–1630

Pignatti S, Guarino R, La Rosa M (2017–2019) Flora d’Italia 2° Edizione. Edagricole, Edizioni agricole di New Business Media.

Poldini L, Sbrulino G (2005) Terminologia fitosociologica essenziale. Fitosociologia vol. 42 (1): 57–69

Regione Piemonte (2021) Piano regionale per la programmazione delle attività di previsione, prevenzione e lotta attiva contro gli incendi boschivi 2021–2025.

Royer JM, Ferrez Y (2020) Contribution au Prodrome des végétations de France: les Festuco valesiacae-Brometea erecti BraunBlanq. & Tüxen ex Klika & Hadač 1944. Documents phytosociologiques, 3e série, 13, à paraître.

Sbrulino G, Buffa G, Ghirelli L (1996) L’analisi corologica nell’interpretazione sintassonomiche: L’esempio delle praterie a Festuca paniculata (L.) Sch. et Th. Giornale Botanico Italiano, 130(1): 236–247. https://doi.org/10.1080/1126350690439530

Stampfli A, Guggisberg F, Berli S, Pestalozzi H (1994) The abandoned Festuca valesiacae-Brometea erecti community composis. Ecological Modelling 78: 59–78

Tasser E, Tappeiner U (2004) New model to predict rooting in diverse plant community composition. Ecological Modelling 185 (2005): 195–211. https://doi.org/10.1016/j.ecolmodel.2004.11.024

Taylor K, Rowland AP, Jones HE (2001) Biological flora of the British Isles. Molinia caerulea (L.) Moench. Journal of Ecology 89: 126–144. https://doi.org/10.1046/j.1463-7245.2001.00534.x

Terzi M, Di Petro R, Theurillat JP (2016) Nomenclature of the class Festuco-Brometea in Italy and remarks on the interpretation of articles 1 and 2b ICPN, Botany Letters 163(3): 307-319. https://doi.org/10.1080/17445647.2016.1201692

Theurillat JP, Aeschimann D, Kupfer P, Schipcher R (1995) The higher vegetation units of the Alps. Colloques et Congrès Internationaux de Phytosociologie 23: 189–239

Theurillat JP, Willner W, Fernández-González F, Bultmann H, Ćarni A, Gigante D, Mucina L, Weber H (2020) International Code of Phytosociological Nomenclature. 4th edition. Applied Vegetation Science 23:1–40. https://doi.org/10.1111/avsc.12491

Van der Maarel E (1979) Transformation of cover-abundance values in phytosociology and its effects on community similarity. Vegetatio 39: 97–114. https://doi.org/10.1007/BF00052021
Appendixes

Appendix I-Date and site of the phytosociological relevés

Tab 2 - Rel 01: LAN15, Lanzo Torinese (TO), 10/06/2021, 7°28'28.308''E, 45°14'26.2428''N; Rel 02: LAN10, Lanzo Torinese (TO), 10/06/2021, 7°28'25.3604''E, 45°14'27.6144''N; Rel 03: LAN12, Lanzo Torinese (TO), 10/06/2021, 7°29'1.3236''E, 45°14'23.1504''N; Rel 04: LAN14, Lanzo Torinese (TO), 10/06/2021, 7°28'51.7116''E, 45°14'22.4088''N; Rel 05: LAN11, Lanzo Torinese (TO), 10/06/2021, 7°29'4.0308''E, 45°14'22.4088''N; Rel 07: VAL02, Valglioie (TO), 07/05/2021, 7°21'2.2284''E, 45°4'31.1592''N; Rel 08: VAL05, Valglioie (TO), 07/05/2021, 7°20'55.662''E, 45°4'33.6216''N; Rel 09: VAL03, Valglioie (TO), 07/05/2021, 7°21'6.7716''E, 45°4'29.0208''N; Rel 10: VAL04, Valglioie (TO), 07/05/2021, 7°21'2.2284''E, 45°4'31.1592''N; Rel 11: AVI01, Avigliana (TO), 07/05/2021, 7°23'0.006''E, 45°4'35.76''N; Rel 12: VAL06, Valglioie (TO), 07/05/2021, 7°20'57.6276''E, 45°4'32.16''N; Rel 13: PIO07, Piosasco (TO), 21/05/2021, 7°26'53.9484''E, 44°59'50.1972''N; Rel 14: PIO08, Piosasco (TO), 21/05/2021, 7°26'54.2436''E, 44°59'49.4232''N; Rel 15: PIO09, Piosasco (TO), 21/05/2021, 7°26'54.978''E, 44°59'49.3044''N.

Appendix II-Sporadic species

Tab 2 - Rel 1: Convallaria majalis (1), Cytisus hirsutus (1), Melittis melissophyllum (1), Polygaloides chamaebuxus (1); Rel 2: Gentiana acaulis (1), Narcissus poëticus (1), Acer pseudoplatanus (+); Rel 4: Succisa pratensis (1); Rel 8: Poa chaixii (2a), Pinus sylvestris (1); Rel 9: Jacobaea vulgaris (+); Rel 10: Agrostis capillaris (1), Anthoxanthum odoratum (1), Leucanthemum adustum (1), Prunus mahaleb (+); Rel 11: Aristolochia pallida (+), Celtis australis (+), Centaurea valesiaca (+), Centaurium erythraea (+), Dioscorea communis (+), Erigeron annuus (+), Hedera helix (+), Pentanema spiraeifolium (+), Taraxacum officinale agg. (+); Rel 12: Ornithogalum kochii subsp. monticola (+), Petrosedum montanum (+), Vicia sativa (+); Rel 13: Erythronium dens-canis (+), Fallopia convolvulus (+), Geranium columbinum (+), Hylotelephium maximum (+), Saponaria ocymoides (1), Armeria arenaria (+).