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

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## 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 (Siliceous 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 chamaebuxi-Festucetum paniculatae* (Vittoz, Selldorf, Eggemberg & Maire) 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 substrate, 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-

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dino (1975, 1997). 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

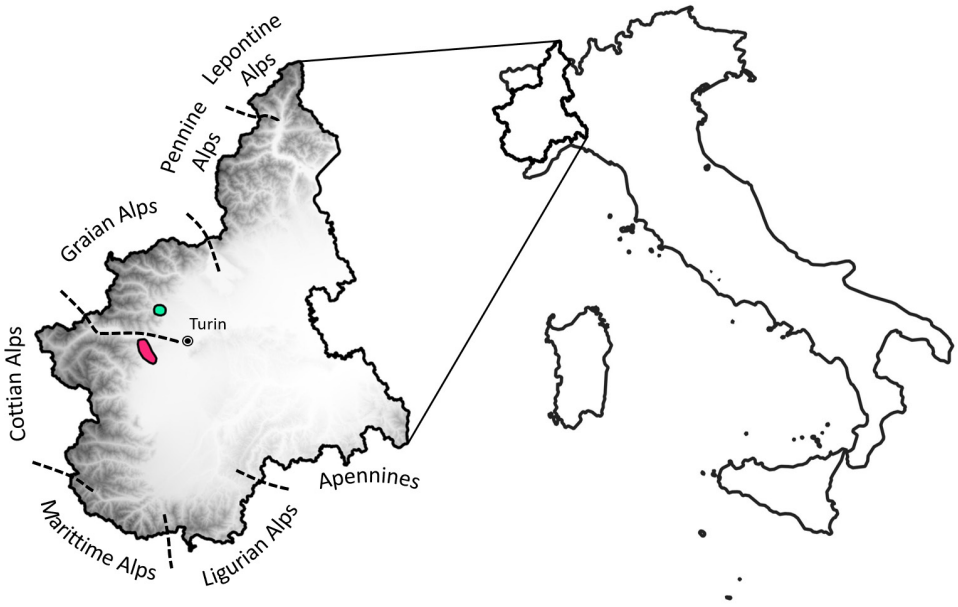


**Figure 1.** Map of the study area. Location of the study area inside the Piemonte Region and Italy. Distribution of the studied communities is defined by colored polygons; the blue area represents the Graian populations, while the red area represents the Cottian populations.

**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 |

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-Brometea 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

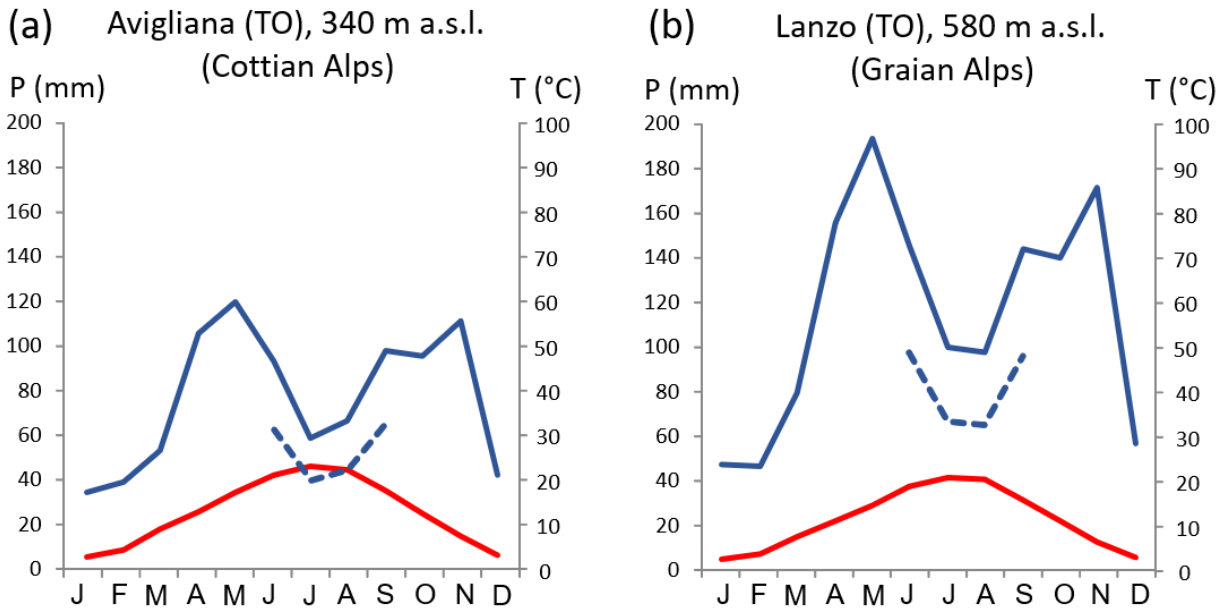


**Figure 2.** Climograph of the weather stations. a) Avigliana (Cottian Alps) and b) Lanzo (Graian Alps). The red line indicates monthly average temperature (°C). Precipitations (mm) are indicated by the blue solid line (20 mm = 10 ° C). The intersection of the dashed blue line (30 mm = 10 °C) with the 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 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Variant with *Molinia arundinacea* | | | | | | Variant with *Bromopsis erecta* | | | | | | | | | |
| | Code | LAN15 | LAN10 | LAN12 | LAN14 | LAN11 | LAN13 | VAL02 | VAL05 | VAL03 | VAL04 | AVI01 | VAL06 | PIO07 | PIO08 | PIO09 | |
| | 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 (°) | 2 | 18 | 15 | 20 | 20 | 18 | 45 | 30 | 25 | 45 | 35 | 15 | 20 | 15 | 10 | |
| | Area ($m^2$) | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | |
| | Vegetation cover (%) | 90 | 95 | 90 | 90 | 95 | 90 | 65 | 65 | 74 | 75 | 80 | 83 | 90 | 90 | 85 | |
| **Characteristic species of *Potentillo albae-Patzkeetum paniculatae* ass. nova** | | | | | | | | | | | | | | | | | |
| | *Patzkea paniculata* | 3 | 3 | 3 | 3 | 2b | 2b | 2b | 2b | 3 | 3 | 2b | 3 | 3 | 3 | 3 | V |
| | *Potentilla alba* | 1 | 1 | 1 | 1 | 1 | 1 | + | 1 | 1 | 1 | 1 | 1 | 1 | . | . | V |
| | *Vincetoxicum hirundinaria* | 1 | . | + | . | + | + | . | . | . | + | 1 | . | 1 | + | + | III |
| | *Campanula bertolae* | + | 1 | + | . | 1 | 1 | + | + | + | 1 | . | . | . | + | . | III |
| | *Oreoselinum nigrum* | + | + | + | 1 | 1 | 1 | 1 | . | . | . | . | . | . | + | 1 | III |
| | *Pentanema hirtum* | . | 1 | 1 | . | 1 | 1 | + | . | . | . | 1 | . | 1 | 1 | 1 | III |
| | *Cervaria rivini* | . | 1 | . | + | + | + | 1 | . | + | + | 1 | . | . | 1 | . | III |
| **Characteristic (c) and differential (d) species of *Bromion erecti* (BR) and *Leucanthemo vulgaris-Bromenalia erecti* (BE)** | | | | | | | | | | | | | | | | | |
| dBE | *Lotus corniculatus* | . | + | 1 | . | + | + | . | . | + | + | + | + | + | + | + | IV |
| cBE | *Anthericum liliago* | . | 1 | 1 | 1 | 1 | 1 | . | . | . | . | 1 | . | . | . | . | II |
| dBE | *Achillea millefolium* | . | . | . | . | . | . | . | . | + | + | . | + | 1 | + | + | II |
| dBE | *Knautia arvensis* | . | . | . | . | . | . | . | 1 | 1 | + | . | 1 | . | . | . | II |
| cBE | *Ranunculus bulbosus* | . | . | . | . | . | . | . | . | + | . | + | + | 1 | . | . | II |
| dBR | *Vicia cracca* | 1 | . | . | . | . | . | . | . | . | . | . | . | . | . | + | I |
| cBE | *Prunella grandiflora* | . | 1 | 1 | . | . | . | . | . | . | + | . | . | . | . | . | I |
| cBE | *Euphorbia verrucosa* | . | + | . | + | + | . | . | . | . | . | . | . | 1 | 1 | . | I |
| cBE | *Carlina acaulis* | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | I |
| cBE | *Carex montana* | . | + | . | . | . | . | . | . | . | . | . | . | . | . | . | I |
| cBE | *Leontodon hispidus* | . | . | . | + | . | . | . | . | . | . | . | . | . | . | . | I |
| dBE | *Plantago lanceolata* | . | . | . | . | . | . | + | . | . | . | . | . | . | + | + | I |
| cBE | *Campanula glomerata* | . | . | . | . | . | . | . | . | + | . | . | . | + | + | . | I |
| dBE | *Dactylis glomerata* | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | . | I |
| dBE | *Briza media* | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | . | I |
| cBR | *Trifolium montanum* | . | . | . | . | . | . | . | . | . | . | . | . | 1 | + | . | I |
| cBE | *Plantago media* | . | . | . | . | . | . | . | . | . | . | . | . | + | . | . | I |
| **Characteristic species of *Brometalia erecti*** | | | | | | | | | | | | | | | | | |
| | *Bromopsis erecta* | 1 | + | . | . | . | + | 2a | 2a | 2b | 2b | 2a | 1 | 2a | 2a | 2a | IV |
| | *Hippocrepis comosa* | . | 1 | 1 | . | 1 | 1 | . | 1 | 1 | . | 1 | + | 1 | + | 1 | IV |
| | *Carex caryophyllea* | . | . | 1 | + | 1 | . | 1 | + | 1 | + | 1 | + | . | . | . | III |
| | *Helianthemum nummularium subsp. nummularium* | + | . | . | . | . | . | + | . | 1 | . | + | . | . | 1 | 1 | II |
| | *Koeleria pyramidata* | 1 | . | . | . | . | + | . | . | . | . | . | . | . | 1 | . | I |
| | *Dianthus carthusianorum* | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | 1 | I |
| | *Potentilla verna* | . | . | . | . | . | . | . | . | . | . | . | . | . | + | 1 | I |
| **Characteristic species of *Festuco valesiacae-Brometea erecti* and subordinate unities** | | | | | | | | | | | | | | | | | |
| | *Teucrium chamaedrys* | 2a | 1 | 1 | . | 1 | 1 | 2a | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | V |
| | *Brachypodium rupestre* | 1 | 1 | 1 | 1 | . | 2a | 2a | 2a | 2a | 2b | + | 2b | 2a | 2a | 2a | V |
| | *Centaurea jacea* subsp. *gaudinii* | + | . | 1 | + | 1 | 1 | 1 | + | + | + | . | . | 1 | + | 1 | IV |
| | *Danthonia alpina* | 1 | 2a | 1 | . | 2a | 1 | . | . | . | . | . | . | 1 | + | 1 | III |
| | *Dianthus seguieri* | 1 | + | + | . | . | . | . | . | + | 1 | + | 1 | . | . | . | III |
| | *Centaurea scabiosa* | . | 1 | 1 | 1 | 1 | . | . | . | . | . | . | . | 1 | 1 | 1 | III |
| | *Polygala comosa* | 1 | + | + | . | . | . | . | . | . | . | . | . | . | + | + | II |
| | *Koeleria macrantha* | + | + | . | . | . | . | . | + | . | . | . | 1 | . | + | . | II |
| | *Thesium linophyllon* | . | . | . | + | . | . | . | . | . | . | . | . | + | + | 1 | II |
| | *Pilosella officinarum* | . | . | . | . | . | . | 1 | 1 | + | . | . | . | . | 1 | . | II |
| | *Cleistogenes serotina* | . | . | . | . | . | . | + | 2a | + | 1 | 1 | . | . | . | . | II |
| | *Stachys recta* | . | . | . | . | . | . | . | . | . | . | + | . | + | + | + | II |
| | *Potentilla pusilla* | . | . | . | . | . | . | . | . | 1 | . | . | . | . | . | . | I |
| | *Pimpinella saxifraga* | . | . | . | . | . | . | . | . | + | . | . | . | . | + | + | I |
| | *Phleum phleoides* | . | . | . | . | . | . | . | . | + | . | . | . | . | . | . | I |
| | *Veronica spicata* | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | + | I |
| | *Euphorbia cyparissias* | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | . | I |
| | *Filipendula vulgaris* | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | 1 | I |
| **Companion species** | | | | | | | | | | | | | | | | | |
| **Ingressive species of *Trifolio medii-Geranietea sanguinei* and subordinate units** | | | | | | | | | | | | | | | | | |
| | *Geranium sanguineum* | 1 | . | + | . | . | . | . | . | . | . | 1 | . | 1 | + | 1 | II |
| | *Hypericum perforatum* | . | . | . | . | . | . | . | . | + | + | + | + | . | + | + | II |
| | *Silene nutans* | . | . | . | . | . | . | . | . | + | . | 1 | 1 | . | + | . | II |
| | *Veronica angustifolia* | + | + | . | . | . | . | . | . | . | . | . | . | . | . | + | I |
| | *Thalictrum minus* | + | . | . | . | . | . | . | . | . | . | . | . | 1 | . | + | I |
| | *Teucrium scorodonia* | . | . | + | . | . | + | . | . | . | . | . | . | . | . | . | I |

**Table 2.** Continuation.

| Number | 1 | 2 | 3 | 4 | 5 | 6 | 7* | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Variant with *Molinia arundinacea* | | | | | | Variant with *Bromopsis erecta* | | | | | | | | | |
| Code | LAN15 | LAN10 | LAN12 | LAN14 | LAN11 | LAN13 | VAL02 | VAL05 | VAL03 | VAL04 | AVI01 | VAL06 | PIO07 | PIO08 | PIO09 | |
| 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 (°) | 2 | 18 | 15 | 20 | 20 | 18 | 45 | 30 | 25 | 45 | 35 | 15 | 20 | 15 | 10 | |
| Area ($m^2$) | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | 25 | |
| Vegetation cover (%) | 90 | 95 | 90 | 90 | 95 | 90 | 65 | 65 | 74 | 75 | 80 | 83 | 90 | 90 | 85 | |
| *Hieracium umbellatum aggr.* | . | . | . | . | . | . | + | . | . | . | . | . | . | . | . | I |
| *Trifolium rubens* | . | . | . | . | . | . | . | . | . | . | + | . | . | + | . | I |
| *Melampyrum cristatum* | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | I |
| *Galium verum* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | I |
| *Polygonatum odoratum* | . | . | . | . | . | . | . | . | . | . | . | . | . | . | + | I |
| **Ingressive species of *Rhamno catharticae-Prunetea spinose*** | | | | | | | | | | | | | | | | |
| *Rosa canina* | . | . | . | . | . | . | . | . | . | . | + | 1 | + | . | + | II |
| *Rubus fruticosus* aggr. | . | . | . | . | . | . | . | . | . | 1 | . | 1 | . | 1 | + | II |
| *Prunus spinosa* | . | . | . | . | . | . | . | . | 1 | + | . | 1 | . | . | . | I |
| *Crataegus monogyna* | . | . | . | . | . | . | . | . | . | . | 3 | . | . | . | . | I |
| *Ligustrum vulgare* | . | . | . | . | . | . | . | . | . | . | 2a | . | . | . | . | I |
| *Acer campestre* | . | . | . | . | . | . | . | . | . | . | + | . | . | . | . | I |
| *Rhamnus cathartica* | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | . | I |
| **Other companion species** | | | | | | | | | | | | | | | | |
| *Carex humilis* | 2a | 2a | 1 | 2a | 2a | 2a | 2a | . | . | . | 1 | . | 1 | 2a | 2a | IV |
| *Betonica officinalis* | + | 1 | 1 | + | 1 | 1 | . | . | + | + | 1 | . | 1 | 1 | 1 | IV |
| *Galium lucidum* | + | + | . | . | + | . | + | . | 1 | 1 | 1 | 1 | 1 | 1 | 1 | IV |
| *Festuca ovina* aggr. | 2a | + | 1 | . | . | 1 | . | + | . | . | 1 | . | 1 | 1 | . | III |
| *Genista tinctoria* | 1 | 1 | . | 1 | 1 | 1 | . | . | . | . | . | . | + | 1 | 1 | III |
| *Viola canina* | + | + | 1 | 1 | 1 | 1 | . | . | 1 | + | . | . | . | . | . | III |
| *Viola hirta* | . | 1 | 1 | 1 | 1 | + | . | . | . | . | 1 | + | + | . | 1 | III |
| *Calluna vulgaris* | . | 1 | 1 | 1 | + | 1 | . | + | 1 | + | . | . | . | . | . | III |
| *Biscutella laevigata* | . | + | . | . | 1 | + | . | 1 | 1 | + | . | 1 | + | + | . | III |
| *Thymus pulegioides* | . | . | 1 | . | . | 1 | 1 | 1 | 1 | + | 1 | 1 | . | + | . | III |
| *Molinia arundinacea* | 2a | 2b | 2a | 3 | 2b | 2b | . | . | . | . | . | . | . | . | . | II |
| *Daphne cneorum* | 1 | 2a | 1 | . | 1 | 1 | . | . | . | . | . | . | . | . | . | II |
| *Cruciata laevipes* | 1 | 1 | 1 | . | . | . | . | . | . | 1 | . | . | . | . | + | II |
| *Hypericum richeri* | 1 | + | 1 | . | + | . | . | . | . | . | . | . | . | . | . | II |
| *Anemonoides nemorosa* | 1 | . | + | 1 | + | . | . | . | . | . | . | . | . | . | . | II |
| *Serratula tinctoria* | + | 1 | 1 | 1 | + | 1 | . | . | . | . | . | . | . | . | . | II |
| *Campanula rotundifolia* | + | + | . | . | + | 1 | . | . | . | . | . | . | + | . | + | II |
| *Muscari botryoides* | . | 1 | . | + | 1 | + | . | . | 1 | 1 | . | . | . | . | . | II |
| *Plantago maritima* subsp. *serpentina* | . | + | . | . | + | . | + | 1 | 1 | + | . | . | . | . | . | II |
| *Sorbus aria* | . | + | . | . | . | . | . | 1 | 1 | 1 | . | . | . | . | . | II |
| *Platanthera chlorantha* | . | . | + | . | . | . | . | + | 1 | + | . | . | . | . | . | II |
| *Solidago virgaurea* | . | . | . | + | . | + | . | + | . | + | . | . | . | . | . | II |
| *Allium sphaerocephalon* | . | . | . | . | . | + | . | . | . | . | + | . | . | + | + | II |
| *Cherleria laricifolia* | . | . | . | . | . | . | 1 | + | + | . | . | . | . | + | . | II |
| *Quercus pubescens* | . | . | . | . | . | . | + | . | 1 | . | 2a | . | . | . | 1 | II |
| *Fraxinus excelsior* | . | . | . | . | . | . | . | . | + | + | + | + | . | . | . | II |
| *Corylus avellana* | 1 | . | + | 1 | . | . | . | . | . | . | . | . | . | . | . | I |
| *Pteridium aquilinum* | 1 | . | . | . | . | . | . | . | . | . | . | 1 | . | . | . | I |
| *Potentilla erecta* | . | 1 | + | 1 | . | . | . | . | . | . | . | . | . | . | . | I |
| *Leucanthemum heterophyllum* | . | + | . | . | + | 1 | . | . | . | . | . | . | . | . | . | I |
| *Pulmonaria australis* | . | + | . | . | 1 | . | . | . | . | . | . | . | . | . | . | I |
| *Gentiana pneumonanthe* | . | + | . | . | + | . | . | . | . | . | . | . | . | . | . | I |
| *Fumana procumbens* | . | . | . | . | . | . | 1 | . | + | . | . | . | . | . | . | I |
| *Carex ornithopoda* | . | . | . | . | . | . | . | 1 | . | 1 | . | . | . | . | . | I |
| *Avenella flexuosa* | . | . | . | . | . | . | . | + | . | + | . | . | . | . | . | I |
| *Noccaea praecox* | . | . | . | . | . | . | . | + | . | + | . | . | . | . | . | I |
| *Phyteuma italicum* | . | . | . | . | . | . | . | + | . | 1 | . | . | . | + | . | I |
| *Festuca rubra* | . | . | . | . | . | . | . | + | . | . | . | . | 1 | . | . | I |
| *Genista germanica* | . | . | . | . | . | . | . | . | 1 | . | + | . | . | . | . | I |
| *Scrophularia canina* | . | . | . | . | . | . | . | . | + | . | . | + | . | . | . | I |
| *Luzula campestris* | . | . | . | . | . | . | . | . | . | + | . | . | 1 | . | . | I |
| *Muscari comosum* | . | . | . | . | . | . | . | . | . | . | . | + | + | . | + | I |
| *Knautia mollis* | . | . | . | . | . | . | . | . | . | . | . | . | 1 | 1 | + | I |
| *Phleum hirsutum* | . | . | . | . | . | . | . | . | . | . | . | . | 1 | . | + | I |
| *Takhtajaniantha austriaca* | . | . | . | . | . | . | . | . | . | . | . | . | + | + | 1 | I |
| *Poa pratensis* | . | . | . | . | . | . | . | . | . | . | . | . | + | + | . | I |
| *Cerastium arvense* | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | + | I |
| *Odontarrhena argentea* | . | . | . | . | . | . | . | . | . | . | . | . | . | 1 | + | I |
| *Pulsatilla montana* | . | . | . | . | . | . | . | . | . | . | . | . | . | + | + | I |

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 variae* alliance (order *Festucetalia spadiceae*, class *Caricetea 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-Brometea erecti*. In particular, these stands can be placed in the order *Brometalia erecti*, suborder *Leucanthemo vulgar-*

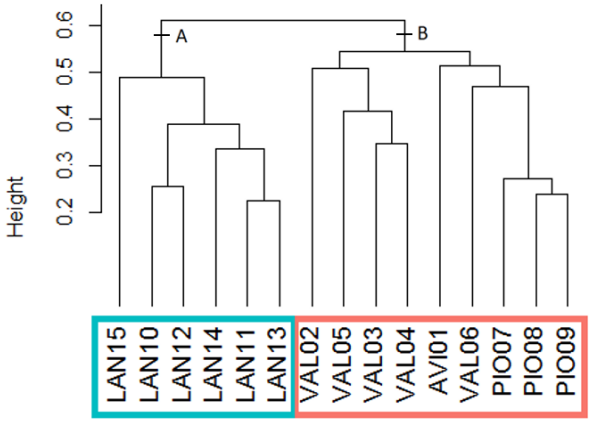


**Figure 3.** Cluster dendrogram. Two separated groups can be distinguished from the dendrogram, group A is highlighted with blue, while group B is highlighted with red.

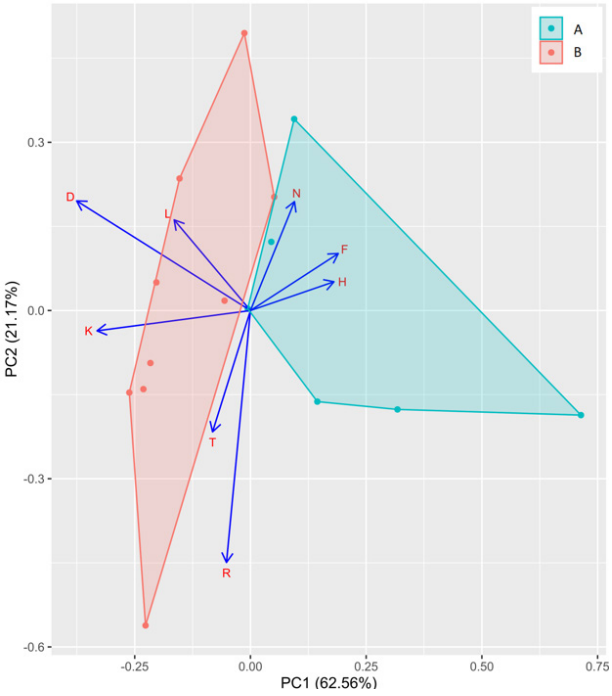


**Figure 4.** Principal Component Analysis biplot. The surveys of the two groups are highlighted with different colors (group A, blue; group B, red) and are encircled by convex hulls. Blue arrows indicate the average indicator values: temperature (T), continentality (K), light (L), moisture (F), reaction (R), nutrients (N), humus (H), aeration (D) from Landolt et al. (2010).

*is-Bromenalia erecti*, alliance *Bromion erecti*. At high elevations, the stands dominated by *P. paniculata* are typically placed in *Caricetea 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 ambigui-Bromion erecti* Biondi, Ballelli, Allegrezza & Zuccarello ex Biondi & Galdenzi, 2012, of *Scorzonero-Chrysopogonetalia* Horvatic et Horvat in Horvatic, 1963 (Sburlino et al. 1996). It should be noted that the high altitude coenosis can also contain some species characteristic of *Festuco valesiacae-Brometea erecti*, but with much more limited cover; these include e.g. *Carex caryophyllea*, *Festuca ovina* aggr., *Prunella grandiflora* (Négre 1950; Vittoz et al. 2005; Lonati 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 *Festuco valesiacae-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 P*otentillo albae-Quercetum 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. nigrum*, *P. hirtum*, and *C. rivini*, are ingressive species from the class *Trifolio medii-Geranietea 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. arundinacea* can also colonize grasslands belonging to *Bromion* and is considered a pyrophytic species (Stampfli 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. 2000; Øien and Moen 2001; Güsewell 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-Patzkeetum paniculatae* ass. nova is dynamically linked to the vegetation of the downy oak forests (*Quercion pubescenti-petraea*), 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-

ly woodlands is considerably slowed down by the harsh environmental conditions, the absence of grazing management could progressively lead towards the downy oak woodlands. Some neighboring areas probably already underwent this change, as indicated by the presence of single tufts of *P. paniculata* in the surrounding woody areas. The natural dynamism of the vegetation is highlighted by the great abundance of ingressive species of both thermophilic forest edge communities (*Trifolio medii-Geranietea sanguinei*) and meso-xerophilic shrub communities (*Rhamno catharticae-Prunetea spinosae*), causing the probable loss of grasslands over time in case the disturbances stop (Table 2). Shrub species such as *Crataegus monogyna*, *P. spinosa* and *Ligustrum vulgare* are also considered species of low intrinsic value, because they are very common, responsible for further loss of open habitats and their biodiversity, both in terms of plant species, entomofauna and avifauna (Calaciura and Spinelli 2008).

In the variant with *M. arundinacea*, located on less rocky soils with higher water availability, the coexistence of other species with *M. arundinacea* is threatened by its vigorous growth. The abundant dead dry matter accumulates, forming a very thick layer of litter (Stampfli et al. 1994) that favor fires, which are frequent in winter, particularly in dry areas of Piemonte Region, NW-Italy (Regione Piemonte 2021). Its resistance to fire and its competitiveness in deeper soils make *M. arundinacea* a potential threat to species of these grasslands. It is realistic to assume that frequent fires and lack of management could also lead to the disappearance of *P. paniculata*. Moreover, the abundant litter accumulation can slow down the succession towards the woodlands. Indeed, the absence of ingressive species of the class *Rhamno catharticae-Prunetea spinosae* in the variant with *M. arundinacea* could indicate a less mature evolutionary stage, compared to the variant with *B. erecta*.

## Conclusions

The new association *Potentillo albae-Patzkeetum 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 *Festuco-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-BROMETEA 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-Patzkeetum 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.

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## Competing interests

The authors have declared that no competing interests exist.

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# 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), 10/06/202, 7°28'53.3604"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°28'59.7504"E, 45°14'23.5824"N; Rel 06: LAN13, Lanzo Torinese (TO), 10/06/2021, 7°29'4.0308"E, 45°14'21.4044"N; Rel 07: VAL02, Valgioie (TO), 07/05/2021, 7°21'12.6504"E, 45°4'26.6088"N; Rel 08: VAL05, Valgioie (TO), 07/05/2021, 7°20'55.662"E, 45°4'33.6216"N; Rel 09: VAL03, Valgioie (TO), 07/05/2021, 7°21'6.7716"E, 45°4'29.0208"N; Rel 10: VAL04, Valgioie (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, Valgioie (TO), 07/05/2021, 7°20'57.6276"E, 45°4'32.16"N; Rel 13: PIO07, Piossasco (TO), 21/05/2021, 7°26'53.9484"E, 44°59'50.1972"N; Rel 14: PIO08, Piossasco (TO), 21/05/2021, 7°26'54.2436"E, 44°59'49.4232"N; Rel 15: PIO09, Piossasco (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* aggr. (+); 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* (+).