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The Summit Vegetation of the Sirino-Papa Massif (Southern Apennines, S. Italy)

By

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With 3 Figures

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Summary

TOMASELLI M., DOWGIALLO G., PETRAGLIA A. & CONSIGLIO L. 2007. The summit vegetation of the Sirino-Papa massif (Southern Apennines, S. Italy). – Phyton (Horn, Austria) 47 (1–2): 133–160, with 3 figures. – English with German summary.

This study aims, primarily, at characterizing, from the floristic, chorological and life-form viewpoint, the plant communities occurring in the alpine life zone of a mountain area in the southern Apennines (Basilicata, Italy) and, secondarily, at relating them to the main habitat factors. We used a data set of 47 relevés taken according to the phytosociological method in the summit areas of the Sirino-Papa massif. Their numerical classification produced a dendrogram where five main vegetation types could be detected. The Galio magellensis-Festucetum dimorphae and the phytocoenon of *Rumex scutatus* colonize different habitats on the N-faced scree slope of Mt. Papa. The Pimpinello lithophilae-Astragaletum sirinici, subdivided into three different subassociations (two subass. novae), includes thorny-cushion scrubs extensively occurring mostly on the southern slopes of both Mt. Sirino and Mt. Papa (two subass. on N. slopes) The closed grassland associations (Plantagino serpentinae-

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Nardetum strictae and Bellidi pusillae-Alopecuretum gerardi) are restricted to the sites where snow cover lasts longer. From the life-form viewpoint the vegetation types are differentiated mostly by the higher occurrence of chamaephytes in all subtypes of the Pimpinello lithophilae-Astragaletum sirinici. The percentage sum of S-European orophytes and Apennine endemics, representing the "southern" floristic component, exceeds 60% in most of vegetation types, declining only in the Plantagino serpentinae-Nardetum strictae, where these species are replaced by Eurasian species representative of the "temperate" flora. The Pimpinello lithophilae-Astragaletum sirinici typicum and its subassociation seslerietosum nitidae have a "xeric" soil moisture regime and their soil profiles are of a shallow rendzina type. The soil profile of the variant of Brachypodium genuense of the Pimpinello lithophilae-Astragaletum sirinici and that of the Plantagino serpentinae-Nardetum strictae correspond to acid brown soil. The soil profile taken at the Bellidi pusillae-Alopecuretum gerardii is differentiated by a BC horizon where $CaCO_3$ and basic cations are accumulated.

Zusammenfassung

Tomaselli M., Dowgiallo G., Petraglia A. & Consiglio L. 2007. Die Gipfel-Vegetation im Sirino-Papa-Massiv (Süd-Apennin, S-Italien). – Phyton (Horn, Austria) 47 (1–2): 133–160, mit 3 Abbildungen. – Englisch mit deutscher Zusammenfassung.

Der Zweck dieser Studie war es, die Pflanzengesellschaften in der alpinen Stufe des Sirino-Papa-Massivs im Süd-Apennin (Basilicata, Italien) im Hinblick auf floristische und chorologische Zusammensetzung sowie Lebensformen zu charakterisieren; weiters sollten die Gesellschaften in Beziehung zu den wichtigsten Standortsfaktoren gesetzt werden. Wir verwendeten den Datensatz von 47 Vegetationsaufnahmen nach der Braun-Blanquet-Methode aus den Gipfelbereichen des Mt. Sirino - Mt. Papa-Massivs. Die numerische Klassifizierung ergab ein Dendrogramm, das fünf Hauptvegetationstypen erkennen ließ. Das Galio magellensis-Festucetum dimorphae und die *Rumex scutatus*-Gesellschaft besiedeln verschiedene Standorte am nordseitigen Schutthang des Mt. Papa. Das Pimpinello lithophilae-Astragaletum sirinici umfaßt drei Subassoziationen (davon 2 subass. novae) der Dornpolstergesellschaft, die hauptsächlich an den Südhängen von Mt. Sirino und Mt. Papa verbreitet ist (2 Subass. auch an N-Hängen). Die geschlossenen Grasland-Gesellschaften (Plantagino serpentinae-Nardetum strictae und Bellidi pusillae-Alopecuretum gerardi) sind auf Stellen mit längerer Andauer der Schneedecke beschränkt. Von den Lebensformen her sind diese Gesellschaften vor allem durch den höheren Prozentsatz an Chamaephyten im gesamten Pimpinello lithophilae-Astragaletum sirinici verschieden. Die "südliche" floristische Komponente setzt sich aus Süd-Europäischen Orophyten und aus Apennin-Endemiten zusammen und übersteigt in den meisten Vegetationstypen 60 % der Artenanzahl; geringer ist sie nur im Plantagino serpentinae-Nardetum strictae, wo jene durch eurasiatische Arten, Vertreter der "temperaten" Flora, ersetzt ist. Das Pimpinello lithophilae-Astragaletum sirinici typicum und die Subass. seslerietosum nitidae haben ein "xerisches" Bodenfeuchtigkeitsregime und Bodenprofile mit flachgründigen Rendzina-Typen. Die Variante mit Brachypodium genuense und das Plantagino serpentinae-Nardetum strictae kommen über sauren Braunerden vor. Die Profile unter dem Bellidi pusillae-Alopecuretum gerardi sind durch einem BC-Horizont mit Anreicherung von $CaCO_3$ und basischen Kationen charakterisiert.

1. Introduction

The alpine life zone includes all mountain areas above timberline of the world (Körner 1999). In most regions, the flora of this zone attains a high degree of taxonomic richness (Vareschi 1970, Mark & Adams 1979, Ozenda 1985, Hadley 1987, Polunin & Stainton 1988, Agakhanyanz & Breckle 1995, Odland & Birks 1999, Körner 2002, Virtanen & al. 2002, Wohlgemuth 2002 and others). Generally, these biodiversity hotspots host substantial numbers of endemic species (Packer 1974, Salgado-Labouriau 1986, Agakhanyanz & Breckle 2002) with abundant taxa which are known from a single mountain (Mark 1995, Nakhutsrishvili & Gagnidze 1999, Safford 1999).

In the alpine zone of the European mountains species richness and degree of endemism decline with increasing latitude (Körner 1995). The number of endemic species is particularly high in the Alps, Pyrenees and Carpathians (Pawłowski 1970, Küpfer 1974, Villar & Laínz 1990). Also the mountain systems of southern Europe harbour a summit flora rich in endemic species (Rivas-Martinez 1969, Pignatti & al. 1980, Strid 1986, 1993, Pignatti 1986, Foggi 1990, Caputo & al. 1997), mostly of ancient origin and preserved during the glacial age. In the alpine life zone of the S-European mountains, endemic species grow together with oromediterranean and oroboreal taxa along typical floristic gradients (Passalacqua 1998, Lucchese & De Simone 2000, Tomaselli & Gualmini 2000). These species form floristic assemblages that attracted a number of vegetation scientists for a long time. Investigations on vegetation above timberline have been intensive and have led to a good knowledge of the vegetation of the most relevant mountains. The phytosociological studies range from the pioneer contributions of Quézel 1953, 1964, 1967, Poli 1965, Rivas-Martinez 1963, 1969 to the synthesis of Horvat & al. 1974, Gamisans 1976, 1977, Bonin 1978, Pignatti & al. 1980 to the more recent contributions on the Balkan mountains by Mucina & al. 1990 and on the central Apennines by Petriccione 1993, Petriccione & Persia 1995, Biondi & al. 1999, 2000 and Blasi & al. 2003, 2005.

In the mountains of the southernmost part of the Italian Peninsula the alpine life zone is considerably reduced and restricted to isolated small areas. Only on the two highest massifs (M. Pollino and M. Sirino-M. Papa) the land area above timberline achieves a relatively extended size. Most vegetation studies have focussed on the more widespread alpine life zone of M. Pollino (Bonin 1972, 1978, Avena & Bruno 1975), whereas the vegetation of the smaller summit areas of the Sirino-Papa massif was only partially investigated, primarily by Caputo 1969 and, more recently, by Tomaselli & al. 2003.

This paper proposes a first attempt of a complete survey on the vegetation occurring in the alpine life zone of the Sirino-Papa massif which lies isolated in the southern Apennines and is therefore a especially fitted for phytogeographical analyses. The goal is to document present species distribution patterns along with a phytocoenological assessment within an area characterized by a floristic concurrence of temperate and oromediterranean flora harbouring rare or endemic species. Some of these species are presumably threatened as a consequence of atmospheric changes (THEURILLAT & GUISAN 2001, TOMASELLI & al. 2003). With this aim, both a phytosociological arrangement and a phytogeographic characterization of the vegetation are presented combined with the analysis of the relationships between vegetation and the major habitat factors.

2. Description of the Study Area.

The massif of Sirino-Papa (40° 05' – 40° 11' N, 15° 44' – 15° 53' E) is part of the southern Apennines and entirely comprised within the Basilicata region. It is limited by the valley of the Noce river from west to north and by the valleys of the Sinni river and of some of its minor tributaries

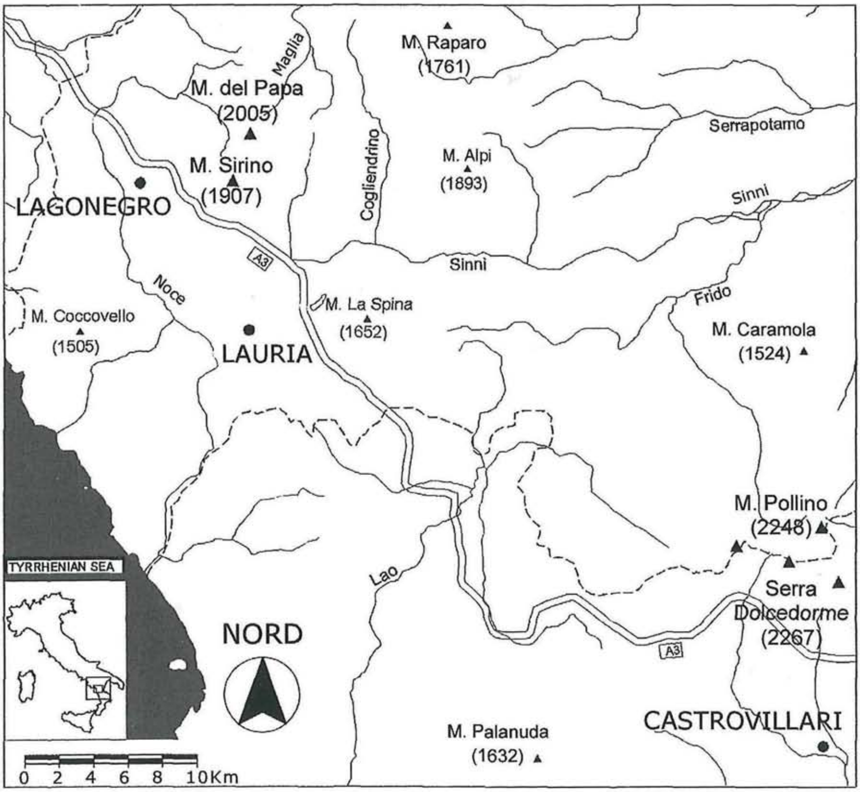

Fig. 1. Schematic map of the study area in Basilicata, Italy.

from east to south (Fig. 1). The highest peak scarcely exceeds 2000 m a.s.l. (M. Papa, 2005 m). Among the other summits of the massif, only two exceed 1900 m a.s.l. (Timpa Scazzariddo, 1930 m and M. Sirino, 1907 m).

The massif is made up of rock-types belonging to the Lagonegro terrains, including upwards: i) limestones dating back to the Upper Triassic, formed by grey calcilutites with chert nodules and bands; ii) siliceous schists, dating from the Jurassic formed by siliceous claystones and shales (SCANDONE 1972). From a geomorphological viewpoint, the northern slope of M. Papa preserves traces of modelling by the Würmian glaciers (ACQUAFREDDA & PALMENTOLA 1986).

The climate of the Sirino-Papa massif is conditioned by its proximity to the Tyrrhenian Sea. Precipitation with a mean annual value of about 2000 mm is strongly influenced by the humid winds blowing from the sea (CANTORE & al. 1987). The average annual temperature is comprised between 12 °C at the foothills of the massif and 6 °C at the summit areas.

Despite the human impact, particularly strong at the lowest altitudes, vegetation belts are still recognizable. The mediterranean vegetation belt with woods dominated by *Quercus ilex* is confined to the southern periphery of the massif up to 900 m. It is succeeded in altitude by a supramediterranean belt, characterized by deciduous mixed woods, with a prevalence of *Quercus cerris* and from about 1000 or 1400 m, according to the aspect of the slope, by a montane vegetation belt, dominated by beech (*Fagus sylvatica*) woods. Above timberline (from about 1700 to 2005 m) the vegetation of the actual alpine life zone of the Sirino-Papa massif is a patchy mosaic of thorny-cushion low shrubs, grasslands and poorly vegetated scree slopes.

3. Material and Methods

3.1. Vegetation Analysis

The vegetation was studied using the phytosociological method (BRAUN-BLANQUET 1964; WESTHOFF & VAN DER MAAREL 1973). A systematic vegetation sampling was made through the whole range of the study area by taking 39 phytosociological relevés. The sites of relevés are the following ones: M. Papa (PA), Schiena d'Asino (SA), M. Sirino (SI), Timpa Scazzariddo (TS). This relevé set was integrated by adding eight phytosociological relevés drawn from CAPUTO 1969.

The cover of species in the relevés was estimated using the Braun-Blanquet cover-abundance scale, as modified by PIGNATTI & MENGARDA 1962: r = rare species; + = cover <1%; 1 = cover >1–20%; 2 = cover >20–40%; 3 = cover >40–60%; 4 = cover >60–80%; 5 = cover >80–100%.

The vegetation relevés were combined within a floristic table containing the cover-abundance estimates transformed according to VAN DER MAAREL 1979. Species occurring only once were excluded from the analysis. The resulting table, consisting of 95 species x 47 relevés, was subjected to a numerical classification in order to obtain clusters of relevés. The clustering procedure was the average linkage (UPGMA) based on the chord distance. Computation was performed by the package SYN-TAX 2000 (PODÁNI 2001).

The clusters obtained were considered as local vegetation types to be compared with the Braun-Blanquet syntaxa. Comparison was based on both local monographic studies (TOMASELLI & al. 2003) and more general vegetation surveys covering broader areas, mostly BONIN 1978, FEOLI-CHIAPELLA 1983, BIONDI & al. 1999 and BLASI & al. 2003.

The arrangement to syntaxa higher than association was based on FEOLI-CHIAPELLA 1983, ELLMAUER 1993 and BIONDI & al. 1995, 2005. The source of taxonomic nomenclature is PIGNATTI 1982, with the exception of *Brachypodium genuense* (LUCCHESE 1987). The syntaxonomical nomenclature of syntaxa is in accordance with the rules defined by WEBER & al. 2000.

Both weighted chorological and life-form spectra were calculated for each vegetation type. The list of chorotypes was established according to TOMASELLI & GUALMINI 2000. These authors used as basis the chorotypes defined by PIGNATTI 1982 grouping them within more synthetical units, more suitable for chorological analyses at a local scale. Both chorological and life-form diversity among different vegetation types was calculated through Simpson's diversity index (SDI; PIELOU 1969). SDI is calculated as follows:

$$SDI = 1 - \sum_{i=1}^{n} p_i^2$$

where p_i is the proportion occupied by category i (in our case, chorotype or life form).

3.2. Site Parameter and Soil Analyses

At each relevé, three local-scale topographic variables were recorded: altitude, slope angle and exposition. Subsequently, exposition and slope angle of each relevé were used for the calculation of a radiation index (RI). For this calculation also the latitude of the study area was considered. RI corresponds to the ratio of total annual potential solar irradiation to maximum annual potential solar irradiation at a site (FRANK & LEE 1966, LAUSI & CODOGNO 1985). Although potential direct solar irradiation differs from actual direct irradiation, it is an appropriate basis for comparing the energy flux among different sites and it may be considered as a permanent site factor (FRANK & LEE 1966).

To properly enhance different behaviours of vegetation types with respect to elevation and potential solar radiation, we used a graphical method known as mosaic display (MD; FRIENDLY 1994). MD represents the counts in a contingency table cross-classified by one or more explanatory factors directly by tiles whose area is proportional to the cell frequency (i.e. to the frequency of observations in that partition). First, continuous predictor factors have to be meaningfully splitted (i.e., below and above a significative split point). As a result, a space-filling design composed of contiguous shapes describes a meaningful partitioning of the whole dataset with selective information on the cut-off levels (one for each factor, i.e. elevation and potential solar radiation) at which dataset behaviour changes. The relative frequencies of different vegetation types reflect their preferences (suitability) with respect to elevation and potential solar radiation. To determine such cut-off levels, we used a well-known statistical method based on Gini's index of diversity (BREIMAN & al. 1984) which allowed us the segmentation of data into mutually exclusive sub-groups each as pure or homogeneous as possible concerning vegetation types. The Gini index (also known as impurity index) of a group with n observations and c possible classes (i.e., vegetation types) is defined as:

$$GINI=1-\sum_{j=1}^{c}\left(\frac{n_j}{n}\right)^2$$

where n_j is the number of observations from class j present in the group. Cut-off levels are chosen as split points giving the highest reduction of impurity in the resulting sub-groups.

Within each of the most frequent vegetation types, a representative soil profile was described and sampled following the FAO guidelines for soil survey (FAO-ISRIC 1990). Soil colours were estimated in the field using the Munsell Soil Color Charts. Samples were taken from different horizons, air-dried, then passed through a 2 mm-sieve. The following analyses were carried out according to U.S.D.A. standard laboratory methods (1996): pH in H_2O and in KCl, available P_2O_5, exchangeable bases, exchangeable acidity, organic carbon and organic matter, total N, total $CaCO_3$ and particle size distribution.

Diagnostic horizons as well as soil profiles were classified to the subgroup level of the Soil Taxonomy (U.S.D.A. 1999, 2006). Both soil temperature and moisture regimes, important for classification purposes according to Soil Taxonomy, were estimated using mean monthly temperature and precipitation recorded at Lagonegro (period 1921–1984), but taking into consideration that there is a significative difference in altitude between this meteorological station (660 m) and the study area (ranging between about 1700 and 2000 m). To evaluate soil water balance and to estimate the length of the dry period, available water capacity (AWC) was calculated for each profile, using the equation proposed by SALTER & WILLIAMS 1969 based on textural composition and organic carbon content.

4. Results

4.1. Vegetation Analysis

Numerical classification of 47 phytosociological relevés yielded a dendrogram, where the clusters detected at the level of three partitions correspond respectively to mesophytic grasslands (A), to thorny-cushion scrubs (B) and to species-poor scree communities (C) (Fig. 2).

Cluster C is isolated at the right side of the dendrogram (Fig. 2). It comprises five relevés taken at species-poor stands occurring on the N-faced scree slopes of M. Papa. All stands are characterized by the occurrence of *Festuca dimorpha* and *Rumex scutatus* as constant species and by the predominance of diagnostic species of the class Thlaspietea rotundifolii (Tab. 1).

The stands corresponding to relevés 1, 2 and 3 are physiognomically marked by the compact tussocks of *Festuca dimorpha* sparsely occurring on the screes and hosting some smaller grasses and herbaceous dicotyledons. These stands lie at the bottoms of the talus slopes where the resting boulders offer a more stable habitat to the plants. They can be assigned to the association Galio magellensis-Festucetum dimorphae FEOLI-

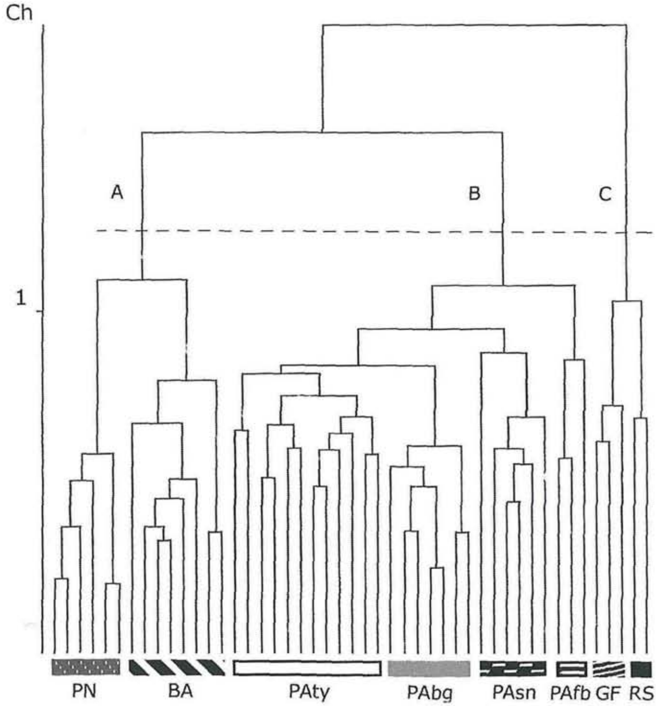

Fig. 2. Classification dendrogram of vegetation relevés. Ch: chord distance; BA: Bellidi pusillae-Alopecuretum gerardi; GF: Galio magellensis-Festucetum dimorphae; PAty: typical variant of the Pimpinello lithophilae-Astragaletum sirinici typicum; PAbg: variant of *Brachypodium genuense* of the Pimpinello lithophilae-Astragaletum sirinici typicum; PAsn: Pimpinello lithophilae-Astragaletum sirinici seslerietosum nitidae; PAfb: Pimpinello lithophilae-Astragaletum sirinici festucetosum bosniacae; PN: Plantagini serpentinae-Nardetum strictae; RS: phytocoenon of *Rumex scutatus*.

Chiapella 1983 in spite of a certain degree of impoverishment in diagnostic species due to chorological reasons (cf. Bonin 1978). Among the characteristic species only *Carduus chrysacanthus* is, in fact, still present, whereas *Galium magellense* and *Viola eugeniae* are lacking at all, because their southern distribution limits lie north of Sirino-Papa massif. *Sedum magellense* subsp. *olympicum* is to be added as differential species to the original characteristic species combination of the association. The Galio magellensis-Festucetum dimorphae is an association hitherto known only from the central Apennines, where it colonizes resting scree slopes with medium-sized clasts (Feoli-Chiapella 1983).

Relevés 4 and 5 are characterized by the dominance of *Rumex scutatus*, a typical species moving passively along scree slopes (Schröter 1926). The corresponding stands are close to the summit of still active talus slopes

Table 1. Galio magellensis-Festucetum dimorphae and phytocoenon of *Rumex scutatus*. – D: differential species.

N. of relevés	1	2	3	4	5	Fr
Site	PA	PA	PA	PA	PA	
Elevation (m x 10)	175	180	170	185	180	
Exposition	NNW	NNW	N	NNW	NE	
Slope angle ()	20	25	20	30	30	
Average clast size (cm)	50	30	50	3	3	
Relevé area (sqm)	100	50	200	50	200	
Total Cover (%)	30	25	10	25	20	
N. of species	13	5	12	10	16	
Rare species	2	–	4	–	5	
Ch. Associations						
Carduus chrysacanthus	+	+	+	.	+	80
Sedum magellense subsp. olympicum (D)	+	+	+	.	+	80
Rumex scutatus	1	1	+	2	2	100
Ch. A. Linario-Festucion dimorphae						
Festuca dimorpha	2	2	1	+	+	100
Cerastium tomentosum	+	.	.	.	.	20
Linaria purpurea	.	.	.	r	.	20
Ch. O. Thlaspietalia stylosi						
Cerastium thomasii	.	.	.	.	+	20
Myosotis ambigens	.	.	.	.	+	20
Ch. C. Thlaspietea rotundifolii						
Scrophularia juratensis	.	+	.	+	+	60
Doronicum columnae	1	.	+	.	.	40
Asplenium fissum	1	.	.	.	.	20
Hypochoeris cretensis	.	.	.	.	r	20
Companions						
Poa alpina	+	.	+	+	.	60
Crepis aurea subsp. glabrescens	+	.	.	r	+	60
Cystopteris fragilis	1	.	+	.	.	40
Leontodon hispidus	.	.	.	+	+	40
Ranunculus pollinensis	.	.	.	+	+	40
Asperula aristata subsp.scabra	.	.	+	r	.	40

Rare species: Rel. 1: Campanula scheuchzeri (+), Festuca italica (+), Rumex nebroides (+); Rel 3: Carduus affinis (+), Gentiana lutea (+), Globularia meridionalis (+), Saxifraga paniculata subsp. stabiana (+); Rel. 4: Sesleria nitida (1); Rel.5: Arabis hirsuta (+), Avenula praetutiana (+), Biscutella laevigata (+), Pimpinella lithophila (+), Viola aethnensis subsp. splendida (r).

Table 2. Pimpinello lithophilae-Astragaletum sirinici. – D: differential species.

N. of relevés	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	Fr
Site	PA	PA	SI	SI	PA	SI	SI	SI	PA	PA	SI	PA	PA	SI	SI	TS	PA	PA	TS	PA	TS	TS	PA	SI	PA	PA	PA	PA	
Elevation (m x 10)	198	200	168	185	177	185	170	170	185	185	160	190	195	188	188	186	190	190	189	196	191	192	190	181	190	186	196	180	
Exposition	S	S	–	S	S	SE	WSW	SE	SE	S	WSW	S	E	WSW	W	E	E	E	SSW	ENE	N	NE	ENE	W	WNW	NW	NW	N	
Slope angle ()	30	5	–	20	30	20	15	40	25	40	35	30	30	25	25	20	25	20	25	30	30	30	35	30	30	30	35	30	
Relevé area (sqm)	80	100	80	100	80	100	60	100	100	100	80	100	150	200	200	150	100	150	200	200	150	200	100	150	100	150	100	100	
Cover (%)	65	75	80	70	70	75	80	70	60	80	60	70	90	75	90	95	90	75	90	70	75	80	75	85	85	80	80	60	
Rare species	1	1	–	–	3	2	–	–	–	1	–	1	1	–	–	1	–	–	–	1	1	–	–	1	–	2	1	3	
N. of species	21	20	23	27	36	32	22	16	14	22	26	10	24	23	19	29	21	20	20	22	28	35	19	25	22	27	22	21	
Ch. Ass. Pimpinello lithophilae-Astragaletum sirinici																													
Astragalus sirinicus	3	3	3	3	3	3	4	4	3	3	2	2	2	3	4	4	3	2	2	+	1	2	2	2	1	2	2	1	100
Pimpinella tragium subsp. lithophila	1	2	2	2	2	2	1	1	1	1	1	1	+	1	2	2	2	2	1	2	1	2	1	1	.	2	+	1	96
Diff. Brachypodium genuense-variant																													
Poa alpina	+	1	.	+	.	+	.	.	1	.	+	1	1	+	1	1	1	1	1	.	1	+	.	.	1	+	.	.	64
Festuca rubra subsp.microphylla	.	+	.	.	+	.	.	.	.	.	.	.	+	2	2	2	2	1	1	.	.	.	.	.	.	.	.	.	32
Stachys tymphaea	.	.	.	.	+	.	.	.	.	.	.	.	+	+	.	+	+	.	.	+	.	.	.	.	.	.	.	.	21
Diff. Subass. Seslerietosum nitidae																													
Sesleria nitida	.	.	+	+	+	.	1	1	.	.	2	2	+	2	1	.	.	.	.	1	3	3	3	3	3	.	.	1	61
Diff. Subass. Festucetosum bosniacae																													
Festuca bosniaca	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	.	.	+	1	3	3	2	25
Saxifraga paniculata subsp. stabiana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	1	1	14
Biscutella laevigata	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	11
Ch. SA. Sideritenion italicae																													
Thymus striatus	+	1	+	+	.	.	1	1	1	1	+	1	+	2	1	2	1	+	+	1	1	1	1	1	1	1	+	1	93
Asperula aristata subsp.scabra	1	1	+	+	+	2	+	.	1	.	+	+	.	.	+	1	.	.	.	+	.	+	.	.	+	+	+	+	64
Sideritis syriaca	.	.	+	1	1	1	1	1	1	+	+	.	.	+	.	.	.	.	.	.	.	.	.	+	+	+	.	.	46
Hypochoeris cretensis (D)	1	.	.	+	+	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	18
Potentilla calabra	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	11
Ch. A. Phleo ambigui-Bromion erecti																													
Koeleria splendens	.	1	+	1	1	+	+	1	2	1	1	1	.	+	1	+	+	1	1	1	.	+	.	+	1	+	.	.	79
Avenula praetutiana	.	1	.	.	+	2	.	1	.	1	1	.	1	1	1	1	1	1	2	1	1	1	1	2	1	.	1	.	71
Carex macrolepis	.	.	+	+	+	+	1	.	.	+	.	+	+	1	+	.	.	2	1	2	.	1	.	+	.	1	.	+	61
Acinos alpinus	1	.	.	1	2	1	1	+	1	1	+	+	.	.	+	.	.	.	.	.	+	.	.	.	.	.	.	+	46
Festuca circummediterranea	.	.	+	+	.	1	.	.	1	2	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	21
Helianthemum canum	.	.	.	+	.	.	.	.	+	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	14
Phleum ambiguum	.	.	+	.	.	.	.	.	.	1	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	11
Bunium petraeum	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Ch.SO. Artemiso albae-Bromenalia erecti																													
Petrorhagia saxifraga	.	.	+	.	1	1	+	.	.	.	.	+	.	+	.	+	+	+	1	.	+	+	.	+	.	+	.	+	54
Dianthus sylvestris	.	.	.	+	+	.	+	.	1	1	+	.	.	+	+	.	+	+	.	.	+	+	.	.	.	+	.	1	14
Teucrium montanum	.	.	.	.	+	.	+	1	2	.	.	.	.	.	.	.	.	+	1	.	+	+	.	.	.	+	.	.	32
Stachys recta subsp. labiosa	1	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4

Table 2: continuation

N. of relevés	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	Fr
Ch. C. Festuco-Brometea and Ch. O. Brometalia erecti																													
Bromus erectus	+	.	+	.	.	1	+	1	2	1	2	1	+	1	.	.	+	+	2	1	1	+	1	1	.	+	+	.	75
Hippocrepis comosa	.	.	+	+	+	1	.	+	.	1	.	.	.	.	.	.	.	+	.	.	+	.	1	+	+	.	1	+	46
Scabiosa holosericea	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	+	1	+	+	+	.	1	+	+	+	+	.	1	46
Thlaspi praecox	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	1	+	.	+	.	+	+	.	.	.	+	.	.	25
Galium lucidum	+	.	+	+	+	+	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	21
Astragalus depressus	.	+	.	+	.	.	+	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	18
Astragalus sempervirens subsp. gussonei	.	.	2	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	.	.	14
Armeria canescens subsp. gracilis	.	.	.	.	.	.	.	.	.	.	.	1	+	.	.	+	1	.	.	.	.	.	.	.	.	.	.	.	14
Helianthemum nummularium subsp.obscurum	.	.	.	.	+	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	14
Carlina utzka	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Thesium linophyllon	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Trifolium ochroleucum	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Companions C. Elyno-Seslerieta																													
Minuartia verna subsp. attica	.	1	.	.	.	1	.	.	.	.	.	.	.	+	.	.	+	.	.	+	.	1	1	.	.	+	+	+	36
Edraianthus graminifolius	+	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+	.	1	r	+	.	32
Trinia dalechampii	+	+	.	.	.	.	.	.	.	.	.	+	.	+	.	+	.	.	r	.	.	.	+	.	.	.	+	+	32
Alyssum diffusum	.	.	.	.	.	.	.	.	.	+	.	.	1	+	+	.	.	.	.	1	1	.	+	.	.	.	.	1	29
Carduus carlinaefolius	.	.	.	.	+	.	.	.	.	.	.	.	1	+	+	+	.	.	.	.	+	.	.	+	.	.	.	.	25
Carex kitaibeliana	.	+	.	+	+	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1	.	.	.	.	21
Globularia meridionalis	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	+	.	.	.	+	.	+	.	+	+	.	21
Anthyllis montana subsp. atropurpurea	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	1	1	+	+	.	18
Euphrasia salisburgensis	.	+	.	.	.	+	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	14
Senecio tenorei	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	+	.	11
Anthyllis vulneraria subsp. pulchella	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	7
Linum capitatum	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	7
Alchemilla nitida	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	4
Draba aizoides	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Myosotis ambigens	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4
Other companions																													
Brachypodium genuense	.	.	+	1	1	+	1	.	.	+	1	1	3	1	1	2	2	1	2	1	.	1	1	1	+	.	+	.	75
Trifolium pratense subsp. semipurpureum	+	1	.	.	+	+	+	1	.	1	1	.	1	.	1	2	2	.	1	1	1	.	+	.	1	+	1	.	68
Lotus corniculatus	1	+	2	1	+	+	+	.	.	1	+	.	1	+	+	1	+	.	.	2	.	+	1	.	1	.	.	.	64
Cerastium tomentosum	1	1	+	2	.	+	.	1	.	.	+	1	1	.	1	1	+	.	+	.	+	1	+	.	.	+	1	.	64
Plantago atrata	1	.	1	+	1	.	.	.	.	.	.	.	+	.	.	1	2	.	.	+	1	+	2	+	.	+	+	+	54
Viola aethnensis subsp.splendida	.	.	.	.	+	.	.	.	.	.	.	.	+	+	.	+	.	+	.	.	+	.	.	+	+	+	+	.	36
Campanula scheuchzeri	+	.	.	.	+	+	+	.	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.	+	.	+	+	.	32
Hieracium pilosella	.	.	1	+	.	.	.	.	.	.	.	.	1	.	.	+	.	.	1	+	+	+	.	.	.	.	.	.	29
Potentilla rigoana	.	.	+	.	+	+	.	.	.	.	.	.	.	.	.	r	.	+	+	+	.	.	.	.	.	.	+	.	29
Silene multicaulis	+	.	.	.	+	.	.	.	.	.	+	.	.	.	.	+	.	r	+	.	.	.	.	.	.	+	+	.	29
Carduus affinis	+	.	.	.	+	+	+	.	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	21
Sempervivum tectorum	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	14
Plantago serpentina	+	1	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	11
Anthoxanthum odoratum s.l.	.	.	.	+	.	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	11

Rare species: Rel. 1: Sedum album (+); Rel. 2: Sedum acre (+); Rel. 5: Doronicum columnae (+), Polygala angelisii (+), Trifolium repens (+); Rel. 6: Sedum album (1), Trifolium repens (+); Rel. 10: Hypericum barbatum (1); Rel. 12: Dianthus deltoides (+); Rel. 13: Rumex nebroides (+); Rel. 16: Dianthus deltoides (+); Rel. 20: Polygala angelisii (+); Rel. 21: Leontodon hispidus (r); Rel. 24: Leontodon hispidus (+); Rel. 26: Hypericum barbatum (+), Rumex nebroides (r); Rel. 27: Sedum acre (r); Rel. 28: Arabis hirsuta (1), Linaria purpurea (1), Sedum magellense subsp. olympicum (1).

and, therefore, exposed to the fall of rock fragments from above and subjected to substrate movements. The stands dominated by *Rumex scutatus* can be evaluated as an independent vegetation unit, but they cannot be referred an association, because the dominant species has a weak diagnostic power and no other species can be retained as characteristic. Consequently, we propose here to assign these stands to a phytocoenon of *Rumex scutatus* according to the BRAUN-BLANQUET suggestions.

Regarding the higher syntaxonomic ranks both vegetation types belong to the alliance Linario-Festucion dimorphae, the order Thlaspietalia stylosi and the class Thlaspietea rotundifolii, because the diagnostic species of these syntaxa are well represented in the floristic combination (Tab. 1).

The second cluster (B) comprises the highest number of relevés (28) and shows the highest degree of floristic heterogeneity (see Fig. 2 and Tab. 2). All stands are characterized by the occurrence of the thorny-cushion low shrub *Astragalus sirinicus* that is also the dominant species in a large number of relevés. Other constant species are *Pimpinella tragium* subsp. *lithophila* and *Thymus striatus*. All relevés can be ascribed to the association Pimpinello lithophilae-Astragaletum sirinici BIONDI & BLASI 1982. The characteristic species combination of the association includes *Astragalus sirinicus* (as characteristic species) and *Pimpinella lithophila* (as differential species). According to BIONDI & al. 1995, 2005, the Pimpinello lithophilae-Astragaletum sirinici is to be assigned to the suballiance Sideridenion italicae belonging to the alliance Phleo ambigui-Bromion erecti (order Brometalia erecti, class Festuco-Brometea).

According to our data which considerably enlarge the original relevé set reported by CAPUTO 1969, the Pimpinello lithophilae-Astragaletum sirinici can be subdivided into three different subassociations (Tab. 2). The first subassociation (Tab. 2, rel. 1–19) is the typical one (Pimpinello lithophilae-Astragaletum sirinici typicum). According to the dendrogram (Fig. 2) it can be subdivided into two variants. Releves from 1 to 12, having no differential species, correspond to the typical variant. Here, the vegetation has a compact xeromorphic physiognomy and primarily contains dwarf shrubs. In the second variant (Tab. 2, rel. 13–19) physiognomy is marked by *Brachypodium genuense*, dominant or codominant with *Astragalus sirinicus* (variant of *Brachypodium genuense*). It is differentiated by some mesophilous species ordinarily occurring on soils relatively rich in nutrients (*Poa alpina, Festuca rubra* subsp. *microphylla, Stachys tymphaea*).

The second subassociation (Tab. 2, rel. 20–25) is differentiated by the constant occurrence and the high cover values of *Sesleria nitida*, representing the dominant species in most relevés, by the increased occurrence of primary grassland species belonging to the class Elyno-Seslerietea and by the reduced incidence of both diagnostic species of the association. This subassociation is here newly described:

Pimpinello lithophilae-Astragaletum sirinici seslerietosum nitidae Tomaselli, Dowgiallo, Petraglia & Consiglio subass. nova hoc loco; Tab. 2, nomenclatural type: rel. 22 (holotypus).

The third subassociation has been scarcely encountered in the summit areas of the Sirino-Papa massif. For this reason, it is here represented by only three relevés, where *Festuca bosniaca* is the dominant species (Tab. 2, rel. 26–28). Both diagnostic species of the association are constantly present, but in general, the bulk of the diagnostic species of the higher syntaxa is reduced with respect to the other two subassociations. Also here, the Elyno-Seslerietea species group is well represented. This subassociation is herein newly described:

Pimpinello lithophilae-Astragaletum sirinici festucetosum bosniacae Tomaselli, Dowgiallo, Petraglia & Consiglio subass. nova hoc loco; Tab. 2, nomenclatural type: rel. 27 (holotypus).

Festuca bosniaca, Saxifraga paniculata subsp. *stabiana* and *Biscutella laevigata* can be regarded as differential species of the subassociation.

The third cluster (A) is subdivided into two subclusters (PN and BA) corresponding to mesophytic grasslands respectively dominated by *Nardus stricta* (PN) and by *Crepis aurea* subsp. *glabrescens* and *Plantago atrata* (BA). The relevés included within these two clusters have been already analyzed and classified by Tomaselli & al. 2003.

The cluster NL includes close swards where three species are constant and codominant in all stands: *Nardus stricta, Festuca rubra* subsp. *microphylla* and the mat-forming herb *Plantago serpentina* (Tab. 3). The corresponding relevés were assigned to the association Plantagini serpentinae-Nardetum strictae by Tomaselli & al. 2003. *Plantago serpentina* is the regional characteristic species of the association, whereas *Asperula aristata* subsp. *scabra, Brachypodium genuense, Euphrasia stricta* and *Carex caryophyllea* are regarded as differential species.

The cluster BA includes stands formed by a very low and closed turf, in which mat-forming herbs and tussock grasses are dominant. The mat-forming herbs *Crepis aurea* subsp. *glabrescens* and *Plantago atrata* are constant throughout and codominant or alternatively dominant (Tab. 4). This community was described as an independent association (Bellidi pusillae-Alopecuretum gerardi) by Tomaselli & al. 2003. The diagnostic species of the association are *Alopecurus gerardi, Trifolium repens* subsp. *prostratum* and *Bellis pusilla*. The relevés taken in the Sirino-Papa massif correspond to the subassociation differentiated by *Armeria canescens* subsp. *gracilis, Lotus corniculatus* and *Potentilla rigoana* (Bellidi pusillae-Alopecuretum gerardi armerietosum gracilis) and to the variant differentiated by *Carex kitaibeliana* and *Plantago serpentina* (see Tomaselli & al. 2003). The relevés 7 and 8 (Tab. 4), where *Astragalus sirinicus* is particularly abundant, correspond to stands with transitional

Table 3. Plantagini serpentinae-Nardetum strictae. – D: differential species. R: regional character species.

N. of relevés	1	2	3	4	5	6	Fr
Site	SI	SI	SA	PA	PA	PA	
Elevation (m x 10)	184	185	183	197	196	198	
Exposition	E	ESE	WSW	ESE	NE	NE	
Slope angle (°)	20	25	25	5	30	10	
Relevé area (sqm)	100	100	100	50	100	80	
Cover (%)	95	100	100	100	100	100	
Rare species	2	3	2	–	1	1	
N. of species	26	21	22	18	22	18	
Ch. Ass. Plantagino serpentinae-Nardetum strictae							
Plantago serpentina (R)	3	2	3	2	3	2	100
Asperula aristata subsp.scabra (D)	1	+	+	+	1	1	100
Euphrasia stricta (D)	+	+	+	+	+	.	83
Brachypodium genuense (D)	2	2	2	.	+	.	67
Carex caryophyllea (D)	1	1	1	.	.	.	50
Ch. A. Ranunculo-Nardion							
Potentilla rigoana	+	1	+	+	+	+	100
Viola aethnensis subsp.splendida	.	r	+	.	+	+	67
Plantago atrata (R)	.	.	.	1	1	1	50
Polygala angelisii	.	+	.	+	+	.	50
Crepis aurea subsp. glabrescens	.	.	.	.	1	2	33
Bellis pusilla	+	.	1	.	.	.	33
Ranunculus pollinensis	.	.	.	+	+	.	33
Ch. O. Nardetalia							
Nardus stricta	3	3	3	4	3	2	100
Dianthus deltoides	+	+	1	2	+	.	83
Botrychium lunaria (D)	.	.	.	.	+	1	33
Meum athamanticum	.	.	+	.	.	.	17
Ch. C. Calluno-Ulicetea							
Anthoxanthum odoratum s.l.	1	2	1	.	2	1	83
Hieracium pilosella	2	1	1	+	.	.	67
Luzula multiflora	.	.	1	+	.	.	33
Danthonia decumbens	.	.	1	.	.	.	17
Companions							
Festuca rubra subsp.microphylla	3	3	3	3	3	3	100
Lotus corniculatus	1	+	+	+	1	1	100
Trifolium pratense subsp. semipurpureum	1	1	.	+	1	1	83
Poa alpina	1	.	1	1	+	.	67
Cerastium tomentosum	+	.	.	+	+	+	67
Hippocrepis comosa	+	1	.	.	.	+	50
Armeria canescens subsp. gracilis	.	.	+	.	+	+	50
Minuartia verna subsp. attica	r	+	.	+	.	.	50
Carex kitaibeliana	.	.	.	.	1	1	33
Jasione orbiculata	+	.	1	.	.	.	33
Carduus carlinaefolius	.	.	.	.	+	+	33
Cirsium tenoreanum	+	+	.	.	.	.	33
Galium anisophyllum	+	.	.	+	.	.	33
Petrorhagia saxifraga	+	+	.	.	.	.	33
Pimpinella lithophila	+	+	.	.	.	.	33
Silene multicaulis	+	r	.	.	.	.	33

Rare species: Rel. 1: Trifolium ochroleucum (+), Leontodon hispidus (r); Rel. 2: Dianthus sylvestris (+), Hypericum barbatum (r), Thlaspi praecox (r); Rel. 3: Thesium linophyllon (1), Avenula praetutiana (r); Rel. 5: Carduus affinis (+); Rel. 6: Campanula scheuchzeri (+).

Table 4. Bellidi pusillae-Alopecuretum gerardi. – D: differential species. R: regional character species.

N. of relevés	1	2	3	4	5	6	7	8	Fr
Site	PA	PA	PA	PA	PA	PA	PA	PA	
Elevation (m x 10)	190	199	196	198	188	198	200	198	
Exposition	E	E	NE	NE	NE	NE	N	NNE	
Inclination (°)	15	5	30	25	35	10	25	30	
Relevé area (sqm)	5	5	15	5	5	5	10	15	
Total cover (%)	95	100	90	100	85	100	95	100	
N. of species	15	16	18	18	17	15	25	24	
Rare species	1	1	2	1	1	1	4	–	
Ch. Ass. Bellido pusillae-Alopecuretum gerardi									
Alopecurus gerardi	.	1	1	.	.	1	.	.	38
Bellis pusilla	.	+	.	r	.	1	.	.	38
Trifolium repens subsp. prostratum	1	.	.	.	.	.	.	+	25
Diff. Subass. armerietosum gracilis									
Armeria canescens subsp. gracilis	+	1	1	+	1	1	+	1	100
Lotus corniculatus	1	.	2	2	1	+	1	.	75
Potentilla rigoana	+	+	.	r	.	+	.	+	63
Diff. Carex kitaibeliana-variant									
Carex kitaibeliana	.	1	1	1	3	3	3	2	88
Plantago serpentina	.	+	2	1	.	1	1	2	75
Ch. A. Ranunculo-Nardion									
Crepis aurea subsp. glabrescens	3	3	2	3	2	2	+	+	100
Plantago atrata (R)	1	2	2	+	2	2	2	1	100
Ranunculus pollinensis	.	+	1	+	+	1	+	.	75
Viola aethnensis subsp. splendida	.	+	+	+	+	+	+	.	75
Polygala angelisii	.	.	.	1	.	+	.	.	25
Ch. O. Nardetalia									
Botrychium lunaria (D)	.	+	.	r	.	.	.	r	38
Dianthus deltoides	.	.	.	.	.	.	.	+	13
Ch. C. Calluno-Ulicetea									
Anthoxanthum odoratum s.l.	.	.	.	+	.	.	+	1	38
Companions									
Poa alpina	1	1	1	1	1	2	1	1	100
Cerastium tomentosum	+	+	1	1	1	+	+	+	100
Festuca rubra subsp.microphylla	2	2	2	2	2	.	+	2	88
Trifolium pratense subsp. semipurpureum	1	1	1	1	1	.	1	2	88
Astragalus sirinicus	+	.	.	.	.	.	3	2	38
Asperula aristata subsp.scabra	+	.	.	.	.	.	1	1	38
Hypochoeris cretensis	.	.	+	.	.	.	1	+	38
Thymus polytrichus	+	.	.	.	.	.	1	+	38
Galium anisophyllum	+	.	.	.	.	.	+	+	38
Petrorhagia saxifraga	.	.	.	.	+	.	r	r	38
Carduus carlinaefolius	.	.	+	.	1	.	.	.	25
Leontodon cichoraceus	.	.	+	.	1	.	.	.	25
Anthyllis montana subsp. atropurpurea	.	.	.	.	.	.	+	+	25
Avenula praetutiana	.	.	.	.	.	.	+	+	25
Campanula scheuchzeri	.	.	.	.	+	.	.	+	25
Rumex nebroides	.	.	.	.	+	.	.	r	25

Rare species: Rel. 1: Brachypodium genuense (+); Rel. 2: Cirsium tenoreanum (+); Rel. 3: Bromus erectus (+), Minuartia verna subsp. attica (+); Rel. 4: Hippocrepis comosa (r); Rel. 5: Trifolium ochroleucum (+); Rel. 6: Linum alpinum subsp. gracilius (+); Rel. 7: Alyssum diffusum (+), Luzula multiflora (+), Pimpinella lithophila (+), Trinia dalechampii (+).

features to the Pimpinello lithophilae-Astragaletum sirinici. Both Plantagini serpentinae-Nardetum strictae and Bellidi pusillae-Alopecuretum gerardi were included within the alliance Ranunculo-Nardion. This alliance belongs to the order Nardetalia strictae and to the class Calluno-Ulicetea, of which the name Nardetea strictae is to be regarded as a synonym, according to ELLMAUER's opinion (1993).

4.2. Chorology and Life Forms

The values of SDI, calculated on both chorological and life-form matrices (Tab. 5), show that the distribution of life-forms is much more dishomogeneous than that of the chorotypes in all the vegetation types. That is due to the general marked predominance of hemicryptophytes over chamaephytes. Chamaephytes increase their representation in all the subtypes of the Pimpinello lithophilae-Astragaletum sirinici attaining their highest values in the typical variant and in the subassociation of *Festuca bosniaca*, where they exceed 40%.

From the chorological viewpoint, the less homogeneous vegetation types occur within the Pimpinello lithophilae-Astragaletum sirinici, where the variant of *Brachypodium genuense* and the subassociations of *Sesleria nitida* and *Festuca bosniaca* have values of SDI lower than 0.70. In most of the vegetation types the percentage sum of S-European orophytes and Apennine endemics, representing the "southern" floristic component, ex-

Table 5. Chorological spectrum (A) and life form spectrum (B) of vegetation types. – Abbreviations as in Fig. 2.

A) Chorological spectrum	**GF**	**RS**	**PAty**	**PAbg**	**PAsn**	**PAfb**	**PN**	**BA**
Chorotypes								
Cosmopolitan	7,14	0	0	0	0	0	1,26	0,99
Circumboreal	5,71	3,64	2,27	3,9	2,2	1,05	4,02	6,62
Eurasian	11,43	29,09	12,84	12,39	10,99	7,85	34,67	8,61
Central European orophytes	12,86	10,9	13,9	9,63	11,26	17,28	15,83	17,55
S - European orophytes	42,86	27,27	38,23	39,68	36,54	47,62	8,04	29,14
Apennine endemics	20	29,09	27,94	34,4	39,01	27,23	36,18	37,09
Mediterranean	0	0	4,81	0	0	0	0	0
Simpson's index	**0,74**	**0,74**	**0,74**	**0,7**	**0,69**	**0,67**	**0,72**	**0,74**

B) Life form spectrum	**GF**	**RS**	**PAty**	**PAbg**	**PAsn**	**PAfb**	**PN**	**BA**
Life forms								
Chamaephytes	18,18	7,69	40,43	28,95	32,77	41,84	5,74	10,8
Hemicryptophytes	74,24	92,31	57,95	71,05	67,23	58,16	90,34	88,26
Geophytes	7,58	0	0,54	0	0	0	1,31	0,94
Therophytes	0	0	1,08	0	0	0	2,61	0
Simpson's index	**0,41**	**0,14**	**0,5**	**0,41**	**0,44**	**0,49**	**0,18**	**0,21**

ceeds 60%, or even 70% (see Tab. 5A). The S-European orophytes markedly decline in the Plantagino serpentinae-Nardetum strictae, where they are replaced by the Eurasian element, representing the "temperate" flora. The Eurasian species play a major compositional role also in the chorological spectrum of the phytocoenon of *Rumex scutatus*.

4.3. Site and Soil Parameters

The northern slope of M. Papa is covered with very extensive screes from about 1700 m to the foot of the rocky summit ridges. The Galio magellensis-Festucetum dimorphae colonises the coarse-grained resting screes at altitudes ranging from about 1700 to 1800 m. At these sites the average clast size is of decimetric order (between 30 and 50 cm). The phytocoenon of *Rumex scutatus* ordinarily occurs about 100 m higher in that part of the scree still active and built-up of pebbles of centimetric order, with an average diameter of about 3 cm.

The Pimpinello lithophilae-Astragaletum sirinici covers extensive areas mostly on the S-exposed sites above timberline, free from both scree cover and rock outcrops. On the northern slopes the association is part of a patchy mosaic including also grasslands and scree slopes. The typical variant of the Pimpinello lithophilae-Astragaletum sirinici typicum is confined to the southern slope, occurring within a broad elevational range from 1600 m, where it fills the gaps within beech woods, to 2000 m. The variant of *Brachypodium genuense* is restricted to altitudes comprised between 1860 and 1950 m and to the southern exposition quadrants. Slope is not too steep, with an angle ranging from 20° to 30°. When observed in the field, the stands of this variant seem to be confined to sites with pockets of relatively deep soil, able to sustain the vigorous growth of *Brachypodium genuense*, instead of that of *Astragalus sirinicus*.

The Pimpinello lithophilae-Astragaletum sirinici seslerietosum nitidae occurs exclusively on the northern slopes, mostly at altitudes from 1900 to 1960 m. Slope angle is generally high, never lower than 30°. The stands form longitudinal grassland stripes within the context of N-faced scree slopes. These stripes are originated by the protective "shadow" of boulders against the effects of the downward movement and the fall of fresh material.

The Pimpinello lithophilae-Astragaletum sirinici festucetosum bosniacae was sporadically encountered only at N-exposed and steep windswept ridges. Its stands have a certain degree of surface stoniness allowing several lithophilous speces to settle (*Saxifraga paniculata* subsp. *stabiana, Sempervivum tectorum, Sedum magellense* subsp. *olympicum, Linaria purpurea*).

The Plantagino serpentinae-Nardetum strictae occurs at altitudes ranging from 1830 to 1980 m, generally on moderately inclined and E-ex-

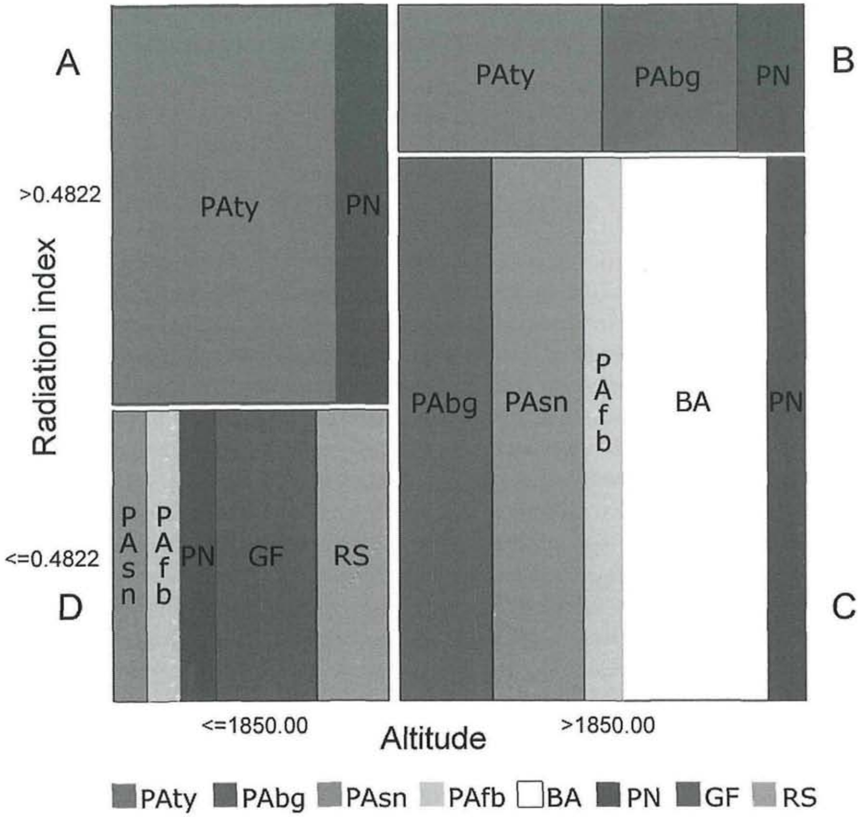

Fig. 3. Mosaic display resulting from the application of the impurity reduction method to the observation space. See text for further detail. Captions as in Fig. 2.

posed slopes. The variant of *Carex kitaibeliana* of the Bellidi pusillae-Alopecuretum gerardii armerietosum gracilis was encountered at altitudes from 1880 to 2000 m over variably inclined and N-exposed slopes. Both associations are confined to sites with a prolonged duration of snow cover. Floristic differences can be explained by the different grazing impact, heavier in the Plantagino serpentinae-Nardetum strictae, and by different microclimatic conditions. The Bellidi pusillae-Alopecuretum gerardi occurs at higher altitudes and at sites where snow lingers for a long time.

On the basis of the two predictor variables (altitude and potential solar radiation), the whole dataset resulted statistically separable into four different sub-groups (Fig. 3). Such sub-groups meaningfully diverge because of the relative frequencies of the different vegetation codes laying inside. Meaningful cut-off values for altitude and RI resulted to be 1850 m and 0.4822 respectively. The Pimpinello lithophilae-Astragaletum sirinici typicum is dominant in the sub-group A, characterized by altitude values lower than 1850 m and RI values greater than 0.4822, and in the sub-group B having altitude values higher than 1850 m and RI values greater than 0.4822. The Bellidi pusillae-Alopecuretum gerardi occurs only in the sub-group C, whose altitude values are greater than 1850 and RI values lower than 0.4822. The Galio magellensis-Festucetum dimorphae and the phytocoenon of *Rumex scutatus* are restricted to the sub-group D (altitude lower than 1850 m and RI lower than 0.4822). The other vegetation types are not so clearly concentrated within one specific subgroup.

The morphological characteristics of the selected soil profiles as determined in the field are summarized in Table 6 and the results of laboratory analyses are reported in Tab. 7. For all the profiles soil temperature regime resulted to be “frigid” as the mean annual soil temperature is lower than 8 °C and the difference between winter and summer soil temperature is more than 6 °C. As for soil water balance, prof. 1 and 2 resulted to have a “xeric” moisture regime, as they are dry throughout the summer period, due to low water capacity (AWC $<$ 80 mm); whereas prof. 3, 4 and 5, with considerably higher AWC values (100–150 mm), resulted to have a “udic” moisture regime, their control section being dry in all parts only for one month in summer (August).

Table 6. Morphological data and site parameters for 5 selected soil profiles. – The name of vegetation types are abbreviated as in Fig. 2. T = field texture; Ston. = stoniness; C = consistence; B = boundaries; Exp.. = exposition.

Pedon/ Horizon	Depth (cm)	Munsell color (moist)	T	Ston. (%)	Structure	B	C	Altitude (m a.s.l.)	Exp.	Inclination (°)
1) LITHIC ULTIC HAPLOXEROLL (PAty)										
A1	0–15	7.5YR3/3	ls	–	f.cr.mo	g.s.	vfr			
A2	15–30	7.5YR3/3	lf	–	f/m.sa.s.	a.w	fr	1850	SE	25
2) LITHIC HAPLOXEROLL (PAsn)										
A1	0–15/18	10YR3/3	ls	25	f.cr.s	g.w	vfr			
A2	15/18–30–38	10YR3/4	fl	35	f.sa.mo	a.w	fr	1900	ENE	35
3) HUMIC DYSTRUDEPT (PN)										
A1	0–10/12	7.5YR3/3	sl	–	f.cr.mo	g.w.	vfr			
A2	10.12.2028	7.5YR3/3	ls	–	f.cr.mo	g.w.	fr			
B1	28–55	7.5YR4/4	l	10	f.sa.mo	g.w.	fr			
B2	55–70–78	7.5YR4/4	l	20	f.sa.s	a.w.	–	1980	NE	10
4) ENTIC HAPLUDOLL (PAbg)										
A1	0–20	10YR3/3	ls	–	f.cr.w	a.w.	fr			
A2	20–50	7.5YR3/3	ls	–	f/m.sa.mo	g.s.	fr			
Bw	50–70	7.5YR4/4	lf	–	f/m.sa.s	a.w.	fr			
BC	70–80	7.5YR5/6	lf	70	f.sa.s	ir	vf	1900	E	25
5) HUMIC EUTRUDEPT (BA)										
A1	0–4/5	7.5YR2/3	ls	–	f.cr.s	a.w.	v.fr			
A2	4/5–28/30	7.5YR3/3	l	–	m.sa.mo	a.w.	fr			
BC	28/30–50/+	10YR5/4	c	80	f.bl.mo	n.d.	f	1980	NE	10

Texture: sl – loamy sand; l – loam; ls – sandy loam; lf – silty loam; c – clay
Structure: f – fine; m – medium; cr – crumb; sa – subangular blocky ; bl – blocky; w – weak; mo – moderate; s – strong
Boundaries: a – abrupt; g – gradual; n.d. – not determined; w – wavy; s – smooth; ir – irregular
Consistence : vfr – very friable; fr – friable; f – firm; vf – very firm

Table 7. Physical-chemical characteristics of 5 selected soil profiles. – Abbreviations as in Fig. 2. – O.C. = organic carbon; O.M. = organic matter; C Sand = coarse sand; F Sand = fine sand.

Profile	Hor.	pH (H_2O)	pH (KCl)	$CaCO_3$ (%)	O.C. (%)	O.M. (%)	Tot. N (%)	C/N (%)	Av. P_2O_5 (ppm)	Exch. Bases (cmol/kg)				Exch. H^+ (cmol/kg)	C.E.C. (cmol/kg)	Bases Sat. (%)	C sand (%)	F sand (%)	Silt (%)	Clay (%)
										Ca	Mg	K	Na							
PAty	A1	6,3	5,6	0	6,95	11,95	0,7	9,9	51,1	23,7	2,05	0,57	0,3	14,4	41,04	64,9	36,7	15	36,2	12,1
	A2	7,3	6,4	2	3,66	6,3	0,51	7,2	38	31,88	1,14	0,36	0,24	6,16	39,78	84,5	22,1	11,3	52,5	14,1
PAsn	A1	6,8	6,2	2	7,15	12,3	0,71	10,1	51,5	35,06	3,05	0,75	0,24	10,1	49,2	79,5	46,4	15,8	21,1	16,7
	A2	7,3	6,4	3,5	5,7	9,83	0,53	10,8	26,3	34,5	1,6	0,49	0,17	7,2	43,95	83,6	25,8	8,3	52,3	13,6
PN	A1	5,1	4,5	0	7,17	12,34	0,86	8,3	44,4	14	2,05	0,57	0,24	22,86	39,72	42,4	62,9	15,1	15,8	6,2
	A2	5,4	4,4	0	4,77	8,2	0,58	8,2	30,9	6,65	0,91	0,32	0,24	21,97	30,09	27	38,1	28,9	25,2	6,8
	B1	5,6	4,6	0	3,09	5,32	0,35	8,8	20,6	11,09	1,14	0,29	0,37	15,67	28,56	45,1	22,6	14	48,8	14,6
	B2	5,7	4,7	0	1,7	2,92	0,28	6,1	26,8	11,5	1,37	0,18	0,24	11,45	24,74	53,7	14,2	5,1	60,4	20,4
PAbg	A1	6,1	5,3	0	5,52	9,49	0,59	9,3	49,5	22,45	1,83	0,68	0,24	12,64	37,84	66,6	36,7	14,1	35,9	13,2
	A2	6,3	5,3	0	4,37	7,52	0,5	8,7	49,3	19,4	1,6	0,36	0,24	8,9	30,49	70,8	36,7	12,2	37	14
	Bw	6,5	5,8	2	2,69	4,63	0,37	7,3	15,6	24,53	1,37	0,32	0,3	7,25	33,77	78,5	19,5	4	55,8	20,8
	BC	6,8	6	3	0,43	0,74	0,18	2,4	19,2	24,12	1,14	0,25	0,3	4,46	30,27	85,3	14	6,2	50,2	29,6
BA	A1	5,1	4,5	0	10,26	17,65	0,93	11	53,8	19,11	3,2	1	0,3	28,1	51,73	45,7	61,7	10,3	19,1	8,8
	A2	5,3	4,3	0	3,84	6,6	0,43	8,9	18,5	10,67	1,37	0,36	0,3	19,95	32,65	38,9	27,8	15,2	38,3	18,7
	BC	7,6	6,9	10	1,29	2,22	0,16	8,1	13,7	49,06	1,37	0,26	0,22	0,55	51,46	98,9	11,1	4,4	42,6	41,9

Profile 1, corresponding to the Pimpinello lithophilae-Astragaletum sirinici typicum (rel. 9), represents a shallow rendzina (Lithic Ultic Haploxeroll) on a rather stabilized limestone debris, consisting of a mollic epipedon, dark brown, 30 cm thick, with a crumb to subangular blocky structure, directly overlying coarse fragments of calcareous rocks. Its texture is sandy loam to silt loam, showing a significant increase of the silt fraction with depth; the water storage capacity is rather low (AWC = 70 mm). Soil reaction is slightly acid to neutral and the matrix is non- to slightly calcareous. Base saturation ranges from 65% in the topsoil to 85% in the subsoil, pointing to initial processes of Ca removal in the surface horizon. The organic matter content is very high throughout the epipedon and the low C/N ratio (<10) indicates a rather rapid decomposition of plant residues, leading to formation of eutrophic mull humus.

Profile 2, corresponding to the Pimpinello lithophilae-Astragaletum sirinici seslerietosum nitidae (rel. 23), is a shallow rendzina (Lithic Haploxeroll) located on a steep slope, with a mollic epipedon, dark coloured, 30/38 cm thick, and directly below a gravelly and stony C horizon. It is similar to profile 1 in morphological and textural characteristics, but it has a slightly lower available water capacity (AWC = 60 mm) due to the presence of calcareous fragments of various sizes throughout the epipedon. In comparison with prof. 1, organic matter contents are higher both in A_1 and A_2 subhorizons although C/N values are not significantly different; also the surface horizon, slightly calcareous, has considerably higher pH values (nearly neutral) and a higher base saturation status, reaching 80%.

Profile 3, corresponding to the Plantagino serpentinae-Nardetum strictae (rel. 6), is a moderately deep acid brown soil (Humic Dystrudept) with an AB_wC profile, consisting of an umbric epipedon, dark brown, with a crumb structure and a cambic B horizon, brown, with a moderate subangular blocky structure. Limestone fragments are found throughout the profile, increasing with depth, as well as at the base of the solum; nevertheless, due to advanced processes of carbonate dissolution and Ca removal, this soil is strongly to moderately acid (pH 5.1–5.7), free of primary carbonates, and rather desaturated (base saturation ranging from 43% in A1 to 53,7% in B2). The texture changes from loamy sand in the topsoil to loam in the subsoil, due to a significant increase of the silt and clay fractions with depth. Thus this soil has a much higher available water capacity than profiles 1 and 2 (150 mm).

Profile 4, corresponding to the variant of *Brachypodium genuense* of the Pimpinello lithophilae-Astragaletum sirinici typicum (rel. 17), is a moderately deep soil with a comparable profile development (ABwBC sequence), but leaching has not been as strong as in profile 3. In fact, this soil has higher pH values, ranging from subacid to neutral (6.1–6.8), it is slightly calcareous in the subsurface horizons, has higher levels of basic cations, particularly Ca, and a much higher base saturation (66–85%). It can be classified as Entic Hapludoll, being characterized by a thick mollic epipedon, dark coloured, underlain by a brown cambic B horizon containing free carbonates. Below this horizon, pockets of a yellowish brown loamy material, very rich of calcareous fragments, may be present (BC horizon). Particle size analysis showed a gradual downward increase of the clay and silt fractions, which are responsible for a rather high water storage capacity (AWC = 164 mm).

Profile 5, corresponding to the Bellidi pusillae-Alopecuretum gerardi (rel. 6), consists of a well developed umbric epipedon, highly humiferous, particularly in the 0–5 cm layer, with a strong crumb to subangular blocky structure, and a yellowish brown, blocky structured BC horizon composed of silty clayey materials mixed with abundant limestone fragments. Chemical analyses indicate that the pH is strongly acid in the epipedon (5.1–5.3) and sharply increases to slightly alkaline values (7.6) in the BC horizon, where calcium carbonate, leached from the upper horizons, accumulates. Also exchangeable Ca, rather low in the A horizons, becomes abundant in BC, increasing base saturation status to near 100%. All these chemical characteristics are a consequence of the strong leaching caused by snow melting in spring. However, due to the presence of a fine textured subsurface horizon, which is somewhat poorly drained, $CaCO_3$ and basic cations are not completely leached from the soil but they accumulate in BC. According to Soil Taxonomy this soil can be classified as Humic Eutrudept, considering the presence of a layer with free carbonates and a high base saturation and also the presence of an umbric epipedon.

5. Discussion and Conclusions

The watershed ridges of the Sirino-Papa massif have a prevailing W-E orientation. As a consequence, the northern and southern slopes of the relief are markedly more extended than the eastern and western ones. Because southern and northern slopes of a relief are generally considered those more climatically contrasting, vegetation diversity of the massif is expected to be enhanced. Our study offers a clear confirmation of this assumption, even if limited to the summit areas of the massif. In fact, the thorny cushion vegetation is confined to the southern slopes in a sharp physiognomical and structural contrast with the closed grasslands occurring on the northern slopes. The occurrence of summit areas extensively covered by a thorny cushion vegetation which is pratically unique along the whole range of the Apennines, can be explained by the position isolated and exposed to the humid winds blowing from the sea, of the Sirino-Papa massif (PIGNATTI & al. 1980). The contrast between northern and southern slopes has also a phytogeographic meaning as a consequence of the peculiar geographic position of the Sirino-Papa massif, lying in the northern portion of the southern Apennines, a mountain district phytogeographically "ecotonal" between the C-European and Mediterranean mountains, as clearly demonstrated by PASSALACQUA 1998. From the phytogeographical viewpoint the thorny-cushion shrubs are, in fact, a typical oromediterranean vegetation of ancient eastern origin (PIGNATTI & al. 1980), whereas the *Nardus stricta*-grasslands belonging to the Plantagino serpentinae-Nardetum strictae are a southern plant community vicariant of a typical eurasian-eurosibirian vegetation (TOMASELLI & al. 2003) and represent the remnants of a temperate-boreal vegetation. In any case, the prevailing phytogeographic characterization of the massif seems to be in the oromediterranean sense, because when the soil has a "xeric" moisture regime and a high surface stoninesss, as in the plant communities dominated by *Sesleria nitida* and by *Festuca bosniaca*, the thorny *Astragalus sirinicus* spreads also on the northern side of the relief.

The asymmetry of the vegetation of the alpine life zone in the Sirino-Papa massif, documented by the phytosociological analysis, is furthermore confirmed by the life-form distribution, reflecting different structural vegetation assessments and, more markedly, by the distributions of chorotypes within vegetation types. The chamaephytes have, in fact, their higher frequency values on the southern slope, and only the Plantagino serpentinae-Nardetum strictae and the phytocoenon of *Rumex scutatus* exhibit a clear "eurasian" mark. As regards the habitat condition, opposite situations are represented by the Pimpinello lithophilae-Astragaletum sirinici typicum and the Bellido pusillae-Alopecuretum gerardi. The first one requires high values of solar radiation and results sufficiently invariant with respect to altitude. Thus, radiation accessibility results to be its limiting factor. On the contrary, the Bellido pusillae-Alopecuretum gerardi is characterized by high values of elevation and low values of solar radiation.

Also soil profiles reflect the general asymmetry of the summit vegetation, mostly with reference to the soil moisture regime. Other important differences seem to be related to microtopographic variations conditioning the abundance of rock fragments and debris, the depth of the horizons and the leaching of calcium and other mineral nutrients. The Pimpinello lithophilae-Astragaletum sirinici typicum and the Pimpinello lithophilae-Astragaletum sirinici seslerietosum nitidae have shallow soil profiles lying on a rather stabilized limestone debris. The Plantagino serpentinae-Nardetum strictae and the variant of *Brachypodium genuense* of the Pimpinello lithophilae-Astragaletum sirinici typicum, occurring on gentler slopes, have comparable moderately deep soil profiles poor in rock fragments. The soil profile of the Bellidi pusillae-Alopecuretum gerardi is strongly influenced by the rapid melting of the abundant snow cover determining the differences in pH between the acid epipedon and the alkaline BC horizon, where $CaCO_3$ and basic cations are accumulated.

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