J. Plant Develop.
20(2013)*: *121 – 140

THE DWARF SHRUBS COMMUNITIES WITHIN *LOISELEURIO-VACCINIETEA* Eggler ex Schubert 1960 FROM ROMANIAN EASTERN CARPATHIANS

MARDARI Constantin[1*], OPREA Adrian[1],
MÂNZU Ciprian[2], BÎRSAN Ciprian[1]

Abstract: A numerical analysis of dwarf shrubs communities within *Loiseleurio-Vaccinietea* Eggler ex Schubert 1960 class, based on 181 relevés assigned to *Loiseleurio-Vaccinion*, *Rhododendro-Vaccinion* and a part of *Pinion mugo* is presented in this paper. An agglomerative hierarchical clustering (Flexible beta algorithm with Bray-Curtis dissimilarity) was performed. Six vegetal associations were distinguished and characterized: *Cetrario islandicae-Loiseleurietum procumbentis*, *Empetro-Vaccinietum gaultherioidis*, *Rhododendro myrtifolii-Vaccinietum gaultherioidis*, *Campanulo abietinae-Juniperetum nanae*, *Campanulo abietinae-Vaccinietum myrtilli* and *Bruckenthalio-Vaccinietum myrtilli*. Detrended correspondence analysis complementarily confirmed the hierarchical clustering. Main environmental factors influencing the floristic composition of clusters were analyzed by canonical correspondence analysis using altitude and Ellenberg indicator values of plants species as variables. Canonical correspondence analysis confirmed that altitude, light and temperature are the main factors influencing the floristic composition of the vegetal communities from *Loiseleurio-Vaccinietea*.

Key words: vegetation, *Loiseleurio-Vaccinietea*, diagnostic species, numerical classification.

Introduction

Loiseleurio-Vaccinietea Eggler ex Schubert 1960 class groups together alpine and subalpine dwarf shrubs communities from boreal and arctic regions [MUCINA, 1997] edified by *Ericaceae* species (e.g. *Loiseleuria*, *Vaccinium* spp., *Rhododendron* spp., *Bruckenthalia* spp. etc.). This vegetation class include one phytosociological order, *Rhododendro-Vaccinietalia* Br.-Bl. in Br.-Bl. et Jenny 1926 (arctic-boreal and (sub-)alpine ericoid dwarf shrub heathlands), with two alliances (in the Romanian Carpathians): *Loiseleurio-Vaccinion* Br.-Bl. in Br.-Bl. et Jenny 1926 (cryophilous dwarf-shrub heathlands on wind-swept slopes and edges) and *Rhododendro-Vaccinion* Br.-Bl. in Br.-Bl. et Jenny 1926 (subalpine chionophilous wind-swept dwarf shrub heathlands) [CHIFU & al. 2006].

The syntaxonomic affiliation of the alliances of *Loiseleurio-Vaccinietea* Eggler ex Schubert 1960 was questionable from the beginning. Both *Loiseleurio-Vaccinion* Br.-Bl. in Br.-Bl. et Jenny 1926 and *Rhododendro-Vaccinion* Br.-Bl. in Br.-Bl. et Jenny 1926 alliances were first classified, based on floristic and physiognomic criteria, in the *Rhododendro-Vaccinietalia* Br.-Bl. in Br.-Bl. et Jenny 1926 order within *Vaccinio-Piceetea* Br.-Bl. in Br.-Bl. et al. 1939 class. Later, on exclusively floristic considerents, Braun-Blanquet included *Loiseleurio-Vaccinion* Br.-Bl. in Br.-Bl. et Jenny 1926 alliance in the

---

[1] "Anastasie Fătu" Botanical Garden of "Alexandru Ioan Cuza" University, Dumbrava Roşie 7-9, 700487, Iaşi – Romania
[2] "Alexandru Ioan Cuza" University, Biology Department, Carol I 11, 700506, Iaşi – Romania
* Corresponding author. E-mail: mardariconstantin@yahoo.com

Piceetalia excelsae Pawłowski in Pawłowski et al. 1928 order [BRAUN-BLANQUET, 1964]. In an other classification system (of Krajina, 1933) [BOŞCAIU, 1971], the *Loiseleurio-Vaccinion* Br.-Bl. in Br.-Bl. et Jenny 1926 alliance is included in *Caricetalia curvulae* Br.-Bl. in Br.-Bl. et Jenny 1926 within *Juncetea trifidi* Hadač 1946 class, while the *Rhododendro-Vaccinion* Br.-Bl. in Br.-Bl. et Jenny 1926 is classified under *Vaccinio-Piceetea* Br.-Bl. in Br.-Bl. et al. 1939 class [BOŞCAIU, 1971]. Eggler unite all the communities edified by nanophanerophytes from the subalpine and alpine regions in one class, *Loiseleurio-Vaccinietea* Eggler ex Schubert 1960, including one order (*Empetretalia hermaphroditae* Schubert 1960) and three alliances (*Cetrario-Loiseleurion* Br.-Bl. et Siss. 1939, *Rhododendro-Vaccinion* Br.-Bl. in Br.-Bl. et Jenny 1926, and *Juniperion nanae* Br.-Bl. et Siss. 1939) [BOŞCAIU, 1971]. Other studies using physiognomic, quantitative and qualitative parameters support also a delimitation among vegetal communities of *Juncetea trifidi* Hadač 1946 and *Loiseleurio-Vaccinietea* Eggler ex Schubert 1960 [DÚBRAVCOVÁ & al. 2005]. Classification of the alpine and subalpine dwarf shrubs communities in one vegetation class is also retained in newer books and papers [GRABHERR, 1993; RIVAS-MARTINEZ & al. 1999; RODWELL & al. 2002; ŠIBÍK & al. 2006; KLIMENT & al. 2010].

Another problem which generated different opinions is the classification of the secondary pure communities edified by *Vaccinium myrtillus* in *Loiseleurio-Vaccinietea* Eggler ex Schubert 1960. Initially, *Vaccinietum myrtilli* Szafer 1923 has been classified in *Calamagrostion villosae* Pawłowski in Pawłowski et al. 1928 (within *Juncetea trifidi* Hadač 1946) and later in *Vaccinion myrtilli* Krajina 1933 alongside dwarf pine communities and spruce forests (within *Vaccinio-Piceetea* Br.-Bl. in Br.-Bl. et al. 1939 class). An interesting approach [ŠIBÍK & al. 2006] is that to restrict the *Vaccinion myrtilli* Krajina 1933 alliance only to the acid mesophilous dwarf-shrub communities of the subalpine belt (of Western Carpahians and High Sudeten) and include it in *Loiseleurio-Vaccinietea* Eggler ex Schubert 1960 class. Another perspective was to unite the phytocoenoses edified by *Vaccinium myrtillus* with those of *Bruckenthalia spiculifolia* and *Juniperus sibirica* from the subalpine areas (of Romanian Carpathians) in a particular alliance, namely *Junipero-Bruckenthalion* (Horvat 1949) Boşcaiu 1971, within *Junipero-Pinetalia mugi* Boşcaiu 1971 and *Vaccinio-Piceetea* Br.-Bl. in Br.-Bl. et al. 1939. In this context, the *Junipero-Bruckenthalion* alliance represents a vicariant syntaxon of the *Juniperion nanae* Br.-Bl. et Siss. 1939 from Alps and Pyrrenees [BOŞCAIU, 1971], which is integrated in the class of *Loiseleurio-Vaccinietea* Eggler ex Schubert 1960 [GRABHERR, 1993; RODWELL & al. 2002]. Taking into consideration all these aspects, we also included in the analisys the communities of *Juniperus sibirica* and *Vaccinium myrtillus* from the (sub-) alpine belt of vegetation in the Romanian Eastern Carpathians.

Vegetal communities from *Loiseleurio-Vaccinietea* Eggler ex Schubert 1960 have been well documented for Romanian Carpathians [BORZA, 1934; BELDIE, 1967; VICOL & al. 1967; RESMERIȚĂ, 1979; BOŞCAIU, 1971; MITITELU & al. 1986; COLDEA, 1990; CHIFU & al. 2006]. Also, in romanian phytosociological literature there are some synthesis papers in which different opinions on classification of (sub-) alpine dwarf-shrubs exists [COLDEA, 1991; SANDA & al. 1997; CHIFU & al. 2006; SANDA & al. 2008], each one with its particularities. Based on the altitudinal location and the floristic composition, rich in microtherm elements characteristic to the order *Caricetalia curvulae* Br.-Bl. in Br.-Bl. et Jenny 1926, Coldea (1991) include the *Loiseleurio-Vaccinon* Br.-Bl. in Br.-Bl. et Jenny 1926 alliance under the *Juncetea trifidi* Hadač 1946 vegetation class. Also, *Rhododendro-Vaccinion* Br.-Bl. in Br.-Bl. et Jenny 1926 alliance representing dwarf shrubs from subalpine belt vegetation (edified by *Vaccinium myrtillus* and *Rhododendron myrtifolium*) has a suballiance status (*Rhododendro-Vaccinenion* Br.-Bl. 1926 em. Oberd. 1957) included under the *Pinion mugi* Pawłowski 1928 alliance and *Junipero-Pinetalia mugo* Boşcaiu 1971, from *Vaccinio-Piceetea* Br.-Bl. in Br.-Bl. et al. 1939 class. A similar opinion on the classification of *Loiseleurio-Vaccinon* Br.-Bl. in Br.-Bl. et Jenny 1926 alliance presents SANDA & al. 2008. Referring to *Rhododendro-Vaccinion* Br.-Bl. in Br.-Bl. et Jenny 1926 alliance, SANDA & al. (2008) include it under the *Athyrio-Piceetalia* Hadač 1962 order from *Vaccinio-Piceetea* class. CHIFU & al. (2006) choose to classify all the dwarf-shrub heathlands communities from subalpine and alpine belts in one class, namely *Loiseleurio-Vaccinietea* Eggler ex Schubert 1960.

The article's main task is to present a numerical classification (hierarchical, agglomerative), an ordination of these vegetal communities, to see if it is consistent with classifications realized in the spirit of Central European School made and published in time by numerous prestigious Romanian phytosociologists. Another objective is to detect the diagnostic species for the distinguished vegetation units and the main ecological factors with a significant influence on their floristic composition.

Material and method

Study area

Eastern Carpathians (Romania) represents the largest geographic unit of the all South-Eastern Carpathians (33,584 km²) and are situated between the northern border of the country and the Prahova valley (Fig. 1). They are relatively "young" mountains, presenting parallel ridges, fragmented by valleys and depressions. Average altitude varies around 1,025 m (the highest altitude – 2,303 m – the summit of Pietrosul Rodnei). Eastern Carpathians includes three geomorphological units, as: the *crystalline* (including Maramureşului, Rodnei, Suhardului and Bistriţei Mountains), the *flysch* (including Stânişoarei, Ceahlău, Tarcăului, Nemirei and Vrancei Mountains) and the *neo-volcanic* unit (including Gutâi, Ţibleş, Călimani-Harghita Mountains). The climate is temperate-continental moderate, characterized by average annual temperatures of 0-2 ºC and average annual precipitations of >1200 mm/m^2 in the highest areas, to 4-6 ºC and 700-800 mm/m^2 in the intra-mountain depressions [BADEA & al. 1987].

The main zonal vegetation units include the boreal forests (coniferous forests extending up to 1700-1750 m), the subalpine belt (of *Pinus mugo* communities, extending up to 1900-2000 m) and alpine belt (alpine dwarf shrubs and meadows, up to 2300 m) [CHIFU & al. 2006]. From a floristic perspective, the Eastern Carpathians are integrated in the Central European floristic region and Carpathian province, including six floristic districts [CIOCÂRLAN, 2000]. According to the Habitats Directive (1992) Eastern Carpathians belong to alpine biogeographic region.

Fig. 1. Geographical position of Eastern Carpathians reported to Romanian territory

Vegetation data

For vegetation analysis, an initial set of 256 relevés (including 242 species) was used. The selection process was based on their assignment to *Loiseleurio-Vaccinon*, *Rhododendro-Vaccinion* and a part of *Pinion mugo* by the original authors. There are more relevés in the phytosociological literature, but they are included in synoptic tables and consequently unusable for this analysis. All relevés were made using the standard method elaborated by the Central European phytosociologic school [BRAUN-BLANQUET, 1964], adapted for Romanian vegetation [BORZA & BOŞCAIU, 1965]. Provenience of relevés is presented in App. 1. Relevés have 2-200 m^2 in size. From the initial dataset, only relevés realized at altitudes exceeding 1400 m and relevés in which the sum of the covering percentages of the dwarf shrubs species was at least 50% were retained. Duplicates or highly-similar relevés (values 0.9-1) were identified using Sorensen similarity index (on presence-absence data) and one member of the relevés pair was randomly removed. Rare species (occurring in less than 5 relevés) were also removed. In these conditions, the final dataset, which was analyzed, included only 181 relevés (with 91 species).

Juvenile trees, bryophytes and lichens were included in the analysis, although they have not been recorded in all relevés. Nomenclature of plants species follows CIOCÂRLAN (2000), of bryophytes follows HILL & al. (2006) and of lichens follows *Index Fungorum*. The term of "diagnostic species" is used only in the context of the studied area (Eastern Carpathians, Romania).

Data analysis

Hierarchical agglomerative clustering has been realized using the GINKGO program from the VEGANA software package [de CÁCERES, 2003; BOUXIN, 2005]. For hierarchical clustering, the mid-percentages values corresponding to the 6 degrees Braun-Blanquet scale were used. These values were square-root transformed and used to create a dissimilarity matrix using the Bray-Curtis index. The flexible beta algorithm (ß = -0.25) was used in order to realize the hierarchical clustering. Afterthat, 19 partitions with 2-20 clusters were computed by pruning the output dendrogram at different hierarchical levels. Optimal number of clusters was determined using the *corrected Rand index* and the *average mean Silhouette index*, both implemented in GINGKO [de CÁCERES, 2003]. Determination of the diagnostic species was realized a posteriori, using the *indicator value* (**IndVal**) coefficient [DUFRÊNE & LEGENDRE, 1997] which is independent of the relative size of the target vegetation unit. Square-rooted values of the **IndVal** were the subject of a permutation test (999 iterations) in order to observe which are the species significantly associated with the clusters [DE CÁCERES & LEGENDRE, 2009]. The results are presented in a table in which the diagnostic species are ranked by decreasing permutation test values alongside its P-values ≤ 0.01.

Detrended Correspondence Analysis (DCA) was performed for two reasons: first, in order to validate the hierarchical agglomerative classification (exclusively from vegetation data) and second, as an indirect gradient analysis in order to relate the relevés ordination to environmental data. The square root transformation, detrending by segments and non weighted average values of the Ellenberg indices -EIVs- (as environmental variables, passive projected) for light (L), temperature (T), continentality (C), soil moisture (H), soil pH (R) and nutrients (N), alongside altitude were used [ELLENBERG & al. 1992]. Also, *Canonical Correspondence Analysis* (CCA) was realized in order to observe the effect of each variable (altitude and Ellenberg's indicator values) on the species composition of each vegetal community within *Loiseleurio-Vaccinietea*. DCAs and CCAs were realized in CANOCO 4.5 [TER BRAAK & ŠMILAUER, 2002].

The box-plots with Ellenberg's indicator values made in order to compare the clusters' ecological features were realized in PAST software [HAMMER & al. 2001]. Environmental differences among the six associations were highlighted using the Kruskal-Wallis non-parametric test and the Mann-Whitney post-hoc test (Bonferroni corrected). Both tests were also carried out in PAST software [HAMMER & al. 2001].

Results and discussions

Univariate analysis of available data referring to *Loiseleurio-Vaccinietea* (Tab. 1) vegetation class as a whole reveals the fact that, in the studied area, these vegetal communities includes species growing in well lighted places, but also occurring in partial shaded places, still preferring alpine and subalpine climate conditions. Most of the specis from the floristic composition occurr mainly in Central Europe and preffer mainly acid and nitrogen deficient soils, with average humidity.

Tab. 1. Univariate analysis of relevés from *Loiseleurio-Vaccinietea* vegetation class

	L	T	C	H	R	N	Altitude
N	181	181	181	181	181	181	181
Min.	4.6	1.8	2.3	4.0	2.0	1.3	1450
Max.	8.3	4.3	4.5	6.2	4.0	4.5	2150
Mean	6.6812	2.6657	3.5662	5.0513	2.8519	2.3000	1805.448
Std. error	0.0544	0.0363	0.0251	0.0250	0.0258	0.0442	11.1811
Variance	0.5369	0.2394	0.1144	0.1135	0.1213	0.3550	22628.42
Stand. dev.	0.7327	0.4893	0.3383	0.3369	0.3494	0.5958	150.4274
Median	6.7	2.6	3.5	5.0	2.8	2.2	1800

Hierarchical agglomerative clustering (Fig. 2): Bray-Curtis dissimilarity and the Flexible beta algorithm generated an ultrametric matrix, from which 19 partitions with 2-20 clusters were extracted. In order to identify the partition with an optimum number of clusters (App. 2) the *corrected Rand index* which compares the probability that 2 randomly chosen clusters to be treated in the same manner in 2 different partitions was used. The matrix of Rand indices showed three local maxima (App. 2a): (0.955) between 5 and 6

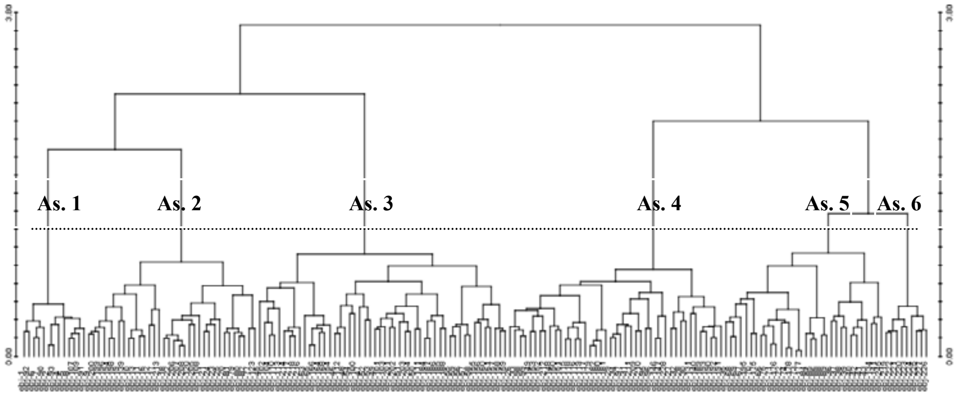


Fig. 2. Dendrogram of the numerical classification (Flexible beta + Bray-Curtis) of the dwarf shrubs communities within *Loiseleurio-Vaccinietea* class in Eastern Carpathians

clusters, (0.979) between 9 and 10 clusters very close to its maximum value (which is 1), indicating that the data clusters are exactly the same. Corroborated with *silhouette statistic* (App. 2b) showing local maxima for the partition with 6 clusters (0.291) and partition with 10 clusters (0.221), the 6 clusters partition was further analyzed at association level (Fig. 2).

Moreover, DCA, complementary used in order to confirm the hierarchical clustering, shows clearly a separation of the six plant communities (Fig. 3). In this case, the relevés are ordonated along the first two axes depending on their floristic similarity. Thus, as more closed are two relevés in the ordination space, the differences regarding their floristic composition are less important. The axes have no ecological meaning (in this case) and represent gradients of floristic similarity.

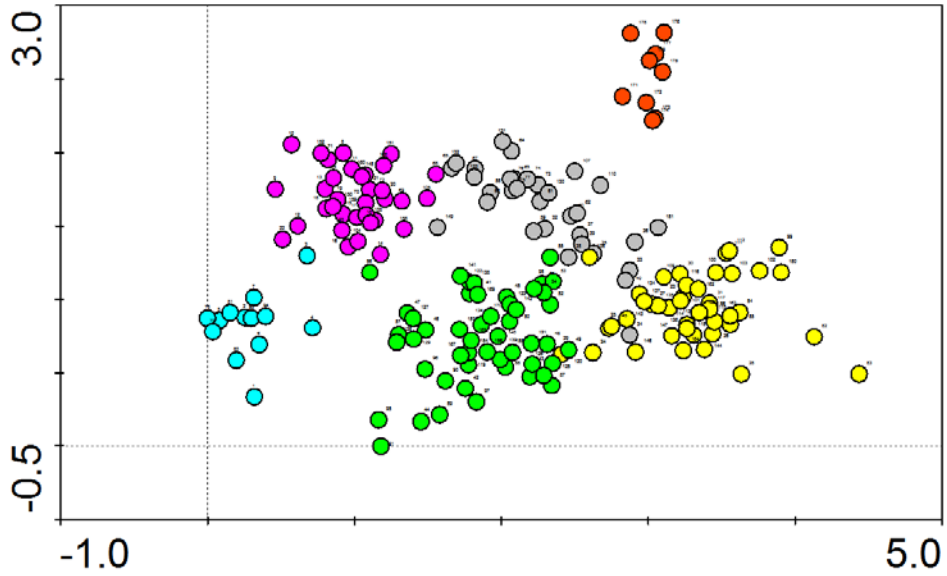


Fig. 3. DCA ordination diagram of the 181 relevés (with clusters generated by hierarchical classification colored as follows: *Cetrario-Loiseleurietum procumbentis*-blue circles, *Empetro-Vaccinietum gaultherioidis*-violet circles, *Rhododendro-Vaccinietum gaultherioidis*-green circles, *Campanulo abietinae-Juniperetum*-yellow circles, *Campanulo abietinae-Vaccinietum*-grey circles, *Bruckenthalio-Vaccinietum*-red circles); first two axes presented. Eigenvalues: 1st axis: 0.535, 2nd axis: 0.242, total inertia: 4.705.

Based on diagnostic species analysis (Tab. 2) we related the groups (clusters) generated by hierarchical clustering to vegetal associations described in literature, which were integrated in the next syntaxa conspectus within *Loiseleurio-Vaccinietea* class, in Eastern Carpathians (Romania):

LOISELEURIO-VACCINIETEA Eggler ex Schubert 1960
RHODODENDRO-VACCINIETALIA Br.-Bl. in Br.-Bl. et Jenny 1926
  Loiseleurio-Vaccinion Br.-Bl. in Br.-Bl. et Jenny 1926
    Cetrario-Loiseleurietum procumbentis Br.-Bl. 1926
  Rhododendro-Vaccinion Br.-Bl. in Br.-Bl. et Jenny 1926
    Empetro-Vaccinietum gaultherioidis Br.-Bl. 1926

Rhododendro-Vaccinietum gaultherioidis Borza 1959 em. Boşcaiu 1971
Junipero-Bruckenthalion (Horvat 1949) Boşcaiu 1971
Campanulo abietinae-Juniperetum nanae Simon 1966
Campanulo abietinae-Vaccinietum myrtilli (Buia et al. 1962) Boşcaiu 1971
Bruckenthalio-Vaccinietum Coldea et al. 2008

Tab. 2. Species significantly associated to the groups resulted from hierarchical clustering (with values of permutation test and P values ≤ 0.01)

Species name	Stat.	P-value
Group 1 Cetrario-Loiseleurietum procumbentis Br.-Bl. 1926		
Loiseleuria procumbens	0.996	0.001
Campanula alpina	0.539	0.003
Carex curvula	0.517	0.001
Group 2 Empetro-Vaccinietum gaultherioidis Br.-Bl. 1926		
Vaccinium gaultherioides	0.782	0.001
Empetrum nigrum subsp. *hermaphroditum*	0.645	0.001
Cetraria islandica	0.539	0.005
Group 3 Rhododendro-Vaccinietum gaultherioidis Borza 1959 em. Boşcaiu 1971		
Rhododendron myrtifolium	0.850	0.001
Ligusticum mutellina	0.646	0.001
Gentiana punctata	0.400	0.004
Group 4 Campanulo abietinae-Juniperetum nanae Simon 1966		
Juniperus sibirica	0.917	0.001
Picea abies	0.686	0.001
Campanula abietina	0.655	0.001
Calamagrostis villosa	0.518	0.005
Achillea distans	0.462	0.004
Oxalis acetosella	0.403	0.008
Poa chaixii	0.403	0.003
Rubus idaeus	0.403	0.01
Senecio ovatus	0.403	0.009
Group 5 Capanulo abietinae-Vaccinietum myrtilli (Buia et al. 1962) Boşcaiu 1971		
Cetraria cucullata	0.685	0.001
Hieracium alpinum	0.637	0.001
Deschampsia flexuosa	0.571	0.002
Hypericum richeri subsp. *grisebachii*	0.523	0.003
Melampyrum saxosum	0.516	0.009
Group 6 Bruckenthalio-Vaccinietum Coldea et al. 2008		
Bruckenthalia spiculifolia	0.876	0.001
Ranunculus montanus subsp. *pseudomontanus*	0.837	0.881
Hylocomium splendens	0.828	0.001
Vaccinium vitis-idaea	0.796	0.001
Nardus stricta	0.744	0.001
Pleurozium screberi	0.741	0.001
Polytrichum commune	0.668	0.001
Potentilla erecta	0.645	0.001
Potentilla ternata	0.612	0.001
Festuca supina	0.520	0.007

Group 1: ***Cetrario-Loiseleurietum procumbentis*** Br.-Bl. 1926

Diagnostic species: *Loiseleuria procumbens*, *Campanula alpina*, *Carex curvula*.

Vegetal communities identified only in Rodnei Mountains [COLDEA & al. 1981; COLDEA & PÎNZARU, 1986; COLDEA, 1990], at high altitudes, ranging between 1930 and 2150 m (mean 2027 m), on plane terrains or with low slopes (mean slope 6º) and various aspects, exposed to cold winds. *Loiseleuria procumbens* is the dominant species (sometimes alongside *Vaccinium gaultherioides* and *Rhododendron myrtifolium*, with increased abundances), and rare specimens of *Juniperus sibirica* or *Pinus mugo* in the shrubs layer. In the herbs layer higher frequencies present *Juncus trifidus*, *Campanula alpina*, *Avenula versicolor*, etc. There are diagnostic species to the *Loiseleurio-Vaccinion* alliance (e.g. *Cetraria islandica*, *Thamnolia vermicularis*, *Primula minima* etc.) and to *Rhododendro-Vaccinietalia* order and *Loiseleurio-Vaccinietea* class (e.g. *Vaccinium gaultherioides*, *V. myrtillus*, *V. vitis-idaea*, *Juniperus sibirica* etc.) in the floristic composition. High constancy presents also some species from the alpine meadows of *Juncetea trifidi* class (e.g. *Festuca supina*, *Juncus trifidus*, *Pulsatilla alba* etc.). These are relative species-poor communities, including heliophyte plants (mean 7.79), indicators of cool conditions specific to subalpine or subalpine sites (mean 2.14). From the continentality perspective, most of the species are transgressive from oceanic (occurring in the western parts of Central Europe) to suboceanic (mean 3.21) species (occurring in the Central Europe), on soils with average humidity (mean 4.89), acid (mean 2.80) and very poor in available nitrogen (mean 1.67).

Group 2: ***Empetro-Vaccinietum gaultherioidis*** Br.-Bl. 1926

Diagnostic species: *Vaccinium gaultherioides*, *Empetrum nigrum* subsp. *hermaphroditum*, *Cetraria islandica*.

Dwarf-shrubs communities edified by *Empetrum nigrum* subsp. *hermaphroditum* and *Vaccinium gaultherioides* in various codominace repports, developed at altitudes varying between 1620 and 2100 m (mean 1845 m), on gentle inclined slopes (mean slope 10°), with various aspects, in Rodnei [RESMERIȚĂ, 1976; COLDEA, 1990], Suhard [COLDEA & PÎNZARU, 1986], Maramureşului [RESMERIȚĂ, 1976], Bistriței [SEGHEDIN, 1983], Hăşmaşul Mare [NECHITA, 2003] and Vrancei Mountains [VICOL & al. 1967; SÂRBU & al. 1999; ŞTEFAN & al. 1999]. The shrubs layer includes few other species, depending on altitude: *Pinus mugo*, *Juniperus sibirica*, *Vaccinium myrtillus*. The herbs layer has a pretty low diversity, *Carex atrata*, *Deschampsia flexuosa*, *Huperzia selago* etc., being among the most frequent species. The lichens layer is very well developed, *Cetraria islandica* presenting coverages up to 75% of the relevé surface. In the floristic composition there are diagnostic species to the *Loiseleurio-Vaccinion* alliance (e.g. *Cetraria islandica*, *Thamnolia vermicularis*, *Primula minima* etc.) and to *Rhododendro-Vaccinietalia* order and *Loiseleurio-Vaccinietea* class (e.g. *Rhododendron myrtifolium*, *Vaccinium gaultherioides*, *V. myrtillus*, *V. vitis-idaea* etc.). High constancy presents also some species from the alpine meadows of *Juncetea trifidi* class (e.g. *Juncus trifidus*, *Festuca supina*, *Campanula alpina* etc.). These phytocoenoses include, generally, species preferring well lighted places, but also occurring in partial shaded places (mean 7.05), and adapted to cool conditions of alpine and subalpine sites (mean 2.31) from Central Europe (mean 3.58). They preffer acid (mean 2.63), medium moisted (mean 4.77) and nitrogen deficient (mean 1.89) soils.

Group 3: ***Rhododendro-Vaccinietum gaultherioidis*** Borza 1959 em. Boşcaiu 1971

Diagnostic species: *Rhododendron myrtifolium*, *Ligusticum mutellina*, *Gentiana punctata*.

Rhododendron myrtifolium and *Vaccinium gaultherioides*, in various codominance repports, edifies vegetal communities from the upper limit of the mountain forests up to the alpine belt, on an altitudinal range of 1600-2120 m, depending on the mountain massif (mean altitude 1890 m), on areas very variable in terms of slopes (5º-50º) and aspects. They were described from Rodnei [COLDEA & al. 1981; RESMERIȚĂ & RAȚIU, 1983; COLDEA & PÎNZARU, 1986; COLDEA, 1990], Călimani [HOREANU & VIȚALARIU, 1991], Suhard [COLDEA & PÎNZARU, 1986] and Maramureşului [RESMERIȚĂ, 1978] mountains and present a floristic composition characterized by a low number of species. The shrubs layer is dominated by the species characteristic for the association, alongside with sporadically species as *Vaccinium myrtillus*, *Juniperus sibirica*, or rare individuals of *Pinus mugo*. The herbs layer presents variable coverages and includes a low number of species (*Homogyne alpina*, *Calamagrostis villosa*, *Agrostis rupestris*, *Oreochloa disticha*, *Deschampsia flexuosa* etc.). High constancy present also diagnostic species for *Rhododendro-Vaccinion* and *Loiseleurio-Vaccinion* alliances (*Cetraria islandica*, *Primula minima*), for *Rhododendro-Vaccinietalia* order and *Loiseleurio-Vaccinietea* class (e.g. *Vaccinium myrtillus*, *V. vitis-idaea, Primula minima*, *Juniperus sibirica* etc.). Also, there are many species infiltrated from *Juncetea trifidi* (e.g. *Campanula alpina*, *Juncus trifidus*, *Pulsatilla alba* etc.) and *Vaccinio-Piceetea* (e.g. *Calamagrostis villosa*, *Soldanella hungarica* etc.). In the floristic composition, most of the species preffer generally well lighted places, but they can also occur in partial shaded places (mean 6.75) and are adapted to the cool conditions of the subalpine and alpine sites (mean 2.57) specific to Central European regions (mean 3.45). They also preffer average humid (mean 5.22), acid (mean 2.95), and deficient in available nitrogen (mean 2.38) soils.

Group 4: ***Campanulo abietinae-Juniperetum nanae*** Simon 1966

Diagnostic species: *Juniperus sibirica*, *Picea abies*, *Campanula abietina*, *Calamagrostis villosa*, *Achillea distans*, *Oxalis acetosella*, *Poa chaixii*, *Rubus idaeus*, *Senecio ovatus*.

Include shrubs communities edified by *Juniperus sibirica* described from Maramureşului [RESMERIȚĂ, 1978; RESMERIȚĂ, 1984], Rodnei [COLDEA & PÎNZARU, 1986; COLDEA, 1990], Suhardului [COLDEA & PÎNZARU, 1986], Hăşmaşul Mare [NECHITA, 2003], Bistriței [SEGHEDIN, 1983; OPREA, 2006] and Vrancei Mountains [ŞTEFAN & al. 1999] but probable much more frequent in Eastern Carpathians. These phytocoenoses are developed from the upper limit of the coniferous forests up to the alpine belt, in an altitudinal range between 1450 and 2000 m (mean 1711 m) on terrains with medium slopes (mean 15º) and various aspects. The shrubs layer is compact, including few species alongside the dominat one (e.g. *Pinus mugo*, *Vaccinium myrtillus* etc.). The herbs layer is the most diversified one, in some cases, some species can present higher cover degrees (as *Deschampsia flexuosa*, *Luzula luzuloides* etc.). The bryophytes and lichens layer is also well developed; among the species presenting higher coverages there are *Pleurozium schreberi*, *Hylocomium splendens* or *Cetraria islandica*. From a phytosociological perspective, high constancies presents diagnostic species to *Junipero-Bruckenthalion* (e.g. *Potentilla ternata*), *Rhododendro-Vaccinietalia* and *Loiseleurio-Vaccinietea* (e.g. *Rhododendron mytifolium*, *Vaccinium myrtillus*, *V. vitis-idaea*, *V. gaultherioides*, *Ligusticum mutellina* etc.). These communities includes a mix of half shade species and heliophytes (mean 6.0), indicators of the cool conditions (mean 3.19) from the montane or subalpine areas of the Central Europe (mean 3.83). Most of them prefer average dampness soils (mean 5.22), acid (mean 3.03) and nitrogen deficient (mean 2.86).

Group 5: ***Campanulo abietinae-Vaccinietum myrtilli*** (Buia et al. 1962) Boşcaiu 1971

Diagnostic species: *Cetraria cucullata*, *Hieracium alpinum*, *Deschampsia flexuosa*, *Hypericum richeri* subsp. *grisebachii*, *Melampyrum saxosum*

Vegetal communities from the upper limit of the coniferous forests described from Maramureşului [RESMERIȚĂ, 1976; RESMERIȚĂ, 1984], Rodnei [COLDEA, 1990], Călimani [MARDARI, 2010], Hăşmaşul Mare [NECHITA, 2003], Ciucaş [PAUCĂ & al. 1960] and Vrancei Mountains [SÂRBU & al. 1999; ŞTEFAN & al. 1999], developed at altitudes ranging between 1580 and 1950m (mean 1727 m) on terrains with various slopes and aspects. Besides the dominant species, in the shrubs layer, sporadically appear species as *Juniperus sibirica*, *Pinus mugo* or juvenile trees of *Picea abies*, and *Sorbus aucuparia*. In the herbaceous layer among the most frequent species there are *Luzula luzuloides*, *Hieracium alpinum*, *Hypericum richeri* subsp. *grisebachii*, *Homogyne alpina* etc. There is also a layer of bryophytes and lichens where *Polytrichum juniperinum*, *Dicranum scoparium* and *Cetraria islandica* have high abundancies. In the floristic composition there are diagnostic species for the superior syntaxa and other for the alpine meadows of *Juncetea trifidi* (e.g. *Festuca supina*, *Juncus trifidus*) or for the forests within *Vaccinio-Piceetea* class (e.g. *Soldanella major*, *Luzula sylvatica*). These are relative species-rich communities compared to other *Loiseleurio-Vaccinietea* associations, including plants generally growing in well lighted places, but also in partial shaded places (mean L 6.66), and in cool conditions specific to high montane and subalpine sites (mean 2.73). Most of them are suboceanic species (mean 3.65), occurring mainly in Central Europe, on soils with average humidity (mean 4.97), acid (mean 2.70) and very poor in available nitrogen (mean 2.17).

Group 6: ***Bruckenthalio-Vaccinietum*** Coldea et al. 2008

Diagnostic species: *Bruckenthalia spiculifolia*, *Ranunculus montanus* subsp. *pseudomontanus*, *Vaccinium vitis-idaea*, *Nardus stricta*, *Pleurozium schreberi*, *Polytrichum commune*, *Potentilla erecta*, *Potentilla ternata*, *Festuca supina*.

Classification of the phytocoenoses included by us in *Bruckenthalio-Vaccinietum* is problematic. In the latest classification [COLDEA & al. 2008] they were included in *Bruckenthalio-Vaccinietum* association within *Genistion pilosae* Duv. 1942 em. Schubert 1960 alliance, from *Vaccinio-Genistetalia* Schubert ex. Passarge 1964 order, and *Calluno-Ulicetea* Br.-Bl. et Tx. ex Klika et Hadac 1944 class. In this association were included also phytocoenoses (very similar to those analyzed by us) initially considered as subassociation with *Vaccinium myrtillus* (*vaccinietosum myrtilli*) within *Bruckenthalietum spiculifoliae* Buia et al. 1962 and classified in *Bruckenthalieto-Vaccinion* alliance within *Vaccinio-Piceetalia* order and *Vaccinio-Piceetea* class [BUIA & al. 1962]. Based on the presence of species characteristic to *Loiseleurio-Vaccinietea* (e.g. *Bruckenthalia spiculifolia, Cetraria islandica, Dicranum fuscescens, Vaccinium gaultherioides*) [MUCINA, 1997] and the presence of only two species characteristic to *Nardo-Callunetea* (*Nardus stricta* and *Potentilla erecta*) we consider that these phytocoenoses are more similar to the arctic-alpine dwarf shrubs vegetation and could be classified in *Junipero-Bruckenthalion* alliance from *Rhododendro-Vaccinietalia* order, within *Loiseleurio-Vaccinietea* class.

From another perspective, these phytoceonoses are not similar to those included in the subassociation *bruckenthalietosum* Coldea 1991 from the *Vaccinio-Callunetum vulgaris* Büker 1942 (*Genistion*, *Nardetalia* and *Nardo-Callunetea*), where there are many species characteristic to the above mentioned syntaxa.

We have chosen to classify the vegetal communities within *Bruckenthalio-Vaccinietum* Coldea et al. 1998 from the Eastern Carpathians of Romania in the *Loiseleurio-Vaccinietea microphylli* class because it groups together the alpine and subalpine dwarf-shrubs communities from the boreal and arctic regions of Europe in contrast with the *Calluno vulgaris-Ulicetea minoris* class which include temperate shrubs landes and associated meadows on nutrients deficient soils [MUCINA, 1997]. We believe that classification of such vegetal communities from Romanian Carpathians in *Calluno vulgaris-Ulicetea minoris* could be somehow forced in the absence of many of its diagnostic species in Romania's flora as: *Agrostis curtisii*, *Alchemilla wichurae*, *Anthyllis vulneraria* subsp. *corbierei*, *Campanula recta*, *Carex binervis*, *Centaurea nigra*, *Cladonia portentosa*, *Conopodium majus*, *Daboecia cantabrica*, *Dianthus seguieri*, *Dicranum spurium*, ***Erica ciliaris***, ***E. cinerea***, ***E. vagans***, *Euphorbia polygalifolia*, *Festuca rubra* subsp. *pruinosa*, *Genista anglica*, *Gentiana pannonica*, *Hypnum jutlandicum*, *Jasione laevis*, *Juncus squarrosus*, *Polygala serpyllifolia*, *Thesium pyrenaicum*, *Thymus arcticus* subsp. *drucei*, ***Ulex cantabricus***, ***U. europaeus***, ***U. gallii***, ***U. minor***, *Viola lutea*. Even if there are present some diagnosis species for *Calluno vulgaris-Ulicetea minoris* class (e.g. *Nardus stricta*, *Potentilla erecta*, *Pseudorchis albida*) [MUCINA, 1997] these are transgressive species in more than one vegetation class in Romania. Moreover, the physiognomy of vegetation within *Calluno vulgaris-Ulicetea minoris* is determined by the presence of some *Fabaceae* and *Ericaceae* species with relative tall habitus (from *Ulex* and *Erica* genera which are absent in Romanian flora) [BARDAT & al. 2001]. From another perspective, in the dwarf-shrubs communities within *Loiseleurio-Vaccinietea* from Romanian Eastern Carpathians there are some many diagnostic species for this vegetation class: *Alectoria ochroleuca*, *Bruckenthalia spiculifolia*, *Cetraria nivalis*, *Dicranum fuscescens*, *Empetrum nigrum subsp. hermaphroditum*, *Hieracium alpinum*, *Loiseleuria procumbens*, *Lycopodium clavatum* sensu lato, *Rhododendron myrtifolium*, *Thamnolia vermicularis, Vaccinium gaultherioides* [MUCINA & al. 1997]. Even in the Western Europe this vegetation class is represented by other alliances, the alliances from the Carpathians can be considered as their vicariants. In contrast, in the *Calluno vulgaris-Ulicetea minoris* there are grouped some alliances without correspondence in Romanian vegetation (e. g. *Cisto salviifolii-Ericion cinereae, Daboecion cantabricae, Dactylido oceanicae-Ulicion maritime, Ulicion minoris, Ulici minoris-Ericenion ciliaris, Genistion micrantho-anglicae* etc.).

These phytocoenoses were identified at increased altitudes (mean 1631 m) in Baiului Mountains [TODOR & CULICĂ, 1967], on relatively inclined terrains (mean 30°) with northern and north-eastern aspects. In the shrubs layer, *Vaccinium myrtillus* is the dominant species. *Bruckenthalia spiculifolia* is present in almost all relevés, with coverages up to 25%. Herbaceous layer includes few species, among which *Deschampsia flexuosa*, *Festuca rubra*, *F. supina*, *Potentilla ternata*, *Geum montanum*, *Ranunculus montanus* subsp. *pseudomontanus* and *Nardus stricta* are more frequent. The bryophytes and lichens are also well developed (e.g. *Pleurozium screberi, Hylocomium splendens, Polytrichum commune*, *Cetraria islandica*). In their floristic composition there are preponderantly species preferring lighted places, but also occurring in partial shaded places (mean 6.45), which are growing in the climate conditions specific to high montane to subalpine sites (mean 2.46). Most of them are suboceanic species (mean 3.43), occurring in the most parts of Central Europe, on soils with average humidity (mean 4.80), acid (mean 2.81), and poor in available nitrogen (mean 2.06).

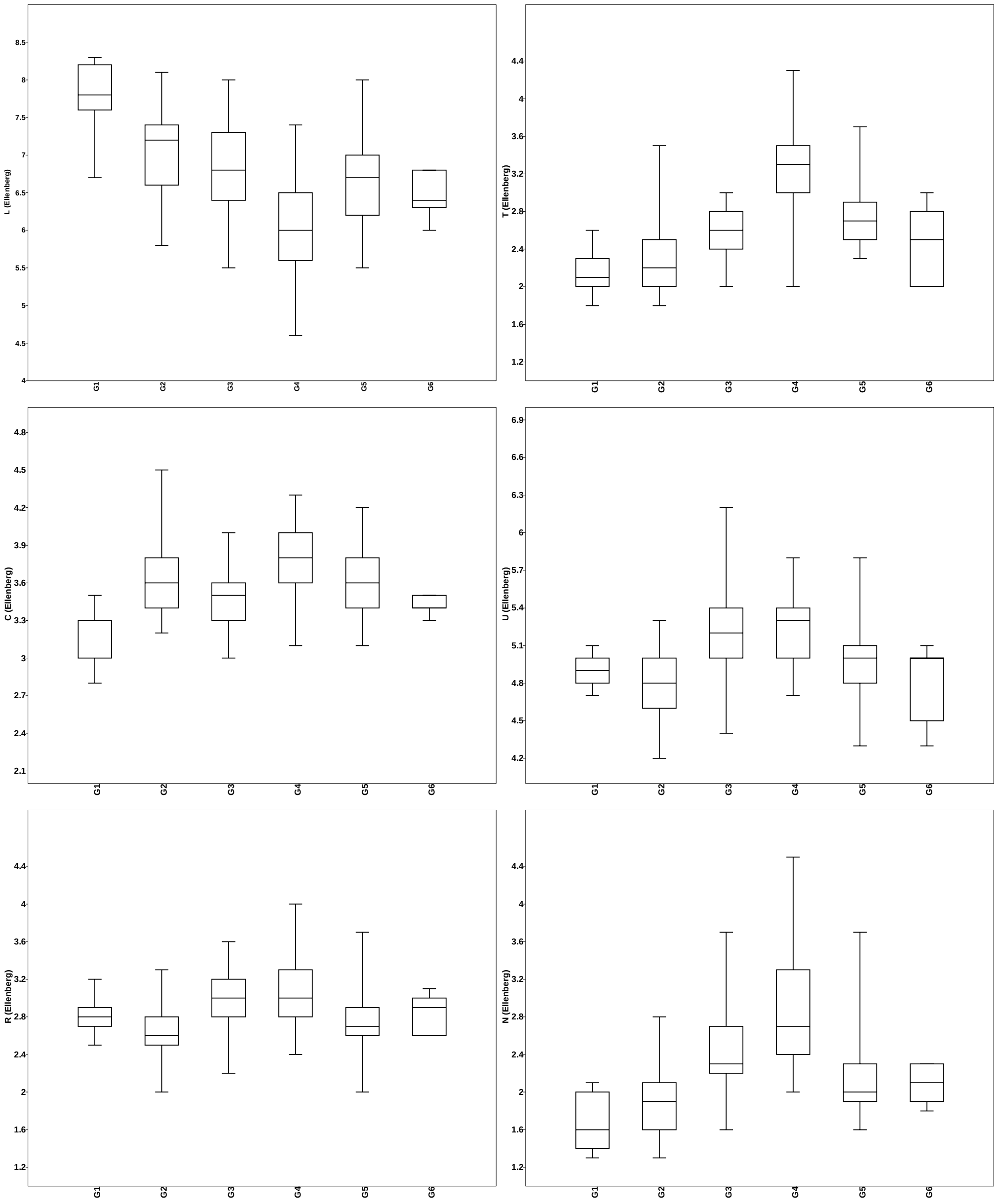


Fig. 4. Box (showing medians) with whisker plots (indicating the minimum and maximum values) of the average Ellenberg indicator values for relevés from the 6 clusters resulted in hierarchical clustering.

Detrended correspondence analysis (DCA)

Detrended correspondence analysis used in order to relate the relevés ordination to environmental data (altitude and means of Ellenberg indicator values) showed that the first axis is the most important one (eigenvalue 0.535), explaining 11.5% of the cumulative percentage variance of species data and 47% of the cumulative percentage variance of species-environment relation. The second axis is less important (eigenvalue 0.242) and explains only 5.1% of the cumulative percentage variance of species data and 16.9% of the cumulative percentage variance of species-environment relation. Together, the first two axes explain 16.5% of the cumulative percentage variance of species data and 63.9% of the cumulative percentage variance of species-environment relation (Tab. 3).

The first DCA axis is strongly positively correlated with EIVs for temperature, for continentality and nutrients and strongly negatively correlated with altitude and EIVs for light and altitude (Fig. 5). This suggests that altitude, light, nutrients and temperature could represent the main factors influencing the floristic composition of the vegetal communities from *Loiseleurio-Vaccinietea*. These ecological factors generate a differentiation among the communities from increased altitudes, including heliophytes species, adapted to more extreme conditions of temperature and low nutrients availability (*Cetrario-Loiseleurietum procumbentis*) from the left side of the ordinogram compared to the communities from lower altitudes including species with the ecological optimum in a higher range of temperature, developed on soils richer in nutrients (*Campanulo abietinae-Juniperetum nanae*) situated in the right side of the ordinogram. The second DCA axis is mainly (negatively) correlated with EIVs for soil moisture and soil reaction (*p*H) indicating that floristic variation is affected also by soil characteristics but in a lower degree as temperature, nutrients, altitude and light. Thus, the more mesophylous vegetal communities developed of less acid substrata, from the inferior part of the ordinogram (*Rhododendro-Vaccinietum gaultherioidis*) can be differentiated from those more xerophylous and developed on more acid soils (*Bruckenthalio-Vaccinietum*) from the superior part of the ordinogram (Fig. 5).

Tab. 3. Summary of detrended correspondence analysis presenting eigenvalues, lengths of gradients and variances of species composition and species environment along axes

Axes	**1**	**2**	**3**	**4**	**Total inertia**
Eigenvalues	0.535	0.242	0.180	0.134	4.705
Lengths of gradient	4.435	2.818	2.367	1.908	
Cumulative percentage variance of species data	11.4	16.5	20.4	23.2	
Cumulative percentage variance of species-environment relation	47.0	63.9	0	0	
Sum of all eigenvalues					4.705

Tab. 4. Characteristics of the six dwarf shrubs communities from Eastern Carpathians (means and standard deviations). *P* values are derived from Kruskal-Wallis non parametric ANOVA.

	Group 1	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**	***P***
EIV L	7.79±0.47	7.05±0.58	6.75±0.59	6.01±0.57	6.65±0.57	6.45±0.50	< 0.001
EIV T	2.14±0.22	2.31±0.40	2.57±0.24	3.19±0.45	2.73±0.33	2.46±0.38	< 0.001
EIV C	3.21±0.21	3.58±0.37	3.44±0.25	3.83±0.30	3.55±0.29	3.43±0.07	< 0.001
EIV U	4.89±0.12	4.77±0.25	5.22±0.29	5.22±0.26	4.97±0.35	4.8±0.28	< 0.001
EIV R	2.80±0.19	2.63±0.30	2.95±0.31	3.03±0.37	2.70±0.29	2.81±0.20	< 0.001
EIV N	1.67±0.30	1.89±0.31	2.38±0.42	2.86±0.68	2.14±0.39	2.06±0.16	< 0.001
Altitude	2027±106	1845±110	1883±112	1711±143	1727±75	1631±57	< 0.001

Significant differences (Fig. 4; Tab. 4; App. 3) among the six vegetal communities have been also detected using Mann-Whitney post-hoc test (Bonferroni corrected). Thus, from the light perspective, *Cetrario-Loiseleurietum procumbentis* association, developed at highest elevations, present the highest exigencies which significantly differ from all the other communities. Other significant differences are between the phytocoenoses within *Campanulo abietinae-Juniperetum nanae*, developed at lower altitudes, including species occurring in more shaded places and those from *Empetro-Vaccinietum gaultherioidis*, *Rhododendro-Vaccinietum gaultherioidis* and *Campanulo abietinae-Vaccinietum myrtilli*. Excepting the *Cetrario-Loiseleurietum procumbentis*, taking into consideration the EIVs for light, between the *Bruckenthalio-Vaccinietum* and the rest of communities there are no significant differences. Temperature separates the communities from *Cetrario-Loiseleurietum procumbentis* and *Empetro-Vaccinietum gaultherioidis* (*Loiseleurio-Vaccinion*) and differentiates them from *Rhododendro-Vaccinietum gaultherioidis* (*Rhododendro-Vaccinion*), and from *Campanulo abietinae-Juniperetum nanae* and *Campanulo abietinae-Vaccinietum myrtilli* (Junipero-Bruckenthalion). Also, the dwarf juniper communities differ in EIVs for temperature from *Rhododendron* and *Vaccinium* communities. EIVs for continentality show that, among all communities, *Cetrario-Loiseleurietum procumbentis* presents the smallest values, due to the presence of more transgressive species from oceanic (mainly in the western parts of Central Europe) to suboceanic (mainly in the Central Europe) areas. Soil moisture also differentiates the communities within *Loiseleurio-Vaccinion* from those of *Rhododendro-Vaccinion* and *Junipero-Bruckenthalion*. Soil reaction shows no difference between *Cetrario-Loiseleurietum* and *Bruckenthalio-Vaccinietum* phytocoenoses and the rest of communities, but differentiate the *Empetrum* from *Rhododendron* edified communities and *Vaccinium myrtillus* from those edified by *Juniperus communis*. Soil available nitrogen differentiates *Cetrario-Loiseleurietum* and *Empetro-Vaccinietum* from *Rhododendro-Vaccinietum*, *Campanulo abietinae-Vaccinietum myrtilli* and *Campanulo abietinae-Juniperetum nanae*. Also EIVs for available nitrogen make the distinction among *Rhododendro-Vaccinietum* and *Campanulo abietinae-Vaccinietum myrtilli* or *Campanulo abietinae-Juniperetum nanae*. Finally, the altitude clearly separates the *Cetrario-Loiseleurietum* from all other vegetal communities, which can also be differentiated among each other on elevation criterion.

As Detrended Correspondence Analysis (DCA) used in order to explore the general variation of floristic composition generated a length of gradient of 4.435 SD units along the first axis, we used further CCA ordination method because it is the most appropriate for our data showing a unimodal response of species to variables [LEPŠ J. & ŠMILAUER, 1999]. Monte Carlo test with 999 permutations (Tab. 5) produced *F* values, measuring the strength of the effect of each variable on species composition, which demonstrated that light, altitude and temperature are the most important factors modeling the floristic composition of vegetal communities within *Loiseleurio-Vaccinietea*.

The influence of light on the floristic composition is significant at higher altitudes, where this ecological factor is more intense and richer in violet rays light and the effect is that the plants are shorter than in lower vegetation levels [ELLENBERG, 1988]. Corroborated with the low temperatures which is another factor responsible for the small growth of plants species, light and altitude differentiate the dwarf shrubs communities of higher altitudes, including almost exclusively heliophytes species, from those of lower altitudes and slightly increased temperatures including species with a taller growth which can generate enough shadow to permit the infiltration of another species normally occurring in more shaded places.

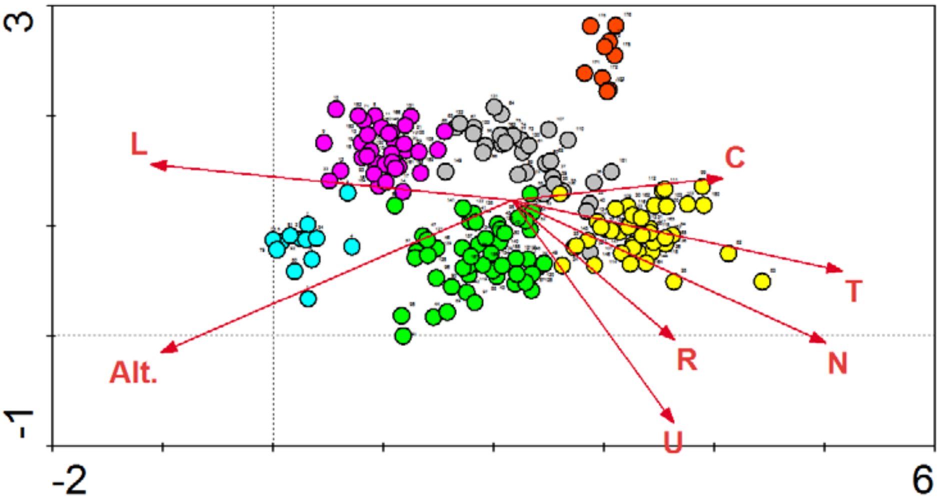


Fig. 5. DCA ordination diagram of the 181 relevés using Ellenberg's indicator values and altitude as passive variables (with clusters generated by hierarchical clustering colored as follows: *Cetrario-Loiseleurietum procumbentis* – blue circles, *Empetro-Vaccinietum gaultherioidis* – violet circles, *Rhododendro-Vaccinietum gaultherioidis* – green circles, *Campanulo abietinae-Juniperetum nanae* – yellow circles, *Campanulo abietinae-Vaccinietum* – grey circles, *Bruckenthalio-Vaccinietum* – red circles); first two axes presented. Eigenvalues: 1st axis: 0.535, 2nd axis: 0.242, total inertia: 4.705. Correlation of DCA axes with variables: L (1st axis: -0.7289, 2nd axis: 0.1127), T (1st axis: 0.6692, 2nd axis: -0.1900), C (1st axis: 0.4243, 2nd axis: 0.0346), H (1st axis: 0.3370, 2nd axis: -0.5281), R (1st axis: 0.3346, 2nd axis: -0.3353), N (1st axis: 0.6393, 2nd axis: -0.3549), altitude (1st axis: -0.6988, 2nd axis: -0.3228).

Tab. 5. Effect of each variable on *Loiseleurio-Vaccinietea* species composition - CCA analysis and Monte Carlo test with 999 permutations, $P = 0.001$. Variables are ranked by decreasing value of the F statistic, measuring the strength of the effect of each variable)

Variable	***F*-value**
EIV light	12.949
altitude	12.442
EIV temperature	10.922
EIV nutrients	10.700
EIV humidity	6.384
EIV continentality	6.354
EIV soil pH	4.757

Conclusions

Multivariate analysis of the dwarf shrubs communities (within *Loiseleurio-Vaccinietea* class) from Eastern Carpathians (Romania) has as result their classification in 6 vegetation types. Based on the identified diagnostic species they can be assigned to the vegetal associations described in phytosociological literature. In their floristic composition there are preponderantly heliophytes species, adapted to low temperatures from subalpine and alpine belts, occurring in the whole Central Europe and preferring moderate humid, acid, and very poor in nutrients soils. Light, altitude, temperature and nutrients are the main factors influencing the floristic composition of these plant communities. The investigated plant communities are all from the Eastern Carpathians and they are not necessarily representative for the whole range of Romanian Carpathians. It is necessary to conduct similar studies in the Southern and Western Carpathians, in order to improve the classification and ecological characterization of Romanian (sub-) alpine dwarf shrubs communities.

References

BADEA L., IORDAN I. & BUGĂ D. (eds.). 1987. *Geografia României*. t. 3. *Carpaţii româneşti şi depresiunea Transilvaniei*. Bucureşti: Edit. Acad. Române, 654 pp.

BARDAT J., BIORET F., BOTINEAU M., BOULLET V., DELPECH R., GÉHU J.-M., HAURY J., LACOSTE A., RAMEAU J.-C., ROYER J.-M., ROUX G. & J. TOUFFET. 2001. Prodrome des Végétations de France // Version 01-2 [14 décembre 2001]. Accessed in 2013.11.15.

BORZA AL. & BOŞCAIU N. 1965. *Introducere în studiul covorului vegetal*. Bucureşti: Edit. Acad. Române, 294 pp.

BOŞCAIU N. 1971. *Flora şi vegetaţia Munţilor Ţarcu, Godeanu şi Cernei*. Bucureşti: Edit. Acad. Române, 494 pp.

BOUXIN G. 2005. Ginkgo, a multivariate analysis package. *J. Veg. Sci*. **16**: 355-359. DOI: 10.1111/j.1654-1103.2005.tb02374.x.

BRAUN-BLANQUET J. 1964. *Pflanzensoziologie*. *Grundzüge der Vegetationskunde*. 3rd Edition. Wien: Springer Verlag, 865 pp.

CHIFU T., MANOLIU A. & TOMA C. (coord.). 2008. *Parcul Naţional Călimani – studii ecologice şi de biodiversitate*. Cluj–Napoca: Edit. Alma Mater, 320 pp.

CHIFU T., MÂNZU C. & ZAMFIRESCU O. 2006. *Flora & Vegetaţia Moldovei (România)*. Iaşi: Edit. Universităţii "Alexandru Ioan Cuza", vol. **2**, 698 pp.

CHYTRÝ M. 2007. Project *Vegetation of the Czech Republic*: *Preface and summary of methods*. In CHYTRÝ M. 2007 (Ed.) *Vegetation of the Czech Republic* 1. Grassland and heathland vegetation Academia. Praha: pp. 35-52.

CHYTRÝ M., TICHÝ L., HOLT J. & BOTTA-DUKÁT Z. 2002. Determination of diagnostic species with statistical fidelity measures. *J. Veg. Sci*. **13**: 79-90. DOI: 10.1111/j.1654-1103.2002.tb02025.x.

CIOCÂRLAN V. 2000. *Flora ilustrată a României*. Bucureşti: Edit. Ceres, 1139 pp.

COLDEA G. 1990. *Munţii Rodnei*. *Studiu geobotanic*. Bucureşti: Edit. Acad. Române, 183 pp.

COLDEA G. 1991. Prodrome des associations vegetales des Carpates du sud-est (Carpates Roumaines). *Documents phytosociologiques*, **13**: 317-539.

COLDEA G. & PÎNZARU G. 1986. La végétation de la reserve Bila-Lala des Monts Rodnei. *Contrib. Bot*. **26**: 153-169.

COLDEA G. & PÎNZARU G. 1987. Vegetaţia rezervaţiei naturale Omul din Munţii Suhard. *Stud. Cerc. Biol., ser. Biol. veg*. **39**(2): 109-118.

COLDEA G., TÄUBER F. & PÎNZARU G. 1981. Asociaţii vegetale din rezervaţia naturală Pietrosul Mare. *Stud. Com. Ocrot. Nat. Suceava*. **5**: 424-452.

COLDEA G., FILIPAŞ L. & STOICA I. A. 2008. Contributions to Romanian vegetation studies (IV). *Contrib. Bot*. **43**: 45-52.

DE CÁCERES M., FONT X., GARCIA R. & OLIVA F. 2003. VEGANA, un paquette des programas para la gestión y análisis de datos ecológicos. *VII Congreso Nacional de la Asociación Española de Ecologia Terrestre*: 1484-1497.

DE CÁCERES M. & LEGENDRE P. 2009. Associations between species and groups of sites: indices and statistical inference. *Ecology*. **90**(12): 3566-3574.

DIHORU G. 1975. *Învelişul vegetal din Muntele Siriu*. Bucureşti: Edit. Acad. Române, 216 pp.

DÚBRAVCOVÁ Z., JAROLÍMEK I., KLIMENT J., PETRÍK A., ŠIBÍK J. & VALACHOVIČ M. 2005. Alpine heaths in the Western Carpathians – a new approach to their classification. *Annali di Botanica*. *Nouva serie*. **5**: 153-160.

DUFRÊNE M. & LEGENDRE P. 1997. Species assemblages and indicator species: the need for a flexible assymmetrical approach. *Ecological Monographs*. **67**: 345-366.

ELLENBERG H. 1988. *Vegetation Ecology of Central Europe*. Ed. 4. Cambridge: Cambridge University Press, 731 pp.

ELLENBERG H., WEBER H. E., DÜLL R., WIRTH V., WERNER W. & PAULIßEN D. 1992. Indicator values of plants in Central Europe. Ed. 2. *Scripta Geobotanica*. **18**: 1-258.

GRABHERR G. 1993. *Loiseleurio-Vaccinietea*. In: GRABHERR G. & MUCINA L. (eds): *Die Pflanzengesellschaften Österreichs*. Teil 2. Natürliche Waldfreie Vegetation. Gustav Fischer Verlag Jena, Stuttgart, New York, 523 pp.

HAMMER Ř., HARPER D. A. T. & RYAN P. D. 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis. *Palaeontologia Electronica*. **4**(1): 1-9.

HILL M. O., BELL N., BRUGGEMAN-NANNENGA M. A., BRUGUÉS M., CANO M. J., ENROTH J., FLATBERG K. I., FRAHM J.-P., GALLEGO M. T., GARILLETI R., GUERRA J., HEDENÄS L., HOLYOAK D. T., HYVÖNEN J., IGNATOV M. S., LARA F., MAZIMPAKA V., MUÑOZ J. & SÖDERSTRÖM L. 2006. An annotated checklist of the mosses of Europe and Macaronesia. *J. Bryol.* **28**: 198-267.

HOREANU CL. & VIŢALARIU GH. 1991. Noi contribuţii la cunoaşterea vegetaţiei din Munţii Călimani. *Anuarul Muz. Bucovinei*, *Fasc. Şti. Nat.* **XI**: 23-32.

KLIMENT J., ŠIBÍK J., ŠIBÍKOVÁ I., JAROLÍMEK I., DÚBRAVCOVÁ Z. & UHLÍŘOVÁ J. 2010. High altitude vegetation of the Western Carpathians - a syntaxonomical review. *Biologia*. **65**(*6*): 965-989.

LEPŠ J. & ŠMILAUER P. 1999. *Multivariate Analysis of Ecological Data*. Faculty of Biological Sciences, University of South Bohemia, České Budějovice. 110 pp. http://www.biodiversity-lorenzomarini.eu/R_manuals/Leps&Smilauer_Multivariate.pdf.

MARDARI C. 2010. *Diversitatea floristică şi fitocenologică a ecosistemelor naturale din bazinul râului Neagra Broştenilor*. Teză de doctorat. Universitatea "Alexandru Ioan Cuza", Iaşi. 326 pp.

MITITELU D., CHIFU T., VIŢALARIU GH., ŞTEFAN N., DĂSCĂLESCU D. & HOREANU CL. 1986. Contribuţie la studiul vegetaţiei lemnoase din Munţii Călimani. *Analele Şti. Univ.* "*Al. I. Cuza" Iaşi,* s. II, a. Biol. **32**: 31-32.

MUCINA L. 1997. Conspectus of classes of European vegetation. *Folia Geobotanica Phytotaxonomica.* **32**: 117-172.

NECHITA N. 2003. *Flora şi vegetaţia cormofitelor din Masivul Hăşmaş*. Piatra Neamţ: Edit. Constantin Mătasă, 383 pp.

OPREA A. 2006-2007. Flora and vegetation of the natural reserve "Zugreni Gorges" (Suceava County). *Rom. J. Biol. Plant biol.* **51-52**: 89-121.

PAUCĂ A., PUŞCARU-SOROCEANU EV. & CIUCĂ M. 1960. Contribuţii la studiul pajiştilor din Masivul Ciucaş. *Com. Bot. SSNG*: 113-136.

RAŢIU O. & MOLDOVAN I. 1974. Consideraţii cenologice asupra vegetaţiei Muntelui Igniş. *Contrib. Bot.* **14**: 85-94.

RESMERIŢĂ I. 1976. Alianţa *Cetrario-Loiseleurion* Br.-Bl. et Siss. 1939 în Munţii Maramureşului. *Contrib. Bot.* **16**: 161-164.

RESMERIŢĂ I. 1978. La classe *Vaccinio-Juniperetea* Pass. et Hoffm. 1968 des montagnes de Maramureş (Roumanie). *Documents Phytosociologiques*. **2**: 365-376.

RESMERIŢĂ I. 1979-1980. Vegetaţia clasei *Vaccinio-Juniperetea* Pass. et Hoffm. 1968 din Carpaţii României. *Stud. Com. Muz. Şti. Nat. Bacău.* **13**: 217-236.

RESMERIŢĂ I. & RAŢIU O. 1983. Contribuţii la cunoaşterea vegetaţiei alpine din Munţii Rodnei. *Contrib. Bot.*: 99-110.

RESMERIŢĂ I. 1983-1984. Recherches sur la flore et la végétation de la Montagne Toroioaga, Maramureş. *Acta Bot. Horti Bucurest.*: 177-184.

RESMERIŢĂ I. 1984. Recherches sur la végétation dans les Montagnes Maramureş-Roumanie. *Documents Phytosociologiques*. **8**: 257-273.

RIVAS-MARTINEZ S., FERNANDEZ-GONZALES F. & LOIDI J. 1999. Ckecklist of plant communities of Iberian Peninsula, Balearic and Canary Islands to suballiance level. *Itinera geobotanica*. **13**: 353-451.

RODWELL J. S., SCHAMINÉE J. H. J., MUCINA L., PIGNATTI S., DRING J. & MOSS D. 2002. *The diversity of European vegetation. An overview of phytosociological alliances and their relationships to EUNIS habitats*. Wageningen. NL. Report EC-LNV no. 2002/54.

SANDA V., POPESCU A. & BARABAŞ N. 1997. Cenotaxonomia şi caracterizarea grupărilor vegetale din România. *Stud. Com. Muz. Şti. Nat. Bacău*. **14**: 1-366.

SANDA V., OLLERER K. & BURESCU P. 2008. *Fitocenozele din România. Sintaxonomie, structură, dinamică şi evoluţie*. Bucureşti: Edit. Ars Docendi, 570 pp.

SÂRBU I., ŞTEFAN N. & OPREA A. 1999. Rezervaţia naturală Lăcăuţi-Izvoarele Putnei (Jud. Vrancea). *Bul. Grăd. Bot. Iaşi*. **8**: 83-92.

SEGHEDIN T. G. 1983. Principalele asociaţii lemnoase din Munţii Bistriţei. Consideraţii metodice. *Anuarul Muz. Jud. Suceava*. **7**: 34-60.

ŠIBÍK J., KLIMENT J., JAROLÍMEK I., DÚBRAVCOVÁ Z., BĚLOHLÁVKOKVÁ R. & PACLOVÁ L. 2006. Syntaxonomy and nomenclature of the alpine heaths (the class *Loiseleurio-Vaccinietea*) in the Western Carpathians. *Hacquetia*. **5**(1): 37-71.

ŞTEFAN N., SÂRBU I. & OPREA A. 1999. Flora şi vegetaţia rezervaţiei naturale “Goru” (jud. Vrancea). *Bul. Grăd. Bot. Iaşi*. **8**: 93-101.

TER BRAAK C. J. F. & ŠMILAUER P. 2002. *CANOCO reference manual and CanoDraw for Windows user’s guide. Software for Canonical Community Ordination (version 4.5)*.-Microcomputer Power, Ithaca, 500 pp.

TICHÝ L. & CHYTRÝ M. 2006. Statistical determination of diagnostic species for site groups of unequal size. *J. Veg. Sci*. **17**: 809-818. DOI: 10.1111/j.1654-1103.2006.tb02504.x.

TODOR I. & CULICĂ S. 1967. Contribuţii la studiul păşunilor din Masivul Gîrbova (studiu geobotanic şi de producţie). *Com. Bot. SSNG*. **IV**: 23-55.

VICOL E., SCHNEIDER-BINDER E. & COLDEA G. 1967. Consideraţii asupra asociaţiei *Empetro-Vaccinietum* Br.-Bl. 1926 din Carpaţii României. *Contrib. Bot.*: 455-463.

***. 1992. Habitats Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora.

***. *Index Fungorum*. www.indexfungorum.org. Accessed at 2013.09.30.

Appendix 1

Provenience of relevés used in analysis

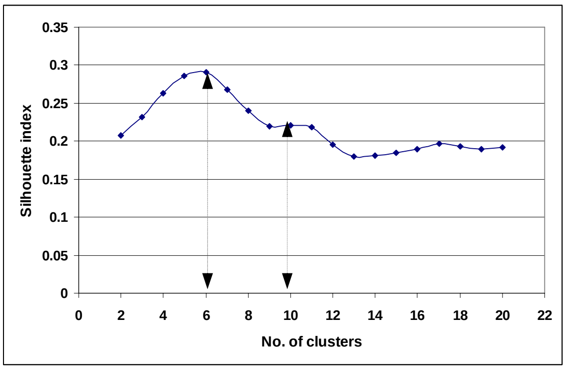
Author(s)	Year	No. of relevés	Mountain massif(s)
COLDEA GH. et al.	1981	10	Rodnei Mountains
COLDEA GH. & PÎNZARU G.	1986	15	Rodnei Mountains
COLDEA GH. & PÎNZARU G.	1987	12	Suhardului Mountains
COLDEA GH.	1990	54	Rodnei Mountains
DIHORU GH.	1975	1	Siriu Mountains
HOREANU CL. & VIŢALARIU GH.	1991	11	Călimani Mountains
MARDARI C.	2010	17	Călimani Mountains
NECHITA N.	2003	16	Hăşmaşul Mare Mountains
OPREA A.	2006-2007	2	Bistriţei Mountains
PAUCĂ et al.	1960	1	Ciucaş Mountains
RAŢIU O. & MOLDOVAN I.	1974	4	Gutâiului Mountains
RESMERIŢĂ I.	1976	24	Maramureşului Mountains
RESMERIŢĂ I.	1978	24	Maramureşului Mountains
RESMERIŢĂ I. & RAŢIU O.	1983	11	Rodnei Mountains
RESMERIŢĂ I.	1984	5	Maramureşului Mountains
RESMERIŢĂ I.	1984	10	Maramureşului Mountains
SÂRBU I. et al.	1999	6	Vrancei Mountains
SEGHEDIN T. G.	1983	10	Bistriţei Mountains
ŞTEFAN N. et al.	1999	8	Vrancei Mountains
TODOR I. & CULICĂ S.	1967	10	Baiului Mountains
VICOL et al.	1967	5	Vrancei, Rodnei Mountains

Appendix 2

a) Incidence matrix presenting the corrected Rand index between partitions with *k* number of clusters

	K=2	K=3	K=4	K=5	**K=6**	K=7	K=8	**K=9**	K=10	K=11	K=12	K=13	K=14	K=15	K=16	K=17	K=18	K=19	K=20
K=2	1,000																		
K=3	0,711	1,000																	
K=4	0,495	0,747	1,000																
K=5	0,441	0,677	0,924	1,000															
K=6	0,405	0,630	0,872	0,947	1,000														
K=7	0,377	0,592	0,828	0,902	**0,955**	1,000													
K=8	0,312	0,502	0,720	0,792	0,843	0,887	1,000												
K=9	0,277	0,452	0,657	0,726	0,776	0,819	0,930	1,000											
K=10	0,268	0,437	0,639	0,707	0,756	0,799	0,910	**0,979**	1,000										
K=11	0,234	0,387	0,574	0,638	0,685	0,726	0,834	0,902	0,923	1,000									
K=12	0,190	0,320	0,485	0,543	0,586	0,624	0,725	0,790	0,810	0,886	1,000								
K=13	0,161	0,274	0,420	0,473	0,512	0,547	0,642	0,704	0,723	0,796	0,908	1,000							
K=14	0,146	0,250	0,387	0,436	0,474	0,507	0,597	0,657	0,676	0,747	0,857	0,948	1,000						
K=15	0,140	0,239	0,372	0,420	0,456	0,488	0,577	0,636	0,654	0,724	0,832	0,923	0,975	1,000					
K=16	0,137	0,234	0,365	0,412	0,448	0,480	0,567	0,626	0,644	0,713	0,821	0,912	0,964	0,989	1,000				
K=17	0,129	0,222	0,346	0,392	0,426	0,457	0,542	0,599	0,616	0,684	0,791	0,880	0,932	0,957	0,968	1,000			
K=18	0,124	0,214	0,336	0,380	0,414	0,444	0,527	0,583	0,601	0,668	0,773	0,862	0,913	0,938	0,950	0,981	1,000		
K=19	0,114	0,197	0,311	0,352	0,384	0,413	0,492	0,546	0,563	0,627	0,730	0,817	0,868	0,892	0,904	0,935	0,954	1,000	
K=20	0,110	0,190	0,300	0,341	0,372	0,400	0,477	0,530	0,546	0,610	0,711	0,798	0,848	0,872	0,884	0,915	0,934	0,980	1,000

b) Determination of the optimum number of clusters using Silhouette index



Appendix 3

***P* values derived from Mann-Whitney post-hoc test (Bonferroni corrected) indicating significant differences between communities from EIV and altitude perspectives.**

a) EIVs light

	Group 1	Group 2	Group 3	Group 4	Group 5	Group 6
Group 1	0					
Group 2	0.003828	0				
Group 3	7.447E-05	n.s.	0			
Group 4	1.882E-06	5.64E-08	3.181E-06	0		
Group 5	0.000142	n.s.	n.s.	0.0002083	0	
Group 6	0.002662	n.s.	n.s.	n.s.	n.s.	0

b) EIVs temperature

	Group 1	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**
Group 1	0					
Group 2	n.s	0				
Group 3	0.0002064	0.002431	0			
Group 4	5.284E-06	6.188E-09	3.591E-09	0		
Group 5	4.309E-05	0.0001648	n.s.	0.0001335	0	
Group 6	n.s.	n.s.	n.s.	0.003634	n.s.	0

c) EIVs continentality

	Group 1	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**
Group 1	0					
Group 2	0.004227	0				
Group 3	0.04367	n.s.	0			
Group 4	1.671E-05	0.02067	1.203E-07	0		
Group 5	0.00774	n.s.	n.s.	0.002799	0	
Group 6	n.s.	n.s.	n.s.	0.001774	n.s.	0

d) EIVs soil moisture

	Group 1	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**
Group 1	0					
Group 2	n.s.	0				
Group 3	0.0004753	2.128E-08	0			
Group 4	0.002606	1.833E-07	n.s.	0		
Group 5	n.s.	n.s.	0.007722	0.02524	0	
Group 6	n.s.	n.s.	0.007885	0.02207	n.s.	0

e) EIVs soil reaction

	Group 1	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**
Group 1	0					
Group 2	n.s.	0				
Group 3	n.s.	0.0003705	0			
Group 4	n.s.	0.000267	n.s.	0		
Group 5	n.s.	n.s.	0.002204	0.003658	0	
Group 6	n.s.	n.s.	n.s.	n.s.	n.s.	0

f) EIVs soil available nitrogen

	Group 1	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**
Group 1	0					
Group 2	n.s.	0				
Group 3	3.937E-05	2.222E-06	0			
Group 4	1.845E-06	3.131E-10	0.00553	0		
Group 5	0.00765	n.s.	0.02603	5.411E-07	0	
Group 6	n.s.	n.s.	n.s.	0.0008066	n.s.	0

g) altitude

	Group 1	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**
Group 1	0					
Group 2	0.000696	0				
Group 3	0.00481	n.s.	0			
Group 4	6.312E-06	0.001345	1.162E-06	0		
Group 5	6.789E-06	0.0002977	1.016E-07	n.s.	0	
Group 6	0.00159	0.0006746	9.362E-05	n.s.	0.02358	0

Received: 19 November 2013 / *Accepted*: 27 November 2013