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HABITAT PREFERENCE OF *LINUM DOLOMITICUM* (LINACEAE)

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Vegetation of the total distribution area of *Linum dolomiticum* was analysed based on 277 phytosociological relevés. After noise elimination by metric multidimensional scaling, relevés were clustered into five groups by Ward's algorithm. The relevé groups were characterised by faithful, constant and dominant species and analysed on the basis of the following species characteristics: phytogeographical area (floral element), phytosociological character, social behaviour type, water and continentality preference categories. Testing the association between *Linum dolomiticum* and other species the u_{hyp} statistics was calculated. With 5 tables.

Key words: dolomite rock grasslands, fidelity, *Linum dolomiticum*, phytosociology

INTRODUCTION

Linum dolomiticum Borbás (Linaceae) is an endemic, pre-glacial relic plant species of Hungary. The distribution of this species is extremely narrow: it lives only on dolomite hills in a region of one square kilometre in Buda Hills near Pilisszentiván (47° 36' N, 18° 52' E). It has one population only, consisting several stands separated by closed deciduous forest.

MÉSZÁROS-DRASKOVITS (1967) and DOBOLYI (2003, 2005) carried out phytosociological studies and multivariate analysis of the habitat of *Linum dolomiticum* in order to determine and characterise the vegetation types of the habitat. 135 relevés were included in those earlier investigations; all of them were marked out so that *Linum dolomiticum* is present in all relevés. Results of these studies revealed that *Linum dolomiticum* occurs mostly in open and closed dolomite grasslands, in the herb layer of open

Quercus pubescens woodlands and rarely in rock steppe. Some parts of the habitat are considered either as transitions among these plant communities or various stages of their degraded forms.

Monitoring of the total distribution area of *Linum dolomiticum* has been ongoing since 2001. Results of the monitoring proved that the distribution of this species shows a peculiar pattern: in certain patches the plant occurs in rather high density, but these alternate with large "empty" areas where it does not occur at all (DOBOLYI 2001–2006).

On the basis of these results and the field experiences the following questions arise:

- Does *Linum dolomiticum* show any preference to any of the surrounding vegetation types?
- Are there any other species in its range that have similar phytosociological preferences to *Linum dolomiticum*?
- Does *Linum dolomiticum* belong to any species-coalition?

To find answers for these questions, phytosociological relevés from the distribution area were analysed by multivariate methods; the faithful, constant and dominant species were determined.

MATERIAL AND METHODS

The present study is based on 277 phytosociological relevés of 2 m × 2 m size taken on the distribution area of *Linum dolomiticum* so that the complete area of distribution and all types of vegetation are represented. *Linum dolomiticum* is present in 137 relevés, absent in 140 relevés.

Nomenclature of the plant names follows HORVÁTH *et al.* (1995).

Numerical classification of the relevés was done by the method proposed by BOTTA-DUKÁT *et al.* (2005): at first principal co-ordinates analysis (PCoA) (LEGENDRE and LEGENDRE 1998) based on relativised Manhattan distances was performed to determine the main gradients in the data set. Possible number of ordination axes in such analysis equals the number of relevés minus 1, but usually only the first few ordination axes contain interpretable ecological information, while the others contain largely noise. To establish the number of interpretable axes, the eigenvalues were compared with random expectations based on the broken-stick model (JACKSON 1993, LEGENDRE and LEGENDRE 1998). In our case the first five axes proved to be significant. The co-ordinates along the significant axes of PCoA were used instead of the raw data as input for the classification. In this way, we were able to avoid the low robustness of agglomerative classification

methods when used on noisy data sets (LAMBERT and WILLIAMS 1966, GAUCH 1982). Ward's algorithm of minimum increment of sum of squares was used for dendrogram construction (WARD 1963, LEGENDRE and LEGENDRE 1998). Both ordination and classification were performed by SYN-TAX 2000 package (PODANI 2001). The number of interpreted groups was selected based on proportion of clusters with more than 4 character species (*i.e.* species with p value lower than 10^{-9} in the Fisher exact test; TICHÝ *et al.* 2008). Thus five clusters were separated and interpreted.

The relevé groups were characterised by faithful ($u_{hyp} > 3$) (CHYTRÝ *et al.* 2002), constant (frequency higher than 60%) and dominant (cover higher than 15% at least 25% of the relevés belonging the group) species and analysed on the basis of the following species characteristics: phytogeographical area (floral element) (HORVÁTH *et al.* 1995), phytosociological character, social behaviour type, water and continentality preference categories (BORHIDI 1993). The values of features characterising the groups of relevés were calculated according to percentage pro rata of plant mass, that is, the sum of the cover values concerning one feature has been expressed in percentage of sum of all cover values of all species.

Testing the association between *Linum dolomiticum* and other species the u_{hyp} statistics was calculated (CHYTRÝ *et al.* 2002). Regarding the high number of pair-wise comparisons, the critical value was set up to 3, instead of the generally used 2 (that correspond the 5% probability of Type I error). The lists of faithful, constant and dominant species were drawn up and the associations between species were calculated by JUICE programme (TICHÝ 2002).

RESULTS

The study of species groups has resulted in five groups of separated relevés.

Group I

Number of relevés: 50.

Characteristics of the group:

- typical exposure: NW, W;
- total cover of vegetation: 90–100%;
- vegetation type: slightly degraded closed dolomite grassland; *Bromus pannonicus* is absent; cover of *Quercus pubescens* and *Fraxinus ornus* is 5–15%;
- diagnostic species: *Anthyllis vulneraria*, *Fraxinus ornus*, *Genista pilosa*, *Linum dolomiticum*, *Phyteuma orbiculare* and *Quercus pubescens*;
- constant species: *Anthericum ramosum*, *Anthyllis vulneraria*, *Carex humilis*, *Festuca pallens*, *Fraxinus ornus*, *Genista pilosa*, *Globularia punctata*, *Helianthemum canum*, *Jurinea mollis*, *Linum dolomiticum*, *Phyteuma orbiculare*, *Quercus pubescens*, *Teucrium montanum*;

- dominant species: *Anthericum ramosum*, *Carex humilis*, *Linum dolomiticum*;
- species characteristics: high proportion of sub-Mediterranean floral elements (Table 1); high proportion of Bromo-Festucion pallentis species, phytosociological composition is similar to group III (Table 2); high proportion of suboceanic species (Table 5).

Group II

Number of relevés: 66.

Characteristics of the group:

- typical exposure: NW, W;
- total cover of vegetation: 80–95%;
- vegetation type: slightly degraded rock steppe; some of the relevés represent close to open grassland communities and seem to be derived from rock steppe by degradation;
- diagnostic species: *Carlina vulgaris*, *Chondrilla juncea*, *Dianthus pontederae* and *Silene otites*;
- constant species: *Anthericum ramosum*, *Anthyllis vulneraria*, *Carex humilis*, *Festuca pallens*, *Genista pilosa*, *Globularia punctata*, *Helianthemum canum*, *Jurinea mollis*, *Teucrium montanum*;
- dominant species: *Carex humilis*;
- species characteristics: high proportion of sub-Mediterranean, Pontic-sub-Mediterranean and Atlantic-sub-Mediterranean floral elements (Table 1); high proportion of specialists (Table 3); high proportion of xerotherm species (Table 4); relatively high continentality preference (Table 5).

Group III

Number of relevés: 52.

Characteristics of the group:

- typical exposure: N, NW;
- total cover of vegetation: 95–100%;
- vegetation type: typical closed dolomite grassland; herb layer of open *Quercus pubescens* woodlands; cover of *Quercus pubescens* and *Fraxinus ornus* is 30–40%;
- diagnostic species: *Allium montanum*, *Biscutella laevigata*, *Bromus pannonicus*, *Campanula rotundifolia* agg., *Chrysanthemum lanceolatum*, *Daphne cneorum*, *Fraxinus ornus*, *Genista pilosa*, *Helianthemum ovatum*, *Phyteuma orbiculare*, *Vincetoxicum hirundinaria*;
- constant species: *Anthericum ramosum*, *Anthyllis vulneraria*, *Asperula cynanchica*, *Biscutella laevigata*, *Bromus pannonicus*, *Campanula rotundifolia* agg., *Carex humilis*, *Festuca pallens*, *Fraxinus ornus*, *Genista pilosa*, *Globularia punctata*, *Helianthemum canum*, *Phyteuma orbiculare*, *Sanguisorba minor*, *Scabiosa canescens*, *Teucrium montanum*;

- dominant species: *Bromus pannonicus*, *Carex humilis*;
- species characteristics: the highest proportion of continental floral elements (Table 1).

Group IV

Number of relevés: 51.

Characteristics of the group:

- typical exposure: S, SW;
- total cover of vegetation: 5–25%;
- vegetation type: slightly degraded type of open dolomite rock grassland; one part of the relevés seems to be derived from rock steppe by degradation;
- diagnostic species: *Alyssum tortuosum*, *Asperula cynanchica*, *Euphorbia seguieriana*, *Fumana procumbens*, *Jovibarba hirta* agg., *Linum dolomiticum*, *Seseli leucospermum*, *Thymus praecox*;
- constant species: *Anthericum ramosum*, *Asperula cynanchica*, *Carex humilis*, *Euphorbia seguieriana*, *Festuca pallens*, *Fumana procumbens*, *Helianthemum canum*, *Jovibarba hirta* agg., *Linum dolomiticum*, *Potentilla arenaria*, *Scabiosa canescens*, *Seseli leucospermum*, *Teucrium montanum*, *Thymus praecox*;
- dominant species: –
- species characteristics: the highest proportion of Central European and Illyric floral elements (Table 1); the highest proportion of the Bromo-Festucion pallentis and indifferent species (Table 2); the highest proportion of the xerotolerant species (Table 4).

Group V

Number of relevés: 58.

Characteristics of the group:

- typical exposure: SE, S, SW;
- total cover of vegetation: 10–35%;
- vegetation type: open dolomite rock grassland;
- diagnostic species: *Carex liparicarpos*, *Dianthus plumarius* subsp. *regis-stephani*, *Euphorbia seguieriana*, *Festuca pallens*, *Fumana procumbens*, *Jovibarba hirta* agg., *Scorzonera austriaca*, *Seseli leucospermum*, *Thymus praecox*;
- constant species: *Anthericum ramosum*, *Carex humilis*, *Carex liparicarpos*, *Euphorbia seguieriana*, *Festuca pallens*, *Fumana procumbens*, *Helianthemum canum*, *Potentilla arenaria*, *Scabiosa canescens*, *Seseli leucospermum*, *Teucrium montanum*, *Thymus praecox*;
- dominant species: –
- species characteristics: high proportion of sub-Mediterranean, Pontic-sub-Mediterranean and Atlantic-sub-Mediterranean floral elements (Table 1); high proportion of the Festucetalia valesiacae and Festucion vaginatae species (Table 2).

According to the u_{hyp} values, no species was found to be associated positively or negatively with *Linum dolomiticum*.

DISCUSSION

Previous phytosociological study of the habitat of *Linum dolomiticum* proved that this species occurs on remarkably different habitats and under various ecological circumstances: either in northern-northwestern exposition in closed dolomite rock grassland and in the herb layer of *Quercus pubescens–Fraxinus ornus* woodlands or in southern exposition in open dolomite rock grassland (DOBOLYI 2003, 2005).

Table 1. The phytogeographical spectrum of the groups of relevés (ranking according to HORVÁTH *et al.* (1995) (expressed in percentage)

	Groups of relevés				
Area	I	II	III	IV	V
Adventive	0.3	0.1	0.5	0.1	0.2
Cosmopolitan	–	0.2	0.4	0.6	0.2
Circumpolar	3.0	2.3	2.8	3.8	2.3
Eurasian	3.2	2.8	4.4	4.2	2.5
Continental	11.7	10.1	18.4	14.0	12.3
European	7.2	3.5	6.7	6.8	4.9
Central European	21.8	18.9	16.4	22.4	19.8
Sub-Mediterranean	14.5	18.7	16.6	9.1	20.9
East-sub-Mediterranean	4.6	0.7	2.1	3.2	0.8
Pontic	–	–	0.5	0.4	0.1
Pontic-sub-Mediterranean	4.2	10.9	5.4	2.9	10.6
Pontic-Pannonian	2.0	1.7	1.5	2.3	1.8
Atlantic-sub-Mediterranean	5.7	8.9	5.4	3.6	9.7
Sub-Atlantic	5.3	0.8	4.2	4.6	0.9
Sarmatic	0.9	3.4	2.4	1.3	3.0
Illyric	3.6	0.1	2.5	13.2	0.0
Pannonian-Balkan	2.1	1.9	2.3	1.6	2.1
Alpin-Balkan	0.3	–	0.8	0.3	0.1
Carpathian endemic	0.3	0.9	0.2	0.3	1.0
Pannonian endemic	1.8	5.5	2.5	1.6	6.4
Local endemic	7.4	8.8	3.9	3.6	–

Table 2. Distribution of phytosociological characters (BORHIDI 1993) (expressed in percentage)

	Groups of relevés				
Phytosociological character	I	II	III	IV	V
Sedo-Scleranthetea	–	0.1	0.1	–	–
Festuco-Brometea	11.6	13.4	16.2	13.5	13.8
Festucetalia valesiacae	38.1	38.8	42.0	34.4	44.1
Festucion valesiacae	0.4	0.3	0.5	0.2	0.5
Asplenio-Festucion pallentis	1.2	5.3	1.7	1.8	4.8
Bromo-Festucion pallentis	25.2	23.7	20.7	30.5	17.7
Festucetalia vaginatae	0.9	4.1	1.0	0.2	3.8
Festucion vaginatae	2.3	8.9	3.0	1.2	9.5
Molinio-Arrhenatheretea	0.1	–	–	0.2	–
Erico-Pinetea	0.3	0.1	0.5	0.1	0.2
Querco-Fagetea	–	–	–	0.3	–
Quercetalia pubescentis-petraeae	5.0	2.4	3.1	2.8	2.5
Orno-Ostryon	6.0	0.7	2.5	4.5	0.8
Fagion sylvaticae	0.3	0.1	0.1	–	0.2
Prunetalia spinosae	0.2	-	0.1	0.1	–
Indifferent	8.4	2.2	8.4	10.1	2.2

Table 3. Distribution of the social behaviour types (BORHIDI 1993) (expressed in percentage)

	Groups of relevés				
Social behaviour type	I	II	III	IV	V
Unique specialists	7.4	8.8	3.9	3.4	–
Rare specialists	0.2	–	0.2	0.7	–
Unique generalists	–	–	–	0.2	–
Specialists	19.3	29.3	19.9	17.5	32.4
Competitors	32.2	15.8	32.6	37.4	19.6
Generalists	38.6	44.7	39.5	37.9	46.6
Natural pioneers	–	0.1	0.1	–	–
Disturbance tolerants	2.0	1.2	3.3	2.6	1.2
Introduced alien species	0.3	0.1	0.5	0.1	0.2

Table 4. Distribution of the water preference categories (BORHIDI 1993) (expressed in percentage)

	Groups of relevés				
Water preference categories	I	II	III	IV	V
1	21.1	45.4	22.5	14.9	37.6
2	21.5	24.3	23.4	18.9	26.2
3	47.4	26.0	46.5	55.6	31.0
4	8.2	4.1	6.8	8.7	5.0
5	1.8	0.1	0.7	1.6	0.2
6	–	–	–	0.1	–
7	–	–	0.1	0.2	–
8–12	–	–	–	–	–

Categorisation of water preference: 1 = plants of extremely dry habitats or bare rocks; 2 = xero-indicators on habitats with long dry period; 3 = xerotolerants, but eventually occurring on fresh soils; 4 = plants of semi-dry habitats; 5 = plants of semi-humid habitats, under intermediate conditions; 6 = plants of fresh soils; 7 = plants of moist soils not drying out and well aerated; 8 = plants of moist soils tolerating short floods; 9 = plants of wet, not well aerated soils; 10 = plants of frequently flooded soils; 11 = water plants with floating or partly emergent leaves; 12 = water plants, most wholly submersed in water.

Table 5. Distribution of the continentality preference categories (BORHIDI 1993) (expressed in percentage)

	Groups of relevés				
Continentality preference categories	I	II	III	IV	V
1	–	–	–	–	–
2	0.3	0.1	0.2	0.1	0.2
3	8.0	4.6	5.4	8.6	4.7
4	49.3	31.3	42.0	48.9	37.3
5	20.9	25.6	29.0	26.0	26.4
6	15.0	23.8	14.5	11.2	15.9
7	6.4	14.6	8.2	5.0	15.3
8	0.1	–	0.7	0.1	0.1
9	–	–	–	–	–

Categorisation of continentality preference: 1 = euoceanic species, reaching Central Europe only in the extreme West, not in Hungary; 2 = oceanic species, mainly in West Europe and western Central Europe; 3 = oceanic-suboceanic species, area in whole Central Europe; 4 = suboceanic species, mainly in Central Europe but reaching to East; 5 = intermediate type with slight suboceanic-subcontinental character; 6 = subcontinental species, main area in eastern Central Europe; 7 = continental-subcontinental species, main area in East Europe; 8 = continental species reaching only eastern part of Central Europe; 9 = eucontinental species, main area in Siberia and East Europe reaching scarcely the eastern part of Central Europe.

The special distribution pattern of *Linum dolomiticum* suggests that this species might have some preference either to vegetation types or to some plant species or to groups of species or to any of ecological factors. The present study has shown that the distribution pattern cannot be explained by the phytosociological pattern of the area.

Although *Linum dolomiticum* occurs in all five types of non-forested vegetation in its geographical range, it prefers group 1 and 4, *i.e.* the slightly degraded open and closed dolomite rock grassland. These two groups represent two distinct vegetation types; lists of their diagnostic species do not overlap except *Linum dolomiticum* itself. It suggests that *Linum dolomiticum* has a private habitat preference. It has been supported by the fact that there are no species significantly associated to *Linum dolomiticum.* These results show that – within the non-forested parts of its range – the distribution of *Linum dolomiticum* has been determined by factors other than the co-occurring species. This factor may possibly be the distribution of its mycorrhiza partner fungi.

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