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Reproductive and distribution patterns in two populations of the rare endemit *Astragalus peterfii* Jáv. (Transylvania, Romania)

Abstract

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Astragalus peterfii Jáv., a narrow endemic species, currently occurs in only 2 close localities and has been classified as endangered and/or rare in different Romanian and European red lists of plants. The goal of this study has been the evaluation of differences in terms of resource allocation between two populations located in contrasting habitats (near-closed meadows, within the Suatu I Natural Reserve and open vegetation on eroded soils) and the influence of community structure on the distribution pattern of ramets.

The *Astragalus* ramets from the eroded, open lands invest much resource in vegetative regeneration by sprouting, but are formed of small shoots. On the contrary, the ramets developed in near-close grasslands tend to produce taller shoots, more flowers and a larger proportion of fertile shoots, whereas a trade-off is reached by minimizing the resource investment in vegetative reproduction (growth of new shoots).

The spatial aggregation of ramets is probably a consequence of both vegetative spreading and short-range dispersal of seeds. The differences in scale of aggregation detected along a coenocline from *Stipa*-rich grasslands (*Stipion lessingianae*) to *Carex humilis*-dominated lawns (*Festuco rupicolae-Caricetum humilis*) are due to a dramatic decline in ramets density. This observed pattern along with the negative correlation between the cover values of *A. peterfii* and *C. humilis* support the hypothesis that the former species multiplication is inhibited in closed-sod lawns dominated by the latter species. The population of *A. peterfii* settled in *Stipa*-rich grasslands reaches the highest levels of ramet density, fertility and fitness, probably because of the gaps occurring among the large grass tussocks. In order to get a genetically vigorous population of *A. peterfii*, the reserve management planning must take into consideration the maintenance of the slightly open *Stipa* communities.

Introduction

Scientists and natural resource managers have become concerned of the increasing number of threatened plant species due to natural habitats loss. The simple creation of small protected areas may be insufficient, if not supported by a good knowledge of the local species biology and community processes. This is the case of *Astragalus peterfii* Jáv., a rare Transylvanian endemic species, which occurs in only two localities about 5 km apart

- Suatu and Căianu. Roman & al. (1996) claim that this species is also present in other two close localities (Văleni and Gădălin), but no herbarium records exist and no specimens have been found so far in the mentioned locations (Bădărău & al. 2000). *A. peterfii* has been classified as an endangered and/or rare species in different red lists of plants (Moldovan & al. 1984; Boşcaiu & al. 1994; Dihoru & Dihoru 1994; Oltean & al. 1994; Walter & Gillett 1998).

Little is known about the reproduction biology and ecology of this species. It has 2n=64 chromosomes and displays a low allozyme polymorphism within the population of Suatu (Borza & al. 1996). The ecologic preferences of *A. peterfii* seem to be circumscribed to carbonatic, shallow soils on sunny, xeric slopes covered by open grasslands (Resmeriţă 1971). The closest matching taxon is *Astragalus vesicarius* L. ssp. *pseudoglaucus* (Klokov) Ciocârlan whose biogenetic centre is located in the Pontic Province, i.e. in the steppes around the Black Sea (Ciocârlan 2000). The phylogenetic ancestor of *A. peterfii* might have migrated along the Danube corridor in the Pannonic Plain and then in the Transylvanian Depression (Podpera 1936), where it given birth to an octoploidic species by adapting to more severe soil conditions.

Nowadays the genetic diversity decline within the Suatu population seems to be the main issue of concern. By revealing the *A. peterfii*'s reproductive and growth strategies in different habitat and community conditions, much valuable information would be available for a successful conservation management. In this context, the aim of our study consisted in estimating: (1) the differences in terms of resource allocation for reproduction and vegetative growth between two populations located in contrasting habitats (near-closed meadows, within the Suatu I Reserve and open vegetation on eroded soils, near the reserve), and (2) the influence of community structure (*Stipa*-dominated versus *Carex humilis*-rich grasslands) on the distribution pattern of individuals (ramets).

Study area

The Suatu I Reserve was created in 1932 and is located 37 km towards east of Cluj-Napoca city (Fig. 1). Many botanists have emphasized the great scientific importance of this protected area due to the occurrence of endemits - *Salvia transsilvanica, Cephalaria radiata, Jurinea mollis* ssp. *transsilvanica*, *Onosma arenaria* ssp. *pseudoarenaria* and xerothermic relicts - *Nepeta ucranica, Iris humilis* (Resmeriţă 1971; Cristea 1994; Roman & al. 1996). Over an area of 3.8 ha covered by xerophilous grasslands (*Festucion valesiacae* Klika 1931 and *Stipion lessingianae* Soó 1947), this reserve protects a population of about 2714 ramets of *A. peterfii* according to the last census (Şuteu & al. 1999). The study area was extended out of the reserve limits, in order to encompass the eroded land on the same orographic slope, whose regular terraces reveal the past use as a vineyard. In this habitat colonized by open pioneer vegetation, a distinct population of *A. peterfii* is established.

The geologic substratum of the study area is formed of alkaline shales and gritstones (Resmeriţă 1971). The altitude varies between 350 m and 470 m, the general aspect is south-west and the mean slope is about 40 degrees. If soil depth were not a moisture-lim-

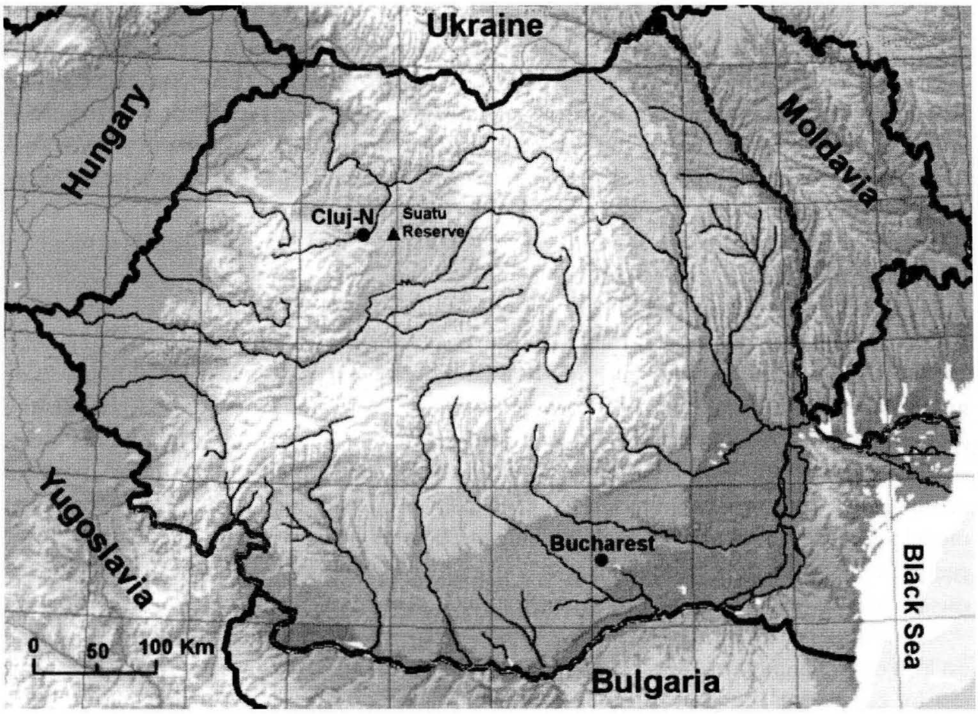

Fig. 1. Geographic location of the Suatu I Natural Reserve. The grey scale is intended to represent roughly the land hypsometry, from white (mountain ranges) to dark grey (low plains).

iting factor, the natural potential vegetation corresponding to such site conditions would be a mixed, xero-mesophilous oak forest (*Aceri tatarici-Quercion petraeae* Zolyomi 1957).

The study area as well as the whole distribution area of *A. peterfii* is included in the GS.28 UTM cell (Lehrer & Lehrer 1990).

Materials and methods

A random sampling was performed by tallying 100 individuals (ramets) of *A. peterfii* in each of the two populations: within the Suatu I Reserve and on the eroded land. The total number of shoots and the number of fertile ones were counted in each ramet, whereas the total height, the number of flowers and the relative height of the lower leaf were recorded for the dominant shoot only. A coloured plastic-made ring with a radius of 30 cm was centred with respect to each target ramet. The relative cover of *A. peterfii* and graminoids as well as the total vegetation cover within the ring were visually estimated according to the following scale: <1%; 1-5%; 5-10%; 10-15%; 15-20%; ... 95-100%.

A 2x94 m transect was placed within the natural reserve so that to overlap the steepest slope line and to reveal the coenocline between the uphill *Stipa*-rich communities

(*Stipetum lessingianae* Soó 1947, *Stipetum capillatae* (Hueck 1931) Krausch 1961 and *Stipetum pulcherrimae* Soó 1942) and the middle slope *Carex humilis*-dominated community (*Festuco rupicolae-Caricetum humilis* Soó (1930) 1947). The coordinates of all *Astragalus* ramets with respect to a pre-determined corner were recorded in 2x2 m adjacent quadrates disposed along the transect. In addition, a complete floristic relevés (but limited to vascular plants) was performed in each quadrate by assigning a relative cover class to each species (see the above scale).

For numerical analysis purposes, the species relative abundance was expressed as a percentage corresponding to the mid-point value of each cover class. Some data were log-transformed prior to their use in parametric tests, in order to approach the normal distribution and to reduce heteroscedasticity in regression analysis (Legendre & Legendre 1998). Whenever the normality assumption could not be accomplished for a reliable significance assignment of the difference between means through one-way ANOVA, the (non-parametric) Wilcoxon test was used instead for comparing median location.

Spearman's correlation coefficient was used to explore the pairwise relationships and subsequently, the corresponding partial coefficient was employed to build a hypothetical model of cause-effect relationships among the best-related variables. The estimation of each parameter in linear regressions was considered satisfactory whenever the null hypothesis associated with the t-test was rejected at 0.01 probability level.

The spatial distribution of ramets was analysed by means of mean distances to the nearest k-th order neighbours (Manly 1997). The test for randomness is based on a Monte Carlo test by comparing the real distribution of such distances with those obtained from 9999 random spatial configuration of ramets. In order to meet the stationary assumption required to perform a spatial point-pattern analysis (Cressie 1993), the transect was split in two relatively homogeneous subplots: 2x20 m (uphill) and 2x74 m (below).

To test the null hypothesis of no difference between the two groups of quadrates in the multidimensional space of species, a multi-response permutation procedure (MRPP) was used (Zimmerman & al. 1985). The Bray-Curtis (1957) percentage difference between all possible pairs of quadrates was used to assess the floristic homogeneity within each group. Subsequently, the degree to which the species discriminate among groups was assessed by using the Dufrêne & Legendre's (1997) indicator species analysis (ISA), which assigns indicator values for each species. These were tested for statistical significance using a Monte Carlo technique based on 9999 permutations.

All numerical analyses were performed with the SAS/STAT software (SAS Institute 1998) except for the MRPP and ISA, which were conducted using PC-ORD (McCune & Mefford 1997).

Results and discussion

The physiognomic contrast between the two study habitats is confirmed by the highly significant difference in relative cover of the vegetation surrounding the *Astragalus peterfii* bushes (Wilcoxon test: $z=12.194$; $p<0.0001$). The low competition for light on the eroded lands is probably responsible for the significantly lower mean height of the dominant *Astragalus* shoots with respect to those developed in *Stipa*-rich grasslands (Fig. 2). The

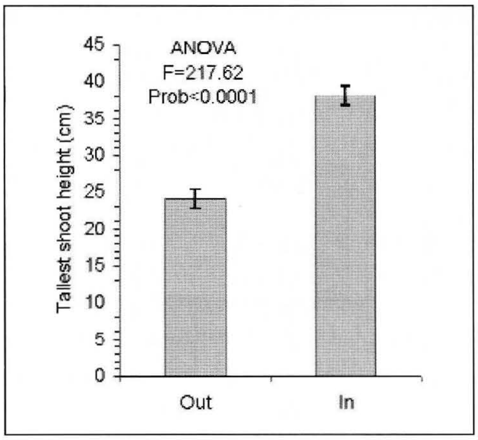

Fig. 2. Mean comparison of the dominant shoot heights in the two study population (Out = eroded land outside the natural reserve; In = grasslands within the natural reserve; error bars refer to 95% confidence limits).

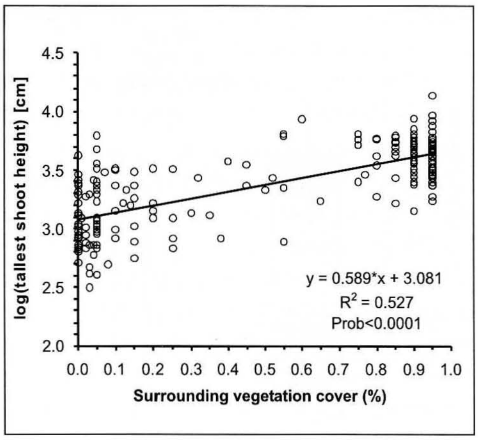

Fig. 3. Linear regression in semi-logarithmic space of the dominant shoot height as a function of the surrounding vegetation cover.

height of the dominant shoot declines with the decrease in relative cover of the surrounding vegetation (Fig. 3), suggesting that growth limitations due to shallow soils are more important than the presumed interspecific competition for light. This hypothesis is supported by finding no significant differences between the mean relative heights of the lowest leaf in the two populations (ANOVA: F=2.62; p=0.1073).

The number of shoots per ramet is significantly higher, but the proportion of the fertile ones significantly lower on the eroded land than in the natural reserve (Figs 4-5). The higher resource investment in sexual reproduction by *A. peterfii* individuals settled in the natural reserve grasslands is supported by the significant difference in the number of flowers occurring on the dominant shoots (Fig. 6). Since the proportion of fertile shoots increases with the dominant shoot fitness (Fig. 7), a trade-off in resource allocation seems to be reached by limited sprouting in the tall, near-closed grasslands.

The web of partial correlations shows that one of the key factors determining the sexual reproductive effort of the *A. peterfii* individuals is the vegetation cover surrounding the ramets (Fig. 8). However, the influence of the large grass tussocks (*Stipa* sp., *Festuca rupicola*) on *Astragalus* fertility seems to be indirect, i.e. by enhancing the height growth of shoots, which in turn may stimulate flower differentiation. On the contrary, the ramets settled on the eroded, open lands are prone to produce many, but small and flower-free shoots.

A significant aggregation of ramets has been detected at scales below 0.8 m and 1.5 m within the uphill and lower subplot, respectively (Fig. 9a-b). The different scales of aggregation between the two areas are certainly related to the dramatic decline in ramet density along the transect, from 3.95 m^{-2} (in the upper subplot) to 0.37 m^{-2} (in the lower one). This

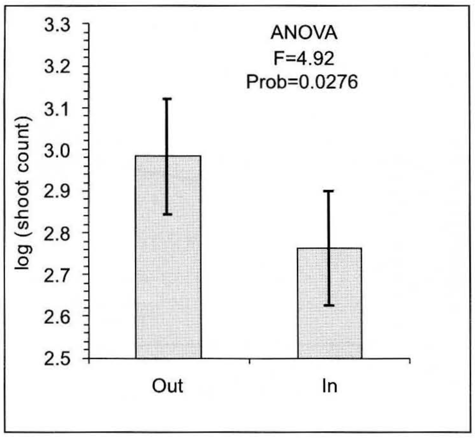

Fig. 4. Mean comparison of the shoot number per ramet in the two study populations (abbreviations and graph explication as in Fig. 2).

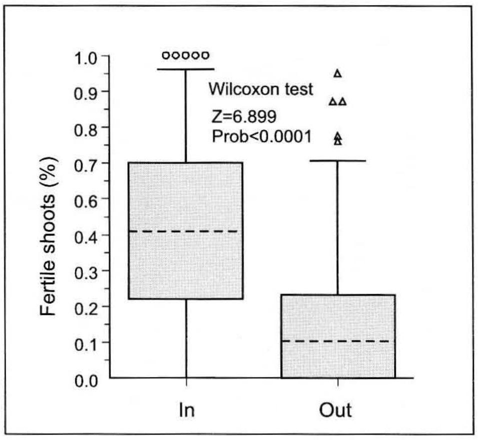

Fig. 5. Distribution of the relative number of fertile shoots per ramet in the two study populations (dash line = median; box limits = the 25th and 75th percentiles; error bars = the 5th and 95th percentiles). Abbreviations as in Fig. 2.

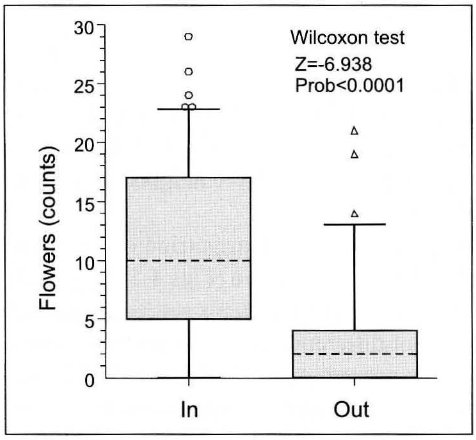

Fig. 6. Distribution of the number of flowers on dominant shoot in the two study populations (abbreviations and graph explication as in Fig. 5).

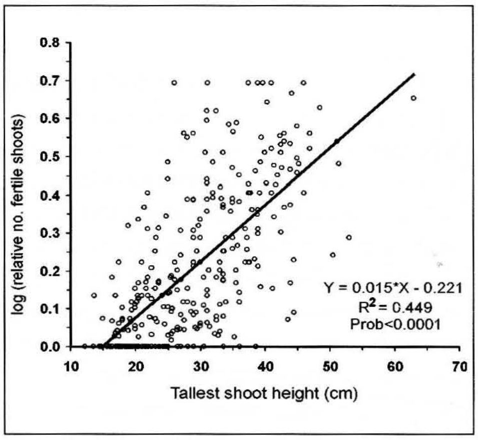

Fig. 7. Linear regression in semi-logarithmic space of the relative number of fertile shoots per ramet as a function of the dominant shoot height.

spatial pattern is probably a consequence of the vegetative spreading (especially in the uphill subplot) and of limitations imposed by the short dispersal range of the seeds (more relevant within the lower subplot).

The cover of *Astragalus peterfii* is best negatively correlated with the relative abundance of *Carex humilis* (r=-0.540; p<0.0001). The discontinuity corresponding to the sharp

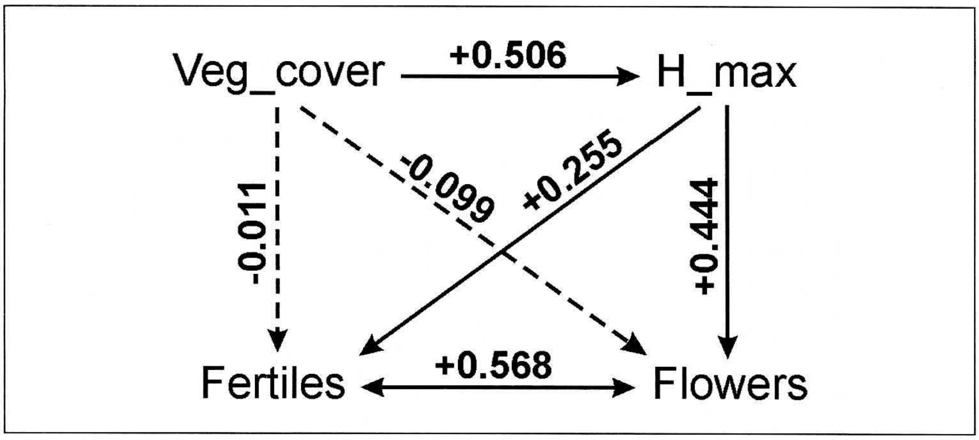

Fig. 8. Diagram of Spearman partial correlations among the best-related variables (full line = highly significant at 0.0001 probability level; dashed line = no significant at 0.05 probability level; single-arrow link = presumed cause-effect relationship; double-arrow link= presumed covariance).

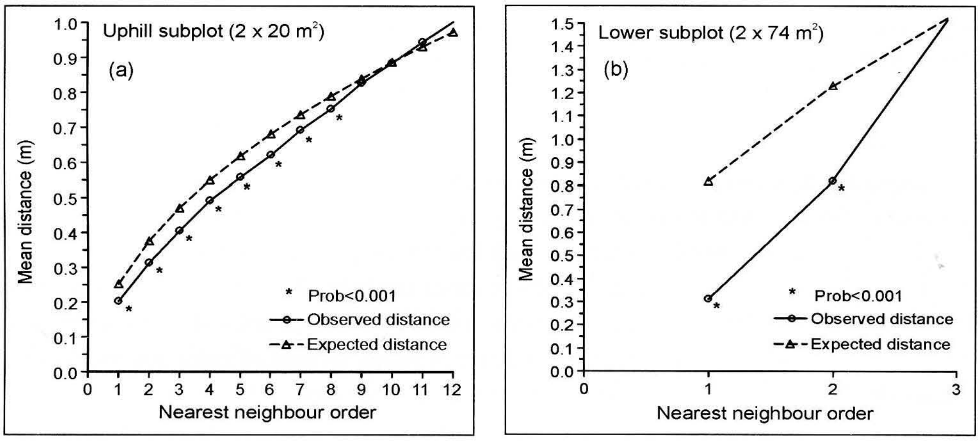

Fig. 9. Distributions of the observed and expected mean distances from each ramet to its nearest neighbours in the uphill (a) and lower (b) subplots (asterisks indicate significant differences at 0.001 probability level).

change in *Carex humilis* cover can be interpreted as a community boundary, because the uphill 18 quadrates are significantly distinct in terms of floristic composition from the remnant 29 located below (Fig. 10). In fact, two vegetation types can be distinguished along the sampled transect: a near-closed, tussock-made meadow (*Stipion lessingianae*) and a closed-sod lawn (*Festuco rupicolae-Caricetum humilis*), respectively. Apart from *Carex humilis*, *A. peterfii* and *Artemisia campestris* has the highest significant indicator value and

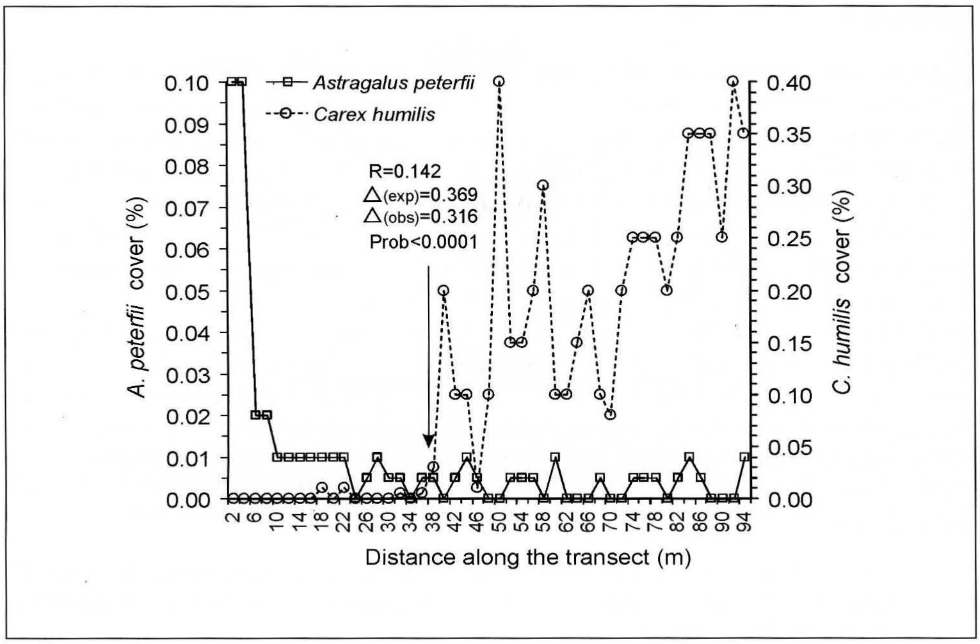

Fig. 10. Variation of *A. peterfii* and *C. humilis* cover along the transect. The arrow indicates a possible, but significant boundary in terms of floristic composition between the two subplots (° = average within-subplot dissimilarity; R = chance-corrected within-subplot agreement).

consequently, they can be considered discriminant species between the two grassland communities (Table 1). On the other hand, *A. peterfii* is best positively related with *Elymus repens* ($r=0.548$; $p<0.0001$), which is well-known as a pioneer, stoloniferous species. These results are consistent with the observations made by Resmeriţă (1971), who suggested that the multiplication of *A. peterfii* is inhibited in the closed-sod lawns dominated by *Carex humilis*. On the contrary, the open grasslands formed of culm and tuft gramineous species seem to be the most suitable for its proliferation.

Table 1. Indicator values and their associated probabilities of the most discriminant species between the uphill and lower communities (*Stipetum* s.l. and *Festuco rupicolae-Caricetum humilis*, respectively).

Species	Indicator values (%)				Prob (exp≥obs)
	Uphill subplot	Lower subplot	Overall (obs)	Overall (exp)	
Astragalus peterfii	77	6	77.2	40.4	<0.0001
Artemisia campestris	65	0	65.2	18.3	<0.0001
Carex humilis	0	99	99.2	43.1	<0.0001

Conclusions

In *Stipa*-rich meadows *A. peterfii* individuals reach the best fitness in terms of growth and fertility, whereas the number of shoots per ramet tends to be higher on eroded lands. These patterns indicate in near-closed grasslands a population strategy oriented toward the promotion of sexual reproduction, as opportunities (gaps) for sprouting are less frequent.

The aggregated distribution of the *Astragalus* ramets in grasslands may be an outcome of both vegetative sprouting and short seed dispersal, but also a consequence of the low germination rate. The establishment of new *Astragalus* seedlings might be enhanced by the occurrence of scattered, small-scale disturbances in *Carex humilis*-dominated lawns.

Based on these preliminary results some guide-lines for the conservation management can be given: a) secondary successions should be inhibited by clearing the tall shrubs (e.g., *Rosa canina, Prunus spinosa, Crataegus monogyna*); b) soil erosion and landslides must be controlled by maintaining a reasonable cover of *Stipa* species; c) *Carex humilis*-dominated lawns should not be mown, but burned occasionally in very small patches.

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