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Diversity of communities dominated by *Glycyrrhiza uralensis*, an endangered medicinal plant species, along a precipitation gradient in China

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ABSTRACT. *Glycyrrhiza uralensis* is an endangered and nationally-protected medicinal plant species in China with great market demand. It is mainly distributed in arid and semi-arid regions and its habitats have rapidly degraded over the last 40 years. Conservation of this species and its communities has become urgent. We aimed to reveal the relationships between *G. uralensis* and environmental variables along an east to west precipitation gradient in northern China. Floristic and environmental data from 100 5 m × 5 m quadrats were analyzed using TWINSPAN, DCA, CCA and species diversity indices. TWINSPAN recognized twelve vegetation communities, which were the communities most dominated by *G. uralensis* in China. DCA and CCA results showed that the vegetation patterns were significantly correlated with both soil and climatic variables. Soil N, P, K, organic matter, annual mean temperature, relative humidity, annual mean precipitation, annual mean highest temperature and annual mean lowest temperature were significant to these communities, and precipitation was the most important factor explaining the spatial patterns of vegetation. Species richness, diversity and evenness varied obviously among communities and were significantly correlated with environmental gradients. Further measures for conservation of *G. uralensis* and its communities are discussed.

Keywords: Biodiversity; Ecological restoration; Licorice; Medicinal resources; Semi-arid and arid region.

INTRODUCTION

Medicinal plants are valuable natural resources that are essential to urban and rural populations in many countries and regions, such as China, India, Japan, Korea, Taiwan and so on (Hussain and Hore, 2007; Nautiyal et al., 2009). Millions of people rely on, or choose to use, medicinal plants for all or part of their healthcare needs, making their usage the most likely common use of biodiversity by humans (WHO, 2002; Larsen and Olsen, 2007). The annual world market for botanical medicines is estimated at over US$ 35 billion, with an annual growth rate of 15% (Kate and Laird, 1999). Most medicinal plant species are harvested in the wild and the extent of their use has led to species endangerment and extinction. Thus, the conservation of these species has become urgent (Schippmann et al., 2002; Larsen and Olsen, 2007). Medicinal plant conservation is an important aspect of biodiversity conservation and is a high priority in the environmental policies of many countries and regions (Kate and Laird, 1999; Ji et al., 2004).

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Licorice (*Glycyrrhiza* spp.) is one of the most useful Chinese herbal medicines and an important resource plant, widely used in medicine, food, tobacco, chemical industries and for ecological protection in arid and semi-arid areas of China (Zhou, 2006; Zhang and Chen, 2007). Licorice medicine consists of the dried roots and rhizomes of plant species in the *Glycyrrhiza* genus of the Legume family. Licorice contains many biologically active chemicals such as glycyrrhizin, flavonoids, coumarins, polysaccharides, alkaloids, amino acids and so on, which have pharmacological effects against pain, cough, inflammation, allergy, toxicity, HIV and so on (Hu and Shen, 1995; Shen et al., 2003; Ji et al., 2004). Although three species, *Glycyrrhiza uralensis, G. inflata* and *G. glabra,* are used medicinally in China, Ural licorice (*G. uralensis*) is the most important (Zhao et al., 2006). The annual production of herbal medicine from this species in China is over 60,000 tons. *Glycyrrhiza uralensis* is widely distributed from east to west in northern China. However, its habitats are severely disturbed and many of them are degraded or undergoing desertification (Zhang, 2005). The wild resources of this medicinal plant have diminished rapidly since the 1970s and it is now a nationally-protected plant. The medicinal market for licorice now mainly depends on its extensive cultivation (Zhou, 2003; 2006). The conservation and restoration of this species and its habitats are imperative and urgent (Pan and Zhang, 2002; Zhang et al., 2006). A general understanding of the ecology of this species and its community is crucial for its conservation and restoration. This study is about the ecological characteristics of *G. uralensis* and its communities. Although recent research has been conducted on the taxonomy, biochemistry, pharmacology and genetics of this species (Hu and Shen, 1995; Zhang et al., 2001), only limited research has been conducted concerning its ecology.

Our study mainly focuses on *G. uralensis* ecology with the objectives of: (1) identifying the communities of *G. uralensis* and analyzing their composition and structure; (2) elucidating the relationships between vegetation and environmental variables to find the most important ones between endangered species and their communities; and finally, (3) discussing some measures of conservation management for this species and its communities.

MATERIALS AND METHODS

Sampling

Based on a general survey of *G. uralensis* and its communities, a sampling transect across its main distribution area was established from east to west in northern China (Figure 1). Five study sites, Chifeng (in inner Mongolia Autonomous Region), Hengjinqi (in inner Mongolia Autonomous Region), Minqin (in Ganshu Province), Aletai (in Xinjing Autonomous Region) and Kashi (in Xinjing Autonomous Region), were selected as sampling sites (Figure 1). The area of each sampling site was about 40 ha. Twenty quadrats of 5 m × 5 m were established randomly at each site and their respective cover, height, abundance of shrubs and herbs were measured. Plant cover was visually estimated, and heights were measured using a ruler. Altogether, 191 plant species were recorded in 100 quadrats. Elevation, slope and aspect for each quadrat were also measured and recorded. Elevation was measured by GPS, slope and aspect were measured by compass meter. From each quadrat, five soil samples of 30 cm in depth were taken using a small spade. These were thoroughly mixed, then one quarter was collected and taken to a laboratory for chemical analysis. In the laboratory, soil samples were air-dried and soil pH, organic matter, available N, available P and available K were measured as soil variables. These variables were selected because they are most important nutrient elements, particularly in arid and semi-arid areas. A 1:2.5 ratio of soil to distilled water suspension was used to measure pH with a Whatman pH sensor meter. Nitrogen content was estimated using Kjeldahl extraction, and the phosphorus content was measured via the $HClO_4$-H_2SO_4 Colorimetric method (Molybdovanadate method). Potassium content was measured using an Atomic Absorption Spectrophotometer and the content of organic matter was measured using the $K_2Cr_2O_7$ - Capacitance method. Climatic data from the nearest weather stations were used.

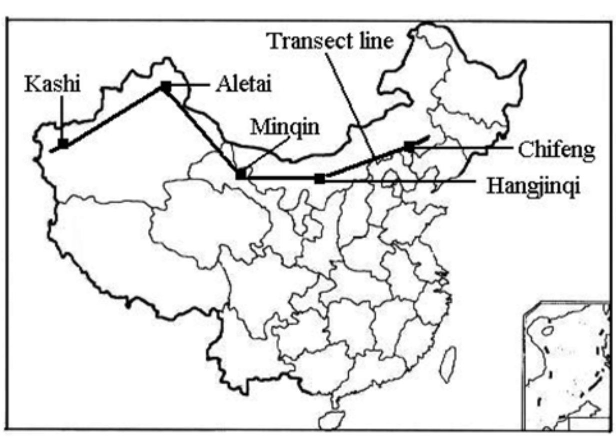

Figure 1. Sampling transect line and sampling sites for *Glycyrrhiza uralensis* communities along a precipitation gradient in Northern China.

Data analysis

The Importance Value of each species was used as data in community analysis and diversity indices calculation. The importance value was calculated by the formulas (Zhang et al., 2006b):

IV_{Shrubs} = (Relative density +Relative cover + Relative height)/3

IV_{Herbs} = (Relative cover + Relative height)/2

The relative density refers to the percentage of one species density over the sum of all species density in a quadrat, relative cover to the percentage of one species cover over the sum of all species cover in a quadrat, and relative height to the percentage of one species mean height over the sum of all species mean height in a quadrat. The species data matrix is consisted of importance values for 191 species in 100 quadrats.

The environmental data matrix consisted of values for ten variables, five soil factors plus five climatic variables, annual mean temperature, relative humidity, annual mean precipitation, annual mean highest temperature and annual mean lowest temperature, in 100 quadrats. Elevation, slope and aspect were not analyzed because their differences were not significant.

Two-way Indicator Species Analysis (TWINSPAN) (Hill, 1979) was used for classification, Detrended Correspondence Analysis (DCA) and Canonical Correspondence Analysis (CCA) (Ter Braak and Smilauer, 2001) were used for ordination to analyze the variation of communities and their relationships with environmental variables. TWINSPAN, DCA and CCA calculations were carried out using TWINSPAN (Hill, 1979) and CANOCO (Ter Braak and Smilauer, 2001) computer programs.

Three separate species diversity indices, for species richness, diversity, and evenness, were used to calculate species diversity in *G. uralensis* communities. They were:

Species number (as a richness index):

$D = S$

Shannon-Wiener diversity index:

$H' = -\sum P_i \ln P_i$

Pielou evenness index:

$E = (-\sum P_i \ln P_i)/\ln S$

Where P_i is the relative importance value of species i, N_i the importance value of species i, $P_i = N_i /N$, N the sum of importance values for all species in a quadrat, S the species number present in a quadrat (Pielou, 1975; Zhang, 2004).

RESULTS

Community classification

TWINSPAN classified 100 quadrats into 12 groups, representing 12 *G. uralensis* plant communities (Figure 2). The name and main species composition of each community are listed in Table 1.

Ordination analysis

The first DCA axis represents a comprehensive gradient of water and heat, i.e. the precipitation and temperature gradient. The precipitation and annual temperature are decreasing from left to right in the ordination diagram (Figure 3). The second DCA axis represents a comprehensive gradient of soil nutrients and pH. The soil nutrients are increasing and the soil pH values decreasing from bottom to top in the diagram (Figure 3). The distribution of vegetation communities is correlated to these gradients. The partitioning of the 100 quadrats in the DCA ordination space is closely related to their grouping by TWINSPAN. The communities preferring moisture and a warm climate, such as communities I-VII, distributed in the left area of the diagram, and communities preferring dry and cold climates, such as communities IX, XI and XII, occurred in the right area of the diagram (Zhang, 2004). Communities II, III, VI and VII, with comparatively rich soil nutrients, occurred in the top area of the ordination diagram, and Communities IV and V, with poor soil, in the bottom area (Wu, 1980).

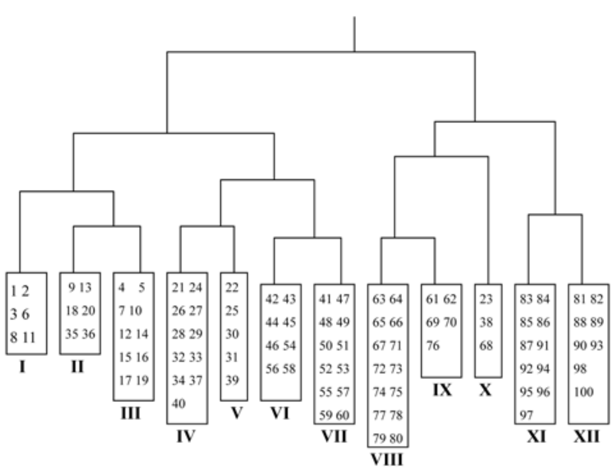

Figure 2. Classification dendrogram yielded by TWINSPAN analysis of 100 quadrats and 191 species for *Glycyrrhiza uralensis* communities along a precipitation gradient in Northern China. 1, 2, …, 100 representing quadrat number; I, II, …, XII representing communities: I. *G. uralensis + Stipa bungeana,* II. *G. uralensis + Aneurolepidium chinense,* III. *G. uralensis + Potentilla anserine,* IV. *G. uralensis + Artemisia ordosica,* V. *G. uralensis + Carex duriuscul + Aneurolepidium chinense,* VI. *G. uralensis + Polygonum bistorta,* VII. *G. uralensis + Ephedra przewalskii+ Cancrinia discoidea,* VIII. *G. uralensis + Artemisia frigida,* IX. *G. uralensis + Carex pediformis +Stipa sareptana,* X. *G. uralensis + Astragalinae triloa + Stipa sareptana,* XI. *G. uralensis + Aneurolepidium chinense +Stipa sareptana,* XII. *G. uralensis + Festuca logae + Stipa sareptana.*

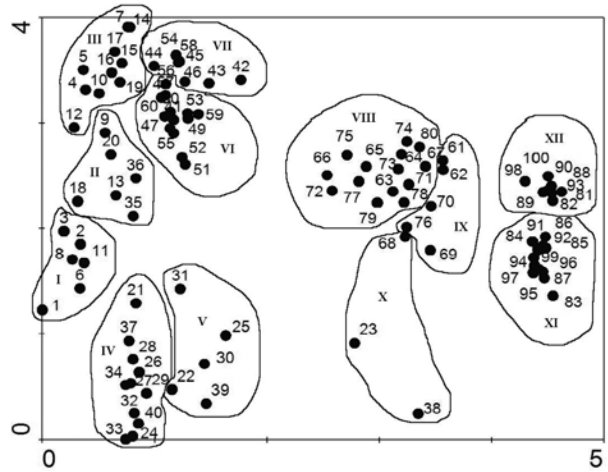

Figure 3. Two-dimensional DCA ordination diagram of 100 quadrats and 191 species for *Glycyrrhiza uralensis* communities along a precipitation gradient in Northern China. 1, 2, …, 100 representing quadrat number; I, II, …, XII representing communities recognized by TWINSPAN. Community names see Figure 2.

In the CCA ordination, the Monte Carlo permutation test indicated that the eigenvalues for the first canonical axis, and for all canonical axes examined, were significant ($P < 0.001$) (Ter Braak, 1986). The eigenvalues for the first three axes were 0.648, 0.563 and 0.442, and species-environment correlations for the first three axes were 0.980, 0.984 and 0.972, respectively (Figure 4). The canonical eigenvalues indicated separation along the measured environmental gradients. The distribution of species and community of *G. uralensis* were significantly correlated with all ten environmental variables (Figure 4, Table 2). The most significant variable correlated with the first CCA axis was annual precipitation, with a correlation coefficient of 0.908, and the first CCA axis, in fact, is a comprehensive gradient dominated by precipitation. Besides precipitation, soil P and pH were very significantly correlated to the first CCA axis, and other variables such as soil N, K, annual mean temperature, lowest temperature, highest temperature and relative humidity were also significant to the first CCA axis (Figure 4, Table 2). The most important variables correlating with the second CCA axis were soil K, organic matter, pH, N, relative humidity, lowest temperature and soil P (Figure 4, Table 2).

Table 1. Community types identified by TWINSPAN and their main species composition of *Glycyrrhiza uralensis* communities along a precipitation gradient in Northern China.

Community No. and name	Total community cover (%)	Cover of *G. uralensis* (%)	Density of *G. uralensis* (n. ha^{-1})	Common species
I. *G. uralensis* + *Stipa bungeana*	50	23	3500	*Pedicularis resupinata*, *Artemisia sacrorum*, *Saussurea epilobioides, Artemisia mongolica*, *Potentilla anserine*, *Vicia amoena* and *Cynanchum hancockianum*
II. *G. uralensis* + *Aneurolepidium chinense*	55	27	3900	*Lespedeza darurica, Haloxylon Ammodendron, Berberis sibirica*, *Stipa glareosa*, *Artemisia mongolica*, *Caragana pygmaea*, *Carex duriuscul*, *Carex stenophylloides* and *Astragalus melilotoides*
III. *G. uralensis* + *Potentilla anserine*	60	26	4120	*Lespedeza darurica, Potentilla anserine*, *Stipa bungeana, Artemisia mongolica, Vicia amoena* and *Saussurea amara*
IV. *G. uralensis* + *Artemisia ordosica*	60	26	3700	*Lespedeza darurica, Caryopteris mongolica*, *Trigonella ruthenica, Ephedra przewalskii* and *Trigonella ruthenica*
V. *G. uralensis* + *Carex duriuscul* + *Aneurolepidium chinense*	65	25	4560	*Lespedeza darurica, Haloxylon Ammodendron, Berberis sibirica*, *Stipa glareosa*, *Caragana pygmaea*, *Carex duriuscul*, *Carex stenophylloides*, *Astragalus melilotoides, Vicia amoena* and *Cynanchum hancockianum*
VI. *G. uralensis* + *Polygonum bistorta*	65	35	5700	*Polygonum divaricatum, Adenophora gmeliniia*, *Potencilla acaulis*, *Oxytropis myriophylla*, *Astragalus melilotoides, Suaeda prostrate, Allium condensatum*, *Oxytropis grandiflora* and *Artemisia ordosica*
VII. *G. uralensis* + *Ephedra przewalskii*+ *Cancrinia discoidea*	70	41	5982	*Elaeagnus, mooceroftii Caragana korshinskii, Suaeda prostrate*, *Saussurea laciniata*, *Artemisias phaerocephala, Saposhnikovia divariicata*, *Artemisia ordosica* and *Oxytropis glabra*
VIII. *G. uralensis* + *Artemisia frigida*	65	37	4900	*Carex duriuscula*, *Salicornia Bigelivii, Stipa sareptana, Alopecurus pratensis* and *Carex pediformis*
IX. *G. uralensis* + *Carex pediformis* +*Stipa sareptana*	65	33	5590	*Caragana pygmaea*, *Cleistogenes squarrosa*, *Ephedra sinica, Achnatherum sibiricum*, *Viola tianschanica*, *Artemisia frigida*, *Hordeum brevisublatum* and *Alopecurus pratensis*.
X. *G. uralensis* + *Astragalinae triloa* + *Stipa sareptana*	75	41	6020	*Artemisia scoparia*, *Potencilla acaulis*, *Atraphaxis frutescus, Ceratoides lates* and *Kochia prostrate*
XI. *G. uralensis* + *Aneurolepidium chinense* +*Stipa sareptana*	70	29	4100	*Stipa parpurea*, *Artemisia kaschgarica*, *Glycyrrhiza inflate*, *Polygonum viiiparum*, *Festuca logae*, *Ephedra equisetina* and *Alyssum desertorum*
XII. *G. uralensis* + *Festuca logae* + *Stipa sareptana*	70	31	3980	*Artemisia parvula, Roegneria kamoji*, *Scorzonera divaricata, Potentilla bifurca*, *Ranunculus japonicas* and *Carex duriuscula*

Both soil and climatic variables were significant in affecting the spatial variation of vegetation and species in *G. uralensis* communities, due to their interactions and influences on each other (Glaser et al., 2000; Zhang, 2002). All other variables were significantly correlated with precipitation (Table 3). Soil nutrients, such as N, P, K and organic matter were significantly correlated with each other as were climatic variables, such as annual mean temperature, lowest temperature, highest temperature and relative humidity (Table 3). Soil pH was significantly correlated with all climatic variables and with soil P, but showed no significant relation to soil N, K and organic matter content.

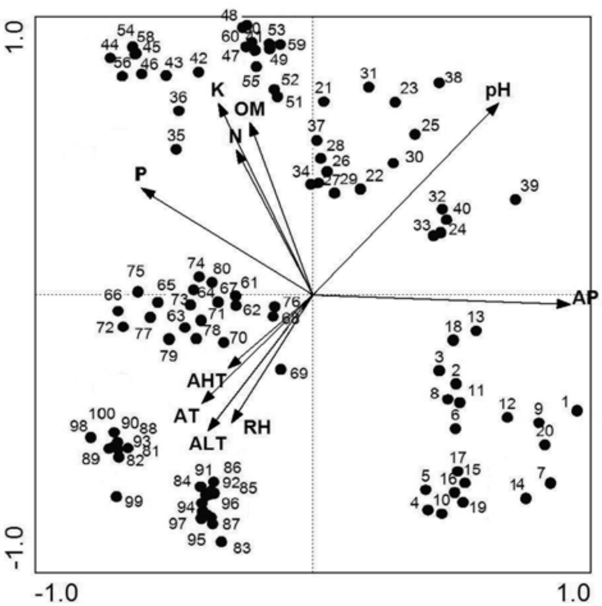

Figure 4. Biplot of 100 quadrats and 10 environmental variables in CCA ordination of *Glycyrrhiza uralensis* communities along a precipitation gradient in Northern China. Biplot vectors shown represent the major explanatory environmental variables. AT-annual mean temperature, RH-relative humidity, AP-annual mean precipitation, AHT-annual mean highest temperature and ALT-annual mean lowest temperature, pH-Soil pH, OM-soil organic matter, N-soil available N, P-soil available P and K-soil available K.

Species diversity analysis

The species richness varied from 8 to 10 species per *G. uralensis* community and was comparatively low due to the arid and semi-arid study areas in China. Changes in species diversity and evenness in the twelve communities were obvious but change in species richness was not significant (Figure 5). Changes in the pattern of species diversity and evenness were similar, i.e. species diversity and evenness decreased from east to west (Figure 5), which was consistent with the precipitation gradient. These relationships were confirmed by the regression analysis between species diversity and the first DCA axis (a comprehensive gradient dominated by precipitation) (Figure 6). The quadratic curve relationships of species richness, diversity and evenness with the first DCA axis were statistically significant (P<0.01).

DISCUSSION

Glycyrrhiza uralensis-dominated communities varied in composition and structure. The twelve communities recognized by TWINSPAN represent the general vegetation of *G. uralensis* in northern China (Wu, 1980; Zhang et al., 2006a). These communities distribute from temperate grassland to temperate desert regions and are significant not only for medicinal plant resource conservation but also for arid and semi-arid ecological zone protection in China (Pan and Zhang, 2002). The classification scheme of these communities is reasonable according to the Chinese vegetation classification system (Wu, 1980). The indicator species in the TWINSPAN divisions such as *Stipa sareptana, Carex duriuscula*, *Cancrinia discoidea*, *Artemisia ordosica*, *Aneurolepidium chinense*, *Astragalinae triloa*, *Polygonum bistorta*, *Stipa caucasica* and *Carex pediformis* were dominant species in communities because their cover

Table 2. Correlation coefficients between environmental variables and CCA axes of *Glycyrrhiza uralensis* communities along a precipitation gradient in Northern China.

Environmental variables	Axis 1	Axis 2	Axis 3	Axis 4
Annual mean temperature	-0.393***	-0.383***	-0.270	-0.745***
Relative humidity	-0.287**	-0.453***	0.158	0.784***
Annual mean precipitation	0.908***	-0.033	0.335***	0.144
Annual mean highest temperature	-0.299**	-0.259**	-0.324***	-0.813***
Annual mean lowest temperature	-0.371***	-0.480***	-0.223*	-0.717***
Soil N	-0.271**	0.513***	-0.760***	0.190
Soil P	-0.605***	0.378***	-0.666***	0.044
Soil K	-0.334***	0.677***	-0.586***	0.204*
Soil organic matter	-0.223*	0.610***	-0.704***	0.189
Soil pH	0.655***	0.679***	0.269**	-0.028

Note: *P<0.05; **P<0.01; ***P<0.001.

Table 3. Correlation coefficients between environmental variables in *Glycyrrhiza uralensis* communities along a precipitation gradient in Northern China.

Environmental variables	Annual mean temperature	Relative humidity	Annual mean precipitation	Annual mean highest temperature	Annual mean lowest temperature	N	P	K	Organic matter
Relative humidity	-0.391^{***}								
Annual mean precipitation	-0.572^{***}	-0.075							
Annual mean highest temperature	0.984^{***}	-0.544^{***}	-0.517^{***}						
Annual mean lowest temperature	0.993^{***}	-0.320^{**}	-0.526^{***}	0.962^{***}					
N	-0.031	-0.122	-0.513^{***}	0.038	-0.120				
P	0.252^{*}	-0.070	-0.813^{***}	0.276^{**}	0.169	0.916^{***}			
K	-0.131	-0.139	-0.514^{***}	-0.059	-0.230^{*}	0.968^{***}	0.898^{***}		
Organic matter	-0.104	-0.173	-0.451^{***}	-0.022	-0.200^{*}	0.992^{***}	0.884^{***}	0.984^{***}	
pH	-0.590^{***}	-0.492^{***}	0.686^{***}	-0.453^{***}	-0.631^{***}	-0.047	-0.338^{***}	0.075	0.070

Note: * $P<0.05$; ** $P<0.01$; *** $P<0.001$.

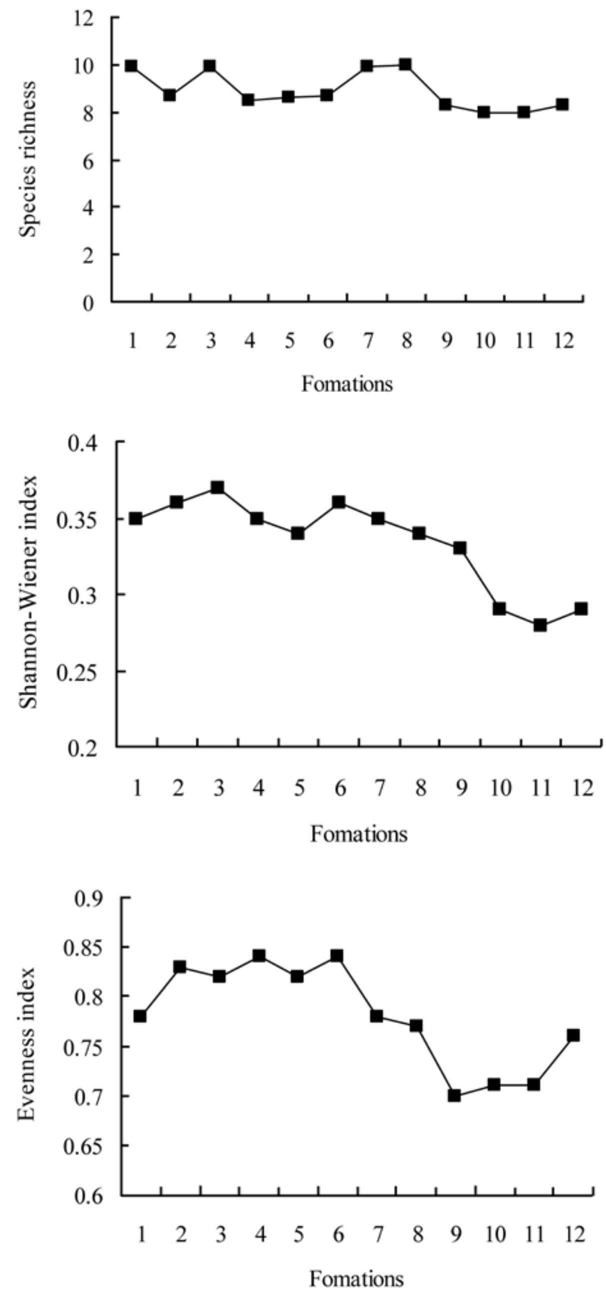

Figure 5. Species richness, diversity and evenness of each vegetation Community of *Glycyrrhiza uralensis* communities in Northern China. The values are the average values of species richness, diversity and evenness indices of all quadrats in a Community.

was over 20% and they played a dominant role in community structure in at least one community type (Zhang, 2002). Other indicator species such as *Gentiana decumbens*, *Glycyrrhiza inflata*, *Oxytropis glabra*, *Ajania parviflora*, *Saposhnikovia divariicata*, *Scutellaria baicalensis*, *Agriophyllum squarrosum*, *Iris bungei*, *Carex stenophylloides*, *Ceratoides lates*, *Ephedra sinica*, *Ephedra przewalskii*, *Agropyron cristatum*, *Kochia svoparia*, *Astragalus galactites* and *Arundinella hirta* covered about 10% and

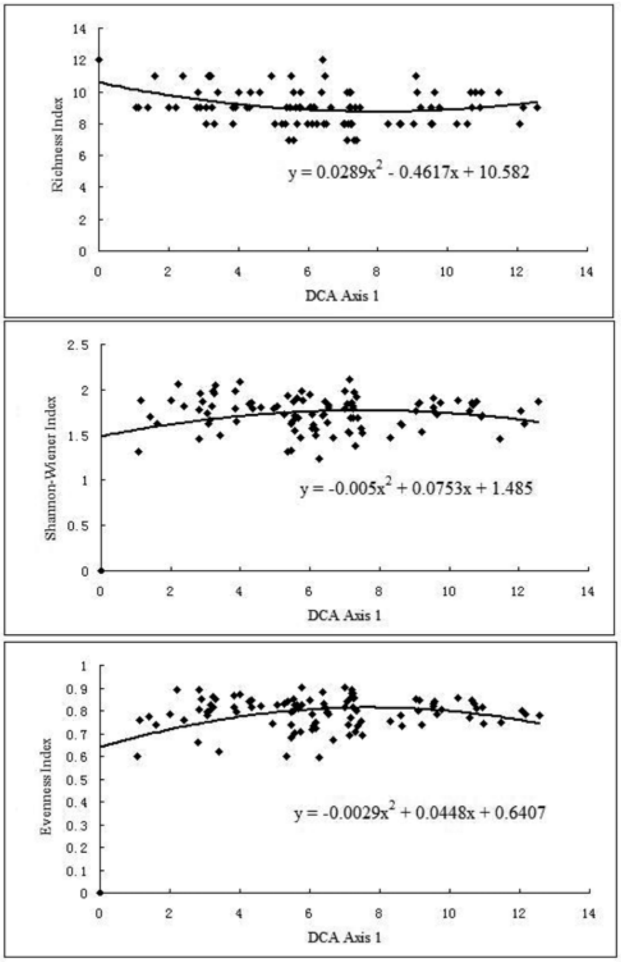

Figure 6. Variation of species richness, diversity and evenness along the first DCA axis of *Glycyrrhiza uralensis* communities in Northern China. The first DCA axis is a comprehensive gradient dominated by precipitation.

played important secondary roles to the dominant species in at least one community (Wu, 1980).

TWINSPAN results were validated by DCA analysis. Each community had its own distribution area and clear boundary in the DCA space, and their ordination was related to environmental gradients. This suggests that there are some advantages in combining TWINSPAN and DCA analyses for ecological studies (Ter Braak and Smilauer, 2001; Zhang, 2004). The first DCA axis represents a comprehensive gradient of precipitation and temperature and the second DCA axis represents a comprehensive gradient of soil nutrients and pH. This showed that precipitation, temperature and soil nutrients are important factors to *G. uralensis* communities in arid and semi-arid regions, which were identical to the CCA results (Oyonarte et al., 2008).

CCA analysis indicated that both climatic and soil variables were important to *G. uralensis* communities (Ter Braak, 1986; Zhang, 2005). All the ten variables were significantly correlated with the distribution of species and communities, among which precipitation and annual temperature were dominant factors. This is due to the large east-west distribution area of *G. uralensis* and its communities, where temperature and precipitation vary greatly. Precipitation and annual temperature had obvious effects on the structure, composition and community environment. These results are consistent with those of many other vegetation ecology studies (Paschke et al., 2003; Zhang and Chen, 2007; Saeki, 2007). Besides precipitation and mean temperature, the mean lowest temperature, relative humidity, and the mean highest temperature contributed significantly to the vegetation. Soil nutrients are key factors in plant growth and vegetation development and their importance in a community or region depends on their quantity and distribution (Brunner et al., 1999; Saarsalmi et al., 2001; Oyonarte et al., 2008). The measured soil elements, soil K, P, organic matter and N, were greatly correlated with community distribution and variation, which suggest that soil nutrients were more important in these arid and semi-arid regions where soil was usually coarse and poor (Zhang, 2002; Fosaa, 2004). Soil pH was also significant to *G. uralensis* communities due to its varied values (Pan and Zhang, 2002; Schippmann et al., 2002).

All ecological factors coexist and act on plants and vegetation simultaneously in communities and ecosystems (Molles, 2002; Zhang et al., 2006a). These factors, including climatic and soil variables, interact with each other, and this interaction is very complex. In our study, all other variables were significantly correlated to precipitation, which suggests that precipitation is a key factor affecting *G. uralensis* communities (Larsen and Olsen, 2007). This conclusion was verified many times in ecological studies conducted in arid and semi-arid areas (Kate and Laird, 1999). The most important soil nutrients, soil N, P, K and organic matter were significantly correlated with each other, and the climatic variables, annual mean temperature, lowest temperature, highest temperature and relative humidity were also significantly interrelated (Pan and Zhang, 2002; Schippmann et al., 2002). The interactions between these environmental factors must be emphasized in the management of *G. uralensis* communities (Zhang and Zhang, 2007; Nautiyal et al., 2009).

Species richness was comparatively low in a community of *G. uralensis,* as in other studies conducted in arid and semi-arid areas in China (Pan and Zhang, 2002; Ji et al., 2004). Because of this, the structure, composition and function of these communities were simple and easily disturbed. The changes in species diversity and evenness in the twelve communities were apparent, which was related to the different environmental variables (Hu and Shen, 1995; Zhang et al., 2006a; Zhao, 2006). The change pattern of species diversity and evenness was similar along the precipitation gradient, i.e. species diversity and evenness were decreasing from east to west in northern China. These relationships were consistent with the regression analysis between species diversity and the comprehensive gradient dominated by precipitation (the first DCA axis) (Zhang, 2004; Hussain and Hore, 2007). The species richness along this gradient decreased and then increased, in contrast to species diversity and evenness, which increased and then decreased. These suggest that environmental variables significantly impact species diversity in *G. uralensis* communities. These results are identical to those of other ecological studies conducted in arid and semi-arid regions in China (Pan and Zhang, 2002; Zhao et al., 2003; Zhang and Chen, 2007).

The diversity described above provides the basis for the conservation of wild *G. uralensis* and its communities, but their conservation is comparatively difficult due to the great market demand for this species and its disturbed and continually degrading habitats (Wu, 1980; Pan and Zhang, 2002; Kathe, 2006; Hussain and Hore, 2007). Some measures must be considered: First, more large-scale cultivation bases for medicinal purposes should be set up and developed in different areas of northern China. Second, the management of wild *G. uralensis* and its communities must be legal and effective, e.g. digging must be strictly controlled (Zhou, 2003; 2006; Nautiyal et al., 2009) and grazing should be limited to keep its ecosystem composition, structure and function intact (Shen and Yang, 2003; Larsen and Olsen, 2007). Third, soil fertilization and irrigation, should be used to improve *G. uralensis* habitat conditions (Zhou, 2006).

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中國瀕危藥用植物烏拉爾甘草群落之多樣性沿降水梯度的變化

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烏拉爾甘草是重要的國家瀕危保護藥用植物，在中國有巨大的市場需求。它主要分佈在半乾旱和乾旱地區，其棲息環境在過去 40 年中退化嚴重。該物種及其群落的保護已成爲當務之急。本研究的目的是揭示中國北方從東到西烏拉爾甘草群落與環境因數間的關係沿降水梯度的變化。取自 100 個 5 m × 5 m 樣方的物種資料和環境資料用 TWINSPAN 分類、DCA 和 CCA 排序、物種多樣性指數進行了分析。TWINSPAN 將 100 個樣方分爲 12 個植物群落類型，這些是中國以甘草佔優勢的主要群落。DCA 和 CCA 排序結果表明，植被分佈與土壤和氣候因數均有顯著的相關性。土壤氮、磷、鉀、有機質，年均氣溫、相對濕度、年均降水量、年均最高溫和年平均最低溫對這些群落的結構和分佈有重要影響，其中降水量是解釋植被空間格局的最重要因數。物種豐富度、多樣性和均勻度在群落之間有明顯的差異，它們的變化與環境梯度有顯著的相關性。最後對於烏拉爾甘草及其群落的進一步保護進行了討論。

關鍵詞：藥用資源；甘草；生物多樣性；生態恢復；半乾旱和乾旱地區。