

Quantitative analysis of endangered *Acanthopanax senticosus* communities in Dongling Mountain of Beijing

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Abstract Based on the survey of community plots, a quantitative analysis of endangered *Acanthopanax senticosus* communities in Dongling Mountain was performed with two way indicator species analysis (TWINSPAN), detrended correspondence analysis (DCA) and canonical correspondence analysis (CCA). The communities of *A. senticosus* were classified into 9 types by TWINSPAN and the results were validated by DCA. On the DCA graph, the first axis reflected the gradient of altitude and the second axis reflected the aspect and slope. Most of *A. senticosus* were distributed in the thick forests at a high altitude with little light. With the exception of being a dominant species of shrub layers in a few communities, *A. senticosus* has a relatively scarce distribution. In accordance with DCA, the results of CCA also show the trend that the distribution of *A. senticosus* communities varied along with the gradient change of environmental factors. Altitude and light are the main factors affecting *A. senticosus* growth.

Keywords endangered plant, *Acanthopanax senticosus*, classification of community, ordination

1 Introduction

Acanthopanax senticosus (*A. senticosus*), a perennial xylophyta species in the family of Araliaceae, prefers warm and wet habitats but can bear shading and cold conditions. It is mainly distributed in the mountainous broad-leaved forest, mixed forest and forest edge, such as Northeast China, Hebei Province and Shanxi Province. *A. senticosus* can be used both as medicinal and as a food plant in China. Its roots, containing phlorizin, are used as medicine and its seeds, rich in oil, are used as materials for

the production of soap. Therefore, *A. senticosus* is an important economic plant species in China.

A number of research demonstrate that *A. senticosus* has significant therapeutic effects on severe neurosis (Fan et al., 2003; Li, 2003), fatigue, cardiovascular disease (Li, 2003) and tumors. It can also improve the immune function. Therefore, it is a valuable woody plant with promising prospects. However, because of over cutting by humans and a low reproduction capability, the distribution of *A. senticosus* has decreased gradually. Now it has been listed as an endangered and nationally protected species (Biology Department of Beijing Normal University, 1992; Zhang, 2004a, 2004b; Zhang and Song, 2004; Zhu et al., 1998; Zhu and Zang, 1993). Over the recent years, studies on the breeding technique (Zhang, 2004a, 2004b; Zhang and Song, 2004), pharmaceutical composition (Fan et al., 2003) and clinical application (Song et al., 2004; Pan et al., 2002; Zhang, 2004a, 2004b; Zhang and Song, 2004) of *A. senticosus* have been carried out. However, relevant research on its ecological environment is few. The present work aims to study the community types of *A. senticosus* and their living environment, to interpret the relationships between *A. senticosus* and environmental variables and to find the most suitable habitats for *A. senticosus*.

2 Study site and methods

2.1 Study site

Dongling Mountains, located at 39°48′–40°00′N, 115°24′–115°36′E in the Men Tougou region of western Beijing, 100 km away from downtown Beijing, belongs to the Xiaowutai Mountain branch of the Taihang Mountain range. The majority of the mountainous areas are over 1000 m in altitude with the highest peak of 2303 m which is the highest point in Beijing.

The climate of this area is temperate, humid and monsoon. It is hot and rainy in the summer subjected to the

Translated from *Chinese Journal of Ecology*, 2007, 26(3): 314–318
[译自: 生态学杂志]

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southeastern monsoon. It is cold and dry in the winter subjected to Siberian cold current. The average annual precipitation is 638.8 mm, with 400–500 mm falling during June to August, which is 60%–80% of the total precipitation per year. The annual mean temperature is 2–7°C and the accumulative temperature over 10°C is 2300–3600°C. The annual sunshine hour is 2600 h and frost-free period is less than 160 d (Ma et al., 1999; Lou, 2004). The soil of this area is generally acidic mountainous brown soil. Subalpine meadow soil and brown forest soil are also widely distributed. With more than 90% coverage, the warm temperate coniferous forest and broad-leaved deciduous forest are typical forest communities and zonal vegetation in the Dongling mountainous region. *Pinus tabulaeformis*, *Juglans mandshurica*, *Larix principis-ruprechtii*, and *Quercus mongolica* are the dominant species in the forests (Lou, 2004). Because of human interference, the primary forest has been exhausted long since and the secondary woodlands and artificial coniferous forests are the main vegetation.

2.2 Methods

2.2.1 Sampling

According to the characteristics of the environment, 30 samples of 10 m × 10 m were set up from the foot to the top of the mountain in Gou Shicao and Nan Gou valleys where *A. senticosus* could be found in the Xiao Longmen region of Beijing in August, 2005. The height, cover and dbh for trees as well as the height and cover for shrubs and herbs in each sample were measured and recorded, respectively. Totally 125 species in 30 samples were recorded. The importance value for each species in each sample was calculated and the data matrix was the importance values of 125 species in 30 samples. In the meantime, the altitude, slope, aspect and the depth of litters of each sample were recorded. In addition, the cover of the tree layer was taken as an environmental factor on account of its obvious influence on growth and distribution of *A. senticosus*. Thus, the environment data matrix was values of 5 environmental variables in 30 samples.

2.2.2 Quantitative analysis

TWINSPAN (Two-way indicator species analysis) and DCA (Detrended correspondence analysis), the most common methods in ecology, were used to classify and ordinate the communities of *A. senticosus*. CCA (Canonical correspondence analysis) was used to analyze the relationship between the communities of *A. senticosus* and their environments. TWINSPAN was calculated with the software of VESPAN, and DCA and CCA were calculated with CANOCO. The details of mathematical principles can be found in the reference (Zhang, 2004).

3 Results

3.1 TWINSPAN classification

Thirty samples were divided into 9 groups by TWINSPAN (Fig. 1) which represents 9 forest communities:

- I. Comm. *Betula dahurica* – *Corylus mandshurica* – *Prenanthes tatarinowii* + *Phlomis umbrosa*.
- II. Comm. *Betula dahurica* – *Acanthopanax senticosus* – *Matteuccia struthiopteris*.
- III. Comm. *Betula dahurica* + *Populus maximoweczii* – *Acanthopanax senticosus* – *Matteuccia struthiopteris* + *Potentilla simalatrix*.
- IV. Comm. *Juglans mandshurica* – *Deutzia parviflora* – *Phlomis umbrosa*.
- V. Comm. *Juglans mandshurica* – *Deutzia parviflora* – *Adenocaulon himalaicum*.
- VI. Comm. *Juglans mandshurica* – *Deutzia parviflora* – *Cardamine leucantha*.
- VII. Comm. *Juglans mandshurica* + *Corylus heterophylla* – *Acanthopanax senticosus* – *Chrysosplenium pilosum* var. *valdepilosum* + *Cardamine leucantha*.
- VIII. Comm. *Juglans mandshurica* + *Acer truncatum* – *Corylus mandshurica* + *Acanthopanax senticosus* – *Matteuccia struthiopteris*.
- IX. Comm. *Juglans mandshurica* – *Spiraea pubescens* – *Artemisia lavandulaefolia* + *Artemisia gmelinii*.

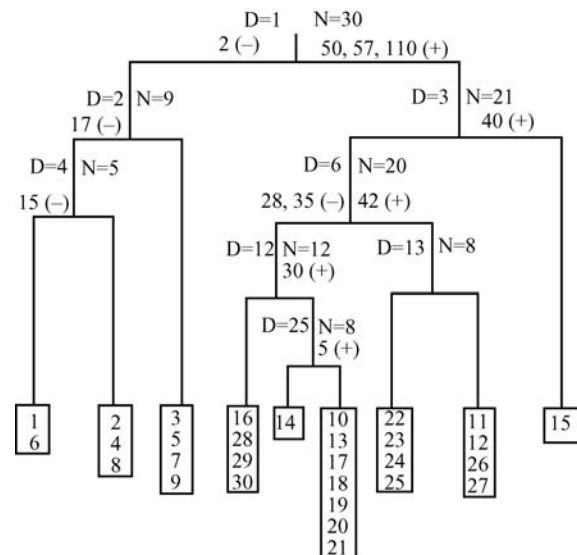


Fig. 1 Dendrogram of TWINSPAN classification of 30 samples of *A. senticosus* communities. Note: N: number of samples; D: division times; plot numbers are in boxes

The main characteristics of each community are listed in Table 1.

3.2 DCA ordination

The eigenvalues of the first four DCA axes are 0.421, 0.266, 0.150 and 0.118, respectively. A two dimensional

Table 1 Main characteristics of the nine *A. senticosus* communities classified by TWINSpan

community types	altitude/m	slope/°	aspect	depth of litters/cm	cover of the tree layer/%	cover of the shrub layer/%	cover of the herb layer/%	other common species
I	1420–1330	25	N	9.5	70	40	20	<i>Betula platyphylla</i> , <i>Lonicera chrysantha</i> , <i>Acer truncatum</i> , <i>Carex siderosticta</i> , and so on
II	1380–1310	20	N	8	60	75	16	<i>Acer truncatum</i> , <i>Deutzia parviflora</i> , <i>Cornus bretschneideri</i> , <i>Carex siderosticta</i> , <i>Potentilla simalatrix</i> , <i>Aster ageratoides</i> , and so on
III	1370–1300	25	N	10	80	50	30	<i>Corylus mandshurica</i> , <i>Cardamine leucantha</i> , <i>Carex planiculmis</i> , and so on
IV	1340–1250	5	W	8	80	20	65	<i>Acer truncatum</i> , <i>Fraxinus bungeana</i> , <i>Rubus crataegifolius</i> , <i>Sambucus sieboldiana</i> , <i>Artemisia igniaria</i> , <i>Potentilla simalatrix</i> , <i>Corydalis raddeana</i> , and so on
V	1190	5	E	0	95	10	40	<i>Acer truncatum</i> , <i>Aconitum kusnezoffii</i> , <i>Agrimonia pilosa</i> , <i>Laportea macrostachya</i> , and so on
VI	1300–1240	30	N	10	80	50	28	<i>Betula dahurica</i> , <i>Corylus mandshurica</i> , <i>Lonicera chrysantha</i> , <i>Hydrangea bretschneideri</i> , <i>Ribes mandshuricum</i> , <i>Adenocaulon himalaicum</i> , <i>Prenanthes tatarinowii</i> , <i>Smilacina japonica</i> , and so on
VII	1360–1320	25	N	7.5	30	60	25	<i>Quercus mongolica</i> , <i>Acer truncatum</i> , <i>Deutzia parviflora</i> , <i>Corylus heterophylla</i> , <i>Matteuccia struthiopteris</i> , <i>Smilacina japonica</i> , and so on
VIII	1400–1240	20	N	14	55	45	13	<i>Populus maximoweczii</i> , <i>Quercus mongolica</i> , <i>Deutzia parviflora</i> , <i>Ursica laetivirens</i> , <i>Cardamine leucantha</i> , and so on
IX	1040	15	N	0	60	15	95	<i>Deutzia parviflora</i> , <i>Syringa pekinensis</i> , <i>Ostericum sieboldii</i> , <i>Humulus scandens</i> , <i>Aconitum kusnezoffii</i> , <i>Rabdosia japonica</i> var. <i>glaucoalyx</i> , and so on

DCA ordination graph was plotted based on the first two axes (Fig. 2).

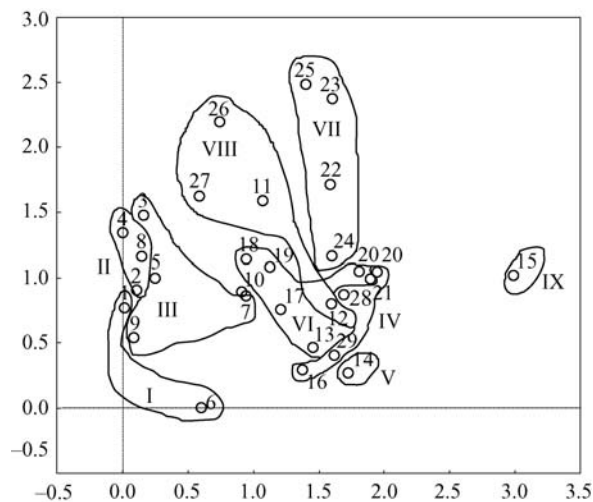


Fig. 2 Two dimensional DCA ordination diagram of 30 samples.

Each of the nine community types classified by TWINSpan has its own distribution scope in the DCA diagram indicating that DCA describes the

relationships of species, communities and environment clearly.

From left to right of the first DCA axis, the communities changed in the order of *Betula dahurica* – *Corylus mandshurica* – *Prenanthes tatarinowii* + *Phlomis umbrosa* (I) (AX1 = 0.0–0.6) distributed in 1420–1330 m; *Betula dahurica* – *Acanthopanax senticosus* – *Matteuccia struthiopteris* (II) (AX1 = 0.0–0.1) distributed in 1380–1310 m; *Betula dahurica* + *Populus maximoweczii* – *Acanthopanax senticosus* – *Matteuccia struthiopteris* + *Potentilla simalatrix* (III) (AX1 = 0.1–1.0) distributed in 1370–1300 m; *Juglans mandshurica* + *Acer truncatum* – *Corylus mandshurica* + *Acanthopanax senticosus* – *Matteuccia struthiopteris* (VIII) (AX1 = 0.6–1.7) distributed in 1400–1240 m; *Juglans mandshurica* + *Corylus heterophylla* – *Acanthopanax senticosus* – *Chrysosplenium pilosum* var. *valdepilosum* + *Cardamine leucantha* (VII) (AX1 = 1.5–1.7) distributed in 1360–1320 m; *Juglans mandshurica* – *Deutzia parviflora* – *Phlomis umbrosa* (IV) (AX1 = 1.5–2.0) distributed in 1340–1250 m; *Juglans mandshurica* – *Deutzia parviflora* – *Adenocaulon himalaicum* (V) (AX1 = 1.7) distributed in 1190 m; *Juglans mandshurica* – *Deutzia parviflora* – *Cardamine leucantha* (VI) (AX1 = 1.0–2.0) distributed in 1300–1240 m; and *Juglans mandshurica* – *Spiraea pubescens* – *Artemisia*

lavandulaefolia + *Artemisia gmelinii* (IX) (AX1 = 3.0) distributed in 1040 m. This suggests that the first DCA axis represents an altitudinal gradient, i.e. altitude was gradually decreased from left to right.

Thirty samples could be classified into 3 groups approximately along the first DCA axis. Most samples were in the center of the graph. Some were in the left and only one was in the right. This indicates that *Acanthopanax senticosus* mainly grew in middle and high altitudinal areas and elevation was one of the important environment factors influencing *A. senticosus* and its communities.

The second DCA axis reflects the changes of slope and aspect. From the top to the bottom, the aspect varied from the north to the west and the east and the slope varied from steep to gentle and then to steep again. The intensity of light in the communities changed markedly along with the change of aspect and slope. Meanwhile, the temperature and humidity of communities also varied greatly. Communities VIII and VII at the top of the graph usually lived in steep hills in the north with weak sunlight. Communities II, III, VI and IX in the middle of the graph lived in the gentle hills in the northeast and northwest with moderate sunlight. Communities I, IV and V at the bottom of the graph lived in the steep hills with ample sunlight. Therefore, the intensity of light of the community was increased along the second axis.

Although the intensity of sunlight influences the community and species, the communities investigated mainly lived in an environment with weak sunlight on the whole. In other words, *A. senticosus* preferred environments under forest canopy with weak sunlight and strong moisture and most species in the communities also lived in similar habitats.

3.3 CCA ordination

On the CCA diagram (Fig. 3), the points represent samples and arrowheads represent environmental variables. The first CCA axis is positively related to the cover of the tree layer (0.9737) and negatively related to altitude (-0.3737). The second CCA axis is positively related to slope (0.9486) and negatively related to altitude (-0.1481). The covers of *A. senticosus* in samples 29, 17, 28, 30, 16 and 14 were less than 10%. However, that in samples 23, 24, 19 and 27 were more than 40% and it became the dominant species in the shrub layer in these samples. The cover of the tree layer can evidently affect the intensity of sunlight in community and consequently, altitude and intensity of sunlight were the main environmental factors that limited the growth and distribution of *A. senticosus*. In the closed forests with little light in higher altitude areas, the stronger the light and the lower the altitude was, the smaller the *A. senticosus* population size was.

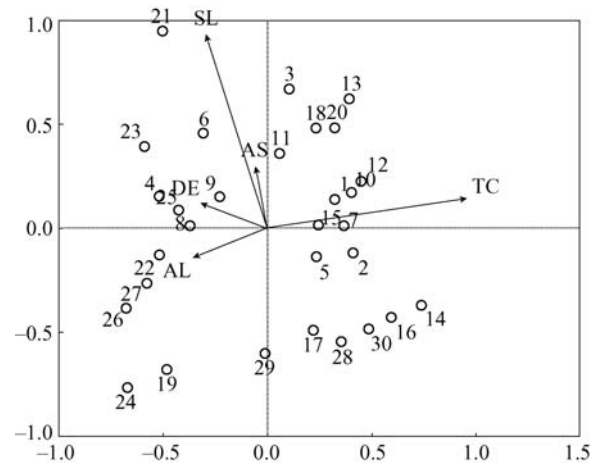


Fig. 3 Two dimensional CCA ordination diagram of 30 samples. Note: SL is slope, AS the aspect, DE the depth of litters, TC the cover of tree layer and AL the altitude

4 Discussion

The nine communities classified by TWINSpan represent the main types of *A. senticosus* communities in Beijing which are natural secondary forests with obvious layer structure and little human interference. In the communities of *Betula dahurica* - *Acanthopanax senticosus* - *Matteuccia struthiopteris* (II), *Betula dahurica* + *Populus maximowiczii* - *Acanthopanax senticosus* - *Matteuccia struthiopteris* + *Potentilla simalatrix* (III), *Juglans mandshurica* + *Corylus heterophylla* - *Acanthopanax senticosus* - *Chrysosplenium pilosum* var. *valdepilosum* + *Cardamine leucantha* (VII) and *Juglans mandshurica* + *Acer truncatum* - *Corylus mandshurica* + *Acanthopanax senticosus* - *Matteuccia struthiopteris* (VIII), *Acanthopanax senticosus* was the dominant species in the shrub layers. These communities grew at comparatively high altitude with slow aspect in northern slope and their depth of litters was about 10 cm. However, *Acanthopanax senticosus* were less in communities in the low altitude areas with stronger light. The tree layer and dominant tree species had obvious effects on the inner environment of the communities and played an important role in keeping the stability of communities. Consequently, they had direct or indirect influences on the growth of *A. senticosus* (Zhu and Zang, 1993).

The distribution of samples in the DCA diagram is a testament of the rationality of classification of TWINSpan and reflected the relationships between communities, species and environment. The DCA diagram shows that altitude and intensity of light were the main environmental factors influencing the community types and species composition in *A. senticosus* communities. The CCA diagram shows that the cover of *A. senticosus* was negatively related to the cover of tree layer and altitude and positively related to slope and aspect. Among the environmental factors analyzed, the cover of tree layer

was most important for growth of *A. senticosus*. Although *A. senticosus* grew in the shade and in damp environments under the forest canopy (Biology Department of Beijing Normal University, 1992; Zhu et al., 1998; Zhu and Zang, 1993), it also preferred sunlight. Usually it grew slowly in heavy closed forestry, but once it got ample sunlight, it would grow quickly and blossom (Zhao et al., 2004; Zhu and Zang, 1993). Zhu et al. (1998) described that the more the coverage of community was, the smaller the density of *A. senticosus* was. Our analysis also indicated that the more the cover of the tree layer was, the less the cover of *A. senticosus* was. Altitude was another important environmental factor affecting the growth of *A. senticosus*. With the decrease in altitude, the dominance of the grass layer was increased which increased interspecies competition in community and the existence of *A. senticosus* saplings would be threatened (Zhu and Zang, 1993).

A. senticosus with low adaptability to the environment mainly live in woodlands. In communities in low altitudes, the cover of *A. senticosus* was small, but in communities higher than 1300 m, it gradually became the dominant species in the shrub layers. In the heavy closed forests, it could not grow well and was not the dominant species in the shrub layer. Subsequently, the *A. senticosus* population was obviously decreased. The communities in which *A. senticosus* was dominant in the shrub layer mainly grew in the high altitude regions. This may be related to the intensity of sunlight. Human interference might be another important factor affecting *A. senticosus* in this region. Additionally, the depth and property of litters in communities might influence the seed dispersal and germination because *A. senticosus* mainly grew in the northern hills (Guo and Shangguan, 2005).

The sexual reproduction and regeneration of *A. senticosus* is strictly limited because of its low maturity rate, poor dispersal ability and low germination ratio for seeds. In addition, the over cutting for medicinal use and the degradation of its environment (Zhang, 2004a, 2004b; Li et al., 2005) make *A. senticosus* a precarious situation. To protect this valuable species, it is necessary to forbid cutting, to create and protect suitable community environments for *A. senticosus* and deepen the research on the cloning and reproduction of this species.

Acknowledgements This study was supported by the National Natural Science Foundation (Grant No. 30070140). We thank Bai Fan, Bian Anqi, Jia Hanchao, Liu Liyu and Liang Shuting for their assistant in the field work.

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