The Habitat of *Astragalus adsurgens* PALL. Populations Indigenous to Yunwu Mountain in the Loess Plateau, North-west China

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Abstract

In order to clarify the characteristics of the habitat of *Astragalus adsurgens* Pall. populations, the vegetation of a shrub-steppe was examined on various slope directions in Yumwu Mountain in 1990 as a part of a program on the restoration of the Loess Plateau. Principal component analysis was applied to the vegetation data. Soil samples were taken and analyzed.

Indigenous populations of *A. adsurgens* were observed only on the northern slopes. From the results of ordination, the habitat of *A. adsurgens* was characterized by humus-rich soil with comparatively high soil moisture. Soil pH within a range of 8.0 to 8.3 had little effect on the occurrence pattern of *A.adsurgens*. Correlations between *A.adsurgens* and other species were discussed.

Key words:*Astragalus adsurgens*, Loess Plateau,ordination, shrub-steppe, slope directions.

Introduction

Astragalus adsurgens Pall. is said to be one of the most important herbage legumes in semi-arid zones in China (Wang & Ren, 1989). It has great advantages over other legumes or grasses because of its cold and drought resistance and high productivity. As a result of these advantages, local governments have encouraged its cultivation.

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A. adsurgens is known as "erect milkvetch" in English, "Shadawang" in Chinese (Wang & Ren, 1989) and "Murasaki momenzuru" in Japanese (Ohwi, 1978). It has a wide distribution from north-east China to Siberia including northern Japan. Two types of *A. adsurgens* are observed in Japan. One erect type is distributed over northern Honshu and Hokkaido. Another type is characterized by creeping growth and has a limited distr ibution being found only on Mt. Fuji and some other mountains in Shinshu (Ohwi, 1978). In China, the same tendency is observed (Xiu, 1990).

The erect cultivated type of *A. adsurgens* is said to be unsuitable for the Loess Plateau which has an altitudinal range of 1500 to 2000 m and which is situated in the semi-arid zone of north-west China. The plants rarely reach maturity to allow natural reseeding on the Loess Plateau. An early-maturing variety was developed by radiation breeding and five-generation selection during the period from 1980 to 1984. The new variety was named as early-ripe "Kefuxi" in Chinese (Ma, 1986). At present, it is widely used in the Loess Plateau because of its approximately 60-day earlier maturity than the original variety.

However, undesirable agronomic characteristics such as a thick stem, low palatability and so on exist in the new variety. In order to develop a better new variety, another promising procedure is the introduction of genes from the creeping wild type to the cultivated type of *A. adsurgens*. For this purpose, fundamental research is needed with respect to the ecology of the wild type of *A. adsurgens*.

To examine the suitable management of land resources from a global point of view, a rehabilitation program was commenced in the Loess Plateau in 1988 by Japanese and Chinese scientists (Tamura, 1991). This report is based on part of the results of this program.

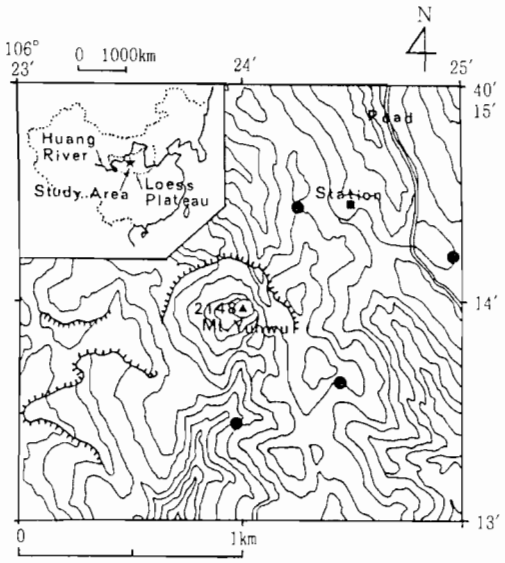

Fig.1 The study area Yunwu Mountian. Solid circles show sampling sites. Contour lines are placed at 40m intervals.

Materials and Methods

This study was carried out in the Yunwu Mountain Pastoral Preserve Zone (latitute 36° 13′−19′ north and longitude 106° 24′−28′ east) in Guyuan Country, Ningxia Hui Autonomous Region, situated in the western part of the Loess Plateau (Fig. 1). For many years the grassland was used tograze animals or harvest hay by the surrounding inhabitants. But in 1983, a pastoral preserve including 3200 hectares with an altitudinal range from 1500 to 2100 m was established in order to preserve the vegetationas a typical shrub-steppe (Zou et al., 1986). After 4 years of conservations, however, the grasslands of the preserve zone were again grazed in 1987 because of a shortage of animal feeds due to a severe drought (less than 300mm annual precipitation) in the previous year.

The conservation of the grassland commenced again in 1988. The creepingwild type of *A. adsurgens* is indigenous to this preserve zone.

The survey was conducted during the period from July 28 until August 6 in 1990. Four study sites were selected (Fig.1). At each site, vegetational surveys were carried out on two adjoining slopes: one slope including the creeping type of *A. adsurgens* and another slope without any plants of *A. adsurgens*. On each slope, the vegetation was sampled at three points selected at random. At each point, a 0.25-㎡ square quadrat was laid down. The cover and height of all vascular plants within the quadrat were recorded. The eight sites studied had an inclination of 22 to 30 degress and an altitudinal range of 2000 to 2100 m.

The ordination method was used to analyze the vegetation data. To interpret the main environmental gradients related to variation in vegetation, principal component analysis (PCA) was carried out (Goodall, 1970). The analysis was a form of PCA reported by Dye and Walker (1980), which allows for the inclusion of both species and environmental factors (Grein-Smith, 1983). The standardization of original coverage data for species was done prior to PCA (Noy-Meir, 1973). Since rare species were statistically inactive (Barkham & Norris, 1970), abundant species occurring with greater than 10% frequency were used for the analysis. As a criterion of species diversity, or heterogeneity, the information content (I) was calculated (Greing-Smith,1983; Clifford & Williams, 1976). To determine species groups associated with *A. adsurgens*, chi-squared values were calculated for testing significance.

Soil samples were taken from the 2.5㎝ layer down to the 45㎝ layer in the soil. Soils were dried and passed through a 2-㎜ sieve. The ordinary methods of chemical analyses described in another report (Nanjing Soil Research Institute,1978) were used.

Meteorological observations were carried out during the period from May to August in 1989 and 1990 at the experimental station of the preserve zone at an altitude of 1800 m. Air temperature, soil temperature at depths of 5 and 15 cm, precipitation and total integrated solar radiation were measured.

Results and Discussion

Climatic conditions

The climatic conditions at the Yunwu Mountain Pastoral Preserve Zone were estimated from data from the nearest meteorological staion by using an altitudinal lapse. The mean annual air temperature is 5-6℃, which is similar to the 6.1℃ figure for Obihiro, Japan, the frost-free period is 120-150 days, and the mean annual precipitation is 400-480㎜ (Zou, et al., 1986). The meteorological observations carried out in this study showed annual precipitation of 413㎜ during May to August in 1989 (Fig. 2). About 60% of the total annual precipitation fell during July and August. The meandecade maximum temperature of the hottest month is 17.8℃ in the second decade of July.

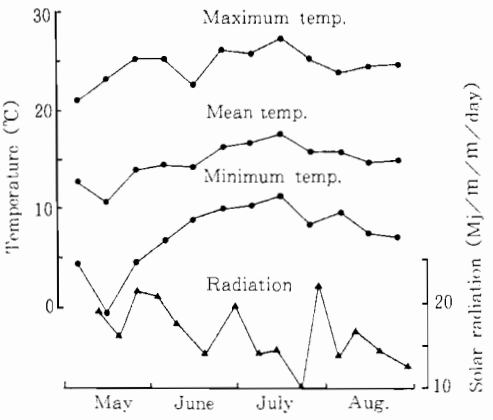

Fig.2 Mean decade temperatures and total decade solar radiations in 1989 at the preserve station of Yunwu Mountain.

Vegetation of the shrub-steppe

The mean coverage of the 34 main species is shown in Table 1. *A. adsurgens* had a high coverage on northern slopes and no plants were found on the western or eastern slopes. It seems therefore that its tolerance for drought stress is comparatively low. *Stipa bungeana* was the most predominat plant on all slopes with an average coverage of 64%. Other grasses, such as *S.grandis*, *Poa sphondylodes* and *Agropyron cristatum*, were also important species, Especially on the northern slopes, the dense vegetation was mostly composed of these grasses, Other herbs such as *Thymus mongolicus* belonging to the family *Labiatae*, and *Artemisia sacrorum* were also dominant species, A patch of *T. mongolicus* occupied a large space on each of the western or eastern slopes. *Artemisia* species are said to have great tolerance for drought (Zou et al., 1986).

The species diversity on the northern slopes was very similar to that on the other slopes. The information content as a criterion of species diversity was 228 on each slope.

Table 1. Mean coverage of 34 main species on the different slopes in shrub-steppe of Yunwu Mountain

No.	Scientific name	Northern slope	Western or eastern slopes	No.	Scientific name	Northern slope	Western or eastern slopes
1	*Stipa bungeana*	56.3	70.8	21	*Pedicularis spp.*	5.1	0.8
2	*Artemisia sacrorum*	43.8	31.3	22	*Bupleurum scorzonerifolium*	3.3	2.5
3	*Poa sphondylodes*	6.3	18.8	23	*Tanacetum nematolobum*	4.8	0.8
4	*Trigonella ruthenica*	16.3	8.4	24	*Arenaria giraldii*	4.7	0.5
5	*Stipa grandis*	10.4	10.4	25	*Gentiana squarrosa*	1.5	3.3
6	*Leontopodium leontopodioides*	8.8	11.8	26	*Potentilla bifurca*	1.1	3.6
7	*Carex enervis*	10.6	7.5	27	*Oxytropis ochrantha*	0.6	3.5
8	*Thymus mongolicus*	2.2	15.8	28	*Viola patrinii*	1.1	1.5
9	*Allium lolidum*	6.7	9.2	29	*Stellera chmaejasme*	1.3	0.9
10	*Hoegneria purpurascens*	9.2	4.2	30	*Cleistogenes squarrosa*	–	2.2
11	*Carex rigescens*	6.7	6.7	31	*Potentilla tanacetifolia*	0.9	0.5
12	*Agropyron cristatum*	6.7	5.0	32	*Gentiana daurica*	0.8	0.5
13	*Astragalus scaberrimus*	6.8	4.7	33	*Kalimeris indica*	0.1	0.1
14	*Saussurea japonica*	8.8	1.0	34	*Delphinum grandiflorum*	0.4	0.5
15	*Astragalus adsurgens*	9.6	–				
16	*Potentilla chinensis*	6.8	1.3		Information content (I) within slope	228	228
17	*Hierochloe odorata*	2.1	5.9				
18	*Carum buriaticum*	3.4	4.6		Total I	493	
19	*Dracocephalum heterophyllum*	3.8	2.7				
20	*Artemisia scoparis*	2.6	3.5				

An ordination diagram is shown in Fig. 3 for 8 stand-scores and in Fig.4 for 34 species. The first and second axes of the ordination accounted for 19.4% and 14.1% of the variance of the data, respectively.

The trends represented by axes I and II correspond to the different slope directions and the different sites on each slope, respectively. Stands at the positive side along axis I were identified as those of the northern slopes and at the negative side those of the western or eastern slopes (Fig. 3). The environmental factors along axis I, therefore, appear to be related to the micro-topography. It was not possible, though, to find particular environmental variables related to axis II with respect to stan ordination.

According to the species ordination (Fig. 4), *A. adsurgens* and *Tanacetum nematolobum*, *Chrysanthemum*, were highly loaded at the positive end of axis I. These species had a high coverage on the northern slopes. Environmental factors such as soil moisture, organic matter and nitrogen at depths of both 5 and 15cm were also situated at the positive end. Therefore, the habitat of *A. adsurgens* was restricted to sites having good soil conditions, which are associated with the high moisture and fertility of soils on the northern slopes. In contrast, some species such as *S.bungeana, P. sphondy lodes* and *T. mongolicus* with lower loadings on axis I showed lower coverage on the northern slopes than on other slopes. Environmental factors such as slope directions, inclination and pH at a 5cm depth were also situated at the negative end. These factors indicate that soils at the surface layer are dry and erode easily especially on the western and eastern slopes.

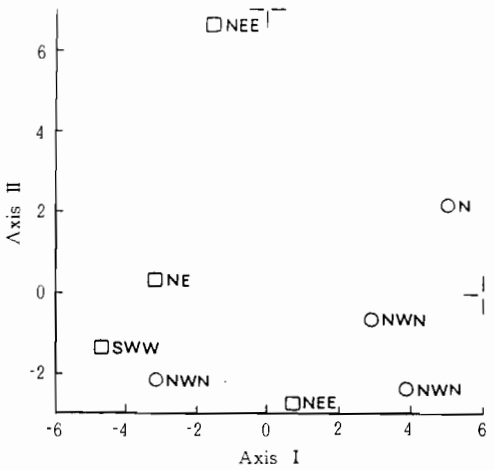

Fig. 3. Ordination diagram of 8 sampling slopes on axes I and II by principal component analysis. Letters attached to circles and squares show slope direction.
○ : northern slope.
□ : eastern or western slopes.

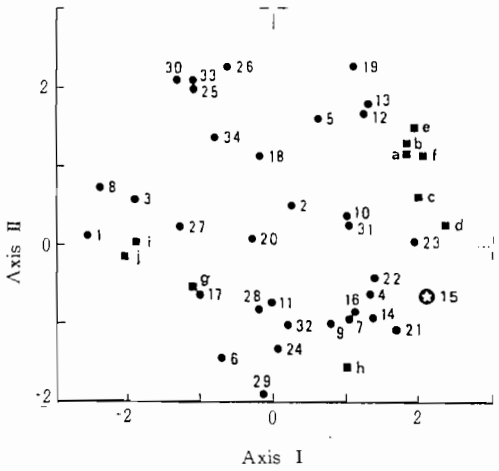

Fig. 4. Ordination diagram of 34 main species (●) and environmental factors (■) on axes I and II by principal component analysis. Numbers attached to solid circles show species number, equivalent to those shown in Table 1. Letters attached to solid squares mean as follows :
Soil moisture : a ; at 5cm, b ; at 15cm,
Organic matter : c ; at 5cm, d ; at 15cm,
Total nitrogen : e ; at 5cm, f ; at 15cm,
pH : g ; at 5cm, h ; at 15cm,
i : slope direction, j : inclination.

Some species at the positive end along axis II showed high frequencies on the western or eastern slopes. The reverse trend was observed in the abundance patterns of some species located at the negative end. There fore, the environmental variables indicated by axis II were related to the vegetational variation within one slope. The pH at a 15cm depth which is located at the negative end seems to affect the abundance patterns of species on the eastern and western slopes.

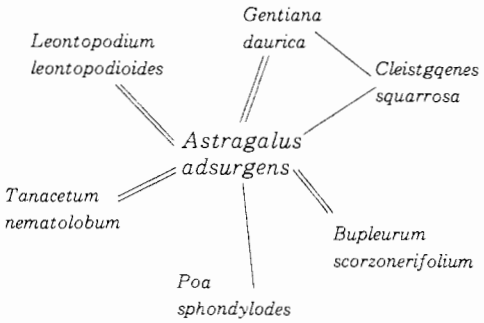

Fig. 5. Correlations between *Astragalus adsurgens* and six species based on chi-squared values. Parallel and single lines show the positively and negatively significant correlations at p=0.01, respectively.

Species groups significantly correlated with *A. adsurgens* are shown in Fig.5. *A.adsurgens* positively correlated with *Bupleurum scorzonerifolium*, *Tanacetum nematolobum*, *Leontopodium leontopodioides* and *Gentiana daurica*, and negatively with *Poa sphondylodes* and *Cleistogenes squarrosa*. The positively correlated species occurred mostly on the northern slopes.

Vertical Distribution of Soil Properties

The results of chemical analyses of soils are shown in Fig. 6. Soil moistures at all depths were apparently higher on the northern slopes than on other slopes. The soil moisture content decreased to depths down to about 15cm but then maintained the same level at greater depths on all slopes. The higher moisture at the surface was caused by precipitation occurring immediately before the soil sampling. According to meteorological observations at Shunghuang-sun about 20km due south of Yunwu Mountain, it rained at a rate of 6mm and 6.5mm two days and three days before the samplings, respectively.

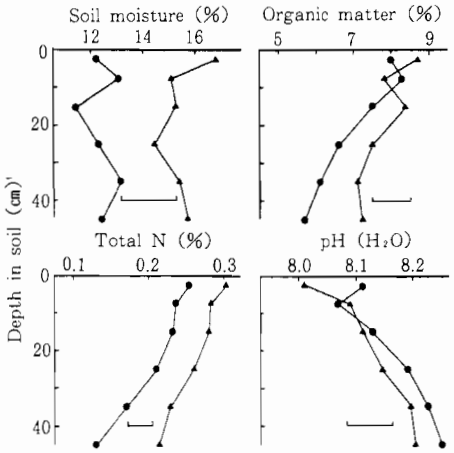

Fig. 6. Vertical distribution of soil properties on the northern slope (▲) and on the western or eastern slopes (●) .
Horizontal bars show the standard error of the difference between means.

On the surface, the pH(H_2O) was apparently low on the northern slopes (8.01), compared with that on the western or eastern slopes (8.11). With increasing depths, the pH increased with the same pattern on different slopes, but the differance between slopes was very small. Mean values of pH at 45cm depth were 8.21 on the northern slopes and 8.25 on other slopes. These suggest that pH has little effect on the occurrence pattern of *A. adsurgens*.

Organic matter and total nitrogen at the surface layer were higher on the northern slopes than on other slopes. Their content markedly decreased of increasing depths. Below the 15cm depth, the decreasing pattern

was similar on all slopes.

These vertical patterns clearly reflect the water movement in each soil profile (Jeffrey, 1987), It is suggested that water moves downward in soil on northern slopes, but on western or eastern slopes upward movement of water is caused by severe evaporation at the soil surface, resulting in the accumulation of calcium carbonate in the upper layers. This difference may explain the variation in floristic composition or grassland production. It also suggests that *A. adsurgens* can grow on wet and humus-rich soil in the shrub-steppe of Yunwu Mountain.

Agricultural importance of A. adsurgens

Generally, two types of *A. adsurgens*, the erect cultivated type and the creeping wild type, have been recognized in China. The cultivated type of *A. adsurgens* is said to have high productivity and superior resistance to the droughts and cold weather of the semi-arid region in China (Wang & Ren, 1989). According to Zou et al.(1988), monocultural grassland using the cultivated type of *A. adsurgens* produced 9200 kg dry matter per hectare in the fourth year after the establishment, but its productivity decreased sharply down to 3000 kg per hectare in the seventh year. In spite of this reduction, the cultivated type of *A. adsurgens* still has importance for grassland improvement.

Fu et al.(1982) reported that it might be reasonable to classify *A. adsurgens* as two species due to the differences in the morphology of their pollen grains and their karyotype, although the number of chromosome is the same (2m=16) for both species. The wild type of *A. adsurgens* has some outstanding agronomic characters such as early maturity, a fine stem and high palatability. The cultivated type, which was developed by radiation breeding, has undesirable agronomic characteristics such as a thick stem and low palatability. In order to create an improved variety in the future, it may be invaluable to use the creeping wild type of *A. adsurgens* as an important gene source. In this case, attention must be paid to the drought resistance of the wild type, Further studies are needed on the relationship between the cultivated and wild types of *A. adsurgens* from the viewpoint of ecology, physiology and plant breeding or genetics.

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中国北西部の黄土高原の雲霧山に自生するムラサキモメンズル (Astragalus adsurgens Pall.) 集団の生育地

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摘　　要

マメ科植物のムラサキモメンズル集団が自生する生育地の特性を明らかにするために、雲霧山の異なった斜面において低木ステップの植生を1990年に調査した。主成分分析法を植生データに応用した。土壌も採取し、分析した。なお、この研究は、黄土高原の緑化に関するプロジェクトの一環である。

ムラサキモメンズルの自生集団は、北向きの斜面にのみ生育していたので、腐食に富んだ、土壌水分の高い場所にのみ生育できるものと思われる。土壌pHはムラサキモメンズルの分布にほとんど影響をおよぼさなかった。さらに、ムラサキモメンズルと他の草種との関連性についても検討した。

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