

Composition and Distribution of Soil Spider Assemblages in Three Natural Secondary Forests in Ziwuling, Gansu

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Abstract: Soil spiders were pitfall-trapped once every month in three forest vegetation types of Ziwuling natural secondary forest region, Gansu Province from April to October, 2004. A total of 2 164 spiders were collected, belonging to 43 species in 19 families, captured in 630 pitfall trap collections. Linyphiidae, Gnaphosidae and Lycosodae were found to be the dominant families in all habitat types, and the composition of soil spider assemblages was different between the three habitats. Ecological indices of diversity, richness and evenness were significantly different between the three habitats ($P < 0.05$). The relative abundance of guilds (based on numbers of individuals) varied greatly ($P < 0.01$), which may reflect resource availability within habitat types. The existence of different patterns within the assemblages reflects the importance of maintaining habitat heterogeneity and vegetation types in order to preserve soil spider biodiversity.

Key words: Soil spider; Pitfall trap; Community structure; Secondary forest

甘肃子午岭天然次生林区三种植被类型中土壤蜘蛛群落的组成及多样性

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摘要: 2004年4—10月,在甘肃子午岭天然次生林区采用巴氏诱罐法采集土壤蜘蛛2 164头,隶属于19科43种。研究表明:辽东栎林(*Quercus liaotungensis*)、油松林(*Pinus tabulaeformis*)和杨树林(*Populus davidiana*)3种森林植被类型中土壤蜘蛛群落组成有明显的差异;不同生境蜘蛛群落的组成成分和多样性指数各异;从各生境中捕获的蜘蛛个体数量分析,皿蛛科、平腹蛛科和科狼蛛科的数量最多,优势类群的组成相似;各生境类型中蜘蛛功能集团的组成及多样性也有明显差异。同时,分析了影响蜘蛛群落组成和多样性的主要因子是生境的植被类型和生境异质性。

关键词: 土壤蜘蛛; 陷阱诱捕; 群落结构; 次生林

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Spiders are the most diverse and abundant invertebrate predators in terrestrial ecosystems (Wise, 1993; Nyffeler, 2000), foraging primarily on insects. Because of their high abundance and insectivorous foraging, spiders are considered the major agent controlling insect communities in terrestrial ecosystems (Riechert

& Lockley, 1984; Young & Edwards, 1990; Carter & Rypstra, 1995; Nyffeler, 2000). These characteristics make spiders a good indicator for comparing the biodiversity of various environments and for assessing the effects of habitat differences on biodiversity (Bultman & Uetz, 1982; Marc & Canard, 1997; Gao & Li, 2002;

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Huhta, 2002; Lie et al, 2004). However, most studies have focused on agricultural ecosystems in temperate zones, including China and the US (Gao & Li, 2002; Young & Edwards, 1990), while studies of spider diversity in natural secondary forest areas are rare. Although the area of Ziwuling secondary forest is small, it is home to various secondary forest vegetations of the Loess Plateau, China.

Natural secondary forest management is now a priority for governments and forest agencies worldwide. In this context, recent research has centred on various aspects of biodiversity and its conservation in the Ziwuling secondary forest region, including plants (Zou et al, 2002; Li et al, 2004) and insects (Jiang et al, 2006). However, the spider fauna associated with the plant communities in Ziwuling secondary forest region are poorly understood. Our primary purposes were to compare the structure and diversity of soil spider communities in *Populus davidiana*, *Quercus liaotungensis* and *Pinus tabulaeformis* forest vegetations. In addition, we aimed to construct spider guilds for the three forest vegetations.

1 Methods

1.1 Study area

The study area is located at Ziwuling in Zengning County, Gansu Province, China, (109°11'E and 36°01'N). The climate is semi-arid in the warm temperate zone, with average annual precipitation of 576.7 mm and average temperature of 9°C. The soil type is grey-cinnamon soils, which is low in organic matter. It is in the northern border of the deciduous broad forest belt. *Populus davidiana*, *Quercus liaotungensis* and *Pinus tabulaeformis* were chosen as the canopy species because they dominate the forest vegetation types. In the research area three habitats were studied: 1) *P. tabulaeformis* forest (PT: sites A, B, C), with distant shrubs and grasses. A large accumulation of leaf litter was present; 2) *Q. liaotungensis* forest (QL: sites D, E, F), with dense litter layer, moderate herbaceous and shrub layer. Dominant shrubs were *Cerasus tomentosa*, *Rubus* spp., and saplings of the canopy trees; 3) *P. davidiana* forest (PD: sites G, H, I), with a distant litter layer and dense herbaceous vegetation. The shrub layer was also distant in this habitat, consisting mainly of *Ostryopsis davidiana*, *Acanthopanax brachypus*, *Rosa* spp., and *Lespedeza* spp. See Jiang et al (2006) for a more detailed description of the plants in each community.

We measured six environmental variables to inves-

tigate whether any of the environmental measurements could predict the diversity of spiders among the three habitat types. We measured the thickness of the leaf litter and the air temperature on the ground surface and the relative air moisture near traps. Moreover, we estimated the percentage cover of the herbs, the shrubs and the canopy layer within a radius of 2 m around each trap.

1.2 Sampling

The three communities were sampled once in the middle of every month from April to October, 2004. Ninety pitfall traps were deployed. Ten traps were placed in each of three sites of each plant community. Pitfall traps were placed along a line transect with each trap at least 10 m apart. Trap lines were approximately 20–50 m apart. Each trap contained a 0.47-litre mixture of ethylene glycol, 95% ethanol, and water in a ratio of 2:1:2. See Uetz & Unzicker (1976) and Jiang et al (2006) for a more detailed description of pitfall trap design.

Thirty collections per plant community were made each collection month for a total of 630 pitfall collections. During each collection month, the pitfall traps remained open for 10 days. After that time, the contents of each trap were separated from the fluid using a fine-mesh wire screen and emptied into a glass bottle containing 70% ethanol. After each trap collection, the fluid was filtered, reconstituted back to its original volume and reused.

All spiders were identified using the available identification keys (Song & Zhu, 1989; Song et al, 1999, 2004; Chen & Zhang, 1991; Zhang et al, 2003). Some immature spiders could not be identified to family; these specimens are reported as undetermined (see Tab. 1).

1.3 Community structure and guild composition comparison

The community structure of soil spiders was described using the traditional Margalef species richness, Shannon-Weiner index, Simpson index and evenness (Krebs, 1989). In addition, guild compositions of the three different habitats were compared to examine how community structure varied between habitats. A comparison of guild composition can provide insight into the effects of habitat alteration and disturbances on arthropod biodiversity (Stork, 1987). Spiders collected from this study were divided into the five guilds according to the classification system proposed by Young & Edwards (1990) and Moran & Southwood (1982). Chi-square tests of homogeneity were used to compare the abun-

Tab. 1 Number of individuals collected and percent of spiders by family for the three communities in Ziwuling, Gansu

Family	QL forest		PT forest		PD forest		Total	
	No.	%	No.	%	No.	%	No.	%
Nesticidae	1	0.1	2	0.3	0	0.0	3	0.1
Uloboridae	3	0.3	0	0.0	2	0.4	5	0.2
Dictynidae	2	0.2	1	0.1	3	0.6	6	0.3
Theridiidae	2	0.2	2	0.3	1	0.2	5	0.2
Lycosidae	101	11.3	98	13.4	118	22.1	317	14.6
Araneidae	3	0.3	0	0.0	11	2.1	14	0.6
Tetragnathidae	6	0.7	4	0.5	2	0.4	12	0.6
Agelenidae	2	0.2	1	0.1	3	0.6	6	0.3
Hahniidae	1	0.1	6	0.8	0	0.0	7	0.3
Pisauridae	2	0.2	6	0.8	0	0.0	8	0.4
Oxyopidae	1	0.1	9	1.2	0	0.0	10	0.5
Linyphiidae	323	36.1	118	16.1	195	36.4	636	29.4
Gnaphosidae	198	22.1	223	30.4	75	14.0	496	22.9
Clubionidae	46	5.1	61	8.3	19	3.6	126	5.8
Zoridae	3	0.3	6	0.8	0	0.0	9	0.4
Atypidae	8	0.9	19	2.6	0	0.0	27	1.2
Thomisidae	65	7.3	57	7.8	48	9.0	170	7.9
Salticidae	83	9.3	53	7.2	44	7.8	179	8.3
Philodromidae	45	5.0	68	9.3	14	2.6	127	5.9
Undetermined	65	–	31	–	20	–	116	–
Total	895	100.0	734	100.0	535	100.0	2164	100.0

QL = *Quercus liaotungensis*; PT = *Pinus tabulaeformis*; PD = *Populus davidiana*.

dance of each guild between each pair of habitats. Sorensen's Index of Similarity (Kerbs, 1989) was used to determine the similarities of spider species composition among the communities.

1.4 Data analysis

Numbers of individual spiders and richness of spider species were log transformed ($x + 1$), and proportion data transformed using a square-root transformation before analysis. One-way analysis of variance (ANOVA) tests were used to compare relative spider abundances among the three types of habitat, and means were performed with Fisher protected least significant difference (LSD) at the 0.05 level of significance. Chi-square tests of homogeneity were used to compare the abundance of each guild between each pair of habitats. Multiple linear regression analyses were conducted between the distribution of spiders and the environmental variables. All analyses were performed using SYSTAT 5.2 (Wilkinson et al, 1992).

2 Results

2.1 Spider abundance and distribution

The 2 164 spiders sampled belong to 43 species in 19 families, captured in 630 pitfall trap collections from three habitats. An overall average of 3.43 spiders was caught per pitfall trap. Total numbers of spiders collected from three habitat types varied significantly ($F = 4.87$; $df = 2, 6$; $P < 0.05$). Most individuals were

identified to species but 116 individuals could not be identified. Vegetation type influenced spider individuals significantly: *Quercus liaotungensis* yielded 895 individuals, 36 species, and 19 families; *Pinus tabulaeformis*, 734 individuals, 30 species, and 17 families; and *Populus davidiana*, 535 individuals, 25 species, and 13 families. *Quercus liaotungensis* accounted for 42% of the combined spider assemblage for the three communities, *Pi. tabulaeformis* for 33.9% and *Po. davidiana* for 24.7%. The most abundant family was Linyphiidae with 636 individuals, representing 29.4% of the total, followed by Gnaphosidae with 496 individuals (22.9% of the total) and Lycosidae with 317 individuals (14.6% of the total). These three families were more abundant in each vegetation type (Tab. 1).

More spiders were trapped in July than in any other month, except for *Pi. tabulaeformis* forest which contained the greatest number of spiders in August. Most spiders were captured during summer months, and few spiders were collected in both April and October (Fig. 1).

2.2 Comparison of community structures and guild composition between habitats

The difference in individuals per trap was the highest in *Q. liaotungensis* and the lowest in *Po. davidiana* forest. The diversities (as assessed by Margalef species richness, Shannon index and Evenness) were significantly different in all three habitats (Tab. 2). However,

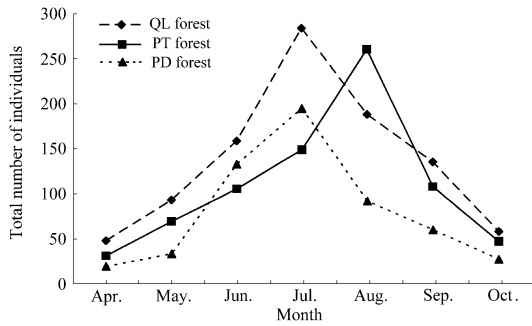


Fig. 1 Total number of spiders caught on the ground surface using pitfall traps in the three communities in Ziwojing, Gansu

Tab. 2 Comparison of community structures from specimens collected in three types of habitat in Ziwojing, Gansu

Habitats	Mean \pm SE				
	Indivi./per trap	Richness	Shannon index	Simpson index	Evenness
QL forest	4.75 \pm 0.61 ^a	4.31 \pm 0.25 ^a	2.83 \pm 0.19 ^a	0.95 \pm 0.07 ^a	0.71 \pm 0.02 ^a
PT forest	2.98 \pm 0.76 ^b	2.79 \pm 0.68 ^b	1.95 \pm 0.15 ^b	0.87 \pm 0.09 ^a	0.62 \pm 0.01 ^a
PD forest	1.48 \pm 1.01 ^c	1.36 \pm 0.91 ^c	1.08 \pm 0.11 ^c	0.83 \pm 0.05 ^a	0.35 \pm 0.08 ^b

QL = *Quercus liaotungensis*; PT = *Pinus tabulaeformis*; PD = *Populus davidiana*.

Means within columns followed by the same letter are not significantly different (Fisher protected LSD; $P > 0.05$).

are shown in Fig. 2. This study's guilds are: (1) wandering-active spiders, Lycosidae, Pisauridae, Oxyopidae, Gnaphosidae, Clubionidae and Salticidae; (2) web-sheet spiders, Linyphiidae, Agelenidae, Hahniidae, Nesticidae and Dictynidae; (3) wandering-ambush spiders, Thomisidae, Philodromidae and Zoridae; (4) web-matrix spiders, Theridiidae, Atypidae; and (5) web-orb spiders, Araneidae, Tetragnathidae and Uloboridae. The results of Chi-square tests between each pair of habitats showed that the composition of guilds differed significantly between habitats (QL and PT: $\chi_{0.01,16} = 148.22$; PT and PD: $\chi_{0.01,16} = 321.7$; QL and PD: $\chi_{0.01,16} = 283.15$; all of them $> \chi_{0.01,1} = 32.00$ and $P < 0.01$) (Fig. 2). All habitats were dominated by wandering-active spiders, followed by web-sheet builders, and then wandering-ambush spiders (Fig. 2). In all habitat types wandering-active spiders comprised around 70% of the specimens collected, mostly consisting of Lycosidae and Gnaphosidae. These two families comprised around 38% of the total captures. However, less than 30% of the specimens found in all habitat types belonged to other guilds: web-sheet spiders, wandering-ambush spiders, web-matrix and web-orb spiders.

2.3 Habitat preferences of dominant species

Tab. 3 shows the 15 most common species collected by frequency and relative abundance. The two most common species for each plant community were *Zelotes*

er, the Simpson index did not significantly differ between the three types of habitat, which were probably caused by the abundance of the three dominant families, Linyphiidae, Gnaphosidae and Lycosidae; these families appear to be the key groups, given their high abundance in all three habitats.

Species composition was most similar between *Q. liaotungensis* and *Pi. tabulaeformis* forest (0.68), then between *Pi. tabulaeformis* and *Po. davidiana* forest (0.57). *Quercus liaotungensis* and *Po. davidiana* forest (0.52) were the least similar.

Spider guild compositions of the three habitat types

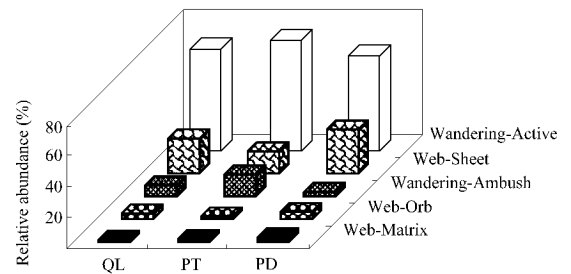


Fig. 2 Guild composition of spider communities from the three study in Ziwojing, Gansu

sites: QL = *Quercus liaotungensis* forest; PT = *Pinus tabulaeformis* forest; PD = *Populus davidiana* forest

asiaticus and *Pardosa astrigera*; *P. astrigera* was common in all communities, and *Z. asiaticus* was common in *Q. liaotungensis* and *Pi. tabulaeformis* forest. Species that specialized in only one habitat were: *Alopecosa pinetorum* in *Pi. tabulaeformis* forest, and *Drassodes* sp. in *Po. davidiana* forest. Species that preferred two habitats but not all habitats were: *Evarcha falcate* in the *Q. liaotungensis* and *Po. davidiana* forest; and *Clubiona* sp. in all forest types except *Po. davidiana* forest (Tab. 3).

Effects of the three habitat types on the abundance of fifteen most common species was significantly correlated with vegetation heterogeneity (ANOVA, $F = 5.9$, $df = 2, 6$; $P < 0.01$). Multiple linear regression analyses showed that the thickness of the leaf litter (x) on

the individuals per trap was a significant positive ($y = -0.3852 + 1.0419x$; $F = 8.92$, $r = 0.8783$, $n = 40$, $P = 0.005$). The air temperature (x) on the ground surface was a significant negative predictor for the individuals per trap ($y = 2.8733 - 0.0629x$; $F = 12.57$, $r = -0.6299$, $n = 18$, $P = 0.003$). The relative air moisture (x) near traps was a significant posi-

tive predictor for the individuals per trap ($y = -11.8928 + 1.7831 \sqrt{x}$; $F = 4.71$, $r = 0.6512$, $n = 18$, $P = 0.046$). The percentage cover (x) of the herbs, the shrubs and the canopy layer was a significant positive predictor for the individuals per trap ($y = -5.001 + 1.0314 \sqrt{x}$; $F = 15.78$, $r = 0.8917$, $n = 18$, $P = 0.001$).

Tab. 3 The 15 most common spider species ranked by frequency of occurrence within each plant community and relative abundance in Ziwuling, Gansu

Species	QL forest		PT forest		PD forest	
	Rank	Relative abundance	Rank	Relative abundance	Rank	Relative abundance
<i>Neriere emphana</i>	1	C	10	R	4	P
<i>Zelotes asiaticus</i>	2	C	1	C	5	P
<i>Pardosa astrigera</i>	3	C	2	C	2	C
<i>Gnathonarium dentatum</i>	4	P	9	R	1	C
<i>Gnaphosa kompirensis</i>	5	P	4	P	7	R
<i>Neriere liupanensis</i>	6	P	3	C	13	R
<i>Xysticus ephippiatus</i>	7	P	12	R	10	R
<i>Pardosa kupupa</i>	8	R	5	P	12	R
<i>Evarcha falcate</i>	9	R	-	-	11	R
<i>Clubions japonicola</i>	10	R	6	P	8	R
<i>Misumenops tricuspoidatus</i>	11	R	7	P	9	R
<i>Philodromus cespitum</i>	12	R	13	R	6	P
<i>Clubiona</i> sp.	13	R	9	R	-	-
<i>Plexippus paykulli</i>	14	R	14	R	15	R
<i>Erigonidium graminicolum</i>	15	R	11	R	3	C
<i>Drassodes</i> sp.	-	-	-	-	14	R
<i>Alopecosa pinetorum</i>	-	-	15	R	-	-

QL = *Quercus liaotungensis*; PT = *Pinus tabulaeformis*; PD = *Populus davidiana*.

R = rare, less than 1% of the total population for that community; P = present, 1–4.9%; and C = common, 5% or more.

3 Discussion

The composition and structure of the spider assemblages have significantly differed between the three types of habitat. Within each plant community, the three dominant families were Linyphiidae, Gnaphosidae and Lycosidae, with more than 60% of individuals being from one of these families (Tab. 1). Our study and that of Gao et al (2002) show great differences in dominant family compositions of spider communities. Since the vast majority of spider fauna is in natural habitats, this pattern is likely to reflect regional differences in the composition of spider fauna (Bultman & Uetz, 1982; Day et al, 1993; Huhta, 2002).

The diversity indices of spider assemblages were significantly different in the three habitats. The spider abundance, species richness, Shannon index and Evenness were the highest in *Quercus liaotungensis* forest and lowest in *Po. davidiana* forest (Tab. 2), which may be correlated with its dense litter and generally

moist ground surface. Litter and soil moisture have been shown to be correlated with spider species richness, abundance, and diversity by Uetz (1975, 1977, 1979), Bultman & Uetz (1982), Lie et al (2004). Most spiders were captured during summer months (Fig. 1); similar results have been reported by Uetz (1975) and Abraham (1985).

Spider guild structure (proportional abundance) varied between the three habitats (Fig. 2). Results of Chi-square tests between each pair of habitats showed that the compositions of guilds differed significantly between the habitats. The most common explanation for the observed patterns of spider guild are structural diversity, microenvironment or the level of disturbance of the habitat (Moran & Southwood, 1982; Young & Edwards, 1990; Marshall & Rypstra, 1999). Ample observations and more recent experimental evidence suggests that habitat structure maintains diverse spider assemblages (Jaksic, 1981; Pettersson, 1996) and may be critical to successful insect suppression (Carter &

Rypstra 1995; Marc & Canard, 1997; and reviews in Wise, 1993).

The distributions of 15 dominant species showed significant differences between the different habitat types however 13 of these species occurred in all three habitats. Over all communities, the four most common species were *Zelotes asiaticus* and *Pardosa astrigera* representing almost 60% of all spiders captured in pit-fall traps. In our study, there were clear habitat differences in the distribution and abundance of the 15 most common spider species that may reflect species-specific differences in habitat requirements. Ground surface spiders have been shown to demonstrate microhabitat pref-

erences along forest litter gradients (Uetz, 1975, 1977, 1979) and in agroecosystems (Marshall & Rypstra, 1999). They may select microhabitats based on available moisture, leaf litter, and herbaceous vegetation (Richman, 1995). Therefore, the main factor affecting the communities are spacial heterogeneity, vegetation type and food.

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