ECOLOGICAL DISTRIBUTION CHARACTERISTICS OF SOIL FAUNA COMMUNITIES IN DIFFERENT ALTITUDINAL GRADIENTS OF *PICEA SCHRENKIANA* IN THE WESTERN TIANSHAN MOUNTAINS, CHINA

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Abstract. In order to understand the characteristics of soil fauna community structure in different altitudes of *Picea schrenkiana* in the Western Tianshan Mountains, the soil fauna under *P. schrenkiana* at different altitudes (1414 m, 1595 m, 1724 m, 1868 m) was selected as the research object. According to the altitude from low to high, they were taken as plot-I, II, III, and IV. A total of 4003 soil fauna, belonging to 3 phyla, 7 classes, 21 orders and 41 kinds were collected. The average density of soil fauna in plot-IV was the highest, and the number of soil fauna groups was the highest in the plot-I. The richness index of soil fauna was the highest in the plot-I and the lowest in the plot-IV, and there was a significant difference between the plot-I and the plot-IV (P<0.05). The density, number of groups and diversity of soil fauna are different under different altitude gradients. In short, the change of altitude gradient leads to a different ecological distribution of soil fauna. In addition, this study has shown that organic matter, total nitrogen, total phosphorus, total potassium and readily available P are the dominant factors affecting the diversity and distribution of soil fauna communities.
Keywords: *altitude, soil macro-fauna, soil meso-fauna, community structure, environmental factors*

Introduction

Soil fauna is an important part of forest ecosystem (Bardgett and Vanderputten, 2014; Zhao et al., 2015). Community composition and function have a significant impact on soil formation, material circulation and energy flow (Wolters et al., 2000). Soil fauna is an important biological indicator of forest soil fertility. Moreover, it is closely related to the formation, development and succession of forest soil and the cycle of biological elements in forest ecosystem. The differences in community composition can reflect slight changes in the environment. Soil fauna research in China started late and made rapid progress, but the development is not balanced. In general, soil fauna studies in China mainly concentrate on Northeast, North, Central, South and Southwest China, among which the forest system is the most frequent. Farmland and grassland studies take the second place (Su et al., 2004; Tian et al., 2021; Dang et al., 2021). However, there are few comprehensive studies on Northwest China and various ecosystems. Xinjiang is one of the regions with special biodiversity in China, with a long history of animal groups,

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unique fauna and rich animal resources. The investigation, protection, exploitation and utilization of soil fauna and its diversity in various ecological environments have just started in Xinjiang. In the arid ecological environment of Xinjiang, the ecological functions of soil animals and their protection, development and utilization need to be studied systematically and comprehensively (Anwar and Omar, 2008; Omar et al., 2013; Gulbostan et al., 2013).

Picea schrenkiana is the main part of forest ecosystem in Tianshan Mountains. It plays an important role in water conservation, soil and water conservation, formation and maintenance of forest ecosystem, ecological balance of oasis in Xinjiang, and sustainable development of economy and society. At present, many scholars have done a lot of research work on the *P. schrenkiana* in Tianshan Mountain from different perspectives, and achieved a lot of research results, which made important contributions to the related research. Previous studies on *P. schrenkiana* forest mainly focused on spatial pattern (Zhang et al., 2011), biomass and productivity (Luo, 1996; Chen et al., 2011), disturbance and regeneration (Liang et al., 2002), the relationship among geographical factors (Liu et al., 2009), the tree-ring ecology (Yuan and Li, 1994; Zhang et al., 1996; Peng et al., 2006), the relationship between the forest of *P. schrenkiana* and soil factors (Chen et al., 2008), stoichiometric characteristics (Sun et al., 2018; Li et al., 2019), and population dynamics of *P. schrenkiana* (Wang et al., 2006).

Therefore, this paper studies the composition and structure characteristics of soil fauna community under *P. schrenkiana* at different altitudes in the Western Tianshan Mountain, discusses the correlation between soil fauna communities and environmental factors, provides data basis for soil fauna diversity and provides an important theoretical basis for the management and control of local forest resources, and promotes the research on the ecological system of *P. schrenkiana* in the Western Tianshan Mountains and the conservation of its biodiversity.

Materials and Methods

Experimental site

The study site is located in Western Tianshan mountains National Nature Reserve experimental area of Gongliu County, Yili Kazak Autonomous Prefecture, Xinjiang Uygur Autonomous Region, China. As shown in the *Figure 1*, the soil fauna under *P. schrenkiana* at different altitudes (1414 m, 1595 m, 1724 m, 1868 m) was selected as the research object. According to the altitude from low to high, they were taken as the plot-I, II, III and IV. The altitude interval is set between 100-200 m, and the altitude interval is adjusted within the controllable range according to the change of natural environment. The annual average temperature of the environmental and natural reserve is 5-7°. The annual average precipitation is 600-800 mm and 60% of the annual precipitation is concentrated in May and June. The annual average evaporation is 1100-1200 mm. The average annual relative humidity is over 70%. The annual frost-free period is 120 days (Liu et al., 2007). The soil is the mountain leached brown forest soil. The altitude of plot-I is 1414 m, the canopy density was 50%, and the vegetation coverage was 0.75. The altitude of plot-II is 1595 m, the canopy density was 60%, and the vegetation coverage was 0.50. The altitude of plot-III is 1724 m, the canopy density was 50%, and the vegetation coverage was 0.30. The altitude of plot-IV is 1868 m, the canopy density was 50%, and the vegetation coverage was 0.10. The vegetation under

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P. schrenkiana was composed of herbaceous plants. Natural condition of the study sites is shown in *Table 1*.

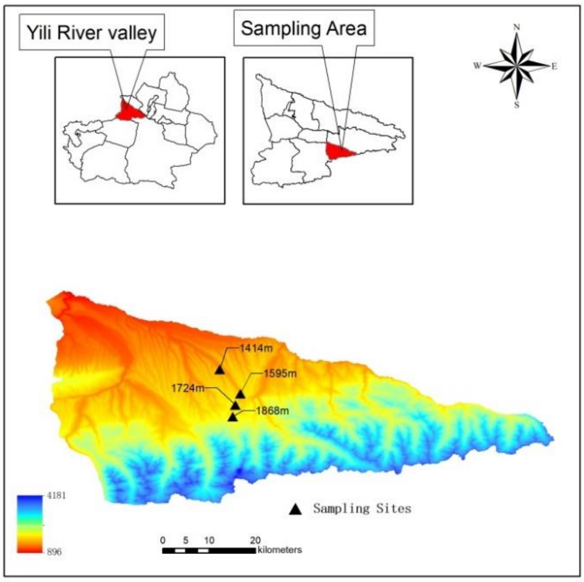

Figure 1. *Sketch map of the study area*

Table 1. *Natural condition of study sites*

Plots	I	II	III	IV
altitude (m)	1414	1595	1724	1868
Longitude	82°47′27″E	82°49′51″E	82°49′16″E	82°48′56″E
Latitude	43°11′36″N	43°08′44″N	43°07'25"N	43°06′04″N
slope (°)	20	4	35	3
Slope direction	north slope	north slope	north slope	north slope
Canopy density（%）	50	60	50	85
herb coverage	0.75	0.50	0.30	0.10
Human disturbance intensity	weak	strong	weak	nothing

Experimental method

The plots (5×5 m) were set up in the distribution area of *P. schrenkiana* at different altitudes. Three replicates (small replicates) were selected in each plot according to the diagonal method. The sampling area of soil macro-fauna is 25×25 cm, and 10×10 cm for soil meso-fauna. According to the litter layer, 0-5 cm, 5-10 cm and 10-15 cm soil layers, a total of 96 soil samples were collected. The soil macro-fauna and soil meso-fauna were separated by hand picking method and Tullgren. The soil fauna was generally identified to families, and some were identified to orders (suborders). The main reference materials are pictorial keys to soil animals of China (Yin, 1998) and soil animal of China (Yin, 2000). Appropriate amount of soil samples was taken from each layer of the plots for the determination of soil physical and chemical properties. The soil samples were ground after air drying. The organic matter, total effective nutrients (N, P, and K), available nutrients (P and K), ammonium nitrogen nitrate nitrogen contents and pH were determined by conventional methods. The measurement results are shown in *Table 2*.

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Table 2. *Physical and chemical properties of soil*

Plots	Layers	SOM (g/kg)	TN (g/kg)	TP (g/kg)	TK (g/kg)	P (mg/kg)	K (mg/kg)	NN (mg/kg)	AN (mg/kg)	pH
Plot-I	Litter layer	239.41	7.57	1.21	19.49	33.67	766.11	29.37	24.15	7.01
	0-5cm	231.59	6.59	1.12	19.73	17.55	490.98	11.97	11.11	7.04
	5-10cm	170.59	6.05	1.08	19.43	13.59	211.67	13.87	8.52	7.05
	10-15cm	129.15	4.87	1.04	19.87	10.45	168.98	3.48	6.40	6.97
Plot-II	Litter layer	285.89	10.46	1.69	16.67	90.58	1010.66	13.13	105.49	6.81
	0-5cm	254.13	8.27	1.38	17.17	64.76	692.58	6.46	18.59	6.89
	5-10cm	201.92	6.64	0.13	17.93	65.33	572.31	5.69	12.62	6.88
	10-15cm	147.24	5.49	1.24	18.05	36.95	446.49	15.10	11.67	6.95
Plot-III	Litter layer	359.00	10.81	0.11	17.46	79.75	842.24	55.25	31.99	6.70
	0-5cm	267.15	9.13	1.30	17.08	65.01	557.61	29.17	14.70	6.86
	5-10cm	255.93	7.51	1.12	16.84	58.89	649.53	21.44	13.06	6.94
	10-15cm	211.70	6.52	0.94	16.87	50.33	472.42	14.93	10.27	7.02
Plot-IV	Litter layer	450.69	12.03	1.43	11.97	180.84	744.01	30.32	41.98	6.94
	0-5cm	392.44	11.32	1.34	12.48	49.50	483.57	19.18	20.01	6.96
	5-10cm	314.62	9.53	1.21	13.08	30.17	429.83	11.70	11.29	6.89
	10-15cm	227.97	8.77	0.94	17.50	56.15	502.00	6.89	8.27	6.93

SOM: Soil organic matter, TN: Total nitrogen, TP: Total phosphorus, TK: Total potassium, P: Readily available P, K: Readily available K, NN: Nitrate nitrogen, AN: Ammonia nitrogen

Soil sample determination

Soil samples were determined according to soil agrochemical analysis (Bao, 2000). The specific determination method is as follows. The organic matter was determined by external heating method. Total N was determined by perchloric acid sulfuric acid digestion method (FOSS 1035 automatic nitrogen analyzer determination). Total P was determined by molybdenum antimony anti Colorimetry (Agilent cary60 UV spectrophotometer). Total K is dissolved in acid and then determined by atomic absorption spectrometry. Readily available P was determined by molybdenum antimony anti Colorimetry (Agilent cary60 UV spectrophotometer). Readily available K was determined by atomic absorption spectrometry. Nitrate nitrogen and ammonium nitrogen were determined by 0.01M calcium chloride extraction (BRAN+LUEBBE AA3 flow analyzer). pH was determined by Mettler Toledo FiveEasy Plus pH meter.

Data statistics and analysis

Diversity index (H'), richness index (D), evenness index (J) and dominance index (C) were used to analyze the diversity of soil fauna (Yin, 2000).

Diversity index (H'):

$$H' = -\sum_{i=1}^{S} P_i \ln P_i \quad \text{(Eq.1)}$$

The S is the number of groups, P_i is the percentage of the i-th group.

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Richness index (*D*):

$$D = (S - 1)/\text{LnN} \quad \text{(Eq.2)}$$

The S is the number of groups; the N is the individual number of all species in the area.

Evenness index (*J*):

$$J = H'/\text{LnS} \quad \text{(Eq.3)}$$

The S is the number of groups.

Dominance index (*C*):

$$C = \sum_{i=1}^{S} \left(\frac{n_i}{N}\right)^2 \quad \text{(Eq.4)}$$

The n_i is the number of individual of the i-th species and the N is the individual number of all species in the area. The S is the number of groups.

Excel 2010 and SPSS 24.0 software were used for data processing and analysis. One-way ANOVA was used to test the differences of community structure and diversity characteristics of soil animals in the different plots. The least significant difference (LSD) method was used for multiple comparisons. Canoco 4.5 software was used to analyze the relationship between species importance and environmental variables. Before ranking analysis, the species matrix was analyzed by detrended correspondence analysis (DCA). The results showed that the longest axis length of all sorts less than 3, so it is suitable to select the redundancy analysis (RDA) sorting method. The significance of all ranking was tested by Monte Carlo random permutation (499 times, $P<0.05$).

Results

Composition and quantitative characteristics of soil fauna community

A total of 4003 soil fauna were captured in this survey, belonging to 3 phyla, 7 classes, 21 orders, 41 kinds (as shown in *Table 3*). Oribatida and Isotomidae were the dominant groups, accounting for 60.44% of the total number of the captured. The common groups were Geophilidae, Enchytraeidae, Diptera larvae, Coleoptera larvae, Gamasida, Actinedida, Hypogastruridae, Onychiuridae and Paronellidae, accounting for 30.60% of the total number of the captured. The remaining 30 kinds, such as Sminthuridae, Staphylinidae and Lithobiidae, constitute a rare group, accounting for 8.96% of the total number of the captured. In plot-I, a total of 831 soil fauna were captured, belonging to 34 groups. The dominant group was Oribatida, accounting for 57.76% of the total number of the captured. In plot-II, a total of 380 soil fauna were captured, belonging to 19 groups. The dominant groups were Oribatida and Enchytraeidae, accounting for 34.47% and 12.37% of the total number of the captured. In plot-III, a total of 735 soil fauna were captured, which belonged to 25 groups. The dominant groups were Oribatida, Isotomidae and Actinedida, accounting for 33.06%, 14.83% and 13.47% of the total number of the captured. In plot-IV, a total of 2057 soil fauna were captured, belonging to 23 groups. The dominant groups were Oribatida and Isotomidae, accounting for 49.54% and 17.40% of the total number of the captured (as shown in *Table 4*).

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Table 3. *Composition of the soil fauna in different altitudinal gradients of P. schrenkiana*

Phylum	Class	Order	suborder/family
Annelida	Oligochaeta	Plesiopora	Enchytraeidae
		Opisthopora	Lumbricidae
Molluscs	Chilopoda	Araneida	Succineidae
		Araneida	
		Parasitiformes	
		Acariformes	Gamasida
		Glomerida	Actinedida Oribatida
		Lithobiomorpha	Glomeridae
		Geophilomorpha	Lithobiidae
		Symphyla	Geophilidae
		Collembola	Scolopendrellidae
			Isotomidae
			Sminthuridae
			Hypogastruridae
			Tomoceridae
			Entomobryidae
			Onychiuridae
	Arachnida		
		Diplura	Paronellidae
		Homoptera	Gampodeidae
		Homoptera	Cicadellidae Aphididae
	Diplopoda		
Arthropods		Homoptera	Acridiidae
	Chilopoda		
		Hemiptera	Labiduridae
		Thysanoptera	Scutelleridae
	Symphyla		
		Coleoptera	Thripidae
	Insecta		
		(Coleoptera Larvae)	Scarabaeidae
			Staphylinidae
			Elateridae
			Nitidulidae
			Curculionidae
			Coccinellidae
			Carabidae
		Diptera	Tenebrionidae
		(Diptera Larvae)	Mycetophilidae
			Bibionidae
		Hymenoptera	Sarcophagidae
			Chalcidoidea
		Lepidoptera	Formicidae
		(Lepidoptera Larvae)	

Horizontal distribution characteristics of soil fauna community

The horizontal distribution characteristics of soil fauna were shown in *Figure 2*. The results showed that the average density of soil fauna in plot-IV was the highest, and that in plot-II was the lowest. The average density of soil fauna in plot-II was significantly lower than that in plot-IV (P<0.05).

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Table 4. *Composition of soil fauna in plot-I, II, III, and IV*

Soil fauna	I		II		III		IV	
	Number（n）	P/%	Number（n）	P/%	Number（n）	P/%	Number（n）	P/%
Enchytraeidae	33	3.97	47	12.37	50	6.80	57	2.77
Lumbricidae	6	0.72	15	3.95	28	3.81	7	0.34
Succineidae					1	0.14		
Araneida	2	0.24			1	0.14	3	0.15
Gamasida	14	1.68	32	8.42	22	2.99	70	3.40
Actinedida	81	9.75	32	8.42	99	13.47	107	5.20
Oribatida	480	57.76	131	34.47	243	33.06	1019	49.54
Glomeridae			1	0.26			1	0.05
Lithobiidae	1	0.12			10	1.36		
Geophilidae	1	0.12	11	2.89	14	1.90	21	1.02
Scolopendrellidae	8	0.96						
Isotomidae	43	5.17	36	9.47	109	14.83	358	17.40
Sminthuridae	1	0.12	3	0.79	4	0.54	25	1.22
Hypogastruridae	6	0.72	4	1.05	34	4.63	71	3.45
Tomoceridae					7	0.95	30	1.46
Entomobryidae					1	0.14		
Onychiuridae	2	0.24			18	2.45	170	8.26
Paronellidae	51	6.14	7	1.84	4	0.54	10	0.49
Gampodeidae					1	0.14		
Cicadellidae	3	0.36						
Aphididae	31	3.73			3	0.41	1	0.05
Acridiidae	1	0.12						
Labiduridae	1	0.12						
Scutelleridae	2	0.24						
Thripidae	1	0.12						
Scarabaeidae	2	0.24	1	0.26				
Staphylinidae			1	0.26	17	2.31	4	0.19
Elateridae	4	0.48						
Nitidulidae	6	0.72			1	0.14		
Curculionidae	1	0.12					2	0.10
Coccinellidae	1	0.12						
Carabidae	13	1.56			8	1.09	1	0.05

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Tenebrionidae	1	0.12						
Mycetophilidae	2	0.24	1	0.26	1	0.14	4	0.19
Bibionidae	1	0.12						
sarcophagidae			1	0.26				
Chalcidoidea	4	0.48	1	0.26				
Formicidae	3	0.36	2	0.53			1	0.05
Coleoptera Larvae	23	2.77	30	7.89	36	4.90	40	1.94
Diptera Larvae	1	0.12	24	6.32	22	2.99	54	2.63
Lepidoptera Larvae	1	0.12			1	0.14	1	0.05
Number	831	100	380	100	735	100	2057	100
Groups	34		19		25		23	

Number: Number of individuals, Dominant groups (>10%), Common groups (1%-10%), Rare groups (<1%)

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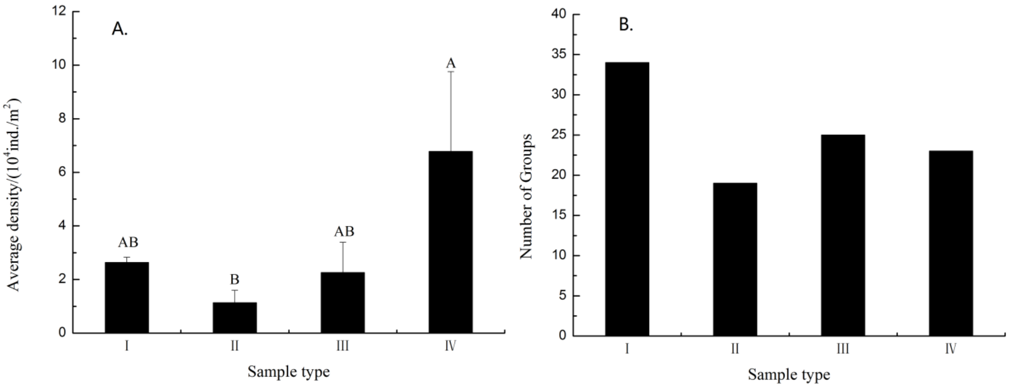

Figure 2. *Average density and group number of soil fauna in different altitudinal gradients in horizontal distribution, A and B represent significant differences in different plots (P<0.05). Average density: Average density of three duplicate samples. Number of groups: Total number of groups of three duplicate samples*

Vertical distribution characteristics of soil fauna community

The vertical distribution characteristics of soil fauna were shown in *Figure 3*. Except for the plot-III, the number of soil fauna in other plots showed obvious characteristics of surface aggregation. The density of soil fauna in litter layer in the plot-IV was much higher than that in other plots. The results of significant test analysis showed that: there were significant differences in the average density of soil fauna of litter layer between plot-IV and other plots (F=9.177, P = 0.006). There was no significant difference in 0-5 cm, 5-10 cm, and 10-15 cm layers among other plots (F=1.271, P=0.348, F=1.335, P=0.330, F=1.007, P=0.438).

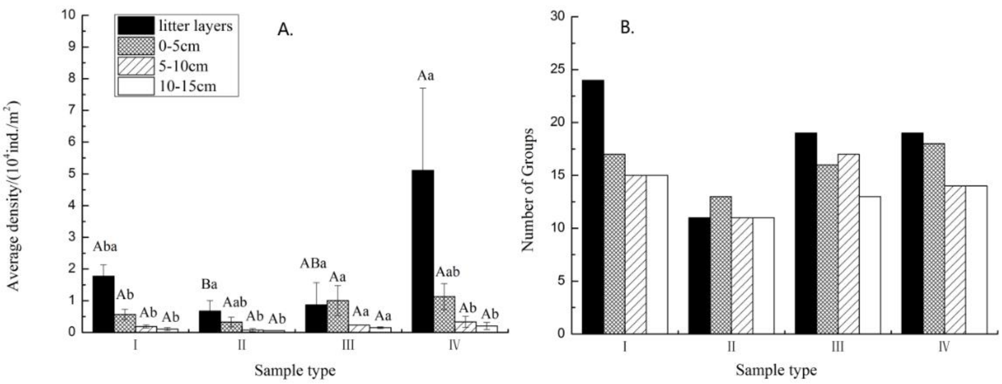

Figure 3. *Average density and group number of soil fauna in different elevation gradients in vertical distribution, A and B represent significant differences among soil layers in different plots (P<0.05) and a and b represent significant differences among the different soil layer in the same plot (P<0.05). Average density: Average density of three duplicate samples in each layer. Number of groups: Total number of groups of three duplicate samples in each layer*

Diversity characteristics of soil fauna community

As shown in *Figure 4*, there were no significant differences in the diversity index of soil fauna among different plots. There were significant differences in evenness index,

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dominance index and richness index between plot- I and plot-II (*P*<0.05). The richness index of soil fauna was the highest in plot-I and the lowest in plot-IV, and there was a very significant difference between plots-I and IV (*P*<0.01). There were no significant differences in diversity index, dominance index, evenness index and richness index between plot-III and other plots.

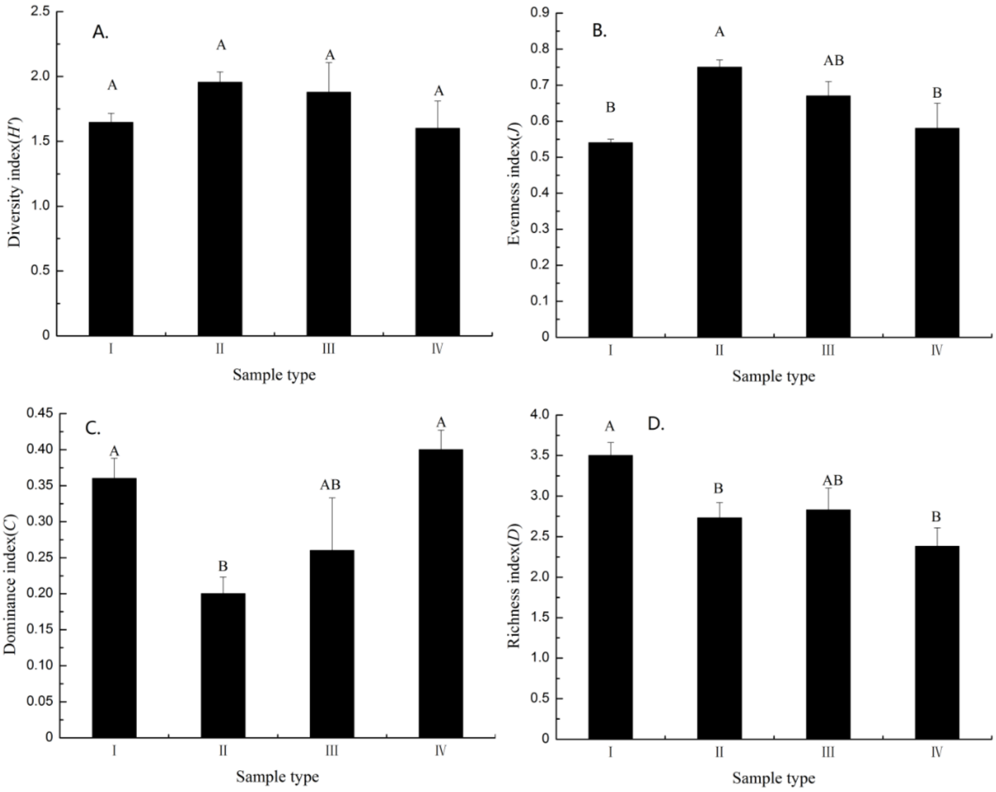

Figure 4. *Diversity, evenness, dominance and richness indexes of soil faunas in different elevation gradients, A and B represent significant differences in different plots (P<0.05)*

Analysis of soil fauna community and soil environmental factors

The results of RDA analysis were shown in *Figure 5* and *Tables 5,6*. The first order axis explained 43.0% of the habitat change, and the correlation coefficient with soil environmental factors was 0.884. The second order axis explained 9.4% of the habitat change, and the correlation coefficient with soil environmental factors was 0.946. The first order axis was positively correlated with total phosphorus (TP), readily available potassium (K), ammonia nitrogen (AN), organic matter (SOM), readily available phosphorus (P), and total nitrogen (TN). And it was negatively correlated with total potassium (TK). In the first order axis, soil fauna are densely distributed. The second order axis was positively correlated with pH, TK, AN, TP, and K and negatively correlated with TN, NN, and SOM. The distribution of soil fauna is sparse in the order axis. Soil fauna (Oribatida, Gamasida, Actinedida, Enchytraeidae, Isotomidae and Diptera Larvae and so on) gathered on the right side of the ordination axis, indicating that these soil faunas responded positively to soil nutrient content.

Different environmental factors have different effects on the distribution of common soil fauna. The influence degree of environmental factors on common soil fauna were as

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follows: TP>TK>P>SOM>TN>K>AN> pH>NN. TP, TK, P, SOM, and TN had significant effects on distribution of soil fauna (*P*<0.05), while K, AN, pH, and NN had no significant effects on distribution of soil fauna.

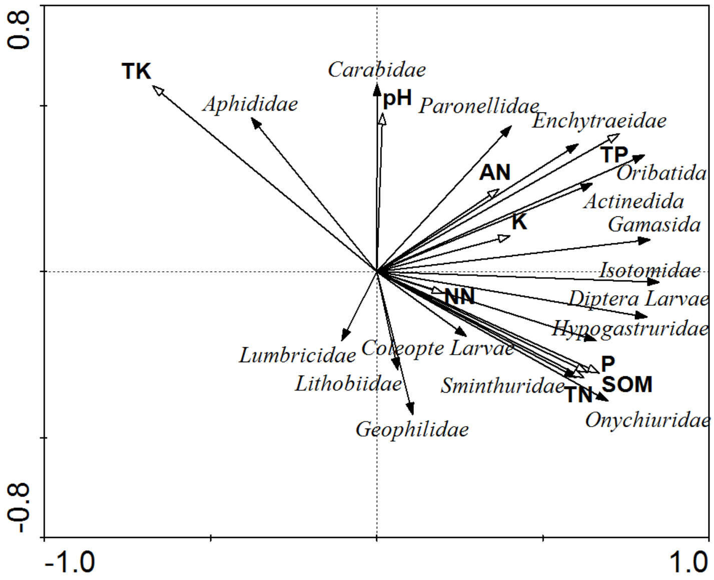

Figure 5. *Redundancy analysis (RDA) of composition of the soil fauna with soil environmental factors, SOM: Soil Organic matter, TN: Total nitrogen, TP: Total phosphorus, TK: Total potassium, P: Readily available P, K: Readily available K, NN: Nitrate nitrogen, AN: Ammonia nitrogen*

Table 5. *Ordination summary of composition of the soil fauna with soil environmental factors*

Axes	Axis1	Axis2	Axis3	Axis4
Eigenvalues	0.430	0.094	0.057	0.041
Species-environment correlations	0.884	0.946	0.935	0.770
Cumulative percentage variance of species data	43.0	52.4	58.1	62.2
Cumulative percentage variance of species-environment relation	59.7	72.8	80.7	86.4
Sum of all eigenvalues		1		
Sum of all canonical eigenvalues		0.72		

Table 6. *Importance ranking of soil environmental factors*

Environmental factor	Importance ranking	the percentage of interpretation	F	P
TP	1	25.0	4.676	0.012
TK	2	23.0	4.171	0.010
P	3	21.6	3.856	0.010
SOM	4	19.4	3.376	0.022
TN	5	19.4	3.361	0.024
K	6	10.5	1.635	0.180
AN	7	9.7	1.502	0.176
pH	8	5.8	0.865	0.396
NN	9	2.9	0.418	0.816

SOM: Soil organic matter, TN: Total nitrogen, TP: Total phosphorus, TK: Total potassium, P: Readily available P, K: Readily available K, NN: Nitrate nitrogen, AN: Ammonia nitrogen

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Discussion

Community structure characteristics of soil fauna

P. schrenkiana belongs to coniferous tree species. Its leaves are mostly thick leathery, with well-developed cuticle. It contains more lignin, cellulose, tannin and other substances, which hinder the decomposition of substances by microorganisms, and is not conducive to leaching and mechanical damage of soil fauna (Wu et al., 2006). But the increase of the number of soil animals was beneficial to the decomposition of litter (Wang et al., 2013). When litter content of N and P and C:N and C:P ratios were higher, it was more conducive to the development of group number and individual number of soil animals (Zhao et al., 2006). The average density of soil animals in plot-IV is the highest, and that in plot-II is the lowest, which is mainly related to the fact that the number of Oribatida and Isotomidae in plot-IV is much higher than that in other plots. Mites and springtails often have a great impact on litter fragmentation, and can regulate soil microbial community through feeding (Scheu et al., 2005). The thickness of litter in plot-IV is significantly higher than that in other plots. The snowmelt flows through the plot-IV, and the soil moisture is sufficient, which made the number of soil fauna in the soil and litter under the forest increased significantly. The litter layer was obviously thinner in other plots with lower altitude, and the number of soil fauna also decreased significantly. Because the plots were divided by altitude, the elevation of plot-I was the lowest and there are other arbors and shrubs distributed in the same altitude area. The vegetation coverage of associated herbs in the plot-I increased significantly compared with other altitudes, which provides more abundant food sources for soil fauna. It is one of the reasons that the number of soil fauna groups in plot-I is higher than that in other plots.

Most of the soil fauna in this study are distributed in the soil surface, and the performance of small and medium-sized soil fauna are more obvious, which is the same as the research results of most scholars (Doblas-Miranda et al., 2009). The surface aggregation of soil fauna is closely related to soil physical and chemical properties. Soil fauna live in the soil environment, and most of the groups live in the soil for all their life. Therefore, soil physical and chemical properties are very important for soil fauna community. While the migration ability of small and medium-sized and soil fauna is relatively weak, so they are more dependent on the soil environment. Therefore, it is more easily restricted by soil physical and chemical properties (Li et al., 2017). Relevant studies have shown that the water content of different soil layers directly affects the community composition and individual density of soil animals, especially the distribution of nematodes and Collembola (Riutta et al., 2012). In this study, the number and density of soil fauna in litter layer of plot-III were less than 0-5 cm layer. The density of soil animals in litter layer was greatly affected by the large slope and the lower coverage of herb population. The water holding capacity and water content of soil layer are better than that of litter layer, which is one of the reasons that affect the community composition and density of soil fauna.

Diversity characteristics of soil fauna

The study of soil fauna diversity is of great significance for the study of the whole ecosystem. It is an important indicator of ecological environment evaluation, and its index size can reflect the stability of the community (Wang et al., 2018). Diversity index reflects the complexity of community composition, while evenness can reflect the evenness of

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individual number distribution of each species. Higher diversity index and evenness indicate that there are longer food chains and more complex interspecific relationships in the ecosystem, which may have stronger control in the negative feedback (Peng et al., 2019). In this study, there was no significant difference in Shannon-Wiener diversity index (H') among the plots at different altitudes, and Pielou evenness index (J) was the highest in plot-II, indicating that the individual number of each species was more evenly distributed. The community structure of plot-II was stable under long-term human disturbance. Simpson dominance index (C) was the highest in plot-IV, followed by plot-I. This was mainly due to the fact that the proportion of the dominant group Oribatida in the total number of individuals in plot-I and plot-IV reached 57.88% and 49.53%, which led to the increase of dominance index of community structure. The Margalef richness index (D) is the highest in plot-I, indicating that the higher the number of groups, the higher the richness, which will have an impact on the stability of community structure.

Correlation between soil fauna diversity and environmental factors

Relevant studies have shown that the relationship between soil fauna community and environmental factors was the comprehensive effect of many factors such as altitude, temperature, precipitation, litter and human disturbance, which can affect the diversity of soil fauna community by changing soil physical and chemical properties (Kamczyc et al., 2017; Minor et al., 2017). Therefore, the characteristics of soil fauna community not only depend on the richness of herbaceous plant composition, but also on the physical and chemical properties of soil. Due to the different microenvironments at different altitudes, soil physical and chemical properties are different, which further affects the community characteristics and diversity of soil fauna. With the increase of altitude, the coverage of aboveground plants and the material and energy of underground ecosystem were changed, and the group composition of soil fauna was changed to a certain extent, so that the soil fauna community was different at different altitudes. The research of Culik et al. (2002) showed that the coverage of organic matter in the surface layer was reduced, and the richness of Collembola in the soil was lower. The results showed that both Oribatida and Isotomidae responded to different altitudes, indicating that the change of altitude had a great influence on the number of mites and springtails in soil (Tan, 2013). Different altitudes lead to changes in environmental conditions, which directly or indirectly change the living environment of soil fauna, thus having a significant impact on the survival and reproduction of soil fauna. There are obvious differences in life history, nutrition mode, reproductive characteristics and adaptation mechanism among different groups of soil fauna (Shao et al., 2015). Therefore, Oribatida and Isotomidae respond to environmental changes at different altitudes. The response of soil fauna is different to various environmental changes. This study found that most soil animals showed a significant positive response to pH of soil. Relevant studies have shown that soil fauna have certain adaptability to their living environment, and are more suitable for soil fauna to survive under micro acidic and neutral conditions (Ke et al., 2002). Soil organic matter is closely related to soil fertility, and its content is of great significance to plant growth. Sufficient soil organic matter can make plants grow luxuriantly and provide sufficient food for soil fauna, which plays an important function in maintaining the survival of soil fauna (Ayuke et al., 2011). At the same time, this study also found that most soil animals showed a significant positive response to soil organic matter. This is the same as the research results of most scholars (Li et al., 2017). This study also found that most soil fauna also showed a positive response to soil readily available phosphorus. Tripathi and Sharma (2005)

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showed that the content of soil readily available phosphorus was positively correlated with the abundance of soil fauna, which was the same as the results of this study.

Conclusions

The soil fauna of *P. schrenkiana* in the western Tianshan Mountains, Xinjiang, belongs to 3 phyla, 7 classes, 21 orders, 41 kinds. The average density of soil fauna was the highest in plot-IV, and the number of soil fauna groups was the highest in plot-I. Except for plot-III, the vertical distribution of soil fauna in other plots gradually decreased with the deepening of soil layer, showing the characteristics of surface aggregation. There were no significant differences in diversity index, dominance index, evenness index and richness index between plot-III and other plots.

RDA analysis showed that the ecological distribution of soil fauna was closely related to environmental factors. Organic matter, total nitrogen, total phosphorus, total potassium and readily available phosphorus were the dominant factors affecting the diversity and distribution of soil fauna community.

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