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Plant species richness and composition along edaphic gradients in Caragana aurantiaca community in Riparian zone of Yili valley in Xinjiang, China

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Abstract

In riparian meadows, narrow zonation of the dominant vegetation frequently occurs along the elevational gradient from the river edge to the hillslope at lateral dimension. We described the plant species richness and composition in *caragana aurantiaca* community of three habitat types, defined as river-edge, floodplain and terrace, at lateral dimension and in two plots along Tekesi River at longitudinal dimension in Yili valley, Xinjiang, China in relation to edaphic gradients. Total of six transect were established. Samples within each of the transect across three habitat types were classified into plant communities using Multivariate Regression Tree (MRT) and species-environment relationships were examined using Redundancy Analysis (RDA). The lateral patterns of plant species richness varied at longitudinal dimension. The highest species richness per quadrate in two plots both occurred in floodplain habitat, whereas

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the lowest species richness per quadrate occurred in either river-edge meadow or terrace habitat. The highest total number of species per transect, β diversity index and number of rare species all occurred in river-edge habitat in two plots. The indicator species in terrace habitat mainly comprised *Rosa spinosissima, Roegneria kamoji* and *Agrostis tenuis*. Floodplain habitat mainly comprised *Plantago major, Leontopodium leontopodioides* and *Achillea asiatica*. River-edge habitat mainly comprised *Salix rosmarinifolia, Leymus chinensis* and *Oxytropis podoloba*. MRT analysis and RDA ordinations indicated that the community distribution and species composition were largely driven by soil nutrient concentrations, particularly by available phosphorus at longitudinal dimension, and by soil pH, total nitrogen and soil water content at lateral dimension across three habitats. These results suggest that *Caragana aurantiaca* shrub favor more different species, but higher local species richness. The available phosphorus is the most key ecological factor in shaping plant species composition and distribution of *Caragana aurantiaca* community in Yili Valley, Xinjiang.

1. Introduction

Riparian zone is a water and land transition region with strong environmental gradient (Gregory et al. 1991; Naiman et al. 2005; Camporeale and Ridolfi 2006). With rich animal and plant diversity (Fraaije et al. 2015), the riparian zone is a key ecological system for the protection of biological diversity (Lyon and Gross 2005; Sabo et al. 2005). To understand the relationship between vegetation and environment of riparian zone has become a basic requirement for the management and protection of riparian ecosystem. Due to the linear nature of riparian corridors (Bendix 1994), environmental gradients change in the longitudinal (along the river) and lateral dimensions (vertical to the river) (Decocq 2002; Lite et al. 2005; Noe et al. 2013) at the same time. In the lateral dimension, the riparian zone is divided into the river edge, floodplain, low terrace, upper terrace, hillslope and other habitat types along the terrain gradient (Bendix and Hupp 2000). In the longitudinal dimension, affected by the elevation and hydrology, topography and soil nutrient content will occur corresponding spatial differentiation, and thus influence the species richness of plant community structure and species composition (Lite et al. 2005; Kuglerová et al. 2015). Therefore, understanding the relationship between riparian vegetation and the environment needs to explain two issues. The first is the species richness pattern in the horizontal gradient, and the second is the key environmental factors influencing plant community distribution and species composition.

The species richness of riparian vegetation mainly occurred on the horizontal scale. With gradient changes in the habitat topography and nutrient content in the soil, the species richness of the plant community is often expressed as a hump pattern.

In the area near the river, the increase in the soil water content and the impact of flood frequency cause low species richness; according to the result of the moderate disturbance hypothesis, regions with proper interference to soil water content and flood frequency have the highest species richness (Pollock et al. 1998; Decocq 2002; Lite et al. 2005). However, some studies also argue that the species richness of the plant community in the riparian zone shows a monotone increasing pattern with increasing terrain (Dwire et al. 2004; Lite et al. 2005). Based on the above contradict conclusions, this paper attempted to verify the species composition and richness of *Caragana aurantiaca*.

Vegetation distribution and species composition in the riparian zone are closely related to available soil nitrogen and phosphorus content. Due to the difference of the cycle and transformation of nitrogen and phosphorus in soil, the accumulation characteristics of the two elements in soil are different (Ekholm et al., 2005). Studies have shown that phosphorus has long-term effects on grassland community while nitrogen has short-term effects (Willems and Van Nieuwstadt 1996; Marini et al., 2007). Besides, the availability of phosphorus is closely related to the soil moisture condition (Hupfer and Lewandowski 2008; Rydin et al. 2011). In riparian ecosystem, due to the difference of vertical dimension, it is bound to cause the change of hydrological conditions, which can affect the content of phosphorus in the soil, and ultimately affect the composition and distribution of riparian vegetation. Although there were considerable previous studies on the relations between riparian vegetation distribution and transverse and longitudinal environmental factor (Bendix 1994; Merritt et al. 2010; Stromberg et al. 2010; Yang et al. 2011; Kuglerov ndez et al. 2015), as well as the importance of impacts of these factors on vegetation (Sarr and Hibbs 2007), few studies have been conducted on how soil moisture conditions, nitrogen and phosphorus content influence the distribution and composition of vegetation in the horizontal and vertical dimensions of riparian zones.

The *C. aurantiaca* shrub meadow, one of the endemic community types in China, is distributed in the Yili River Valley of North Xinjiang, China. This meadow plays an important role in the protection of bio-diversity and the maintenance of regional ecological function (Ahan et al. 2012). To date, the variations of species composition and abundance of *C. aurantiaca* shrub meadow in both horizontal and vertical dimensions with riparian belt gradient and the relationship with environmental factors are still poorly understood. Therefore, the diversity of *C. aurantiaca* community composition and distribution in the gradient variation of the horizontal and vertical dimensions were investigated in this study. In the longitudinal dimension, two sample plots in the upstream of the Tekes River in the valley were selected. In the lateral dimension, three types of habitats, namely, river edge, floodplain and terrace, were selected to show the gradient distribution along the soil from the river edge to highland. Composition and richness of plant species in each habitat were investigated, and the physical and chemical properties of the soil were monitored. This study aims to solve the following issues: 1) spatial variation pattern of plant richness along the soil gradient of the three habitats in the lateral dimension, with a monotonic increase or hump; 2) difference of species richness pattern and species composition among three habitats in the longitudinal dimension; 3) relationship of plant community distribution and species composition with soil moisture and nutrient conditions. An indicator species analysis on each type of habitat is also performed to further explain the relationship between habitat and plant distribution. This study has important reference significance for the management and protection of riparian shrub ecosystem like in arid area of Xinjiang, China.

2. Study Area and Research Methods

2.1. Study Area

The Yili River Valley is located in the north of Xinjiang, China (42°14'-44°50'N, 80°09'-84°56'E), under the Yili Kazak Autonomous Prefecture. This valley is an intermontane basin in the Tianshan Mountains. This valley is surrounded by mountain on three sides (east, south, and north), forms a horn-shaped valley opening to the west, and has the most abundant rainfall area in Xinjiang (Ahan et al. 2012). The river valley has a semi-arid continental climate of temperate zone, with a mean annual temperature of 2.6–9.2 °C and mean annual rainfall of 200–500 mm (highest rainfall of up to 800 mm) (Li et al. 2011). Owing to the melted ice-snow from the mountains, the water system in the valley is developed. The main rivers in the valley are Yili River and its tributaries, including Tekes River, Kunes River and Qaraqash River. The shrub meadow vegetation is mostly developed along the rivers.

2.2. Site Selection

The study site is located upstream of the Tekes River in Zhaoshu County, Yili Kazak Autonomous Prefecture. Tekes River is a Class I tributary of the Yili River. The flood season is from June to September. The *C. aurantiaca* shrub meadow on both banks widely grew because of the melted snow from the river and mountain. Two study sites (Plots 1 and 2) are selected, such that the distance between the sites is approximately 20 km. Three types of typical habitats, namely, river edge, floodplain and terrace, are selected for each study site. The *C. aurantiaca* shrub meadow is the closest to the river and is located in the lowest terrain; hence, it receives most of the river water supply. The terrain of the floodplain is located in the middle and can receive water supply during the flood. The terrain of the terrace is the highest and occasionally receives river water supply. Plot 1 is in the downstream of Plot 2 and has a flat and wide terrain, widely distributed floodplain and peat accumulation in some sections.

From July–September of 2014, a total of 6 sample zones were arranged in each habitat parallel to the river in Plots 1 and 2. In Plot 1, the *C. aurantiaca* shrub in the terrace was 10–30 cm high. The zones exhibit running water erosion ditches and *Carex heterolepis*. The sod layer of the soil was approximately 15 cm thick. The *C. aurantiaca* shrub in the floodplain sample zone was 30–50 cm high. The running water erosion was serious with 15–30 cm-wide ditches. The sod layer of the soil was approximately 10 cm thick. In the river-edge sample zone, the *C. aurantiaca* shrub was 30–40 cm high and 150 cm away from the highest zone; this shrub also has an increasing gullied area and depth and is completely bare without an obvious sod layer.

In Plot 2, the *C. aurantiaca* shrub in the terrace sample zone was 40–70 cm high and the soil sod layer was approximately 7 cm thick. In the floodplain sample zone, the *C. aurantiaca* shrub was lower than that in the terrain, and the soil sod layer was approximately 7 cm thick. A high number of woody plants grew in the river-edge sample zone, and the dominant species were considerably distributed, including *C. aurantiaca, Salix rosmarinifolia, Hippophae rhamnoides Linn.* and *Rosa spinosissima L.*, with only the *Betula tianschanica* showing an open forest distribution. The running water erosion was unclear, with a vegetation coverage in the running ditches of up to 80–90% and sod layer thickness of approximately 15 cm.

2.3. Plant Species Composition and Soil Property Investigation

To investigate plant composition, each plot was set three sample zones, i.e. terrace, floodplain, and riparian zone. The sample zones are parallel to the river channel. Five shrub quadrates with areas of 5 m×5 m were arranged in each sample zone. The height, area, density and coverage of the *C. aurantiaca* shrub in each shrub quadrat were recorded. Thereafter, 3 herb quadrats with areas of 1 m^2 were randomly arranged in each 5 m × 5 m quadrat to record the category, height, coverage and species density occurring in the quadrat. Each sample zone covered 15 herb quadrats with areas of 1 m^2.

The soil sample collection method was used to synchronously sample each 5 m × 5 m quadrat by using soil auger in the sampling depth of 0–20 cm with five sampling spots in each quadrat. The soil sample was brought back to the laboratory to be air dried and ground. The soil water content, pH, available phosphorus (AP), total phosphorus (TP), available nitrogen (AN), total nitrogen (TN), organic matter, were measured as variables of the soil substrate. The soil sample analysis methods included the drying method for soil water content, Mo–Sb colorimetric method/$NaHCO_3$ leaching method (GB197-90) for AP, Mo–Sb colorimetric method ($HClO_4$–H_2SO_4 method) (GB8937-1988) for TP, Alkaline hydrolysis diffusion method for AN (LY-T 1229-1999), semi-micro Kjeldahl method for TN (K2SO_4–$CuSO_4$–Se Distillation) (GB7173-1987) and pH meter for soil pH (Table 1).

Table 1: Variables of the soil matrix of caragana aurantiaca community in different plot, Yili Valley, Xinjiang (mean±SD)

Variables	Plot 1			Plot 2		
	Terrace	Floodplain	River-edge	Terrace	Floodplain	River-edge
pH	7.70±0.11	8.18±0.14	7.81±0.06	8.03±0.07	7.95±0.14	8.20±0.38
OM (g/kg)	88.85±1.96	88.63±1.08	87.02±1.59	88.43±1.34	85.76±4.91	85.82±2.63
SW (%)	4.63±0.30	4.84±0.26	4.94±0.32	6.19±0.76	6.43±0.48	6.98±0.20
AN (mg/kg)	27.09±1.06	27.20±1.50	27.51±1.52	32.27±2.13	31.85±1.11	32.97±2.25
AP (mg/kg)	3.32±0.10	3.32±0.11	3.43±0.12	2.85±0.06	2.92±0.09	2.87±0.09
TN (g/kg)	0.60±0.01	0.60±0.01	0.59±0.01	0.68±0.02	0.72±0.02	0.66±0.03
TP (g/kg)	0.64±0.03	0.65±0.04	0.67±0.02	0.72±0.02	0.75±0.02	0.73±0.04

Note: OM, organic matter; SW, soil water content; AN, available nitrogen; AP, available phosphorus; TN, total nitrogen; TP, total phosphorus

2.4. Data Analysis

Species richness was described in two levels: R_q refers to the number of species occurring in the quadrat; R_t refers to the total number of species occurring in the sample zone. β refers to diversity in the Whittaker index (Whittaker 1972), and its value is $\beta_w = R_t/R_q - 1$. The mean value of species richness in the 15 quadrats with the area of 1 m² was used as the estimated value of species richness of herb plants in the unit quadrat in this sample zone. After homogeneity of variance was tested, Duncan multiple comparison was conducted for species richness in the unit quadrat in each sample zone to test the significance of its difference p = 0.05. Moreover, to evaluate the influence of rare species on the species richness of the community, the Unique and Duplicate species number in each sample zone was also analysed. Unique refers to the species number occurring in 1 quadrat whereas Duplicate refer to the species number occurring in 2 quadrats (Han et al. 2012).

Redundancy analysis (RDA) was used to analyse the relationship between the species composition of the 3 habitats and soil environmental factor. The important value was used for species abundance data. Important value = (relative height+relative coverage + relative density)/3. A total of 30 species were included in the analysis. The relativity between the soil variables and canonical axis was based on the analysis result of the generalized linear model (McCullagh 1984) and was represented by coefficients of determination R^2. The relativity between the species and canonical axis was based on the RDA analysis result and was represented by Ra^2, which refers to the bi-multivariate redundancy statistic after being corrected and has a value equal to the sum of all the canonical axis characteristic values (Legendre et al. 2009). Monte Carlo residual permutation test method was used to examine the significance of canonical axis and Ra^2. Residual displacement was conducted 999 times. Multivariate regression tree (MRT) and indicator species were used to analyse the relationship between the plant community and environmental factor. MRT was introduced in detail by Lai et al. (2010). RDA and significance test of all canonical axes were achieved by the Vegan Package (Oksanen et al. 2008) of R statistical language (R Core Development Team, 2007). MRT clustering and indicator species were analysed by the mvpart package (De'Ath 2006) and labdsv package (Roberts 2006).

3. Results

3.1. Spatial Patterns of Plant Species Richness

A total of 96 vascular plants were investigated, including 8 woody plants and 88 herb plants, among which 17 and 14 types of Gramineae and Asteraceae species are included. A total of 77 categories in Plot 1 and 68 in Plot 2 were recorded.

The quadrat species richness (R_q), zone species richness (R_t) and β diversity (β_w) in the two plots show different lateral changing patterns. The R_q, R_t and β_w in Plot 1 are the highest in the floodplain and river edge and the lowest in the terrace. However, in Plot 2, R_q is the highest in the floodplain zone and the lowest in the river edge. β_w in the river edge is the highest, and the maximum of R_t occurred in the river-edge zone.

Given that β_w in the floodplain is the lowest, R_t in this plot is also the lowest. The Unique and Duplicate in the two plots are the highest in the river edge (Table 2).

Table 2: Plant species richness of Caragana aurantiaca communities across three habitats in different plots in Yili Valley, Xinjiang, China

Species richness	Plot 1			Plot 2		
	Terrace	Floodplain	River-edge	Terrace	Floodplain	River-edge
R_g	14±1.69b	17.93±2.99a	16.73±2.37a	15.33±2.06a	16.07±1.87a	13.87±3.07b
R_t	36	49	48	38	32	49
β_w	1.57	1.73	1.87	1.48	0.99	2.53
Unique	10	9	11	8	3	17
Duplicate	2	5	8	6	5	8

Note: Different letters in top row indicate that differences are significant (p<0.05)

3.2. Habitat Type and Indicator Species

The relative error of the MRT cluster regression tree is 0.391, and the screened indicator species is 24. In the longitudinal dimension, the 2 plots were divided on the basis of soil AP. In the lateral dimension, the 3 habitats in Plot 1 were divided on the basis of soil pH. Among which, the soil pH in the terrace is the lowest (pH<7.72). A total of 5 indicator species are present, and the most significant indicators include *Agrostis tenuis Sibth* and *Ligularia macrophylla*. The soil pH in the floodplain was the highest (pH>= 7.95). A total of 4 indicator species are present. The most significant indicator species included *Achillea asiatica* and *Inula britanica Linn*. The soil pH in the river edge is moderate (7.72<pH<=7.95), and only 2 indicator species are present (*Calamagrostis pseudophragmites* and *Oxytropis podoloba* Kar. et Kir). The 3 habitats in Plot 2 were mainly divided on the basis of soil TN and SW. Among which, TN was lower than dry soil in the terrace (TN<0.705, SW<6.84). A total of 4 indicator species are present, and the most significant species includes *R. spinosissima*, *Roegneria* and *Euphrasia regelii*. In the floodplain, TN was higher in soil (TN>= 0.705). A total of 5 indicator species are present, and the most significant of which included *Cirsium esculentum, Plantago major L.* and *Leontopodium leontopodioides*. In the river edge, TN was lower in wetter soil (TN< 0.705, SW>= 6.84). A total of 4 indicator species are present, and the most significant of which included *S. rosmarinifolia L.* and *Leymus chinensis* (Fig. 1 and Table 3).

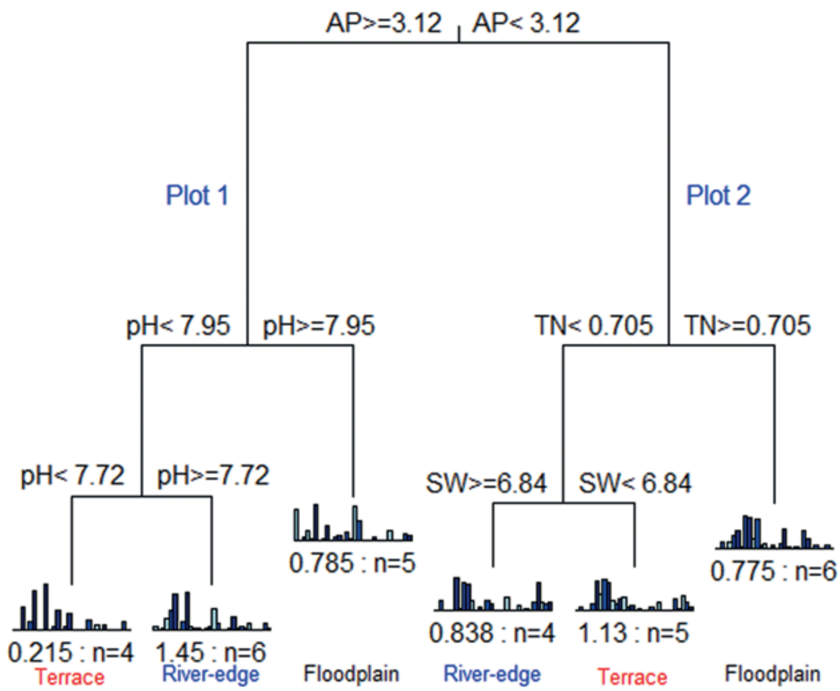

Figure 1: Multivariate Regression Tree (MRT) for caragana aurantiaca community classification across three habitats in two plots in Yili Valley, Xinjiang, China

Table 3: The indicator species of caragana aurantiaca community across three habitats in two plots in Yili Valley, Xinjiang, China (Only significant species presented)

Habitat type	Plant species	Indicator Values	*p*-values
	Plot 1		
Terrace	*Agrostis tenuis*	0.7882	0.001
	Carex turkestanica	0.2466	0.036
	Equisetum hyemale	0.4359	0.007
	Geranium pratense	0.4269	0.007
	Ligularia macrophylla	0.5976	0.001
Floodplain	*Achillea asiatica*	0.9001	0.001
	Inula britannica	0.6207	0.004
	Inula rhizocephala	0.6070	0.001
	Potentilla chrysantha	0.6014	0.001
River-edge	*Calamagrostis pseudophragmites*	0.3852	0.013
	Oxytropis podoloba	0.4993	0.034
	Plot 2		
Terrace	*Carex liparocarpos*	0.5058	0.028
	Euphrasia regelii	0.5196	0.012
	Roegneria kamoji	0.5198	0.009
	Rosa spinosissima	0.9029	0.001
Floodplain	*Carex leiorhyncha*	0.3257	0.038
	Cirsium esculentum	0.6346	0.001
	Leontopodium leontopodioides	0.8027	0.002
	Plantago major	0.7111	0.004
	Potentilla anserina	0.4963	0.005
River-edge	*Agrostis gigantea*	0.3651	0.050
	Galium boreale	0.3810	0.018
	Salix rosmarinifolia	0.5226	0.009
	Leymus chinensis	0.5683	0.017

3.3. RDA Ordination

RDA ordination generates three significant canonical axes ($p<0.05$). The first canonical axis can explain 23.20% of the total variance, and its correlativity with AP (multiple $R^2=0.8643$, $p = 0.001$) is the highest followed by TN (multiple $R^2 = 0.7891$, $p=0.001$) and SW (multiple $R^2 = 0.7163$, $p = 0.001$). This axis is positively correlated with AP and negatively correlated with TN and SW. Along with the direction of the first axis, the three habitats in Plot 1 (S1–S15) are distributed in the left side, and the three habitats in Plot 2 (S16–S30) are distributed in the right side. The second canonical axis can explain 8.76% of the total variance and is positively correlated with pH (multiple $R^2 = 0.3117$, $p = 0.001$). The third canonical axis can explain 5.44% of the total variance and is positively correlated with TP (multiple $R^2 = 0.1728$, $p = 0.005$) (Fig. 2).

A total of 18 species show significant correlations with the first canonical axis. Among which, 10 species can be explained by the first canonical axis with more than 20% variance (representing AP, TN and SW gradient): Cale ($R_a^2 = 0.6163$, $p = 0.001$), Poch ($R_a^2 = 0.5135$, $p = 0.001$), Civi ($R_a^2 = 0.4961$, $p = 0.001$), Inbr ($R_a^2 = 0.4524$, $p = 0.001$), Roka ($R_a^2 = 0.3425$, $p = 0.001$), Aggi ($R_a^2 = 0.3296$, $p = 0.001$), Caau ($R_a^2 = 0.3011$, $p = 0.002$), Acas ($R_a^2 = 0.2521$, $p = 0.001$), Saro ($R_a^2 = 0.2187$, $p = 0.002$) and Eure ($R_a^2 = 0.2099$, $p = 0.011$). Poch, Inbr and Caau are negatively correlated with the first canonical axis; thus, the distribution of these species is closely related to soil AP, TN, and SW (Fig. 2).

A total of 10 species show significant correlations with the second canonical axis. Among which, 5 species can be explained by the second canonical axis with more than 20% variance (representing pH gradient): Viru ($R_a^2 = 0.3255$, $p = 0.001$), Lele ($R_a^2 = 0.2606$, $p = 0.004$), Plma ($R_a^2 = 0.2559$, $p = 0.008$), Rosp ($R_a^2 = 0.2249$, $p = 0.004$) and Gabo ($R_a^2 = 0.2034$, $p = 0.010$). The second canonical axis is negatively correlated with Lele and Plma and is positively correlated with the other species, thus indicating that the distribution of these species is closely related to soil pH (Fig. 2).

Two species show significant correlations with the third canonical axis. The percentage of the variance being explained by the third canonical axis (representing TP gradient) is more than 20%. These species are Oxpo ($R_a^2 = 0.2590$, $p=0.002$) and Eqhy ($R_a^2 = 0.2188$, $p=0.008$), which are negatively correlated with the third canonical axis. This result indicates that these two plants are closely related to soil TP (Fig. 2).

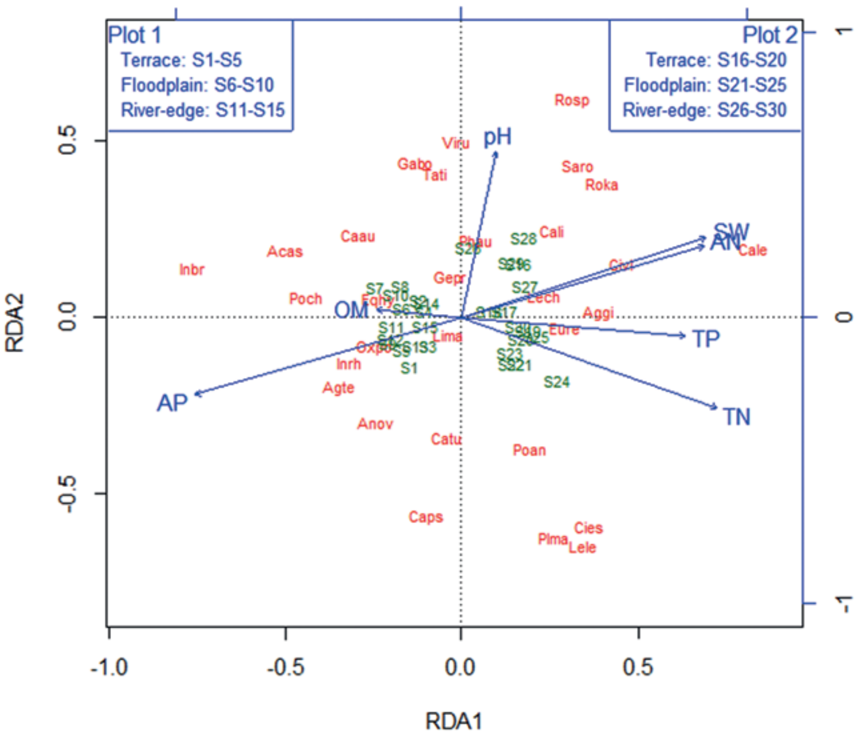

Figure 2: Ordination plot of vascular plant species and explanatory variables along the first two axes of RDA constrained with the seven soil variables

Only those 30 species with a presence above 20% are shown in Fig. 2. The axes are scaled in standard deviation units. The data were obtained from 30 samples across three habitats in the Yili valley. See Table 1 for abbreviations of soil variables names. Abbreviations of species' names: Acas: *Achillea asiatica*; Aggi: *Agrostis gigantea*; Agte: *Agrostis tenuis*; Anov: *Androsace ovczinnikovii*; Caps: *Calamagrostis pseudophragmites*; Caau: *Caragana aurantiaca*; Cali: *Carex liparocarpos*; Cale: *Carex leiorhyncha*; Catu: *Carex turkestanica*; Civi: *Cicuta virosa*; Cies: *Cirsium esculentum*; Eqhy: *Equisetum hyemale*; Eure: *Euphrasia regelii*; Gabo: *Galium boreale*; Gepr: *Geranium pratense*; Inbr: *Inula britannica*; Inrh: *Inula rhizocephala*; Lele: *Leontopodium leontopodioides*; Lech: *Leymus chinensis*; Lima: *Ligularia macrophylla*; Oxpo: *Oxytropis podoloba*; Phau: *Phragmites australis*; Plma: *Plantago major*; Poan: *Potentilla anserina*; Poch: *Potentilla chrysantha*; Roka: *Roegneria kamoji*; Rosp: *Rosa spinosissima*; Saro: *Salix rosmarinifolia*; Tati: *Taraxacum tianschanicum*; Viru: *Viola rupestris*.

4. Discussion

4.1. Spatial Patterns of Plant Species Richness

The species richness of the local community is the result of the common action of regional species pool, environmental filtration, inter-specific interaction and interference (Fraaije et al. 2015; Kuglerová et al. 2015). In the lateral dimension, species richness covers hump pattern (Pollock et al. 1998; Decocq 2002; Lite et al. 2005) and monotone increasing pattern (Dwire et al. 2004; Lite et al. 2005). In this study, the highest value of local species richness occurs in floodplain habitat, which supports a hump changing pattern. However, the longitudinal dimension exhibits an insignificant difference. The lowest value occurs in the river edge (Plot 1) or terrace (Plot 2). On the basis of the analysis of several mechanisms to influence local species richness, the correlation between sample-zone species richness and local species richness R_q is insignificant. Therefore, a high regional species pool does not significantly increase local species richness. Hence, the mechanism of species pool is insignificant. Inter-specific competition has strong and weak scale dependence in the micro-habitat scale and habitat scale, respectively. Environmental filtration is considered to be the major mechanism to influence the species richness of the river-edge plant community (Fraaije et al. 2015). However, environmental filtration is mainly in the regional or larger scale and requires a higher degree of environmental heterogeneity. In this paper, the degree of heterogeneity in the floodplain habitat is low. For example, the β_w of the floodplain in Plot 2 is only 0.99, which is the lowest value among the six sample zones. Hence, environmental filtration is unsuitable for explaining this study result. Compared with the floodplain, the river edge is susceptible to flood pulse interference with high flood frequency and flood duration. Given that the terrace is close to the road, it is more susceptible to human activities. Only the floodplain is susceptible to moderate flood and human interference; hence, it has high local species richness. In summary, the author believes that the species richness of the *C. aurantiaca* community resulted from the interference. As the secondary mechanism, other ecological processes support moderate interference hypothesis. However, the results of the study by Lite et al. (2005) show that the changing pattern of species richness of vegetation in riparian zone with titudinal gradient of the terrain is related to annual rainfall. In dry seasons, the species richness decreases with decreasing water levels. While in the wet seasons, the invasion of annual plants will cause species richness to increase with decreasing water levels. Therefore, local species richness has annual volatility. However, whether the local species richness pattern in this paper has annual volatility needs to be further investigated.

Shrub is an important component of ecosystem function and species diversity in riparian shrub ecosystem, and it has an important influence on the diversity of herbaceous plants. Compared with the local scale, regional-scale species richness is mainly driven by environmental heterogeneity (Cornwell and Grubb 2003). The highest values of species richness in the two plots in this paper occurred in the river-edge quadrat. Furthermore, the β diversity of species richness, as well as the Unique and Duplicate, are also the highest. This result indicates that habitat heterogeneity is high and that rare tree species are numerous in the river edge under the river pulse compared with the other two habitats (Biswas and Malik 2010). The *C. aurantiaca* shrub in the river edge has the highest height, coverage and distribution area, with many woody plants invading, including *B. tianschanica, S. rosmarinifolia, R. spinosissima L.*. These woody plants can form different micro-habitats including running ditch, tatou and canopy gap, resulting in more species to coexist, particularly the coexistence of rare species. However, the coverage and height of *C. aurantiaca* shrub in the floodplain and in the terrace are lower. Particularly, the *C. aurantiaca* shrub in the terrace is low and has an insignificant effect on the improvement of the local environment. From the viewpoint of riparian shrub ecosystem management, maintaining higher *C. aurantiaca* shrub height and coverage has important significances for the protection of the diversity of the species although it does not significantly increase the local species richness while increasing the total species richness.

4.2. Plant Species Composition along Edaphic Gradients

The hydrological regime influences the physical and chemical properties of soil in the riparian zone, including oxidation reduction potential, nutrient content and water content. The comprehensive features of hydrology and soil have direct or indirect effects on the species composition of vegetation in the riparian zone (Bledsoe and Shear 2000; Schickhoff et al. 2002; Dwire et al. 2006). Gould and Walker (1997) conducted a study on the vegetation in the riparian zone in Arctic Canada and shows that soil pH is the driving factor of species composition of plant community in the landscape scale. The result of MRT and RDA analysis shows that a significant difference exists in the AP content in soil between the two plots in the longitudinal dimension; this difference is the key driving factor for the change in plant abundance composition of the *C. aurantiaca* community. However, in the lateral dimension, the three habitats are distributed along the soil pH gradient in Plot 1 and are distributed along the soil TN and SW gradient in Plot 2. This result indicates that AP content in soil is a factor driving the distribution of *C. aurantiaca* community in the longitudinal dimension. In the lateral dimension, soil pH, TN and SW are the driving factors, thus indicating that different soil ecological factors have different acting scales.

Among the 7 soil variables, soil AP can independently explain 18.23% of the variance of species composition ($F=7.466$, $P=0.001$). Soil TN can independently explain 16.94% of the variance ($F=6.914$, $P=0.001$). Among the 30 plants, Poch, Inbr and Caau are positively correlated with the AP content in soil and are negatively correlated with the TN content. Civi, Acas, Eure, Roka, Cale, Aggi and Saro are negatively correlated with the AP content and are positively correlated with the TN content. Indicator species analysis shows that in the 24 kinds of indicator plants, most are in mesophyte, such as Cirsium, Cart, Edelweiss, Acas, Eure, Ligularia macrophylla, short glandular millet grass, and long handle Oxytropis. This suggests that *C. aurantiaca* community is still subjected to the biological climate control in arid area with the characteristics of mesophyte despite the distribution in the riparian zone. Its changes in plant abundance composition are sensitive to hydrological conditions and soil physical and chemical properties, which can lead to the change of community structure. Therefore, the management of local micro-topography and water condition plays an important role in maintaining the species diversity of *C. aurantiaca* community shrub.

Soil N and P are the limiting factors for the productivity and species diversity of terrestrial ecosystems. In this paper, AP, TN and TP are significantly correlated with three canonical axes. Particularly, the AP and TN content have higher spatial differentiation along the longitudinal dimension in the two plots. Among which, the AP content in Plot 1 is higher and the TN and TP contents in Plot 2 are higher. The study on grassland ecosystem has shown that P has a long-term influence on species abundance and species composition, with an accumulating property in soil. However, the effect of N is short and temporary (Willems and van Nieuwstadt 1996; Marini et al. 2007) because the mobility of P in the topsoil is worse than that of N (Ekholm et al. 2005). For the vegetation in the riparian zone, the influence of soil redox potential should be considered (Dwire et al. 2004; 2006) because the AP content in soil is closely related to the TP, Ca^{2+}, Mg^{2+}, Fe^{3+}, Al^{3+} ion contents and to the soil redox potential, particularly Fe^{3+}. Some studies suggest that flood will reduce soil redox potential, thus leading to the release of absorbed phosphorus in soil, which is an important mechanism for influencing the availability of soil phosphorus (Hupfer & Lewandowski, 2008; Rydin et al., 2011). Therefore, flood interference can increase the AP content by reducing the soil redox potential (Noe et al. 2013; Wang et al. 2015). According to the result of the present study, the flood frequency and flood duration in Plot 1 are higher. There are two indirect evidences to prove this result. First, Plot 1 is located in the downstream of Plot 2; thus, the terrain of the former is lower than the latter with wider floodplain development. Furthermore, the peat accumulation in Plot 1 is found in the local section. Second, the investigation shows that the sod layer in Plot 1 is thicker than in Plot 2, thus indicating that flood interference will decrease the decomposition rate of roots. Therefore, Plot 1 has a large soil area in the reduction state for a long time. This large soil area increases the percentage of TP inverted to available phosphorus, thus increasing AP content. Therefore, the difference between the hydrological conditions of the two research plots is an important reason for the spatial differentiation of soil N and P content. In summary, the distribution and species composition of *C. aurantiaca* is affected by the content of soil AP, mainly related to the differences in the hydrological conditions, and occur on a larger spatial scale in the longitudinal dimension, and affected by soil TN content, mainly related with the topography and available water, and occur at a smaller spatial scale in the horizontal dimension.

5. Conclusions

The plant community in the riparian zone shows a gradient distribution with changing soil relief and correspondingly changes in species composition and distribution characteristics. We analysed the changing patterns of species composition and abundance of *C. aurantiaca* community in the Xinjiang Yili River Valley in the lateral and longitudinal dimension and the relationship with soil factor. The study results show that the species abundance of the *C. aurantiaca* community in the lateral dimension have a hump pattern, thus supporting the moderate interference hypothesis. In species composition change, the AP content in soil is a key driving factor in the longitudinal dimension. Furthermore, pH, TN and SW are the key driving factors in the lateral dimension. However, the total soil factors in this paper can only explain 37.4% of the species total variance. Some important variables are not brought in the observation, including precipitation, temperature and other climatic variables, flood frequency, water level, flood duration and other hydrological variables, grazing, reclamation and other human interference variables, and species dispersal process (Fraaije et al. 2015), which all significantly influence the species abundance and species composition. Moreover, the growing situations of *C. aurantiaca* shrub and the feedback regulation mechanism of understory herbaceous plant diversity need to be further studied in the future.

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