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POLLEN REPRESENTATION TO VEGETATION IN HULUN BUIR STEPPE, INNER MONGOLIA

ПАЛИНОЛОГИЧЕСКИЕ СПЕКТРЫ И ИХ СООТВЕТСТВИЕ СОВРЕМЕННОЙ РАСТИТЕЛЬНОСТИ СТЕПИ ХУЛУНЬ БУИЖ (ВНУТРЕННЯЯ МОНГОЛИЯ)

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Accurate reconstruction of past vegetation based on pollen data needs understanding of the relationships between pollen and vegetation. For this aim we placed traps and collected surface samples in typical communities in Hulun Buir steppe. A (association index), O (over-representation index), and U (under-representation index), which measure pollen representation to vegetation, were calculated when combining pollen data with vegetation data. The results suggest that the pollen produced by dominant plants, such as *Artemisia*, *Poaceae, Rosaceae, Asteraceae, Cyperaceae* and *Ranunculaceae, Chenopodium* is well represented and indicates the plant species growing around. It seems there is no significant correlation between the pollen productivity and pollen dispersal. Although pollen assemblages can reflect plant communities in Hulun Buir steppe, the coefficient of similarity was only 0.6, which revealed a high effect of background pollen components on the accuracy of pollen representation to vegetation in this study area.
Key words: pollen, vegetation, trap, surface sample, Hulun Buir steppe, Inner Mongolia.

Точная реконструкция прошлой растительности, основанная на палинологических данных, нуждается в понимании взаимоотношений между отложением пыльцы и характером растительности. С этой целью в типичных сообществах степной местности Хулунь Буиж нами были установлены ловушки для пыльцы и собраны поверхностные образцы почвы. Для комбинирования пыльцевых данных с данными о растительности, были рассчитаны индекс ассоциированности (A), индекс «сверх-представленности» (O) и индекс «недо-представленности» (U), которыми измеряется репрезентативность пыльцевых спектров по отношению к растительности. Результаты исследования показывают, что пыльца, продуцируемая доминантными растениями, такими как *Artemisia*, *Poaceae*, *Rosaceae*, *Asteraceae*, *Cyperaceae* и *Ranunculaceae*, *Chenopodium*, хорошо представлена в спектрах и отражает присутствие видов, образующих окружение пробных площадок. По-видимому, строгая корреляция между продукцией пыльцы и ее рассеиванием отсутствует. Хотя пыльцевые спектры и могут отражать существующие степные сообщества местности Хулунь Буиж, но коэффициент сходства был равен лишь 0.6, что показывает высокий уровень влияния фоновых пыльцевых компонентов на точность оценки репрезентативности пыльцы для состава растительности на изученной территории.
Ключевые слова: пыльца, растительность, ловушка, поверхностные образцы, степь Хулунь Буиж, Внутренняя Монголия.

INTRODUCTION

Pollen records are used widely to reconstruct vegetation history in biogeography (Huntley, Webb, 1988; Colinvaux et al., 1996; Prentice et al., 1996; Birks, 2005; Goring et al., 2009). The reconstruction of vegetation history based on pollen records requires not only possessing the ecological knowledge on modern plant species but also understanding relationships between modern pollen and vegetation. R. Parsons and I. Prentice pointed out that the inaccurately estimate of relationships between pollen and vegetation rather than the disadvantage of pollen records caused the inaccurate of vegetation reconstruction (Parsons, Prentice, 1981).

M. Davis firstly presented the R-value model for studies of relationship of pollen and vegetation (Davis, 1963). She assumed that pollen in a deposition sites entirely come from the vegetation around the sampling locations, without exotic background pollen components. However, the background pollen components are present in any sample sites owing to the characteristics of pollen dispersal. Anderson considered the impact of background pollen components and point out that pollen assemblages from any sample sites contain two components: one is the representation of the plants growing around sampling sites(the source area) and the other is background pollen components from the plants beyond the source area (Andersen, 1973). R-value model with the background components developed by Anderson resulted in more precise vegetation reconstruction. Davis used the values of association (A), under-representation (U) and over-representation (O) to quantify the relationship between pollen assemblages and plant communities (Davis, 1984). He divided pollen taxa into three types named association, under-representation and over-representation according to A, O, U values. The pollen taxa for the over-representation types with high O value do not indicate the surrounding growth of the same plants; whereas the presence of pollen for association and under-representation types can certainly indicate the growth of plants nearby. For example, in Changbai Mountain of China, *Pinus* and *Betula* are over-representation types, *Quercus* and *Fraxinus* are association types, while *Larix* is under-representation (Li et al. 2000). It imply that *Pinus* and *Betula* plants often grow far away from sampling points whereas *Quercus* and *Fraxinus* plants grow around the sampling points. In general, wind-pollinated species, which produce much pollen and have strong dispersal ability, is over-representation type; Insect-pollinated species, which generally produce less pollen and have weak dispersal ability, is under-representation type.

On Inner Mongolia steppe, the open surrounding and high wind speed is helpful for the dispersal of pollen; but low herbaceous plants determine that pollen will not spread far, which bring the relationship between pollen and vegetation more complex. Several palynological studies are being doing in Inner Mongolia steppe (Liu et al., 1999, 2008; Ma et al., 2008; Xu et al., 2009), but pollen representation limited. How is pollen representation to vegetation? How do pollen assemblages reflect the plant community change? The issue we focus on in this study is a key for the accurate reconstruction of steppe vegetation.

STUDY AREA AND METHODS

Hulunbeier steppe is located in the eastern part of Inner Mongolia Plateau (115°31′00″–121°34′30″E, 47°20′00″–50°50′30″N), surrounded by mountains and hills which connected to Daxing'an Mountain range with elevation of 700–1000 m. It is temperate continental monsoon climate with an average annual temperature –3–0 °C. Meadow steppe and typical steppe are dominant vegetation types. *Leymus chinensis* (Trin.) Tzvel., *Stipa baicalensis* Roshev. and *Filifolium sibiricum* (L.) Kitam. communities have a widely distribution.

Traps were placed in different community to collect pollen and surface soil samples were taken near trap. 33 quadrats with 1 x 1 m size were used for vegetation survey in the 20 m radius with trap as the focal point at each site. Name and percentage coverage for all plant species were recorded.

Pollen extracted followed the standard HF acid method. Pollen identification and statistics used Olympus BH-2 biological microscope under 400 times, more than 500 pollen grains were identified for each sample.

A (Association index), *O* (over-representation index), *U* (under- representation index) values are calculated using following formulas:

$$A = B_0/(P_0 + P_1 + B_0);\ \ O = P_0/(P_0 + B_0);\ U = P_1/(P_1 + B_0).$$

There are three basic relationships between pollen and vegetation: (1) the pollen taxon is found at sampling site and associated plant species is present (relationship I); (2) the pollen taxon is not present in sampling site but the plant taxon is present (relationship II);

(3) the pollen taxon is found in sampling site but the plant taxon is not present (relationship III).

Where: B_0 is the number of samples which have relationship I; P_1 is the number of samples which have relationship II, P_0 is the number of samples which have relationship III .

CC, the coefficient of similarity, is usually used to describe the similar between pollen spectrum and plant communities and calculated as follow:

$$CC = \frac{2c}{(a+b)+(b+c)} \times 100\%,$$

where: *c* is the number of taxon found in both pollen assemblages and plant communities; *a* is the number of taxon which present in pollen assemblages but absent in plant communities; *b* is the number of taxon which absent in pollen assemblage but present in plant communities.

R-value is a ratio of pollen abundance to vegetation coverage, R_k is R values of pollen taxon k. R_k is calculated as following:

$$R_k = \frac{1}{n}\sum_{i=1}^{n}(P_k / V_k),$$

where: *n* is total number of sample sites, *I* = sample site, *k* = pollen taxon, P_{ik} = percentage of pollen taxon *k* at sample site *i*, V_{ik} = coverage of plants corresponding to pollen taxon *k* at sample site *i*.

RESULTS AND DISCUSSION

Pollen representation to vegetation

26 pollen taxa were found in trap or surface samples. The taxa present in both trap and surface samples are *Apiaceae, Artemisia*, *Brassicaceae, Campanulaceae, Caryophyllaceae, Chenopodiaceae, Asteraceae, Convolvulaceae, Cyperaceae, Dipsacaceae, Fabaceae, Euphorbiaceae, Iris, Lamiaceae, Liliaceae, Plantago, Poaceae, Polygonaceae, Ranunculaceae, Rosaceae, Rubiaceae, Scrophulariaceae, Stellera, Thalictrum* and *Pinus*. Most of these taxa contain dominant species in regional vegetation.

The corresponding plants of 17 pollen taxa are absent in our study area. There are 12 pollen taxa, such as *Alnus*, *Betula*, *Humulus*, *Salix*, *Typha*, *Urtica*, *Tamarix*, *Elaeagnceae*, *Ephedra*, *Nitraria*, *Papaveraceae* and *Tribulus*, present in both trap and surface samples in the year 2007 and 2008, which suggest that these taxa are generally exotic pollen in this region. The presence of *Alnus* and *Betula* pollen reveals the widely distribution of anemophilous arboreal pollen in the open region; the presence of *Salix* and *Typha* pollen reflects that the pollen produced by tall willow shrubs and aquatic plants have good dispersial; *Humulus* and *Urtica* indicates human activities in the region.

The pollen of *Araceae*, *Boraginaceae*, *Crassulaceae*, *Juncaceae*, *Polygalaceae* are absent in trap and surface samples although their plants species distribute in study area, we find that these plant species grow relatively sporadic or have low pollen productivity. For example although plant species widely distributed *Crassulaceae* pollen can not be found in both the trap and surface samples owing to low pollen productivity and plant height.

A , O, U indexes reflects the pollen representation to vegetation. According to the A value, the pollen taxa can be divided into 3 groups (Table). The pollen taxa with A values higher than 0.5 in both Trap and surface samples were gathered to Group I consisting of *Artemisia, Poaceae, Liliaceae, Ranunculaceae, Rosaceae, Asteraceae, Cyperaceae, Apiaceae* and *Chenopodiaceae*. These pollen taxa for Group I have good representation to plants species which are dominant plants in study area; Group 2 , including *Caryophyllaceae*, *Iris*, *Campanulaceae*, with variable A values reflected unstable character for pollinated species. Group 3 with a A values below 0.5 can be divided into groups according to the O and U values. For example *Pinus* pollen with high O value and zero U value is over- representation and found in every sample although pine is rare in study area. The results are comparable with other studies (Hjelle, 1997; Hicks, 2001; Olivera et al., 2009).

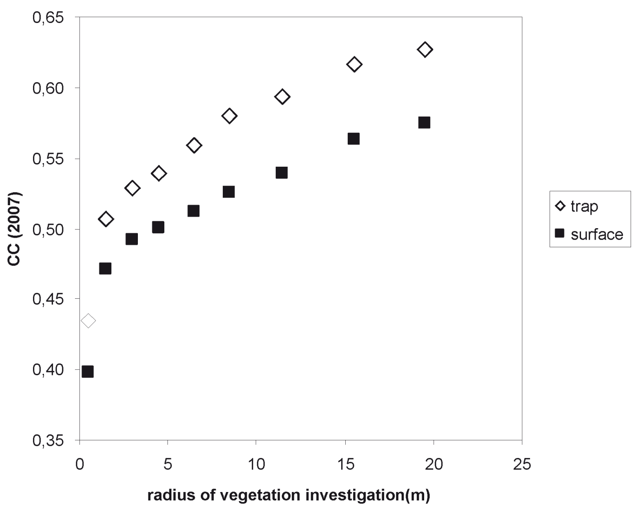
Relationship between pollen assemblages and vegetation

The coefficient of similarity (CC) between pollen spectrum and plant community show that the CC values raise when vegetation investigate radius increase (Fig. 1). In particular CC has a rapid raise within 4 meters radius from the sample sites and increase slowly beyond 4 meters radius. It imply that the vegetation survey radius should not be less than 4 meters to ensure a better similarity between pollen assemblages and plant communities. The average CC of trap samples are higher than the surface samples, suggest that pollen assemblage of trap samples can indicate the vegetation better.

The CC values of pollen assemblages and plant communities have a maximum value of 0.6,which mean background pollen from the open landscape of

Indices for pollen taxa found in Trap and surface samples for different years in Hulun Buir steppe (A = association; U = under-representation; O = over-representation; R = R-value)

Group		2007								2008							
		Trap				Surface				Trap				Surface			
		A	O	U	R	A	O	U	R	A	O	U	R	A	O	U	R
Group 1	*Artemisia*	1.0	0.0	0.0	4.4	1.0	0.0	0.0	14	1.0	0.0	0.0	4.2	1.0	0.0	0.0	6.2
	Poaceae	1.0	0.0	0.0	0.1	1.0	0.0	0.0	0.2	1.0	0.0	0.0	0.1	1.0	0.0	0.0	0.1
	Liliaceae	1.0	0.0	0.0	1.5	1.0	0.0	0.0	0.2	1.0	0.0	0.0	0.7	0.5	0.1	0.5	0.1
	Ranunculaceae	1.0	0.0	0.0	13.0	0.8	0.2	0.0	55.0	0.8	0.2	0.0	33.3	0.8	0.2	0.0	39.2
	Rosaceae	1.0	0.0	0.0	4.7	1.0	0.0	0.0	1.3	1.0	0.0	0.0	3.4	1.0	0.0	0.0	0.8
	Asteraceae	0.9	0.1	0.0	13.5	0.9	0.1	0.0	10.2	0.9	0.1	0.0	7.6	0.9	0.1	0.0	3.0
	Fabaceae	0.9	0.0	0.1	1.2	0.9	0.0	0.1	1.1	0.5	0.1	0.5	0.8	0.7	0.1	0.2	0.4
	Cyperaceae	0.8	0.2	0.0	0.5	0.8	0.2	0.0	1.2	0.9	0.1	0.0	0.3	0.8	0.2	0.0	1.4
	Apiaceae	0.7	0.3	0.1		0.7	0.2	0.2		0.7	0.2	0.2		0.6	0.1	0.3	
	Chenopodiaceae	0.6	0.4	0.0	9.9	0.6	0.4	0.0	19.1	0.6	0.4	0.0	7.6	0.6	0.4	0.0	15.6
Group 2	*Caryophyllaceae*	0.5	0.4	0.1	18.7	0.6	0.4	0.0	9.5	0.6	0.3	0.1	8.4	0.4	0.4	0.4	2.0
	Iris	0.5	0.3	0.5	5.5	0.5	0.3	0.4	1.0	0.1	0.3	0.9	5.9	0.3	0.0	0.7	0.9
	Campanulaceae	0.4	0.5	0.3	7.7	0.1	0.8	0.9	10.6	0.5	0.4	0.3	9.5	0.1	0.0	0.9	0.3
Group 3	*Polygonaceae*	0.4	0.6	0.0	12.4	0.3	0.7	0.0	33.8	0.4	0.4	0.4	21.5	0.4	0.6	0.0	11.2
	Thalictrum	0.4	0.6	0.1		0.3	0.7	0.0		0.3	0.5	0.6		0.2	0.7	0.6	
	Lamiaceae	0.3	0.7	0.1	3.8	0.3	0.6	0.1	1.4	0.3	0.6	0.3	0.8	0.1	0.8	0.9	0.4
	Plantago	0.3	0.7	0.3		0.1	0.9	0.3		0.0	1.0	1.0		0.2	0.8	0.3	
	Rutaceae	0.2	0.8	0.0		0.2	0.8	0.3									
	Euphorbiaceae	0.2	0.6	0.7		0.0	1.0	1.0		0.1	0.5	0.9		0.0	1.0	1.0	
	Brassicaceae	0.2	0.0	0.8	5.5	0.0	1.0	1.0	12.2	0.3	0.7	0.2	46.9	0.4	0.6	0.2	19.1
	Dipsacaceae	0.2	0.8	0.5		0.0	1.0	1.0									
	Rubiaceae	0.1	0.8	0.8	35.7	0.2	0.8	0.6	0.5	0.3	0.7	0.5	2.2	0.1	0.8	0.8	0.6
	Scrophulariaceae	0.2	0.8	0.4		0.4	0.0	0.6		0.1	0.9	0.8		0.0	1.0	1.0	
	Pinus	0.1	0.9	0.0		0.1	0.9	0.0		0.1	0.9	0.0		0.1	0.9	0.0	
	Stellera	0.1	0.9	0.5		0.2	0.8	0.5		0.0	1.0	1.0		0.0	1.0	1.0	
	Convolvulaceae	0.0	1.0	1.0		0.0	1.0	1.0									



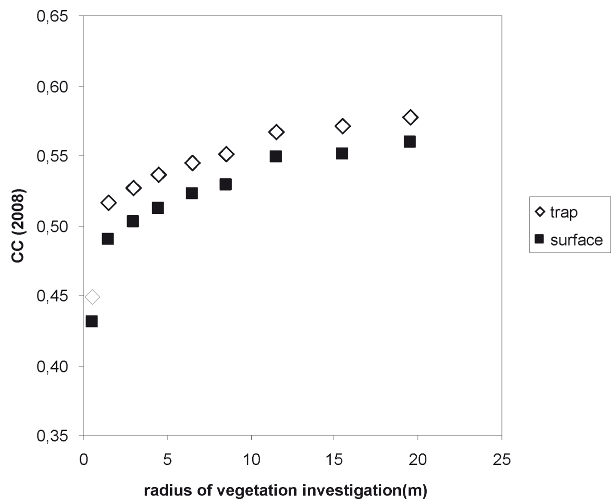


Fig. 1. Diagrams of the coefficient of similarity (CC) (y-axis) versus radius of vegetation data investigation (x-axis) in Hulun Buir steppe

the steppe affect the accurate indications from pollen to plant community.

Relationship between R and A, O, U values

The R value is a ratio of the pollen abundance and the plant coverage showing the ability of plants produce pollen. 16 pollen taxa gave R-values as the plant and pollen can be found simultaneously in sampling sites. R-value is variable in different year and between Trap and surface samples (see Table). The value of A, O and U indicate the pollen dispersal ability. Figure 2 shows that the correlation coefficient (r^2) between R and A, O, U, are less than 0.2. It means there is no significant correlation between the pollen productivity and pollen dispersal in the Inner Mongolia Steppe. In other words, the taxa which have high pollen productivity do not have wide dispersal, and the taxa with low pollen productivity do not always have weak dispersal. A complex relationship between plants and pollens is presented in the Inner Mongolia Steppe.

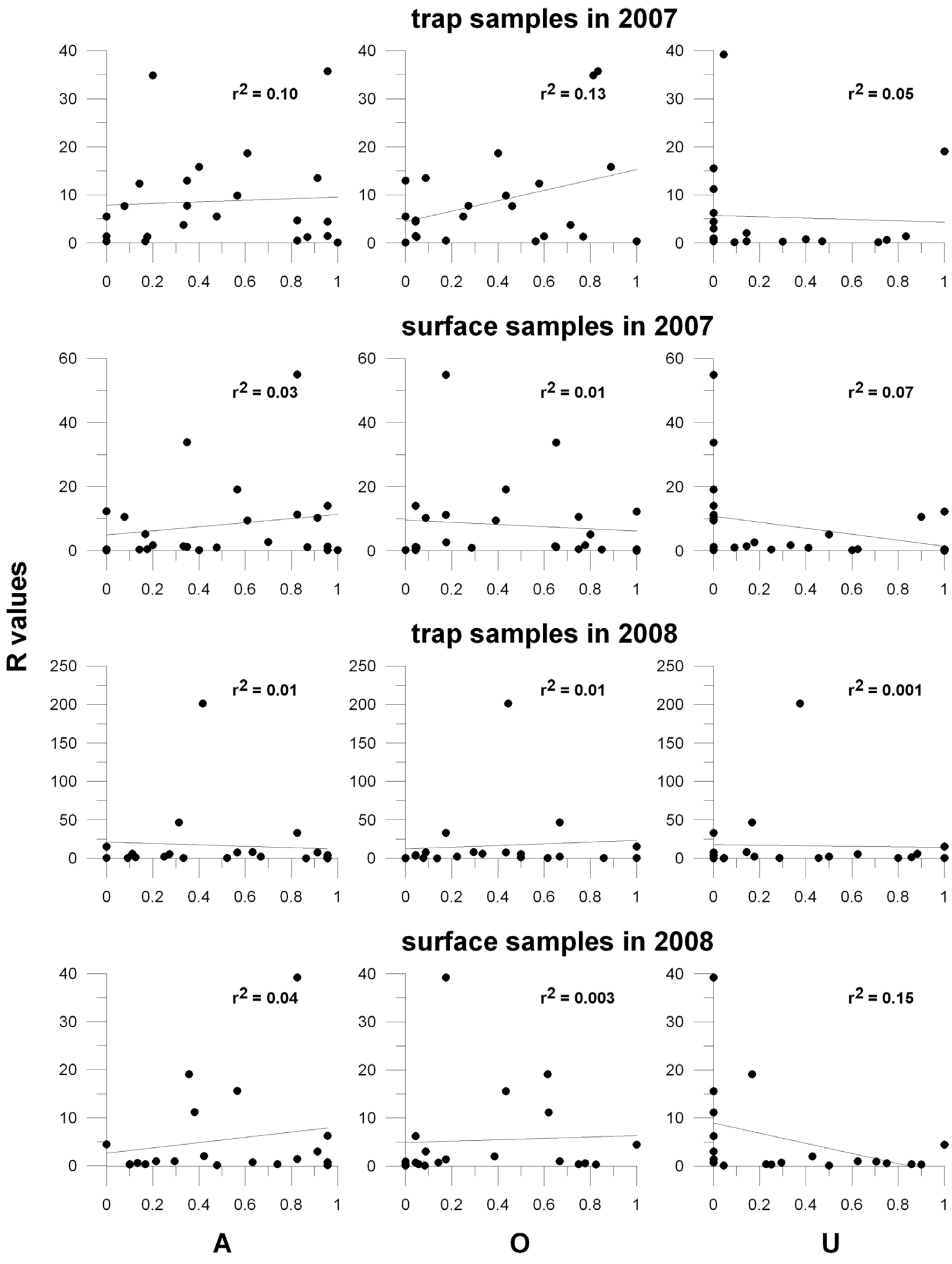


Fig. 2. Scatter plots of R-value and A,O,U values for pollen taxa in years 2007 and 2008

CONCLUSION

In the Inner Mongolia Steppe, the pollen of *Artemisia*, *Poaceae, Rosaceae, Asteraceae, Cyperaceae* and *Ranunculaceae* have better representace to vegetation. Usually the parent plants which produce these pollen taxa are dominant species in the study area although some plants do not always have very high pollen productivity. There is no significant correlation between the pollen productivity and pollen dispersal in the Inner Mongolia Steppe.

The relationship between pollen and vegetation is relative complex in the Inner Mongolia Steppe. Pollen assemblages can reflect the changes of plant community. Abundant background pollen results in the maximum value of 0.6 for coefficient of similarity between pollen assemblages and plant communities and affects the accurate indication to vegetation.

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