Сибирский экологический журнал, 3 (2014) 397–404

УДК 581.1:582.661.15

Study of the relationship between compositions of shrub plant of stable-carbon-isotope and environmental factors in Xinjiang representatives of Chenopodiaceae

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Статья поступила 11.11.2013

ABSTRACT

The paper analyses total of 58 samples representing 32 species of the 14 genera of shrub plant of the carbon isotope composition in Xinjiang representatives of Chenopodiaceae and a detailed discussion on the various factors that can influence them. The value of 38 samples fall between −14.88 ‰ and −11.55 ‰ with a mean of −13.34 ‰, and values of 20 samples between −27.93 ‰ and −22.877 ‰ with a mean of −25.38‰. So we obtained a total of 21 of C_4 species (59.4 %) and 11 of C_3 species (40.6 %) from 32 species studied Chenopodiaceae of shrubs plant. Then the relationship of plant-carbon-isotope and environmental factors has been analyzed. The results showed that the importance environmental factors for the $\delta^{13}C$-value of the Shrubs was annual precipitation (0.78) > temperature (0.66) > elevation (0.55). The three principal components has important factors to influence on C_3/C_4 shrub plant distribution. environmental conditions play significant roles in the distribution and ecophysiological features of different photosynthetic types and even change the photosynthetic pathways. On the other hand, such as geographic location, Sunshine duration, evaporation capacity are more or less correlation with $\delta^{13}C$ values however, they would be interfered by annual precipitation. Desert plants to adapt to drought conditions by increasing water use efficiency (WUE) strategy. In short, plant physiology function is sensitive and timely to adapt environmental change.

Key words: stable-carbon-isotope, environmental factors, relationship, shrub plant, Chenopodiaceae, Xinjiang.

Xinjiang is located in the hinterland of Eurasia, China, there are Altai mountain, Tianshan mountain, and Kunlun mountains with Junggar basin and Tarim basin in distribution, constitute the three mountain clip two basin of the landscape pattern, the atmospheric circulation produce certain effect, blocking the oceanic wet current intrusion of Xinjiang, these creates a unique diversity of dry desert landscape. Xinjiang region is characterized climatologically by continentally, low precipitation, and the hot and dry summer, and the cold, harsh winter. This phyto-group go through physiological and ecological evolution, adapt and competition, and formed a series of survival strategy. Its varied topography and climate have given rise to a remarkable diversity of habitats and a correspondingly diverse array of shrubs plant species. In addition, shrub plants of Chenopodiaceae are the typical desert ecosystem in Xinjiang. It’s widely distributed because it has strong adaptability with drought tolerance and resistance saline and alkaline land. The shrubs play an important role in maintain biodiversity, ecosystem service function and stability of desert ecosystem. Especially shrubs of Chenopodiaceae, there are some fascinating aspects regarding the diversity of adaptive strategies and ultra structure in many species. One of the adaptive strategies which are correlated with morphology, ecology and even taxonomy is the photosynthetic type. Two types of CO_2-fixation, namely C_3 and C_4 are frequently found in Chenopodiaceae [Carolin et al., 1975; Sticker W., 1985; Hossein et al., 1997]. Meanwhile the high proportion of C_4 Chenopods in Xinjiang is very interesting [Feng et al., 2012]. C_4 plants are also known to perform well in arid environments. Plant-carbon-isotope plays an important role in ecological restoration and sustainable development. They have the obvious particularity and regional characteristics. while there is no research work about shrubs of Chenopodiaceae in Xinjiang region at present. So we studied and analyzed the relationship of shrub plant stable-carbon-isotope and environmental factors in Xinjiang representatives of Chenopodiaceae, so as to explore the water use efficiencies of desert plants and provide the theoretical basis for the conservation of desert ecosystems ,as well as to enhance the recognition of greater efficiency in the ecological restoration. It was suggested that shrub be studied further to exert its greater efficiency in arid areas

MATERIALS AND METHODS

A total of 58 samples representing 32 species of the 14 genera of shrub plant in Chenopodiaceae known to occur in Xinjiang were examined. Many of the Shrubs of Chenopodiaceae investigated here were collected during 2010–2012 in Xinjiang, samples of plant collected from arid field sites during the seedy season for carbon isotope analysis. Depending on leaf size, 3 to 20 leaves (mostly 5) from at least three different adult individuals were collected, oven dried and ground. Their relevant vouchers are preserved in herbarium of Xinjiang Institute of Ecology and Geography (XJBI).

These measurements were done at Key Laboratory of Biogeography and Bioresource in Arid Land, (Xinjiang, China). First, dried samples were powdered, then 1–2 mg powder were placed in a tincapsule and combusted in an elemental analyzer (Finnegan MAT 253 mass spectrometer). The resulting N_2 and CO_2 were separated by gas chromatography and then determination of $^{13}C/^{12}C$ ratios (R). $\delta^{13}C$ values were determined where $\delta^{13}C = 1000 \times (R_{sample}/R_{standard}) - 1$. In C_4 plants, $\delta^{13}C$ ratios are usually between −10 ‰ and ?15 ‰, while in C_3 plants, $\delta^{13}C$ ratios range from −21 ‰ to −30 ‰ [Sage et al., 1999]. So carbon isotope analysis can be employed to identify the photosynthetic pathway. The $\delta^{13}C$ value of the Shrubs results are reported with respect to the internationally accepted PDB standard [Bender et al., 1973; Schulze et al., 1996].

The data of growing season environmental factors in Xinjiang has been simulated and extracted, such as precipitation, temperature and sunshine.Then the relationship of plant-carbon-isotope and environmental factors has been analyzed. And thus the affect of the environment to the plant-carbon-isotope has been realized.The tools of the statistical functions of Excel and SPSS, we studied and anglicized the relationship of plant stable-carbon-isotope and environmental factors.

RESULTS AND DICUSSION

Frequency of C_3 or C_4. According to analyzed the Shrubs of stable-carbon-isotope values ($d^{13}C$), we draw the frequency distribution, can be recognized the carbon isotope composition feature and distribution regularities among the 58 analyzed samples (Fig. 1): $\delta^{13}C$ values of 38 samples fall between −14.88 ‰ and −11.55‰ with a mean of −13.34 ‰, and $\delta^{13}C$ values of 20 samples between −27.93 ‰ and −22.877 ‰ with a mean of −25.38 ‰. So we obtained a total of 21 of C_4 species (59.4 %)

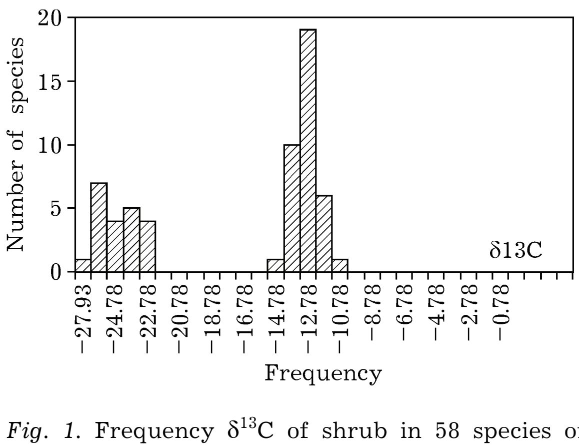

Fig. 1. Frequency $\delta^{13}C$ of shrub in 58 species of Chenopodiaseae

and 11 of C_3 species (40.6 %) from 32 species studied Chenopodiaceae of shrubs in Xinjiang. All examined species of the genus Kalidium, Haloenemum, Halostachys, Ceratoides and Atriplex exhibit C_3-type. Kochia, Camphorosma, Suaeda, Haloxylon, Anabasis, Sympegma, Iijinia and Nanophyton to be a C_4-type, but Salsola is C_3–C_4-type .The shrub plants of Chenopodiaceae we find that species growing in desert dunes are often C_4-pathway. On the other hand, psammophytic species with succulent stems growing in salt and river sands are often C_3-pathway. The family Chenopodiaceae contains a large number of C_4 species, and the greatest biochemical and anatomical diversities among C_4 eudicot lineages [Sage, 2001; Pyankov et al., 2001b; Wen et al., 2011]. Our data thus support the hypothesis that the C_4 syndrome is adaptive in arid areas. It is of special ecological interest that these groups possess different physiological, biochemical, and structural features which result in different rates of photosynthesis and environmental relationships.

C_3 or C_4 relationship with environment factors. In addition to d^{13}C values of Plant affect by their own biological factors, also by environmental factors that affect plant stomata conduction or photosynthetic carboxylase activity, and change δ^{13}C values of plant. [Farquhar et al., 1984; Anderson et al., 1998; Pyankov et al., 2000; Yin et al., 1997; Wang et al., 2000]. In this paper, we analyze plant δ^{13}C values relationship between the environmental factors involved (Table 1) including Sunshine duration, evaporation capacity, Annual average temperature. Annual precipitation and elevation. It is our objective in this report to make clear the mesoscale distribution of C_3 and C_4 the Shrubs of Chenopodiaceae and the associated with the environmental factors from arid of Xinjiang.

Principal Component Analysis. From the proceeding analysis of only a few factors, it can be found that we face a complex problem that is concerning different factors change constantly with temporal and spatial variation. Multivariate analysis is useful in revealing the connections and functions of environmental elements, among which the principal component analysis is one of the most important methods. So five variables of the 58 samples of δ^{13}C values were conducted using statistical package for social science (SPSS) version 16.0 for all calculation. The original statistical data of 58 samples was calculated of 58 × 5 matrix with PCA, The main steps were listed as follows: (1) Original data standardization. (2) Coefficient matrix calculation and the significance level test. (3) Eigenvalue, contribution rate, cumulative contribution rate and eigenvector. (4) Principle component extraction. The standardized eigenvectots from the first five eigenvalues shown in Table 2.

From Table 2 show that the dispersal degree of the samples is high, the first three principal components whose Eigenvalue is over 1.00 can be extracted. the cumulative rate of the first three factors of PCA high covers 85.21 % of original statistic data. Obviously, 1st, 2nd and 3rd are the most important factor to δ^{13}C values.

Meanwhile shows that the first principal component is biggest (0.66), which is consisted of heat type. In second principal component is biggest (0.78) of annual average, it means that the water type. And in third principal component is biggest (0.55), which is consisted of elevation type. So the results showed that the importance of factors for plant distribution was annual precipitation (0.78) > temperature (0.66) > > elevation (0.55). The three principal components has important factors to influence on C_3/C_4 shrub plant distribution. Form the above description imply that photosynthetic pathways and their characters are largely environment-regulated. However, environmental conditions play significant roles in the distribution and ecophysiological features of different photosynthetic types and even change the photosynthetic pathways.

Linear regression analysis. In order to explore environmental factors how to affect >^{13}C values of shrub plant. So we using the statistical functions of Excel analysis tools. Set up the linear relation between >^{13}C values and environmental factors, and do variance analysis. Our results are as follows. It is evident that Sunshine duration, evaporation capacity. Mean annual temperature and altitude are positively related to >^{13}C values, but negative correlation to Annual precipitation (Fig. 2–6). Gene-

Table 1

Information of sampling sites and shrubs of stable-carbon-isotope values ($\delta^{13}C$) in different climate areas of Xinjiang

Lab N	Name	Location	SD	EC	AT	AP	EL	$\delta^{13}C$ values	PP
yz-3	*Kalidium foliatum*	N 44°13′, E 87°46′	2962.8	2153	5.7	127.6	500	−25.575	C_3
yz-3−1	*K. foliatum*	N 44°01′, E 89°34′	2987	1950	5.2	190	750	−25.28	C_3
yz-3−2	*K. foliatum*	N 47°00′, E 87°43′	1900	1844.4	4	121	516	−25.798	C_3
yz-2	*K. cuspidatum*	N 42°08′, E 83°05′	2500	1600	10	200	1600	−24.762	C_3
yz-2−1	*K. cuspidatum*	N 46°36′, E 89°35′	2900	1734	1.9	158.3	914	−25.027	C_3
yz-1	*K .schrenkianum*	N 44°13′, E 87°46′	2962.8	2153	5.7	127.6	500	−24.164	C_3
yz-4−1	*K. caspicum*	N 46°36′, E 89°35′	2900	1734	1.9	158.3	914	−24.09	C_3
yj-1	*Haloenemum strobiaceum*	N 42°43′, E 89°02′	2912	3500	14	20	−155	−23.307	C_3
ys-1	*Halostachys caspica*	N 41°34′, E 82°54′	2900	2560	11	51.6	960	−24.627	C_3
ys-2	*H. caspica*	N 47°01′, E 87°43′	1900	1844.4	4	121	516	−27.056	C_3
tr-1	*Ceratoides latens*	N 45°35′, E 82°35′	2800	1786	4.3	230	1580	−27.124	C_3
tr-2	*C. latens*	N 44°13′, E 86°07′	2800	1479.6	6.8	145.7	400	−26.51	C_3
xy-1	*C. ewetsmanniana*	N 46°15′, E 90°39′ÿ	3000	1495	1.03	189	1194	−27.081	C_3
xy-2	*C. ewetsmanniana*	N 40°51′, E 98°11′	2912	2838	13.9	16.4	-80	−26.961	C_3
xy-3	*C. ewetsmanniana*	N 47°20′, E 87°52′	2850	1869	3.9	99.5	515	−27.121	C_3
yb-1	*Atriplex verrucifera*	N 46°36′, E89°35′	2900	1844	4.3	121	914	−25.718	C_3
bb-1	*A. cana*	N 46°12′, E84°31′	2858	1786	4.3	253	550	−23.608	C_3
md-1	*Kochia prostrata*	N 46°95′, E 87°38′	1900	1844	3.4	117	482	−14.661	C_4
md-2	*K. prostrata*	N 47°22′, E 88°38′	2900	1950	4.8	115	800	−13.901	C_4
zv-1	*Camphorosma monspeliaca*	N 44°17′, E 87°56′	2933	2000	6.6	164	460	−13.534	C_4
zv-2	*C. monspeliaca*	N 43°40′, E87°19′	2600	2670	3	180	900	−12.334	C_4
jp-3	*Suaeda microphylla*	N 44°13′, E87°47′	2962.8	2153	5.7	127.6	500	−13.933	C_4
jp-1	*S. microphylla*	N 45°14′, E83°01′	2800	3790	7.5	90.9	290	−12.839	C_4
ng-1	*S. physophora*	N 44°17′, E 87°55′	2933	2000	6.6	164	460	−13.517	C_4
bs-1	*Haloxylon persicum*	N 44°28′, E 88°17′	2900	2000	9	50	650	−13.933	C_4
bs-2	*H. persicum*	N 40°51′, E 98°11′	2912	2838	13.9	16.4	-80	−14.406	C_4
ss-1	*H. ammodendron*	N 41°51′, E 85°41′	2990	2788	11	50	917	−14.305	C_4
ss-2	*H. ammodendron*	N 45°35′, E 82°35′	2804	1700	5.6	190	1557	−13.733	C_4
ss-3	*H. ammodendron*	N 40°51′, E 98°11′	2912	2838	13.9	16.4	-80	−12.969	C_4

jmz-g	*Anabasis elatior*	N 44°17′, E 87°56′	2933	2000	6.6	164	460	−13.9	C_4
jmz-2	*A. brevifolia*	N 46°04′, E 85°08′	2694	2742	8.6	105	600	−14.284	C_4
jmz2-1	*A. brevifolia*	N 46°36′, E 89°35′	2900	1734	1.9	158.3	914	−12.93	C_4
jmz-3	*A. aphylla*	N 41°50′, E 82°29′	2790	2338	7.6	171	1234	−12.572	C_4
jmz-3-1	*A. aphylla*	N 42°08′, E 83°05′	2500	1600	10	200	1600	−13.074	C_4
jmz3-3	*A. aphylla*	N 46°40′, E 89°36′	2900	1844	4.3	121	962	−13.656	C_4
jmz-4	*A. salsa*	N 47°10′, E 88°13′	1900	1900	3.5	168	600	−13.685	C_4
jmz4-2	*A. salsa*	N 47°20′, E 88°01′	1900	1844	3.4	117	550	−11.95	C_4
jmz4-3	*A. salsa*	N 44°59′, E 90°16′	2800	1900	2.4	180	1500	-12.848	C_4
jmz7-1	*A. truncata*	N 46°23′, E 90°34′	2900	1495	1.3	189	1217	−12.793	C_4
jmz-8	*A. eriopoda*	N 44°10′, E 87°06′	2900	2300	6	210	500	−11.555	C_4
jmz8-2	*A. eriopoda*	N 46°17′, E 84°45′	2858	1786	5	182	590	−13.351	C_4
ht-1	*Sympegma regelii*	N 42°46′, E 86°19′	3049	2005	5.7	208	1750	−13.586	C_4
ht-2	*S. regelii*	N 39°08′, E 89°59′	3000	2633	1.5	60	2115	−14.88	C_4
ht-3	*S. regelii*	N 43°32′, E 95°07′	3249	2326	3.6	80	2000	−12.067	C_4
ht-4	*S. regelii*	N 40°24′, E 79°10′	2726	2300	11.4	72	1143	−11.97	C_4
gb-1	*Iijinia regelii*	N 42°16′, E 88°07′	3167	2136	8.6	78.9	1123	−12.97	C_4
gb-2	*I. regelii*	N 45°20′, E 83°20′	2800	3790	7.5	91	450	−13.417	C_4
df-1	*S. orientalis*	N 43°43′, E 82°46′	2900	1500	9.3	200	900	−12.838	C_4
zg-1	*S. dachungarica*	N 47°24′, E 83°28′	3000	1600	7	290	400	−13.387	C_4
mb-1	*S. arbuscula*	N 43°25′, 82°3′	2852	1571	9	269	894	−13.804	C_4
ay-1	*S. abrotanoides*	N 37°52′, E89°31′	3000	1800	0.1	100	3500	−12.273	C_4
ts-1	*S. junatovii*	N 42°08′, E 83°05′	2500	1600	10	200	1600	−22.877	C_3
sy-1	*S. laricifolia*	N 47°07′, E 87°02′	2918	1909	3.8	136	950	−23.677	C_3
sy-2	*S. laricifolia*	N 46°18′, E 83°22′	3122	1859	6.7	280	1200	−24.597	C_3
bz-1	*S. arbusculiformis*	N 43°43′, E 83°29′	2732	1437	7.4	256	980	−27.93	C_3
xp-1	*Nanophyton erinaceum*	N 44°09′, E 82°04′	2852	1571	9	269	950	−13.636	C_4
xp-2	*N. erinaceum*	N 44°07′, E 87°61′	2700	2564.6	5.1	243	1080	−13.49	C_4
xp-3	*N. erinaceum*	N 47°22′, E 88°38′	2900	1700	3.5	190	1000	−14.71	C_4

N o t e. SD − Sunshine duration; EC − Evaporation capacity; AT − Annual average temperature; PP − Photosynthetic pathways; AP − Annual precipitation; EL − elevation.

Table 2

Contribution of Various principal components

Climatic index	Principal component				
	1st	2nd	3rd	4th	5th
SUN	−0.06	−0.59	−0.45	0.37	0.25
EVA	−1.28	−0.20	0.02	0.08	−0.26
TEM	0.66	−0.28	0.45	0.23	−0.27
PRE	−0.40	0.78	−0.05	−0.01	0.37
ALT	−0.25	−0.15	0.55	0.25	0.10
Eigenvalue	2.18	1.10	1.03	0.53	0.36
Proportion, %	43.53	21.98	19.70	9.69	7.10
Cumulative rate, %	43.53	65.51	85.21	92.90	100.00

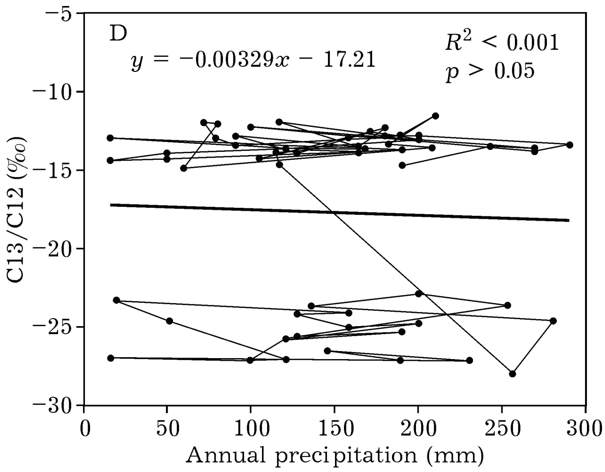

Fig. 2. Annual precipitation (mm)

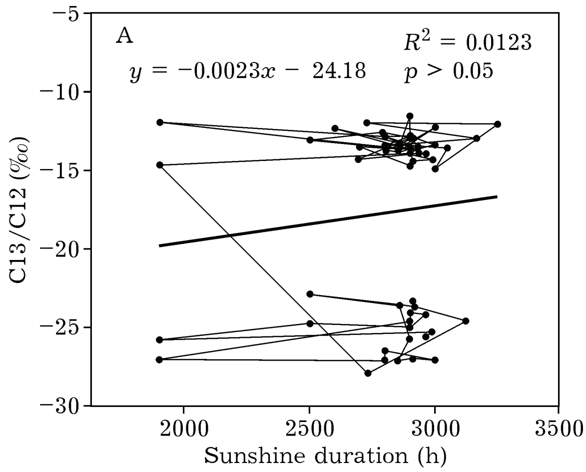

Fig. 3. Sunhine duration (h)

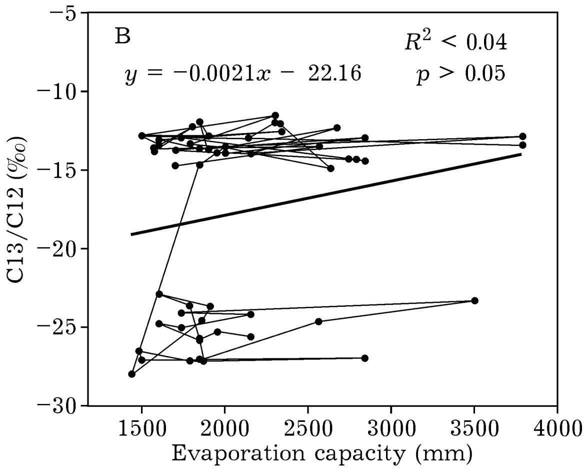

Fig. 4. Evaporation capacity (mm)

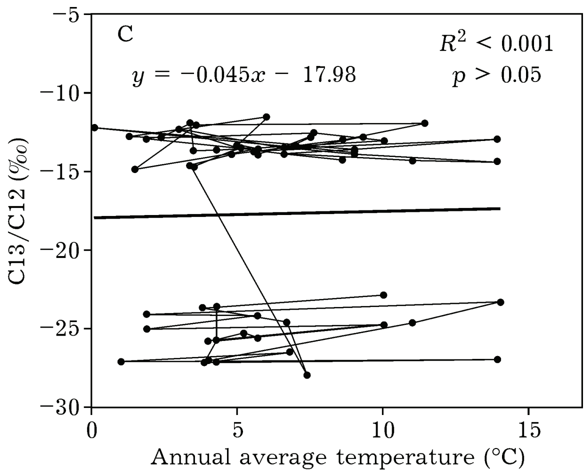

Fig. 2. Annual averade temptrature (°C)

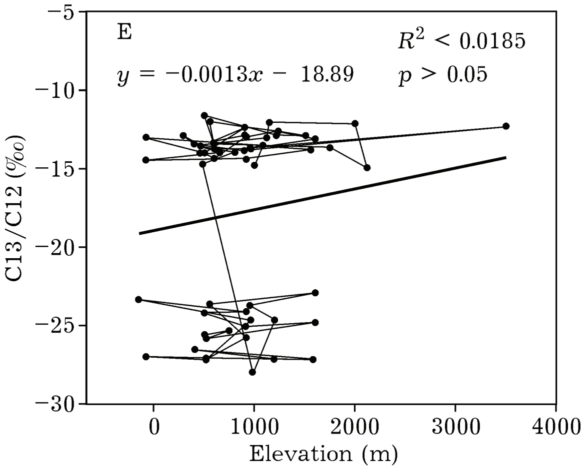

Fig. 6. Elevation (m)

rally, when precipitation increase 100 mm, $\delta^{13}C$ values be negative 0.33 ‰, when sunshine hours increase 100 h, $\delta^{13}C$ values be positive about 0.23 ‰, when evaporation capacity increase 100 mm, $\delta^{13}C$ values be positive about 0.21 ‰. Annual average temperature increase 10 °C $\delta^{13}C$ values be positive about 0.45 ‰, altitude increase 100 m $\delta^{13}C$ values be positive about 0.13 ‰. In comparison, the temperature and precipitation also have the most impact on the shrubs of Chenopodiaceae $\delta^{13}C$ values. Synthesized, the study area most of average annual precipitations which are with under 300 mm, in particular, they are less than 200 mm in arid areas. In such areas, water, which can control the stomata of plant on closing and opening, and influences the Pi/Pa values of plant, will be the main restrictive factor for plants growth. Many studies [Farquhar et al., 1984; Condon et al., 2004] have shown that the $\delta^{13}C$ values of plants and water use efficiency (WUE) are related to the stomata with closing, opening and Pi/Pa values. For one thing, $\delta^{13}C$ values of can reflect Pi/Pa values. For another, plants which are with high WUE values, the $\delta^{13}C$ values of are also high. Above all, WUE values can be reflected by $\delta^{13}C$ values. Other environmental factors, such as Mean annual temperature, altitude, Sunshine duration, evaporation capacity are more or less correlation with $\delta^{13}C$ values, however, they would be interfered by annual precipitation. Desert plants to adapt to drought conditions by increasing water use efficiency (WUE) strategy. In short, plant physiology function is sensitive and timely to adapt environmental change.

CONCLUSION

With living in high temperature, drought and increase CO_2 concentration environment for a long time, plants gradually formed a series of physiological and ecological evolution type. So C_4 pathway are thought to have evolved is higher than C_3 pathway. The occurrence of the C_4 plant therefore is of great importance in the environment change during the late Cenozoic and in the setting up of the framework of modern environment [Han, 2002]. We also found that plants growing in good habitats had lower $\delta^{13}C$ values than those growing in dry and infertile habitats. Plant adapting arid environment is along the direction conducive to improve the water use efficiency.

The strong relationships between $\delta^{13}C$ value of plants and annual precipitation and temperature obtained from this study show that the study transect is an ideal place to explore the relationships between plant isotopic signals and climatic factors. The results can some explain the status of the water utilization efficiency of C_4 plants in Xinjiang and its relationship with spatial precipitation distribution. However, the complicated environmental factors and variation of $\delta^{13}C$ values can not be explained by any single factor, it rather may be a result of the interacting effects of many factors. The study suggests that a lot of information reflecting the change of nature environmental can be recorded in plants. We can through the analysis of stable isotope composition of the plant, to reveal natural environment spatial feature and developing trends.

Desertification and sandstorm affect the economic development and human survival not only in northwest China but also in the arid regions of whole world. The occurring frequency and intensity of natural disasters will be in an increase trend in human on future. Our data thus support the hypothesis that the C_4 syndrome have higher tolerance to environmental stresses (especially, presence of C_4 plants are limited in extremely high temperature and arid conditions) and could make greater contribution to sand land restoration of botanic characters. The Shrub of family Chenopodiaceae contains a large number of C_4 species in Xinjiang [Feng et al., 2012]. Which playing an important role in the maintenance of the stability and continuity of desert ecosystem . Therefore, it is suggested to carry out the study on breeding introduction and popularization of C_4 plants and so as to solve desertification in the arid regions in northwest China. The complete investigation of the plant resources and their distribution and succession in the region will provide the scientific basis for protecting the plant resources in the region. Furthermore, under the conditions of future global changes in plant physiological ecology research should further in depth at the molecular level.

This work was supported by Xinjiang Natural Science Foundation (N 2012211A103):"Study on compositions of shrub plant of stable − carbon − isotope in Xinjiang representatives of Chenopodiaceae" and National Natural Science Foundation of China (N Y326021001). Thank to Key Laboratory of Biogeography and Bioresource in Arid Land, (Xinjiang, China) for their kind helps in carbon isotope examined. The authors gratefully acknowledge the data collection assistance by Liu xuli and Hu zengyun.

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