ARTICLES

Chinese Science Bulletin 2006 Vol. 51 Supp. I 110—116

DOI: 10.1007/s11434-006-8214-z

Responses of ephemeral plant germination and growth to water and heat conditions in the southern part of Gurbantunggut Desert

WANG Xueqing[1], JIANG Jin[1], WANG Yuanchao[2], LUO Weilin[2], SONG Chunwu[1,3] & CHEN Junjie[1,3]

1. Xinjiang Institute of Ecology and Geography, Chinese Academy of Sciences, Urumqi 830011, China;
2. Xinjiang Administration of Engineering Construction in Erqis River Basin, Urumqi 830000, China;
3. Graduate School of Chinese Academy of Sciences, Beijing 100039, China

Correspondence should be addressed to Wang Xueqin (xqwang@ms.xjb.ac.cn)

Received July 20, 2005; accepted January 16, 2006

Abstract Ephemeral plants in the southern part of Gurbantunggut Desert were systematically monitored from 2002 to 2004 and the meteorological data and soil moisture during the same period were analyzed. The results show that the ephemeral plants germination and growth are sensitive to the changes of water and heat condition. The time for daily temperature over 0℃ in early spring in 2003 was delayed nearly 10 d compared with that in 2002, while the soil water changed little in the same period. Observation showed that there were 28 ephemeral species germinated in 2002, their life period was about 70 d in spring, and the maximum cover of ephemeral synusia reached 46.4%. However, only 17 ephemeral species germinated in 2003, their life period was about 50 d in spring, and their maximum cover was only 20.8%. The height of ephemeral plants was significantly higher in 2002 than that in 2003. It can be seen that ephemeral plant germination and growth in spring are strongly dependent on temperature. The changes of water conditions can affect ephemerals germination and growth as well. Because no heavy precipitation occurred during summer in 2002, only a few ephemerophytes were observed in autumn after ephemerals completed their life circle in early spring. However, about 60 mm precipitation was recorded from July to August both in 2003 and in 2004. Some ephemerals such as *Erodium oxyrrhynchum* and *Carex physodes*, etc. covered the dune surface rapidly with a cover >10%. Therefore, the ephemerals not only germinate in autumn after the early spring, some species may germinate in summer if adequate rainfall occurs. The study on responses of ephemerals growth to water and heat conditions not only has a certain ecological significance but also contributes a better understanding to the effect of climate changes on the desert surface stability.

Keywords: germination and growth of ephemerals, water and heat variation, active response, Gurbantunggut Desert.

Ephemeral plants are considered to be a special herbaceous population that can take the advantage of water resources and temperature conditions to rapidly complete their life-circle within about two or three months in spring, when the climate turns warm, snow-cover melts, spring rainfall starts and soil moisture increases[1]. They mainly occur in Central Asia, Junggar, Mediterranean Coast, West Asia and North Africa. In China they are only distributed in north Xinjiang, with the east edge of Junggar Basin as its easternmost limit[2]. In Gurbantunggut Desert, the ephemeral species accounts for 37.1% of total plant species number and its fresh weight in spring accounts for over 60% of total community yield[3,4]. As an important and unique component of the desert flora, ephemeral plants have attracted some botanists attention, whose works mostly focused on the plant flora[2,5], plant geography[6,7], phonology[1] and bioecology[8−12] etc. Previous study indicated that ephemeral plants have a selective distribution on dune surface due to soil moisture differentiation on dune sites[13]. Our studies in this paper will demonstrate that the seasonal change of precipitation affects the temporal distribution of ephemeral plants as well and their germination and growth in early spring also strongly depend on the temperature condition[12]. Gurbantunggut Desert is the largest fixed and semi-fixed desert in China, whose sand surface stability is closely related to temporal and spatial distribution of ephemeral plants[14]. Since the vegetation controlling wind erosion is influenced by climatic environment to a great degree[15], the study on responses of ephemeral plants growth to water and heat conditions will be helpful to understand the relationship between sand surface stability and regional climate change. In this paper, the authors conducted a monitoring on ephemeral plants and soil moisture from 2002 to 2004 and comprehensively analyzed corresponding precipitation and temperature conditions so as to explore the sensitive responses of ephemeral plans to environmental variation in Gurbantunggut Desert.

1 Study area and methods

1.1 Study area

Gurbantunggut Desert, with an area of 4.88×10^4 km^2, is located in the hinterland of the Junggar Basin in northwest China (44°11′N−46°20′N, 84°31′E−90°00′E). Main morphological dune types are longitudinal dunes with a few hundred meters to more than 10 km in length, 10−50 m in height and orientated north-south. Interdune and middle to lower part of slope are stabilized but the crest often has 10−40 m wide mobile zone[16]. Annual accumulated temperature ≥10℃ varies between 3000−3500℃ and precipitation is about 70−150 mm, with pan evaporation exceeds 2000 mm. There is about 20 cm snow cover in winter. Affected by the West Current, precipitation in spring and summer is higher than that in autumn and winter and rainfall from April to July accounts for 47.6% of the whole year's amount. Such a temporal allocation pattern of water and heat creates a favorable condition for the growth and development of ephemeral plants[4]. *Haloxylon persicum* is the dominant species in the desert and mainly appears in the middle to upper parts of dunes. Interdune and middle to lower slopes are covered by *Ephedra distachya* communities and beneath them are ephemeral plants and black microbiotic crusts.

1.2 Methods

The dune for the case study (44°32′30″N, 88°6″42″E) orients NW 18°. It is 23 m in height, and 210 m in width. Its western slope is steeper than the eastern one. A systematic monitoring was conducted in a representative transect of a dune from February in 2002 to December in 2004. The transect mentioned above is perpendicular to the longitudinal dune orientation. The long-term monitoring quadrats were arranged at the different geomorphologic position in the transect. Tree and shrub quadrats are 10 m×10 m and three small quadrats of 1 m×1 m were arranged in each large one for herbaceous survey. Plant species, height, crown diameter and coverage etc. were measured at 15−20-d intervals. For the height measurement, 5−10 plants were selected in each quadrat and the average values were taken. At the same time, soil samples in each quadrat were collected and their water contents were calculated after oven-dried at 105℃. Since the ephemeral plant roots are mainly concentrated in 30 cm depth below the ground surface, the soil samples were collected by using aluminium boxes at 10, 20 and 30 cm depth respectively and average soil moisture were calculated. In addition, soil samples of surface 10 cm layer in typical quadrats were collected in order to determinate the physical and chemical properties in the laboratory[17]. The meteorological data for result analyzing in the meantime were provided by the "Department of Desert Engineering Project".

2 Results

2.1 Soil properties and ephemeral species composition

Analysis showed that the top-layer soil at the upper slope and crest is well-sorted with a standard deviation of 0.38 only, in which medium and fine sands account for 55.28% and 41.28% in weight respectively. The soil profile differentiation is not clear and surface layer is poor in organic matter in the area. Mixed sands occur in the interdune with a standard deviation of 0.78, in which medium, fine, extra-fine and silt materials account for 26.22%, 39.08%, 30.16% and 4.42% respectively, and there is a little organic matter in the surface layer. The poorly sorted deposits in interdune can increase the contact area between sand grains and form effective infiltration barrier, which make water easily retain in surface layer of soil, while the well-sorted particles in upper slopes and crest are favorable to water infiltration[18]. Analytical results also revealed that the soluble salt content in the whole dune surface layer is low and pH value changes little (Table 1).

Table 1 Chemical characteristics of soil on longitudinal dune surface

Site	Organic matter (%)	Total (%)			Available (mg · kg^{-1})			pH (1:5)	Electrical conductivity (ms · cm^{-1})	Salt content (%)
		N	P	K	N	P	K			
Interdune	0.189	0.021	0.034	0.693	16.44	7.34	128	7.82	0.06	0.028
Midslope	0.079	0.008	0.033	0.784	8.21	3.44	98	7.90	0.06	0.025
Upslope	0.036	0.003	0.018	0.528	9.3	3.07	73	7.69	0.04	0.023

Ephemeral plants include ephemeretum species and ephemeroid species. The former completed their life-circle in current years and produced new individuals from seeds in the next spring. The above-ground parts of the latter died off in current years, but their underground organs remained alive and produced new individuals from underground buds or seeds in the next spring. In the study area a total of 45 plant species were identified, including 6 life forms namely dwarf subtrees, shrubs, subshrubs, perennial herbs, annuals with long vegetative period and ephemeral plants. Among them, 28 species are ephemeral plants. They mainly belong to Cruciferae, Compositae, Borraginaceae, Geraniaceae, Leguminosae and Liliaceae families (Table 2). There were 23 ephemeral species growing in the interdune and on the middle to lower parts of dune, 11 species on the crest and upslope and 18—21 species on the midslope of dune. *Lappula rupestris*, *Hypecoum parvifiorum*, *Chrozophora sabulosa* and *Carex physodes* extensively occurred in various geomorphic positions; *Torularia torulosa*, *Erysimum cheiranthoides* and *Eremurus anisopteris* only occurred on semi-fixed sand surface at upper and top parts of dune; *Isatis violascens*, *Lactuca tatarica*, *Tragopogon sablosus*, *Garhadiolus papposus*, *Plantago minuta*, *Gagea* sp., etc. only occurred on the fixed sand surface in the interdune and middle-lower slopes of dunes. The length above ground and under ground parts of ephemeral plants was concentrated within 30 cm of the sand surface. They were small in size but distributed uniformly.

2.2 *Response of ephemeral plants germination and growth to temperature change*

Daily mean air temperature at beginning of March in 2002 was −14℃, and from then on it began to rise. By March 14 it rose to about 0℃ and until April 9 the daily minimum air temperature also exceeded over 0℃ (Fig. 1(a)). In spring of 2003, the daily mean temperature over 0℃ was delayed to March 23 and that of daily minimum temperature over 0℃ delayed to April 19

Table 2 Composition and distribution of ephemeral species on the longitudinal dune in study area

Ephemerals species	Family	Spatial distribution					Plant height	
		interdune	west midslope	crest	east upslope	east lowslope	above ground	below ground
Alyssum linifolium	Cruciferae	+	+		+	+	25	22
T. torulosa	Cruciferae			+	+		28	14
I. violascens	Cruciferae	+				+	50	44
L. tatarica	Compositae	+				+	13	20
T. sablosus[a)]	Compositae	+	+			+	23	27
Echinops gmelinii	Compositae		+		+		18	19
Senecio subdentatus	Compositae		+	+	+	+	15	23
G. papposus	Compositae					+	15	17
L. rupestris	Borraginaceae	+	+	+	+	+	16	30
L. semiglabra	Borraginaceae	+	+		+	+	20	28
Onosma sp.	Borraginaceae	+	+			+	12	30
Arnebia sp.	Borraginaceae	+	+		+	+	20	28
Eremopyrum orientale	Gramineae	+	+		+	+	13	25
Schismus arabicus	Gramineae	+	+		+	+	8	12
Trigonella tenella	Leguminosae	+	+			+	6	25
Astragalus oxyglottis	Leguminosae	+	+			+	5	14
Nepeta micrantha	Labiayae			+			22	28
Nepeta pungens	Labiayae					+	28	21
Gagea sp.[a)]	Liliaceae	+				+	17	18
E. anisopteris[a)]	Liliaceae		+	+	+		65	20
H. parvifiorum	Papaveraceae	+	+	+	+	+	17	17
P. minuta	Plantaginaceae	+				+	5	9
C. sabulosa	Euphorbiaceae	+	+	+	+	+	10	19
Erodium oxyrrhynchum	Geraniaceae	+	+		+	+	20	21
Soranthus meyeri[a)]	Umbelliferae	+	+		+		40	33
C. physodes[a)]	Cyperaceae	+	+	+	+	+	12	17
Ixiolirion tataricum[a)]	Amaryllidaceae	+	+			+	26	30
Cerastium sp.	Caryophyllaceae			+			13	15

a) Ephemeroid species.

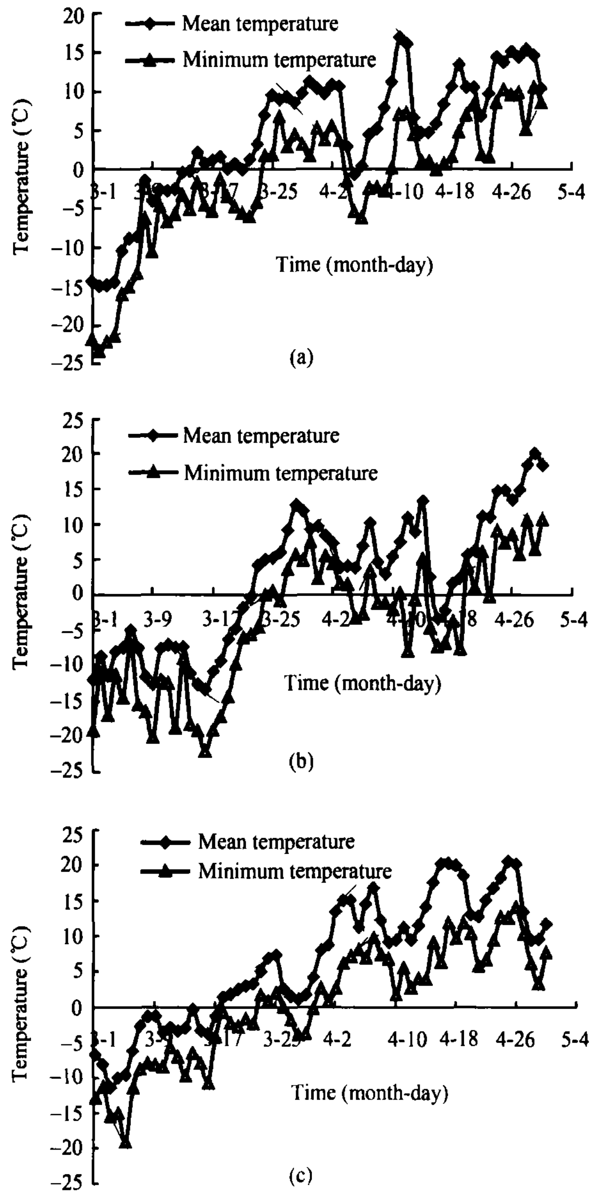

Fig. 1. Comparison of mean and minimum temperature during Mar. and Apr. in 2002 (a), 2003 (b) and 2004 (c).

(Fig. 1(b)). The 10-d mean temperature in early, middle and late March in 2002 were –9.4℃, 0.1℃ and 7.3℃ respectively, while the corresponding figures in 2003 were –9.2℃, –9℃ and 6.5℃ respectively, and the latter is significantly lower than the former. The mean soil moisture measured on March 25 and April 26 in 2002 was 4.4% and 2.9% respectively, while the corresponding figures were 6.0% and 2.8% in 2003, and the latter is higher than the former. Consequently, a total of 28 ephemeral species were identified in 2002, of which *A. linifolium* and *E. oxyrrhynchum* were dominant. That is the highest number of ephemeral species recorded during 2002—2004. At end of March in 2002 the ephemeral plants successively germinated and their mean cover on most part of dune surface reached 5.3%, with the plant height of less than 3 cm; by late April the mean cover reached 20.8% and the mean height was about 10 cm; in mid-May the mean cover reached 40.2% (maximum to 46.4%) and the plants height was 20 cm or so; by mid-June the majority of ephemeral plants began to fade and in early July all ephemeral plants completed their life-circle. In 2003 only 17 ephemeral species were identified, of which *E. oxyrrhynchum* and *C. physodes* were dominant. Some ephemeral species germination was not observed, such as *Gagea* sp., *I. tataricum*, *N. pungens*, *Cerastium* sp., *I. violascens*, *L. tatarica* and *P. minuta* etc. In early April ephemeral plants emerged, and by mid-late April their mean cover only reached 9.4% on most part of dune surface and the ephemeral plants height was less than 5 cm; in mid-May the mean cover reached 18.1% (maximum to 20.8%) and the mean height was less than 15 cm; in late-May the soil moisture reduced rapidly with temperature rising, ephemeral plants started to fade and their mean cover was 13.2%. All ephemeral plants completed their life-circle in late June.

From the description mentioned above, we can see that the time of temperature over 0℃ in 2003 was delayed nearly 10 d than that in 2002, while the soil water condition was better in 2003 than in 2002. We observed that the life-circle of ephemeral plants in 2003 was shortened about 20 d as compared with that in 2002. The number of ephemeral plant species, synusium cover and their height, etc. were also higher in 2002 (Table 3). The time of temperature over 0℃ in 2004 was later than that in 2003 and earlier than that in 2003 (Fig. 1(c)), but air temperature rose rapidly in spring and soil water condition was better, compared with previous two years. A total of 21 ephemeral species were identified in 2004, their life period started in the first 10 d in April and ended at the beginning of July. Both mean cover and height of ephemerals were lower than those in 2002 but higher than those in 2003, which show that the temperature condition in early spring has a significant influence on ephemeral plants germination, growth and development.

2.3 Response of ephemeral plants germination and growth to precipitation change

Ephemeral plants have an obvious selectivity distribution on dune surface, which is an ecological adaptation

Table 3 Comparison of coverage and height of main ephemeral plants in 2002, 2003 and 2004

Date	*E. oxyrrhynchum*		*A. linifolium*		*C. physodes*		*T. tenella*	
	cover (%)	height (cm)	cover (%)	height (cm)	cover (%)	height (cm)	cover (%)	height (cm)
2002-3-28	0.9	0.7	1.1	1.5	none	—	none	—
2002-4-15	2.3	1.2	2.2	4.5	1.0	8.2	0.2	0.8
2002-4-26	5.0	2.3	11.0	10.3	2.0	12.1	0.7	1.2
2002-5-16	17.3	6.6	19.7	21.0	6.6	12.4	2.8	4.2
2002-5-28	14.7	23.0	20.0	22.4	1.6	14.5	0.9	4.3
2002-6-13	2.8	17.5	14.3	18.0	1.0	wilt	0.1	wilt
2003-3-28	none	—	none	—	none	—	none	—
2003-4-15	none	—	none	—	none	—	none	—
2003-4-25	0.7	0.8	0.5	1.5	0.2	4.0	0.1	<0.5
2003-5-10	9.7	3.6	5.5	4.5	4.0	10.7	0.4	1.2
2003-5-28	8.2	3.0	7.3	3.8	5.5	5.0	—	fade
2003-6-10	7.3	wilt	6.0	wilt	4.7	wilt	none	—
2004-3-28	none	—	none	—	none	—	none	—
2004-4-14	3.2	2.4	0.1	2.1	2.0	8.5	0.1	0.8
2004-4-25	5.5	6.0	0.2	11.1	3.8	12.0	0.2	1.7
2004-5-10	13.5	14.2	0.2	4.0	4.3	9.4	0.4	3.6
2004-5-28	15.0	22.4	0.1	wilt	4.0	10.6	0.1	wilt
2004-6-12	15.8	31.0	—	fade	4.0	11.0	—	fade

of plants to soil water condition essentially[13]. Then, what would take place for ephemeral plants as the seasonal change of precipitation occurred? The largest precipitation after June in 2002 was only 15.5 mm, which happened on July 26. The rainfall in other times did not exceed 5 mm and only wet the surface of soil layer, in which the water evaporated quickly. In 2003 two unusual precipitation events with 26.7 and 20.6 mm occurred on July 14 and August 6 respectively, which affected about 40 cm soil layer below the sand surface. The soil moisture measured in corresponding time in 2002 and 2003 also differed significantly (Figs. 2 and 3). The water content in up 30 cm soil layer maintained a low value from June to October in 2002, of which the maximum value was no more than 1.2%, while a peak value of soil moisture (4.7%) existed during July and August in 2003. In September and October the soil moisture decreased but still maintain higher than that in corresponding time in 2003. Under such water condition in the two years mentioned above, the ephemeral plant germination and growth showed a distinct temporal change. In 2002, after ephemeral plants completed their life period in spring, only a few autumn-germinated ephemerals were found in October, which is consistent with the result observed by Wang *et al.*[1]. In 2003, however, ephemeral plants not only germinated in spring but also in summer. Influenced by heavy precipitation during July and August, some ephemerals such as *E. oxyrrhynchum* and *C. physodes* etc. germinated in batches and rapidly covered the dune surface with a total cover of 10%−15% in August. Compared with that in spring, the number of germi-

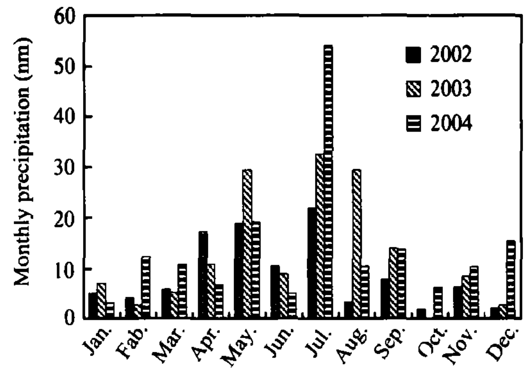

Fig. 2. Comparison of monthly precipitation in 2002, 2003 and 2004.

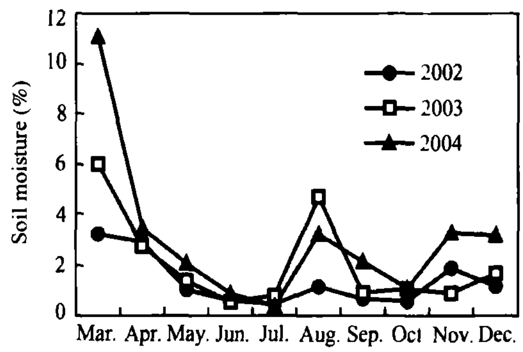

Fig. 3. Comparison of soil moisture in upper 30 cm soil layer in 2002, 2003 and 2004.

nated species and the plants height were lower in summer. For example, the plant height of *E. oxyrrhynchum* on August 7, September 4, October 13 and November 13 were 4, 4.6, 5.1 and 5.5 cm respectively; the corresponding figures of *C. physodes* were 10.5, 12, 8.5 and 7.6 cm respectively. Meanwhile, no flowering and seed-setting phenomena were found for both species. Fortunately, the precipitation condition similar to that in 2003 appeared again in 2004, only one precipitation on July 20 reached 45.8 mm and on August 4 also reached 7.5 mm. As a result, *E. oxyrrhynchum* and *C. physodes*, etc. germinated in batches again and their coverage variations are shown in Fig. 4.

3 Discussion

Ephemerals are a kind of special ecotype plants. They are adapted to a special environment gradually following retreat of ancient Mediterranean Sea and are regarded as a unique component of desert flora in China. Through long-term evolution, they have developed some special strategies to adapt the climatic condition in Gurbantunggut Desert, where there is a 20—30 cm thickness snow-cover in winter, spring is relatively warm and humid but summer is hot and arid. They germinate in early spring and complete their life circle within two or three months. Previous study indicated that some ephemeral species may also germinate in autumn but no information is available on the mass germination of some dominant species in summer. Our systematic observation during 2002—2004 shows that if precipitation is adequate some ephemeral species can germinate in batches in summer.

The studies also show that the germination, growth and quantitative development of ephemeral plants in early spring are strongly dependent on temperature condition. In the study of climatic influence on physiological characteristics of ephemeral plants, Lapointe suggested that the high photoeffect is a prerequisite of carbon accumulation for ephemeral plants and complete their life circle during a shot period[12]. Therefore, the ephemeral plants have to require a suitable temperature to absorb a large amount of available water and nutrients. In Gurbantunggut Desert there is a steady thickness snow-cover in winter, it melts in early spring and supplies to soil water. Coupling with relatively rich spring rainfall in this time, soil moisture from end March to April generally could reach >4% and thus the air temperature is important for ephemeral plants germination in the desert during this time. When air temperature rises significantly, soil water content may inevitably become a limiting factor to growth and development of ephemeral plants.

The changes of soil moisture due to terrain differentiation affect the spatial distribution of ephemeral plants[13]. When soil water content has a seasonal change, the temporal variation of ephemeral plants germination will occur as well. Previous studies have showed that drought stress often prolongs the dormant period or shortens the life span of some ephemeral plants[19]. Some ephemeral plants spread is also affected by soil water condition to a great degree[20]. From the survival ability of desert plant population in Egypt, Hegazy[21] found that the ephemeral plant seeds in soil are accumulated from different years and generally have a life span of 7—8 years. The number of ephemeral plant seeds in the area nearly account for 72.7% of total number in local seed bank, but their survival ability is far lower than that of long vegetative-period plants. It is concluded that the ephemeral plants may be likely to cope with the adverse environment in the form of seed

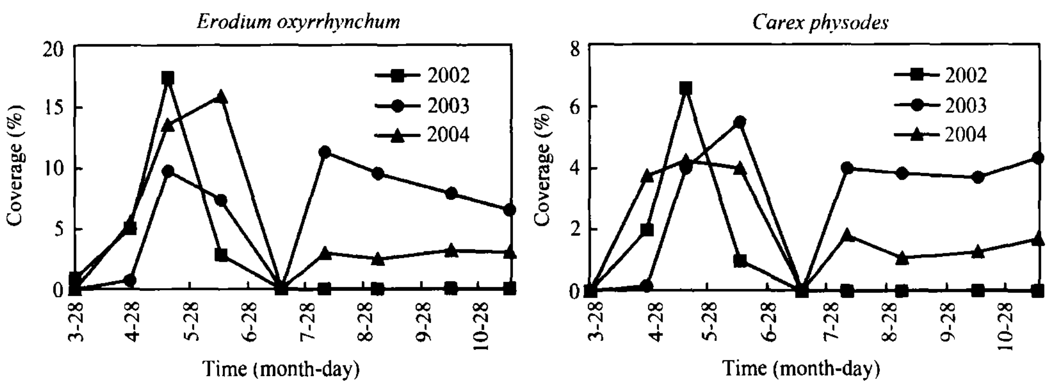

Fig. 4. Comparison of the two ephemeral plants coverage, *E. oxyrrhynchum* and *C. physodes* in 2002, 2003 and 2004.

dormancy. They germinate in suitable time in order to optimize their growth and development, which also reflects the sensitive response of ephemeral plants to precipitation from another aspect.

Acknowledgements The authors wish to express their deep appreciation to Prof. Zhang Liyun for identifying plant species and giving a valuable suggestion on this paper. This work was supported by the Key Knowledge Innovation Project of the Chinese Academy of Sciences (Grant Nos. KZCX3-SW-343-3 & KZCX3-SW-326-4), the Natural Science Foundation of Xinjiang Uygur Autonomous Region (Grant No. 200421128), and the Project of Oasis Person with Ability in Xinjiang.

References

1 Wang Y. Phenological observation of the early spring ephemeral and ephemeroid plant in Xinjiang. Arid Zone Research (in Chinese), 1993, 10(3): 34−39
2 Mao Z M, Zhang D M. The conspectus of ephemeral flora in northern Xinjiang. Arid Zone Research (in Chinese), 1994, 11(3): 1−26
3 Zhang L Y. A preliminary study on the ephemerals in the Mosowan district, Xinjiang. Acta Phytoecologica et Geobotanica Sinica (in Chinese), 1985, 9(3): 213−222
4 Zhang L Y. On the general characteristics of plant diversity of Gurbantonggut sandy desert. Acta Ecologica Sinica (in Chinese), 2002, 22(11): 1923−1932
5 Liu Y X. Observations on the formation of Chinese desert floras. Acta Phytotaxonomica Sinica (in Chinese), 1982, 20(2): 131−141
6 Hu S Z, Lu Y T, Wu Z, et al. The scientific investigation of the desert of Junggar Basin in Xinjiang. In: Sand Control Research (No. 3) (in Chinese). Beijing: Science Press, 1962. 43−64
7 Chen C D, Zhang L Y. The basic characteristics of sandy plant communities, flora and their distributions of Gurbantonggut sandy desert. Acta Phytoecologica et Geobotanica Sinica (in Chinese), 1983, 7(2): 89−99
8 Zhen D. Study on the desert vegetation and its environment in Junggar Desert in Xinjiang. In: Chinese Academy of Sciences, eds. Collected Research Works of the First Sand Control Congress (Natural Geography) (in Chinese). Beijing: Science Press, 1962. 327−341
9 Liu X Y, Liu S. The ecological and biological characteristics of ephemerals and ephemeroides. Arid Zone Research (in Chinese), 1992, 9(Supp): 46−55
10 Liu X Y, Liu S. Analysis of dynamics of plant weight in ephemerals. Acta Phytoecologica Sinica (in Chinese), 1996, 20(2): 177−183
11 Li X Y. Preliminary study on the characteristic of roots and relations between roots and and environment of ephemerals in Xinjiang. Arid Zone Research (in Chinese), 2000, 17(3): 28−34
12 Lapointe L. How phenology influences physiology in deciduous forest spring ephemerals. Physiologia Plantarum, 2001, 113: 151−157
13 Wang X Q, Jiang J, Lei J Q, et al. Relationship between ephemeral plants distribution and soil moisture on longitudinal dune surface in Gurbantunggut Desert. Chinese Journal of Applied Ecology (in Chinese), 2004, 15(4): 556−560
14 Wang X Q, Jiang J, Lei J Q, et al. Distribution of ephemeral plants and their significance in dune stabilization in Gurbantunggut Desert. Journal of Geographical Sciences (in Chinese), 2003, 13(3): 323−330
15 Lancaster N, Paula H. A test of climate index of dune mobility using measurement from south-western United State. Earth Surface Processes and Landforms, 2000, 25(2): 197−207
16 Wang X Q, Wang T, Jiang J, et al. On the sand surface stability in the southern part of Gurbantunggut Desert. Sci China Ser D-Earth Sci, 2005, 48(6): 778−785
17 Nanjing Institute of Pedology, Chinese Academy of Sciences. Soil Physical and Chemical Analysis (in Chinese). Shanghai: Science and Technology Press, 1978. 62−146, 196−233, 466, 481−489
18 Mckee E D. A Study of Global Sand Sea (Translated by Zhao, X. L.). Yinchuan: Ningxia People Press, 1993. 29−32
19 Liette V, Daniel G. Survival and growth of Allium tricoccum AIT. Transplants in different habitats. Biological Conservation, 1994, 68(2): 107−114
20 Steyn H M, Van Rooyen N, Van Rooyen M W, et al. The phenology of Namaqualand ephemeral species: The effect of water stress. Journal of Arid Environments, 1996, 33(1): 49−62
21 Hegazy A K. Reproductive diversity and survival of the potential annual *Diplotaxis harra* (Forssk.) Boiss (Brassicaceae) in Egypt. Ecography, 2001, 24: 403−412