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Responses of Reproduction and Important Value of Dominant Plant Species in Different Plant Functional Type in *Kobresia* Meadow to Temperature Increase[1]

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Abstract—Responses of reproduction and IV (important value) of dominant plant species in different PFT to warming were studied at a *Kobresia* meadow in the Tibetan Autonomous State of Qinghai Province, China (37°29′–37°45′ N, 101°12′–101°33′ E, 3900 m asl) using the temperature gradient method formalized by the ITEX. Responses of *Elymus nutans* and *Poa pratensis* (Gramineous PFT) to increasing temperature were similar. The numbers of tillers, buds and IV increased in the chambers treated with higher temperature compared to the control without treatments (CK). Responses of *Kobresia humilis* and *Carex alrofusca* (Cyperaceae PFT) to increasing temperature were different, that is, the numbers of tillers and IV reached the maximum in different temperature among species, the numbers of buds decreased with the temperature increasing. The number of buds and IV of *Lagotis brachystachya* (Forbs PFT) decreased with the warming, but the number of stolons was initially large, and then decreased with increasing temperature. The number of buds of *Ranunculus brotherusii* (Forbs PFT) increased with the temperature increasing in the first year, but decreased in the second year; and IV decreased with the temperature warming. Under conditions of continued warming in the future, PFT structure will be significantly changed, Cyperaceae PFT dominant plant species original position will be replaced by Gramineae PFT dominant plant species. Cyperaceae plants will become the dominant species, and some species belonging to Forbs PFT will be eliminated from the community.

Keywords: buds, height, PFT, temperature, tiller

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1. INTRODUCTION

According to the fourth appraisal report content of Intergovernmental Panel on Climate Change, global mean temperature will increase by 1.8–4.0°C till the end of this century (IPCC 2007). In the past 100 years, the mean temperature of China has increased by 0.4–0.6°C, and it may increase by 1.7°C till 2030, and 2.2°C till 2050 (Qin 2003). From 1982 to 1999, the average annual temperature increased 0.071°C during the growing season on Qinghai-Tibet Plateau, which was higher than the national average of 0.046°C (Piao et al., 2004). Ice core records show that during both the ancient and modern ages, the temperature changes on Qinghai-Tibet Plateau have been greater than that of the lower altitude areas (Yao et al., 2000). Recent studies show that the grassland vegetation in Qinghai-Tibet Plateau has been activated in biomass production, size formation and reproduction, and the changes are closely related to climate change (especially temperature rise) (Yang and Piao, 2006). Therefore, Qinghai-Tibet Plateau, which is an area sensitive to climate change and an ecologically fragile zone (Sun and Zheng, 1998), is an ideal place to study terrestrial ecosystem responses to climate change.

Studies based on International Tundra Experiment (ITEX) method using OTCs warming manipulation have showed significant changes in various aspects of community characteristics in response to experimental warming (e.g. plant physiology, biomass, growth and reproduction, litter decomposition, physiological performance, species diversity, species composition and dominant species) (Zhao et al., 2009; Walker et al., 2006; Zhou et al., 2000; Julia et al., 2007). In a plant community, the species that controls energy flow and the material cycle effectively and has obvious the most apparent effects on community composition and community environment formation is called the dominant species (Magurran, 1988). Dominant species are those that comprise the greatest proportion of the production and/or resource uptake in local plant communi-

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ties, there by playing an important role in driving community dynamics and regulating ecosystem processes (Hooper and Vitousek, 1997; Hooper, 1998; Hector et al., 1999; Wardle et al., 1999; Chapin et al., 2000; Grime, 2001; Dangles and Malmqvist, 2004; Hooper et al., 2005). When dominant species alter the structure of the subdominant community and affect ecosystem processes, they may also influence community invisibility (Bazzaz, 1996; Meiners et al., 2002). For instance, there is some evidence that dominant plant species can hinder plant invasions in grasslands and old-field communities via resource competition for limiting nutrients and/or space (Dukes, 2002; Smith et al., 2004; Emery and Gross, 2006; 2007). Of course, not all dominant species are equal and have equivalent effects on the rest of the community. That is, dominant species identity affects community structure and invasibility in a variety of ways. For example, Emery and Gross (2006) found that the effect of dominant species on invasibility varied among dominant species, with some dominant species having positive effects on the establishment by exotic species and others having negative effects. Each different layer of community has own dominant species, and the dominant species in dominant layer is edificatory (Sun et al., 1993).

Investigations to clarify the function, adaptation and response of plants to environmental changes, and the mechanisms to maintain stability of vegetation, has become the one of main focus from the viewpoint of the plant functional group (Sun et al., 2007; Oechel et al., 1994; Oechel et al., 1997; Oechel et al., 1998). Studies on the relationships between PFT (plant functional type) and the environment at local, regional and global scales, as well as along specific gradients such as climate, disturbance, and land use, have recently been emphasized (Aguiar et al., 1996; Box, 1996; Diaz and Cabido, 1997; Smith et al., 1997; Pyankov et al., 2000). However, these earlier studies have not discussed the intrerspecific competition and replacement of dominant plant species between PFTs, and have not explained the reproduction of dominant plant species response to environmental gradients and its role in ecological processes. In this study, we discussed the responses of reproduction and important value of dominant plant species in different PFTs in Kobresia meadow to temperature increase by gradients in temperature in order to help us understand how plants respond to the environment and furthermore global climate changes.

2. SITE DISCRETION

The site selected was located in Dawu town, Maqen County, in the Tibetan Autonomous State of Qinghai Province (37°29′–37°45′ N, 101°12′–101°33′ E, 3900 m asl.). The cold season lasts for 7, 8 months, and is dry and cold, while the warm season for 4, 5 months, and is wet and cool with an average temperature below 0°C. Each calendar year, the average hours of sunshine is greater than 2500 h, with a total radiation of 623.8–629.9 kj m^{-2}. A detailed site description can be found in document (Liu et al., 2005).

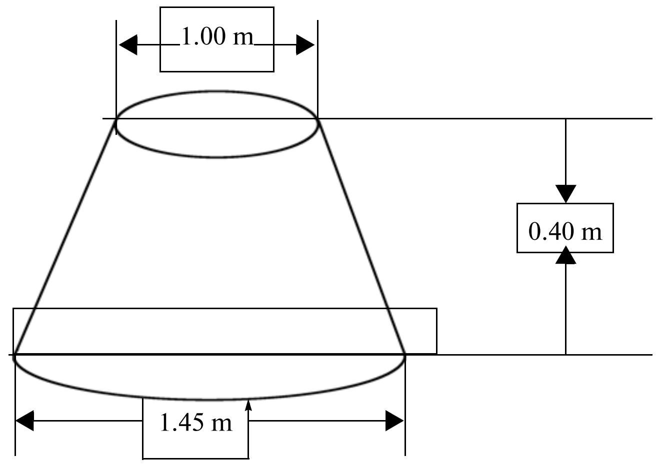

Fig. 1. Sketch of the OTCs in treatment C.

3. MATERIAL AND METHOD

3.1. PFT (Plant Function Types)

According to plant life and economic groups, the plants in this area are divided into three kinds of PFTs (Sun, 2000). Cyperaceae PFT includes Kobresia, *Carex alrofusca*, *Kobresia pygmaea*, *Scirpus distig.* Gramineous PFT includes *Elymus nutans*, *Poa pratensis*, *Stipa aliena*, *Lagotis brachystachya*, *Ranunculus brotherusii*, *Leontopodium* Forbs PFT includes *Lagotis brachystachya*, *Ranunculus brotherusii*, *Leontopodium nanum*, *Ajania tenuifolia*, *Lancea tibetica*, *Saussurea superba.*

3.2. Experimental Design

We established an experiment site in a typical *Kobresia* meadow degenerated slightly, on the plots placed the conical OTCs made by transparent plastics (Fig. 1), which is an ideal method to simulate temperature changing (Ren et al., 2010). The plot was fenced to exclude grazing animals. We randomized block designed five treatments by gradient based on the OTCs size, and each treatment included four replications. The treatments were labeled as A, B, C, D and E according to the OTC's size from small to big ones. The bottom diameters of OTCs were 0.85, 1.15, 1.45, 1.75 and 2.05 m, and the top diameters were 0.40, 0.70, 1.00, 1.30, 1.60 m. The height of all OTCs was 0.4 m. To examine how well the OTCs simulated the effect of climate warming, we set a control check site (CK) outside each OTC in each experimental plot.

Commonly abundance and coverage of the edificatory is over 80% (Wang et al., 1996). We selected six different species that could represent the different PFTs dominant plant species for the five kinds of treatment and the CK, which abundance and coverage is

Table 1. Yearly changes of variations in ground surface temperature between treatments

Treatments	Surface temperature, °C				Subsurfase temperature, °C			
	2004	2005	2006	average	2004	2005	2006	average
A	108	11.7	13.2	11.9	11.2	11.4	12.4	11.7
B	9.6	10.7	12.6	11.0	10.4	10.8	11.8	11.0
C	9.4	10.2	12.2	10.6	10.2	10.5	11.4	10.7
D	9.1	10.2	11.8	10.4	10.0	10.3	11.2	10.5
E	8.9	9.7	11.4	10.0	9.7	10.0	10.8	10.2
CK	8.7	9.3	11.1	9.7	9.3	9.6	10.4	9.8

A, bottom diameter was 0.85 m, top diameter was 0.40 m; B, bottom diameter was 1.15 m, top diameter was 0.70 m; C, bottom diameter was 1.45 m, top diameter was 1.00 m; D, bottom diameter was 1.75 m, top diameter was 1.30 m; E, bottom diameter was 2.05 m, top diameter was 1.60 m. The height was 0.4 m for all cases. CK, set outside OTCs in the plot.

over 80%. They are *Kobresia humilis* and *Carex alrofusca* (Cyperaceae PFT), *Elymus nutans* and *Poa pratensis* (Gramineae PFT), *Lagotis brachystachya* and *Ranunculus brotherusii* (Forb PFT). Five individuals of each species were designated in each replication, and twenty individuals of each species were designated in a treatment and CK. The following characteristics regarding plant reproduction were recorded during the growing period (May to September): the numbers of tillers and buds for Cyperaceae and Gramineae plants, the number of buds and stolons for *Lagotis brachystachya*, and the number of buds for *Ranunculus brotherusitiali*.

Community survey was done in late August each year, there were six survey quadrats (25 × 25 cm) in each treatment and CK. Observed items included the height, coverage and avoveground biomass. Then the important value was calculated. Choice the species that found in each treatment and CK during first experimental year were discussed. The selected species in different PFT included as following. Cyperaceae PFT: *Kobresia humilis*, *Carex alrofusca*, *Scirpus distigmaticus*; Gramineae PFT: *Elymus nutans*, *Poa pratensis*, *Ptilagrostis concinna*; Forb PFT: *Lagotis brachystachya*, *Ranunculus brotherusii*, *Potentilla anserine*, *Leontopodium pusillum*, *Swertia franchetiana*, *Lancea tibetica*, *Parnassia trinervis*, *Glaux maritime*, *Veronica eriogyne*, *Oxytropis kansuensis*.

Ground surface temperature (at 10 cm above ground) and subsurface temperature (at 10 cm depth under ground surface) were recorded by HOBO–H8 4–channel temperature data logger every two hours from May to September. The average daily temperature was used to statistical analysis. Temperature increased from CK to A (Table 1), and detailed analysis can be found in another paper Zhao (2006).

3.3. Data Analysis

The variance of tillers is the difference between the maximum in August and the minimum in May.

Important value was calculated the following equation (Kuramato and Bliss, 1970):

$$IV = (RH + RC + RB)/3$$

IV: import value; RH: relative height; RC: relative coverage; RB: relative biomass. All data were analyzed by Excel (2003), SPSS (18.0) software.

4. RESULTS

4.1. Important Value Variation

Total IV variation of Cyperaceae PFT was not clear among treatments through experimental years; however, the IV was initially large, and then decreased with increasing temperature, where the minimum was in the OTC-A, and the maximum in the OTC-E in 2005, 2006 (Fig. 2). The IV of *C. alrofusca* in OTC-E and CK were higher than other treatments in 2004, 2005, and the tendency of IV for *C. alrofusca* was same as the result of Total IV in 2005, 2006, but the maximum was in the OTC-D in 2006 (Fig. 2). The tendency of IV for *K. humilis* was same as the result of Total IV in 2005, 2006 (Fig. 2).

Total IV variation of Gramineae PFT was vear clear among treatments and experimental years. It increased with increasing temperature, where the minimum was in the CK, and the maximum in the OTC-A through the three years of experiment, and increased gradually each year (Fig. 3). It increased very large in 2006 compared with 2004 (Fig. 3). The tendency of IV for *E. nutans* and *P. pratensis* was same as the result of Total IV that increased with increasing temperature (Fig. 3). The tendency of IV for *P. concinna* was same as the result of Total IV in 2006, and it was not clear among treatments in 2004, 2005.

The IV variation of Forb PFT species was very clear, some species disappeared during experiment (Fig. 4). *S. franchetiana* disappeared in 2005, *R. brotherusii* disappeared in 2006, *L. pusillum* disappeared in 2006 except in the CK (Fig. 4). The IV of *L. brachystachya* was initially large, and then decreased with increasing temperature, where the minimum was in the OTC-A, and the maximum in the OTC-E in 2004, 2005; and it increased with increasing temperature in

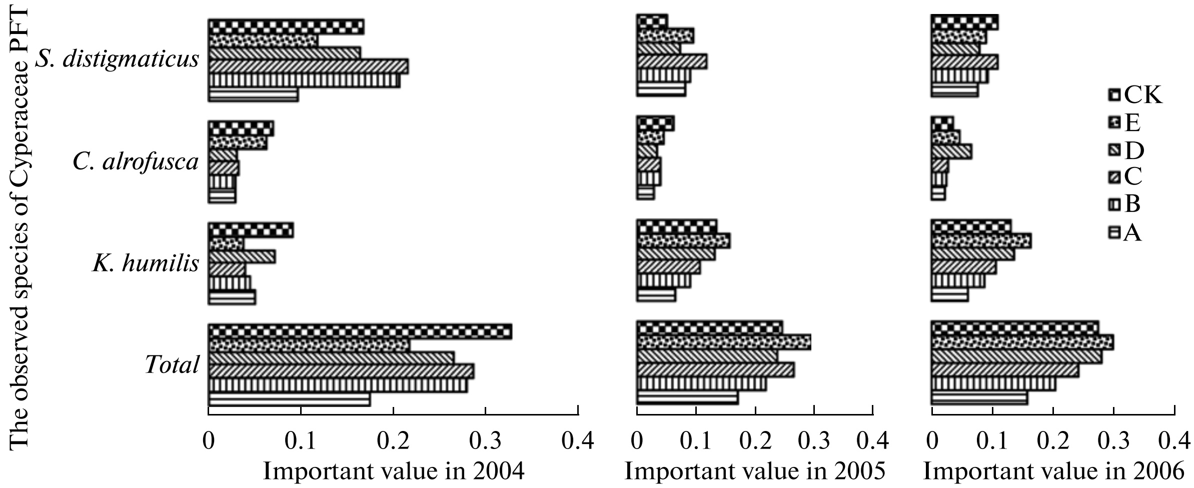

Fig. 2. Important value of Cyperaceae PFT species for different treatments through three years.

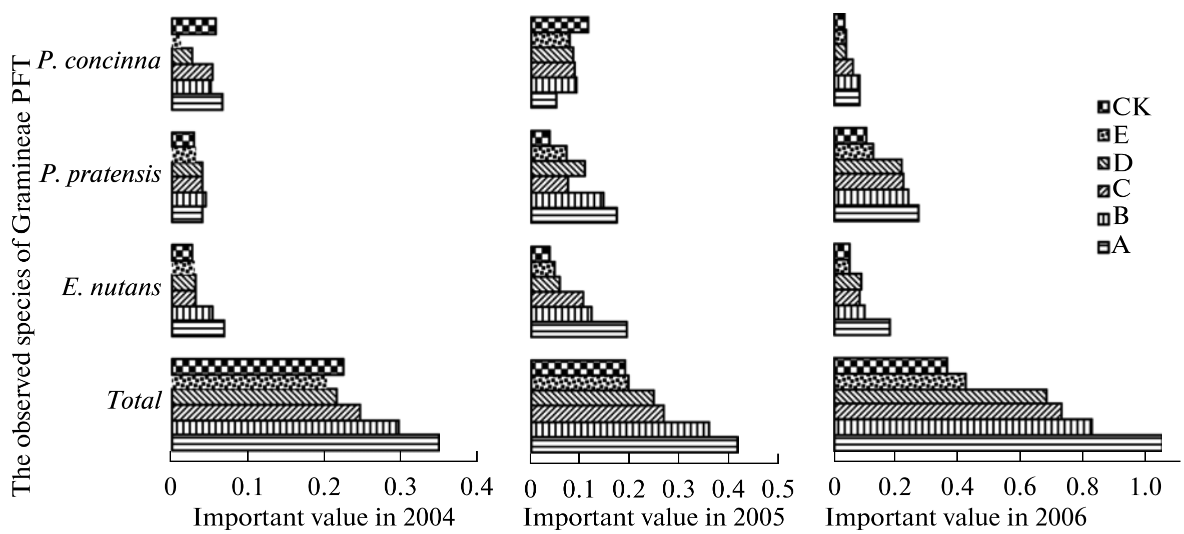

Fig. 3. Important value of Gramineae PFT species for different treatments through three years.

2006, where the minimum was in the OTC-A, and the maximum in the CK (Fig. 4). The tendency of total IV of Forb PFT was same as the result of *L. brachystachya*, and it decreased with experimental years (Fig. 4).

4.2. Tiller Variation

Difference in the numbers of tillers of *K. humilis* among treatments was initially large, and then decreased with increasing temperature, where the minimum was in the OTC-A, and the maximum in the OTC-E through the three years (Fig. 5). There were significant differences between the OTC-E and the OTC-A through the experiment time (Fig. 5). The tendency in the numbers of tillers for *C. alrofusca* was same as the result for *K. humilis*, but the maximum was in the OTC-D (Fig. 5). There were significant differences between the OTC-D and the OTC-A through the experiment time (Fig. 5).

Differences in the numbers of tillers in *E. nutans* and *P. pratensis* among treatments increased with increasing temperature, where the minimum was in the CK, and the maximum in the OTC-A through the three years of experiment (Fig. 5). There were significant differences between the OTC-A and the CK through the experiment time (Fig. 5).

4.3. Bud Variation

The numbers of buds of *K. humilis* among treatments was initially large, and then decreased with increasing temperature, where the minimum was in the OTC-A, and the maximum in the OTC-E in 2004, 2005, but the numbers were decreased with increasing

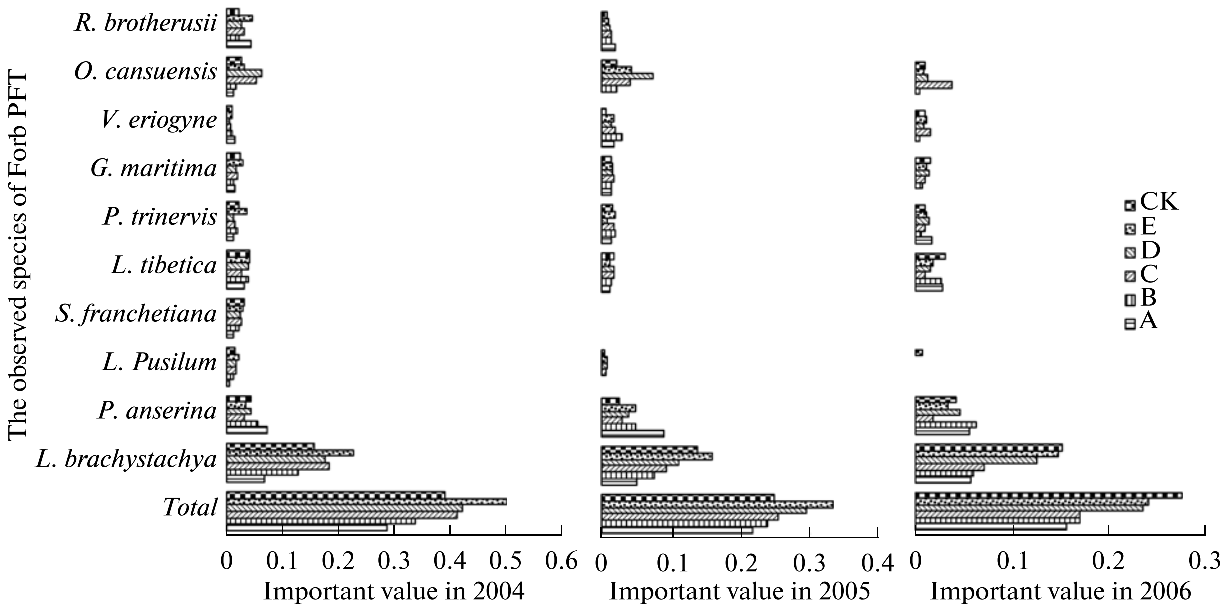

Fig. 4. Important value of Forb PFT species for different treatments through three years.

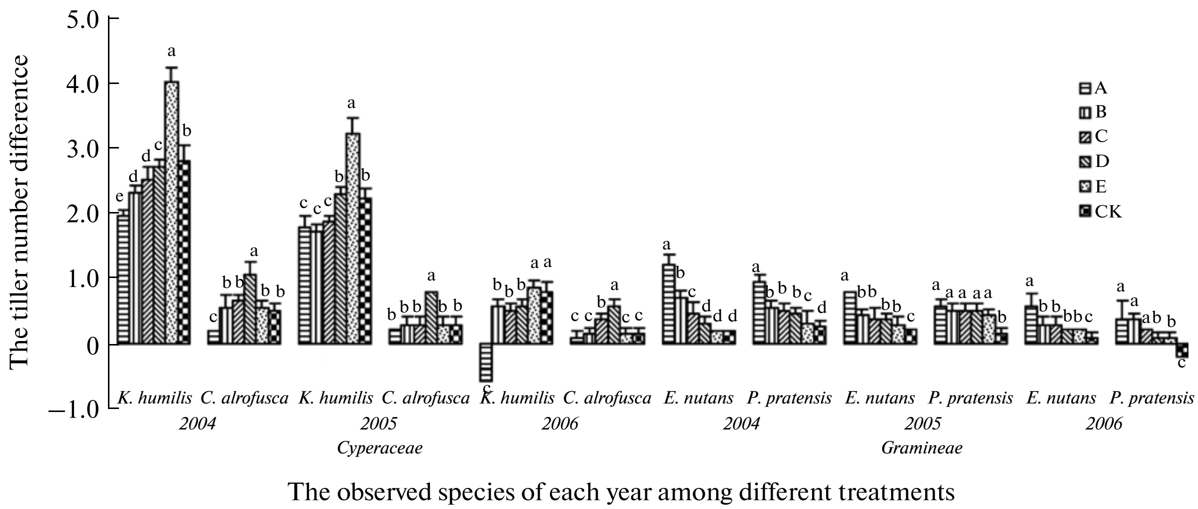

Fig. 5. The number of tillers of Cyperaceae and Gramineae for different treatments through three years.

temperature in 2006, where the minimum was in the OTC-A, and the maximum in the CK (Fig. 6). There were significant differences between the OTC-A and CK in 2006 (Fig. 6). The tendency in the numbers of buds for *C. alrofusca* was same as the result for *K. humilis*, and there were not significant differences among the treatments through the experiment time (Fig. 6).

The numbers of buds in *E. nutans* and *P. pratensis* among treatments increased with increasing temperature, where the minimum was in the CK, and the maximum in the OTC-A through the three years of experiment (Fig. 6). The numbers of buds in *E. nutans* was significant differences between the OTC-A and the CK in 2004, the numbers of buds in *P. pratensis* were not significant among the treatments (Fig. 6).

The number of buds of *L. brachystachya* decreased with temperature increasing in 2004, 2005, and there were significant between the OTC-A and the CK (Table 2). The number of buds of *R. brotherusii* increased with temperature increasing in the first year of the experiment, but it decreased with the temperature increasing in the second year (Table 2). The number of buds was obviously higher in 2004 than in 2005 (Table 2). *R. brotherusii* was almost disappeared in 2006.

4.4. Stolon Variation

The number of stolons of *L. brachystachya* was initially large, and then decreased with increasing temperature, where the minimum was in the OTC-A, and

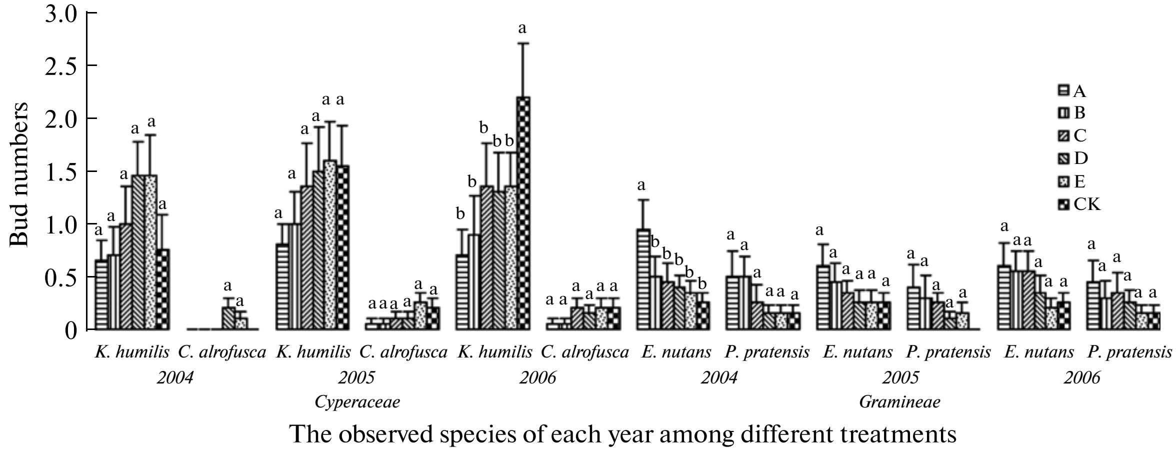

Fig. 6. Bud number of Cyperaceae and Gramineae for different treatments through three years.

the maximum in the OTC-C in 2004 and 2005 (Table 2). The number of stolons of *L. brachystachya* in 2004 was more than that in 2005 (Table 2), it was disappeared almost in the third years of experiment.

5. DISCUSSION

5.1. Variation of Cyperaceae PFT

Plants of the Cyperaceae PFT groups are mostly reproduced with clone (Li et al., 2001; Yang et al., 2004). Previous studies suggest that when resource and environmental conditions such as water and temperature are limited, the plants strongly rely on clonal reproduction but not on the process of sexual reproduction (Philbrick and Les, 1996; Sculthorpe, 1967). Our results also showed that only a small increase in temperature is favorable but a large increase is unfavorable to clonal reproduction of Cyperaceae PFT such as *K. humilis,* and *C. alrofusca*. The variation of IV was same as the tiller's, the variation of buds were same as the tiller's in 2004, 2005, but they decreased with temperature increasing in 2006. It suggests that a small increase in warming favorable to Cyperaceae PFT, but a long-term, large increase in warming causes a disadvantage to them.

5.2. Variation of Gramineae PFT

The reproduction of species belong to Gramineae PFT main rely on sexual reproduction, while they also rely on clonal reproduction. The number of tillers, buds and IV of Gramineae PFT increased with temperature increasing (Figs. 2–4), so warming was favorable to their growth and reproduction. This is because the plants of the Gramineae PFT are able to allocate resource not only through the large leaf size, but by their distribution through different height (Campbell et al., 1995). Therefore, under the warmer condition they can exhibit a great photosynthetic ability through tillering and reproduction (Campbell et al., 1995), their position in community will be increase.

5.3. Variation of Forb PFT

The reproduction of *L. brachystachya* rely on stolons (clonal reproduction) and buds (sexual reproduction). In our study, the sexal reproductive ability of

Table 2. Yearly bud and stolon number's (± standard error) change of *L. brachystachea*, and bud number's (± standard error) change of *R. brotherusii* in different treatments

Treatments	*L. brachystachya*				*R. brotherusii*	
	bud number		stolon number		bud number	
	2004	2005	2004	2005	2004	2005
A	0.55b ± 0.15	0.30b ± 0.11	0.25a ± 0.12	0.15a ± 0.08	4.15a ± 0.77	0.30a ± 0.13
B	0.80a ± 0.21	0.45a ± 0.15	0.35a ± 0.11	0.25a ± 0.10	3.30a ± 0.70	0.40a ± 0.15
C	0.95a ± 0.25	0.75a ± 0.23	0.70a ± 0.23	0.30a ± 0.13	2.40a ± 0.35	0.60a ± 0.15
D	0.95a ± 0.22	0.85a ± 0.22	0.50a ± 0.14	0.30a ± 0.11	1.95b ± 0.33	0.55a ± 0.22
E	1.20a ± 0.25	1.05a ± 0.23	0.50a ± 0.11	0.25a ± 0.14	1.90b ± 0.28	0.70a ± 0.18
CK	1.55a ± 0.25	1.25a ± 0.24	0.45a ± 0.14	0.20a ± 0.12	1.65b ± 0.29	0.75a ± 0.14

forbs PFT decreased with temperature increasing, but its sexual reproduction was initially large, and then decreased with increasing temperature (Table 6), indicating that continue warming is not favorable to their reproduction. The result was similar to the findings by Shi et al. (2008) in Sichuan, Zhang (2000) in Qinghai, and Harte and Shaw (1995) in Rocky Mountains. IV of *L. brachystachya* was initially large, and then decreased with increasing temperature in 2004, 2005, but it decreased with temperature warming in 2006 (Fig. 4). It was showed that continue warming is not favorable to their reproduction and its position in community will be decrease.

Reekie et al. (1998) showed that soil warming accelerated a vegetative growth and caused a decrease in the number of roots and root accumulation, leading to a gradual decrease in the availability of resources to the aboveground parts of plants from the roots, eventually leading to increased mortality of plant roots. Reekie et al. (1998) believe that reproductive allocation to root decreases with body size increase. Shi et al. (2008) found that within OTC the proportion of underground biomass from increased in depth of 0–10 cm, and decreased in depth of 20–30 cm, and the result showed that resource obtained by plant root will be decrease. The number of buds of forb PFT increased with warming from CK to OTC-A in 2004, but they decreased in 2005 (Table 3). Especially IV of R. brotherusii decreased with year and completely disappeared in 2006 (Fig. 4). These results provided evidence that under the condition of warming and limited resources, the forbs PFT the reproductive ability was reduced.

CONCLUSION

Alward et al. (1999) and Pauli et al. (2001) showed that, under the condition of global warming, there are always individuals from some plant species that have a more sensitive to temperature increase than others, which in turn breaks the original competitive relationship among species and the composition changes the dominant species. Cyperaceae PFT will be replaced by Gramineae PFT and Gramineae becomes the dominant species (Figs. 2 and 3), and some species of the forbs PFT will be eliminated (Table 6) in this area with the global warming.

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