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Intra-specific variations of two *Leymus chinensis* divergence populations in Songnen Plain, Northeast China

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Abstract: Population demography, seed production, biomass allocation, net photosynthesis and transpiration of two *Leymus chinensis* divergent populations and between two years in Songnen plain, northeast China were compared. Strong differences between the dry 1997 and moist 1998 occurred in vegetative shoot and sexual shoot densities, sexual differentiation and tiller densities, as well as in the lengths of inflorescence, seed numbers per inflorescence, seed weights and biomass allocation in each population respectively ($P < 0.01$). While strong differences between the two populations occurred in vegetative shoot densities, sexual shoot densities, sexual differentiation and seed weights in each year ($P < 0.01$). The differences between the two populations in tiller densities and in biomass allocation to sexual shoots were significant ($P < 0.05$). But there were no significant differences between the two populations in the lengths of inflorescence, seed numbers per inflorescence and biomass allocation to rhizomes and vegetative shoots ($P > 0.05$). Excepting the transpiration rate in the early June, the differences between the two populations in net photosynthesis and transpiration rate of vegetative shoots and sexual shoots were strongly significant in the early June and July respectively ($P < 0.01$). Relative stable variations in population demography and physiological traits between the two populations indicated that they are divergently in the Songnen Plain.

Keywords: population demography; seed productions; biomass allocation; net photosynthetic rate; transpiration rate; *Leymus chinensis* populations; Songnen Plain

Introduction

The intra- and inter-specific variations of plant populations have been well documented for many plant populations (Bassow, 1997; Callaway, 1994; Delph, 1993; Ford, 1981; Jones, 1999; Monson, 1989; Pavone, 1985; Vavre, 1997). However, most of the studies focused on inter-specific variations in males, females, apomicts and ramet mortality between different sites (Ford, 1981; Jones, 1999; Monson, 1989), seed or fruit production (Delph, 1993; Wang, 1997), biomass allocation to offspring production, seedling survivorship or to sapwood and leaf (Harper, 1970; Michaels, 1986; Newell, 1978; Rozijn, 1986; Wang, 1999), as well as on photosynthesis and transpiration between habitats or month (Bassow, 1997; Jiang, 1999; Monson, 1989). None has systematically tested the annual and intra-specific variations in population demography, seed production, biomass allocation, photosynthesis and transpiration of grassland herbage.

The Songnen Plain lies in the central part of northeastern China (43°30′ to 48°40′N; 121°30′ to 127°00′E), about 40% of which are *Leymus chinensis* (Trin.) Tzvel. grasslands (Newell, 1978; Pavone, 1985). The grasslands mainly dominated by this species are widely distributed at the Songnen Plain and the eastern part of the Inner Mongolian Plateau (Xiao, 1995; Li, 1983; Wang, 1997). The high palatability of the species and the herbage production superior both in quality and in quantity make the grasslands ideal for animal husbandry in northeastern China (Wang, 1997). There are two main types of *Leymus chinensis* populations distributed in the plain and their morphological differences can be found in Jia (Jia, 1989). Although there are many reports on reproduction *of Leymus chinensis*, and a few on morphological differences and the population age of the two populations distributed in the plain (Xiao, 1995), but study on the differences of population densities, seed productions, biomass allocations and ecophysiological traits between the two populations are few. The objectives of this study were: (1) to study

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the responses of each population to the annual climate change, and (2) to compare the differences of two populations in population densities, seed productions, biomass allocations and ecophysiological traits in the dry 1997 and moist 1998. This may provide ecological basis of the type distinction in *Leymus chinensis* populations in Songnen Plain.

1 Materials and methods

1.1 Study sites

The study area are large expanse of native *Leymus chinensis* grasslands and dunes surrounded the grasslands, located between latitude 44°41′ and 44°44′N, and longitude 123°44′ and 123°47′E, near the Grassland Ecology Field Station of Northeast Normal University, on the Changling Horse Breeding Farm, Jilin Province, China. Large expanses of *L. chinensis* grasslands are often broken by dunes which rise as high as 26m above the average grassland elevation of 141m a.s.l. Although the dunes in the plain have been strongly disturbed by both cultivation and forestry management, there are still many grey-green *L. chinensis* patches and a few yellow-green *L. chinensis* patches distributed on the tops of the dunes. Most area of dunes has a sandy chernozem with relative low soil pH. The differences of soil environments were not significant between the two sites (Table 1). Because of the disturbances of farming and foresting management, *L. chinensis* patches are putting back in the plain.

1.2 Climate

Table 1 The topographical, soil characteristics, and climate for the sites used for study in Songnen Plain, northeastern China 1997 and 1998

Site precipitation, mm	Year	Elevation, m a.s.l.	Soil moisture, %	Soil organic, %	Soil pH matter, %
Grey-green 345.18	1997	≈167	2.66 ± 0.48	1.19 ± 0.04	7.80 ± 0.08
L. chinensis 491.5	1998		8.11 ± 0.36	-	7.36 ± 0.14
Yellow-green 345.18	1997	≈165	3.12 ± 0.51	2.03 ± 0.07	7.45 ± 0.08
L. chinensis 491.5	1998		9.48 ± 0.23	-	7.33 ± 0.13

Note: a.s.l. = above sea level.

The area has a continental climate, with large seasonal temperature and precipitation changes. Mean annual air temperature is about 5℃, with monthly changes ranging from -18℃ in January to 23℃ in July. Annual precipitation ranges from 300 to 600 mm, with uneven distributed in the growing season. The main characteristics of the climate of the region are: a cold, dry, frequent windy spring; a warm, wet summer, with clear droughts; early autumn frosts; and a long cold winter with relatively little snowfall. More detailed descriptions of the climate of the area were reported by Ripley *et al*. (Ripley, 1996) and Domros and Peng (Domros, 1988). The precipitation in 1997 was 345.18 mm, 75.86% of which total falls in August, but that in 1998 was 491.5 mm and distributed much evenly (Fig.1). There was clear serious drought periods before August in 1997.

1.3 Field methods

The experiment consisted of two sites on the tops of dunes, one was dominated by grey-green *L. chinensis* (GL) and the other by yellow-green *L. chinensis* (YL). More than 0.5 hm^2 area in each site was selected as sample plot. The two sites were about 2 km apart and had the same soil type, with *L. chinensis* distributed evenly. Plants were sampled using 8 randomly located (0.25×0.25) m^2 quadrats, then removed the around soil of each quadrate and cut them in monoliths $((0.25 \times 0.25 \times 0.3)\ m^3)$. Monoliths were taken to laboratory and washed with water using flotation. The plants of other species were removed. Numbers of vegetative shoots, sexual shoots and tillers of *L. chinensis* in each quadrate were

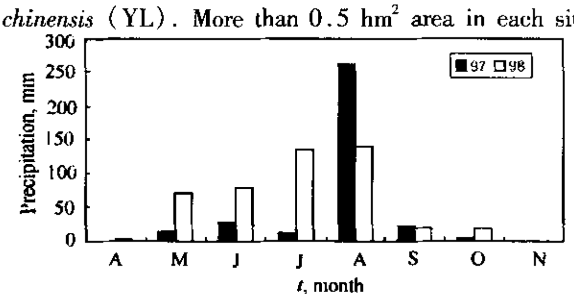

Fig. 1 The comparison of precipitation between the two successive years in the study sites on the Songnen Plain, northeast China

recorded simultaneously. Vegetative and sexual shoots and rhizomes were separated and placed in perforated paper bags, oven dried at 80℃ to constant weight before weighting. Samples were taken on May 19, June 3, June 21, July 20, August 23 and October 3 respectively.

Inflorescences were sampled in the middle July using 50 – 100 randomly inflorescence in each site. Lengths of inflorescence, seed numbers per inflorescence were recorded. Seed samples were placed in perforated paper bags and oven-dried at 80℃ to constant weight and weighed.

Net photosynthetic rate and transpiration rate of the two populations were taken in the early June (the dry season) and early July (the rainy season) in 1998. Only in clear days, were the measurements taken simultaneously every hour from 6 am to 18 pm, by using a CID – 301PS photosynthesis system (CID Scientific Instrument Company, U.S.A.). All the measurements were begun from the second leaf (the lowest one) to the top one, with two repetition in each hour. Instrument was calibrated against a CO_2 standard of 390 μmol/mol each mouth before the field measurements.

1.4 Data analysis

All data of the shoot numbers, seed productions and biomass allocation percentages from each type were averaged respectively by using MINTAB. The variances of two types were analyzed using analysis variance (MINITAB). Sexual differentiation (rate between sexual shoot density and total shoot density) were calculated by Excel program.

2 Results

2.1 Population demography

Because of the differences of precipitation in the two successive years, the annual variations of plant populations were considerable in each population. Vegetative shoot densities, sexual shoot densities and sexual differentiation in 1998 were significantly greater than those in 1997 in GL ($P < 0.05$) and in YL ($P < 0.001$) respectively. Tiller densities in 1998 were also strongly greater than that in 1997 in both populations ($P < 0.01$). The average vegetative shoot density and tiller density in 1998 increased 19.27% and 129.14% in GL, and those in YL increased 59.75% and 209.94%, compared to those in 1997 (Fig.2). While average sexual shoot density and sexual differentiation in moist 1998 increased 80.74% and 66.38% in GL, and as great as 474.53% and 191.21% in YL, compared with dry 1997. This indicated that higher precipitation is favorable for both clone growth and reproduction in each population in the Songnen Plain.

Intra-specific variations of what between the two populations were also remarkable in each of the two years. Differences between the two populations were significantly in vegetative shoot densities ($P < 0.001$) and in tiller densities ($P < 0.05$) no matter whether in the dry 1997 or in the moist 1998. In GL, average vegetative shoot densities were 35.82% and 1.41% greater, and average tiller densities were 70.51% and 26.06% greater respectively. Sexual shoot densities and sexual differentiation in GL were also significantly greater than YL ($P < 0.001$) in the two successive years. In GL, average sexual shoot densities were 362.5% and 45.50% greater, and average sexual differentiation were

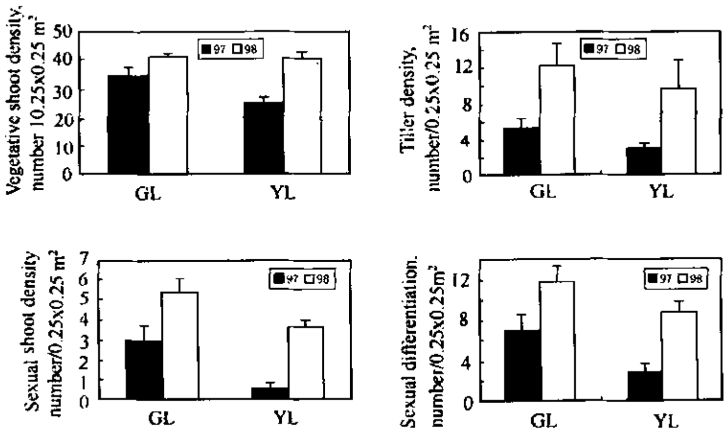

Fig.2 The comparisons of the population demography of the two *Leymus chinensis* populations on the Songnen Plain, northeast China (GL = grey-green type; YL = yellow-green type, the same below)

133.83% and 33.62% greater respectively.

2.2 Seed production

The differences of seed production between the two years were significant in each population. The inflorescence lengths of the species were variable in the two successive years, ranged from 4.5 cm to 13.3 cm in GL and 4.1 cm to 16.0 cm in YL. Inflorescence lengths between the two years were significant different ($P < 0.001$) in each population, with the average values 12.27% greater in GL and 15.82% greater in YL in 1998, compared with those in 1997 (Fig.3). Seed numbers per inflorescence between the dry 1997 and the moist 1998 also varied considerably ($P < 0.001$) in each population. Compared with those in 1997, the average values in 1998 reduced by 29.3% in GL, but a little increase (8.75%) in YL (Fig.3). Seed weights in moist 1998 were strongly greater than that in dry 1997 ($P < 0.001$) in each population, and the average seed weight per thousand seeds in 1998 were 40.95% and 40.82% greater than those in 1997 in GL and YL respectively (Fig.3). The variations of seed productions between two years with different precipitation indicated that the seed productions were strongly response to precipitation changes in the semi-arid Songnen Plain, northeastern China.

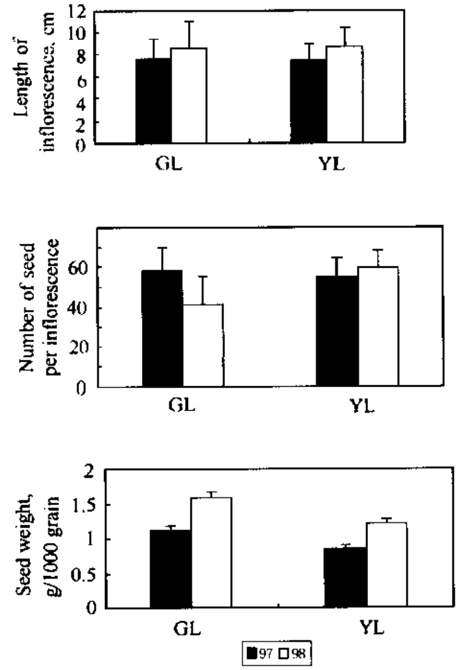

Fig.3 Variations of seed production between the two *Leymus chinensis* populations on the Songnen Plain, northeast China (GL = grey-green type; YL = yellow-green type)

Inflorescence lengths between the two populations were not significant different ($P > 0.05$) in both the dry 1997 and moist 1998. There was also no remarkable differences between the two populations in seed numbers per inflorescence ($P > 0.05$). However, seed weight between the two populations was strong different in the two successive years ($P < 0.001$), with average seed weights 28.41% and 28.62% greater in GL in the two successive years.

2.3 Biomass allocation

Biomass allocation varied both between the two populations and two successive years. Biomass allocation to rhizome between the two successive years were considerably different in each population ($P < 0.001$). Compared with that in 1998, the average proportions to rhizome in 1997 were 14.37% and 35.04% greater in GL and YL (Fig.4). Proportions of biomass allocation to vegetative shoots in the successive two years were remarkably different in each population ($P < 0.001$), with the average proportion to vegetative shoots 4.88% and 12.92% bigger in 1998, in GL and YL respectively. Proportions to sexual shoots were significantly different in GL and YL ($P < 0.01$). Average proportion to sexual shoots in 1998 was about 57.89% higher than that in 1997 in GL and about 423.27% higher in YL.

There were no significantly differences in biomass allocation to rhizome between the two populations ($P > 0.05$). Average proportions to rhizome in the YL were 9.88% greater in 1997 and 7.46% less in 1998. Differences in biomass allocation to vegetative shoots were also not considerable in two years ($P > 0.05$), and the average proportions to vegetative shoots in the YL were 2.53% and 9.84% greater in 1997 and 1998. However, biomass allocation to sexual shoots were remarkably different ($P < 0.05$) in 1997 and 1998, with average proportions to sexual shoots 307.55% and 22.97% higher in the GL in 1997 and 1998 respectively.

2.4 Photosynthetic rate and transpiration rate

Both net photosynthetic and transpiration rates in the early June were strongly greater than those in the early July in each population ($P < 0.01$). Compared with that in the early June, the average transpiration rates of vegetative shoots in the early July reduced by 66.09% and 64.46% in GL and YL, while those of sexual shoots by 19.76% and 52.35%, respectively (Fig. 5). The net photosynthetic rates of vegetative shoots in the early July dropped by 63.11% and 45.5% in GL and YL, and those of sexual shoots dropped by 67.79% and 64.62%, compared with those in the early June. In general, the seasonal differences of net photosynthetic and transpiration rates in each population were related with the leaf age. The older the leaf age, the less the net photosynthetic and transpiration rates.

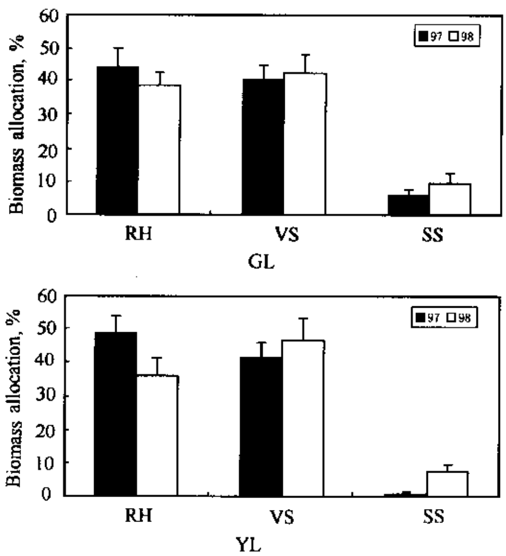

Fig.4 Comparisons of biomass allocations to vegetative shoot, sexual shoot and rhizome of the two *Leymus chinensis* populations on the Songnen Plain, northeast China (VS = vegetative shoot, SS = sexual shoot, RH = rhizome)

Net photosynthetic and transpiration rates between the two populations were remarkably different in both vegetative shoots and sexual shoots ($P < 0.01$). Only in the early June was the average net photosynthetic rate of the sexual shoot in GL 20.75% lower than that in YL. The average net photosynthetic rates of vegetative shoot in GL were about 17.47% and 12.10% greater in the early June and July respectively (Fig.5), and that of sexual shoot was 33.45% higher in the early July, compared with that in the YL. The average transpiration rate of vegetative shoots in GL was 13.10% greater than that in YL in the early June, but about 23.45% lower in the early July. The average transpiration rates of sexual shoots in GL were 25.52% and 32.21% lower in the early June and July, compared with that in YL.

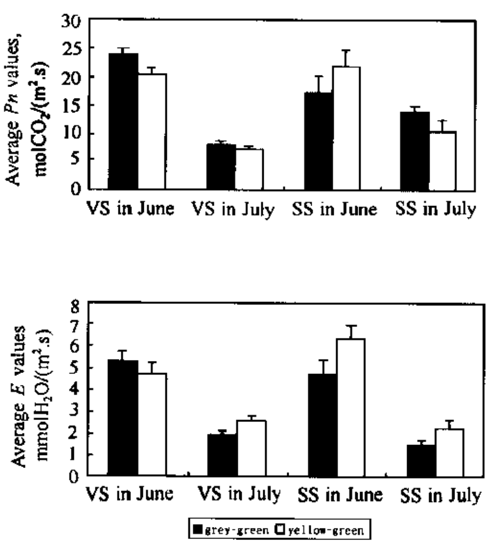

Fig.5 Variations of average net photosynthetic (Pn) and transpiration (E) rates between the two *Leymus chinensis* populations on the Songnen Plain, northeastern China (VS = vegetative shoot; SS = sexual shoot)

3 Discussion

3.1 Annual variations in each type

Plant populations and seed productions in *L. chinensis* populations were consistent with the different grassland utilization (Wang, 1997) and environmental changes, especially annual precipitation and soil moisture in growing season. The differences of annual precipitation and soil moisture in the two successive years were described above. Less precipitation and dry soil environments may reduce tiller production in *L. chinensis*. Less tiller production may reduce vegetative shoots and sexual shoot densities. This was supported by the findings of the strong variations in the vegetative shoot densities, sexual shoot densities and the sexual differentiation in each population in this study (Fig.2). The results of this study indicated that the variations of *L. chinensis* populations did respond to the changes of precipitation in the Songnen Plain. In the moist year, the higher precipitation may increase the soil moisture and make the soil environments more suitable for the tiller development, resulting in increasing of the population shoot densities (Wang, 1997).

Seed productions in *L. chinensis* populations related with annual precipitation and soil moisture in growing season. Relative greater inflorescence lengths and seed numbers per inflorescence in moist year than those in the dry year indicated that the response of seed productions to climate changes had occurred in *L. chinensis* populations (Fig. 3). In the dry year, more biomass was allocated to rhizome and vegetative part, and less to reproduction (Wang, 1999), which indicated that reproduction would be baffled in *L. chinensis* populations. Less biomass allocation to reproduction may reduce the material supply for the inflorescence development and seed bearing in the dry years. However, the relative more material supply to reproductions in the moist year is favorable for the sexual shoot growth and seed production (Wang, 1999). Relative greater biomass allocation to rhizome in the dry year indicated the species tend to allocate some more biomass to its rhizome in the dry environments. This function may help the plants in the dry environments to storage more materials for the growth and reproduction in the next growing season (Callaway, 1994; Michaels, 1986; Wang, 1999). Biomass allocations to vegetative shoots were not varied much between the successive years in *L. chinensis* populations (Fig.4). The relatively constant biomass allocation to vegetative shoot may help the species to get more sufficient carbohydrates by photosynthesis in any change environments (Wang, 1999). The strongly variations of biomass allocation to sexual shoots indicated that the sexual shoot response to the changes of annual precipitation. A lower biomass allocation to the reproduction in the dry environments is to the survival advantages of the species.

3.2 Intra-specific variations between the two populations

Differences between the two populations were not only in morphology, such as leaf color, stoma numbers (Jia, 1989), but also in ecology, for instance in plant population, seed productions and biomass allocation. Significantly greater in vegetative shoot densities, sexual shoot densities, tiller densities, and in sexual differentiation in GL in both dry 1997 and moist 1998 indicated that the traits of clone growth and reproductions between the two populations were different. The vigor of shoots and tillers in GL was greater than YL, and the GL may more fit and survival the environments in the Songnen Plain.

That none significant differences in inflorescence lengths, seed numbers per inflorescence between the two populations implied they alike in some reproductive traits. However, seed weights of GL were remarkably greater in both dry and moist years, this also showed that the vigor of reproduction on GL were greater than YL. Because the greater the seed weights, the higher the seed quality was (Wang. 1997).

The differences in biomass allocation to rhizome and to vegetative shoots were not significant between the two populations in both dry and moist years, however, the average biomass allocation to vegetative shoots in YL was relative greater in the two years. This might indicate the vigor of vegetative growth in the YL was relative greater (Wang, 1999). Biomass allocations to sexual shoots were significantly greater in GL in the both years which may also show that the vigor of reproduction on GL was greater than YL. Relative disadvantages in clone growth and reproduction in YL limit the population diffusion, and this may in part to explain why the patches of this type are less than GL in the Songnen Plain.

3.3 Intra-specific variations of photosynthetic and transpiration rate

Photosynthetic and transpiration rates of the two populations were strongly related with the leaf age in Songnen Plain. In general, the ability of photosynthesis of mature leaves is less than young ones (Du, 1988). The leaves had matured in early July and their photosynthetic and transpiration rates were getting less in both vegetative and sexual shoots respectively (Fig.5).

The experiments also showed that net photosynthetic and transpiration rates between the two populations were significantly different, even they distributed in the same habitats and the measurements were taken simultaneously. Although the average net photosynthetic rate in YL was 21.190% greater in the early June, those in the other treatments were significantly lower than GL. Such phenomenon suggested the photosynthetic ability in GL was greater than YL in the Songnen Plain. Transpiration rate values in YL were considerably greater than that in the GL, although the average transpiration rate in GL was 13.10% greater in the early June. This reflected that the transpiration in YL was greater and this type may need more water in growing season. This may be a crucial limit for this type to distribute in the Songnen Plain.

4 Conclusions

In summary, the greater population densities, seed productions and biomass allocation to reproductions and to vegetative growth in moist year reflected the response of *L. chinensis* populations to the climate changes, such as precipitation, in the Songnen Plain. While the greater differences in population densities, some traits of seed productions, biomass allocations to reproductions and ecophysiological traits demonstrated that the two ecotypes are divergently in the Songnen Plain. This can also be proved by the studies on morphological differences (Vavre, 1997; Xiao, 1995). The finding of this study indicated the two populations should be taken different utilization in pasture management, because of their differences in population, reproductions and ecophysiological traits. If the pastures are to remain productive under increasing utilization, the other detail scientifically-based management practices are need, including the use of seeded pasture to reduce pressure on the pastures and deterioration pastures restorations and conservation (Ripley, 1996; Rozijn, 1986; Vavre, 1997).

References:

Bassow S L, Bazzaz F A, 1997. Intra and inter-specific variation in canopy photosynthesis in a mixed deciduous forest[J]. Oecologia, 109: 507—515.

Callaway R M, Delucia F H, 1994. Biomass allocation of montane and desert ponderosa pine: an analog for response to climate change[J]. Ecology, 75(5): 1474—1481.

Delph L F, 1993. Factors affecting intraplant variation in flowering and fruiting in the gynodioecious *species Hehe subalpine*[J]. J Ecol, 81: 287—296.

Domros M, Peng G B, 1988. The climate of China[M]. Berlin: Springer-Verlag, 360.

Du Z C, Yang Z G, 1988. A preliminary study on light photosynthetic characteristic in the leaves at various age for *Aneurolepidium chinense* [J]. Acta Bot Sini, 30: 196—206.

Ford H, 1981. The demography of three populations of dandelion[J]. Biol J Linn Soci, 15: 1—11.

Harper L J, Ogden J, 1970. The reproductive strategies of higher plants. 1. The concept of strategy with species reference to *Senecio vulgaris* L[J]. J Ecol, 58: 681—698.

Jia S X, 1989. Chinese forage flora[M]. Agriculture Press. 20—29.

Jiang G M, He W M, 1999. Species- and habitat-variability of photosynthesis, transpiration and water use efficiency of different plant species in Maowusu sand area[J]. Acta Bota Sini, 41:1114—1124.

Jones M H, Macdonald S E, Henry G H R, 1999. Sex- and habitat-specific responses of a high arctic willow, Salix arctica, to experimental climate change[J]. Oikos, 87:129—138.

Li C H, Zheng X L, Zhao K Y *et al*., 1983. Basic types of pasture vegetation in the Songnen Plain[C]. In: Proceedings of XIV International Grassland Congress, 15—24 June 1981, Lexington, KY, 432—434. Boulder, CO: Westview Press. 876.

Michaels H J, Bazzaz F A, 1986. Resource allocation and demography of sexual and *apomictic Antennaria parlinii*[J]. Ecology, 67: 27—36.

Monson R K, Grant M C, 1989. Experimental studies of ponderosa pine. III. Differences in photosynthesis, stomatal conductance, and water use efficiency between two genetic lines[J]. Amer J Bota, 76: 1041—1047.

Newell S J, Tramer E J, 1978. Reproductive strategies in herbaceous plant communities during sucession[J]. Ecology. 59(2): 228— 234.

Pavone L V, Reader R J, 1985. Effect of microtopography on the survival and reproduction of *Medicago lupulina*[J]. J Ecol, 73:605—614.

Ripley E A, Wang R Z, Zhu T C, 1996. The climate of the Songnen Plain, northeast China[J]. Inte J Ecol and Envi Scie, 22:1—22.

Rozijn N A M G, Werf D C V D, 1986. Effect of drought during different stages in the lifecycle on the growth and biomass allocation of two air species[J]. J Ecol, 74: 507—523.

Vavre M C, Mcgraw J B, Yang H S, 1997. Within-population variation in the demography of Taraxacum officinal, season- and size-dependent survival, growth and reproduction[J]. J Ecol, 85:277—288.

Wang R Z, Ripley E A, 1997. Effects of grazing on a *Leymus chinensis* grassland on the Songnen Plain of northeastern China[J]. J Air Envi, 36: 307—318.

Wang R Z, Zu Y G, Nie S Q, 1999. Preliminary study on biomass reproductive allocation in *Leymus chinensis* population[J]. Chin J Appl Ecol, 10(5): 553—555.

Xiao X M, Wang Y F, Jiang S *et al*., 1995. Interannual variation in the climate and above-ground biomass of *Leymus chinensis* steppe and Stipa grandis steppe in the Xilin River basin, Inner Mongolia, China[J]. J Air Envi, 31:283—299.

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