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Full Length Research Paper

The dynamics of age structures on *Agropyron michnoi* and *Leymus chinensis* in community with two dominant species populations

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In this study, the method of unit sampling was adopted for two years to investigate and analyze the age structure of clonal tillers and seedlings of *Agropyron michnoi* and *Leymus chinensis* in the secondary succession process of Hulunbeier sandy vegetation in north China. The results indicate that in single and mixed communities, tillers of *A. michnoi* were composed of 3 or 4 age classes respectively, and those of *L. chinensis* were composed of 2 age classes. Seedlings of *A. michnoi* were all composed of 4 age classes, while those of *L. chinensis* were composed of 2 or 3 age classes, respectively. The tillers number of *A. michnoi* and *L. chinensis* in single community reduced by 10.8 and 29.7%, respectively in 2010 when compared with those in 2009; while in mixed community, the tillers number of *A. michnoi* reduced by 8.9%, but that of *L. chinensis* increased by 15.9%. In single community, the seedlings numbers of *A. michnoi* and *L. chinensis*, respectively reduced by 26.3 and 31.2%, while in mixed community, the seedlings number of *A. michnoi* reduced to 22.0%, but that of *L. chinensis* increased by 7.1%. The number ratio of various age classes of *A. michnoi* and *L. chinensis* seedlings in 2009 was basically the same as that of tillers in 2010. Both in single and mixed communities, the *A. michnoi* population tended to change from growing type to stable type or declining type, while *L. chinensis* population always remained increasing with slight reduction. The general tendency was obviously shown specially in mixed community. *L. chinensis* could be considered as the dominant species, while *A. michnoi* lost its dominant status and made the companion species in the community.

Key words: Tillers, seedlings, clone, age structures, single community, mixed community.

INTRODUCTION

Clone is also called individual population, which consists of different ramets from the same genotype (Harper, 1981). Clonal plants play an important role in both communities and ecological process (Oborny and Bartha, 1995; de Kroon and van Groenendael, 1997). Ecologists have began to focus increasing attention on the biology of clonal species (Cook, 1983; Jackson et al., 1985; Harper et al., 1986). The development of plants, consiered as organisms with modular construction, results from the addition of new iterative units or modules (Harper and White, 1974; Harper and Bell, 1979; White,1979; Waller, 1986; Watkinson, 1986). Modular growth can be described as the overall consequence of the different developmental outcomes of the modules (a module being a developmental unit that is reiterated as the plant grows) (Watson, 1986; Lovett, 1989; Bell, 1991).

Rhizome-derived tillers and ramets have a greater ability than seedlings to emerge through the low light conditions of accumulated unburned detritus and have greater competitive ability once they emerge, presumably because of their developed root system, stored food reserves and the potential for physiological integration among ramets (Hartnett and Keeler, 1995). The reproductive potential of an individual plant will depend

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on how these modules grow, both in number and in size (Harper, 1981; Watson and Casper, 1984; Fox, 1995; Preston, 1998). A population's age structure is simultaneously the outcome of past demographic events and an indicator of its demographic future (James et al., 1996). Present age structure reflects previous temporal variation in recruitment and mortality and, because vital rates in many populations are age-dependent, future age structure can be projected from present structure (Caswell, 1989). There are many studies on the age structures of population (Noble et al., 1979; Gatsuk et al., 1980; Silva et al., 1991; O'Connor, 1993), but a study on the age structures of two dominant populations in one community with two dominant species has not been reported.

Both *Agropyron michnoi* and *Leymus chinensis* are typical rhizome grass in clonal plants. *A. michnoi* shows good adaptability in sandy land, settling down in moving sand by seed reproduction. Therefore, it becomes a pioneer species and also a dominant population of single species as a result of vegetative propagation to expand its later generations. On the other hand, *L. chinensis* is the dominant species in Meadow Steppe. During the secondary succession process of Hulunbeier sandy vegetation, *A. michnoi* and *L. chinensis* appeared simultaneously in community, indicating that the secondary succession process of vegetation was in transitional stage. So, to study the clonal age structure of *A. michnoi* and *L. chinensis* and to analyze the dynamic law of population change which is crucial in judging the trend of community succession, we hypothesized that the intraspecific and interspecific competitions of *A. michnoi* and *L. chinensis,* as well as the secondary succession process of vegetation could have affected the tendency of plant population by changing the population age structure. In this study, the age structure of tillers and seedlings of *A. michnoi* and *L. chinensis* were investigated in two years. In addition, the relationship of age structure between tillers and seedlings was analyzed. The changes of age structure of tillers and seedlings were compared between single and mixed communities in the same year, as well as in the same community between different years.

MATERIALS AND METHODS

This study was conducted in Hulunbeier sandy soil of north China, located at east longitudes 11°44′75″ ~ 118°54′76″, north latitudes 49°08′87″ ~ 49°11′48″, and altitude from 588.4 to 618.0 m. After fenced enclosures in the shifting sandy land in 2005, the vegetation has naturally recovered and the single species dominancy community dominated by *A. michnoi* was formed from the subsequent 2 to 4 years. In the 5th year, *L. chinensis* population patches of unequal size appeared in the community and were found in *A. michnoi* community, among which the coverage of *A. michnoi* accounted for 35 to 45% of that of *L. chinensis*, while it accounted for 25 to 35% of that of other few species. Therefore, the two species dominant population which was dominated by *A. michnoi* and *L. chinensis* came into being.

There were three arrangements of sample plots. First plot was a single species community dominated by *A. michnoi,* which could be regarded as the intraspecific competition area of *A. michnoi*. The second plot was single species community dominated by *L. chinensis*, which could be regarded as the intraspecific competition area of *L. chinensis*. The third was a mixed species community where *A. michnoi* and *L. chinensis* dominated this juncture area, which could be regards as the interspecific competition area.

The observations and measurements were made in late August of 2009 and 2010, when it was the vegetative period of *A. michnoi* and *L. chinensis* after fruiting. In the single species community and the mixed species community, they were sampled randomly in the unit areas. Sample area was planted at a spacing of 25 x 25 cm in single species community; 50 x 50 cm in mixed species community. Five replicates were selected from different patches or interpatches. Plants of *A. michnoi* and *L. chinensis,* including their overground and underground parts were excavated as a whole with their root soil cleared off. They were then bagged according to the sample plots.

The tiller growing up from the tip and internode was named one year tiller. The tiller burgeoning from the tillering nodes of one year tiller was named two years strains; analogously, that burgeoning from the tillering nodes of two-year tiller was named three-year strains (Yang et al., 1998). As for the standards of dividing seedling age, seedlings growing diagonally from the tip and internode of roots were named one year seedlings. The seedlings growing up and burgeoning from the nodes of one year shoot was named two years shoot. Other seedling ages were analogized in the same way (Yang et al., 1998).

The tested numbers from various sampling areas were converted into quantitative index, that is, standard unit area (at a spacing of 1 x 1m). The numbers of tillers and seedlings in the same age class were accumulated to obtain the quantity age structure of tillers and seedlings. When the numbers of tillers and seedlings in various age classes were accumulated, the total number of tillers and seedlings were obtained. The percentage of tillers in various age classes to all tillers was calculated, so that age spectrum of tiller numbers was achieved. The age spectrum of seedling numbers was achieved after the percentage of seedlings in various age classes to all seedlings was calculated. The total number of tillers and seedlings in age structure and the proportion of the same age class in age spectrum were then subjected to one-way analysis of variance. It allowed us to compare the difference between single and mixed communities in the same year, as well as that in the same community and different years for a clone. Duncan test was used for determining homogenous groups. Variables were tested for normality and homogeneity of variances and logarithmic transformation for counting values were made. Differences were considered significant at $P<0.05$ level.

RESULTS

Age structures of tillers' number

Table 1 displays the statistics of the total tillers of various communities in different years. *A. michnoi* in the same community between 2009 and 2010 showed no obvious difference. But *L. chinensis* growing in single communities had significant differences, while in a mixed community, it had no remarkable difference. As for tillers quantity proportion in the same communities in 2010 as compared to that in 2009, *A. michnoi* and *L. chinensis* in single community, respectively, was reduced by 10.8 and 29.7%, but in mixed community, *A. Michnoi* was reduced by 8.9%, while *L. chinensis* was increased by 15.9%.

Table 1. The number of tillers and seedlings of *A. michnoi* and *L. chinensis* clonal population in different community (M±SD).

species	community	Time	Tillers	Seedlings (No./m^2)
A. michnoi	Single	2009	1478.4±605.7^a	2794.4±744.0^a
		2010	1318.4±436.8^a	2059.8±539.8^b
	Mixed	2009	954.4±470.6^a	1318.8±463.4^c
		2010	869.6±295.5^a	1029.2±223.7^c
L. chinensis	Single	2009	883.2±275.6^a	645.8±297.7^a
		2010	620.8±165.7^b	444.4±215.8^{ab}
	Mixed	2009	191.2±55.5^c	292.6±167.0^b
		2010	221.6±94.0^c	315.1±129.8^b

Different letters indicate different statistical significance ($p<0.05$).

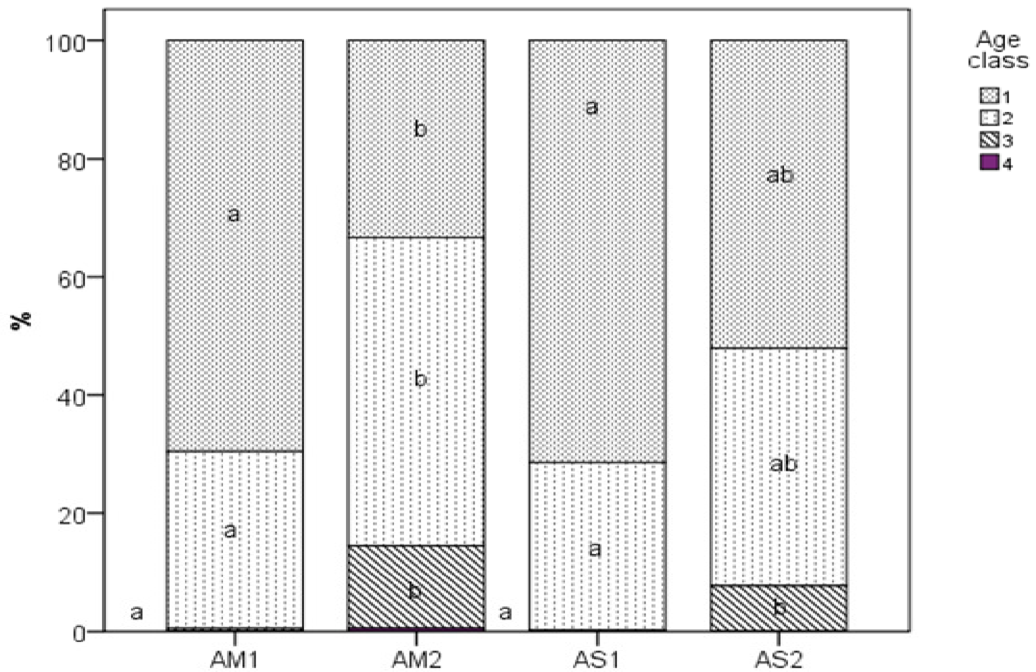
The age spectrum of tillers number showed that in single and mixed communities, tillers of *A. michnoi* were composed of 3 and 4 age classes, respectively, and those of *L. chinensis* were composed of 2 age classes. The ratios of age classes of tillers number of *A. michnoi* and *L. chinensis* were all different both in single and mixed communities and in different years. For *A. michnoi,* in single or mixed communities, the 1st year tillers were dominant in 2009, with a ratio of the age classes of their tillers from the 1st year to the 3rd year (7:3:0). There was no obvious difference among the same age class of tillers which were all in the increasing age structures. In the single communities in 2010, the ratio of age classes of *A. michnoi* for the 1st-3rd year tillers was 5:4:1 and the population changed from growth type to stable type. When compared with the 1st-3rd year tillers in 2009, their corresponding tillers reduced by 19.3%, increased by 11.8 and 7.4%, respectively. In the mixed community in 2010, the ratio was 3:5:1 and the population was in stable age structures. When compared with the 1st-3rd year tillers in 2009, the corresponding tillers considerably reduced by 36.2%, increased by 22.3 and 13.4%, respectively.

As for the ratio of age class of *L. Chinensis*, the 1st year tillers both in single and mixed communities showed a dominating position for 2 years, but the ratio of age classes for tillers from the 1st-2nd year in the mixed communities in 2010 was 8:2. All the others were 9:1 (including the single and mixed communities of 2009 and the single communities of 2010) and clearly were increasing in age structure. Although, within 2 years, there was no marked difference in the ratios of age class of different communities, the 1st age class ratio of single communities in 2010 increased by 6.9% than that in 2009 and that in the mixed communities in 2010 decreased by 11.1% than that in 2009.

Age structures of seedlings' number

Table 1 also indicates the statistics of differences between seedlings of various communities in different years. When compared with seedlings quantity of *A. michnoi* growing in single community in 2009, that in 2010 was reduced by 26.3%; and that of *L. chinensis* reduced by 31.2%. In mixed community, the corresponding data for *A. Michnoi* reduced by 22.0%, but that of *L. chinensis* increased by 7.1%.

The age spectrum of seedlings number showed that in single and mixed communities, seedlings of *A. michnoi* were all composed of 4 age classes, whereas the seedlings of *L. chinensis* were composed of 2 and 3 age classes, respectively. The ratio of age class of seedling numbers of *A. michnoi* and *L. chinensis* were all different in either the single or mixed communities and among different periods. The 1st year seedlings of the *A. michnoi* in 2009, in single community showed its dominance. The ratio of age class seedlings from 1st year to 4th year was 5:4:1:0, respectively and they were in increasing age structures. In the mixed community, the 2nd year seedlings increased in number, the corresponding ratio of age class seedlings was 3:5:2:0 and they were in stable age structures. In the single communities in 2010, the 2nd year seedlings of *A. michnoi* were higher in numbers. The ratio of age class seedlings from the 1st year to the 4th year was 4:4:2:0, respectively and they were in stable age structures. When compared with the seedlings in 2009, the 1st year seedlings was significantly reduced by 18.1%, while the seedlings of the other three age classes separately increased by 4.4,12.9 and 0.8%, in which the change of the 3rd year seedlings was remarkable. In the mixed community, the 3rd year seedlings gained advantage over others with a ratio of different age classes of 2:3:4:1 and they were in decreasing age structures. When compared with the Figures 1 and 2 in 2009 separately, the 1st-2nd year seedlings obviously reduced by 12.3 and 20.0% respectively; the 3rd-4th year seedlings appreciably increased by 25.2 and 7.1%. With regards to the ratio of age class of *L. chinensis* seedlings, the 1st year seedlings both in single and mixed communities have gained advantages for two years.



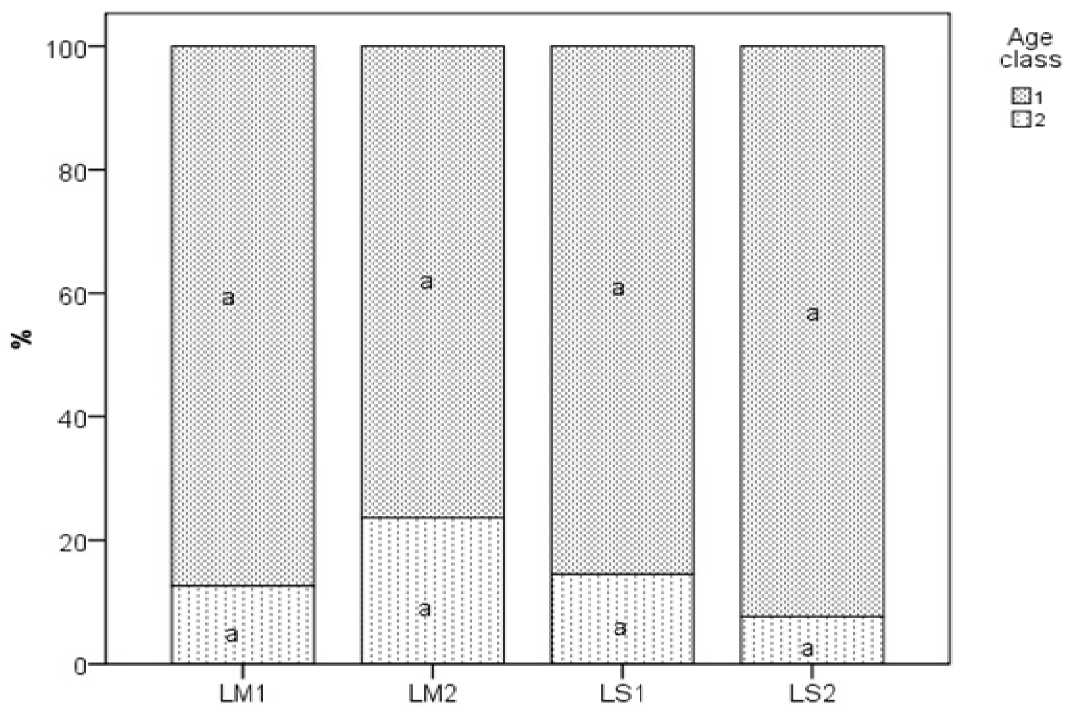


Figure 1. Age spectrum on number of tillers of *A. michnoi* and *L. chinensis* clonal populations in different years of single and mixed community. 'A': *A. michnoi*; 'L': *L. chinensis*; 'S': single community; 'M': mixed community; '1': 2009 year; '2': 2010 year. Different letters indicate different significance (p<0.05), according to Duncan's test.

And they were all in the increasing age structures. The ratio in various age classes in 2009 in the single communities was 9:1 of the 1st and 2nd year seedlings, while that in mixed communities was 7:3. In the single communities in 2010, the ratio of seedlings from the 1st to the 3rd year was 6:4:0; in which the 1st year seedlings

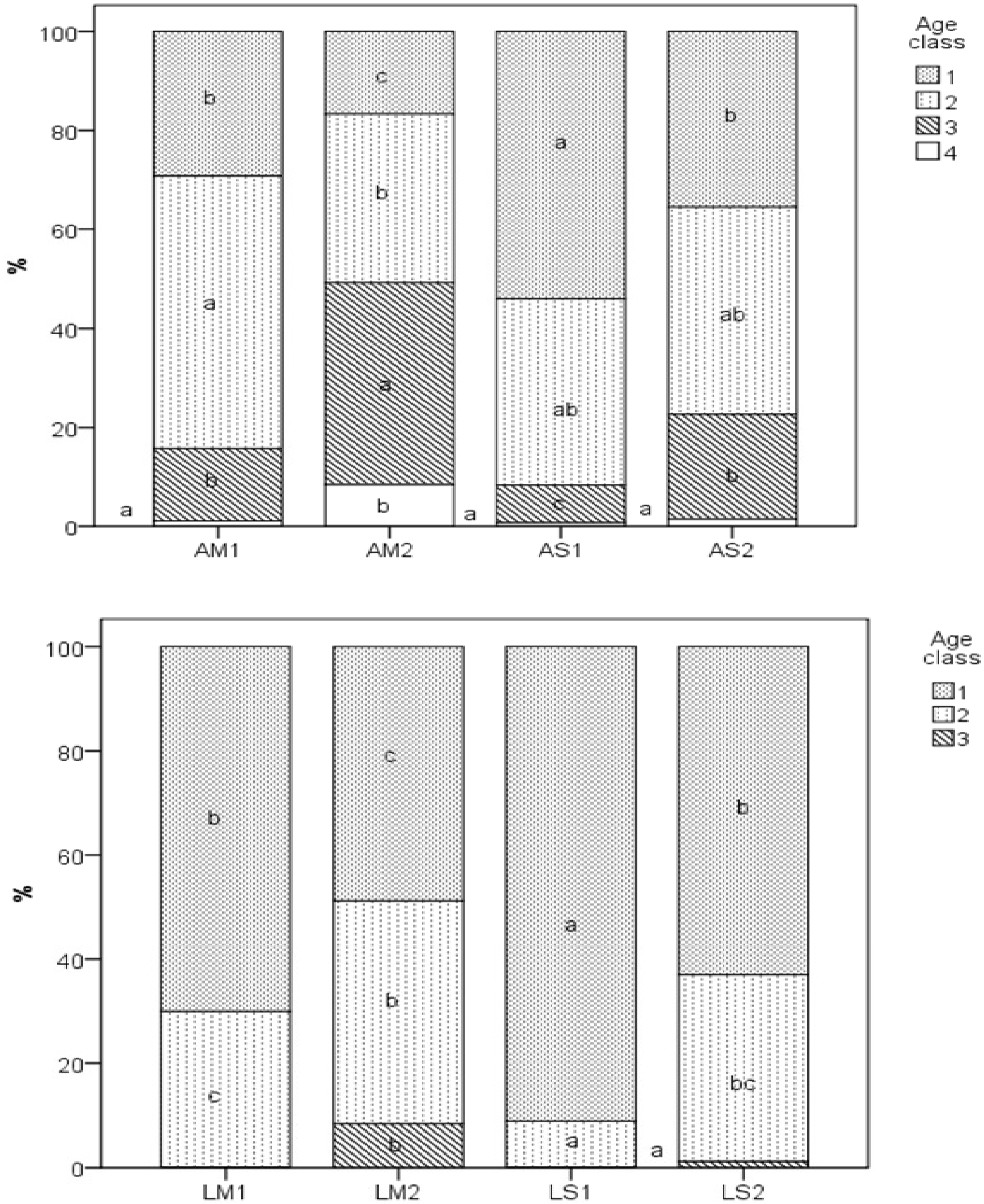


Figure 2. Age spectrum on number of seedings of *A. michnoi* and *L. chinensis* clonal populations in different years of single and mixed community.

seedlings were lower by 27.3% than that in 2009, while the 2nd and 3rd year seedlings separately were 26.1 and 1.2% more than that of the previous year, with a pronounced change in the second year age class. In the mixed communities in 2010, the ratio of 1st-3rd year seedlings was 5:4:1, with the 1st year seedlings 20.8% lower than that in 2009, and the ratio of 2nd and 3rd year seedlings obviously increasing by 13.1 and 7.6%.

DISCUSSION

The population age structure which indicates the regeneration and the turnover of the species reveals to a large extent the interrelationship between the species and the environment as well as their significance and status in the community (Yang, 1994; Su, 2000). Thus, the length of the update process and speed is reflected in the population of the structure (Dai, 2002). In Hulunbeier sandy soil, plants stop growing and go into dormancy in the first ten days of September. Seedlings and active buds shaped in this period begin to experience winter in the form of dormancy seeding and dormancy buds, respectively (Meng, 2011). It is reported that on the Songnei plain in China, the overwintering rate of the dormancy seeding of *Hordeum brevisubulatum* is 96%, while in June of the growing seasons, winter tillers formed by the dormancy seedlings accounted for 95% of the tillers in the community. Spring tillers formed by dormancy buds merely account for 5% of the tillers (Yang, 2004). That is to say, the number of seedlings could be basically reflected in the quantitative characteristics of population, while the tiller population can reflect the factual characteristics of the population of the species.

In this study, in terms of the age structures of both species, the seedlings of 2009 and the tillers of 2010 shared the same type, in that in the single community with regards to *A. michnoi*, the age structure of the seedling and that of the tillers were both in the increasing type; while in the mixed community, the age structure of the seedling of 2009 and that of the tillers of 2010 were in the stable type. In both single and mixed communities, with regards to *L. chinensis,* the age structure of the seedling of 2009 and that of the tillers of 2010 were in the increasing type. It could be inferred that the age structure of the potential species was with the real age structure of the species of the next year. The same conclusion can be seen in the experiment on the factual characters of the age and population structure of *L. chinensis* on the restoration of degraded vegetation on the Songneng plain (Meng, 2011).

It could be concluded that making use of the quantity age classes of potential population is feasible to predict real populations, for example, the quantity of age classes of potential population in 2011 can be predicted based on the real populations in 2010 by analogy. So, with the extension of secondary succession process of vegetation over time in Hulunbeier sandy soil, the change regularity of quantity age structure of *A. michnoi* clone population in single communities was summarized from the increasing type to the stable type, while in the mixed communities, the change regularity was from the increasing type to the stable or decaying type. In other words, the population type has changed from increasing to stable or decaying type. The quantity age structure of *L. chinensis* clone population, in single or mixed communities, is an increasing type and close to stable population, yet the stable structure is weak, which is remarkable in mixed communities. It showed that in the restoration process of the degraded vegetation in Hulunbeier, only in the mono-dominant community of the interspecific competition can both species develop steadily in the age structure. But when there is competition between the two dominant species, the age structure can indicate the population succession, in that *A. michnoi*, the dominant species of decaying type was replaced by *L. chinensis*, the dominant species of the increasing type, which made *L. chinensis* the dominant species in the community and *A. michnoi* lose its value as the dominant species and became the companion species in the community. The same conclusion can also be achieved by the mixed experimental population dynamics and structure of both species (Zheng, 2008).

The previous experiments showed that natural recovery of desertification grassland belonged to the progressive succession type, which was similar to the secondary succession of bare land, in which the community succession appeared from simplicity to complexity, from dynamics to stability and finally developed into zonal vegetation (Wang, 2004). The essence of community succession is the replacement of dominant species. In the restoration succession of sandy grassland, there is high competition between dominant species, which has a lot to do with the environment of the vegetation and soil (Wang, 2004). The early stage of community succession helps to prepare for the late stage of community succession with suitable conditions of soil nutrients (Zhang, 2009). Therefore, it is shown furthered that secondary succession of Hulunbeier desertification grassland was developed from pioneer species of vegetation to the zonal vegetation, in that the community where *A. michnoi* became the dominant species appeared in the early stage of community succession, while the community where *L. chinensis* became the dominant species appeared in the late stage of community succession and the community was in the stage of progressive succession.

To minimize the intensity of competition and achieve the harmonious coexistence, plants in the natural community could utilize one or more limited resources from different depth and patches of soil (Silvertown, 2004). This is one of the phenomenon of spatial niche separation and the interaction of different species (Klanderud, 2005). When there is overlapping in the niches between two plants in the same community, the intraspecific competition gets more and more tense with increase in the parts overlapped (Berendse, 1983). The roots of *A. michnoi* and *L. chinensis* were both in the depth of 0 to 30 cm in soil. In the sandy environment, water dictates the growth of a plant (Zhu, 2005; Grime, 1973). In this study, the trends of the population change in both tillers of potential and real species were the same, in that with the extension of the growth period, both reduced in population in the single community and at the same time the population of *L. chinensis* became much smaller. In the mixed community, the population of *A. michnoi* declined, while that of *L. chinensis* was increased.

The changes happening in the single community indicated the change in the environment such as climate. Minimum amount of resources of a certain ecological factor limited the reproduction of the species. Under such a circumstance, in order to minimize the intraspecific competition, both species adopted the policy of reducing their overground ramets and *L. chinensis* achieved a much better goal, effectively. The change in the mixed community showed that under the circumstance where there is interspecific competition and where there is limited resources, *L. chinensis* could utilize the limited resources and increase its population and gain a dominant status in the interspecific competition. It was completely opposite with *A. michnoi*, thus it increased the rate of its community succession. The trend of the change in the population of both species coincides with that in their age structures.

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