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DYNAMICS OF THE POPULATION QUANTITY OF *JUGLANS MANDSHURICA* MAXIM. IN DIFFERENT HABITATS IN XINJIANG, CHINA

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Abstract

Transects were arranged on the shady and sunny slopes, as well as at different elevations of the main, eastern, central, and western gullies in the Wild Walnut Nature Reserve in Xinjiang, China to survey a large sample of *Juglans mandshurica*. The structures of height class and diameter at breast height (DBH) class were used to represent age structure to compare and analyze the dynamics of the population quantity of *J. mandshurica* in different habitats. Results showed that *J. mandshurica* population comprises numerous young seedlings, which develop into young plants with a high death rate. The number of adult plants is stable. *J. mandshurica* population is r-strategists in the young stage, and k-strategists supplemented by r-strategists in the juvenile and subsequent stages. The structures of height class and DBH class fluctuate at different slope aspects and elevations. The growth of young seedlings into adult plants is discontinuous. Tree height and DBH are relatively uniform in the same age class, and the coefficient of variation is independent of slope aspect and elevation. The maximum numbers of age classes in *J. mandshurica* population with different height and DBH classes differ at three elevations. Low- and medium-age classes are dominant in all situations. That is, population is mainly composed of juvenile and adult trees, and age structure is classified as a growth type. Without strong external interference, *J. mandshurica* population will maintain its superior position in the community.

Keywords: *Juglans mandshurica*; Population; Age structure; Slope aspect; Elevational gradient.

Introduction

Age structure is a major attribute in a population because it has a decisive role in the reproductive capability and development potential of a population (Li *et al.,* 2002; Wang *et al.,* 1998). The age structure of a population reflects the combination of individuals from different age classes, site conditions, and interactions with the environment (Li *et al.,* 2002; Yang *et al.,* 1998). A survey of the age structure of a plant population can benefit understanding on the current structure of the population and reveal the outcome of a plant population that is adapting to the environment. In addition, the information is also provided to analyze and reconstruct the past structure of a population and to predict the future dynamics of the population structure (Fuchsa *et al.,* 2000; Harper, 1977; Lorimer, 1980; Stewart & Rose, 1990). Thus, the effects of seed dissemination, germination, and seedling establishment on the dynamics of a plant population are measured with respect to a time scale (Armesto *et al.,* 1992; Skoglund & Verwijst, 1989). Hence, a study of the age structure of a population is significant to clarify the formation and ecological characteristics of a population and to update the strategy (Guo *et al.,* 1997).

Juglans mandshurica Maxim. (*J. mandshurica* Dode) is a species of the genus *Juglans* and the family Juglandaceae; it is a national grade II vulnerable species (National Environmental Protection Agency, 1987). *J. mandshurica* is a hybrid between the Tertiary relict broad-leaved tree species and the Pleiotropic northern "emigrant;" it has a large natural community in western Tianshan Mountain and Pamir-Alai Mountain in the former Soviet Union (Zhang, 1973). In Asia, the only extensive distribution of *J. mandshurica* population can be found in Wild Walnut Gully, Gongliu County, Xinjiang, China, which belongs to an island-like relict distribution. *J. mandshurica* is the direct ancestor of cultivated walnut (Zhang, 1973). It is a valuable species for walnut breeding, as well as for exploring the origin and evolution of cultivated walnut (Wang *et al.,* 1997). Many studies have examined the following aspects of *J. mandshurica*: geographical and climate characteristics (Xu, 1989; Xu & Zhu, 1991), formation of forest soil (Liu *et al.,* 1998; She, 1994), community (Zhang, 1973), current status of resources (Dong *et al.,* 2012), germplasm resource classification (Wang *et al.,* 1997, 1998), seed genotypic variation (Zhang *et al.,* 2013), growth of compound leaves, and biomass allocation characteristics (Zhang *et al.,* 2011, 2012). No report on the dynamics of the population quantity of *J. mandshurica* from the perspective of population statistics has yet been made.

Determining the actual age of endangered tree species with a small population is difficult without obvious and identifiable morphological indicators. Diameter at breast height (DBH) and tree height can be classified to develop a structure of DBH class and height class, respectively. These two indicators are easy to acquire through field surveys, and their accuracy is high. Therefore, the structures of DBH class and height class are frequently used to characterize age structure in the structural characteristic analysis of a population. The analysis results can also reveal the age structure of a population with similar effectiveness (Bi, 1999; Feng *et al.,* 2003; Hu *et al.,* 2013; Song *et al.,* 2008). In the present study, transects were arranged in the shady and sunny slopes of four gullies in the Wild Walnut Nature Reserve in Xinjiang, China. A survey was performed on a large sample of *J. mandshurica* using the structures of height class and DBH class to reflect age structure. "Age inference based on spatial structure" was employed to obtain population quantity statistics, and consequently, reveal the dynamics of the population structure and the current state of the population. Finally, the endangerment mechanism of *J. mandshurica* was proposed.

Overview of the study area: The Wild Walnut Nature Reserve is located on the gully in front of Kaiteming Mountain 20 km away from the south of Gongliu County, Xinjiang Province (82°15′28″–82°17′23″E, 43°22′56″–43°25′40″N); it has a total area of 1180 hm^2. The nature reserve consists of the main, eastern, central, and western gullies (Dong *et al.*, 2012), each of which runs from north to south. Elevation gradually rises from the main gully to the western gully, and the slope is 30°–50°. Rain is heavy in spring and summer, and winter snow has a depth of 0.7–1.0 m. The annual mean air temperature is 7.6°C; the mean air temperature in January is −3.3°C; and the mean air temperature in July is 19.7°C. The extreme low air temperature is −25.3°C. The ≥10°C accumulated temperature ranges from 1865.4–2338.9°C; the annual mean precipitation is 580 mm; the annual mean evaporation is 1200 mm; the relative humidity is 70%–80%; and the frost-free period is approximately 150 d (Xu & Zhu, 1991). The distribution site of *J. mandshurica* has an obvious temperature inversion layer. According to the sounding observation record from 1965 to 1969 at Yili Meteorological Station, the intensity of the inversion layer in January is 9.5 °C and the maximum value is 22.6 °C. Meanwhile, the average thickness of the inversion layer in January is 950 m and the maximum value is 2077 m. The area with the concentrated distribution of *J. mandshurica* is approximately 45 hm^2, with a total of approximately 5500 plants (Dong *et al.*, 2012; Zhang *et al.*, 2013) (DBH≥2 cm). The plants are mainly distributed in gullies and slopes with elevations ranging from 1250 m to 1550 m. *J. mandshurica* is the dominant species in the nature reserve. Associated trees include *Malus sieversii*, *Armeniaca vulgaris*, *Betula tianschanica*, and *Populus tremula*. Understory shrubs are mainly *Spiraea hypericifolia*, *Lonicera altmannii*, *Rosa multiflora*, *Rhamnus davurica*, and *Berberis heteropoda*. Herbaceous plants mainly include *Bromus benekeni*, *Festuca gigantea*, *Aegopodium alpestre*, *Brachypodium sylvaticum*, *Codonopsis clematidea*, and *Impatiens noli-tangere*.

Research Methods

Field survey: From May to October 2012, 4–6 transects with a width of 20 m were arranged on the shady and sunny slopes of the main, eastern, central, and western gullies in the Wild Walnut Nature Reserve. For each transect, investigation was performed for each tree at the unit of 20 m × 20 m from the bottom of each slope to the upper limit of *J. mandshurica* distribution. Slope aspect, elevation, DBH (DBH≥2 cm), and tree height, as well as the number and height of young seedlings and young plants with a DBH<2 cm, were recorded. Quadrats that measured 5 m × 5 m and 1 m × 1 m were used for a vegetation survey of the shrub layer and the herbaceous layer at each plot, respectively. A total of 20 quadrats for the shrub and herbaceous layers were randomly sampled in each plot. The habitat environment for the entire plot was also recorded.

Division of age class: (1) Height (H) class division (Cao *et al.*, 1991; Lieberman & Lieberman, 1988): The tree height of *J. mandshurica* population was divided into 11 classes: 0.0 m<H<0.6 m (DBH<2 cm) as the first height class, 0.6 m<H<1.4 m (DBH<2 cm) as the second height class, and 1.4 m<H<3.0 m (DBH≥2 cm) as the third height class. Beyond the third height class, one age class was classified for every 3 m of tree height.

(2) DBH class division (Wang *et al.*, 1995): The DBH of *J. mandshurica* population was divided into 19 classes, with 0–2 cm as the first class. Afterward, every 5 cm of DBH was considered as the interval between two adjacent classes. That is, 2–7 cm was the second DBH class, 7–12 cm was the third DBH class, and so on. The ascending order of height class or DBH class corresponds to plant development from young to old: the first height/DBH class corresponds to age class 1, the second height/DBH class corresponds to age class 2, and so on. The numbers of plants or seedlings in each age class were counted. The field survey showed that tree height, density, and DBH varied greatly with elevational gradient at an elevation of approximately 1380 m and 1490 m. Three habitats were obtained according to elevational gradient, namely, 1241–1380 m (H_1), 1381–1490 m (H_2), and 1491–1670 m (H_3). Grouping and recording were performed separately.

Results

Height class structures for different slope aspects: The number of plants and seedlings for each height class on the shady and sunny slopes are shown in Table 1. The tree height of *J. mandshurica* on the shady and sunny slopes increased with age class. The maximum age class was 11, which corresponds to a height of 25.4 m. Although the number of plants and seedlings in each age class at different slope aspects considerably differed, the variance analysis showed that slope aspect and population had no significant effect on the height of *J. mandshurica* plants in the same age class (p>0.05). The standard deviation of height for each age class is considerably smaller than the mean value, which indicates the homogeneity of the height of the plants in the same age class. On the shady slope, the coefficients of variation (CVs) for the same slope aspect were greater than those among different slope aspects for four age classes. The CVs for the same slope aspect were smaller than those among different slope aspects for five age classes. The CVs for the same slope aspect for two age classes were identical to those among different slope aspects. On the sunny slope, the CVs for the same slope aspect were greater than those among different slope aspects for seven age classes. The CVs for the same slope were smaller than those among different slope aspects for four age classes. Thus, the CV of height of *J. mandshurica* population was independent of the slope aspect. The variation could be attributed to the biological and ecological characteristics of *J. mandshurica* population.

Table 1. Numbers of seedlings and plants in each height class on different slope aspects.

Age class	Shady slope			Sunny slope			Total		
	N	***H M±SD*(m)**	***CV*(%)**	***N***	***H M±SD*(m)**	***CV*(%)**	***N***	***H M±SD*(m)**	***CV*(%)**
1	622	0.2 ± 0.08	40.0	452	0.2 ± 0.09	45.0	1074	0.2 ± 0.08	40.0
2	8	0.8 ± 0.20	25.0	13	0.9 ± 0.25	27.8	21	0.9 ± 0.23	25.6
3	60	2.5 ± 0.44	17.4	53	2.4 ± 0.50	20.7	113	2.5 ± 0.47	19.0
4	207	4.9 ± 0.90	18.6	178	5.1 ± 0.90	17.7	385	5.0 ± 0.91	18.3
5	396	8.0 ± 0.85	10.6	382	8.1 ± 0.90	11.2	778	8.0 ± 0.87	10.8
6	422	11.1 ± 0.83	7.5	433	10.9 ± 0.89	8.2	855	11.0 ± 0.87	7.9
7	244	13.8 ± 0.93	6.7	230	13.7 ± 0.89	6.5	474	13.8 ± 0.91	6.6
8	115	17.0 ± 0.79	4.6	85	17.1 ± 0.80	4.7	200	17.0 ± 0.79	4.6
9	50	19.6 ± 0.83	4.2	37	20.0 ± 0.73	3.7	87	19.8 ± 0.80	4.0
10	14	23.1 ± 0.86	3.7	12	22.6 ± 0.67	3.0	26	22.9 ± 0.82	3.6
11	3	25.3 ± 0.20	0.8	4	25.4 ± 0.30	1.2	7	25.4 ± 0.25	1.0

Table 2. Numbers of *J. mandshurica* plants in each height class on different elevational gradients.

Age class	1241m-1380m			1381m-1490m			1491m-1670m		
	n	***H M±SD*(m)**	***CV*(%)**	***n***	***H M±SD*(m)**	***CV*(%)**	***n***	***H M±SD*(m)**	***CV*(%)**
1	499	0.2 ± 0.08	40.0	356	0.2 ± 0.09	45.0	219	0.2 ±0.8	40.0
2	13	0.9 ± 0.23	25.6	5	0.8 ± 0.25	31.3	3	0.7 ± 0.17	24.3
3	16	2.7 ± 0.42	15.7	62	2.5 ± 0.43	17.4	35	2.4 ± 0.54	22.5
4	72	4.7 ± 0.94	20.1	187	4.9 ± 0.89	18.1	126	5.2 ± 0.86	16.5
5	195	8.0 ± 0.89	11.1	372	8.1 ± 0.89	11.0	211	8.0 ± 0.83	10.4
6	302	11.1 ± 0.86	7.7	401	10.9 ± 0.87	8.0	152	10.9 ± 0.83	7.6
7	172	13.7 ± 0.86	6.3	204	13.6 ± 0.89	6.5	98	14.1 ± 0.96	6.8
8	39	17.3 ± 1.10	6.4	96	17.0 ± 0.82	4.8	72	17.2 ± 0.73	4.2
9	4	20.5 ± 0.58	2.8	38	19.9 ± 0.84	4.2	38	19.8 ± 0.75	3.8
10	0	-	-	15	23.2 ± 0.68	2.9	11	22.5 ± 0.82	3.7
11	0	-	-	6	25.5 ± 0.30	1.2	1	25.3 ± 0.00	-

The age class (as the X axis) was plotted against the percentage of plants in each age class to the total number of plants (as the Y axis). The height class structures of *J. mandshurica* population for different slope aspects were obtained (Fig. 1). The percentage of first age-class plants was the highest on both the shady and sunny slopes, followed by that of sixth age-class plants. The percentage of plants in other age classes did not vary regularly with age class. Thus, the height class structure of *J. mandshurica* population varied between the shady and sunny slopes. The death rates of individual plants in the population varied with age class. In contrast to the high percentage of first age-class plants, the percentage of second age-class plants was considerably small. Thus, the development from young seedlings to adult plants is discontinuous. However, adult plants exhibit stable survival. The number of seedlings was high during the initial stage of population development. Given the effect of the environmental sieve, death rate was surprisingly high. Once the seedlings developed into adult plants, their probability of completing their life cycle was high. For example, the number of seedlings in the first age class on the shady slope was 622, and that in the second age class was only 8. The death rate was as high as 98.7%. The percentage of first age-class seedlings on the shady slope was higher than that on the sunny slope, whereas the situation was the reverse for the second age class. Thus, the death rate of first age-class seedlings on the shady slope was higher than that on the sunny slope. As shown in Fig. 1, the percentages of seedlings in each age class differed significantly on the shady and sunny slopes. However, height class structures were basically the same. If the first to third age classes were considered as young seedlings, then the percentages of low age- and moderate age-class seedlings dominated *J. mandshurica* population. The percentage of high age-class seedlings was small. That is, young, juvenile, and adult trees held dominant positions. Thus, the age structure was classified as a growth type.

Height class structure at different elevations: The numbers of *J. mandshurica* plants in each height class at three different elevations are shown in Table 2. H_2 and H_3 had 11 age classes, with age class 11 corresponding to a height of 25.5 m and 25.3 m, respectively. H_1 had 9 age classes, with age class 11 corresponding to a height of 20.5 m. Variance analysis revealed that tree height differed significantly among H_1, H_2, and H_3 ($p<0.05$). Tree height did not differ significantly between H_2 and H_3 ($p>0.05$). The standard deviations of tree height for each age class in H_1, H_2, and H_3 populations were all considerably smaller than the mean values. Thus, for different elevational gradients, tree height was homogeneous among *J. mandshurica* plants in the same age class. Table 2 (combined with the overall population in Table 1) shows that the CVs of height for the same elevational gradient were greater than those among different elevational heights for three age classes in H_1. The CVs of height for the same elevational gradient for four age classes were smaller than those among different elevational gradients. The CVs of height for the same elevational gradient in two age classes were identical with those among different elevational gradients. The situations in H_2 and H_3 were similar to that in H_1. The CVs of height in each age class overlapped with that of the overall population. Thus, the CV of height of *J. mandshurica* plants in each age class was independent of the elevational gradient.

The age class (as the *X* axis) was plotted against the percentage of plants in each age class to the total number of plants (as the Y axis). The height class structures of *J. mandshurica* population at different elevational gradients were obtained (Fig. 2). As shown in the figure, plants in different age classes had various percentages at varying elevational gradients. For example, first age-class seedlings had the maximum percentage in H_1, followed by sixth age-class seedlings. Meanwhile, sixth age-class seedlings had the maximum percentage in H_2, followed by fifth age-class seedlings. In addition, first age-class seedlings had the maximum percentage in H_3, followed by fifth age-class seedlings. Seedlings in other age classes had no regular variation trend of percentage. Thus, the height class structure in *J. mandshurica* population varied at the three elevational gradients. The death rates of individual plants varied significantly with age class. First age-class seedlings in H_1 were far greater than those in H_2 and H_3. Thus, first age-class seedlings were more abundant at relatively low elevational gradients. The percentages of first age-class seedlings in H_1, H_2, and H_3 were all over 20.4%, whereas those of second age-class seedlings were below 1.1%. Thus, development from young seedlings to adult plants is also discontinuous at different elevational gradients. Although young seedlings are abundant, the death rate is extremely high. The percentages of seedlings in each age class varied significantly among the three elevational gradients. However, height class structures were similar. If the first age- to third age-class plants were considered as young seedlings, then low age- and moderate age-class seedlings held the dominant positions. The percentage of high age-class seedlings was small. Thus, the age structure at different elevational gradients was classified as a growth type in *J. mandshurica* population. The height class structure of the overall population [Fig. 2(d)] showed that the three population groups had a growth-type age structure.

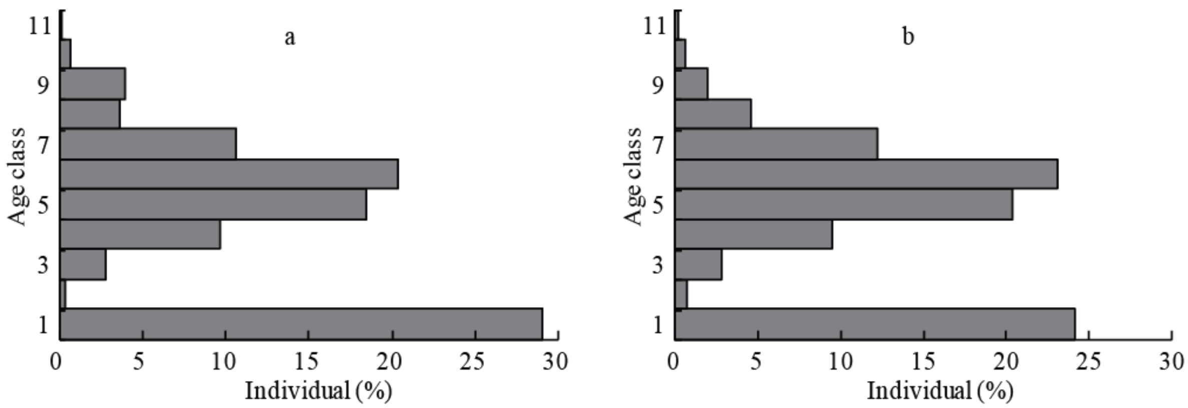

Fig. 1. Height class structures of *J. mandshurica* population on the shady (a) and sunny (b) slopes.

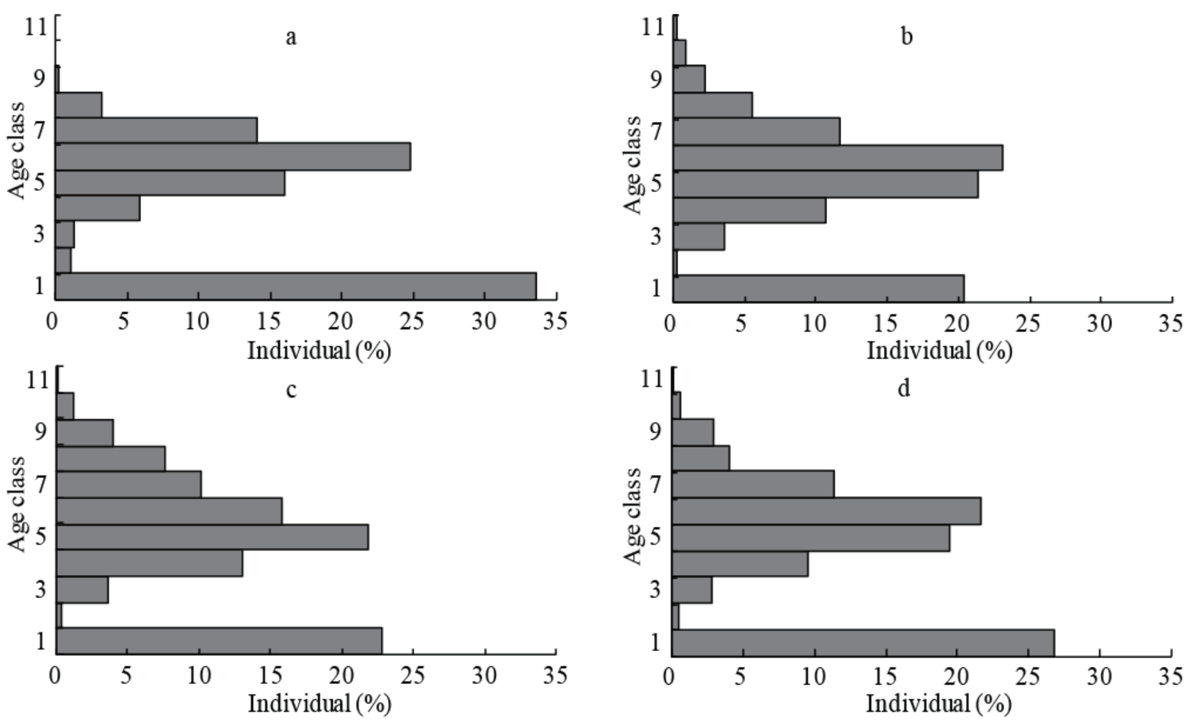

Fig. 2. Height class structures of *J. mandshurica* populations in H_1 (a), H_2 (b), and H_3 (c), and the overall population (d).

Table 3. Numbers of *J. mandshurica* plants in each DBH class on different slope aspects.

Age class	Shady slope			Sunny slope			Total		
	n	***DBH M±SD*(cm)**	***CV*(%)**	***n***	***DBH M±SD*(cm)**	***CV*(%)**	***n***	***DBH M±SD*(cm)**	***CV*(%)**
1	630	-	-	465	-	-	1095	-	-
2	109	5.3 ± 1.31	24.5	118	5.5 ± 1.26	23.1	227	5.4 ± 1.28	23.7
3	184	9.6 ± 1.28	13.3	170	9.8 ± 1.33	13.6	354	9.7 ± 1.30	13.4
4	264	14.7 ± 1.47	10.0	240	14.5 ± 1.44	9.9	504	14.6 ± 1.45	9.9
5	238	19.4 ± 1.33	6.9	235	19.4 ± 1.40	7.2	473	19.4 ± 1.36	7.0
6	194	24.2 ± 1.48	6.1	223	24.3 ± 1.28	5.3	417	24.2 ± 1.37	5.6
7	196	29.4 ±1 .51	5.1	158	29.7 ± 1.55	5.2	354	29.5 ± 1.53	5.2
8	122	34.8 ± 1.34	3.9	101	34.8 ± 1.21	3.5	223	34.8 ± 1.28	3.7
9	91	39.4 ± 1.33	3.4	82	39.3 ± 1.37	3.5	173	39.4 ± 1.35	3.4
10	34	44.4 ± 1.30	2.9	23	44.2 ± 1.27	2.9	57	44.3 ± 1.29	2.9
11	23	48.9 ± 1.36	2.8	36	48.7 ± 1.29	2.6	59	48.8 ± 1.31	2.7
12	17	54.3 ± 1.34	2.5	5	53.1 ± 1.43	2.7	22	54.1 ± 1.42	2.6
13	15	59.2 ± 1.25	2.1	8	58.5 ± 0.87	1.5	23	59.0 ± 1.16	2.0
14	10	64.7 ± 1.59	2.5	6	64.0 ± 2.27	3.5	16	64.5 ± 1.83	2.8
15	2	70.1 ± 2.26	3.2	4	70.1 ± 1.85	2.6	6	70.1 ± 1.75	2.5
16	5	74.0 ± 0.80	1.1	2	74.4 ± 2.90	3.9	7	74.1 ± 1.36	1.8
17	2	79.6 ± 0.00	0.0	3	79.0 ± 2.21	2.8	5	79.2 ± 1.60	2.0
18	4	83.6 ± 1.6	1.9	0	-	-	4	83.6 ± 1.60	1.9
19	1	91.7 ± 0.00	-	0	-	-	1	91.7 ± 0.00	-

DBH class structure at different slope aspects: The numbers of plants in each DBH class at different slope aspects are shown in Table 3. The maximum number of age classes of *J. mandshurica* population differed between the shady and sunny slopes. The shady slope had 19 age classes. The DBH that corresponds to age class 19 was 91.7 cm. The sunny slope had 17 age classes. The DBH that corresponds to age class 17 (i.e., the highest age class) was 79.6 cm. *J. mandshurica* prefers warmth, humidity, and fertile soil. Given that water and fertility on the sunny slope are lower than those on the shady slope, the difference in the maximum number of age classes on the shady and sunny slopes is mainly affected by water and fertility. Variance analysis suggested that DBH did not significantly differed for the same age class of *J. mandshurica* plants on the sunny and shady slopes ($p>0.05$). The standard deviations of DBH in each age class were lower than the mean values, which indicated the homogeneity of DBH in the same age class of plants on the shady and sunny slopes. The CVs of *J. mandshurica* population in the seventh and eighth age classes for the same slope aspect were larger than those among different slope aspects on the shady and sunny slopes, respectively. The CVs in the seventh and fifth age classes for the same slope aspect were smaller than those among different slope aspects on the shady and sunny slopes, respectively. Thus, similar to the CVs of tree height, the CVs of DBH were also independent of slope aspect. The variation was mainly attributed to the biological and ecological characteristics of *J. mandshurica* population.

The age class (as the X axis) was plotted against the percentage of plants in each age class to the total number of plants (as the Y axis) at different slope aspects. DBH class structures on the shady and sunny slopes were obtained (Fig. 3). As shown in the figure, the DBH class structure of the *J. mandshurica* population varied on the shady and sunny slopes. The development from young seedlings to adult plants is discontinuous, and adult plants are relatively stable. First age-class seedlings had the highest percentage on both the shady and sunny slopes, whereas second age-class seedlings had an extremely small percentage. Moreover, the young plants in *J. mandshurica* population were abundant, but the death rate was high. First age- to ninth age-class seedlings on the shady and sunny slopes accounted for 94.72% and 95.38%, respectively, of the number total of plants. Most seedlings belonged to the low and moderate age classes (young or adult trees). Thus, *J. mandshurica* population had a growth-type age structure.

DBH class structures at different elevational gradients: The numbers of *J. mandshurica* plants in each DBH class at different elevational gradients are shown in Table 4. A significant variation in the number of age classes in the *J. mandshurica* population was observed at three elevational gradients. As elevation increased, the number of age classes in the population decreased. Plants with a large DBH were few. H_1 had 19 age classes, with age class 19 corresponding to a DBH of 91.7 cm. H_2 had 16 age classes but no 15th and 16th age classes. Age class 18, which is the maximum on the scale, corresponded to a DBH of 82.8 cm. H_3 had only 13 age classes, with age class 13 corresponding to a DBH of 58.9 cm. The annual mean air temperature and extreme low temperature at low elevations were higher than those at high elevations. Thus, the difference in age class at different elevational gradients was probably caused by temperature. Variance analysis showed that the difference in DBH among H_1, H_2, and H_3 was significant ($p<0.05$), but the difference between H_2 and H_3 was insignificant ($p>0.05$). The standard deviations of DBH for each age class in H_1, H_2, and H_3 were considerably smaller than the mean values. DBH exhibited homogeneity among *J. mandshurica* plants in the same age class at different elevational gradients. The CVs of DBH of plants in different age classes were higher at high elevations than at low elevations in H_1, H_2, and H_3. For other age classes, however, the CVs of DBH were lower at high elevations than at low elevations. Thus, the CVs of the DBH of plants in different age classes were independent of elevational gradient.

Table 4. Numbers of *J. mandshurica* plants in each DBH class on different elevational gradients.

Age class	1241m-1380m			1381m-1490m			1491m-1670m		
	n	*DBH M±SD*(cm)	*CV*(%)	*n*	*DBH M±SD*(cm)	*CV*(%)	*n*	*DBH M±SD*(cm)	*CV*(%)
1	512	-	-	361	-	-	222	-	-
2	34	5.8 ± 0.94	16.2	125	5.5 ± 1.27	23.1	68	5.1 ± 1.37	27.1
3	77	9.7 ±1 .27	13.1	152	9.6 ± 1.31	13.6	125	9.8 ± 1.32	13.5
4	76	14.4 ± 1.43	9.9	281	14.8 ± 1.50	10.2	147	14.4 ± 1.35	9.4
5	77	19.7 ± 1.53	7.8	268	19.3 ± 1.33	6.9	128	19.3 ± 1.30	6.7
6	102	24.6 ± 1.26	5.1	208	24.1 ± 1.45	6.0	107	24.2 ± 1.26	5.2
7	136	29.4 ± 1.48	5.0	140	29.4 ± 1.57	5.3	78	29.9 ± 1.51	5.0
8	85	34.7 ± 1.39	4.0	85	34.8 ± 1.22	3.5	53	34.8 ± 1.21	3.5
9	82	39.8 ± 1.24	3.1	68	39.2 ± 1.43	3.6	23	38.6 ± 0.99	2.6
10	33	44.3 ± 1.31	3.0	17	44.4 ± 1.31	3.0	7	44.6 ± 1.27	2.8
11	29	49.1 ± 1.39	2.8	24	48.5 ± 1.11	2.3	6	48.4 ± 1.43	3.0
12	17	54.1 ± 1.38	2.6	4	54.5 ± 1.73	3.2	1	52.5 ± 0.00	-
13	18	58.9 ± 1.24	2.1	4	59.4 ± 0.91	1.5	1	58.9 ± 0.00	-
14	13	64.6 ± 1.65	2.6	3	63.7 ± 2.77	4.3	0	-	-
15	6	70.1 ± 1.75	2.5	0	-	-	0	-	-
16	7	74.1 ± 1.36	1.8	0	-	-	0	-	-
17	4	79.5 ± 1.68	2.1	1	78.0 ± 0.00	-	0	-	-
18	3	83.9 ± 1.85	2.2	1	82.8 ± 0.00	-	0	-	-
19	1	91.7 ± 0.00	-	0	-	-	0	-	-

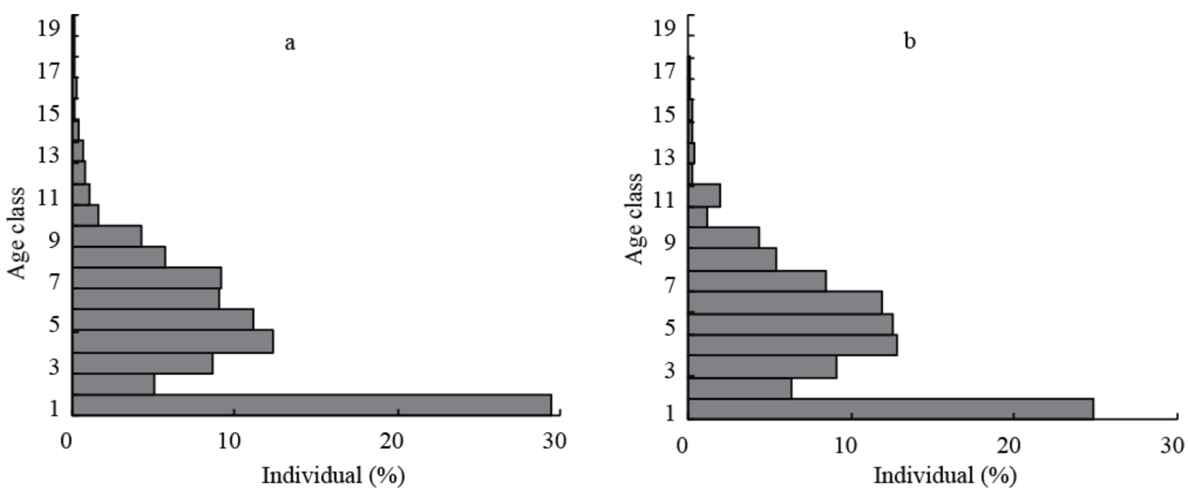

Fig. 3. DBH class structures of *J. mandshurica* population on the shady (a) and sunny (b) slopes.

The age class (as the X axis) was plotted against the percentage of plants in different age classes to the total number of plants (as the Y axis). The DBH class structures of *J. mandshurica* population at different elevational gradients were obtained (Fig. 4). The DBH class structures in H_1, H_2, and H_3 varied. The development from young seedlings to adult plants is discontinuous. The adult plants are relatively stable. The percentage of first age-class plants was the highest at all elevational gradients, which accounted for 39.0%, 20.7%, and 23.0% of the total plants, respectively. The percentage of second age-class plants accounted for 2.6%, 7.2%, and 12.9% of the total plants, respectively. Through the environmental sieve, first age-class seedlings developed into adult plants with a high death rate at different elevational gradients. The percentages of *J. mandshurica* plants in different age classes varied at the three elevational gradients. First age- to ninth age-class plants in H_1, H_2, and H_3 accounted for 90.01%, 96.90%, and 98.45% of the total plants, respectively. Thus, young and adult trees held a dominant position at different elevational gradients. The age structures were classified as a growth type. The DBH class structure of the overall population [Fig. 4(d)] showed that the age structure also belonged to a growth type.

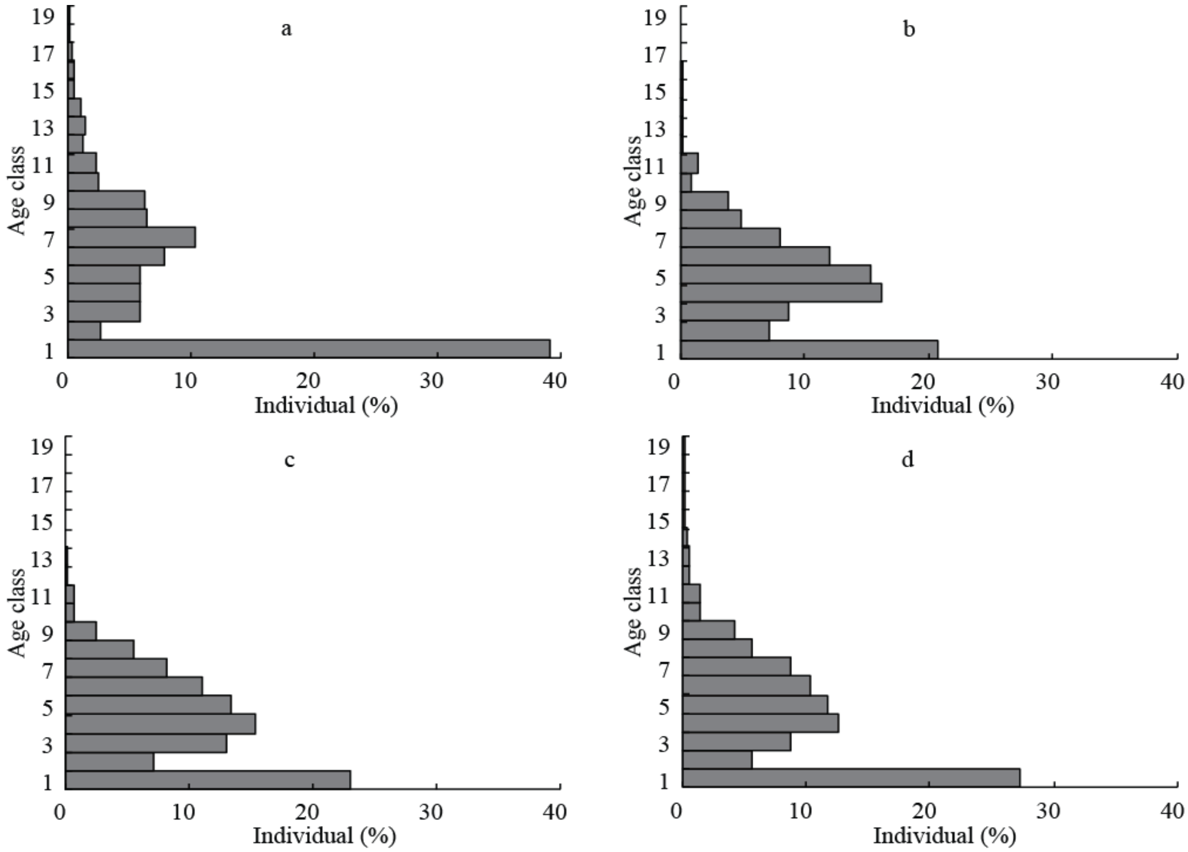

Fig. 4. DBH class structures of *J. mandshurica* populations in H_1 (a), H_2 (b), and H_3 (c), and the overall population (d).

Discussion

J. mandshurica plants in the same age class exhibit homogeneous DBH and tree height at different slope aspects and elevational gradients. The CVs of DBH and tree height for plants in the same age class are independent of slope aspect and elevational gradient. Such variation is mainly attributed to the biological and ecological characteristics of *J. mandshurica* population. Although first age-class seedlings have a high death rate, DBH class and height class structures are dominated by young and adult trees on the shady and sunny slopes and at different elevational gradients. The age structure belongs to a growth type. The number of *J. mandshurica* plants in the Wild Walnut Nature Reserve was over 2000 in 1961 (Dong *et al.,* 2012), over 3100 in 1989 (Xu, 1989; Xu & Zhu, 1991), and over 5500 in 2009 (Dong *et al.,* 2012; Zhang *et al.,* 2013). This finding confirms that *J. mandshurica* population belongs to the growth-type group. The age structure and quantity dynamics of *J. mandshurica* population in Gongliu County, Xinjiang can be revealed by replacing the age structure with DBH class or height class structures.

First age-class seedlings are the most abundant in *J. mandshurica* population. The high death rate of these seedlings directly leads to the extremely small percentage of seedlings in the second age class. However, the plants in the classes beyond the second age class tend to have a high survival rate. Thus, *J. mandshurica* population at the seedling age is r-strategist, but primarily K-strategist and secondarily r-strategist at the juvenile stage. The high death rate of young *J. mandshurica* seedlings is probably associated with *J. mandshurica* being a heliophile species. Population regeneration is difficult under a forest canopy with a large canopy closure (Bi, 1999). A field survey shows that *J. mandshurica* seedlings grow slowly. Before the 4th age class, the growth speed is only 4–6 cm annually. Growth is accelerated after the 5th age class (over 12 cm annually). The associated trees are mainly shade-tolerant evergreen or deciduous broad-leaved plants that grow rapidly, such as *B. tianschanica* Ruprecht and *P. tremula*. These broad-leaved plants are probably the main factors that contribute to the high death rate of young seedlings of *J. mandshurica*. The percentage of high age-class seedlings is extremely small in *J. mandshurica* population. Nutrient space requirement increases as juvenile and adult plants grow. A niche overlap with trees in the upper layer occurs. Thus, interplant competition is enhanced. In addition, plants in the high age class are already entering the decline phase. Such low competitiveness directly leads to an increased death rate.

The field investigation shows that the mean number of seedlings in first age class per hectare in the Wild Walnut Nature Reserve in 2006–2009 was 641 and that in 2012–2013 was 96, which is mainly the result of the lack of germplasm sources. The high price of wild walnut results in the excessive picking of seeds. The surviving seeds are foraged by rodents (wild walnut forests have many squirrels). The author only found over 60 seeds of *J. mandshurica* in the 3000 m^2 land surveyed during the field investigation in early April 2013. The artificial factor is undoubtedly another key influence in the regeneration of *J. mandshurica* population in Gongliu County, Xinjiang Province. *J. mandshurica* cannot propagate through root shoots. Moreover, given that young plants of *J. mandshurica* population are difficult to grow into adult plants through the environmental sieve, the prospect of the *J. mandshurica* population in China is not optimistic.

Plant organisms live in complex communities and the reasons for their death may be diverse. The biological environment, climate, and natural disasters influence plant growth (Feng *et al.,* 2003). The CVs of the height and the DBH for the same age class of *J. mandshurica* show that the age structure of the population is independent of slope aspect and elevational gradient. Although the overall desert landscape of the Yili Region in Xinjiang provides unfavorable conditions to *J. mandshurica*, the population in Xinjiang is mostly distributed in a relatively favorable climate environment with less frequent cold waves and dry wind. Typical sites with such favorable conditions include wide, violently carved front hills; mountainous river valleys; and canyons. *J. mandshurica* population is only distributed in four gullies in the Wild Walnut Nature Reserve, with similar community environments, temperatures, and precipitation patterns. Thus, data on the distribution area of *J. mandshurica* population are insufficient to analyze whether the height and DBH of seedlings in the same age class vary at different slope aspects and elevational gradients. Although the young seedlings of *J. mandshurica* population have a high death rate, this species remains dominant in the Wild Walnut Nature Reserve. Moreover, *J. mandshurica* is a tree species with a long life span. Young and adult trees dominate the population structure, which can be classified as a growth type. Without intensive external interference, *J. mandshurica* population will maintain such dominance in the community in the foreseeable future.

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