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MULTIPLE BANDS CHARACTERISTICS OF TREE-RING AND AGE OF *HALOXYLON AMMODENDRON* IN GURBANTUNGGUT DESERT

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Abstract

The characteristics of the multiple bands of *Haloxylon ammodendron* (C.A. Mey) Bunge tree-ring were studied in three edaphic types. Age equations were derived relating ground diameter and tree height, and the effects of irrigation on numbers and widths of growth bands at the longest radius were analyzed. Results showed that the number of growth bands ranged from 3.3 to 6.3 per year, the widths ranged between 0.181 mm and 0.473 mm. Multiple growth bands formed every growing season, leading to the conclusion that multiple growth bands in *H. ammodendron* tree-ring are a natural feature. A dark brown layer and a light brown one make up one growth band. The dark brown layers consists of fibres and vessels as well as some ray parenchyma, and each fibres layers with 22–35 cell layers; the light brown layers formed by vessels, fibres and abundant paratracheal axial parenchyma are 4–15 cell layers. The widths of growth bands at the longest radius increased significantly as the irrigation amount increased in three edaphic types ($p<0.01$). The numbers of growth bands at the longest radius had significant positive correlation with irrigation times. The ratio of dark brown layers to light brown layers of growth bands at the longest radius appeared to have a rising tendency with the increase in irrigation amount and times.

Key words: *Haloxylon ammodendron* (C.A. Mey) Bunge, Edaphic type, Widths of growth bands, Numbers of growth bands, Irrigation amount.

Introduction

Tree rings offered insights concerning the impacts of environmental variability on local ecosystems and natural resources (Liu *et al*., 2005). The features of tree rings varied in different environment: most trees formed one rings per year (Worbes, 1999; Borchert, 1999), while some tropical ring studies had reported the occurrence of two rings per year (Jacoby, 1989; Gourlay, 1995). Simultaneously, anomalous ring can be produced under the conditions of air pollution, periodic flooding, drought stress and mild frosts (Kramer & Kozlowski, 1979; Young *et al*., 1993; Kurczynska *et al*., 1997; Kozlov & Kisternaya, 2004). In *Callitris columellaris* F. Muell in central Australia, multiple rings were formed in some year in response to non-seasonal precipitation (Lange, 1965).

Haloxylon ammodendron belong to the family Chenopodiaceae. The main stem of the plant tends to form multiple growth bands. Carlquist (2001) believed that, in parenchyma outside of the vascular tissue in Chenopodiaceae, the multiple concentric rings of vascular tissue produced by successive cambia continually and form the secondary vascular tissue. The multiple growth bands are generated from successive cambium division (Carlquist, 2001; Toghraie, 2012). Toghraie (2012) proposed that wood structure of *Haloxylon persicum* is included phloem which lies between regions of secondary xylem and form a collection of wedges. These wedges through the phloem zone are connected with axial parenchyma, though they form a complete ring, where these rings demonstrate periods of growth. Yang *et al*. (2003) implied that in wood anatomy of *H. ammodendron*, there were no distinct growth ring boundaries, included phloem of foraminate type was distinct. In observation of tree-ring of *H. ammodendron*, we found that a dark brown layer and a light brown layer make up one growth band in *H. ammodendron* tree-ring, the number of growth bands could up to 6.3. But little was previously known about the causes of such growth bands. Studies showed that the radial growth in any given year integrates the effects of climate conditions, such as precipitation, of the plant in prior years (Fritts, 1976; Yu *et al*., 2008). During the growing season, the precipitation have a significant effect on the tree growth, ring width was positively correlated with precipitation (Akkemik, 2000). In Gurbantünggüt Desert, precipitation was the main factors effecting plants growth (Xu & Li, 2006), the question arises: how did the numbers and widths of growth bands in *H. ammodendron* change to cope with different edaphic types?

H. ammodendron is a typical desert plant, primarily found on shifting or semi-shifting sand dunes of the narrow sub-desert areas in middle and western Asia (Zou *et al*., 2010). The species is also termed a "super xerophyte" due to its particular drought tolerance that enables it to survive in prohibitive environments (Gao *et al*., 2010). This species had been selected as a pioneer plant for sand dune stabilization, and it is an excellent plant for evaluating disturbance and vegetation restoration in Gurbantünggüt Desert (Bedunah & Schmidt, 2000). With regard to *H. ammodendron*, more than one growth bands are formed in *H. ammodendron* tree rings, which increased the difficulty on age estimation through the tree-ring. The deviation generated when diameter class instead of the age class to study the physiological and ecological characteristics of *H. ammodendron* populations. We found that a significant correlation between tree height, diameter and age, consequently tree height and diameter could be used to establish the *H. ammodendron* age.

The objectives of this study are: (1) to reveal multiple growth bands features and analyze the strategies of the plant to adapt to drought conditions; and (2) to analyze the effects of irrigation on numbers and widths of growth bands at longest radius.

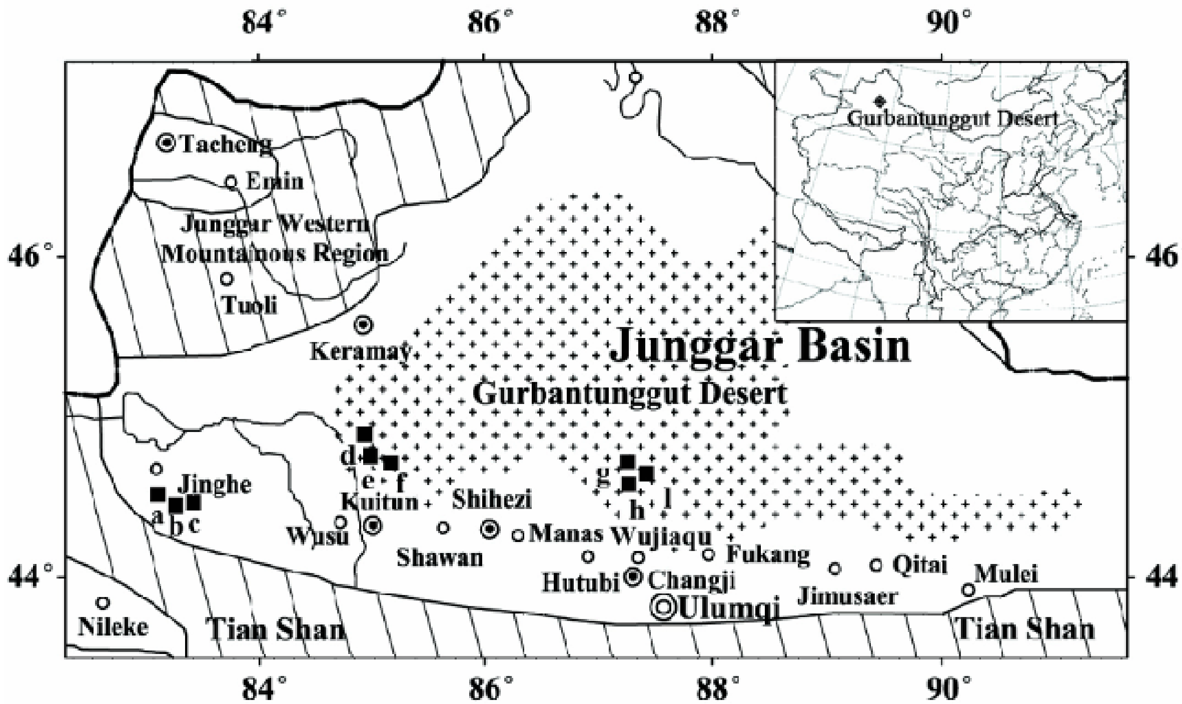

Fig. 1. Locations of sampling sites in Gurbantunggut desert.
The sampling sites are showed by letter: a, b, c, d, e, f, g, h, i and are set from west to east.

Materials and Methods

Study area: The three study sites, Jinghe, Kuitun and Wujiaqu, are located in southern Gurbantünggüt Desert (44°17.322′ – 45°01.681′ N, 83°12.079′ – 90°02.541′ E, Fig. 1). The area has an arid climate, with an average annual temperature of 5–5.7°C, evaporation of 2000–2800 mm, strong winds for 25–77 days, wind velocity of 2–3.6 m/s, precipitation of 80–190 mm and 2700–3050 hours of sunlight (climate data provided by weather stations for the years 1979–2008). Unlike most other arid zones, the study area also has snow cover for about 95–110 days per year on average, lasting from late November until the middle of the following March. The predominant soil is stable or semi-stable aeolian sand or gravel. In the areas studied, the edaphic type at Jinghe is gravel, with sand at Kuitun and loam at Wujiaqu. Soil texture composition was analyzed by a laser diffraction system (Sympatec GmbH, System-Partikel-Technik, and Clausthal-Zellerfeld, Germany). The percentages of pebble or stone block, sand and clay, were 35.9, 51.5 and 12.6% in gravel, but for the sandy soil and loam, the respective percentages of sand, silt and clay were 3.4, 91, 5.6%, and 5.9, 62.5, 31.6%. Stable or semi-stable dunes account for 96% of the total area of the desert, with psammophytic and drought-resistant plants being the main desert vegetation.

Tree selection and sampling: To analyze characteristics of the multiple growth bands, we selected trees of known age taken from the records of recent afforestation. At each site, samples of trees aged from five to ten years were selected at one-year-old age intervals, i.e. 5, 6, 7, 8, 9 and 10 years old. Three sampling sites were located within each edaphic type. In 2008, three trees in each age class were randomly selected at each sampling site from among the dominant trees, with the restriction that they had a healthy crown and no visible damage or abnormality on either the stem or crown. A total of 135 trees were selected in each of the three edaphic types. Two radii were selected on each disk for measuring growth band width to the nearest 0.001 mm using a Leica DM 2000 trinocular research microscope.

In order to derive a general empirical formula from the data for the age of any tree, sample trees having diameters at ground diameters of 1 cm, 2 cm, 3 cm, …, 16 cm were selected in each edaphic type (growth bands could not be detected clearly for trees with ground diameter >16 cm due to deterioration, limiting selection to trees with ground diameter 1 cm -16 cm). Four trees were selected in each diameter class, sixty-four individuals at each edaphic type, totalling 192 trees across the three edaphic types. Three sets of data were used to derive the formulas, one data set being used to back-check the accuracy of the formula. In the field, the height and ground diameter all sampled trees were measured using either a staff gauge or vernier calliper.

Growth band measurements: Trees were cut at ground diameter and discs l.0 cm thick were removed from each stem, air-dried and sanded until the cells could be seen clearly under a microscope.

Pot experiment: One-year-old seedlings of *H. ammodendron* with similar size and vigor were planted on beginning of April, 2008. Pot experiment was conducted to analyze the effects of irrigation times on numbers of growth band at longest radius and irrigation amount on width of growth band at longest radius. The experiment was conducted in greenhouse of Agriculture Institute, Shihezi University, The temperature in the greenhouse was 26 ± 4 , RH 60–65%, and 14/10 h day/night. Both the diameter and height of pot were 50 cm, loam, sandy and gravel soil were selected and each pot was filled with 70 kg of dried soil that come from Wujiaqu, Kuitun and Jinghe, respectively. A total of 290 individuals were selected on April 20th, 2009 (200 individuals were used to research the influences of irrigation times on numbers of growth band at longest radius, the residual 90 individuals were used to research the influences of irrigation amount on widths of growth band at longest radius). Ten individuals were cut at ground diameter before germination; the numbers and widths of growth band at longest radius were measured and were used as basic data of growth bands of three-year old individuals.

Effects of irrigation times on numbers of growth band at longest radius: from April 20th to October 20th, 2009, the irrigation is carried out four times (interval 45 days), six times (interval 30 days) and nine times (interval 20 days). The irrigation reached saturated water content at first time. Thereafter, the irrigation amount each time was 10% of dried soil weight (7 kg water). After the first irrigation, ten individuals were randomly selected and cut before every irrigation at ground diameter according to different intervals. The numbers and widths of growth band at longest radius were measured. The last cut of all treatments were carried on October 20th.

Effects of irrigation amount on widths of growth band at longest radius: from April 20th to October 20th, 2009, the irrigation is carried out six times (interval 30 days). The seedlings were irrigated using different amounts of water in each treatment as follows: 5%, 10% and 15% of dried soil weight. Trees in each treatment were cut at ground diameter on October 20th; both the light brown layer and dark brown layer widths of growth band at longest radius were measured.

Derivation of age equations: The number of growth bands at longest radius was determined from the frequency distribution of growth bands: the weighted mean number of growth bands in sand, loam and gravel was 4.8, 5.4 and 3.9 respectively. Data was fitted to linear, exponential and polynomial regressions to estimate the ages of all trees for the three edaphic types, choosing ground diameter and tree height as the variables.

Observation of anatomy of growth bands: Three samples, 25×10×10 mm axially, contained phloem, cambium, developing and older outer xylem were cut on July 1th, 2009. They were fixed in formalin-ethanol-acetic acid (FEA) solution, then reduced to blocks of dimensions 2×2×3 mm, dehydrated in iso-butanol and embedded in paraffin, after the method of Rossi *et al*. (2006). Transverse sections of 12 μm thickness were stained with safranin (1 g in 100 ml of 70% ethanol) and hematoxylin (0.5 g in 100 ml water) and observed under a Nikon Eclipse 800 light microscope (bright field and polarized light) and analyzed with a Lucia G 4.8 image analyser. The vessels, fibres, axial parenchyma and ray parenchyma (number of cell layers along vertical sections) were then examined.

Statistical analysis: Simple linear regression was used to investigate the correlations between irrigation times and numbers of growth band at longest radius. Analysis of variance was used to check for differences in average growth band number and width, ratio of light brown layer and dark brown layer among the loam, sandy and gravel edaphic types or irrigation times, as well as the ages among the loam, sandy and gravel edaphic types.

Linear, exponential and polynomial etc. regression models were used to establish the age function of *H. ammodendron*. The total relative error, average relative error, average absolute relative error and prediction precision were used to evaluate age equation. The optimal equations were selected by back-check. Statistical analyses were performed using the SPSS 11.5 software, and results plotted using Origin 7.5 software. A one-way ANOVA was applied to test the significance of the above. A confidence interval of 0.05 was used in all tests.

Results

Multiple growth bands features: The main stems of *Haloxylon ammodendron* exhibited obvious multiple growth bands and partial growth. The longest and shortest radius displays the largest and smallest number of rings, respectively. The remaining part is located within it. The number of growth bands along each radius was then counted under a microscope for all samples. The numbers of growth band both the longest and shortest radius were ordered similarly at each site ($p<0.01$): most growth bands for loam, followed by sand, and fewest for gravel (Table 1). The numbers of growth band were more at the longest radius than the shortest radius at three edaphic types. There were differences among different ages at each edaphic type. The numbers of growth band in loam ranged from 4.53 to 6.25, for sandy and gravel soil, the numbers of growth band ranged from 4.37 to 5.84 and 3.25 to 5.21, respectively.

The widths of growth band at the longest radius were wider than for the shortest radius at three edaphic types. There were differences among different ages at each edaphic type. The widths of growth band in loam ranged from 0.267 mm to 0.473 mm, for sandy soil was from 0.241 mm to 0.326 mm and for gravel soil was from 0.181 mm to 0.265 mm. The mean widths of growth band at the longest and the shortest radius in descending order: loam > sandy > gravel (Table 2).

Table 1. Mean number of the growth band of tree-ring in three edaphic types.

Age	Loam		Sandy		Gravel	
	Mean numbers of growth band at the longest radius	Mean numbers of growth band at the shortest radius	Mean numbers of growth band at the longest radius	Mean numbers of growth band at the shortest radius	Mean numbers of growth band at the longest radius	Mean numbers of growth band at the shortest radius
5	6.11 ± 0.08 d	4.64 ± 0.11 d	5.60 ± 0.18 c	4.41 ± 0.11 e	5.10 ± 0.18 e	3.40 ± 0.10 e
6	6.25 ± 0.04 a	4.74 ± 0.09 a	5.84 ± 0.15 a	4.57 ± 0.12 a	5.21 ± 0.09 a	3.68 ± 0.14 a
7	6.22 ± 0.05 b	4.69 ± 0.13 b	5.73 ± 0.11 d	4.55 ± 0.17 d	5.15 ± 0.18 d	3.59 ± 0.15c
8	6.18 ± 0.05 b	4.67 ± 0.07 b	5.67 ± 0.18 b	4.52 ± 0.12 b	5.08 ± 0.14 b	3.51 ± 0.12 b
9	5.92 ± 0.13 b	4.62 ± 0.11 b	5.45 ± 0.06 d	4.68 ± 0.11 d	4.95 ± 0.18 d	3.42 ± 0.10 c
10	5.87 ± 0.04 c	4.53 ± 0.09 c	5.36 ± 0.14 e	4.37 ± 0.10 c	4.86 ± 0.13 c	3.25 ± 0.17 d
Ft	999.9	237.2	61	102.2	93.4	32.2
Mean	6.09	4.65	5.61	4.52	5.06	3.48
p-value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

Values are means ±S.E (the standard error of the mean). a-e: letters signify differences among the different ages

Table 2. Mean width of growth band of tree-ring in three edaphic types (mm).

Age	Loam		Sandy		Gravel	
	Mean widths of growth band at the longest radius	Mean widths of growth band at the shortest radius	Mean widths of growth band at the longest radius	Mean widths of growth band at the shortest radius	Mean widths of growth band at the longest radius	Mean widths of growth band at the shortest radius
5	0.465 ± 0.007 d	0.276 ± 0.014 d	0.314 ± 0.014 d	0.251 ± 0.009 d	0.259 ± 0.017 d	0.196 ± 0.009 d
6	0.473 ± 0.005 a	0.281 ± 0.011 a	0.326 ± 0.010 a	0.259 ± 0.007 a	0.265 ± 0.011 a	0.201 ± 0.008 a
7	0.468 ± 0.003 d	0.276 ± 0.006 d	0.221 ± 0.011 d	0.252 ± 0.009 d	0.261 ± 0.009 d	0.199 ± 0.013 d
8	0.461 ± 0.003 b	0.275 ± 0.007 b	0.318 ± 0.013 b	0.248 ± 0.010 b	0.256 ± 0.008 b	0.194 ± 0.010 b
9	0.458 ± 0.009 e	0.271 ± 0.011 e	0.312 ± 0.014 e	0.244 ± 0.007 e	0.249 ± 0.014 e	0.188 ± 0.008 e
10	0.455 ± 0.003 c	0.267 ± 0.004 c	0.297 ± 0.009 c	0.241 ± 0.013 c	0.243 ± 0.009 c	0.181 ± 0.009 c
Ft	0.42	0.251	0.292	0.227	0.241	0.18
Mean	72.88	17.26	4.45	7.43	6.79	2.34
p-value	62.60%	37.40%	56.30%	43.70%	57.20%	42.80%

Values are means ± S.E (the standard error of the mean). a-e: letters signify differences among different ages
Mean proportion refers to widths at the longest or shortest radius account for proportion of the total ground diameter

Growth band at the longest radius and irrigation: Different irrigation times caused the variation of total irrigation amount. The widths of growth band at the longest radius increased significantly as the total irrigation amount increased in three edaphic types (p<0.01). In the same irrigation amount, the widths of growth band at the longest radius were differed among edaphic types, which showed the tendency of loam > sandy > gravel under three irrigation amount (p<0.01). The total irrigation amount also had influences on the ratio of light brown layer and dark brown layer. The ratio of light brown layer and dark brown layer appeared to have a rising tendency with the increase in irrigation amount (Table 3).

Based on mean value of numbers of growth band at the longest radius of three edaphic types, the significant regression equations were developed between irrigation times and the numbers of growth band at the longest radius. Irrigation times had significant positive correlation with numbers of growth band at the longest radius (Fig. 2). At interval 45 days, the numbers of growth band at the longest radius increased from 7.2 to 11.5. When intervals were 30 days and 20 days, the numbers of growth band at the longest radius increased from 7.2 to 12.7 and 14.1, respectively. There were strongly differences among numbers of growth band at the longest radius of three irrigation times. The ratio of light brown layer and dark brown layer at the longest radius was analyzed, and which significantly decreased as irrigation times decreased (Fig. 3).

Derived formula for tree age: Equations with optimization were used to estimate the age of *H. ammodendron* in the three edaphic types. Three significant regression equations were derived from the observed data:

For sand: $A = 5.52611\ D + 2.90390\ H + 13.92827$, (Eq. 1)
For loam: $A = 6.7891\ D + 4.3666\ H + 24.\text{-}0235$, (Eq. 2)

For gravel: $$A = \frac{18.535\left(D^2 H\right)^{0.2809}}{3.9},$$ (Eq. 3)

where A is tree age, D is ground diameter, and H is tree height.

High back-check accuracy was found for the three edaphic types (sand 98.4%, loam 95.8% and gravel 96.1%) indicating that, under desert conditions, the age of *H. ammodendron* plants is a function of ground diameter and tree height.

Table 3. Effects of irrigation amount on ratio of light brown layer to dark brown layer and width of growth band at the longest radius.

Edaphic types	Items	Irrigation amount (Kg)			
		21.0	42.0	63.0	Ft
Loam	Ratio of light brown layer to dark brown layer	0.724±0.013 c B	0.791±0.018 b B	0.853±0.021 a A	88.3
	Average width of growth band at the longest radius (mm)	1.010±0.022 c A	1.244±0.046 b A	1.286±0.027 a A	35.1
Sandy	Ratio of light brown layer to dark brown layer	0.711±0.028 c A	0.786±0.029 b A	0.835±0.025 a A	120.3
	Average width of growth band at the longest radius (mm)	0.983±0.019 c B	1.125±0.035 b B	1.247±0.029 a B	59.2
Gravel	Ratio of light brown layer to dark brown layer	0.583±0.012 c C	0.652±0.025 b C	0.715±0.019 a B	71.0
	Average width of growth band at the longest radius (mm)	0.834±0.035 c C	1.099±0.009 b B	1.186±0.028 a C	86.3

Values are means ±S.E (the standard error of the mean). a-c: letters signify differences among the different irrigation amount
A-C: letters signify differences among the different edaphic types

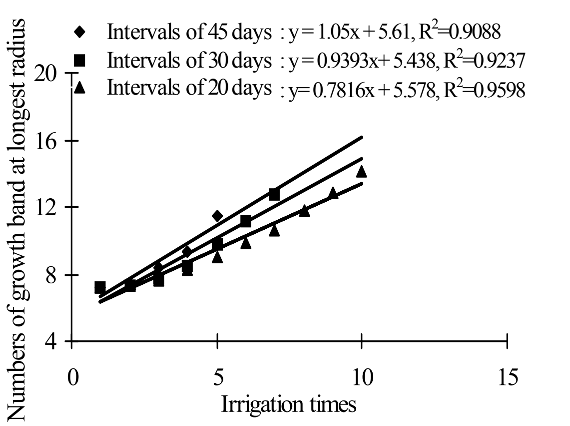

Fig. 2. Correlations between irrigation times and numbers of growth band at longest radius.

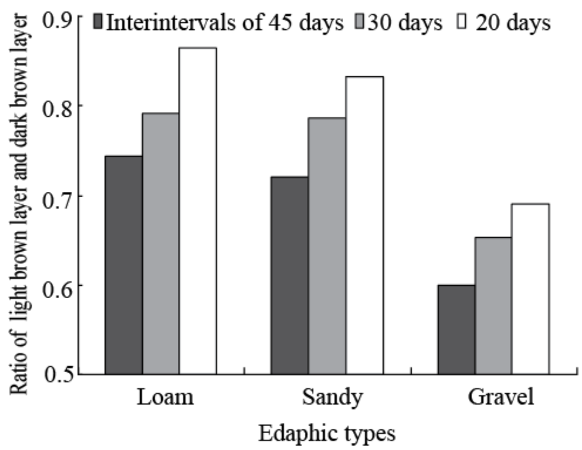

Fig. 3. Correlations between irrigation times and ratio of light brown layer and dark brown layer in three edaphic types

Age features in different edaphic types: Based on the *D* and *H* values in Eqs (1) – (3), the weighted mean ages of the population (basing on age proportion of plants in the same edaphic type × corresponding age) and maximal ages (basing on the maximal ground diameter and height of plants in the same edaphic type) were calculated for the three edaphic types. A significant difference in age characteristic was evident between the three edaphic types: the maximal age of plants in loam were greater than for the other edaphic types, with weighted mean population ages of 14.6 yr in loam, 10.9 yr in sand and 8.2 yr in gravel (Fig. 4).

Discussion

Growth bands features and causes: In the present case, growth band width measurements showed that the proportion of light brown component to dark brown component was 59.9% -86.4% (Fig. 3). The dark brown layers consisting of fibres and vessels as well as some ray parenchyma, each fibres layered with 22-35 cell layers; the light brown layers formed by vessels, fibres and abundant paratracheal axial parenchyma with 4–15 cell layers (Fig. 5). The vessels are solitary or grouped in clusters consisting of 4 to 9, the cross sections of vessels are full of tyloses and adjacent fibres (Fig. 5). At scanning image and close up photograph of cross section, xylem rays are radial distribution from pith to phloem (Fig. 6a, b). In close up photograph of radial section and tangential section, we could observe the thick-walled rays in this plant had two types: uniseriate and multiseriate (Fig. 6d).

It is well known that most deciduous trees form one ring per year (Worbes, 1999; Borchert, 1999), two rings in tropical areas with two distinct dry seasons per year (Jacoby, 1989; Gourlay, 1995), or an irregular formation of rings (Sass *et al*., 1995). Nonetheless, growth ring production may vary. For example, some tropical rainforest trees do not produce annual rings (Lieberman *et al*., 1985; Whitmore, 1998). In Central Australia where rainfall is non-seasonal, the conifer *Callitris columellaris* F. Muell produces multiple rings in some years and none in others. Lange (1965) found that the broad regional pattern of tree rings in *C. columellaris* shown by the variable number of rings -from about 55 to 80 in different trees of the same age-implies variability in the number of rings produced over a given time by trees from the same area, an example of what are known as “false” rings.

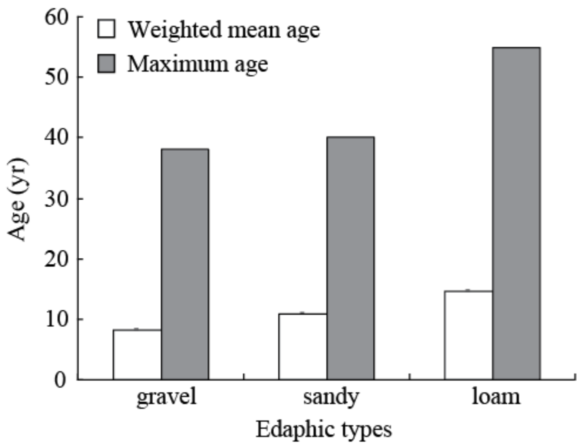

Fig. 4. Characteristic of ages in three edaphic types
For gravel, n = 946, for sandy, n = 1455, and for loam, n = 790

Usually, cambial growth of tree rings stops briefly in response to some form of stress, then resumes at different times (Kramer & Kozlowski, 1979; Fritts, 1976). Affected by desert climate, *H. ammodendron* tree-ring always forms multiple growth bands in the growing season. This phenomenon can be testified by pot experiment. The widths of growth band at the longest radius increased significantly as the irrigation amount increased in three edaphic types in the greenhouse ($p<0.01$). The ratio of light brown layer and dark brown layer at the longest radius appeared to have a rising tendency with the increase in irrigation amount and times (Fig. 3, Table 3). With irrigation amount and times increased, the ratio of light brown layer to dark brown layer increased 19.3% and 15.21%, respectively. Indicating that the light brown layer was sensitive to irrigation amount and the dark brown layer was corresponding to sustained drought. The plants in the present study produced more than 3.3 growth bands at the shortest radius and 4.9 growth bands at the longest radius (Table 1). We can conclude from the pot experiment that the numbers of growth band at the longest radius had significant positive correlation with irrigation times (Fig. 2). Therefore, it was concluded that formation of multiple growth bands were triggered by precipitation pulse events that led to high soil water content and moderate soil temperature in desert systems. The multiple growth bands characteristics of *H. ammodendron* in Gurbantünggüt desert is similar to *H. persicum* in central Iran.

Life span of *Haloxylon ammodendron* in different edaphic types: In arid regions, drought stress decreases C and N mineralization, mineral N pools, and nutrient supply to plant roots (Huxman *et al*., 2004; Ford *et al*., 2007), causing marked effects on plant growth. *H. ammodendron* has become generally well adjusted to an arid environment through a variety of physiological and morphological adaptations including photosynthesis, transpiration rate, water use efficiency, and aboveground/underground biomass allocation (Wei *et al*., 2007; Shan *et al*., 2009; Zou *et al*., 2010), and we may anticipate life span strategies that ensure regeneration in drought conditions. In this study, the maximal life span of individuals was 55 yr (Fig. 4), which is similar to that of *Tamarix hispida* Willd. in the Lower Reaches of Tarim River (Wang & Pan, 2009), but less than for *Reaumurta soongorica* in the Loess Plateau (Xiao *et al*., 2006). Thus, the life span of *H. ammodendron* is certainly orders of magnitude shorter than, for instance, living bristlecone pines are more than 4000 years old (Flanary & Kletetschka, 2005); the life spans of different species may be explained by variation of genetic factors (Finch & Tanzi, 1997). The differences in life span of individuals within the same species may be due to environmental factors. It was well known that water availability is a key factor limiting ecosystem processes in deserts (Dube & Pickup, 2001), and the differences in life span of *H. ammodendron* in the three edaphic types seem to be related to water availability. This was investigated in the present study.

Polymorphism in morphology and variations in life span between different populations of the same species (MacCallum *et al*., 1998) can often be explained by differences in habitat, climate or evolutionary constraints (Hastings, 1997). Different life-cycle strategies within the same population are much harder to explain (Lampert & Linsenmair, 2002). The size or life span of some individual plants may have evolved to survive a variable environment (Dong, 1995); in general, increase in external hazards correlates with reduced life span (Kirkwood & Austad, 2000). In the present study, the availability of water to plants growing in gravel soil is problematical. Their maximal individual life span was found to be 38 yr, and the weighed mean life span of the population was 8.2 yr-both shorter than the life span of plants in the other edaphic types (Fig. 4). This indicated that in gravel soil, the roots growth was limited by heavy-textured soil, which could have severe consequences for water and nutrients absorption of desert plants, thereby affected the life span (Zou *et al*., 2010; Rosenvald *et al*., 2013). Plants with a short life span have a rapid generational turnover, which benefits the species by preventing overcrowding (Kirkwood, 2005): the small size and short life span may therefore have evolved to enable these plants to survive in an arid environment. In loam soil, the maximal individual life span was 55 yr and the weighed mean life span of the population was 14.6 yr. Good soil-moisture conditions satisfy the water requirement of large-sized individual plants, increase C and N mineralization, mineral N, and plant growth (Ford *et al*., 2007). Plants were found to live longer in loam than in the other edaphic types, enhancing their chances of survival and maintaining a high capacity for avoiding extinction (Morris *et al*., 2008): this indicates a strategy for adaptation to an environment more conducive to growth. Overall we can conclude that the life span of *H. ammodendron* can be adjusted by availability of water. That is to say, life span of *H. ammodendron* is reduced under poor water conditions; otherwise, the life span is prolonged. Such flexible strategies in life span in different edaphic types seem to be an evolutionary feature for survival in conditions of natural variation of water availability in desert regions.

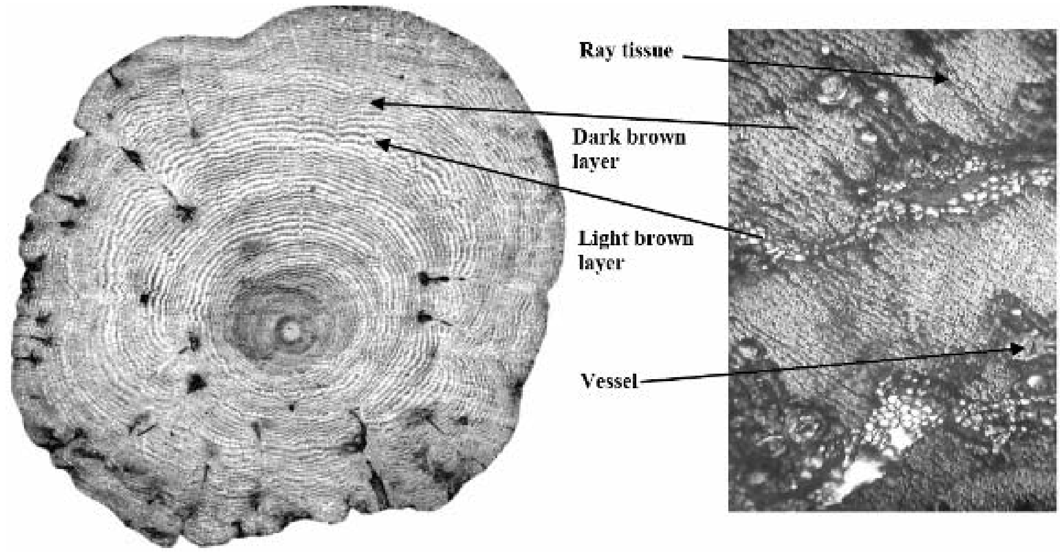

Fig. 5. Anatomical structure and sketch map of multiple growth band in *H. ammodendron* tree disc come from Kuitun with 15 year old and 72 rings.

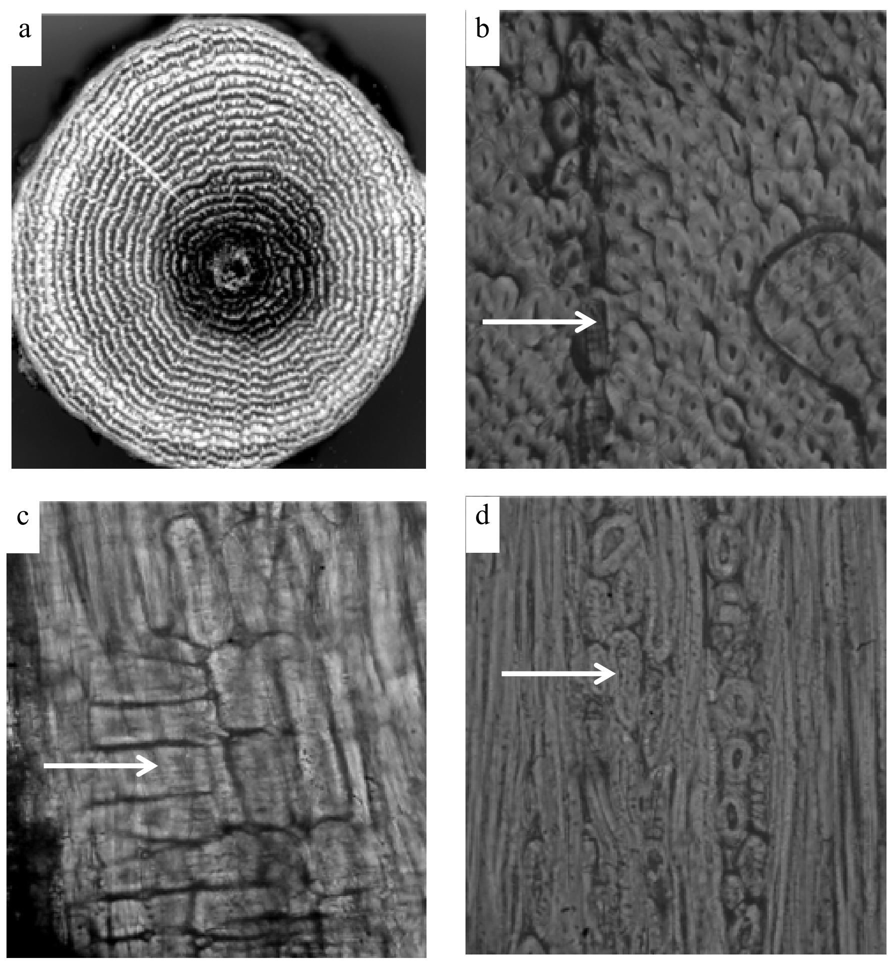

Fig. 6. Wood section and ray tissue of *H. ammodendron*.
a, scanning image of cross section; b, Close up photograph of cross section; c, Close up photograph of radial section; d, Close up photograph of tangential section. The arrows show the rays distribution.

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