The differences in the transpiration of non-irrigated *Haloxylon ammodendron* in hinterland of Gurbantunggut desert based on diameter

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ABSTRACT

The stem sap flow exhibited a bi-peaked or multi-peaked curve, with lower values at night than during the day. The ambiguous noon-depression phenomenon usually occurs during 14:00~16:00 from mid-May to the early September. Under the same environmental conditions, the larger the stem diameter, the larger the stem sap flow, and the more obvious the ambiguous noon-depression phenomenon. The daily changes of the sap flow were highest in June and lowest in September. There were differences in the monthly mean value in different plants, which may result from the differences in the crown and the number of assimilation organ. The daily accumulation showed a "S" trend between May and the end of August, and showed a straight line with the same slope in September and October. The larger the stem diameter, the larger the daily water use and the accumulative rate were. The sap flow was influenced by meterological factors, it was positively correlated with solar radiation, air temperature and wind speed, and negatively correlated with the air relative humidity, in which the solar radiation had the greatest impact on the sap flow. Under the same environmental condition, the larger the stem diameter, the better the correlation was. The correlation was the largest water use in July, and least in May and October. The larger the stem diameter, the more the water consumption was.

Keywords: the stem sap flow rate, *Haloxylon ammodendron*, differences, diameter, transpiration

1 INTRODUCTION

Evapotranspiration (ET) is the final stage of water consumption in the inland water cycle of arid land. Transpiration plays a critical role in the configuration of water resources in arid land and the maintenance of the energy balance in the ecological system (Bodner et al. 2007). *Haloxylon ammodendron* is a small deciduous tree or large shrub, and is the most widely distributed in the Central Asian desert vegetation. Due to the large drought resistance, *Haloxylon ammodendron* plays an extremely important role in the study of water transpiration in arid lands. In Chinese research field, there have been a lot of studies on transpiration of *Haloxylon ammodendron* in the Gansu Tengger

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Desert (Zhang et al. 2004), the Badan Jaran Desert (Xu et al. 2008), Gurbantunggut desert native *Haloxylon* forest (Sun et al. 2010). However, there have been limit studies on the transpiration differences resulted from diameter. In this study, the heat balance sap flow meter was used to measure the stem sap flow rate of *Haloxylon ammodendron* in the Gurbantunggut desert. The differences of the temporal changes of transpiration, water consumption, the relations between stem sap flow and meteorological factors resulted from diameter were studied.

2 STUDY AREA

The study area is located at the southern edge of the Gurbantunggut desert on the northern slope of the Tianshan Mountains, where there is a large area occupied by native saline desert vegetation (Cao et al. 2011). The climate is temperate zone continental desert, where it is hot and dry in summer and cold in winter. The average annual temperature is 6.6 ºC, the average precipitation is 160 mm, the average annual ET is 2,000 mm (Xu et al. 2007). Precipitation and soil water are the main water sources for the vegetation. Typical desert subshrubs such as *Haloxylon ammodendron* are distributed here, and it is an important area for ecological processes and preservation in arid central Asia (Fig.1).

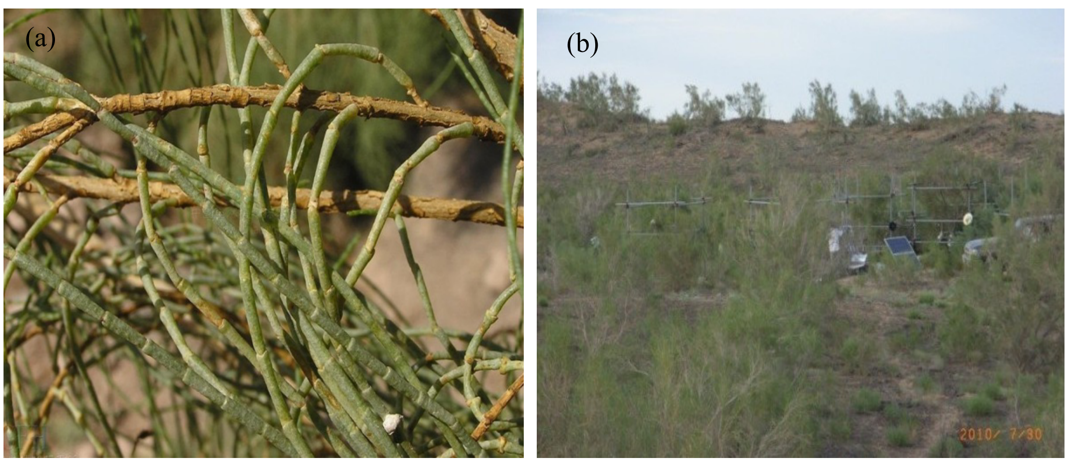

Fig. 1 The assimilation organ of *Haloxylon ammodendron* (a) and the natural landscape of the quadrat (b)

3 METHODS

3.1 The stem sap flow rate

The stem sap flow rate of *Haloxylon ammodendron* was measured by Sakuratani (1984) sap flow gauges, which were based on the heat balance method (Sakuratani 1981). A DT Logger80 was used to record and store the average data every 10 minutes. The diameters of all the branches were measured using a micrometer. The physical parameters of the each *Haloxylon ammodendron* in the quadrat (e.g. the height, the crown diameters, the stem base diameters) were also measured by a tape. 3 model trees were selected in the quadrat to studied (Table 1).

Table. 1 The physical parameter of *Haloxylon ammodendron*

	Diameter (cm)		height	East-west	Southeast-northwest	South-north	Southwest-northeast
No.	branch	plant	(m)	(m)	(m)	(m)	(m)

S1	1.07	22.9	3.4	2.27	1.2	2.52	0.81	1.8	1.5	1.07	22.9
S2	1.03	13.4	2.14	1.93	1.6	1.62	1.53	1.91	1.4	1.03	13.4
S3	1.04	9.9	1.88	1.58	1.30	1.40	1.10	1.44	1.10	1.20	0.90

3.2 Calculation of vegetation transpiration

The vegetation transpiration was calculated using the cross-sectional area method (Vertessy et al. 1995; 1997):

$$Q = \frac{f}{s} \times S_A \times H \tag{1}$$

Where s (cm^2) is the cross-sectional area of the branch installed a sap flow gauge; S_A (cm^2) is the total cross-sectional area of one plant, all the cross-sectional area was calculated from the diameters of the branches; f (g / h) is the stem sap flow rate of the branch installed a sap flow gauge; H (h) is the period of collecting the stem sap flow rate; Q (g) is the single-plant water consumption during the period of H.

3.3 The collection of meteorological data

A portable automatic weather station (Vatange Pro2Tm) was set in the quadrat to collect meteorological data with an interval of 0.5 h. The main parameters included average temperature, maximum temperature, minimum temperature, relative temperature, dew point, wind speed, wind direction, barometric pressure, rainfall, solar radiation. The collection of meteorological data were collected synchronizing with the stem sap flow rate.

4 RESULTS AND DISCUSSION

4.1 The differences of sap flow rate due to diameter

There were differences of stem sap flow rate of difference diameter. Fig 2 revealed that in the same day, the stem sap flow rate fluctuated in same trend. In night, there was no differences between *Haloxylon ammodendron* of different diameters, maintained at 0 ~ 0.1 L/h. In daytime, the differences of sap flow rate increased with the increase of sap flow, and it reached the peak during 14:00 ~ 16:00. Under the same environment, the larger of the diameter, the obvious of the "noon peak".

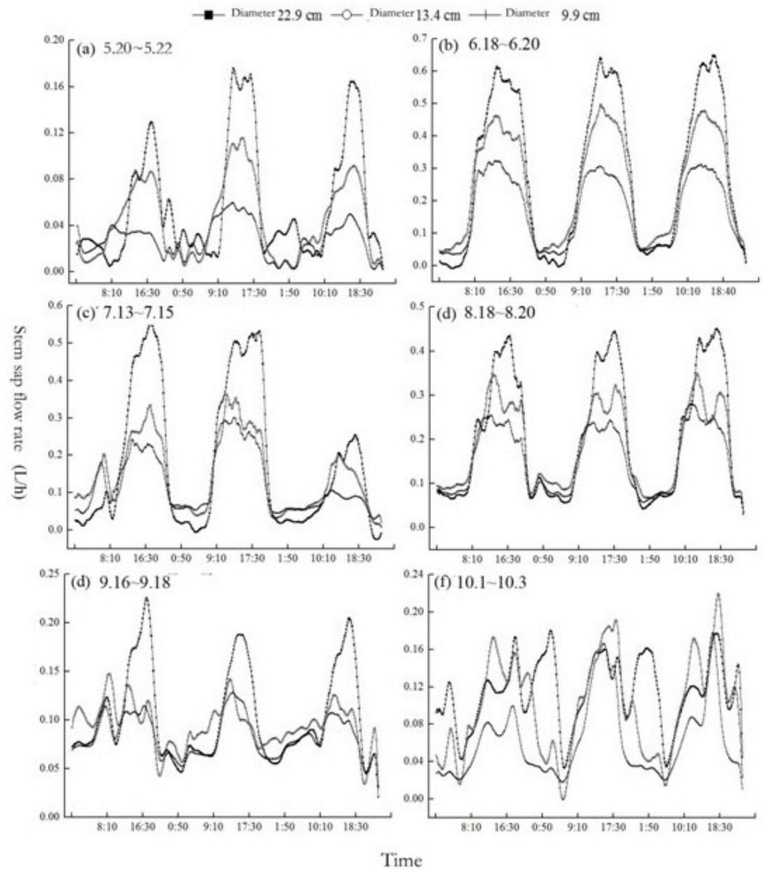

Fig. 2 Daily fluctuation of stem sap flow under different diameters

In the study period, the average stem sap flow rate of s1, s2, s3 was 0.276 L / h, 0.186 L / h, 0.136 L / h, respectively, which revealed the larger of the diameter, the larger of the average stem sap flow rate. There appeared some differences in the stem sap flow for different *Haloxylon ammodendron*, which may resulted from the individual size and assimilation of the number of branches required more exploration in the future.

Table 2 The month variety of the stem sap flow (L/h)

No.	May	June	July	August	September	the average value
1	0.167	0.359	0.407	0.282	0.164	0.276
2	0.060	0.208	0.276	0.204	0.182	0.186
3	0.051	0.135	0.177	0.189	0.128	0.136

4.2 The differences of water consumption due to diameter

The daily accumulative processes of stem sap flow were studied in the period of sunny weather. The larger the slope was, the faster the stem sap flow rate was. Fig 3 showed that the daily accumulative process showed an obvious "S" trend with two inflection points in the day and night respectively. In September and October, the stem sap flow rate maintains at 0.1 L/h, and there were no obvious peaks and valleys. The daily integral process showed some like a straight line.

Before and after sunrise, the stem sap flow accumulated slowly, and there was no difference of the slope. After the start of the flow, the first inflection point appeared during 5:00 ~ 7:30. S1 arrived earliest, and S3 arrived latest. The transpiration enhanced with the acceleration of sap flow accumulation. The slope was largest during 11:00 ~ 16:00, when the largest differences of the slopes appeared. The second inflection point appeared during 20:30 ~ 22:00. S3 arrived earliest, and S1 arrived latest. The accumulation appeared gently. The larger the diameter was, the larger the daily accumulation and its slope were, the earlier the first inflection point arrived, the later the second inflection point arrived, which revealed there would be greater water stress suffered by the plant.

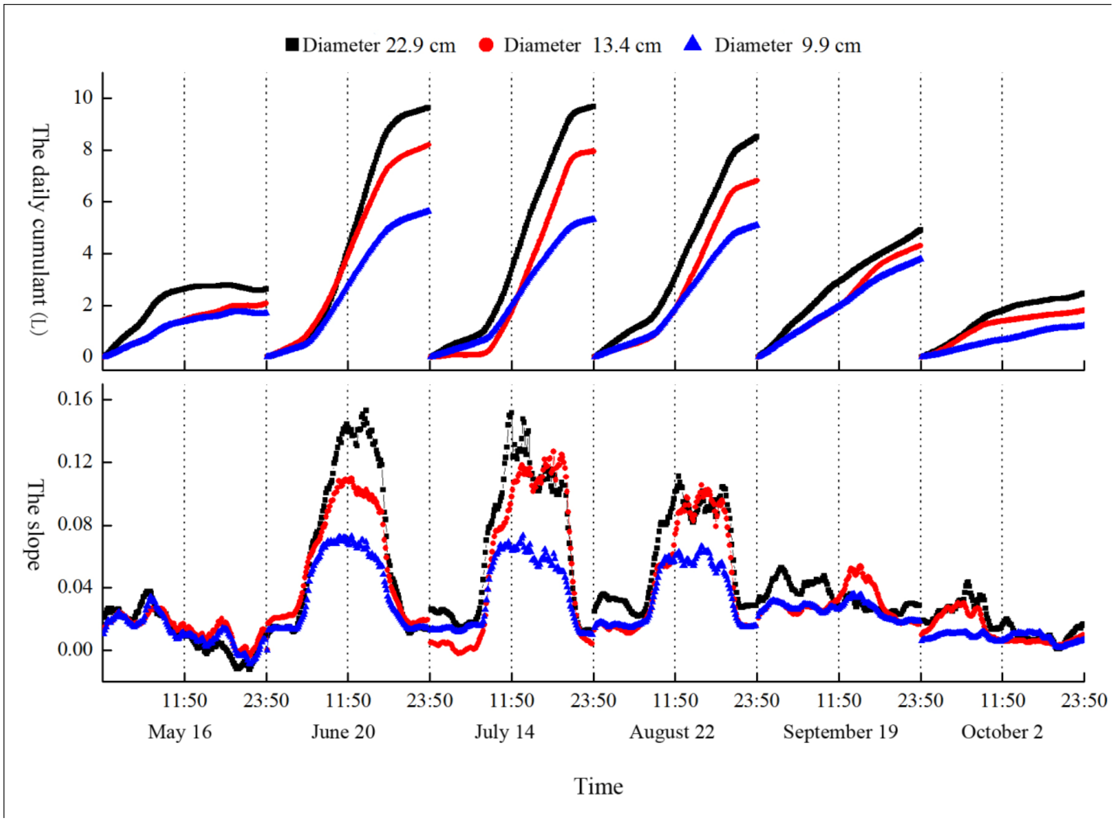

Fig. 3 The daily accumulation process and the corresponding slope of stem sap flow

Table 3 The time of break point in different days

	diameter(cm)	5.16	6.20	7.14	8.22	9.19	10.2
the first inflection point	22.9	—	5:00	6:10	7:00	—	—
	13.4	—	5:00	6:20	7:30	—	—
	9.9	—	5:10	6:40	7:30	—	—
the second inflection point	22.9	—	21:00	21:50	21:00	—	—
	13.4	—	20:50	21:50	20:50	—	—
	9.9	—	20:40	21:40	20:40	—	—

P.S：—. means there was on inflection point.

4.3 The differences of the meteorological response to stem sap flow rate due to diameter

There were positive correlations between the stem sap flow rate and temperature, solar radiation, wind speed, while there was a negative correlation between the stem sap flow rate and relative humidity. There was the most obvious relation between the stem sap flow rate and solar radiation, with a maximum of 0.906 (July, diameter of 22.9 cm), a minimum of 0.541 (May, diameter of 9.9 cm), followed by temperature, relative humidity and wind speed, which have been similar studies (Xie et al. 2008, Xu et al. 2008, Cao 2011, Gu et al. 2002). Moreover, there was an obvious temporal characteristics of the correlation, the most obvious correlation appeared in July, June and August, followed by May, September and October.

Sun suggested that spring flow is mainly affected by soil moisture ranged from 0~ 100 cm, while after 25, May, the soil volumetric water content ranged from 0 ~ 100 cm was less than 8.7% (Sun et al. 2010). In September and October, meteorological factors were not the main factors to affect the stem sap flow rate. The larger the stem sap flow is, the more affection by the meteorological factors is (Bao and Wang 2011). Shao pointed that higher temperatures are conducive to photosynthesis and radial growth of trees, increasing the width of tree rings (Shao et al. 1999). Therefore, under the same environmental conditions, the greater the diameter is, the greater the impact of the plants affected by meteorological factors was.

Table 4 Correlation analysis between sap flow rate of *Haloxylon ammodendron* and meterological factors

Months	Diameter cm		Temperature (ºC)	Relative humidity (%)	Solar energy (W/m^2)	Wind speed (m/s)
May	22.9	Related coefficient	0.596	-0.264	0.605	0.327
		Significant Level	0.003	0.003	0.003	0.003
	13.4	Related coefficient	0.535	-0.352	0.587	0.283
		Significant Level	0.003	0.003	0.003	0.003
	9.9	Related coefficient	0.521	-0.064	0.541	0.279
		Significant Level	0.003	0.003	0.003	0.003
June	22.9	Related coefficient	0.764	-0.624	0.882	0.294
		Significant Level	0.001	0.001	0.001	0.001
	13.4	Related coefficient	0.742	-0.585	0.856	0.339
		Significant Level	0.001	0.001	0.001	0.001
	9.9	Related coefficient	0.703	-0.544	0.803	0.314
		Significant Level	0.001	0.001	0.001	0.001
July	22.9	Related coefficient	0.896	-0.802	0.906	0.367
		Significant Level	0.001	0.001	0.001	0.001
	13.4	Related coefficient	0.724	-0.759	0.828	0.335
		Significant Level	0.001	0.001	0.001	0.001

	9.9	Related coefficient	0.686	-0.722	0.826	0.328
		Significant Level	0.001	0.001	0.001	0.001
	22.9	Related coefficient	0.821	-0.721	0.837	0.355
		Significant Level	0.002	0.002	0.002	0.002
August	13.4	Related coefficient	0.756	-0.665	0.794	0.328
		Significant Level	0.002	0.002	0.002	0.002
	9.9	Related coefficient	0.753	-0.679	0.728	0.321
		Significant Level	0.002	0.002	0.002	0.002
	22.9	Related coefficient	0.608	—	—	—
		Significant Level	0.003	—	—	—
September	13.4	Related coefficient	0.632	—	—	—
		Significant Level	0.528	—	—	—
	9.9	Related coefficient	0.508	—	—	—
		Significant Level	0.003	—	—	—
	22.9	Related coefficient	0.546	—	—	—
		Significant Level	0.003	—	—	—
October	13.4	Related coefficient	0.538	—	—	—
		Significant Level	0.003	—	—	—
	9.9	Related coefficient	0.53	—	—	—
		Significant Level	0.003	—	—	—

P.S：—. means no data.

5 CONCLUSION

(1) There were differences of stem sap flow rate of difference diameter. In night, there was no differences between *Haloxylon ammodendron* of different diameters, maintained at 0 ~ 0.1 L/h. In daytime, the differences of sap flow rate increased with the increase of sap flow, and it reached the peak during 14:00 ~ 16:00. Under the same environment, the larger of the diameter, the obvious of the “noon peak”. The larger of the diameter, the larger of the average stem sap flow rate. There appeared some differences in the stem sap flow for different *Haloxylon ammodendron*, which may resulted from the individual size and assimilation of the number of branches required more exploration in the future.

(2) The daily accumulative process showed an obvious “S” trend with two inflection points in the day and night respectively. In September and October, the stem sap flow rate maintains at 0.1 L/h, and there were no obvious peaks and valleys. The daily accumulative process showed some like a straight line. The larger the diameter was, the larger the daily accumulation and its slope were, the earlier the first inflection point arrived, the later the second inflection point arrived, which revealed there would be greater water stress suffered by the plant.

(3) There were positive correlations between the stem sap flow rate and temperature, solar radiation, wind speed, while there was a negative correlation between the stem sap flow rate and relative humidity. There was the most obvious relation between the stem sap flow rate and solar

radiation, followed by temperature, relative humidity and wind speed. Moreover, there was an obvious temporal characteristic of the correlations, the most obvious correlation appeared in July, June and August, followed by May, September and October. Under the same environmental conditions, the greater the diameter is, the greater the impact of the plants affected by meteorological factors was.

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