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A Study on the Characteristics of Water Consumption by Transpiration of Four Garden Plants in Linzhi City, Tibet

SU Xunfan[a],*

[a]Agricultural and Animal Husbandry College of Tibet University, Linzhi, China.
*Corresponding author.

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Abstract

Characteristics of water consumption by transpiration of the four garden plants in the nursery of Agricultural and Animal Husbandry College of Tibet University has been studied using the 2-year-old potted seedlings. The experiment shows that: All of the four plants had a higher water consumption by transpiration in the full light condition than in the full shade condition. The four plants had a basically same process of water consumption in the two conditions: All of them had a lower value in the morning and evening, and a peak during noon 13:00-15:00. In the full light and shade conditions, the water consumption rate of the four plants represented the same sequencing: *Sorbaria sorbifolia*> *Rosa chinensis Jacq.*> *Syringa oblata Lindl*> *Ligustrum quihoui Carr.*. In the full light condition, all four plants had the maximal water consumption rate in August and minimal water consumption rate in December. Among them, the water consumption rate of *Sorbaria sorbifolia* in December accounted for 79.26% that of August, and the water consumption rate of *Ligustrum quihoui Carr.* in December accounted for 84.22% that of August.

Key words: Linzhi, Tibet; Garden plants; Rate of water consumption by transpiration; Characteristics of water consumption by transpiration

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INTRODUCTION

In recent years, with the development of transportation and growth of immigrant population in Tibet, Linzhi City has developed rapidly and constructed many new commercial and residential buildings. This burgeoning city with increasingly denser buildings and modified streets has become a building block made by cement, asphalt and other materials of high heat capacity and strong conductivity. In addition, there are vehicle emissions, anthropogenic emissions that continue to increase heat and the blocks that do not help to spread heat, leading to a higher temperature in the city than the suburbs. The growth and ecological habit of the forest is particularly important for Linzhi city, which has been praised as the "region south of the Yangtze River". In autumn especially, Linzhi is often windy, dry and has other inclement weathers, which accelerates the water consumption of trees and soil desiccation. Plants, however, can spread water into air by transpiration and absorb heat from the surrounding environment, which reduces the ambient air temperature and increase air humidity. This ecological effect can improve the urban microclimate and improve urban residents' living comfort. Therefore, the study on the use of plant water, especially on transpiration, is crucial for understanding the living process of plants and the ecological relationship between plants and environment. The water consumption rate, environmental factors and water consumption quantity of *Sorbaria sorbifolia, Rosa chinensis Jacq., Syringa oblata Lindl. and Ligustrum quihoui Carr.* has been observed to study the law of their water consumption and to provide a reference for a rational allocation of urban tree species.

1. THE EXPERIMENTAL FIELD

Linzhi city is located in southeastern Tibet and the downstream of southeastern Brahmaputra River, with an

average altitude of 2960m. Its coordinate is 92°09′43″-98°18′30″E, 27°33′02″-30°04′26″N, and has a higher terrain in northwest and lower terrain in southeast, which are largely different in vertical geomorphology. Many rare plants and well-preserved native forests make it a natural museum. Linzhi also has a greatly different average temperatures in regions, which are gradually reduced from 18℃ to 0℃ from the south to north, and that of the east is higher than the west. The general trend of annual precipitation distribution is gradually reduced from the south to the east, north and west. The water distribution is uneven and there are evident wet and dry seasons. Linzhi has an annual rainfall of about 650 mm, an annual average temperature of 8.4-8.7℃, an annual average sunshine of 2,022.2 h, a frost-free period of 180 days, and an annual average relative humidity of 63%. Its evaporation capacities are largely different in regions, whose general rule is that the west> the east> the south. Due to the long-term warm air of Bengal Bay and the influences of Himalayas Mountain and Mira Hill, it has a fairly mild winter and rather cool summer, and is a humid and semi-humid region with wind in all four seasons. It is not only rich in natural resources, but also has a pleasant climate, plenty of sunshine, fresh air, abundant groundwater resources and plant species and fertile land, which provide a good natural condition for the growth of a variety of plants. Linzhi is the third largest forest area and the largest virgin forest area, with the forest area of 2.64 million hm^2 and the forest coverage rate of 46.1%, accounting for 42.3% of the forest reserves of Tibet—and 7.5% that of the country. Linzhi has a total of 19 soil types, 28 soil sub types, 91 soil genuses and 306 soil species. Its principal type of vegetation is *sparse alpine cushion vegetation*, including the dark coniferous forest represented by *Picea-Abies*, the bright coniferous forest represented by *alpine pine* and *Yunnan pine*, the evergreen hardwood forest represented by Quercus aquifolioides and the deciduous broad-leaved forest represented by birch.

The experimental field is the nursery in Agricultural and Animal Husbandry College of Tibet University located in Linzhi city, Tibet with an area of 100 hm^2. The soil is mostly sandy loam with a groundwater level of 1.5 m.

2. EXPERIMENTAL MATERIALS AND METHODS

2.1 Experimental Materials

The materials are the five representative plants in Agricultural and Animal Husbandry College of Tibet University: *Sorbaria sorbifolia, Syringa oblata Lindl., Ligustrum quihoui Carr*. and *Rosa chinensis Jacq.*.

The materials have been prepared two months in advance of the study. Five kinds of well-grown plants, six two-year-old seedlings per kind sharing resemblance were selected for the experiment. The materials were transplanted into the 20 cm-high, 26 cm-diametered plastic pots, with the original soil from the nursery and an appropriate amount of humus soil. The pots were then placed on the ground of the nursery and under routine conservation to ensure a healthy growth.

2.2 Experimental Methods

Two treatments were conducted in the experiment, full light and full shade (with an injection of scattered light). Materials were observed repeatedly six times for a consecutive seven days per month, from August, the first month after the transplantation, to December. The seedlings were well watered the night before observation, and the pots were sealed with plastic at the bottom and edge to avoid moisture evaporation and seepage. The observation was performed from 07:00-19:00 every two hours during observation. Soil samples were taken from each pot for drying everyday before the test.

2.3 Test Methods

(a) Leaf Area

A representative leaf would be selected for area determination by the use of graph paper, and then the number of leaves of the seedlings would be calculated for the total leaf area. The unit was m^2.

(b) Water Consumption

Water consumption of the seedlings would be measured every two hours with a BP-3400 balance whose weighting precision was 0.1g. The unit was g/h.

(c) Soil Moisture

It was measured before and after drying of the soil samples.

(d) Water Consumption Rate by Transpiration

The rate between water consumption and leaf area measured every two hours was water consumption rate. The unit was g/m^2.

3. RESULTS AND ANALYSIS

3.1 Water Consumption Rate Under Different Light Conditions

3.1.1 Daily Water Consumption Process Under Different Light Conditions

As can be seen from Figure 1, the water consumption rates of the four plants in full light were all higher than that in full shade, reflecting the significant impact of light on the water consumption rates of plants. *Sorbaria sorbifolia* had the largest difference in water consumption under different lighting conditions, whose water consumption in shade was 81.7% of that in full light. *Lingustrum quihoui Car.*. had the smallest difference in water consumption under the two lighting conditions, whose water consumption in shade was 95.2% of that in full light. Among the four

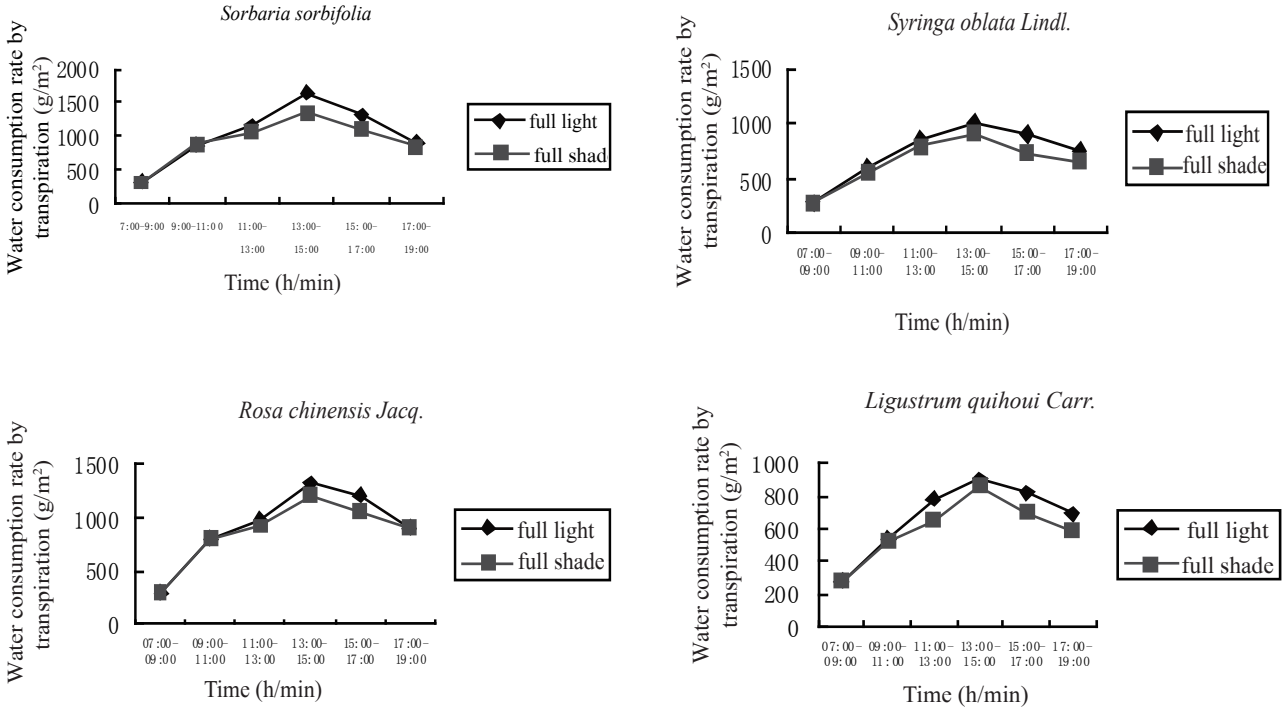

Figure 1
The Water Consumption Rates by Transpiration of the Four Plants Under Different Lighting Conditions

plants, the water consumption rate of *Sorbaria sorbifolia* was affected the most by light, thus it should be given appropriate shading in planting. In addition, the daily water consumption process of the four plants were basically the same under different lighting conditions, showing a single peak curve with a lower point in the morning and evening, and a peak at noon 13:00-15:00. *Sorbaria sorbifolia,* for example, in the morning at 09:00-11:00 in full light, had a water consumption rate of 878.42 g/m^2, and in full shade a water consumption rate of 879.21 g/m^2. At noon 13:00-15:00 in full light, it had a water consumption rate of 1652.11 g/m^2, and in full shade, it had a water consumption rate of 1350.23 g/m^2.

3.1.2 Comparison of Water Consumption Rates by Transpiration in Full Light

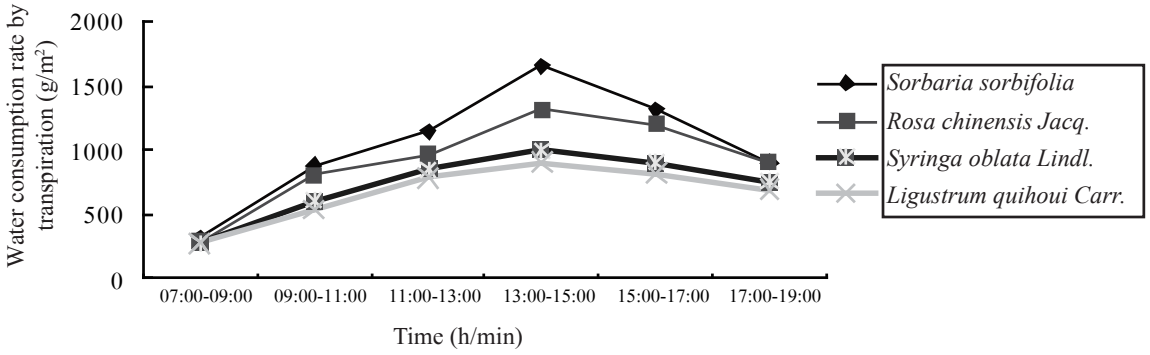

Figure 2
The Water Consumption Rates by Transpiration of the Four Plants in Full Light

As can be seen from Figure 2, in full light, the water consumption rate of *Sorbaria sorbifolia* was significantly higher in each period in one day than the other three plants, which was 318.58 g/m^2 during 07:00 to 09:00, reached the highest point 1,652.11 g/m^2 during 13:00 to 15:00, and dropped to 905.23 g/m^2 during 17:00 to 19:00. Syringa oblata Lindal. and *Ligustrum quihoui Carr.* changed relatively flatly. The water consumption rate of *Ligustrum quihoui Carr.* was the lowest in every period in one day, only 59.7% of that of *Sorbaria sorbifolia.* The ranking of daily water consumption rates of the four plants was: *Sorbaria sorbifolia* > *Rosa chinensis Jacq.*

> *Syringa oblata Lindl.* > *Ligustrum quihoui Carr.*. Therefore, we need to grow plants in a matching way as per their different water consumption rates in order to achieve a balance in soil moisture supply.

3.1.3 Comparison of the Water Consumption Rates by Transpiration in Full Shade

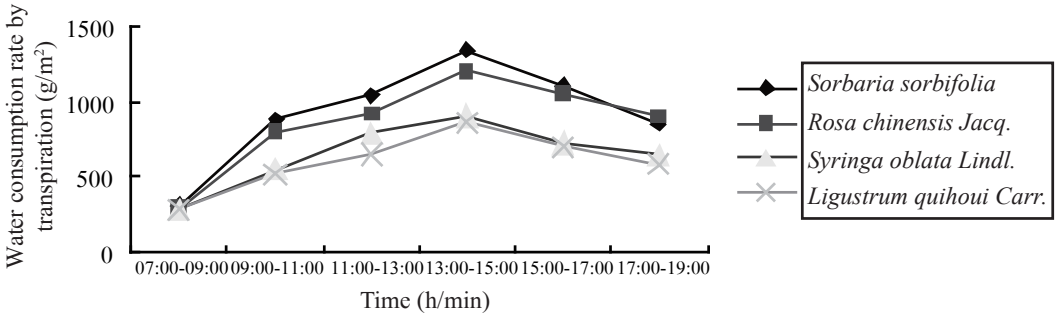

Figure 3
The Water Consumption Rates by Transpiration of the Four Plants in Full Shade

As can be seen from Figure 3, in full shade, the water consumption rate of *Sorbaria sorbifolia* was obviously higher in each period in one day than the other three plants, which was 311.01g/m^2 during 07:00 to 09:00, with the highest point of 1350.23 g/m^2 during 13:00 to 15:00, and 854.46 g/ m^2 during 17:00 to 19:00. Furthermore, *Ligustrum quihoui Carr.* and *Syringa oblata Lindal.* changed stably and similarly. The water consumption rate of *Ligustrum quihoui Carr.* was the lowest in one day, only 61.7% of that of *Sorbaria sorbifolia.* In full shade, the sequence of daily water consumption rates of the four plants were: *Sorbaria sorbifolia* > *Rosa chinensis Jacq.* > *Syringa oblata Lindl.* > *Ligustrum quihoui Carr.*.

From Figure 2 and Figure 3 it can be concluded that in either full light or full shade, the sequence of daily water consumption rates of the four plants was the same: *Sorbaria sorbifolia* > *Rosa chinensis Jacq.* > *Syringa oblata Lindl.* > *Ligustrum quihoui Carr.*.

3.2 The Water Consumption Rates by Transpiration in Full Light in Different Months

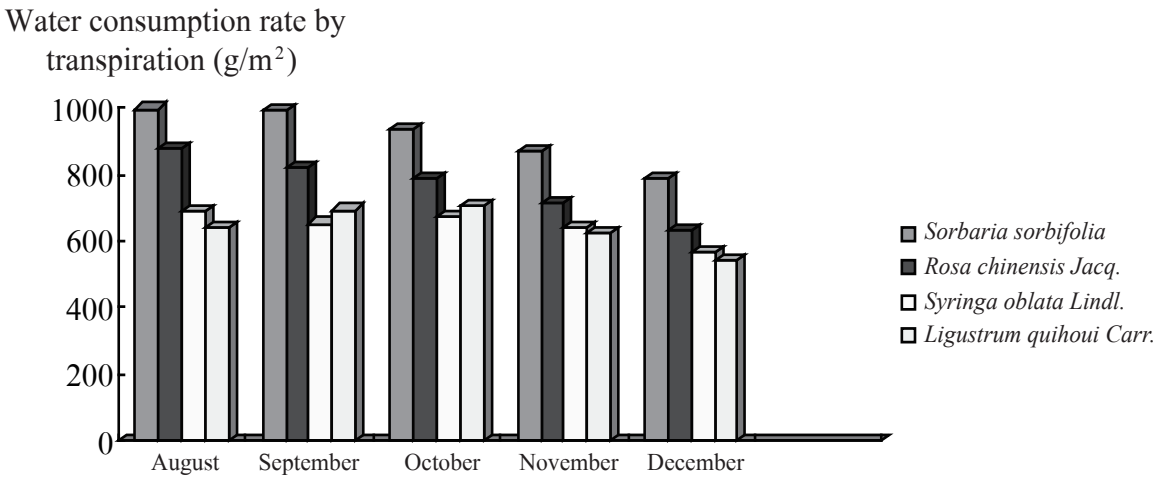

Figure 4
Comparison of the Water Consumption Rates by Transpiration of the Four Plants in Full Light From August to December

As can be seen from Figure 4, the four plants had different water consumption rates in different months. During the five months, *Sorbaria sorbifolia* had the highest water consumption rate, which was up to 994.97 g/m^2 in August and 788.69 g/m^2 in December. *Ligustrum quihoui Carr.* had a relatively lower water consumption rate, which was 639.66 g/m^2 in August and 538.68 g/m^2 in December. The water consumption rates of the four garden plants in August, November and December were ranked as: *Sorbaria sorbifolia* > *Rosa chinensis Jacq.* > *Syringa oblata Lindl.* > *Ligustrum quihoui Carr.*. Their water consumption rates in September and October were ranked as: *Sorbaria sorbifolia* > *Rosa chinensis Jacq.* > *Ligustrum quihoui Carr.* > *Syringa oblata Lindl.* In the routine maintenance, we should adjust the amount of irrigation

according to their water consumption rates, increase the amount of irrigation in August and September, and reduce the amount of irrigation in November and December.

CONCLUSION AND DISCUSSION

(a) The water consumption rates of the four garden plants were all higher in full light than in full shade. *Sorbaria sorbifolia* had the greatest rangeability under the two illumination conditions, whose water consumption rate in full shade was 81.7% that in the full light.

(b) The daily water consumption rates of the four garden plants in full light and full shade were ranked both as *Sorbaria sorbifolia* > *Rosa chinensis Jacq.* > *Syringa oblata Lindl.* > *Ligustrum quihoui Carr.*. In full light, the water consumption rate of *Sorbaria sorbifolia* was significantly higher in each period in one day than the other three plants, which was 318.58 g/m^2 during 07:00 to 09:00, reaching the highest point 1652.11 g/m^2 during 13:00 to 15:00, and dropping to 905.23 g/ m^2 during 17:00 to 19:00. In full shade, its water consumption rate was still much higher in each period in one day than all other three plants, which was 311.01 g/m^2 during 07:00 to 09:00, achieving the highest point 1350.23 g/m^2 during 13:00 to 15:00, and reducing to 854.46 g/m^2 during 17:00 to 19:00.

(c) In full light, the four garden plants had different water consumption rates in different months. The sequence of their water consumption rates in August, November and December was: *Sorbaria sorbifolia* > *Rosa chinensis Jacq.* > *Syringa oblata Lindl.* > *Ligustrum quihoui Carr.,* and the sequence of their water consumption rates in September and October was: *Sorbaria sorbifolia* > *Rosa chinensis Jacq*. > *Ligustrum quihoui Carr.* > *Syringa oblata Lindl.*

(d) In the full light condition, all of the four kinds of plants had the highest water consumption rates in August and the lowest water consumption rates in December. *Sorbaria sorbifolia* had the highest water consumption rate in both months, which was up to the highest 994.97 g/m^2 in August and 788.69 g/m^2 in December. The latter accounted for 79.26% of the former. *Ligustrum quihoui Carr.* had a relatively lower water consumption rate, which was 639.66 g/m^2 in August and 538.68 g/ m^2 in December. The latter accounted for 84.22% of the former.

(e) Different plants in the same environment represented a similar curve of water consumption rate, indicating that water consumption of plants is greatly affected by environment.

(f) Due to the indistinct summer climate in Linzhi, which has the highest temperature of 25-28℃, more rainy days, long lighting time and high lighting intensity in sunny days, the water consumption rates of plants are the highest in August and September. Then from October, the precipitation gradually reduces; the temperature declines rapidly; the climate tends to be dry, and the sunlight intensity decreases. Therefore, it can be seen from the experimental results that, the water consumption rates of the four plants in December changed more flatly compared to that in August.

(g) Water consumption rate of a plant is affected by soil moisture, air temperature, air humidity, sunlight, rain, and other factors, out of which lighting time and intensity are the major factors affecting the water consumption of a garden plant. Transpiration refers to the process that moisture losses from the surface of a living plant (mainly leaves) to the atmosphere in the form of vapor. Different from the evaporation process in physics, transpiration is not only affected by external environments, but also by the regulation and control of the plant, so it is a complex physiological process. The main process is: soil moisture→root hair→vessel inside root→vessel inside stem→vessel inside leaf→stoma→atmosphere. When a plant is young, its surface exposed to the air can be entirely transpired. In the morning and evening, with less sunlight radiation and smaller stomatal apertures, stomatal resistance will increase and water consumption rate by transpiration will be lower. At noon, with the maximum solar radiation and bigger stomatal apertures, stomatal resistance will be reduced and water consumption rate will be relatively higher. At noon, due to the highest temperature and solar radiation, increased respiration of plant cells will cause an increase of CO_2 in leaves, leading to closure of stomata and decline of transpiration rate. There will be a phenomenon of human-like “lunch break”. In the afternoon, with reduced sunlight radiation and bigger stomatal apertures, stomatal resistance will be reduced and water consumption rate by transpiration will rise again.

(h) With the changes of geographical features, climate and other factors, garden plants will change their water consumption rates accordingly, especially when transplanted to a new field, they will change their water consumption significantly to adapt to the new environment.

(i) This experiment has been carried out in Agricultural and Animal Husbandry College of Tibet University. Due to the location and the humid microclimate, the water consumption rates by transpiration of plants would be slightly lower than that in the city.

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