VARIATION OF POPLAR SAP FLOW AND ITS RESPONSE TO METEOROLOGICAL FACTORS

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ABSTRACT

Furong Sun, 2020. Variation of poplar sap flow and its response to meteorological factors. 13pp.

Key Words: sap flow rate, poplar, meteorological.

The purpose of this paper was to analyze the changes of poplar sap flow, to explore the meteorological factors affecting the changes of poplar sap flow and their response laws, so as to provide a theoretical basis for the follow-up study on the improvement of poplar living tree and the rising mechanism of its liquid medicine. The sap flow rate of poplar was measured by Flow 32A-1K wrapped sap flow meter, and meteorological factors were measured simultaneously by solar meter and temperature and humidity meter. The results showed that there was a significant positive correlation between poplar stem velocity and solar radiation intensity and air temperature, but a negative correlation with air relative humidity. Therefore, the influence degree of different meteorological factors on poplar sap flow rate is different.

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1 INTRODUCTION

Weather refers to the specific state of the atmosphere close to the surface of the earth in a short period of time. The weather condition is described using a range of specific variables, such as temperature, air pressure, humidity, wind, rain, snow, frost, thunder, hail etc. Bad weather conditions can negatively affect the normal growth of plants, and even lead to severe stresses or damages to plants, such as drought, flood, sandstorm, and hail. Weather conditions can greatly affect the physiological processes of plants, e.g., photosynthesis and respiration, which are closely related to temperature and humidity. Temperature and precipitation are key drivers of plant population dynamics (Doak and Morris 2010, Nicole et al. 2011, Salguero-Gomez et al. 2012, Sletvold et al. 2013, Dahlgren et al. 2016). A good understanding how weathers affect the physiological processes and traits of trees is very important to forest managers and horticulturists.

Poplar(*Populus x euramericana*) is a widely distributed group of tree species and they generally grow fast, particularly during the juvenile stage. It is widely planted in the Anhui Province of China. The industry associated with the planting, managing and processing the species has become the pillar for the economy of many cities in the province. However, there are some shortcomings in this species as such low density and soft wood, easiness of undesired color change and decaying. Such drawbacks limit the scope of its utilization. Decay-resistant treatments are often applied to improve the durability of its wood.. The research on the change of poplar sap flow is the basis of carrying out the preservative treatment of living poplar. Sap flow rate is related to transpiration rate, radiation, air and soil moisture conditions. The daily sap flow rate was greatly affected by the weather conditions, e.g., precipitation and relative humidity (Xia et al. 2008). Sap flow rate is also affected by transpiration, radiation, and soil moisture (Barbour, M.M, 2003, Juice, Stephanie M, et al, 2016,Whitehead. D, 2003). Humidity has a negative effect on the growth of plants (Tenhumberg et al. 2018). By studying the variation of poplar sap flow, its correlation with environmental factors, such as solar radiation, temperature and humidity meteorological factors may be important for determining the injection time of preservative solution.

The purpose of this study was to examine the daily and seasonal variations of poplar sap flow and its responses to changes in environmental factors. According to the literature, the environmental factors that significantly affect the sap flow of Artemisia ordosica are, in descending order of the magnitude of their influence: solar radiation, vapour pressure deficit, relative humidity, air temperature and wind speed(Lei et al. 2010). I hypothesized that the sap flow rate of poplar trees would be positively correlated with solar radiation and relative humidity, and negatively correlated with air temperature.

Transpiration is an important way for forest ecosystems to transport water to the atmosphere (Bernacchi et al. 2015), and stand transpiration accounts for a large proportion in the forest water cycle. 90% of the water absorbed by trees from the soil is used for transpiration, and more than 99.8% of the water consumption of trees is from sap flow Therefore, accurate measurement of sap flow can basically reflect the transpiration water consumption of plants (Baker et al., 1987).

In recent years, many scholars have studied sap flow of different tree species from different perspectives. For example, studies on Pinus tabuliformis and Robinia pseudoacacia showed that the diurnal variation curve of sap flow of tree species in sunny days during peak growing season was single peak (Yu et al. 2009), but there were some special cases, in which the sap flow curve of Pinus tabuliformis in Beijing appeared double peak (Lin et al. 2006). In rainy days, the meteorological conditions are more complex, and the sap flow is in an irregular fluctuation state, such as the bimodal pattern of Picea crassifolia (Lin et al. 2006), and the unimodal and irregular variation of poplar 107 (Zhou et al. 2010). In the study of sap flow activities of most tree species, the peak season of sap flow is summer (June to August), the sap flow in rainy season is greater than that in dry season, and the start time of sap flow in summer is early (Ma Da, 2006). The main influencing factor of sap flow is environmental factors, and domestic scholars have done more research on this aspect. Some scholars also explored the characteristics of sap flow changes in different time scales, different types of trees, and the characteristics of sap flow changes in days, months and seasons, and analyzed the response relationship between sap flow and environmental factors (Yang et al. 2013). Due to the different time scales of sap flow, the influencing factors are also different. The main environmental factors affecting instantaneous sap flow rate are radiation and air temperature. The main environmental factors affecting daily sap flow are air temperature, soil moisture content and photosynthetic radiation. The main environmental factors affecting monthly sap flow are canopy air temperature and relative humidity (Zhao et al. 2009).

2.0. MATERIALS AND METHODS

2.1 Study area

Anhui, China, is a transitional region between warm temperate zone and subtropical zone. Its main characteristics are: the monsoon is obvious; the four seasons are distinct; the spring is warm and climate varies greatly, the summer rain is concentrated, the autumn is crisp, and the winter is cold. Anhui is located in the middle latitude zone, with the monsoon transfer and obvious seasonality of precipitation, and is one of the regions with typical s monsoonclimate. The annual average temperature is 14-17 ℃, the average temperature in January is minus 1-4 ℃, and the average temperature in July is 28-29 ℃. The summer rainfall is abundant, accounting for 40% - 60% of the annual precipitation. The experimental area was located in the experimental site of Anhui Agricultural University (31 ° 51' N, 117 ° 15' E), which is located in the subtropical monsoon climate zone. The annual average temperature of the experimental area is 15.4 ℃. The average annual precipitation is 1106 mm, and the pH value of soil is 4 ~ 6.

2.2. Experiment design

Poplar trees with normal growth and development, without defects and diseases and insect pests were selected as the research objects. Three poplar trees with a diameter at breast height of 1.20 cm (Table 1) were selected to measure sap flow rate for 3 consecutive days in April 2020. Three days(27, 28 and 29) with similar weather conditions were selected for recording to reduce the influence of unrelated factors. Using Flow 32A-1K wrapped stem flow meter, three poplar trees were wrapped with wrapped sensors respectively. According to the need of the experiment, the average value of stem flow rate was calculated every 15 minutes and stored. While the stem flow meter was running, the solar radiation intensity and temperature and humidity were recorded every 15 minutes by using the recording solar energy meter and temperature and humidity meter.

Table 1..Main characteristics of poplar sample trees.

Plot Number	Plant height (m)	Crown width (m)	Diameter of wrapping(cm)	Height of wrapping(m)
A	2.11	0.83	1.11	1.02
B	2.30	0.93	1.21	1.03
C	2.65	1.11	1.27	1.05
Average	2.35	0.96	1.20	1.03

3.0 RESULTS

3.1. Diurnal variation of poplar stem flow

The sap rate of the sample trees had similar patterns of diurnal variation among the three sampling days, we can observe through the figure 1 of the data obtained by the Flow 32A-1K wrapped stem flow meter: Sap flow started at sunrise around 06:00, increased rapidly with as solar radiation increased in the morning during the period from 07:00 to 08:00, the growth rate of sap flow was the largest. At the same time, the temperature is also increasing, and the relative humidity is decreasing. At 12:00, the solar radiation intensity was the highest, and the temperature was the highest. At this time, transpiration slowed down, and the growth rate of sap flow slowed down. After a period, the sap flow rate reached the peak around 14:00. The peak values of sap flow rate were 42.79 g / h, 46.45 g / h and 54.01 g / h on April 27-29, respectively. Then, the intensity of solar radiation gradually weakened, and the sap flow rate decreased, with the largest decrease between 17:00 and 18:00. At the same time, the temperature also decreased, and the relative humidity of air increased. After sunset, the sap flow tends to be stable. At this time, the sap flow rate is at a low level, but not completely zero.

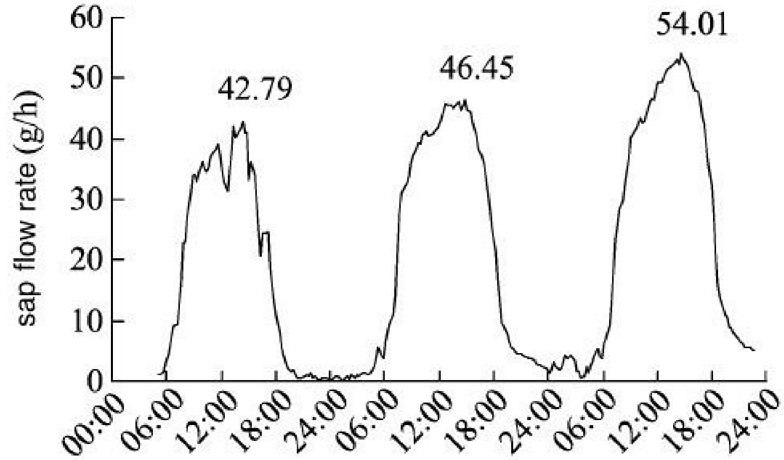

Figure 1. Diurnal variation of sap flow rate of Poplar.

3.2 variation of stem flow of poplar in between sunny and cloudy days.

In Figure 1, it is cloudy on April 27 and sunny on April 28 and 29. It is easy to find that the stem flow rate of poplar has obvious diurnal rhythm in cloudy and sunny days, but the diurnal variation trend of stem flow is different in sunny and cloudy days. In sunny days, the meteorological factors changed regularly, and the trend of stem flow showed obvious single peak. On cloudy days, the solar radiation intensity is unstable and has a certain fluctuation, which leads to the instability of the stem flow rate of poplar, and makes the stem flow rate curve present a multi peak shape. In addition, the solar radiation intensity and air temperature are lower in cloudy days, so the sap flow rate of poplar is lower than that in sunny days, and the peak value of the former is slightly lower than that of the latter.

3.3 Response of sap flow change to meteorological factors

3.3.1 Relationships between stem flow rate and solar radiation intensity.

The variation trend of stem flow rate of poplar is similar to that of solar radiation intensity (Fig. 2), Regression analysis results (Fig. 3) show that the sap flow rate is positively correlated with solar radiation intensity. After the start of sap flow, the sap flow rate increased with the increasing of solar radiation, and decreased with the decreasing of solar radiation. Due to the "midday rest effect" of poplar, the peak time of stem flow rate was about 2 hours later than the solar radiation intensity. The intensity of solar radiation is the main factor causing the change of stem flow. It can affect the opening and closing of stomata and control the start of sap flow(Zhou and Ma, 2010).

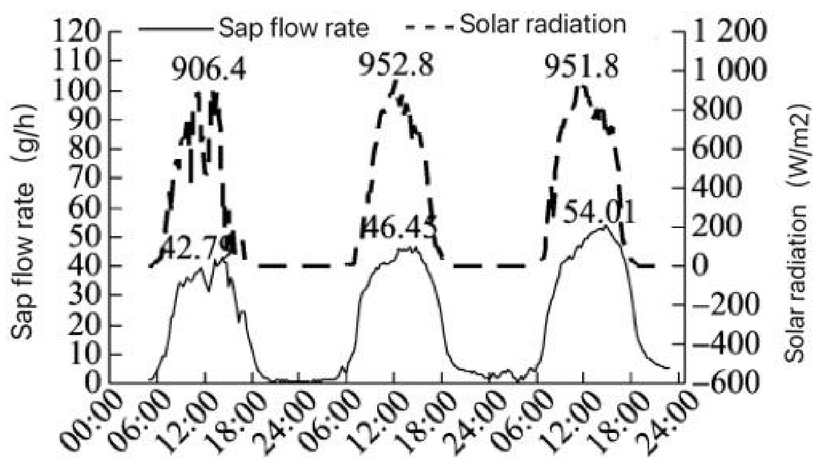

Figure 2. The change rate of solar radiation intensity and sap flow.

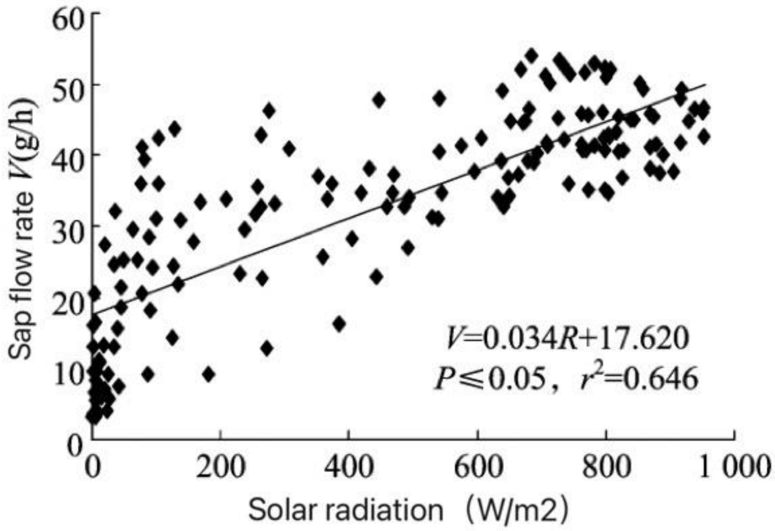

Figure 3.0. Regression analysis of sap flow rate and solar radiation intensity.

3.3.2 Relationship between sap flow and air temperature.

From the daily variation of poplar stem flow rate and air temperature (Fig. 4) and regression analysis results (Fig. 5), it can be seen that air temperature has a significant effect on poplar stem flow rate, and they are positively correlated(Wang et al. 2002). With the increase of air temperature, the stemflow rate increased; with the decrease of air temperature, the stemflow rate decreased. The peak value of air temperature appeared between 12:30 and 13:30, about 2 hours earlier than the peak value of stem flow rate. At the same time, we can find that with the highest air temperature rising from April 27 to 29, the peak value of stem flow rate also changed significantly.

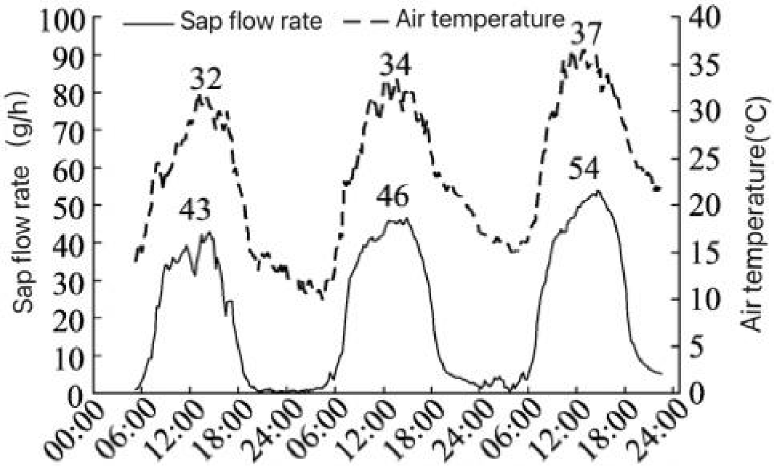

Figure 4.0. Diurnal variation of sap flow rate and air temperature.

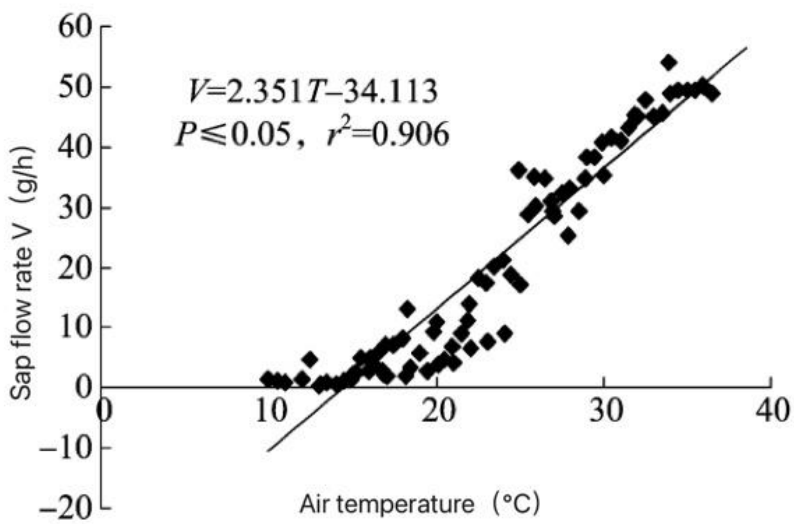

Figure 5.0. Regression analysis of sap flow rate and air temperature.

3.3.3. Stem flow change and air relative humidity

The variation trend of air relative humidity was opposite to that of poplar stem flow rate, showing a negative correlation (Fig. 6, Fig. 7). When the sap flow of poplar started, poplar was in a high humidity environment. As the sun rises, the humidity decreases and the stem flow rate increases. 12: The relative humidity of air decreased to the lowest value, and then the sap flow rate reached the peak value. After that, relative humidity increased and stem flow rate decreased (Wang et al., 2011). There was no significant difference between the minimum relative humidity and the maximum stem flow rate for three consecutive days. Therefore, compared with air temperature and solar radiation intensity, the effect of air relative humidity on stem flow rate is relatively small.

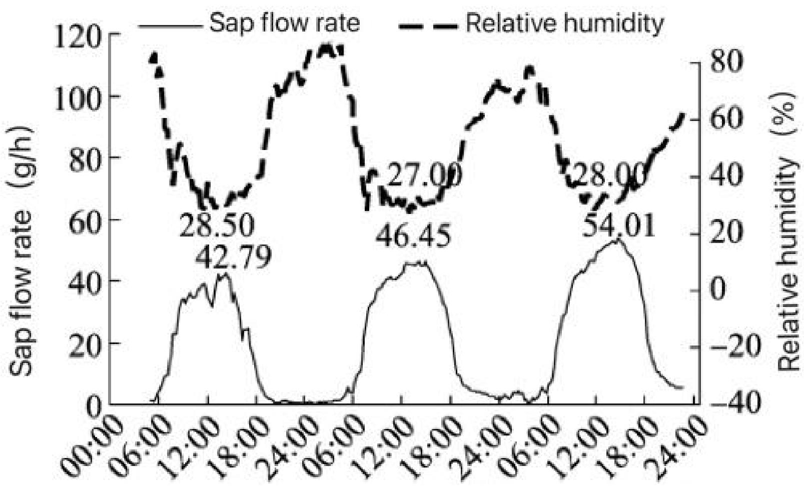

Figure 6.0. Diurnal variation of sap flow rate and air relative humidity.

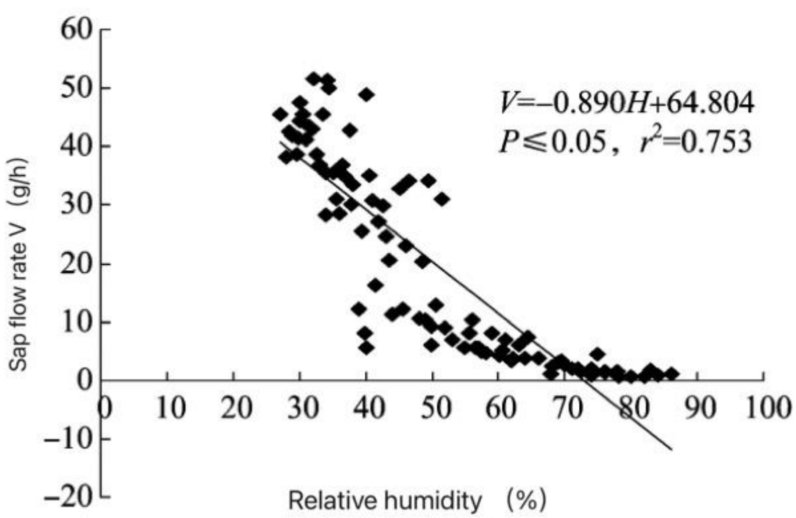

Figure 7.0. Regression analysis of sap flow rate and air relative humidity.

DISCUSSION

Sap flow rate is not only affected by its own biological structure and soil water supply level, but also restricted by climate factors (Shi et al., 2010). Sap flow of trees is a complex process, which is not only determined by its own physiological growth characteristics, but also closely related to air temperature, air relative humidity, light radiation, soil temperature and humidity and other environmental factors. These factors interact and coordinate with each other to affect the stem flow changes of poplar. Therefore, the accurate study of poplar stem flow depends on a comprehensive understanding of its stem flow dynamics and its environmental impact factors. On the basis of previous studies on tree stem flow, the relationship between poplar stem flow and environmental factors was discussed. It was found that solar radiation and air temperature were positively correlated with poplar stem flow, while air relative humidity was negatively correlated with poplar stem flow. This is consistent with previous studies on the relationship between stem flow and environmental factors in Ginkgo (*Ginkgo biloba L.)*(Sun et al. 2007), maize(*Zea mays L.*)(Wenguo et al. 2009) and flower stick(*Hedysarum scoparium Fisch. Et mey.*)(JIN et al. 2006). This may be due to the larger stomatal opening of poplar leaves under high light radiation, and the trees need more gas exchange, resulting in the increase of transpiration and stem flow. In addition to light radiation, air temperature is also a meteorological factor which has a great influence on poplar stem flow. In theory, in a certain temperature range, higher temperature makes stomatal opening greater than that in low temperature, so the transpiration of plants in high temperature is greater, and the stem flow increases. Through the statistical analysis of the experimental data, the sap flow rate increased with the increase of air temperature. The change of air relative humidity has many effects on the growth, development and physiological and ecological characteristics of poplar through the continuum of soil plant atmosphere. Air relative humidity is related to the resistance of water vapor escaping from leaf stomata, which affects the degree of water vapor diffusing from leaf surface to air. Thus the size of stem flow was affected(FENG et al. 2007).

At noon, the temperature is the highest and the solar radiation is the strongest. However, the stem flow rate in the table shows a short decline. This is because the poplar closed the stomata in order to protect itself (Feng, et al. 2013). At this time, the transpiration rate slows down and the sap flow growth rate slows down. After a period of rest, the stomata of poplar opened and the sap flow reached the peak at about 14:00. At night, the stem flow rate of poplar is close to zero but not completely zero in the absence of solar radiation and low temperature. This is due to the existence of root pressure in poplar at night, so that water enters into the poplar body, resulting in weak sap flow(Ma et al., 2005).

5.0. CONCLUSION

Through the experimental results, we can get the following conclusions: 1) poplar stem flow rate had a regular day and night variation with a single peak, and the stem flow rate did not stop completely at night,; 2) there were significant positive correlations between stem velocity rate and solar radiation intensity, air temperature, and a negative correlation between stem velocity rate and air relative humidity. It is necessary to further determine the relative contributions of each of the environmental factors towards the diurnal variations in sap flow rate.

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