Variation characteristics of stem water content in *Lagerstroemia indica* and its response to microenvironment

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To achieve a rational allocation of limited water resources, and formulation of an appropriate irrigation system, this research studied the change characteristics of stem water content (StWC) in plant and its response to micro-environmental factors. In this study, the StWC and micro-environmental factors of *Lagerstroemia indica* in Beijing were continuously observed by BD-IV plant stem water content sensor and a forest microclimate monitoring station from 2017 to 2018. The variation of StWC and its correlation with environmental factors were analyzed. The results showed the StWC of *Lagerstroemia indica* varies regularly day and night during the growth cycle. Meanwhile, the rising time, valley time, and falling time of StWC were various at the different growth stages of Lagerstroemia indica. The results of correlation analysis between StWC and micro-environmental factors indicated that the StWC of *Lagerstroemia indica* was positively correlated with air relative humidity, while it was negatively correlated with total radiation and air temperature. The multiple regression equation of StWC and micro-environmental factors of *Lagerstroemia indica* was $StWC = 11.789 - 1.402Rn - 0.931T - 1.132Ws + 0.933RH - 3.368ST + 2.168SMC$, and the coefficient of determination of the equation was of 0.87. Furthermore, the results illustrated that the irrigation should pay attention to supplementing irrigation in time during the peak growing season of fruit.

1 Variation Characteristics of Stem Water Content in
2 *Lagerstroemia indica* and Its Response to
3 Microenvironment

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20 Abstract

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22 irrigation system, this research studied the change characteristics of stem water content (StWC)
23 in plant and its response to micro-environmental factors. In this study, the StWC and micro-
24 environmental factors of *Lagerstroemia indica* in Beijing were continuously observed by BD-IV
25 plant stem water content sensor and a forest microclimate monitoring station from 2017 to 2018.
26 The variation of StWC and its correlation with environmental factors were analyzed. The results
27 showed the StWC of *Lagerstroemia indica* varies regularly day and night during the growth
28 cycle. Meanwhile, the rising time, valley time, and falling time of StWC were various at the
29 different growth stages of *Lagerstroemia indica*. The results of correlation analysis between
30 StWC and micro-environmental factors indicated that the StWC of *Lagerstroemia indica* was
31 positively correlated with air relative humidity, while it was negatively correlated with total
32 radiation and air temperature. The multiple regression equation of StWC and micro-
33 environmental factors of *Lagerstroemia indica* was $StWC = 11.789 - 1.402Rn - 0.931T -$
34 $1.132Ws + 0.933RH - 3.368ST + 2.168SMC$, and the coefficient of determination of the equation was
35 of 0.87. Furthermore, the results illustrated that the irrigation should pay attention to
36 supplementing irrigation in time during the peak growing season of fruit.
37 **Keywords:** stem water content (StWC); micro-environmental factors; growth stages;
38 *Lagerstroemia indica*

39 Introduction

40 The stem is one of the two main structural axes of vascular plants, which plays a variety of roles
41 in plants, such as mechanical support of leaves, flowers and fruits, water transport between root
42 and shoots in xylem and phloem, and water storage [1-2]. The variation of steam water content
43 (StWC) is an important segment of water transport in soil-plant-atmosphere continuum, and also
44 affects the transport of nutrients and the storage of carbohydrates. StWC is the result of
45 interaction and feedback between different organs and their environment. A good understanding
46 of StWC contributes to solving forestry research hotspots, such as cold resistance [3], drought
47 resistance [4], and health assessment [5]. Moreover, accurately mastering the characteristics of
48 StWC and its environmental coupling mechanism is of great significance for formulating a
49 reasonable irrigation system and making efficient use of water resources [6].
50 As a drought-resistant and pollution-resistant tree species, *Lagerstroemia indica* has been widely
51 used in the nursery cultivation and greening of cities in China. Water is one of the main factors
52 restricting the growth and yield of *Lagerstroemia indica,* to assure the survival rate of
53 *Lagerstroemia indica*, the irrigation strategies can be formulated more precisely according to the
54 pattern of StWC of trees in different growth stages and the response to different environments,
55 which also can improve the utilization rate of irrigation. In recent years, the research on the
56 change of StWC in trees mainly focuses on fruit tree species such as jujube, walnut and grape [7-
57 9]. However, the research on tree species used in landscape greening is rare. In addition, the
58 relationship between StWC and micro-environmental factors in the whole growth cycle of plants
59 has not been thoroughly explored.
60 Researchers have proposed many methods for measuring the StWC of plants. Oven-drying
61 method is a traditional way to estimate the water content in stem. The StWC can be directly
62 calculated by measuring the weight difference between the original wet stem and the stem dried
63 by an oven. The method is the most accurate but a destructive way, which cannot be used for situ
64 detection and also cost a long period for measurement. Therefore, oven-drying is commonly used
65 as a calibration of the other measurements. To achieve non-destructive and situ measurement,
66 some image analysis methods are introduced, including gamma-ray densitometry [10], X-ray
67 computer tomography [11], and magnetic resonance imaging (MRI) [12]. Both gamma-ray
68 densitometry and X-ray computer tomography are highly sensitive, which can acquire the StWC
69 of plants accurately, while the potential safety risks restricted the further applying of them [13].
70 Although MRI system can safely obtain the StWC of plants accurately, it still cannot achieve in-
71 situ and real-time detection, which is not suitable for long-term monitoring at a fixed site in the
72 field. With the development of electronic detection technology, dielectric constant method has
73 been widely used in StWC real-time and in situ monitoring, including time-domain
74 reflection(TDR) technology [14-16] and frequency-domain (FD) [17-19] technology, and the
75 TDR method has been the most commonly used. On the basis of TDR method, Constantz used
76 parallel waveguide probe to detect the volume moisture content of pine stem [20]. Wullschleger
77 used double-needle parallel stainless steel probe to monitor the seasonal variation of water
78 content of four deciduous broad-leaved tree species. The calibration formulas suitable for the
79 relationship between volume water content of stem and effective dielectric constant of tree

80   species were summarized [21]. By summarizing the results of the previous studies of the
81   researchers, it was feasible to detect StWC based on plant dielectric constant, but the length of
82   TDR probe restricted the detection effect. A short probe can reduce the damage to plants and the
83   errors caused by the difference of water distribution, but the system resolution will be reduced,
84   too. On the other hand, if the probes are too long, the signal attenuation will be very large. In
85   addtion, the TDR technology has high requirements and high production costs. Therefore, we
86   used a non-destructive and real-time detection method of StWC on standing wave rate principle.
87   In this paper, *Lagerstroemia indica* growing in Beijing is selected as research object. The area is
88   affected by the cold wave and the winter is cold and long, and the annual sunshine hours are
89   significantly lower than other regions. The environmental conditions in Beijing vary widely,
90   which leads the requirements of irrigation management for trees are high. The aims of our
91   research were to monitor the StWC of *Lagerstroemia indica* trees in situ continuously based on
92   the theory of standing wave ratio (SWR), analyze the variation characteristics of StWC and its
93   response to meteorological factors at different scales. Furthermore, we studied the correlation
94   between the StWC and meteorological factors by using cross-correlation, path analysis methods,
95   and modeling, and to provide more empirical data for *Lagerstroemia indica* trees for planting
96   and management by revealing the patterns of StWC changes. Our results will be of significance
97   in the management of guiding the scientific irrigation of nursery garden reasonably and
98   efficiently, and providing a scientific basis for the comprehensive evaluation of ecological and
99   hydrological processes and influencing factors of garden tree species in Beijing, China.

Materials & Methods

Study site

The study site is located in the Sanqingyuan nursery garden in Haidian District, Beijing, China
(40°0' N, 116°20' E). The region is characterized by a semi-humid warm temperate continental
monsoon climate zone, with an annual temperature of 12.6 °C and annual precipitation of 620
mm, for which 80% of rainfall occurs primarily from June to August. With monthly percent
possible sunshine ranging from 47% in July to 65% in January and February, the region receives
2,671 hours of bright sunshine annually. The mean annual evaporation of this area is 1,800 mm,
which is greater than precipitation by a factor of 3. The height of the nursery is about 50 meters
above sea level and the terrain is flat, covering an area of about 31200 m^2. The soil is the site is
clay loam with a pH between 7 and 8. Vegetation at the site consists of deciduous broad-leaved
trees dominated by *Lagerstroemia indica*, *Juglans mandshurica*, and *Malus spectabilis*.

Tree Material Preparation

We selected twelve *Lagerstroemia indica* tree samples with a similar diameter at breast height
(DBH) for stem water content monitoring, which were determined to be healthy, straight, non-
stressed, and well-grown specimens, for each year of the experimental period. The DBH ranged
from approximately 4.5 ± 0.5 cm and the average tree height was 250 ± 5 cm. Irrigation in the
site was carried out by small tube outflow, once a month for 1-2 days. In case of persistent high
temperature and drought weather, irrigation was added 1-2 times a month. The amount of
irrigation depended on the workers' experience. Weed control and pesticide spraying were

120 carried out timely. The growth stages of *Lagerstroemia indica* trees is shown in Table 1.
121 Experiments were carried out under the existing conditions, and monitoring was performed from
122 November, 2017 to November, 2018.

123 **Stem Water Content Sensor**s

124 The BD-IV plant stem water content sensor (School of Technology, Beijing Forestry University,
125 China) was implemented to measure the StWC of *Lagerstroemia indica* samples. The BD-IV,
126 based on SWR, consisted of a 100 MHz sinusoidal oscillator, a coaxial transmission line, a high
127 frequency detector circuit, and a pair of parallel stainless steel metallic electrodes [2, 22]. The
128 electrodes were designed to wrap around stems like an upper and a lower strap-ring (Fig 1). The
129 electromagnetic wave provided by the sinusoidal oscillator spreads along the coaxial
130 transmission line into the strap-ring, and because the impedance of the strap-ring is different
131 from that of the transmission line, a proportion of the incident wave would be reflected back
132 along the line to the oscillator. As a result of the reflected wave interfering with the incident
133 wave, a voltage standing wave would be set up on the transmission line. According to the
134 measuring principle of SWR, the differential voltage of A and B is taken as the output of
135 transducer conversion circuit, which can be expressed as a function of the strap-ring impedance
136 [23-24]:

$$U_{AB} = 2A_1 \frac{Z_L - Z_C}{Z_L + Z_C} \qquad (1)$$

137 where A_1 is the amplitude of electromagnetic wave (V), Z_L is the impedance (Ω) of strap-ring,
138 and Z_C is the impedance (Ω) of transmission line. In this study, the Z_C is equal to 50 Ω. When
139 A_1 and Z_C are constant, the potential difference U_{AB} at both ends of the transmission line is only
140 related to the impedance of Z_L. The variation of StWC can affect the impedance of stem, which
141 leads the change of the impedance of strap-ring (Z_L), and the output voltage (U_{AB}) of the sensor
142 will be changed. In other words, Z_L is determined by StWC of the measured living tree.
143 Therefore, the StWC of living standing trees can be quantified by measuring the output voltage
144 difference of the transmission line (U_{AB}).

145 **Data Collection**

146 StWC sensors (BD-IV) were installed on the trunks of 12 selected *Lagerstroemia indica* tree
147 samples. The installation position of the BD-IV was close to the first bifurcation of the main
148 trunk of the tree sample. A self-designed multi-channel digital collector based on AVR 128 was
149 used to connect the StWC sensors of each trunk. A monitoring station in the experiment is shown
150 in Fig 2. The collector automatically collected and stored a data packet every 10 minutes, and
151 collected 144 data packets in one day. Thus, the collector can record 144 of StWC of each
152 sample every day. During the whole experimental process, the same cultivation and management
153 mode was adopted to ensure the supply of water and nutrients for all the samples. At the same
154 time, the change process of StWC of the samples were recorded.
155 In the study site, a forest microclimate monitoring station was built to measure the parameters of
156 micrometeorological factors in the ecological microenvironment in real time, including air
157 temperature, air relative humidity, global radiation, and wind speed. The station measured and

158   collected the micrometeorological factors every 10 minutes. In addition, soil temperature sensors
159   (DS18B20) and soil volume moisture content sensors (HYSWR-ARC) were installed at four
160   different locations in the study site to monitor the soil temperature, and soil volume moisture
161   content.

162   **Data Processing**

163   The StWC of *Lagerstroemia indica* samples were calculated by the equation 2:

$$V = 1022.1 * St + 324.36 \ (R^2 = 0.998) \tag{2}$$

164   where *V* is the output voltage difference of the transmission line, *St* is the StWC of
165   *Lagerstroemia indica* samples. It is a linear relation between the StWC of the *Lagerstroemia*
166   *indica* and the sensor output with the high sensitivity equal to 1022.1mV $(cm^3 \cdot cm^{-3})^{-1}$. The value
167   of coefficient of determination (R^2) indicated that the sensor was able to measure the StWC of
168   trees precisely.

169   Microsoft Excel (Microsoft Inc. Redmond, USA) was used to collate and calculate the StWC
170   data of *Lagerstroemia indica* samples, SPSS 19.0 (SPSS Inc. Chicago, USA) and Matlab 2015b
171   (Mathworks Inc, Natick, MA) were used to analyze the variance, regression and correlation of
172   the StWC and meteorological factors, and Origin (OriginLab Inc. USA) software was used to
173   draw the charts and graphs.

174   # Results and Discussion

175   **Diurnal Variation Characteristics of Stem Water Content**

176   The StWC data were selected from the typical sunny days. Fig 3 illustrates the diurnal variation
177   characteristics of StWC of *Lagerstroemia indica* in its flowering stage (2017.5.26), fruit growth
178   stage (2017.7.1), fruit maturity stage (2017.10.2), and dormancy period (2017.12.3). It can be
179   found that the diurnal variation of StWC follows the overall trend of first decreasing and then
180   increasing. Take the StWC data of October 2, 2017 as an example, StWC started to rapidly
181   decrease at 6:00, after reaching the first trough at 11:00, the StWC was relatively stable till
182   reaching the minimum value at 15:00, then it began to increase smoothly. The rising process of
183   StWC lasted nearly 16 hours until 5:00 the next day, and then the falling process of StWC
184   happened again. At different growth stages of *Lagerstroemia indica*, the valley time, falling
185   time, and rising time of StWC were also variant. It can be seen from Table 2 that the valley time
186   of StWC reached early, and the falling time of StWC started late in July and October. However,
187   the pattern of StWC in March and December was conversely. This phenomenon may be related
188   to the variation of meteorological factors during the growth period of the sample trees. The
189   diurnal variation of main meteorological factors on observation days at different growth periods
190   is shown in Fig 4. The results indicate that the falling time of StWC in fruit growth stage and
191   fruit maturity stage were early, and the rising time of StWC was late, which was conducive to the
192   accumulation of photosynthates. While the opposite was found in deciduous dormancy period
193   and germination stage. Fig 5 shows the rising time, falling time, and valley time of StWC in the
194   growth cycle of *Lagerstroemia indica*, which illustrates the growth stage influenced the times of
195   StWC greatly. The valley value of StWC was October > July > May > December, the maximum
196   StWC was 57.23% in October, and the minimum StWC was 39.79% in December. In addition,

197 the mean of StWC was October > July > May > December, the maximum StWC was 59.78% in
198 October, and the minimum StWC was 46.18% in December. As a result, StWC of *Lagerstroemia*
199 *indica* was the most at the fruit stage, and the least at the deciduous dormancy period. **Response of**
200 **Stem Water Content to Micro-environmental Factors**
201 The StWC of Lagerstroemia indica at different growth stages were significantly different under
202 the influence of external micro-environmental factors. We selected the data of StWC and
203 meteorological factors for 7 consecutive days (from July 24 to 30, 2017) to analyze the
204 relationship between StWC and micro-environmental factors in Lagerstroemia indic. The
205 variation curve of StWC and meteorological factors of Lagerstroemia indica is shown in Fig 6. It
206 can be concluded that the StWC had strong correlation with total radiation, air temperature, air
207 relative humidity, wind speed, and soil moisture content, but not with soil temperature.
208 Moreover, StWC was contrary to that of total radiation, wind speed and air temperature, but
209 similar to the change trend of relative air humidity, which indicated that the increase of air
210 relative humidity would increase the StWC and have a negative effect on fruit tree transpiration,
211 which was not conducive to the accumulation of photosynthate. While the increase of total
212 radiation and air temperature would decrease the water content of stem, which can promote the
213 transpiration of Lagerstroemia indica and was beneficial to the accumulation of photosynthate.
214 The analysis results of correlation between StWC and micro-environmental factors of
215 Lagerstroemia indica are shown in Table 3. It can be seen that the StWC of Lagerstroemia indica
216 was significantly correlated with total radiation, air temperature, air relative humidity, wind
217 speed, soil temperature and 15 cm soil moisture content at level 0.01. The StWC was negatively
218 correlated with air relative humidity and 15cm soil moisture content, but positively correlated
219 with the other factors. The StWC had the strongest correlation with total radiation, and the
220 correlation coefficient was 0.732. The degree of correlation was: $r(Rn)=-0.732** > r(T)=-0.556*$
221 $* > r(Ws)=-0.549** > r(RH)=0.505** > r(SMC)=0.414** > r(ST)=-0.141**$ (** indicates
222 significant bilateral correlation at 0.01 level).
223 **Quantitative Correlation Analysis Between Stem Water Content and Micro-environmental**
224 **Factors**
225 **Multiple Regression Analysis**
226 The experiment took the StWC of *Lagerstroemia indica* as dependent variable and micro-
227 environmental factors as independent variable, and established a comprehensive relationship
228 model between StWC and micro-environmental factors based on the multiple regression
229 analysis. The model was optimal to reflect the effect of micro-environmental factors on StWC of
230 *Lagerstroemia indica*. The multiple regression equation of StWC and micro-environmental
231 factors of *Lagerstroemia indica* is as follows:

$$StWC = 11.789 - 1.402Rn - 0.931T - 1.132Ws + 0.933RH - 3.368ST + 2.168SMC \qquad (3)$$

232 where *St* is the StWC of *Lagerstroemia indica*. The coefficient of determination of the equation
233 is of 0.87 (*R*2). The micro-environmental factors could explain 87.0% of the StWC changes of
234 *Lagerstroemia indic*. The coefficient of determination of the residual factor is 0.49 ($e = \sqrt{1-R^2}$),

235 which indicates that there are other factors having certain influence on StWC of *Lagerstroemia*
236 *indica*, such as stomatal conductance and leaf area index.
237 Furthermore, the path analysis was implemented to study the way of influence and its magnitude
238 of micro-environmental on StWC of *Lagerstroemia indica* (Table 4). The direct effect of micro-
239 environmental factors on StWC is Rn（-0.411）＞T(-0.305)＞Ws（-0.230）＞Ts（0.224）
240 ＞RH（0.137）＞Hs（-0.074）, and the indirect effect of micro-environmental factors on
241 StWC is RH（0.689）＞T(0.625)＞Hs（0.573）＞Ws（0.572）＞Rn（0.522）＞Ts
242 （0.394）. As a result, it shows the direct effect of Total radiation (Rn) is the largest, while that
243 of 15cm soil moisture content (SMC) is the smallest. Air temperature mainly affected the StWC
244 through the combined action of total radiation, relative humidity and soil temperature. The total
245 radiation mainly affected the StWC through the combined effects of air temperature, wind speed
246 and relative humidity.

Conclusions

248 This study confirm that the micro-environmental factors can be significant predictors of daily
249 stem water content (StWC) of *Lagerstroemia indica* in Beijing. According to the experimental
250 results, the following conclusions can be drawn:
251 (1) The StWC of *Lagerstroemia indica* varies regularly day and night, and follows the overall
252 trend of first rising and then falling, which shows a typical valley curve. The rising time, valley
253 time, and falling time of StWC are different at the different growth stages of the *Lagerstroemia*
254 *indica*. Specifically, the galling time of fruit growth stage and fruit maturity stage is ahead of the
255 other stages, while the rising time of fruit growth stage and fruit maturity stage is later than that
256 of the other stages.
257 (2) The StWC of *Lagerstroemia indica* is positively correlated with air relative humidity and
258 15cm soil moisture content, and negatively correlated with total radiation, wind speed, air
259 temperature and soil temperature is the most important factor affecting StWC of *Lagerstroemia*
260 *indica*. Moreover, the multiple regression equation of StWC and micro-environmental factors of
261 *Lagerstroemia indica* is $StWC = 11.789\text{-}1.402Rn\text{-}0.931T\text{-}1.132Ws\text{+}0.933RH\text{-}$
262 $3.368ST\text{+}2.168SMC$, and the coefficient of determination of the equation is of 0.87.
263 (3) The transpiration of *Lagerstroemia indica* in the region of Beijing, China is larger in June-
264 September. The transpiration is highly influenced by micro-environmental factors such as solar
265 radiation and wind speed. The solar radiation is stronger in July and August in this region, and
266 the air temperature is higher. Therefore, the irrigation should pay attention to supplementing
267 irrigation in time during the peak growing season of fruit, i.e. during the period of fruit
268 expansion, especially in the continuous sunny days of July and August. Irrigation frequency
269 ensures that *Lagerstroemia indica* are not affected by water stress during the critical period of
270 growth, and irrigation time should be chosen before sunrise or after sunrise to reduce the loss of
271 irrigation water caused by evaporation.
272
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Figure 1

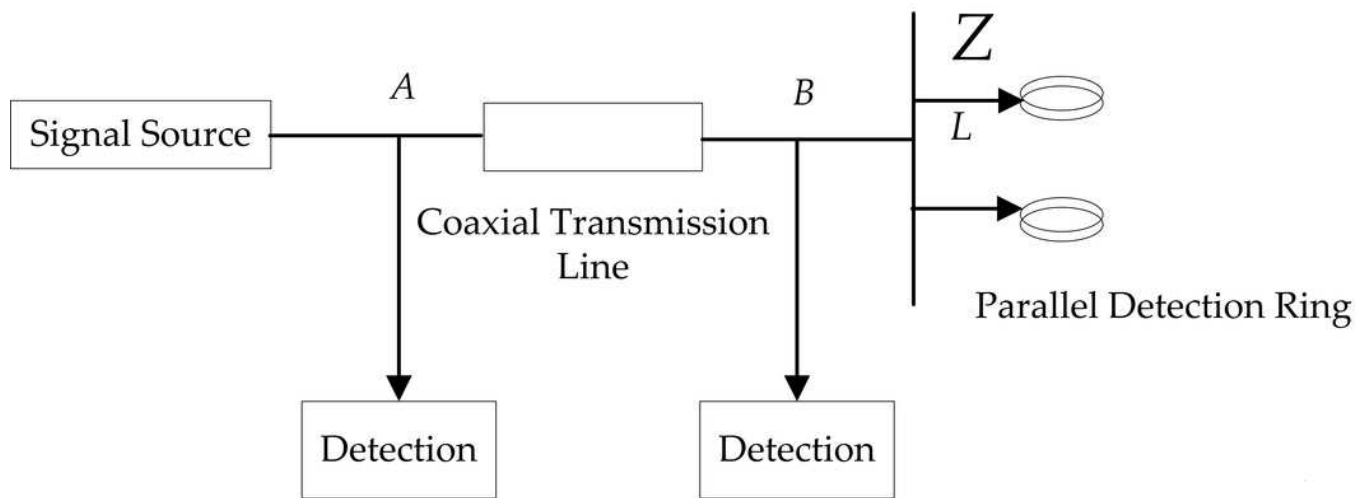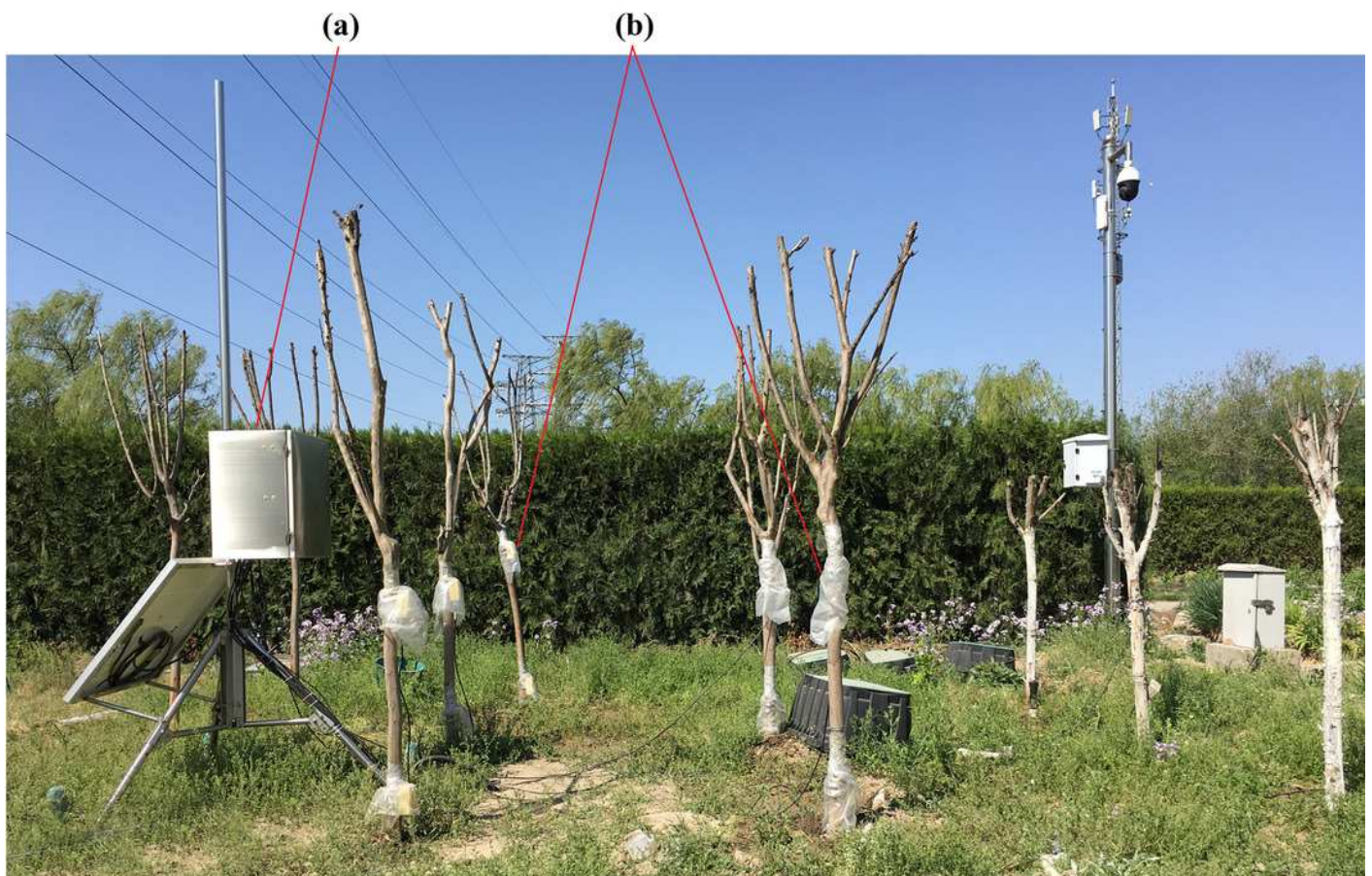Schematic view of the BD-IV

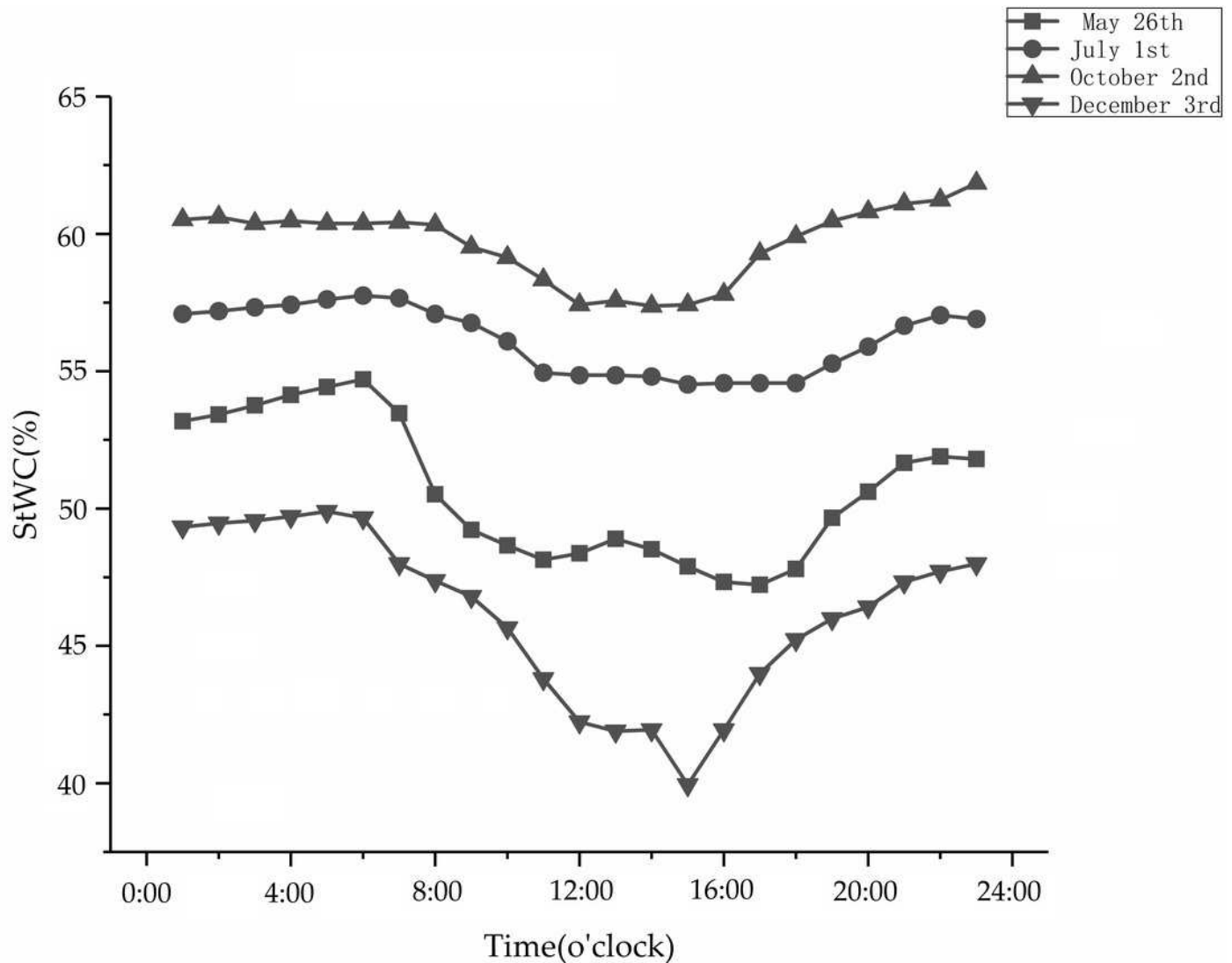**Fig 1. Schematic view of the BD-IV**

Figure 2

Monitoring station of stem water content

(a) digital collector; (b) SWR sensor (BD-IV)

Figure 3

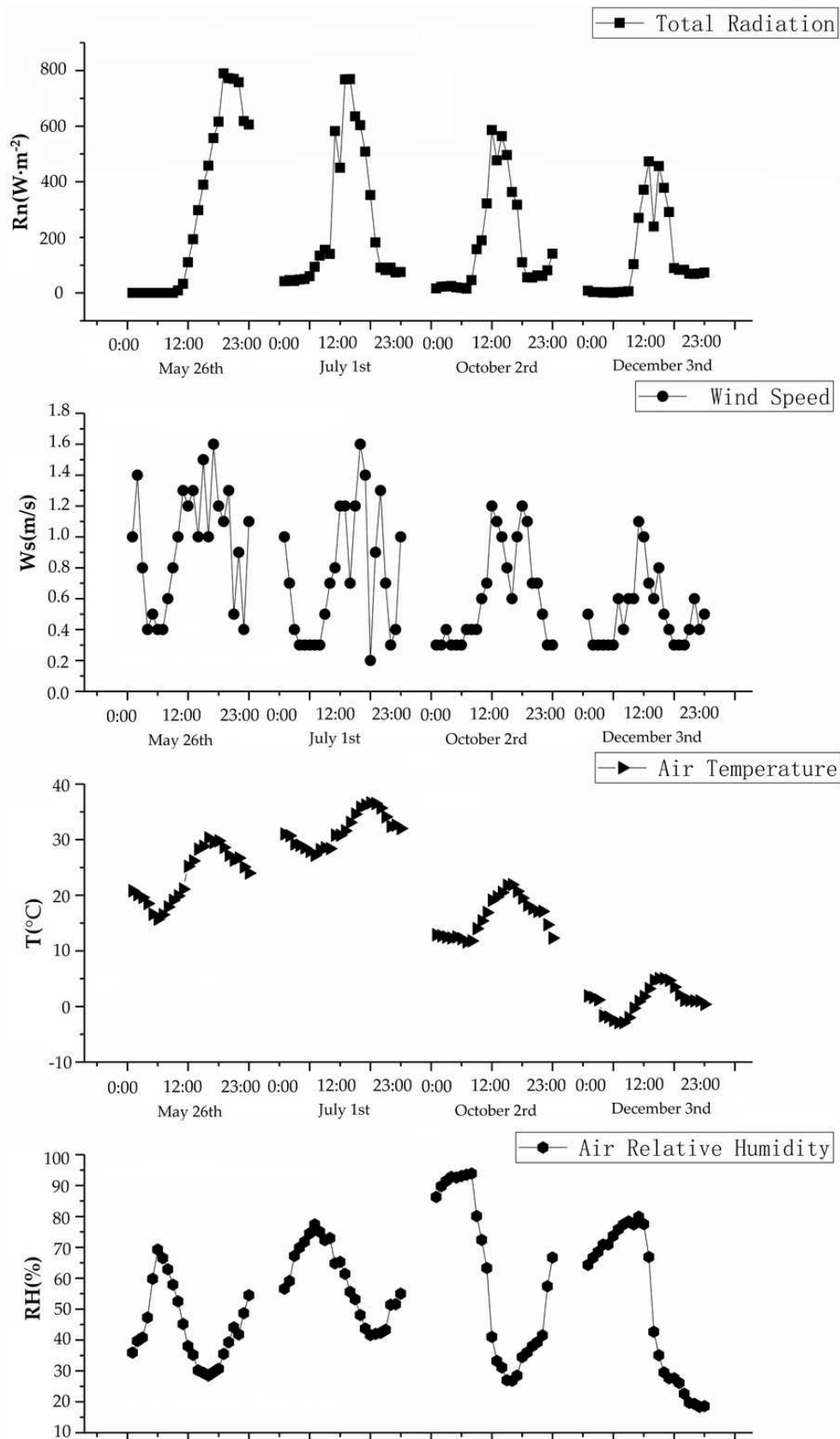Daily variation of StWC in different growth stages of *Lagerstroemia indica*

Fig 3. Daily variation of StWC in different growth stages of *Lagerstroemia indica*

Figure 4

Daily variation of main meteorological factors in different growth stages of
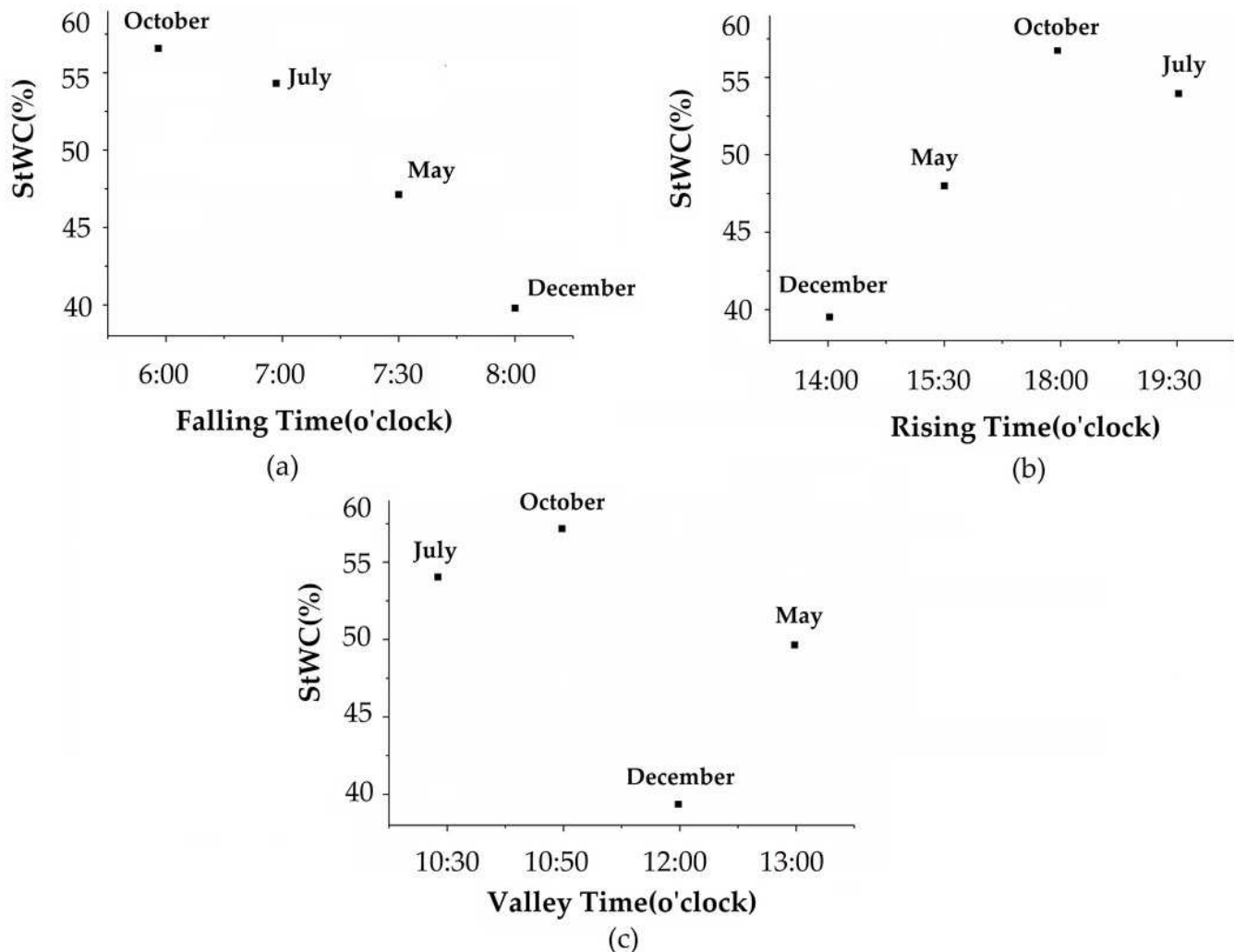*Lagerstroemia indica*

Fig 4. Daily variation of main meteorological factors in different growth stages of *Lagerstroemia indica*

Figure 5

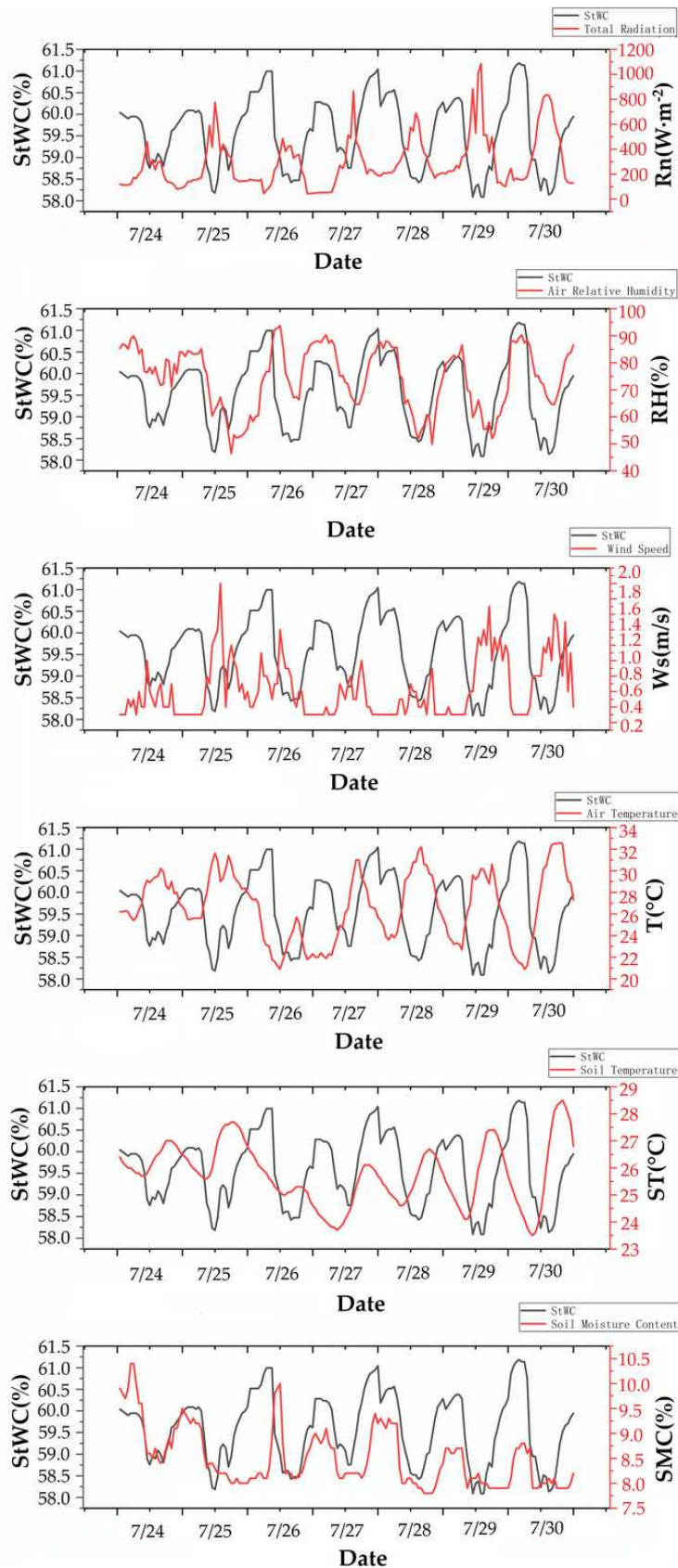Relationship between valley StWC and StWC status

(a) Falling time of StWC; (b) Rising time of StWC; (c) Valley time of StWC.

Fig 5. Relationship between valley StWC and StWC status. (a) Falling time of StWC; (b) Rising time of StWC; (c) Valley time of StWC.

Figure 6

Relationship between StWC and environmental factors of *Lagerstroemia indica*

Fig 6. Relationship between StWC and environmental factors of *Lagerstroemia indica*

Table 1(on next page)

Growth periods of *Lagerstroemia indica*

1   **Table 1. Growth periods of *Lagerstroemia indica***

Flowering Stage	Fruit Growth Stage	Fruit Maturity Stage	Dormancy Stage
2017.3 – 2017.5	2017.6 – 2017. 8	2017.9 – 2017.11	2017.12 – 2018.2

2

Table 2 (on next page)

Inter-monthly dynamic change of StWC on sunny days and environmental factor daily mean of *Lagerstroemia indica*

Rn: Total radiation (W·m^{-2}), T: Air temperature (°C), RH: Relative humidity (%), SMC: 15cm soil moisture content (%)

1 **Table 2. Inter-monthly dynamic change of StWC on sunny days and environmental factor daily mean of**

2 *Lagerstroemia indica*

Month	Date	Daily mean of environmental factor					Falling time	Valley time	Valley value	Rising time	Mean StWC
		Rn (W·m-2)	T (°C)	RH (%)	Ws (m/s)	SMC (%)					
5	2018.5.26	305.05	23.53	44.29	0.97	7.58	8:00	13:00	47.13	15:30	50.69
7	2018.7.1	249.54	31.68	59.07	0.73	8.56	7:00	10:30	54.47	19:30	56.15
10	2018.10.2	185.59	16.01	60.19	0.61	9.98	6:00	10:50	57.23	18:00	59.78
12	2018.12.2	139.78	0.95	50.85	0.50	7.66	7:30	12:00	39.79	14:00	46.18

3 Rn: Total radiation (W·m-2), T: Air temperature (°C), RH: Relative humidity (%), Ws: Wind speed (m/s), SMC: 15cm soil

4 moisture content (%)

Table 3 (on next page)

Correlation between StWC of *Lagerstroemia indica* and environmental factors

Rn: Total radiation (W·m^{-2}), RH:Air Relative humidity (%), Ws: Wind speed (m/s), T: Air temperature (°C), ST: Soil temperature(°C), SMC: 15cm soil moisture content (%), StWC: Stem water content(%). **: Significant correlation at 0.01 level, *: Significant correlation at 0.05 level

1   **Table 3. Correlation between StWC of *Lagerstroemia indica* and environmental factors**

	Rn(W·m⁻²)	RH (%)	Ws(m/s)	T(°C)	ST (%)	SMC (%)	StWC (%)
Rn(W·m⁻²)	1						
RH (%)	-.455**	1					
Ws(m/s)	.550**	-.530**	1				
T(°C)	.566**	-.718**	.481**	1			
ST (%)	-.033	-.475**	.405**	.681**	1		
SMC (%)	-.427**	.739**	-.488**	-.465**	-.194**	1	
StWC (%)	-.732**	.505**	-.549**	-556.**	-.141**	.414**	1

2   Rn: Total radiation (W·m⁻²), RH:Air Relative humidity (%), Ws: Wind speed (m/s), T: Air temperature (°C), ST: Soil

3   temperature(°C), SMC: 15cm soil moisture content (%), StWC: Stem water content(%). **: Significant correlation at 0.01 level,

4   *: Significant correlation at 0.05 level

5

Table 4 (on next page)

Path analysis results between StWC and environmental factors

X_1: Total radiation (W·m^{-2}), X_2: Air Relative humidity (%), X_3: Wind speed (m/s), X_4: Air temperature (°C) , X_5: Soil temperature(°C) , X_6: 15cm soil moisture content (%) ,

1 **Table 4. Path analysis results between StWC and environmental factors**

Independent Variable	Simple correlation coefficient	Direct path coefficient	Indirect path coefficient						Total
			X_1	X_2	X_3	X_4	X_5	X_6	
X_1	-0.732	-0.411	—	0.187	0.127	0.169	0.007	0.032	0.522
X_2	0.505	0.137	0.187	—	0.122	0.219	0.106	0.055	0.689
X_3	-0.549	-0.230	0.226	0.073	—	0.146	0.091	0.036	0.572
X_4	-0.556	-0.305	0.229	0.098	0.111	—	0.153	0.034	0.625
X_5	-0.141	0.224	0.014	0.065	0.093	0.208	—	0.014	0.394
X_6	0.414	-0.074	0.175	0.101	0.112	0.142	0.043	—	0.573

2 X_1: Total radiation (W·m^{-2}), X_2: Air Relative humidity (%), X_3: Wind speed (m/s), X_4: Air temperature (°C) , X_5: Soil

3 temperature(°C) , X_6: 15cm soil moisture content (%) ,

4