Temperature-decreasing and Humidity-increasing Effects of Typical Landscape Plants in Suzhou City

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ABSTRACT: Garden trees play an integral role in supporting healthy urban communities as part of ecological system. 13 typical landscape plants, in Suzhou City, were selected to study the correlations among canopy width, vegetation quantity, branching point height and temperature-decreasing and humidity-increasing effects. This paper showed that different garden plants had various temperature-decreasing and humidity-increasing effects. Osmanthus fragrans (Thunb.) Lour., Zelkova schneideriana Hand.-Mazz., Cinnamomum porrectum (L.) Presl, Magnolia grandiflora L., Pinus massoniana Lamb., Ligustrum Lucidum Ait. and Diospyros Kaki Thunb. had more higher capacity, Platanus acerifolia Willd. and Pinus bungeana Zucc. were a little lower, and Bischofia polycarpa (Levl.) Airy-Shaw, Eriobotrya japonica (Thunb.) Lindl., Albizia julibrissin Durazz. and Liquidambar formosana Hance had the more lower effects on temperature-decreasing and humidity-increasing. Statistics showed that there was a significant positive correlation between the average canopy width and temperature-decreasing and humidity-increasing effects. Vegetation quantity and temperature-lowering had a significant positive correlation, in contrast, the vegetation quantity and humidity-increasing had not a significant positive correlation. Branching point height had effect to decrease temperature and humidity with a certain range.

INTRODUCTION

With dramatically increase of economical development, city size and population speed up the process of urbanization in Suzhou, the heat island effect, city haze, blue-green algae in Taihu lake and other, extreme weather events increased significantly; surface temperature in the urban area of Suzhou City center showed a beam-like distribution. Xiangcheng District, Wuzhong District and other places are the areas of high temperature vale (Yan et al., 2009 & Yan et al., 2012). The heat island effect was found in the urban area of in 1980s; in the mid-1990s it expanded to Kunshan sip and Wujiang; in 2004, the heat island spread to the entire area of Suzhou city (Yan et al., 2010).

Landscape trees play an integral role, which represent a showcase of biodiversity, in supporting healthy urban communities through the provision of environmental, social and economic benefits. Plant is not only a representative to increase biodiversity but also an effective tool for urban Landscaping (Jennifer et al., 2015 & Li et al., 2007 & Stefano, 2014). During non heat extremes, for every 10% increase in the percentage of tree canopy explained a 0.2 ˚C decrease in air temperature variation (Paul et al., 2014). While, the most prominent feature of the garden plants is the ability to reduce the heat of solar radiation by changing the urban heat island effect (Man-zhu, 2009); meanwhile plants release moisture into the air through transpiration to increase air humidity.

In this paper, to provide a reference for the evaluation of the ecological garden city.

EXPERIMENTAL MATERIALS AND METHODS

Experimental Materials

In this paper, 13 typical landscape plants, in Suzhou, *Cinnamomum porrectum* (L.) Presl*, Magnolia grandiflora* L., *Zelkova schneideriana* Hand.-Mazz., *Albizia julibrissin* Durazz., *Bischofia polycarpa* (Levl.) Airy-Shaw, *Diospyros Kaki* Thunb.*, Platanus acerifolia* Willd., *Osmanthus fragrans* (Thunb.) Lour.*, Ligustrum Lucidum* Ait., *Pinus massoniana Lamb*, *Eriobotrya japonica* (Thunb.) Lindl., *Liquidambar formosana* Hance and *Pinus bungeana* Zucc.were selected. Characterized in Table 1.

Table 1. The characteristics of 13 typical landscape plants.

Species	Canopy width (m)	Height of the branching point (m)	Leave area index	vegetation quantity (m^2)
1	9.28	2.31	2.5658	173.46
2	7.11	2.48	2.5215	100.06
3	9.99	2.83	3.0595	239.69
4	6.61	2.30	2.2688	77.82
5	9.90	1.80	1.8382	141.43
6	9.05	2.25	3.6056	231.82
7	11.90	2.90	1.6136	179.37
8	11.40	2.10	1.5930	162.52
9	9.50	1.60	1.1714	82.99
10	11.40	2.50	2.1601	220.37
11	7.60	0.70	2.2585	102.41
12	7.20	2.95	2.1172	86.16
13	9.55	1.55	1.5975	114.37

Note: Vegetation quantity equals the leave area index times the shadow space of the canopy area.
1 *Cinnamomum porrectum* (L.) Presl, 2 *Magnolia grandiflora* L., 3 *Zelkova schneideriana* Hand.-Mazz., 4 *Albizia julibrissin* Durazz., 5 *Bischofia polycarpa* (Levl.) Airy-Shaw, 6 *Diospyros Kaki* Thunb., 7 *Platanus acerifolia* Willd., 8 *Osmanthus fragrans* (Thunb.) Lour., 9 *Ligustrum Lucidum* Ait., 10 *Pinus massoniana* Lamb., 11 *Eriobotrya japonica* (Thunb.) Lindl., 12 *Liquidambar formosana* Hance, 13 *Pinus bungeana* Zucc.

Experimental Methods

The effects of temperature-decreasing and humidity-increasing in summer are most obvious, especially at 13:00-14:00 (Jun et al., 2009). Therefore, we processed at 13:00-14:00 on July 2014, with the breeze or calm winds. Temperature and humidity loggers (China, TES-1365) and wind speed measured equipment (China, FLUKE 923) are used to test the temperature and humidity of air and under the plants, which were 1.5m high from the ground. Besides, laser rangefinder (China, Leica disto D5) was also used to measure the canopy width and branching points height of the garden plants. Used the tape to measure the tree's diameter, digital plant canopy image (China, SY-S01A) was used to analyzer trees leaf area index, leaf inclination and canopy density.

Data Collecting and Processing

WPS 2013, Microsoft Excel 2003 and IBM SPSS STATISTICS 19.0 were used to do the date analyses processing. The experimental data was used in the natural logarithm of the process. The measurement came from the reference researchers (Zhong et al., 2012), the calculation is as follows:

$$c_r = \frac{r_t - ur_t}{r_t} \qquad (1)$$

$$h_r = \frac{ur_h - r_h}{r_h} \qquad (2)$$

Where c_r = cooling rate; r_t = reference temperature; ur_t = under tree temperature; h_r = humidification rate; r_h = humidity reference; ur_h = under tree humidity.

RESULTS AND ANALYSIS

Temperature-decreasing Effect

Figure 1 showed, different landscape plant had various temperature-decreasing function. The temperature drop range of *Platanus acerifolia* Willd. was the highest (3.2 ˚C), the reducing rate of temperature upped to 8.38%, which was about 8 times as much as that of *Liquidambar formosana* Hance. and *Pinus massoniana* Lamb.; the cooling rate of latter were lowest. The cooling rate of *Zelkova schneideriana* Hand.-Mazz. was 7.24%, which was higher than others except *Platanus acerifolia* Willd.. The capacity order of their cooling were as follow: *Platanus acerifolia* Willd. > *Zelkova schneideriana* Hand.-Mazz. > *Cinnamomum porrectum* (L.) Presl > *Magnolia grandiflora* L. > *Pinus massoniana* Lamb. > *Pinus bungeana* Zucc.> *Ligustrum Lucidum* Ait. > *Diospyros Kaki* Thunb. > *Osmanthus fragrans* (Thunb.) Lour. > *Bischofia polycarpa* (Levl.) Airy-Shaw > *Eriobotrya japonica* (Thunb.) Lindl. > *Liquidambar formosana* Hance > *Albizia julibrissin* Durazz.
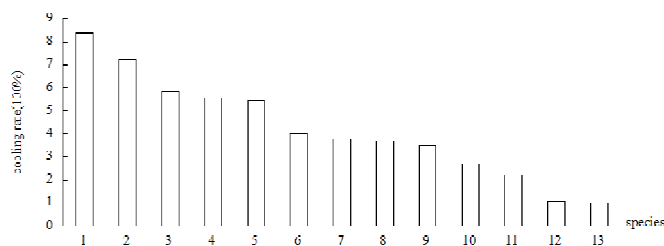

Figure 1. Cooing rate of various landscape plants. Taking the temperature of shadow was 0˚C as 100%.

Note: 1 *Platanus acerifolia* Willd., 2 Zelkova schneideriana Hand.-Mazz., 3 *Cinnamomum porrectum* (L.) Presl, 4 *Magnolia grandiflora* L., 5 *Pinus massoniana* Lamb., 6 *Pinus bungeana* Zucc., 7 *Ligustrum Lucidum* Ait., 8 *Diospyros Kaki* Thunb., 9 *Osmanthus fragrans* (Thunb.) Lour., 10 *Bischofia polycarpa* (Levl.) Airy-Shaw, 11 *Eriobotrya japonica* (Thunb.) Lindl., 12 *Liquidambar formosana* Hance, 13 *Albizia julibrissin* Durazz.

The Correlation between Temperature-increasing Effect and Average Canopy Width, Vegetation quantity, Branching Point Height

Different garden plants also have various temperature-decreasing effects because of their different internal factors. The average canopy width, vegetation quantity and branching point height and the cooling rate correlation were analyst, and the results were shown in Table 2.

(1) There was a significant positive correlation between temperature-decreasing effect and canopy width. From table 2, the correlation coefficient between temperature-decreasing effect and average canopy width was 0.684 that had a significant correlation ($p < 0.01$). With the canopy width increases, the reflection of solar radiation in and around the buildings are up to effectively block, greatly reducing the temperature of the surrounding plants, which play a role to drop the temperature. The larger the plant canopy width is, the temperature-decreasing effect is more obvious.

(2) There was a significant positive correlation between temperature-decreasing effect and vegetation quantity. From Table 2, the correlation coefficient and regression coefficient were 0.677 and 1.108, and $p < 0.01$, its correlation results significantly. With vegetation quantity increasing, the

light energy utilization is raising and the overall transpiration is increasing, so as to achieve the temperature-decreasing effect. Meanwhile, with the increasing of vegetation quantity, the temperature-decreasing increases too.

(3) There was a positive correlation between temperature-decreasing and branching point height. From table 2, the correlation coefficient and regression coefficient were 0.217 and 0.126, $p > 0.05$. Therefore, the temperature-decreasing effect with branching point height had not significant correlated.

Table 2. The correlation between temperature-decreasing effect and average canopy width, vegetation quantity, branching point height.

Term	R	p	Regression coefficient
Canopy width	0.684	0.005	0.198[**]
Vegetation quantity	0.677	0.005	1.108[**]
Height of the branching point	0.217	0.677	0.1257

Note: *means significant difference in the 5% level,   **means significant difference in the 1% level.

Humidity-increasing effect

Different landscape plants had various humidity-increasing effects. According to figure 2, the humidification rate of *Ligustrum Lucidum* Ait. reached 30.11 %, which was about 30 times as much as that of *Liquidambar formosana* Hance. Followed by *Osmanthus fragrans* (Thunb.) Lour., *Zelkova schneideriana* Hand.-Mazz. and *Diospyros Kaki* Thunb., the humidity-increasing effect upped to 16.18%, 14.64% and 10.22%. That of *Cinnamomum porrectum* (L.) Presl, *Magnolia grandiflora* L. and *Pinus massoniana* Lamb. were little lower, the rate were close to 10.00%. The lowest rate which was less than 3.00% was *Liquidambar formosana* Hance and *Albizia julibrissin* Durazz.. The capacity order of their humidification were *Ligustrum Lucidum* Ait. > *Osmanthus fragrans* (Thunb.) Lour. > *Zelkova schneideriana* Hand.-Mazz. > *Diospyros Kaki* Thunb. > *Cinnamomum porrectum* (L.) Presl > *Magnolia grandiflora L* > *Pinus massoniana* Lamb. > *Pinus bungeana* Zucc. > *Platanus acerifolia* Willd. > *Eriobotrya japonica* (Thunb.) Lindl. > *Bischofia polycarpa* (Levl.) Airy-Shaw > *Albizia julibrissin* Durazz. > *Liquidambar formosana* Hance.
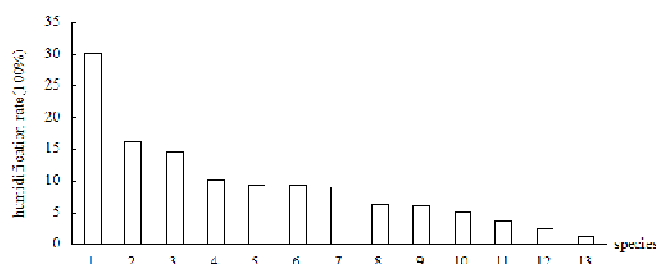

Figure 2. Humidification rate of various landscape plants. Taking the humidity of the shadow was two times of the air as 100%.
Note: 1 *Ligustrum Lucidum* Ait., 2 *Osmanthus fragrans* (Thunb.) Lour., 3 *Zelkova schneideriana* Hand.-Mazz., 4 *Diospyros Kaki* Thunb., 5 *Cinnamomum porrectum* (L.) Presl, 6 *Magnolia grandiflora* L., 7 *Pinus massoniana* Lamb., 8 *Pinus bungeana* Zucc., 9 *Platanus acerifolia* Willd., 10 *Eriobotrya japonica* (Thunb.) Lindl., 11 *Bischofia polycarpa* (Levl.) Airy-Shaw, 12 *Albizia julibrissin* Durazz., 13 *Liquidambar formosana* Hance.

The correlation between humidity-increasing effect and average canopy width, vegetation quantity, branching point height

Different species results vary humidity-increasing effect.

(1) There was a positive correlation between humidity-increasing effect and average canopy width (Table 3). The correlation coefficient was 0.52 and $p < 0.05$. With canopy width increasing, humidity-increasing effect increasing, which was a positive correlation. It is possible to increase the frequency of use of larger canopy width species to create a good living environment combined with other factors.

(2) Vegetation quantity had effect to increase humidity with a certain range from Table 3. The correlation coefficient and the regression coefficients were 0.384 and 0.798 and $p > 0.05$, therefore the humidity-increasing effect and vegetation quantity showed a positive correlation, but the correlation between them was not obvious.

(3) The branching point height had effect to decrease humidity with a certain range (Table 3). The correlation coefficient and regression coefficient were -0.078 and -0.036, humidity-increasing effect and branching point height was negative correlation. With the branching point height of the plant increasing, the permeability increasing, so it is much better for the air under the plant to circulate, That may explained the result.

(4) There was a significant positive correlation between humidity-increasing effect and temperature-lowering effect, which could be seen from Table 3. The correlation coefficient was 0.693, and $p < 0.01$. This indicated humidity-increasing effect and temperature-lowering effect had a significant relationship. With the rate of humidification increasing, the cooling rate increasing, or otherwise.

Table 3. The correlation between humidity-increasing effect and average canopy width, vegetation quantity, branching point height.

Term	R	p	Regression coefficient
Canopy width	0.52	0.034	0.1187*
Vegetation quantity	0.384	0.098	0.798
Height of the branching point	-0.078	0.399	-0.036
Cooling rate	0.693	0.004	0.880**

Note: *means significant difference in the 5% level, **means significant difference in the 1% level.

Conclusions

Osmanthus fragrans (Thunb.) Lour., Zelkova schneideriana Hand.-Mazz., Cinnamomum porrectum (L.) Presl, Magnolia grandiflora L., Pinus massoniana Lamb., Ligustrum Lucidum Ait. and Diospyros Kaki Thunb. had higher capacity, Platanus acerifolia Willd. and Pinus bungeana Zucc.were a little lower, and Bischofia polycarpa (Levl.) Airy-Shaw, Eriobotrya japonica (Thunb.) Lindl., Albizia julibrissin Durazz. and Liquidambar formosana Hance had lower effects on temperature-decreasing and humidity-increasing.

While, there were correlation between humidity-increasing and temperature-lowering effects and vegetation quantity, canopy width and vegetation quantity. Different landscape plants had various temperature-decreasing and humidity-increasing functions. Differences in temperature-decreasing and humidity-increasing effects were greatly affected by plant species, canopy width, vegetation quantity and other factors. There was a significant positive correlation between the average canopy width and temperature-decreasing and humidity-increasing effects. Vegetation quantity and temperature-lowering had a significant positive correlation, in contrast, the vegetation quantity and humidity-increasing had not a significant positive correlation. Branching

point height had effect to decrease temperature and humidity with a certain range. In addition, with the humidification rate increasing, the cooling rate increasing.

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