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FACING CLIMATE CHANGE III. COOLING EFFECTS AND HEAT DISSIPATION OF SOME TREES GROWN AT ISMAILIA CITY

E.M. Koriesh[*] and M.M. Hefni[**]

* Horticulture Department, Faculty of Agriculture, Suez Canal University, Ismailia, Egypt
** Institute of Biotechnology for Postgraduate and Research, Suez Canal University, Ismailia, Egypt

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Corresponding author:
E.M. Koriesh
quriesheid@yahoo.com

ABSTRACT: Trees are considered the most valuable components in the landscape in cities due to their large size and high efficiency in protecting the environment. The trees are recommended to be planted in cities. However, most municipalities look for the aesthetic appearance and economic aspects before any other statements related to environmental protection and the effects of climate change. In this study, we attempt to investigate the high temperatures, one consequence of climate change, that has major economic impacts on societies through high energy consumption and the lack of thermal comfort for citizens. The study focused on identifying the superior trees planted in Ismailia City in terms of their ability to cool the air surrounding the trees and their location. We selected healthy trees representing a variety of trees grown under the same conditions for the experiment. The temperature of the leaves and the temperature of the air directly adjacent to the leaf were measured with the HTC-2 device between 10 and 12 a.m. in August 2023, with repeating the measurement on three successive Sundays. The results indicate that trees belonging to the genus *Enterolobium* have the highest ability to reduce heat and the highest efficiency in increasing heat dissipation, thus reducing the temperature of the surrounding environment, followed by *Schinus molle* trees. Both *Ficus retusa* and *Delonex regia* had a suitable effect on the cooling capacity. *Bombax* trees had the least impact on the environment in terms of cooling capacity in Ismailia City.

Keywords: Trees, climate change, leaf temperature, heat dissipation, cooling capacity

INTRODUCTION

Trees are significant elements in crowded urban areas because of their aesthetic value and cooling effect during hot seasons, directly affecting the local microclimate and globally facing climate change (Feng *et al.,* 2023). Certain trees, however, tolerate high urban temperatures more effectively than other vegetation (Yaşlı *et al.*, 2023). One benefit that trees provide is the ability to regulate the urban microclimate and reduce heat loads through evapotranspiration and shadowing (Meili *et al.*, 2021).

Foliage temperature refers to the resultant leaf temperature or integrated temperature over a plant cover. The foliage temperature has significant implications for the plant and its surrounding environment. Because of their high atmospheric coupling, the tree foliage temperature is vital for the local and global climate (Richter *et al.*, 2022**)**. Foliage temperature can significantly differ among tree species (Ferrante *et al.,* 2016).

Various factors influence the surface temperature of leaves, including ambient air temperature, light spectrum, relative humidity, leaf physiology, genetic/metabolic variations, and pigmentation. Among them, air temperature serves as a baseline for leaf temperature. Large-leaved trees typically remain hotter than small-leaved trees (Leuzinger *et al.,* 2010). Studying plants' heat is essential to understanding plant-environment interactions (Foley *et al.,* 2003). The leaf succulence or the leaf water content per unit area controls the process of heat absorption within the leaf, which influences the dynamics of transpiration and convection.

Plant leaves absorb, disperse, and transfer sunlight of all wavelengths in the visible, shortwave-infrared, and near-infrared spectra. A leaf's optical traits depend on its biophysical and biochemical properties, including its three-dimensional cellular architecture. The nature of a leaf reflectance spectrum depends on its absorption and scattering characteristics (Ustin and Jacquemoud, 2020).

According to Taiz *et al.* (2022), heat dissipation is the process of heat transfer from a warmer object to a colder object and the surrounding environment (Xu *et al.,* 2020). Heat dissipates in three processes: convection, conduction, and radiation (Raschke, 1960). Trafton (2020) suggests that environmental conditions affect the energy dissipation rate, and plants in very sunny conditions convert about 30% of sunlight into sugar, with the rest released as heat.

Analysis of temperature trends shows that temperatures in urban regions have risen since ~1940 by around 0.5-3.0 °C. The temperature rise can have substantial influences due to the cities' heat effects. These heat effects modify the urban environment and mitigate climate change, but can be reversed by urban trees. The temperature of a leaf depends on the energy it receives and eliminates (Rajametov *et al*., 2021). So, urban trees can significantly affect the urban air temperature. Moreover, the foliage temperature of urban trees is of primary relevance from a human standpoint, because of their cooling impact on urban climate (Gillner *et al.,* 2015). Despite the present and prospective aesthetic and microclimatic effects, scant data exist on urban tree temperatures (Harlan *et al.,* 2006).

This study is targeted to analyze tree leaf temperatures of eight tree species commonly planted in Ismailia city.

MATERIALS AND METHODS

We selected eight tree species grown in Ismailia City for this study. Selected plants were *Cassia fistula, Cassia nodosa, Delonex regia, Ficus retusa, Bombax ceiba, Enterolobium contortisiliqua, Schinus mole,* and *Tecoma stans.* Tree ages were 22 years. The surface temperature of leaves and air temperature were measured between 10 and 12 a.m. on Sundays for three consecutive weeks during August 2023. Leaf temperature was measured superficially for leaves on the sunny side of the trees at breast height. Each time, the number of measurements was 10.

Cooling capacity:

Cooling capacity was calculated according to Wang *et al.* (2022). The used equation was:

$$\text{Cooling capacity} = (T_{air} - T_{leaf})/T_{air}$$

Where:

T_{air} is the air temperature, and

T_{leaf} is the leaf temperature.

Heat dissipation:

We calculated heat dissipation according to an online program carried by Savvy calculator, using the following equation:

Heat dissipation rate = thermal conductivity × surface area × temperature difference.

So, if water is the fluid (water in leaves), the following equation can be used (Adepoju *et al*., 2020):

$$Q = mCp\Delta T$$

Where: Q is the heat that the fluid (water) loses or gains, m (kg/s) is the mass flow rate of the fluid (water = 1), Cp is the specific heat of the fluid (water in leaf) in functional temperature during the time of measuring, and ΔT is the temperature difference between the outlet and the inlet (between leaves and air temperatures).

Data analyses:

All results were reported as means. The experiment was conducted in a randomized complete design in ten replicates (the same tree) with eight treatments (species). The differences between the treatments were calculated using LSD According to Midway (2020) diagrams, in some cases, are much more efficient than tables in displaying the data

RESULTS

Fig. (1) shows that the cooling capacity of the studied trees varied according to the plant genera. The cooling ability is helpful in identifying the difference in the temperature of the leaves from the temperature of the surrounding environment, attributed to the air temperature (Wang *et al.,* 2022). This finding indicates that the specific plant influences the temperature of the surrounding air and can cool environmental temperature. *E. contortisiliqua* and *F. retusa* trees showed the highest ability to influence the air of the surrounding environment. The least efficient trees in Ismailia conditions were *B. ceiba*, followed by *C. nodosa*.

Fig. (2) demonstrates thermal dispersion, which explains the ability of heat transfer from high-temperature air to the leaves of these trees having lower temperatures than the surrounding air.

The preeminent trees in heat dissipation value were *E. contortisiliqua* followed by *S. molle*. The plants with the lowest thermal dissipation value were also *B. ceiba* and *C. nodosa*.

DISCUSSION

A substantial amount of research offers a strong hypothesis that there is a relationship between trees and the environment, and this is evident in the temperature of the leaves and the temperature of the surrounding air (Tan *et al*., 2016). The obtained data are in accordance with that reported by Wang *et al.* (2023). They reported that there were different cooling intensities for different tree species (from 5.05 °C to 16.12 °C). This study could be helpful for the construction and planning of urban vegetation to handle city heat waves.

This study reveals that *E. contortisiliqua* trees are the leading and *B. ceiba* are the least efficient in reducing air temperature in Ismailia conditions. In this concern, Tan *et al*. (2016) concluded that trees and vegetation, such as shrubs, bushes, and tall grasses, reduce air and surface temperatures. Also, Gratani *et al*. (2016) suggested that the

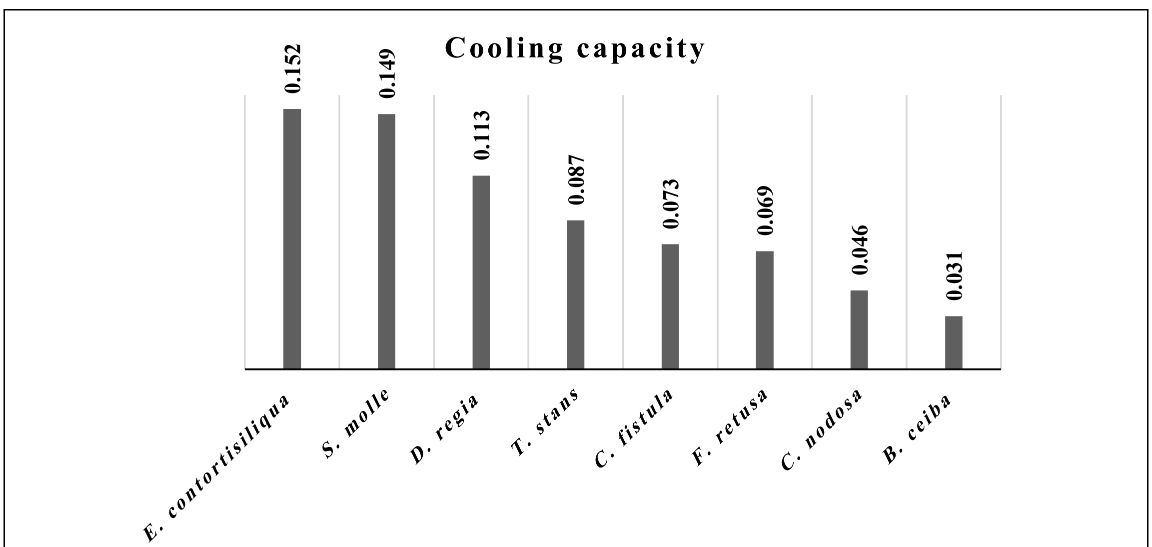

Fig. 1. Cooling capacity of some trees grown in Ismailia city (LSD value = 0.013).

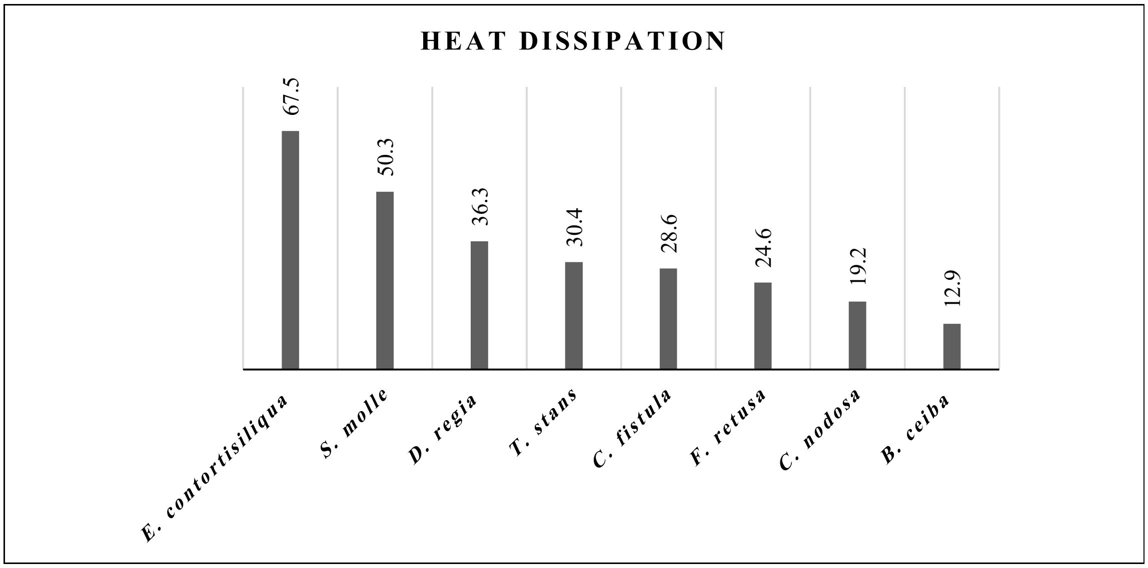

Fig. 2. Heat dissipation of some trees grown in Ismailia city (LSD value = 3.538).

cooling benefits of trees may be more crucial for the environment than their ability to store carbon. Therefore, trees directly influence our climate and play a role in cooling temperatures.

Plants have several mechanisms to avoid heat stress. Plants grown under heat stress demonstrate a faster induction of energy dissipation (Zhang *et al*., 2016; Teskey *et al*., 2015 and Allahverdiyeva and Aro, 2012). The obtained results imply that more attention should be paid to heat dissipation between plants and the environment during summer times.

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مواجهة التغير المناخي: ٣. تأثيرات التبريد وتبدد الحرارة لبعض الأشجار المزروعة بمدينة الإسماعيلية

عيد محمد قريش* ، محمود مختار حفني**

* قسم البساتين، كلية الزراعة، جامعة قناة السويس، الإسماعيلية، مصر
** معهد التقنية الحيوية للدراسات العليا والبحوث، جامعة قناة السويس، الإسماعيلية، مصر

تعتبر الأشجار أهم عناصر التنسيق في المدن لحجمها الكبير وكفاءتها المرتفعة في خدمة البيئة. تختلف أنواع الأشجار التي يمكن أو يوصي بزراعتها في المدن، ولكن أغلب البلديات تبحث عن الشكل الجمالي والنواحي الاقتصادية قبل أي اعتبارات أخري تتعلق بحماية البيئة والتأثيرات على التغيرات المناخية. في هذا العمل العلمي تم دراسة ارتفاع درجة الحرارة كأحد العوامل المؤثرة على التغير المناخي والتي لها تأثيرات اقتصادية كبيرة على المجتمعات في الاستهلاك المرتفع للطاقة وعدم توفر الراحة الحرارية للمواطنين. إهتمت الدراسة بتحديد أفضل الأشجار المنزرعة في الإسماعيلية في قدرتها على تبريد الهواء المحيط بالأشجار وبالتالي الموقع. إستخدم للتجربة أشجار صحية وسليمة وممثلة للصنف ومنزرعة في نفس الظروف وتم قياس درجتي حرارة الأوراق، والهواء المجاور للورقة مباشرة بجهاز HTC-2 في الفترة من ١٠ وحتى ١٢ صباحا في شهر أغسطس للعام ٢٠٢٣ مع تكرار القياس في ثلاثة أيام. تشير النتائج إلى أن أشجار الإنترلوبيوم *Enterolobium* هي الأفضل في قدرة خفض الحرارة وكذلك كفاءتها المرتفعة لزيادة التشتت الحراري والذي ينتج عنه خفض حرارة البيئة حول الأشجار، ويليها بصفة عامة أشجار الفلفل رفيع الأوراق *Schinus molle* وكان لكل من البوانسيانا والفيكس *Ficus retusa and Delonex regia* تأثير مناسب علي قدرة التبريد. أما أشجار البومباكس *Bombax* فكانت الأقل مساعدة للبيئة في قدرة التبريد.