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Effects of High Temperatures on Trees and Cities - How Do Plants Improve Urban Climate?

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Abstract **–** Heat stress affects the metabolism and vitality of plants. High temperatures in plants are caused by direct solar radiation or the high temperature of the surrounding air. Factors such as the leaf shape of the plant, the sunny or shaded environment in which it grows, the age of the tree, the vegetation period, and the reason and duration of the tree's exposure to heat stress affect the tree’s resistance to heat stress. At the same time, plants play an important role in reducing the effects of the urban heat island. In this review, information is given about the effects of plants that are widely used in cities and their role in reducing the urban heat island effect.

Keywords – Heat Stress, Urban Trees, Urban Landscape,

I. INTRODUCTION

Climate change has been progressing since ancient times. Human activities, which have increased since the first day of the Industrial Revolution in 1750, with the human population reaching one billion, are the most important factor in directing the climate on Earth. According to the Intergovernmental Panel on Climate Change (IPCC), carbon dioxide and methane levels have increased by 35% and 148%, respectively since the 1750 industrial revolution (Shahzad, 2015). The global average temperature has risen by 1 °C above the pre-industrial level. (IPCC, 2022). In addition, high temperatures have been measured in recent years (Perkins-Kirkpatrick and Lewis, 2020; Marchin et al., 2022). The urban heat island effect affects about a quarter of the world's population (Tuholske et al., 2021).

Cities have been described as "heat islands" and "dry islands" because the air in urban areas is warmer and drier than the surrounding landscape. As climate change intensifies, the health of urban trees will be increasingly affected (Marchin et al., 2022). In light of this information, the global temperature is the cause of the increase in ocean water temperature, the rise in sea level, the residual destruction of the snow cover in the Northern Hemisphere. At the end of the 21st century, it is predicted that the global average temperature will increase by 4ºC, and even if all greenhouse gas emissions are stopped today, the temperature increase of around 2ºC will not be stopped until 2090-2100 (Mukhopadhyay, 2013).

Trees are used in urban landscape planning in parking lots, boulevards, and squares. Heat loads from surrounding pavements or from convection and advection cause various problems for plants. It causes the relative humidity to decrease and the air and surface temperatures surrounding a tree to increase due to the increase in their temperature. This forces a tree to lose excess water through physical dehydration processes.

Therefore, species and cultivars with high phenotypic plasticity abilities should be taken into account, as should physiological adaptation to changing conditions or stress conditions. But lately, it has been observed that broad-leaved trees have been removed and shrubs or seasonal species have been planted on the streets of our cities. This article will focus on the effect of high temperatures on urban trees.

II. HEAT STRESS

Further integration of results and tools in these approaches is needed to better understand how heat stress associated with global warming will affect plants. Second, there is a growing need to correlate plant responses with tissue temperatures. We review how plant energy budgets determine tissue temperature and discuss the implications of using leaves versus air temperature for heat stress studies. Third, we need to better understand how heat stress affects reproduction, particularly under-studied stages such as floral meristem initiation and development. Fourth, we highlight the need to integrate heat stress recovery into breeding programs to complement recent progress in improving plant heat stress tolerance. Taken together, we provide insights into important research gaps in plant heat stress and offer recommendations for addressing these gaps to increase heat stress resilience in plants (Jagadish et al., 2021).

As is known, photosynthesis is very sensitive to high temperatures. The stress of temperatures leads to cellular energy imbalance. At high temperatures, photochemical reactions in the thylakoid lamellae of chloroplasts and carbon metabolism in the stroma of chloroplasts are most affected (Hu et al., 2020). With problems in parameters such as photosynthesis, stomatal conductivity, growth, the leaves fall off and become necrotic. Depending on the duration, frequency, and severity of heat stress, tree death may occur.

The direct effect of heat stress on trees can be significantly affected by soil moisture conditions. In most cases, trees can cope with ambient temperatures > 40 °C for short periods of time by providing sufficient soil moisture for water uptake to cool leaves by evaporation through transpiration and convective trunk tissues via heat transfer (Kolb and Robberecht, 1996). Measuring the effects of heat stress on trees in urban landscapes largely depends on the capacity to diagnose stress. For example, heat stress can limit the amount of carbohydrates available for growth and reduce nutrient uptake, causing leaf yellowing and necrosis (Percival, 2023).

As all climate models declare, extreme temperature rises will be an annual disaster. Next, heatwaves have the potential to significantly affect the population dynamics of urban trees globally.

III. TREES AND VEGETATION TO REDUCE HEAT ISLANDS

The magnitude of surface urban heat islands varies with seasons due to changes in the sun's intensity as well as ground cover and weather. As a result of such variation, surface urban heat islands are typically largest in the summer. Urban heat islands are most intense in the summer when the skies are clear and there are no winds. Dense cloud cover blocks solar radiation, reducing daytime warming in cities. Strong winds increase atmospheric mixing, lowering the urban-rural temperature difference (Oke, 1982).

The urban climate is generally warmer than its rural surroundings. As cities develop, vegetation decreases and becomes covered with buildings. The change in ground cover results in less shade and humidity. This contributes to the rise in surface and air temperatures. Trees help cool the environment, making vegetation a simple and effective way to reduce urban heat islands.

Urban heat islands negatively affect urban people by increasing peak energy demand in summer, air conditioning costs, air pollution and greenhouse gas emissions, heat-related diseases and deaths, and water quality.

Atmospheric urban heat islands are generally weaker in the late morning and throughout the day and become more pronounced after sunset due to the slow release of heat from urban infrastructure. However, the timing of this cycle depends on the characteristics of urban and rural surfaces, the season, and the prevailing weather conditions. Here, too, the importance of urban landscape and vegetation can be seen.

The use of trees or vegetation in the urban landscape provides many benefits as well as reducing urban heat islands. Urban heat island reduction strategies (for example, trees, vegetation, and green roofs) often provide benefits throughout the year. Trees and vegetation that directly shade buildings reduce air conditioning operating times. Trees and vegetation reduce the production of air pollution and greenhouse gas emissions. It stores carbon dioxide. Plants absorb rainwater, reducing runoff. Tree shade can prevent the deterioration of street pavement and reduce the amount of maintenance required. Trees and vegetation provide aesthetic value, habitat for many species, and can reduce noise (Fig. 1).

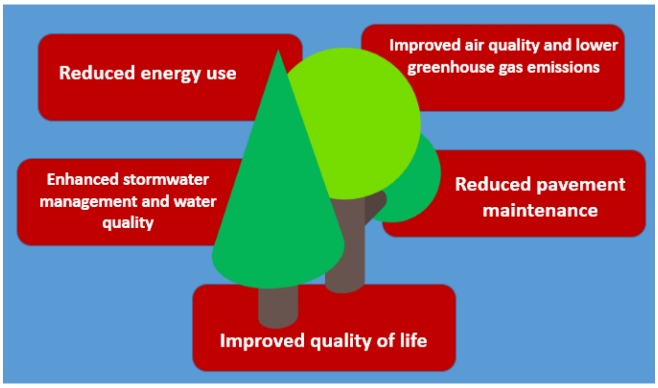

Fig.1. Benefits of plants to the city

IV. TREE SPECIES USED IN HIGH TEMPERATURE AREAS

Cities where the effect of heat is felt most are those in regions where arid or semi-arid conditions are experienced. When these regions are examined, the species commonly used in urban landscape areas have been determined. Generally, similar species are used in these areas. The types used are generally as follows *Acer negundo* L., *Ailanthus altissima* (Mill.) Swingle, *Albizia julibrissin* Durazz., *Catalpa bignonioides* Walter, *Cedrus atlantica* (Endl.) Manetti ex Carriere, *Cedrus libani* A.Rich., *Celtis tournefortii* Lam., *Ceratonia siliqua* L., *Cercis siliquastrum* L., *Cupressocyparis leylandii* (A.B.Jacks. & Dallim.) Dallim., *Cupressus arizonica* Greene, *Cupressus macrocarpa* Hartw., *Cupressus sempervirens* L., *Elaeagnus angustifolia* L., *Eriobotrya japonica* (Thunb.) Lindl., *Fraxinus excelsior* L., *Koelreuteria paniculata* Laxm., *Lagerstroemia indica* L., *Laurus nobilis* L., *Ligustrum japonicum* Thunb., *Magnolia grandiflora* L., *Melia azedarach* L., *Olea europaea* L., *Paulownia tomentosa* Steud., *Pinus brutia* Ten., *Pinus nigra* Lamb., *Pinus pinea* L., *Platanus orientalis* L., *Prunus cerasifera* Ehrh., *Punica granatum* L., *Robinia hispida* L., *Robinia pseudoacacia* L., *Salix babylonica* L., *Schinus molle* L., *Tilia tomentosa* Moench, and *Ulmus glabra* Huds.

Although these species are seen as broad-leaved in quantity, coniferous plants are also widely used in cities. But lately, it has been observed that broad-leaved trees have been removed and shrubs or seasonal species have been planted on the streets of our cities. This article will focus on the effect of high temperatures on urban trees.

In the study conducted in the arid area around the Negev Desert in Israel, *Pinus halepensis* was used, and it was concluded that small seedlings grew faster than large seedlings in arid regions. Generally, it has been determined that there are significant differences in water flow and transpiration between dry and rainy periods (Schiller and Cohen, 1998). In the plantation studies carried out in semi-arid conditions in Jordan, *Pinus halepensis* was used in four different aspects and on sloping areas. Due to moisture and organic matter content, it was stated that the height of the seedlings showed differences in the north, south, east, and west aspects. Due to the high nutrient content of the valley floors, it has been observed that the adaptation of plants is easily achieved in these areas. However, pH levels and electrical conductivity values were found to be low in the valley floors (Al-Omary, 2011). In a study, *Pinus halepensis* was used in arid regions of Spain, and bacteria, fungi, and urban waste were added to the soil. With this technique, the survival and adaptation rates of pines in poor and arid soils have increased. This argument has been strengthened by morphological differences in plants (Rincon et al., 2006).

In Southern Spain, afforestation has been carried out using the *Quercus ilex* species in areas where agricultural activities have not been carried out for a long time. In the spring, mulching was done in organic and inorganic ways, and irrigation was applied. It has been reported that the adaptation of the aforementioned species is achieved, especially with the use of forest manure (Jimenez et al., 2007).

It has been stated that *Rosa* taxa can be used in afforestation studies, especially in fire-sensitive *areas*. At the same time, it has been stated that some Rosa taxa are resistant taxa recommended in regions with semi-arid conditions (Baktır, 2015).

In addition to these, the type of plant material to be used in afforestation studies, the climate, soil, aspect, elevation structure of the area, and the methods to be used (planting type, seedling characteristics, culture processes) play an extremely important role. Paying attention to these parameters will increase the success of the plantation.

The effects of extremely high temperatures vary between species and within genotypes. Drought increases the damage caused by high temperatures.

Of all the physiological processes in trees, the effect of heat on photosynthesis has received the most attention. At the whole tree scale, extreme heat can also cause reduced growth, leaf development, and leaf area, it can cause death when combined with drought.

However, it is important to plant the right types and varieties of street trees to help combat global climate change. Therefore, it is necessary to think more strategically. For this purpose, it is necessary to choose broad-leaved species, such as drought-resistant oak, beech, and maple. Because these species have a larger leaf surface area that produces more photosynthesis, they absorb more heat than coniferous species.

Not only the species of trees but also the location choices play a role in improving the urban climate. Some suggestions regarding this are given in Fig. 2.

Fig.2. Simple suggestions to improve urban climate in plant design

V. CONCLUSIONS AND RECOMMENDATIONS

In addition to the measures to be taken for adaptation to climate change in the cities we live in, the position of urban trees within the urban green fabric should be strengthened. With the right planning in cities, urban trees can reduce high air temperatures. Thus, urban trees will play an important role in the fight against global warming, both directly and indirectly. Climate change is the most pressing environmental, social, and economi problem facing the world.

In light of this information, the temperature increases mentioned cause a physical doubling of respiration and water loss in a plant. Respiration actively involves the breakdown of sugars produced by photosynthesis, releasing both carbon dioxide and water. These small increases in overall temperatures can greatly increase water demands. Trees under heat loads need extra water. This also stands out as a different issue in the world, where scenarios of experiencing water scarcity are written about.

It is extremely important to develop environmental awareness in order to take all these measures. Damages such as flooding, erosion, and siltation will be controlled by appropriate afforestation of degraded forest areas and sloping lands. Some native woody species should be used in landscape reclamation works. *Creteagus*, *Prunus*, *Morus*, *Rosa*, *Celtis*, *Eleagnus*, and *Pistacia* taxa are recommended for afforestation studies applied in arid and semi-arid conditions. In addition, shrub species must be evaluated in these studies.

Although researchers studying urban climate have been studying urban heat islands for decades, the public's interest in and concern about them started in the 2010s. This increased attention to heat-related environmental and health issues has helped develop heat island reduction strategies, particularly trees and vegetation, green roofs, and cold roofs. In this context, positive results will be obtained with multidisciplinary studies.

REFERENCES

1. AL-OMARY, A., 2011. Effects of Aspect and Slope Position on Growth and Nutritional Status of Planted Allepo Pine in a Degraded Land Semi-Arid Areas of Jordan. New Forests, 42(3), 285-300.
2. BAKTIR, İ., 2015. Her Yönüyle Gül ve Gül Yetiştiriciliği. Hasad Yayıncılık ve Reklamcılık Tarım San. Ltd. Şti., ISBN: 978-975-8377-98-5, İstanbul, 136s.
3. HU, S., DING, Y, ZHU, C. 2020. Sensitivity and Responses of Chloroplasts to Heat Stress in Plants. Front. Plant Sci. 11:375. doi: 10.3389/fpls.2020.00375
4. HU, Y., DAI, Z. AND GULDMANN, J.M., 2020. Modeling the impact of 2D/3D urban indicators on the urban heat island over different seasons: A boosted regression tree approach. Journal of Environmental Management, 266, p.110424.
5. JAGADISH, SVK, WAY, AD, SHARKLEY, TD., 2021. Plant heat stress: Concepts directing future research. Plant Cell Environ . 2021 Jul;44(7):1992-2005. doi: 10.1111/pce.14050. Epub 2021 Apr 8.
6. JIMENEZ M.N., FERNANDEZ, O.E., RIPOLL, M.A., NAVARRO, F.B., GALLEGO, E., DE SIMON, E.,

LALLENA, A.M., 2007. Influence of Different Post-Planting Treatments on the Development in Holm Oak Afforestation. Trees, 21: 443-445.

7. KOLB, PF., ROBBERECHT, R, 1996. High temperature and drought stress effects on survival of Pinus ponderosa seedlings. Tree Physiol . 1996 Aug;16(8):665-72.
8. MARCHIN, RM, ESPERON-RODRIGUEZ, M, TJOELKER, MG, ELLSWORTH, DS, 2022. Crown dieback and mortality of urban trees linked to heatwaves during extreme drought. Science of the Total Environment 850 (2022) 157915.
9. MUKHOPADHYAY, B., 2013. Global Warming – A Threat to the Planet. American International Journal of Biology 1(1); July 2013 pp. 29-34.
10. OKE, TR. 1982. The Energetic Basis of the Urban Heat Island. Quarterly Journal of the Royal Meteorological Society. 108:1-24.
11. PERCIVAL, GC., 2023. Heat tolerance of urban trees − A review. Urban Forestry & Urban Greening Vol 86, August 2023, 128021.
12. PERKINS-KIRKPATRICK, S.E., LEWIS, S.C., 2020. Increasing trends in regional heatwaves. Nat. Commun. 11, 3357.
13. RINCON, A., PASCUAL, R.D.M., PROBANZA, A., POZUELO, J.M., DE FLIPE, M.R., 2006. Afforestation of Degraded Soils with Pinus halepensis Mill.: Effects of Inuculation with Selected Microorganism and Soil Amandment on Plant Growth, Rhizopheric Microbial Activity and Ectomycorrizhal Formation. Applied Soil Ecology, 34, 42-51.
14. SCHILLER, G., COHEN, Y. 1998. Water Balance of Pinus halepensis Mill. Afforestation in a Arid Region. Forest Ecology and Management, 105: 121-128.
15. SHAHZAD, U., 2015. Global Warming: Causes, Effects and Solutions. Durresamin Jorunal, 1 (4), ISSN: 2204-9827.
16. TUHOLSKE, C., CAYLOR, K., FUNK, C., VERDIN, A., SWEENEY, S., GRACE, K., et al., 2021. Global urban population exposure to extreme heat. Proc. Natl. Acad. Sci. 118, e2024792118.