WHICH URBAN PLANTS CAN TAKE THE HEAT? CHOOSING TREES FOR THE FUTURE

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Abstract

Urban street trees and road verges are subject to huge variation in temperatures, and in recent years have experienced severe heat-waves from climate cycles as well as warming due to the urban heat island effect. The '*Which Plant Where*' Project at Western Sydney University and Macquarie University initiated a program around screening trees and shrubs for their heat and drought tolerance, aimed toward 1) testing commonly used species and 2) finding new and overlooked species and varieties for horticultural plantings for Australia's urban areas going forward into the middle of the century. We seek to find the characteristics that make trees future-ready based on experimental heat waves conducted in glasshouse trials, that will ultimately allow for greater diversity of planting stocks in urban environments. We present the '*Which Plant Where'* Project, and focus on early results where we have screened over 40 tree and shrub species, mostly Australian natives, for heat and drought tolerance. Whilst an ongoing effort, our measurements to date have documented dieback of vulnerable trees in heatwaves, both natural and experimental, but have also identified heat-tolerant species and varieties suitable for urban horticulture. Our team includes bioclimatic modellers whose work provides the scientific basis of selecting hardy trees for regional urban areas that can survive future heatwaves and underpin the management practices to ensure our street trees thrive in urban environments.

Motivation

The majority of our population (over 85%) lives in urban areas with over two-thirds of us, more than 15 million Australians, living in the eight capital cities (Australian Bureau of Statistics, 2016 Census). On average, our cities show population growth rates exceeding 9%, and with this intensification comes an increasing urban influence on the environment. This includes intensified urban heat surrounding our roads and buildings, commonly known as the urban heat island effect (Kalnay and Cai 2003). It is worth asking, can trees in Australia's urban landscapes tolerate the heatwaves and other climate conditions we expect in urban heat islands, and are we prepared with the varieties and types of trees and shrubs that can withstand the hot future that is expected for Australia's cities (Lewis and Karoly 2013)? If we expect hotter summer conditions in our cities and prepare by appropriately selecting appropriate types of trees and shrubs for planting, we can benefit from the cooling effects of sustainable urban greening for mitigating the consequences of increased temperatures in urban heat islands. On the other hand, persisting with the 'tried and true' mantra of using plant material from past decades and not engaging in adaptive management practices in the face of intensified urban heat will mean increased risk of adverse outcomes such as tree crown dieback and even mortality (Fig. 1). Such events an increase the threat from multiple heat waves, as a tree's ability to ameliorate the local environment by its shade and transpiration is compromised.

The Australian tree flora encompasses an amazing diversity of adaptive capacity for coping with heat (Zhu et al. 2018), some of which can be used to find new options for climate-hardy street trees when other favourable horticultural traits are also considered. The '*Which Plant Where*' Project seeks to align scientific information on plant characteristics, climatic preferences and tolerance, and real-world physiological information and field testing in a database that can be accessed by urban planners, landscapers and others to use location-specific factors for urban tree selection. Our ultimate aim is to increase confidence for growers and practitioners about which plant can be used where, when and why, so we can expand the diversity of options for local urban greening and forestry interventions.

Figure 1. London plane trees (*Platanus* × *acerifolia*) along the street in Richmond, NSW showing acute heat damage just after a heatwave event on 6th-8th January 2018. Photo: D. Ellsworth.

Heat and drought tolerance of tree species in an Australian context are not sufficiently understood to help us minimise losses and ensure future street tree and urban plantings will successfully grow in place for the coming decades. Hence, our project incorporates a comprehensive research program to 1) understand the climatic space of as many horticulturally-viable Australian species as possible and build a database of the species' characteristics useful for horticulture, arboriculture and urban planning, 2) test heat and drought tolerance of species and varieties in a controlled environment and determine vulnerabilities and the ability to survive a set of extreme environmental conditions, and 3) determine how experimental plantings of a diverse set of species and varieties grow and perform in the field and quantify the multiple benefits of this diversity.

Here we describe the second objective in further detail with a focus on trees and shrubs that have been tested for their tolerance of heat waves. The experiments have been designed to help us to understand the plant characteristics we can use for ensuring our planting stock for the future is able to survive heatwaves especially in urban heat islands created by heat-radiating surfaces of the built environment (Arnfield 2003). This is but one facet of the urban conditions that street tree and other urban plantings experience, albeit an important one (Figure 1), and is only a part of the balance of factors that the '*Which Plant Where*' Project will consider and address for plant selection for the future.

Experimental heatwaves for testing plant tolerance

Heat waves can be quantified in terms of their intensity (the peak temperature that is reached) and their duration (length of time that temperatures are unusually high) or heat load (the length of time the temperature exceeds a threshold). The Bureau of Meteorology (BOM) defines a heatwave as three or more consecutive days of high maximum and minimum temperatures that are 'unusual' for that location (Nairn and Fawcett 2013), and we can further qualify 'unusual' as being about 6 °C or more above the average for that location based on 30 or more years of record (Perkins 2015).

We grew our test trees in a background period of standard warm summertime conditions in climate controlled glasshouses for over 12 weeks, then we imposed heatwave conditions by increasing the temperature in computer-controlled glasshouses by an average of 7.5 °C for each of six days.

We aimed to achieve a daily maximum air temperature of about 41.5 °C for the six days, a heat intensity that is moderate for regional Australia but nonetheless a good test of heat tolerance for street trees.

Some trees demonstrated leaf temperatures up to 50 °C, similar to what we have measured for street trees in the outdoors during actual heat waves. We also observed physical damage to some of the glasshouse-grown plants subjected to heat waves (Figure 2). This suggests that our test conditions can be used as an effective tool to compare heat tolerance amongst different tree and shrub species and varieties.

Figure 2. Lilly pillies (*Syzygium wilsonii*) showing heat damage just after a heatwave in the glasshouse. Photo: R. Prokopavicius.

We tested the heatwave responses with quantitative measures related to photosynthetic function using chlorophyll a fluorescence (Murchie and Lawson 2013) as a widely-accepted indicator of plant stress. When a plant is stressed and chloroplasts are damaged the light that is released by leaves has a characteristic pattern that we can detect to measure heat-induced damage. Plant responses to the experimental heatwave have been variable, but 7 out of the 40 woody species tested so far have demonstrated reduced chlorophyll a fluorescence as well as showing visible damage symptoms on leaves, and some did so even though well watered during the heatwave. While more glasshouse experiments are scheduled for 2018-2019, the final results will form a comprehensive body of knowledge that it is integrated with findings from the other modules of the 'Which Plant Where' project (Figure 3)..

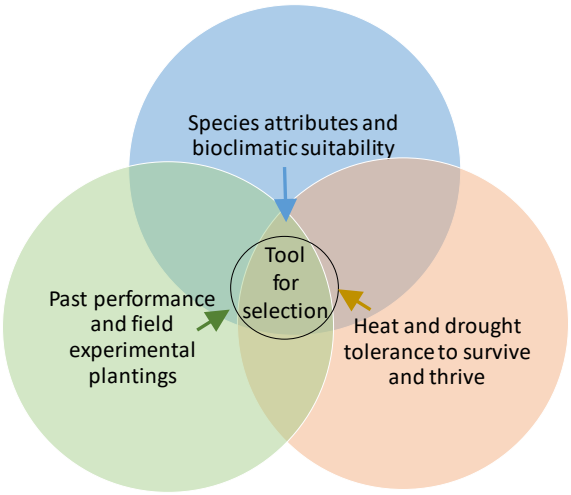

Figure 3. Overall framework for the *'Which Plant Where'* project and how the elements fit together to provide information critical for selecting urban plant species for a more sustainable future for our cities.

In the '*Which Plant Where*' Project we are seeking to combine information generated from the experiments we've described with the other project facets. We would consider what has been learned from past performance of urban plantings, alongside new experimental plantings in our *Living Labs*, together with current biogeographical information on species occurrences and model projections of future suitability. This information combined with the information gained from both heat and drought-testing, will provide a sound evidence-base for species selection for future greening in our cities.

Conclusion

Increasing temperatures and the risk of heat wave events in urban areas poses concerns to plant and human health. We have evaluated responses of common landscape plants to experimental heatwaves using modern glasshouses and instrumentation. Our evidence so far suggests some surprises: whilst heat damage of some tree species can be ameliorated by extra watering during heatwave conditions, other species have low tolerance independently of water conditions. This suggests that selection of appropriate species for high-sun and very hot microhabitats can be more effective than extra watering for avoiding heat damage to trees and shrubs during the sort of heat waves our urban areas experience currently and increasingly into the future.

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