

PLANT RESPONSES TO DROUGHT STRESS: HOW TRADITIONAL AND INNOVATIVE METHODS CAN HELP TO MAINTAIN HEALTHY GREEN AREAS WHILE LIMITING WATER CONSUMPTION

Francesco Ferrini

Department of Agriculture, Food, Environment and Forestry, University of Florence, Section Woody Plants Viale delle Idee, 30 – 50019 Sesto Fiorentino (Florence), Italy

ABSTRACT

Key words

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*Corresponding Author's Email

Francesco.ferrini@unifi.it

The effects of climate changes will be exacerbated in the urban environment which is already characterized by specific microclimatic conditions, such as temperature 3-5°C higher than the surrounding countryside ("urban heat island"), low-quality and impermeable soils that impose several stresses on plants. Also, the multiple interactions between water stress, increased temperature (diurnal and nocturnal) and increased atmospheric CO₂ is particularly interesting and controversial.

Plant tolerance of combined shade and drought, typically considered irresolvable due to trade-offs in morphology and physiology, potentially determines important vegetation patterns, especially as drought spells are becoming more severe worldwide. Existence of inverse correlations between ecological requirements of species involves the ad hoc hypothesis that being tolerant to a certain environmental factor involves a cost such that the plant cannot adjust simultaneously to multiple environmental stresses. Selection of the right species is therefore a primary requirement for successful tree planting. To this regard, pre-conditioning of nursery trees can be a supplementary tool to improve tree performances in the different urban environments. It has been shown that acclimation in the nursery to mild stress resulted in the production of hardened nursery stock, better able to tolerate transplanting and other environmental stress during establishment.

1. Context

Climate change manifests itself in two fundamentally different ways: as a change in the average yearly temperature and/or rainfall, and as a change the frequency and intensity of rain pulses and heat waves (Rumukainen, 2012; IPCC, 2013). The Mediterranean-like environments appear to be more affected by climate change than most of other climatic zones with a drastic reduction in precipitation and an increase in temperatures which will result in extreme drought events during summer, when low water availability is paralleled by heat and high sunlight radiation (Bussotti *et al.*, 2014). Also, the average intensity of rainy events is predicted to increase, but their frequency will decrease to a greater extent, particularly during spring and summer months.

The effects of climate changes will be exacerbated in the urban environment which is already characterized by specific microclimatic conditions, such as temperature 3-5°C higher than the surrounding countryside ("urban heat island")(Mc Carthy *et al.*, 2010), low-quality and impermeable soils (Ferrini and Fini, 2007), that impose several

stresses on plants. Beside this, the multiple interactions between water stress, increased temperature (diurnal and nocturnal) and increased atmospheric CO₂ is particularly interesting and controversial.

This said a question arises: what we know about the effects of climate change on trees and how they will guide our choices?

In order to specify the future effects of climate change on arboriculture and urban forestry, reliable predictions of the transient changes in regional and global climate are required because we need to select plants that will tolerate the climate change. Drought is predicted to be the most significant factor not only in the Mediterranean-like climates and this will strongly affect survival and growth of newly planted trees and will probably influence the development of diseases and tree pest resistance. Not only the short-term effects on growth or survival in extreme years deserve attention, but also the long-term impacts on tree growth have to be considered in selecting planting material. With impending water shortages in many urban areas leading to prohibitions of water usage for landscape irrigation, planting trees that are more tolerant to prolonged drought conditions is the best long-term solution to a healthier, low-maintenance landscape.

In this scenario, possible adaptation measures include changes in the establishment practices and tree management, better matching of species to site, both under current and future climates, and the planting of non-native species and provenances in anticipation of climate change. Current opinion is to encourage the planting of local provenances of native species, citing their adaptation to local conditions, and the requirement to maintain biodiversity and a native genetic base. However, indigenous or naturalized species may not be able to adapt to a changing climate, particularly given the rate of the changes predicted (Ferrini, 2011; Bussotti *et al.*, 2014). Sourcing planting stock from regions with a current climate similar to that predicted for the future, may provide one option, although care must be taken to ensure that suitable provenances are selected which are not at risk from, for example, spring frost damage as a result of early flushing or have a potential to become invasive. It is indeed possible that in the long term, phenological responses from different tree species to temperature changes could lead to permanent changes of the geographical distribution of the same species.

As already said, in the typical urban conditions, plants have often to respond to simultaneous stresses (e.g. drought, plus excessive light and heat) and their response is usually not predictable from single factor studies (Harris and Bassuk, 1993; Schulze *et al.*, 2018; Valladares and Pearcy, 2002; Valladares and Niinemets, 2008). For example, the excess light stress experienced by trees growing in urban plazas, may be exacerbated by drought, which limits the use of radiation in the photosynthetic process because of both biochemical and non-stomatal limitations (Fini *et al.*, 2012). Despite it is conceivable that moderate shading may reduce excess light stress, some research showed that the capacity of tree species to survive severe drought may be reduced by shade, because of shade-induced changes in leaf morphological, physiological and biochemical traits, resulted in lower capacity to counteract oxidative damage and in higher photoinhibition during sunflecks or after transplanting in very sunny environments (Valladares and Pearcy, 2002; Fini *et al.*, 2014). This is particularly true in Mediterranean-like climates, when high irradiance is coupled in the long period with

drought during the summer, all conditions that strongly limit carbon assimilation and promote photoinhibition of the photosynthetic apparatus (Bussotti *et al.*, 2014).

Plant tolerance of combined shade and drought, typically considered irresolvable due to trade-offs in morphology and physiology, potentially determine important vegetation patterns, especially as drought spells are becoming more severe worldwide. Existence of inverse correlations between ecological requirements of species involves the *ad hoc* hypothesis that being tolerant to a certain environmental factor involves a cost such that the plant cannot adjust simultaneously to multiple environmental stresses.

Selection of the right species is therefore a primary requirement for successful tree planting (Ferrini, 2011; Ferrini and Fini, 2013). To this regard, pre-conditioning of nursery trees can be a supplementary tool to improve tree performances in the different urban light environments. It has been shown that acclimation in the nursery to mild stress resulted in the production of hardened nursery stock, better able to tolerate transplanting and other environmental stress during establishment (Franco *et al.*, 2006; Fini *et al.*, 2011; Killi *et al.*, 2018). Exposition to full sunlight during cultivation in the nursery may act as a mild stress and may induce stress tolerance through changes in plant and leaf morpho-anatomical traits, increased leaf solute accumulation and enhanced photosynthetic, photoprotective and antioxidant capacities (Fini *et al.*, 2014). Conversely, shading in the nursery of shade-tolerant trees to be planted in urban canyon can acclimate leaf anatomy and physiology to low light and increase growth rate.

2. Conclusion

In looking to the future, it is progressively critical to understand how plant will respond to climate change and to fully recognize the important role of trees in mitigating the effects of such changes. Beside climate change, other factors must be considered in order to ensure that the proper plant is placed in a specific site in the specific time and with the proper techniques. In general, these factors, which, however, are somewhat influenced by climate change, are divided into three major categories: design, site, and maintenance considerations. More specifically, factors to consider when selecting trees for city streets or park landscapes include pruning requirements and response, tree stability, disease resistance, catastrophic insect pests, soil adaptation, complementary planting, shade or sun tolerance, provenance, and adaptive cultivars.

Finally, the selection should be based on the potential benefits brought by trees in the urban stand though, while we are all aware of these, only in the last ten years some efforts have been done to select plants for this kind of use and to adopt management practices to maximize the net benefits of urban forests on atmospheric carbon dioxide.

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