Botanic Collections: A Tool for Selecting Species Adapted to Climate Change

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ABSTRACT

It is very probable that many tree species currently in place in certain parts of the temperate world will not be able to survive in the face of current climate change. Increased periods and intensity of drought will be one of the principle causes of this and species important for forestry and horticultural alike will suffer. The genus *Quercus* is present in the Temperate Zone in a wide range of ecological niches including the dryer and warmer ones that are similar to what is expected in the future. Both the intra- and inter-specific genetic diversity of oaks is very high as is their capacity to hybridize. This would facilitate the natural transfer of genetic material, specifically, of genes that could confer drought resistance from one oak species to another, making oaks an interesting resource as replacement candidates or as "adaptation aids". There is a large degree of phenotypic similarity between these oak species and this will ensure that while drought-resistant species become dominant the landscape will not be dramatically changed. Intended to be an aid to maintaining forests and landscapes, this "replacement" strategy requires a great deal of care, experimentation and further study. In this context, species introductions in botanic collections are an exceptional source of information. These collections are very varied, but they all have in common long-standing experience planting and growing species that are not in their natural habitat. The successes and the failures, if they can be correlated with climate, represent critical information concerning species' adaptive capacity. New and even more precise information could be obtained by the selective introduction of key species in existing collections or in those to be created in future.

Keywords: climate change, oak collections, adaptation strategy

Introduction

Historically and to this day, the major challenge and obstacle for plant enthusiasts is “Will this plant survive in my climate?” For Temperate Zone inhabitants, winter cold and/or summer drought, represent the major obstacles and often – but not always – sad results for that “special” plant acquired with such high hopes. Nevertheless, it is by definition the nature of plant collectors to spend their time on risky introductions and in so doing furnish valuable information as regards species’ tolerance limits.

1/ *Quercus palustris*, from Eastern North America, growing in the private collection of Peter Laharrgue in Coronel Pringles (Argentina).

A time to take risks?

Obviously, foresters and horticulturists can not operate in the same manner: the important economic constraints within which they function oblige them to bet on “climate resistant” species and therefore choose those species or varieties that have proven hardy for a given location. In the face of current climate change and projected future scenarios, perhaps this “play-it-safe” strategy is not the most instructive and, further, should we be asking ourselves some new questions? If the climate changes, will currently adapted species remain so? In a different climate, can new species be introduced? And, if so, which ones?

For the following reasons, oaks represent a highly interesting group of candidates about which these questions can be asked in order to provide answers to both foresters and horticulturists:

1) Many species fulfill human/economic needs both in respect to timber production and landscape potential;

2) The genus covers nearly all climates where trees are present with the exception of the most northern forests;

3) Oak forests are host to enormous biodiversity;

4) Generic diversity is extremely high (more than 500 taxa) and interspecific genetic transfer is rampant, representing an extremely important asset for adaptation in any changing situation.

Answering the questions of changing bioclimatic envelopes and the consequences for species distribution as well as those concerning possible alternatives requires new concepts and scientific methods. This paper attempts to show that arboreta and botanic gardens have a specific and very important role to play in formulating those answers.

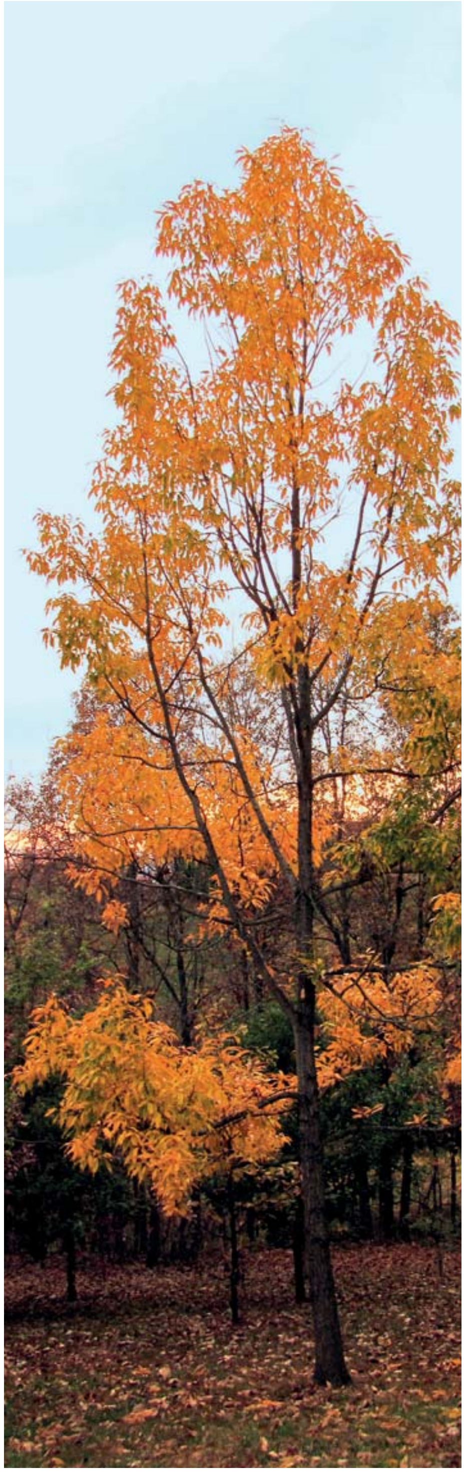
Climate change: perspectives and stakes

Current climate change is the result of the increase in the atmosphere of greenhouse gases. Because of this increase, solar energy remains trapped in the atmosphere and is reflected back on the Earth, thus inducing global warming. The mechanisms and principles of global climate are very complex and warming is neither spatially uniform nor linear in time. In addition, this warming affects all of the other components of climate: air humidity, rainfall, wind speed, etc. The consequences can be observed both on average and in the frequency and intensity of extreme phenomena, i.e., heat waves, drought, storms. Trees, like all plants, cannot get up and move and are therefore very dependent on their local climatic environment.

This dependency is related to several factors, amongst which:

1) The quantity of solar energy available determines growth and regeneration potential. Available energy can be estimated by taking the sum of maximum positive temperatures throughout the year. For each month an average maximum temperature can be calculated and thus the annual sum.

2) Winter cold can be responsible for general damage to the plant or to its vital organs (buds,



2/ *Quercus acutissima* Carruth., from Asia, at Starhill Forest Arboretum in Illinois (USA), founded by Guy and Edie Sternberg, and today part of Illinois College.

evergreen leaves, reproductive organs, seeds, young plants, etc.). A value for winter cold can be expressed by the average minimum temperatures of the coldest months of the year.

3) The water balance, taking into consideration the complex dynamics of water and soil is calculated per month with, on one side, the water deficit (taking into account water lost through evaporation) and, on the other, rainfall and seasonal variations in water availability (depending on type of soil, etc.).

For historical reasons, many botanic collections and arboreta are in the Temperate Zone. Winter cold and summer dry spells or drought are the determining factors in the success of new introductions.

A relational model for vegetation and climate

The following synthesis is based on research on the relationship between species and climate currently being investigated by AFORCE, a multi-disciplinary French initiative that regroups scientists from basic research, forestry management and development, as well as from different educational institutions. (For more information on AFORCE, see, ***www.foretpriveefrancaise.com***). The objective is to coordinate different approaches to the adaptation of forests to current climate change and to provide decision-making tools for forestry management policy.

The model that is being developed is based on the general hypothesis that there are limiting factors (for plants) based on climate, and these can be resumed as: for each species (or, for each geographic or taxonomic subset of trees in its natural range) there are climatic values that delimit the climates in which they can survive from those in which they cannot. The combined study of natural distribution and corresponding climatic values has led to the conclusion that the three determining factors are, as explained above, available solar energy, winter cold and the water balance. Today, values for these three climate factors are available with great precision (to 1 km/0.6 mi) for a great many regions and it is thus possible to map them together with natural range distribution (***www.worldclim.org***).

WorldClim was developed by Robert J. Hijmans, Susan Cameron, and Juan Parra, at the Museum of Vertebrate Zoology, University of California, Berkeley, in collaboration with Peter Jones and Andrew Jarvis (CIAT), and with Karen Richardson (Rainforest CRC).

A case in point : Hardiness Zones

The essential question remains, how can climate description based on these factors be related to species tolerance to new or changing climates? If the tolerance to these three factors is known then it should be possible to estimate species' climate tolerance at any given point. This is of course the approach used in the establishment of Hardiness Zones – but these are only based on tolerance to winter cold. Knowledge about the climatic limitations of each species, or of each population/provenance of a particular species, is obtained essentially through data collected in areas where that species is significantly present and therefore the natural distribution range is the best place to start. Nevertheless, factors other than climate can affect the presence or absence of a species in its "natural distribution range" (biotic, soil or altitudinal factors, for example). The absence of a species in a given location can thus lead to erroneous conclusions concerning its climate tolerance.

The usefulness and limits of arboreta

Knowing where species have been introduced (outside of their natural range) with success provides extremely useful information in the determination of climate tolerance. Conversely, knowing where these introductions have met with failure also provides information. But, the reasons for failure are often more complex, or not as straightforward, as the reasons for success and therefore difficult to interpret.

Introductions in the form of reforestation provide information but these are limited by economic considerations that limit the choices of what is tried. Introductions in botanic collections or arboreta offer a wider range of opportunity because, by definition, collectors are not as inhibited, their creed being, “try everything, everywhere!” This highly unreasonable behavior can provide precious information about the extreme limits of species’ climate tolerance.

Nevertheless, this empirical approach does have its limitations, principally based on the “representative” nature of the taxon in question. These limitations are related to the following points:

1) It is not rare to discover in collections that what has been planted does not in fact correspond to the label.

2) The use of grafted plants is obviously not conclusive because the host is used precisely for its greater climate tolerance.

3) Plants that are raised from non wild-collected seed may be phenotypically correct but because of the hybridization their genome may confer a greater climate tolerance. Clearly, only plants raised from seed collected in the range of the plant’s natural distribution can provide pertinent information.

3/ *Quercus dentata* Thunb. (Asia), *Q. phellos* L. and *Q. velutina* Lam. (Eastern North America) growing side-by-side in Henri de Brem’s private collection, the Quercetum du Hanouard (France).

4) Because of natural annual variation in climate, the length of time that an introduced plant lives in a new climate is crucial. Thirty years with no major problems is a reasonable time frame.

5) In collections, when plants are young they often receive “special care” to help them through this vulnerable period – care that would not be afforded them in a purely natural setting.

6) The mere fact of survival is not the ultimate criteria for determining climate tolerance. It is reproductive success that is crucial.

7) The last, and perhaps most important limitation is the “representative” genetic factor. Often, in collections, few plants are introduced and while they may be introduced into several different arboreta these often all come from the same source and are therefore not genetically representative of the species across its distribution.

Conclusion

To be significant in this context, introductions must be represented by many plants and raised from seed collected in the wild from different provenances. This is easier to accomplish in the context of scientific arboreta that have vaster surface areas and means at their disposal than in private collections.

Nevertheless this constraint of isolated introductions can be overcome through the creation of a collections/arboreta network that would cover a vast geographic area effectively increasing the size of the sample population. This network remains to be created but I am convinced that it is possible, especially for oaks, with the help of the International Oak Society and modern means of communication. Interpreting the resulting data requires specific scientific competence – but I am equally convinced that a network of scientists and plant enthusiasts is possible and desirable. The recent increased scientific interest in private collections/arboreta will contribute to this.

Photographers. Title page: Shaun Haddock (*Quercus hinckleyi* C.H. Mull.*)*. Photo 1: Peter Laharrague. Photo 2: Guy Sternberg. Photo 3: Béatrice Chassé.

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