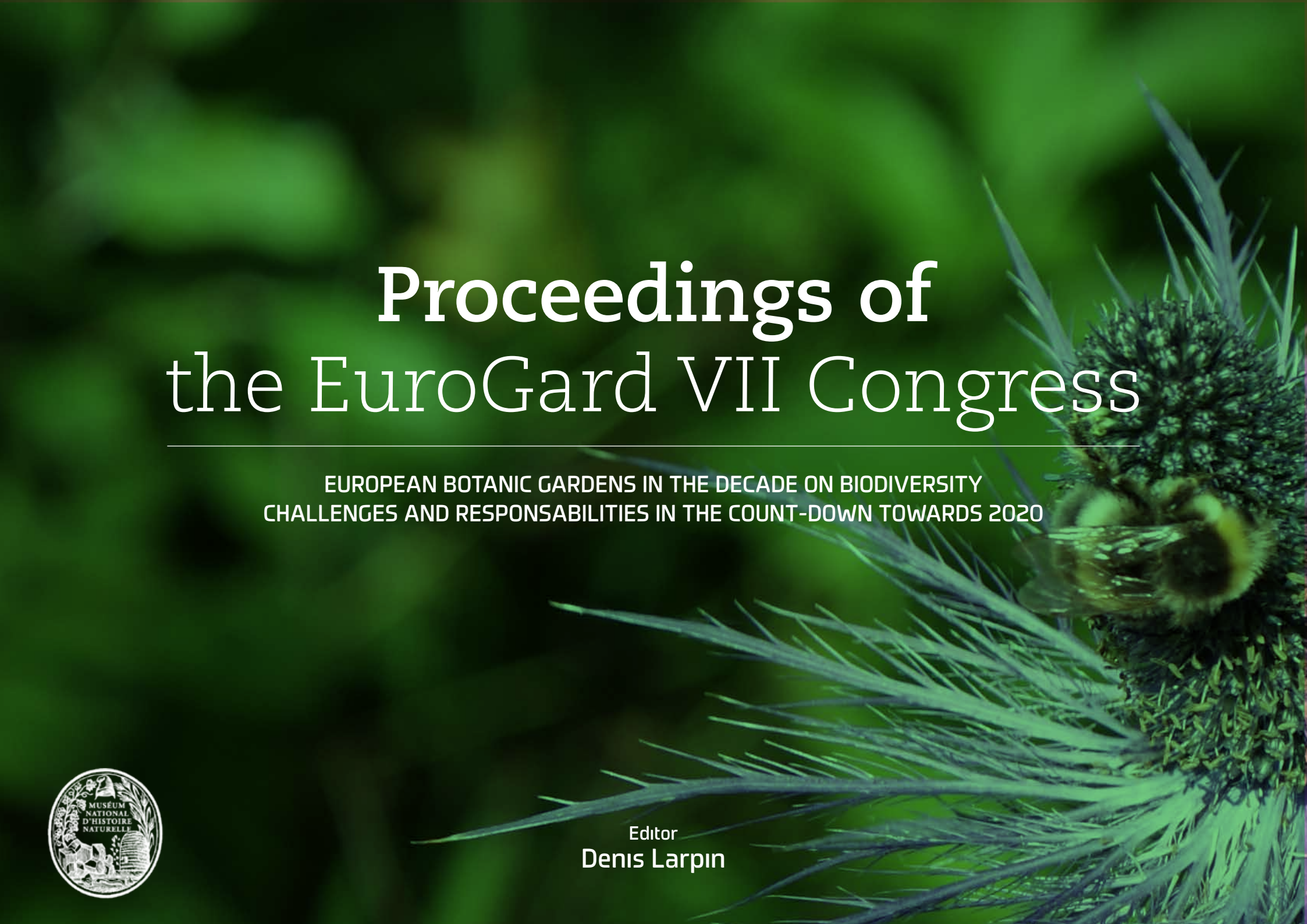

# Proceedings of the EuroGard VII Congress

EUROPEAN BOTANIC GARDENS IN THE DECADE ON BIODIVERSITY
CHALLENGES AND RESPONSABILITIES IN THE COUNT-DOWN TOWARDS 2020

Editor
Denis Larpin

# RELICT TREES DRIVING INTERNATIONAL COOPERATION, RESEARCH AND CONSERVATION – THE EXAMPLE OF *ZELKOVA* SPP. (ULMACEAE)

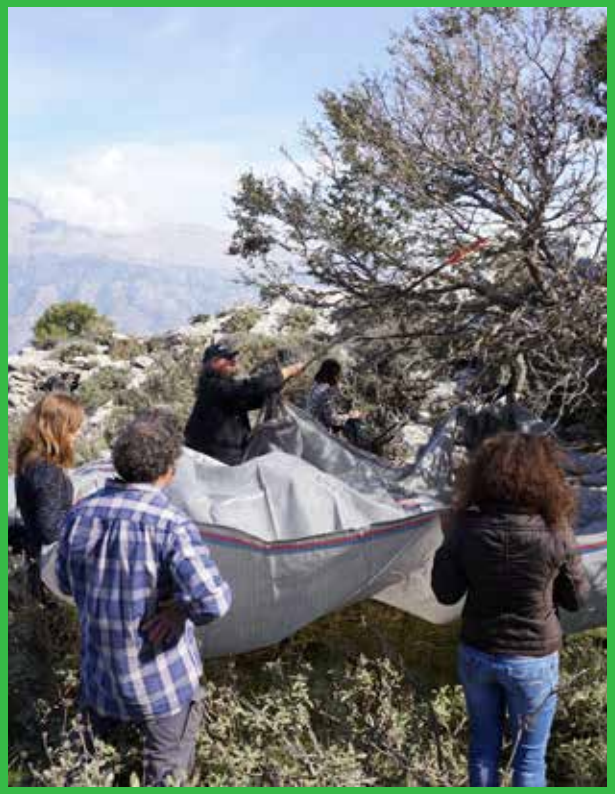

Photo credit : ***left*** : Collection of *Zelkova abelicea* seeds, Kedros, Crete, ***Gregor Kozlowski***
***right*** : Introduction of *Zelkova sicula* saplings, Bosco Ficuzza, Sicily, ***Giuseppe Garfì***

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> Keywords RELICT TREES ZELKOVA GEOGRAPHIC ISOLATION CLIMATE CHANGE INTEGRATED *EX* AND *IN SITU* CONSERVATION CLONAL POPULATION GENETIC DIVERSITY INTERNATIONAL COOPERATION GLOBAL TREES CAMPAIGN

# 07. Abstract

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**THE TREE GENUS *ZELKOVA* FORMS PART OF THE ARCTO-TERTIARY RELICT FLORA THAT EXTENDED OVER LARGE PARTS OF THE NORTHERN HEMISPHERE DURING THE CENOZOIC ERA, SOME 55-2.5 MILLION YEARS AGO. THE HIGHLY DISJUNCT DISTRIBUTION OF THE SIX EXTANT SPECIES – *Z. SICULA*, *Z. ABELICEA*, *Z. CARPINIFOLIA*, *Z. SINICA*, *Z. SCHNEIDERIANA* AND *Z. SERRATA* – FROM THE MEDITERRANEAN TO THE CAUCASUS AND EAST ASIA, MAKES *ZELKOVA* A FASCINATING SUBJECT FOR PHYLOGENETIC AND BIOGEOGRAPHIC STUDIES TO ADVANCE THE UNDERSTANDING OF EVOLUTIONARY PROCESSES.**

The rarity and extreme geographic isolation of some of the species and populations have attracted the attention of researchers, conservation practitioners and horticulturists in recent years, to conserve remaining genetic diversity in the wild and in *ex situ* collections. Inspired by this shared concern, since 2010 a highly interdisciplinary and international research group represented by partners from Europe, the Caucasus and East Asia have been participating in the development and implementation of Project *Zelkova* – an integrated conservation action plan for all the species in the genus (zelkova.ch).

This paper provides an overview of the key research findings gathered and pilot conservation activities initiated over the past five years, with a focus on the two Mediterranean species. As with other initiatives in the framework of the Global Trees Campaign (globaltrees.org) dedicated to saving the world's most threatened woody plants, it highlights the collaborative, multidisciplinary nature of the conservation efforts needed, to secure the values and benefits provided by rare, relict species for future generations.

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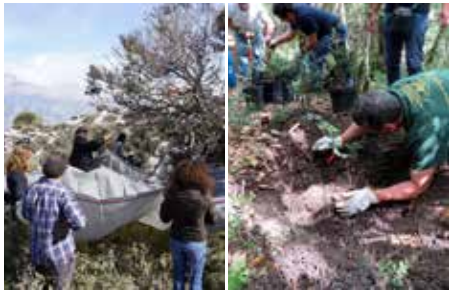

Photo credit : ***left*** : Collection of *Zelkova abelicea* seeds, Kedros, Crete, ***Gregor Kozlowski ; right*** : Introduction of *Zelkova sicula* saplings, Bosco Ficuzza, Sicily, ***Giuseppe Garfì***

**THE GENUS *ZELKOVA* BELONGS TO THE ARCTO-TERTIARY RELICT FLORA THAT COVERED LARGE PARTS OF THE NORTHERN HEMISPHERE DURING THE CENOZOIC ERA (I.E. 55-2.5 MILLION YEARS BEFORE PRESENT).**

Fossil discoveries attributed to the genus, dating back more than 50 million years, give proof of the once circumboreal occurrence of the genus (Tanai & Wolfe, 1977; Manchester, 1989). Today, the highly disjunct distribution of the six extant species – *Z. sicula, Z. abelicea, Z. carpinifolia, Z. schneideriana, Z. sinica* and *Z. serrata* – from the Mediterranean to the Caucasus and East Asia, makes this genus a fascinating subject for phylogenetic and biogeographic studies and other international, collaborative research initiatives to further the knowledge of evolutionary processes.

As with the manifold interests to science, *Zelkova* trees have had long-standing, cultural and socio-economic functions. Specimens – some several hundred years old – planted as ornamentals in private and public venues, or found in places of worship and contemplation in eastern Asia, give evidence of the ancient and close relationship of people with these trees. Likewise, traditional herbal medicine, household items and other objects made from various parts of the plant, are testimony to the important values and customs associated with this genus (Ito, 1981; Kvavadze & Connor, 2005; Fournaraki & Thanos, 2006; Kozlowski & Gratzfeld, 2013).

The relict nature of the genus, however, is no recipe for survival in a rapidly transforming environment. As elsewhere in the world, habitat loss, fast changing climatic conditions and many other drivers of change, including overgrazing (Frederik *et al.*, 2010; Garfì & Buord, 2012; Kozlowski *et al.*, 2012a) and uncontrolled logging (Maharramova et al., 2014) exert high pressure on remaining natural *Zelkova* populations. Especially the two Mediterranean species, *Z. sicula* and *Z. abelicea* count among the most threatened in the genus (Garfì, 2006; Kozlowski *et al.*, 2012a). These species occur in exceptionally isolated and fragmented locations. Among the rarest trees in the world, they require specific management approaches combining a set of integrated in and *ex situ* conservation measures.

## *Zelkova sicula* - one of a kind

Within the genus, *Zelkova sicula* Di Pasq., Garfì & Quézel has a particularly remarkable position. Discovered in 1991 (Di Pasquale *et al.*, 1992), this narrow endemic is known from only two locations, each with a single pop-

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ulation. Both populations cover an area of occupancy of less than one hectare and consist of a few hundred small trees each. Occurring between 320 and 520m above sea level on the north-eastern slopes of the Iblei mountains (south-eastern Sicily), the two populations are found in open forest communities with other tree species such as *Quercus suber, Q. virgiliana, Olea europaea var. sylvestris, Phillyrea latifolia, Pyrus spinosa* and *Calicotome infesta* (Garfì *et al.*, 2011).

## STAYING ALIVE IN A CHANGING CLIMATE

Several of the morphological and life traits of *Z. sicula* can be interpreted as the result of a long-lasting process of adaptation to a rather suboptimal environment. Unlike the other *Zelkova* species, *Z. sicula* generally develops as a shrub or, at the most, grows into a small tree in its present locations (Garfì *et al.*, 2011). Characteristic for plants at the limit of their range (Stahl *et al.*, 2013), this habit likely is a response to water shortage (Garfì *et al.*, 2012). Ongoing investigations on plant-water relationships such as pressure-volume curves, leaf water potential and stomatal conductance, have highlighted a low plasticity as regards standard summer drought conditions in the current habitat (Oddo *et al.*, pers. comm.). The fact that both populations are restricted to the bottom of gullies or occur along narrow streams, suggests that these micro-habitats play a critical role in the species' ability to withstand water stress. Nonetheless, extreme environmental hazards, such as prolonged drought, can cause moderate to severe damage, ranging from withering of leaves to dieback of branches and stems. Rising habitat fragmentation and livestock grazing exert further pressure on both populations (Garfì & Buord, 2012). Due to these threat factors and the rarity of the species, *Z. sicula* has been included as Critically Endangered (CR) on the IUCN Red List of Threatened Species (Garfì, 2006).

## TWO POPULATIONS, TWO CLONES – TWO INDIVIDUALS?

Recent studies suggest that *Z. sicula* has been subject to severe isolation and genetic impoverishment (Fineschi *et al.*, 2002, 2004; Christe *et al.*, 2014a). Fructification is irregular (Garfì, 1997a) and, as with other triploid species (Garfì, 1997b), seeds have always been found to be sterile (Bonga & von Aderkas, 2013). Regeneration occurs by means of vegetative mechanisms such as root suckering and layering. As a result, individuals in both genetically impoverished but distinct populations, are assumed to be of clonal origin; hence, each population could be regarded as a single individual. This, in addition to the extended geographic isolation with reduced potential gene flow, might be the reason for such a low intra-specific genetic variability (Fineschi *et al.*, 2004). On the other hand, clonality and vegetative reproduction are adding a further trait of uniqueness to this species; as with *Lomatia tasmanica* (*Proteaceae*) – known from a single, clonal population estimated to be several ten thousand years of age (Lynch *et al.*, 1998) – each *Z. sicula* population could potentially represent a many thousand year-old genetic unit.

## RESCUE TRIALS IN PROGRESS

Since 2011, a major project funded through the European Commission EC Life Programme (zelkovazione.eu) has been implementing a range of integrated in and ex situ conservation actions in the areas of knowledge consolidation, population monitoring, active conservation, public outreach and communication. To date, a number of key milestones have been achieved, including the exclusion of the grazing pressure in both populations through fencing, the implementation of a sustainable management plan that involves formal agreements with local stakeholders, as well as the legal protection of the species through the enactment of a Councillor's Decree by the Regional Department of Environment (zelkovazione.eu/node/4502).

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The recent successful development of protocols for in vitro and in vivo vegetative multiplication based on the expertise of researchers from the National Research Council, Italy and the Conservatoire Botanique National de Brest, France, is a further major step towards effective *ex* and *in situ* conservation. Indeed, the limited intra-specific variability in the species is facilitating the establishment of genetically representative conservation collections. Likewise, the possibility to generate plants without affecting the wild populations has opened a new, important perspective for *in situ* reinforcement programmes and introduction of the species to other ecosystems.

## INTRODUCTION TO OTHER ECOSYSTEMS

In spite of the recent advances made, securing viable populations in situ remains a main conservation challenge given the vulnerability of the species in its current habitat. Introduction to other ecosystems has been studied to establish further populations in new locations. These have been identified using the guidelines for 'assisted colonisation' (Brooker *et al.*, 2011). Criteria for site selection are based on palaeo-ecological data including Follieri *et al.* (1986) and De Paola *et al.* (1997) and observations of specimens grown under different ex situ conditions. The latter have confirmed the potential of Z. sicula to mature into actual trees (Garfì *et al.*, 2011; Garfì & Buord, 2012) in contrast to the general habit of the plants in their present habitat. These findings suggest that more humid and cooler climatic conditions typical to montane mixed forests with *Fagus, Acer, deciduous Quercus, Ilex* or *Taxus*, may offer a better match for the ecological needs of *Z. sicula*. This conservation approach is applied as the 'last resort' for narrow endemics that are confined to very specific, ecological niches and exposed to changing, unfavourable environmental conditions (Brooker *et al.*, 2011; Thomas, 2011).

## *Zelkova abelicea* - a plant of exceptional diversity

An endemic tree of the east-Mediterranean island of Crete, *Zelkova abelicea* (Lam.) Boiss. is found in open, mountain forest communities between 850 and 1,850 m above sea level. Occurring in association with *Acer sempervirens, Quercus coccifera* and occasionally *Cupressus sempervirens*, all of the four main mountain ranges of Crete, i.e. Levka Ori, Psiloritis, Dikti and Thripti, hold populations of *Z. abelicea*. Primarily, they occupy north-facing slopes, areas around dolines, summer-dry river banks, gullies and screes. Especially at higher altitudes (>1500 m above sea level) however, the species is also found on south-facing slopes with rock outcrops and often bare, thin soil (Egli, 1997; Søndergaard & Egli, 2006; Fazan *et al.*, 2012).

## THREATENED AND FRAGMENTED POPULATIONS

More than 40 populations of *Z. abelicea* are known, mainly in the Levka Ori (ca. 30) and in the Dikti mountains (ca. 10). Two populations occur in the Psiloritis and one small population in the Thripti mountains (Kozlowski *et al.*, 2012a). While the distribution of the species according to the four mountain ranges is explained to be of ancient origin (Christe *et al.*, 2014a), it is not conclusively resolved whether the fragmented pattern of *Z. abelicea* stands within these locations is the result of natural processes or anthropogenic drivers of change (Kozlowski *et al.*, 2014). Nevertheless, in more recent history, overgrazing and browsing by goats and sheep, as well as soil erosion, drought and fire, present serious threats to all populations (Fazan *et al.*, 2012; Kozlowski *et al.*, 2012a). By and large, individuals are heavily browsed and exhibit a dwarfed habit, such as the population of Thripti, whereas large trees

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(>15 m) are rare and encountered especially in the Levka Ori mountains. To date, only fully developed trees have been observed to flower and produce viable seed (Fazan *et al.*, 2012; Kozlowski *et al.*, 2014). Given the level of threat to various populations, *Z. abelicea* has been included as Endangered (EN) on the IUCN Red List of Threatened Species (Kozlowski *et al.*, 2012a).

## EACH MOUNTAIN CHAIN REPRESENTS A SEPARATE GENETIC AND CONSERVATION UNIT

Because of the limited seed dispersal capacity of *Zelkova* spp. (Hoshino, 1990; Wang *et al.*, 2001), gene flow between distant *Z. abelicea* populations is highly unlikely as confirmed by recent genetic studies (Christe *et al.*, 2014a). These demonstrate that the populations are genetically highly diverse within and between the four mountain ranges, and indicate that the colonization by *Z. abelicea* is very ancient (presumably before the early Miocene, over 25 million years ago). Each mountain chain should therefore be considered as a unique genetic entity, each of relevance for conservation.

## *EX SITU* CONSERVATION CHALLENGES

In comparison with other *Zelkova* species, especially those from East Asia, *Z. abelicea* is underrepresented in botanic garden collections (Kozlowski *et al.*, 2012b). In addition, only a very small proportion of the genetic variability in natural populations is found in ex situ collections (Christe *et al.*, 2014b). All surveyed individuals cultivated in botanic gardens and arboreta originate from one single area in western Crete (Omalos Plateau, Levka Ori), while other populations do not appear to be represented in *ex situ* collections (Kozlowski *et al.*, 2012b; Christe *et al.*, 2014b). Future *ex situ* conservation approaches should consider the entire genetic diversity of the species, whilst avoiding genetic mixture of differentiated populations from the four mountain chains, especially when establishing field collections (Kozlowski *et al.*, 2012b, 2014). For heavily browsed and dwarfed populations with no observed or viable seed generation, vegetative propagation remains the only option to establish collections, which in turn enhances the complexity and costs of ex situ conservation.

## *IN SITU* CONSERVATION CHALLENGES

Conventional approaches to protection and management, including methods to limit or completely prevent livestock grazing and browsing by means of fencing, should comprise the entire range of the genetic diversity of the species. Such measures require to be developed in close collaboration with shepherds and other local stakeholders (e.g. local administration, municipalities, national park administration), and accompanied by long-term scientific surveys to monitor progress and allow adaptive management.

## ONGOING CONSERVATION ACTION

Based on the thorough research work undertaken in recent years, an international and interdisciplinary conservation programme for *Z. abelicea* has been initiated. The implementation of the project is assumed by the Mediterranean Agronomic Institute of Chania (MAICh) in collaboration with the four Forest Directorates of Crete (Chania, Rethymno, Heraklio, Lassithi). International collaboration and scientific support are assured by researchers and conservationists from the Universities of Fribourg (Switzerland) and Athens (Greece), Botanic Gardens Conservation International (BGCI, United Kingdom) and the Institute of Biosciences and BioResources of the National Research Council in Palermo (Sicily, Italy). *Ex situ* conservation efforts are progressing with seed stored in the seed bank of MAICh, capitalising also on studies carried out on germination requirements of the species since 2000

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(Fournaraki & Thanos, 2002; Thanos *et al.*, 2010). New and genetically representative *ex situ* collections (field as well as seed bank collections) are being established using seed and vegetative material sampled from all mountain regions. The experiences gained from the successful propagation of *Z. sicula* are of particular value for *ex situ* conservation of the genetically diverse *Z. abelicea* populations in which fruiting has not been observed to date (e.g. Thripti). In addition, selected pilot plots have been fenced throughout Crete and are regularly monitored by the team of MAICh as well as by the researchers and students of the University of Fribourg. Within the fenced plots, *Z. abelicea* dwarfed shrubs have responded immediately to the removal of the browsing pressure by producing new shoots up to 90 cm in length after one year of exclusion of browsing only. Moreover, a range of local and international campaigns and public outreach events have been realized, including scientific seminars, conferences and exhibitions, accompanied by a series of engaging public outreach materials.

## Conclusions

The isolated occurrence and rarity of *Z. sicula* and *Z. abelicea* provide an ideal context to practise integrated conservation action and serve as a model for safeguarding other threatened species as pursued by the Global Trees Campaign. While the exclusion of grazing pressure such as through fencing is the most pragmatic measure for immediate protection in the wild, long-term in situ conservation efforts need to be implemented in close collaboration with local stakeholders and anchored in national legislation and policy. Systematic scientific evaluations to monitor progress and allow adaptive management will in turn inform the nature of population reinforcement programmes and options for potential introduction to other, analogous environments in situations where the original habitat has been lost, or no longer provides a viable option for the species' survival. This is especially crucial for *Z. sicula*, known from only two locations. The first attempt to establish three new populations will be carried out at elevations above 1000 m in the northern, mountainous ranges of Sicily in 2016.

As elsewhere in the world, *ex situ* conservation of *Zelkova* spp. faces the challenge of ensuring genetically representative collections, preferably in the countries of the species' natural distribution, where current *ex situ* holdings are still largely inadequate. The complexity of capturing the whole range of a species' genetic variation for *ex situ* conservation is well-illustrated by the distinct genetic diversity of *Z. abelicea* found in each of its four main areas of occurrence. While the remoteness and inaccessibility of some of the last remaining natural *Zelkova* populations prevent the broader public from appreciating their grandeur in the wild, *ex situ* collections at botanic gardens and associated scientific institutions, play a critical role in enhancing environmental awareness and education. Linking reports of fossil finds with their extant relatives and new population discoveries,

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*Zelkova* spp. and relict plants in general, can provide compelling stories to reach out to the wider society. Relict species from ancient times not only function as storehouses of information of the Earth's transformations over millions of years but also deliver a diverse range of ecosystem services. Though ultimately a matter of societal choice, their conservation therefore presents a vital element in the development of future ecosystem management approaches, especially in a period of unprecedented, rapid global change.

The conservation challenges of the species in the genus *Zelkova* have attracted the attention of researchers, conservation practitioners and horticulturalists in a joint endeavour to secure the remaining genetic diversity in the genus for future generations. Since 2010, this shared concern has brought together a highly interdisciplinary and international research group comprising of partners from Europe, the Caucasus and East Asia, to develop and implement Project *Zelkova* – an integrated conservation action plan for all the species in the genus (Kozlowski & Gratzfeld, 2013). Such multidisciplinary teams of researchers and conservation practitioners are essential to successfully conduct large-scale, complex initiatives that offer sustained management solutions and resonate with stakeholders (Ostrom, 2009; van Riper III *et al.*, 2012). Project *Zelkova* has had a unique ability to bring international partners together, mobilise financial resources, pool the collective expertise and encourage local stakeholders to participate in conservation actions.

By recognising that we live in a rapidly changing environment, and encouraging interdisciplinary science and action, this initiative offers a valuable model for replication in other threatened trees initiatives.

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**Bonga, J.M. & von Aderkas, P.,** 2013. In vitro *culture of trees.* Springer Science+Business Media, 238 pages.

**Brooker, R., Britton, A., Gimona, A., Lennon, J. & Littlewood, N.,** 2011. *Literature review: species translocations as a tool for biodiversity conservation during climate change.* Scottish Natural Heritage Commissioned Report No.440, 68 pages.

**Christe, C., Kozlowski, G., Frey, D., Bétrisey, S., Maharramova, E., Garfì, G., Pirintsos, S. & Naciri, Y.,** 2014a. Footprints of past intensive diversification and structuring in the genus Zelkova (Ulmaceae) in south-western Eurasia. *Journal of Biogeography* 41: 1081-1093.

**Christe, C., Kozlowski, G., Frey, D., Fazan, L., Bétrisey, S., Pirintsos, S., Gratzfeld, J. & Naciri, Y.,** 2014b. Do botanic garden collections capture the genetic variation of wild populations? A molecular analysis of two relict tree species *Zelkova abelicea and Z. carpinifolia*. *Biodiversity and Conservation* 23: 2945-2959.

**De Paola, M., Franco, A., Macchia, F. & Forte, L.,** 1997. Plant macrofossils in Pleistocenic volcanoclastic deposit near Tursi (Basilicata). In: Atti Giornata di Studi in ricordo di Daria Bertolani Marchetti (Formigine, 18 maggio 1996), *Aedes Muratoriana*, Modena: 319-327.

**Di Pasquale, G., Garfì, G. & Quézel, P., 1**992. Sur la présence d'un *Zelkova* nouveau en Sicile sudorientale (*Ulmaceae*). *Biocosme Mésogéen* 8-9: 401-409.

**Egli, B.,** 1997. A project for the preservation of *Zelkova abelicea* (Ulmaceae), a threatened endemic tree species from the mountains of Crete. *Bocconea* 5(2): 505-510.

**Fazan, L., Stoffel, M., Frey, D.J., Pirintsos, S. & Kozlowski, G.,** 2012. Small does not mean young: age estimation of severely browsed trees in anthropogenic Mediterranean landscapes. *Biological Conservation* 153: 97-100.

**Fineschi, S., Anzidei, M., Cafasso, D., Cozzolino, S., Garfì, G., Pastorelli, R., Salvini, D., Taurchini, D. & Vendramin, G.G.,** 2002. Molecular markers reveal a strong genetic differentiation between two European relic tree species: *Zelkova abelicea* (Lam.) Boissier and *Z. sicula* Di Pasquale, Garfì & Quezel (Ulmaceae). *Conservation Genetics* 3: 145-153.

**Fineschi, S., Cozzolino, S., Migliaccio, M. & Vendramin, G.G.,** 2004. Genetic variation of relic tree species: the case of Mediterranean *Zelkova abelicea* (Lam.) Boissier and Z. sicula Di Pasquale, Garfì and Quézel (Ulmaceae). *Forest Ecology and Management* 197: 273-278.

**Follieri, M., Magri, D. & Sadori, L.,** 1986. Late Pleistocene *Zelkova* extinction in central Italy. *New Phytologist* 103: 269-273.

**Fournaraki, C. & Thanos, C.A.,** 2002. Seeds of *Zelkova abelicea*, an endemic tree of Crete. TREE SEEDS 2002, Annual Meeting of IUFRO "Research Group for Seed Physiology and Technology", 11-15 September 2002, MAICh, Chania, Crete. *Book of proceedings*: 83-84.

**Fournaraki, C. & Thanos, C.A.,** 2006. *Zelkova abelicea*, the unique endemic tree of Crete and its conservation. *ENSCONEWS* 1: 14-16.

**Frederik, A.W. Noack, Manthey, M., Ruitenbeek, J.H. & Mohadjer, M.M.,** 2010. Separate or mixed production of timber, livestock and biodiversity in the Caspian Forest. *Ecological Economics* 70: 67-76.

**Garfì, G.,** 1997a. On the flowering of *Zelkova sicula* (Ulmaceae): additional description and comments. *Plant Biosystems* 131(2): 137-142.

**Garfì, G.,** 1997b. *Première contibution à l'étude de Zelkova sicula (Ulmaceae), une relique de la flore tertiaire, endémique de la Sicile Sud-Orientale (Systématique - Caryologie - Dynamique de la croissance - Dendroécologie).* PhD Thesis, Fac. Sci. Techn., Univ. Aix-Marseille III, 235 pages + annexes.

**Garfì, G., Barbero, M. & Tessier, L.,** 2002. Architecture and growth patterns of *Zelkova sicula* (Ulmaceae) in South-East Sicily as a response to environmental conditions. *Journal of Mediterranean Ecology* 3(2-3): 65-76.

**Garfì, G.,** 2006. *Zelkova sicula*. *The IUCN Red List of Threatened Species* 2006. dx.doi.org/10.2305/IUCN.UK.2006.RLTS.T61678A12522379.en

**Garfì, G., Carimi, F., Pasta, S., Rühl, J. & Trigila, S.,** 2011. Additional insights on the ecology of the relic tree *Zelkova sicula* di Pasquale, Garfì et Quézel (Ulmaceae) after the finding of new population. *Flora* 206: 407-417.

**Garfì, G. & Buord, S.,** 2012. Relict species and the challenges for conservation: the emblematic case of *Zelkova sicula* Di Pasquale, Garfì et Quézel and the efforts to save it from extinction. *Biodiversity Journal* 3(4): 281-296.

**Hoshino, Y.,** 1990. Fruiting shoot as a wind-dispersed diaspore assisting the fruit dispersal of *Zelkova serrata* (Thunb.) Makino. *Japanese Journal of Ecology* 40: 35-41.

**Ito, N.,** 1981. Wood as a material for Japanese buildings. *In: Proceedings of the 6th ICOMOS General Assembly and International Symposium "Nessun futuro senza passato"*, ICOMOS, Rome: 391-402.

**Kozlowski, G., Gibbs, D., Huan, F., Frey, D. & Gratzfeld, J.,** 2012b. Conservation of threatened relict trees through living *ex situ* collections: lessons from the global survey of the genus *Zelkova* (Ulmaceae). *Biodiversity and Conservation* 21: 671-685.

**Kozlowski, G. & Gratzfeld, J.,** 2013. *Zelkova – an ancient tree. Global status and conservation action.* Natural History Museum Fribourg, Switzerland, 60 pages.

**Kozlowski, G., Frey, D., Fazan, L., Egli, B., Bétrisey, S., Gratzfeld, J., Garfì, G. & Pirintsos, S.,** 2014. Tertiary relict tree *Zelkova abelicea* (Ulmaceae): distribution, population structure and conservation status. *Oryx* 48: 80-87.

**Kozlowski G., Frey D., Fazan L., Egli B., Pirintsos S.,** 2012a. Zelkova abelicea. *The IUCN Red List of Threatened Species 2012.* dx.doi.org/10.2305/IUCN.UK.2012.RLTS.T30319A17701987.en

**Kvavadze, E.V. & Connor, S.E.,** 2005. *Zelkova carpinifolia* (Pallas) K. Koch in Holocene sediments of Georgia – an indicator of climatic optima. *Review of Palaeobotany and Palynology* 133: 69-89.

**Lynch, A.J.J., Barnes, R.W., Cambecèdes, J. & Vaillancourt, R.E.,** 1998. Genetic evidence that *Lomatia tasmanica* (Proteaceae) is an ancient clone. *Australian Journal of Botany* 46: 25-33.

**Maharramova, E., Muller, L.A., Korotkova, N. & Borsch, T.,** 2014. Development of nuclear microsatellites for the Arcto-Tertiary tree *Zelkova carpinifolia* (Ulmaceae) using 454 pyrosequencing. *Applications in Plant Sciences* 2(3) 1300072.

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# 07. References

• *Gratzfeld Joachim*
• *Kozlowski Gregor*
• *Buord S.*
• *Fazan L.*
• *Christe C.*
• *Bétrisey S.*
• *Garfì G.*
• *Pasta S.*
• *Gotsiou P.*
• *Fournaraki C.*
• *Dimitriou D.*
• *Sklavaki P.*
• *Naciri Y.*
• *Dadashova A.*
• *Selimov R.*
• *Davitashvili N.*
• *Song Y.*

**Manchester, S.R.,** 1989. Systematics and fossil history of the Ulmaceae. In: Crane, P.R. & Blackmore, S. (eds.): *Evolution, systematics, and fossil history of the Hamamelidae, Volume 2: 'Higher' Hamamelidae*. Systematics Association, Special Volume No. 40B, Clarendon Press, Oxford: 221-251.

**Ostrom, E.,** 2009. A general framework for analyzing sustainability of social-ecological systems. *Science* 325(5939): 419-422.

**van Riper III, C., Powell, R.B., Machlis, G., van Wagtendonk, J.W., van Riper, C.J., von Ruschkowski, E., Schwarzbach, S.E. & Galipeau, R.E.,** 2012. Using integrated research and interdisciplinary science: Potential benefits and challenges to managers of parks and protected areas. *The George Wright Forum* 29(2): 216-226.

**Søndergaard, P. & Egli, B.R.,** 2006. *Zelkova abelicea* (Ulmaceae) in Crete: floristics, ecology, propagation and threats. *Willdenowia* 36: 317-322.

**Stahl, U., Reu, B. & Wirth, C.,** 2013. Predicting species' range limits from functional traits for the tree flora of North America. *Proceedings of the National Academy of Sciences of the United States of America* (PNAS) 111(38): 13739-13744.

**Tanai, T. & Wolfe, J.A.,** 1977. *Revisions of* Ulmus *and* Zelkova *in the middle and late Tertiary of western North America*. Geological Survey Professional Paper 1026. United States Government Printing Office, Washington, 28 pages.

**Thanos, C.A., Fournaraki, C., Tsiroukis, A. & Panayiotopoulos, P.,** 2010. Timing of seed germination and life history of trees: case studies from Greece. *In*: Chien, C.-T. & Chen, F.-H. (Eds.) *'Symposium Proceedings'*, TFRI Extension Series No. 212: 103-111; IUFRO Tree Seed Symposium: Recent Advances in Seed Research and *Ex Situ* Conservation, Taipei, Taiwan.

**Thomas, C.D.,** 2011. Translocation of species, climate change, and the end of trying to recreate past ecological communities. *Trends in Ecology & Evolution* 26(5): 216-221.

**Wang, Y.F., Ferguson, D.K., Zetter, R., Denk, T. & Garfi, G.,** 2001. Leaf architecture and epidermal characters in *Zelkova*, Ulmaceae. *Botanical Journal of the Linnean Society* 136: 255-265.