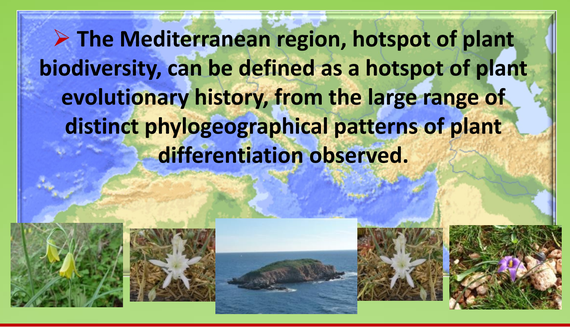
Key phylogeographical insights to explain the diversification of the mediterranean flora

Jeremy Migliore, Alex Baumel, Bruno Fady, Cyrille Conord, Marianick Juin, Frédéric Medail

KEY PHYLOGEOGRAPHICAL INSIGHTS TO EXPLAIN THE DIVERSIFICATION OF THE MEDITERRANEAN FLORA

Jérémy MIGLIORE[1], Alex BAUMEL[1], Bruno FADY[2], Cyrille CONORD[2], Marianick JUIN[1] & Frédéric MEDAIL[1]



➢ **The Mediterranean region, hotspot of plant biodiversity, can be defined as a hotspot of plant evolutionary history, from the large range of distinct phylogeographical patterns of plant differentiation observed.**

MEDITERRANEAN PALAEOGEOGRAPHY

➢ The Mediterranean Basin is characterised by a complex palaeogeography, with orogenic processes and widespread extensional tectonics during the Tertiary, coupled with a high diversity of substrates.

Some examples:

Genetic structure of Quercus suber retains the fragmentation event of the western Mediterranean hercynian mountains, since 25 Ma (Magri et al. 2007, Mol Ecol).

The Messinian desiccation of the Mediterranean (4.5–5.5 Ma) explain the disjunct distribution of Androcymbium gramineum in Almería and Morocco (Caujapé-Castells & Jansen 2003, Mol Ecol).

Mountain ranges of northern Africa could have acted as gene flow barriers inducing the persistence of Silene patula in distinct refugia areas (Naciri et al. 2010, MPE).


Quercus suber


Androcymbium gramineum


Silene patula

HUMAN ACTIVITIES


Pinus pinea

Low geographical structure in genetic variation, arguing for a multidirectional diffusion of the cultivated taxa because of human activity, as documented for Castanea sativa (Fineschi et al. 2000, Mol Ecol) or Pinus pinea (Vendramin et al. 2008, Evolution).


Castanea sativa

MEDITERRANEAN PALAEOCLIMATOLOGY

➢ Current genetic structure of several Mediterranean plant taxa reflects genetic divergence that either pre-dates the onset the Mediterranean climate which took place around 3.2 Ma, or resulted to Quaternary climate oscillations.

Some examples:

Establishment of Mediterranean climates has facilitated the spread of the genus Erodium and been crucial in its diversification.(Fiz-Palacios et al. 2010; Ann Bot)

Several Mediterranean species have adjusted their geographical distributions to the oscillations between glacial and interglacial periods, in a few climatically suitable refugia, like Cedrus libani in Turkey and Lebanon (Fady et al. 2009, Conserv Genet; Médail & Diadema 2009, J Biogeogr).

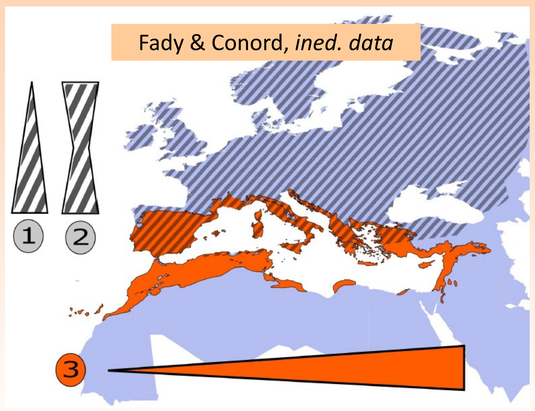
The genetic structure of Senecio rodriguezii within the Balearic archipelago was closely linked to the repeated cycles of sea level changes during the Quaternary (Molins et al. 2009, J. Biogeogr).


Erodium malacoides


Cedrus libani


Senecio rodriguezii

A META-ANALYSIS ON THE GENETIC DIVERSITY AROUND THE MEDITERRANEAN BASIN



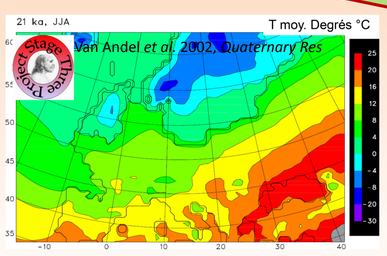
IN EUROPA:

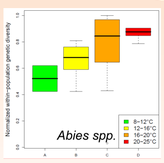
(1) « *Northern purity vs Southern diversity* » (Hewitt 1996, *Biol J Linnean Soc*)

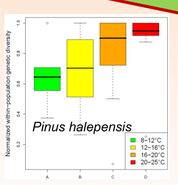
(2) « *Hotspots but not melting pots* » (Petit *et al.* 2003, *Science*)

IN MEDITERRANEAN:

(3) A new longitudinal matrice of genetic diversity




Abies spp.


Pinus halepensis

➢ Meta-analysis approach to combine measures of a tested effect in « primary studies » to obtain a global estimator, whose magnitude and significance can be tested statistically

➢ Queries to ISI Web of Science with several keywords (1980-2009): 202 studies, 13 molecular markers, 244 species within 62 families

➢ Basis model : correlation between genetic diversity and spatial coordinates of populations

➢ Balancing and cumulation of effects with covarioance tests (R metafor 1.3.0: Viechtbauer & MetaWinV2: Rosenberg, Adams & Gurevitch 2000

➢ **A new paradigm for the structure of the genetic diversity around the Mediterranean Basin?**

➢ Asignment to current populations of summer temperature during the Last Glacial Maximum reveals a correlation with the intra-population genetic diversity (Fady & Conord 2010, *Divers Distrib*)

PHYLOGEOGRAPHICAL PERSPECTIVES

➢ The Mediterranean region , it is also:

- an outstanding biogeographical crossroad, at the intersection of three major land masses: Europe, Africa and Asia, with the emergence of very distinctive flora,
- a hotspot of plant evolutionary history where genetic lineages of different Tertiary origins were shaped by palaeogeographical and palaeoclimatical events.

➢ Importance of phylogeographical studies based on circum-Mediterranean species

PHYLOGEOGRAPHY OF THE GENUS *MYRTUS*

➢ Hence, our phylogeographical focus on the genus *Myrtus*, the unique genus of the tropical Myrtaceae family colonizing the Mediterranean basin.

MYRTUS COMMUNIS


Southern France (J. Migliore)

➢ *Mediterranean shrub distributed from the Azores and Madeira to Western Asia (Iran and Afghanistan?)*

➢ *Rather common around the Mediterranean basin, within thermophilous matorrals and forest at low altitude*

MYRTUS NIVELLEI


Algeria (J. Migliore & O. Bernezat)

➢ *Endemic species growing in the mountains of the central Sahara (Algeria: Hoggar, Tassili-n-Ajjer, Immdir; Chad: Tibesti)*

➢ *Restricted and scattered populations with rocky or sandy wadis banks at high altitude (> 1500 m asl)*

➢ *Extensive geographical sampling including the Mediterranean area (173 populations) and the centro-Saharan mountains (23 populations).*

➢ *Sequencing of chloroplast (trnL-F & rpl2-trnH) and ribosomal (ITS & ETS) DNA intergenic spacers.*

➢ *Interpretation of our genetic data with palaeobotanical records and molecular datings.*

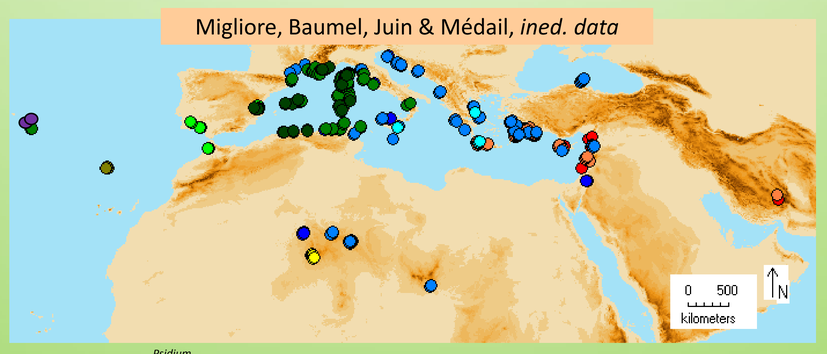
LONG-TERM PERSISTENCE SINCE THE TERTIARY

➢ Palaeobotanical occurrences revealed the Tertiary origin (Miocene) of the genus *Myrtus* throughout the Mediterranean Basin.

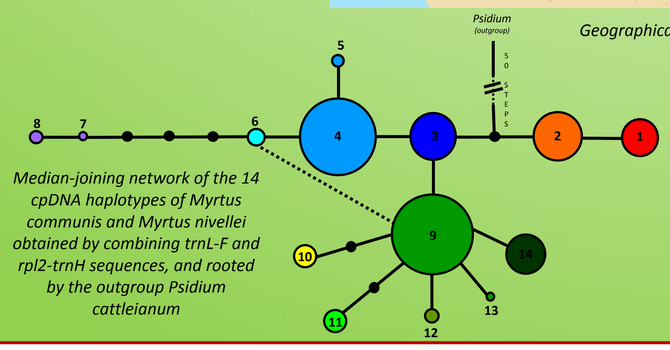
➢ Divergence of the major *Myrtus* lineages during the Late Tertiary (ca. 6 Ma), before the onset of the Mediterranean climate.

➢ Similar genetic patterns for cpDNA and rDNA (data not shown) illustrating a longitudinal genetic differentiation, with an early divergent eastern Mediterranean clade (haplotypes 13 & 14), a peri-Mediterranean clade (hap. 3, 4, 5 & 6) and a Western-Mediterranean clade (hap. 9, 11, 12, 13 & 14).

➢ Higher genetic distances within *M. communis* than between *M. communis* and *M. nivellei*!

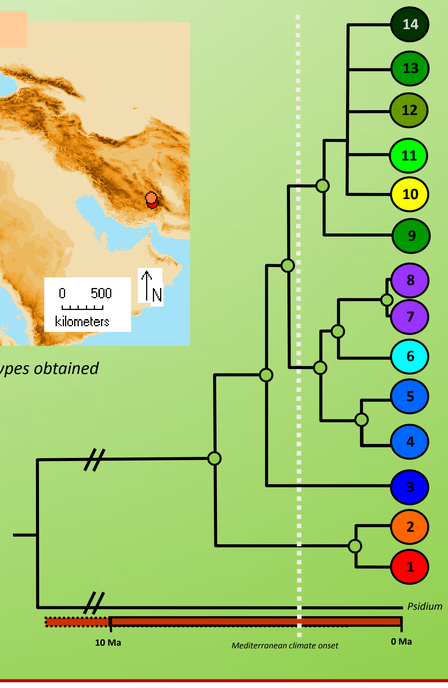


Geographical distribution of the 14 cpDNA haplotypes obtained



Median-joining network of the 14 cpDNA haplotypes of Myrtus communis and Myrtus nivellei obtained by combining trnL-F and rpl2-trnH sequences, and rooted by the outgroup Psidium cattleianum

Chronogram of divergence times determined by using an evolution rate for cpDNA sequences (trnL-F and rpl2-trnH) and the outgroup Psidium cattleianum



QUATERNARY RANGE DYNAMICS

➢ Glacial and interglacial periods could be at the origin of recent patterns of differentiation of *M. communis*, in particular with the radiation of western Mediterranean populations.

➢ Absence of north-south Mediterranean differentiation: role of bird dispersion?

➢ Recent range restrictions have been recorded by palaeobotanical data for *M. nivellei*, mainly in the South near Chad lake, suggesting the key influence of the Saharan aridification during the Quaternary on the migratory patterns of *Myrtus*.

➢ CpDNA markers argues for a minimum of three Mediterranean origins for the Saharan myrtle at different time periods.

HISTORICAL BIOGEOGRAPHY PERSPECTIVES

➢ An east-west Mediterranean genetic pattern of differentiation with a longitudinal gradient of the genetic diversity emerges from a new meta-analysis based on 244 plants.

➢ The study of the genus *Myrtus* exhibits a **more complex phylogeographical pattern**: if some cpDNA haplotypes are characterised by a peri-Mediterranean distribution, others have a more restricted geographical distribution range. It could suggest isolation phenomena (refuge persistence, vicariance) followed by migration events. Bearing witness to different Tertiary and Quaternary climatic vicissitudes up to the present, we found for this taxa a longitudinal pattern of genetic structure but not a genetic diversity gradient.

➢ *Myrtus nivellei* constitutes a striking example of a Mediterranean species with a hitherto unsuspected ability to persist locally and adapt relatively rapidly to extreme environmental changes.

[1] **INSTITUT MÉDITERRANÉEN D'ÉCOLOGIE ET DE PALÉOÉCOLOGIE** *Aix-Marseille University, UMR CNRS/IRD 6116, Aix-en-Provence, FRANCE*

[2] **INRA – URFM ECOLOGIE DES FORÊTS MÉDITERRANÉNNES** *UR 629, Avignon, FRANCE*

CONTACT: jeremy.migliore@etu.univ-cezanne.fr

FINANCIAL SUPPORTS: