

Resisting **increasing** salinity



Pollinating an orange tree, Morocco.
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The case of citrus in the Mediterranean

Citrus fruits originated in tropical and subtropical Asia. They are grown in all the world's warm regions, generally under irrigation, as is the case all around the Mediterranean. On its southern shores, for instance, water resources are becoming increasingly limited, while higher demand for water due to human activity means that water tables are falling and soil salt levels are rising, which is already impacting agriculture. Scientists are investigating the mechanisms of adaptation to salt stress, in order to

orientate breeding programmes and eventually offer farmers more adapted genotypes.

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Citrus trees are amongst the woody species most sensitive to salt stress. Ensuring better adaptation to salinity means 1) managing irrigation practices so as to prevent salt rising up through the soil towards the surface, 2) having rootstocks capable of limiting Na⁺ and Cl⁻ ion uptake at root level, 3) having varieties for grafting onto the selected rootstocks that present physiological and molecular mechanisms that limit the impact of toxic ions.

CIRAD is combining ecophysiology and breeding with a view to:

- ▶ understanding the mechanisms leading to sensitivity and adaptation to salt (role and ratios of K⁺, Na⁺ and Cl⁻ ions, osmotic adjustment, impact of plant morphology), triggering of oxidative stress, detoxification systems, etc
- ▶ analysing the mechanisms used by species to adapt to salinity;
- ▶ identifying candidate genes and genetic markers for selection;
- ▶ breeding varieties that are both tolerant and productive in different salinity conditions.

Creating tolerant varieties

The citrus group comprises three main botanical genera that are sexually compatible: *Citrus*, *Poncirus* and *Fortunella*. Most of the rootstocks in current use belong to the genera *Citrus* and *Poncirus*, or are hybrids obtained by crossing the two. Most citrus varieties (orange, mandarin, lemon, grapefruit and lime) all belong to the genus *Citrus*.



Citrus planting under netting . © Y. Froelicher/CIRAD

Rootstocks

Several CIRAD selections are currently being investigated and should serve to widen the range of possible rootstocks. As regards salt stress tolerance in rootstocks, three main groups have been identified: a tolerant group that comprises sour orange and “Cleopatra” mandarin, which are considered to be adapted to abiotic constraints; a sensitive group that comprises rough lemon and “Carrizo” citrange; and a highly sensitive group represented by *Poncirus* (*Poncirus trifoliata*).

Sensitivity is primarily due to Cl⁻ ions. Leaf Cl⁻ content is a good criterion for assessing the salt sensitivity of seedlings.

▶ Combined with *Poncirus*, the “Cleopatra” mandarin is used in breeding programmes to generate more tolerant diploid, double diploid and allotetraploid genotypes.

▶ Tetraploid rootstocks are more tolerant than the respective diploids, probably because of their greater ability to compartmentalize and detoxify Cl⁻ and Na⁺ ions.

Scions

Another way of addressing the salinity issue is to assess the salt tolerance of newly created fruit varieties (scions).

▶ Several thousand triploid varieties are currently being assessed for fruit quality criteria with private partners. Evaluation of the pre-selected triploid varieties for their salt stress tolerance has been initiated.

Genetic diversity

▶ A recent analysis of the physiological response to salt stress of genotypes representative of the diversity suggested that it should be possible to find new sources of tolerance in rootstocks and also at variety level.

Associating end users

Substantial efforts are being made to be able to offer genotypes more adapted to high salinity. However, it is also necessary to take account of economic and social issues to ensure that human activity has little impact on ecosystems. Likewise, the new innovative genotypes developed by research may mean changing cropping practices. It is therefore vital that end-users be closely associated with the assessment of these new genotypes.

Effects of salt stress on various citrus fruits.

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1. Cleopatra mandarin: no symptoms – plant and fruit



2. Grapefruit: leaf fall and new shoots – plant and fruit



3. Citron: necrosis of leaves and branches – plant and fruit



Partners

INRA, Institut national de la recherche agronomique, France;
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▶ For further information

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Adaptation to salinity. In: Torquebiau E. (ed.). Climate change and agriculture worldwide. Springer (in press)

See also: <http://publications.cirad.fr>