CLIMED-FRUIT

Varietal diversity: building on yesterday's varieties to meet tomorrow's challenges

The Mediterranean region has long been home to a rich diversity of perennial fruit crops, including grapes, citrus, olives, avocado and almonds. These crops face increasing challenges as climate change accelerates, from rising temperatures and prolonged droughts to shifting pest and disease pressures. Addressing these challenges requires a strategic approach that leverages the genetic diversity of existing traditional varieties and the development of new resilient cultivars through breeding programs.

Farmers are adjusting their practices to cope with the challenge, but many of these solutions remain confined to specific regions or agricultural sectors. The EU-funded CLIMED-FRUIT [1] project is working to bridge this gap by collecting and sharing innovative, climate-adaptive practices from various European agricultural groups to enhance resilience and promote effective climate change adaptation and mitigation. This article presents a non-exhaustive list of experimental results from experiences carried out across Europe and identified in the framework of the CLIMED-FRUIT project.

Preserving crop diversity

Climate change is one of the key drivers of biodiversity loss and threatens the survival of the strategic reservoir of crop genetic resources needed to adapt production systems to future challenges. Modern agricultural systems often rely on a narrow genetic base, increasing the risk of genetic erosion and reducing the sector's ability to respond to future challenges. For example, concerning olives, although 139 varieties have been identified across the Mediterranean [2], only a few varieties were planted in modern orchards. In Spain (the largest olive-producing country), only three varieties (Picual, Arbequina and Hojiblanca) are planted in over 90% of the orchards and dominate production.

There are different strategies for conserving and utilising crop genetic resources, from safeguarding traditional varieties to breeding new cultivars, *ex situ* and *in situ* conservation, the rediscovery of old varieties and wild relatives and the development of new resistant cultivars, such as PIWI grape varieties, which aim to reduce chemical inputs while ensuring long-term sustainability.

Among these strategies, ex situ conservation plays a particularly prominent role, as illustrated by numerous gene banks and germplasm collections across Europe that safeguard the rich diversity of cultivated and wild plant species. The conservation of plant genetic resources has traditionally relied on ex situ methods, such as gene banks, where plants are preserved outside their natural habitats. Notable examples include the El Encín Vineyard Collection in Madrid (3,000 grapevine accessions) and the Alameda del Obispo Olive Germplasm Bank in Córdoba (more than 800 olive varieties). In the case of vines, France has developed an extensive grapevine heritage, including ancient varieties, modern crosses and mutations. Collections have documented around 550 varieties [3], with 377 officially authorised for cultivation in the French official national vine variety catalogue.

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Each year, new varieties — whether traditional French and foreign grape varieties or modern breeding selections — are added to this list, enriching France's viticultural diversity. The Mediterranean Germplasm Database [4] is the reference database for the agrifood plant germplasm collection stored at the Institute of Biosciences and Bioresources of the Italian National Research Council in Bari, Italy. The collection contains about 220 accessions of citrus fruits of great agronomic, historical and ornamental value, over 200 accessions of both domestic and wild olive trees and about 480 accessions of grapevine. In addition, the regional centre for the ex situ conservation of native fruit, vine and olive is located at the Basile Caramia Centre for Research, Experimentation and Training in Agriculture, located in Locorotondo (southern Italy). The germplasm conservation fields are situated in various locations to meet different species' soil and climatic requirements. Collections have 540 distinct grapevine cultivars (regional, national and international germplasm), 62 olive cultivars (regional and extra-regional germplasm), 93 accessions of sweet orange, clementine, mandarin, lemon, lime and related hybrids and rootstocks. Moreover, the Locorotondo countryside is home to about 1,000 varieties of fruit species: 210 almond trees, 215 fig trees, 193 pear trees, 80 cherry trees, 70 peach trees, 64 apricot trees, 52 plum trees, 32 apple trees and 60 minor fruit trees.

Exploration of old or wild varieties that could prove of interest in the face of climate change

Exploring old or wild varieties of Mediterranean fruit trees is a promising strategy for improving climate resilience. Many traditional and underutilised cultivars have developed natural adaptations to drought, heat stress, pests and diseases over centuries of cultivation in marginal environments. Additionally, their wild relatives often possess unique genetic traits that can be harnessed to breed more resilient varieties.

In viticulture, *Vitis vinifera ssp. sylvestris* (wild grapevine) genetic resources must be conserved, considering its potential for improving disease resistance and stress tolerance. Wild grapevine is critically endangered, often isolated or in small populations, lacking natural regeneration and facing annual declines. Some of these wild vines are preserved in the national public ampelographic collection (INRAE Domaine de Vassal, France) or regional conservatories (e.g., Charentes, southwestern France). Some varieties may show traits better adapted to climate change (maturity period, acidity level, canopy architecture, etc.), and additional observations include aromatic precursor analysis, water stress assessments and research on disease resistance. Extreme heat and drought are pushing winemakers to explore ancient and climate-adaptable varieties. Old grape varieties such as Assyrtiko from Santorini (Greece), Xynisteri from Cyprus and Listán Prieto (Fig. 1), which has evolved in the high, dry steppes of central Spain's Castile-La Mancha region, have demonstrated exceptional drought resistance, making them valuable in a warming climate [5]. The Valovitis project [6] studied over 60 forgotten grape varieties originating in Pyrenean regions (southwest France and northern Spain). References of their agronomical and

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oenological traits were created, and a catalogue has been produced. Similar work is being done in Spain, through the VITISAD Project [7], and Italy.

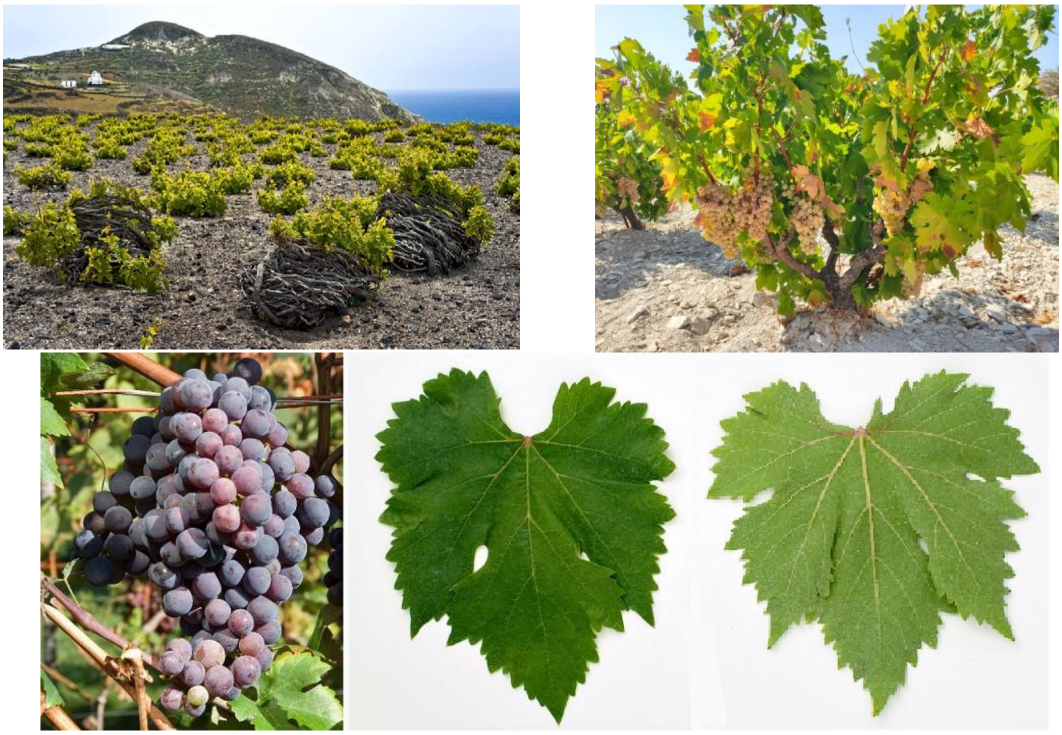

Fig. 1. Left: Assyrtiko grapes in Santorini (source: https://www.the-travel-insiders.com/guide-exhilarating-wine-tasting-santorini); right: Xynisteri grapes (source: https://drinkstack.com/wine/cyprus/); bottom: Listán Prieto (source: https://glossary.wein.plus/listan-prieto)

Olive trees are deeply rooted in Mediterranean agriculture and also have a wealth of resilient traditional varieties. For example, Besbessi, Sayali and Chemchali from Tunisia and Koroneiki from Greece are highly adapted to drought-prone areas [8] [9]. Wild oleaster trees (*Olea europaea subsp. cuspidata*) thrive in extreme environments and could serve as a genetic reservoir for breeding olives with greater tolerance to heat, salinity and poor soils [10].

Almonds, another key Mediterranean crop, have traditional varieties such as Marcona and Desmayo Largueta that perform well under drought conditions. Wild almond relatives, such as *Prunus webbii* and *Prunus fenzliana*, show even greater drought resilience and could be valuable in breeding programs to enhance stress tolerance. A clear example is *Prunus ramonensis*, an almond species with small leaves and higher photosynthetic activity, that is endemic to the hyper-arid Negev desert; it is seemingly unaffected by drought and has been well maintained under drought stress [11]. Identifying and utilising these genetic resources will be crucial for maintaining almond production with increasing water scarcity.

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Fig. 2. Left: Prunus webbii *(source:*
https://photos.google.com/share/AF1QipNTOragGaahxaiV62Hbuo8BgFsXBUoxe1my_tORxFAm7iN2AGn7Lei5HLxVgdwQ5w?pli=1&key=aHNqMUtwaHREMDYzeFhadVpXdlE5QzNXNDkxTzVR*);*
right: Prunus fenzliana*, Daralegis, Armenia (source:*
https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:729709-1*); bottom:* Prunus ramonensis*, Negev Highlands, Israel (source:*
https://powo.science.kew.org/taxon/urn:lsid:ipni.org:names:77149446-1*)*

Gastronomy and agritourism, alongside European Union trademarks and policies, play a key role in supporting the in situ conservation of landraces and local varieties. Protected designation of origin (PDO) and protected geographical indication (PGI) labels encourage farmers to maintain traditional crop varieties by adding market value to their products. These certifications support conservation efforts by ensuring that regional agricultural products are made using specific local landraces, thereby preserving biodiversity and cultural heritage. Across southern Europe, PDO and PGI labels are crucial in conserving traditional olive, grape, citrus and almond varieties, ensuring their economic viability through agritourism and sustainable farming.

Selecting rootstock – citrus example

Citrus tristeza virus (CTV) has devastated citrus production in recent years, leading to the loss of nearly 100 million plants, including sweet oranges, mandarins and grapefruits, propagated on sour orange (*C. aurantium*), which is the historically dominant rootstock in the Mediterranean basin. Few genotypes have shown promise as CTV-tolerant rootstocks, combining high yield, fruit quality and resistance to abiotic (frost, salinity) and biotic (Phytophthora spp., the viroids of citrus exocortis and hop stunt) stressors. Among these,

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Volkamer lemon (*C. volkameriana*), Carrizo citrange (*C. sinensis × Poncirus trifoliata*) and Forner-Alcaide no. 5 (*C. reshni × P. trifoliata*) stand out as viable alternatives [12].

A new disease is currently causing severe damage to citrus crops in areas of Florida, Brazil and California: HLB, caused by the bacterium *Candidatus liberibacter*. This disease has no cure, and it is believed that its control will be based on the use of rootstocks that are resistant or tolerant to the growth of the bacterium.

The first results obtained in field trials within the LIFE VIDA FOR CITRUS project [13] have entailed progress for the research on HLB-resistant rootstocks that are also adapted to Mediterranean conditions and produce quality fruit. Agronomic validation was carried out in experimental plots at the Andalusian Institute for Agricultural, Fisheries, Food and Organic Production Research and Training (IFAPA) in southern Spain. The Lane Late orange variety was combined with selected rootstocks, and parameters such as tree growth during the first years, variety compatibility with the rootstock, flowering intensity and fruit quality were evaluated. The initial results show that the rootstocks C22 Bitters and US897, which are semi-tolerant and tolerant to HLB, showed interesting behaviour with Lane Late under the agroclimatic conditions in IFAPA's experimental plot.

Conclusion

To meet the challenges of climate change and sustainability, Mediterranean fruit crop systems must embrace greater genetic diversity and resilience. Integrating traditional and underutilised varieties alongside innovative practices will strengthen adaptability, productivity and environmental sustainability. A coordinated effort across research, breeding and cultivation is key to building a more resilient agriculture.

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