

Improving resilience of perennial fruit trees facing climatic hazards

The Mediterranean region is experiencing some of climate change's most intense effects on European agriculture, including more frequent extreme heat, droughts, loss of biodiversity and increasing water needs. This is particularly concerning for perennial fruit crops and grapevines, which cover substantial areas and are increasingly affected by these changes. Farmers are adjusting their practices to cope, 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 operational groups (OGs) to enhance resilience and promote effective climate change adaptation and mitigation.

This article presents a non-exhaustive list of experimental results from projects carried out across Europe and identified in the framework of the CLIMED-FRUIT project.

I. Adapting to extreme heat and drought conditions with dry farming practices

The Mediterranean Basin is warming 20% faster than the global average, causing damage to fruit crops and reducing productivity [2]. This trend is causing severe damage to Mediterranean perennial crops, leading to a decrease in productivity and quality. Adaptation strategies include sustainable practices and climate-resilient infrastructure.

Shading nets

Shading nets are highly effective tools for mitigating the impact of extreme heat, reducing solar exposure and, thus, sunburn risk, on fruits. While installation can be costly, shading nets provide dual benefits by protecting against hail, which is increasingly common with changing weather patterns. Recent studies highlight the effectiveness of coloured shade netting in managing canopy temperature and improving agricultural outcomes across various crops. In a Hass avocado orchard, white and blue photoselective shading nets (20% shading intensity, Fig. 1) lowered the photosynthetic radiation ~25% and ~26%, respectively. A similar trend was observed for UV light, where both blue and white nets reduced the radiation by around 32–34%. Canopy temperature was also reduced by 7.6°C and 7.3°C, respectively [3]. Shading nets are also a valuable tool in sweet cherry production, offering several benefits such as sun protection, temperature regulation, uniform fruit ripening, improved yield and water conservation. The appropriate shading percentage should be decided based on local climate conditions and the needs of the cherry variety (typically 30–40% shade) [4]. A study from Japan with silvered polyethylene nets, with shading levels of 53% and 78%, showed a reduction of the daily maximum air temperature by 1.8°C and 3.2°C, respectively, compared to the unshaded control. Reducing light by 78% also reduced the frequency of double pistils to 24% [5].



Fig. 1. Shading nets in an avocado orchard [3]
Upper row: red net (left), blue net (right); bottom row: white net (left), open field (right)

Foliar applications to mitigate stress

Foliar applications of kaolin (KL) and salicylic acid (SA) help reduce water loss and protect plants from heat. KL acts as a barrier, while SA boosts the plant's defence mechanisms. Research by the Portuguese [OG New Practices in Rainfed Olive Groves](#) [6] demonstrated that foliar applications of SA and KL significantly boosted olive productivity (Fig. 2) without compromising olive oil quality. KL 5% and SA 100 μ M were sprayed during summertime when high sunlight and temperatures around 30°C were expected. A second application of KL was done on the same day to ensure uniform adhesion [7]. The dosage per treatment was 750 mL/tree [8].

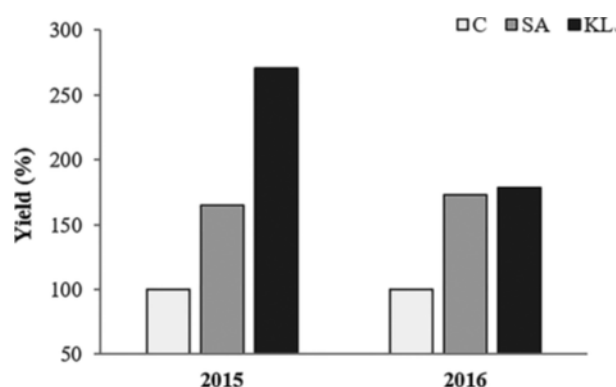


Fig. 2. Influence of salicylic acid (SA) and kaolin (KL) treatments on olive yield (%) in two years of experiment^[7]

Soil cover management: mulching techniques and cover crops

The [OG GO CITRICS](#) [9] applied rice straw as mulch in citrus groves. A mulch thickness of 2–3 cm requires air-dried rice straw chopped between 5 cm and 15 cm in a quantity of 1–2 kg/m². One of the main benefits observed is this material's capacity to reduce the required water supply by around 15%, which is particularly relevant for citrus fruits since they

increase in size in the months of greatest water need. Rice straw helps to control weeds and maintain a more stable soil temperature (lowering the average daily temperature by 3.4°C in comparison with bare soil), protecting citrus roots from thermal stress and maintaining the biological processes that occur in the first few centimetres of soil, such as the mobilisation of nutritional elements by microorganism consortia. Another key aspect is the fact that the decomposition of rice straw enriches the soil with organic matter (increases soil organic carbon concentration by 15.15%), improving its structure, fertility and retention (Fig. 3) [10], [11].

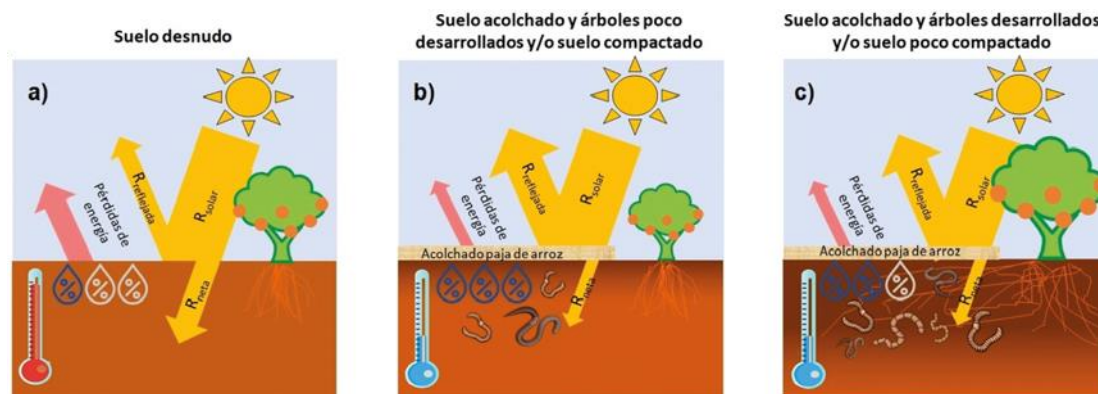


Fig. 3. Soil energy balance in different treatments and plantations: a) bare soil, b) mulched soil and underdeveloped trees and/or compacted soil in Paiporta and c) mulched soil and developed trees and/or loosely compacted soil in Sueca [10]

Adapting plant material

Using drought-tolerant crop rootstocks and varieties is an effective and cost-efficient way to mitigate extreme weather's impact of on agriculture.

The [O4C project](#) [12] observed that traditional olive varieties from arid Mediterranean regions, such as the Syrian cultivars Barri, Maarri, and Abou Satl Mohazama, show similar resilience to drought as popular international varieties cultivated in Italy, such as Arbequina. Studies identified Lechín de Sevilla and Picholine Marocaine as particularly drought-tolerant among 32 olive cultivars [13]<https://www.mdpi.com/2311-7524/8/10/939>. In almond cultivation, the Monegro rootstock is highly drought-resistant, compatible with various cultivars and ideal for non-irrigated regions. Certain cultivars grafted on GF677 rootstock, such as Supernova and Marcona, show superior drought resilience [14][15]. For sweet cherries, the WeiGi®1 [16] rootstock, tested in France, boosts yield and withstands dry conditions without chlorotic symptoms, offering a 50% higher yield than the Gisela 5 rootstock.

II. Adapting to frost hazards

Global warming has led to pronounced shifts in vine phenology, especially in the Mediterranean, resulting in earlier flowering and fruiting events. Studies indicate that

approximately 78% of flowering and fruiting cycles now occur earlier, with 30% of these shifts showing significant advances. Similarly, late autumn frosts have an adverse effect on plants that have not yet entered a dormant phase, collectively resulting in significant yield losses.

Agroclimatic map for anticipating the planting of avocados in Spain

Avocado cultivation is expanding in Europe due to favourable climatic changes. However, since avocados are frost-sensitive, agroclimatic maps are used to guide farmers on optimal planting zones. The **OG GO AVOCADO** [17] developed a regional agroclimatic map [18] (Fig. 4), categorising areas based on frost risk, with the best regions having temperatures that rarely fall below -2°C , in terms of zones recommended for avocado cultivation [19]:

- Optimum: minimum temperatures below 0°C once every 10 years and never below -2°C
- Viable: absolute minimum temperatures below -2°C but never below -4°C
- Potential: absolute minimum temperatures below -4°C once every 10 years
- Unsuitable: all others

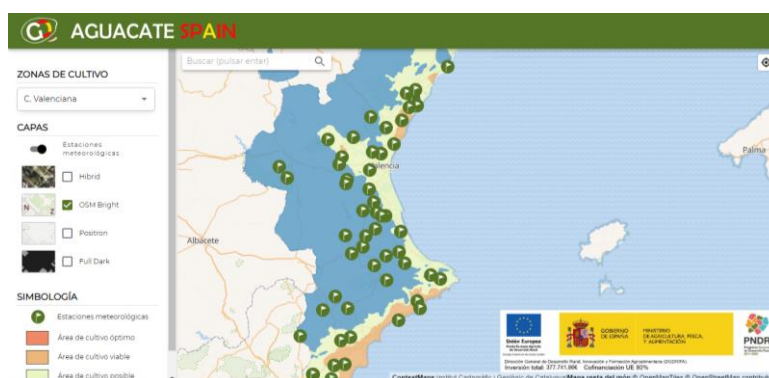


Fig. 4. Agroclimatic map – **OG GO AVOCADO**

Adapting plant material

Selecting late-blooming or later-budding varieties can help reduce frost damage, making phenology an important factor in planting decisions. In almond cultivation, for instance, late and extra-late varieties (such as Antoñeta, Penta and Vialfas) are recommended for frost-prone areas. However, extra-late and ultra-late varieties with high chilling needs may not be suitable for very warm climates as these regions might not provide the necessary low temperatures to break dormancy.

Conclusion

The Mediterranean region faces increasing challenges for perennial fruit crops due to accelerated warming and extreme climatic conditions. Adaptation measures such as shading nets to reduce heat stress, foliar applications of kaolin and salicylic acid to enhance plant resilience and mulching techniques to conserve water and improve soil health are proving effective. Additionally, drought-tolerant plant varieties and agroclimatic

maps help optimize crop selection and planting in frost-prone areas. These strategies offer sustainable solutions to mitigate climate impacts and improve the resilience of Mediterranean agriculture.

Bibliography and sources

- [1] CLIMED FRUIT project, <https://climed-fruit.eu/>
- [2] Urdiales-Flores, D., Zittis, G., Hadjinicolaou, P. et al. (2023). Drivers of accelerated warming in Mediterranean climate-type regions. *npj Clim Atmos Sci* 6, 97 <https://doi.org/10.1038/s41612-023-00423-1>
- [3] Tinyane, P.P., Soundy, P., & Sivakumar, D. (2018). Growing 'Hass' avocado fruit under different coloured shade netting improves the marketable yield and affects fruit ripening. *Scientia Horticulturae*, 230, 43-49. <https://doi.org/10.1016/j.scienta.2017.11.020>
- [4] <https://cherrytimes.it/en/news/multifunctional-covers-key-tools-cherry-orchard-sustainability-morandi>
- [5] Beppu, K., & Kataoka, I. (2000). Artificial shading reduces the occurrence of double pistils in 'Satohnishiki' sweet cherry. *Scientia Horticulturae*, 83, 241-247. [https://doi.org/10.1016/S0304-4238\(99\)00114-4](https://doi.org/10.1016/S0304-4238(99)00114-4)
- [6] OG New Practices in Rainfed Olive Groves
https://www.youtube.com/watch?v=oSl994ugNnl&list=PLqU_4ysqg2Ql8oRs5pa0Ar3zca56c2QyM&index=9
- [7] Brito, C., Dinis, L.-T., Silva, E., Gonçalves, A., Matos, C., Rodrigues, M. A., Moutinho-Pereira, J., Barros, A., & Correia, C. (2018). Kaolin and salicylic acid foliar application modulate yield, quality and phytochemical composition of olive pulp and oil from rainfed trees. *Scientia Horticulturae*, 237, 176-183. <https://doi.org/10.1016/j.scienta.2018.04.019>
- [8] Brito, C.; Dinis, L.T.; Silva, E.; Gonçalves, A.; Matos, C.; Rodrigues, M.A.; Moutinho-Pereira, J.; Barros, A.; Correia, C. Kaolin and salicylic acid foliar application modulate yield, quality and phytochemical composition of olive pulp and oil from rainfed trees. *Sci. Hortic.* 2018, 237, 176-183. <https://doi.org/10.1016/j.scienta.2018.04.019>
- [9] OG GO CITRICS
https://www.youtube.com/watch?v=Thfjk43L1DY&list=PLqU_4ysqg2Ql8oRs5pa0Ar3zca56c2QyM&index=6
- [10] Visconti, F., Peiró, E., Nájera, I., Baixauli, C., Romero, P., & de Paz, J. (2021). Beneficios del acolchado con paja de arroz para la fertilidad del suelo y el secuestro de carbono en plantaciones de cítricos. *Levante Agrícola*, (456), 73-80. <http://hdl.handle.net/20.500.11939/7575>
- [11] Gu C., Liu Y., Mohamed I., Zhang R., Wang X., Nie X., Jiang M., Brooks M., Chen F., Li Z. 2016. Dynamic changes of soil surface organic carbon under different mulching practices in citrus orchards on sloping land. *PLoS ONE*, 11(12), e0168384. <https://doi.org/10.1371/journal.pone.0168384>
- [12] O4C project <https://olive4climate.eu/en/>
- [13] Razouk R, Hssaini L, Alghoum M, Adiba A, Hamdani A. (2022). Phenotyping Olive Cultivars for Drought Tolerance Using Leaf Macro-Characteristics. *Horticulturae*, 8(10):939. <https://doi.org/10.3390/horticulturae8100939>
- [14] Ranjbar, A., Imani, A., Piri, S., Abdoosi, V. (2022). Grafting commercial cultivars of almonds on accurate rootstocks mitigates adverse effects of drought stress. *Scientia Horticulturae*, 293, 110725. <https://www.sciencedirect.com/science/article/abs/pii/S0304423821008323>
- [15] Felipe, A. J. (2009). 'Felinem', 'Garnem', and 'Monegro' Almond × Peach Hybrid Rootstocks. *HortScience*, 44(1), 196-197. <https://doi.org/10.21273/HORTSCI.44.1.196>
- [16] WeiGi®1 https://cerasina.com/wp-content/uploads/2024/01/weigi1_e_a4_web.pdf
- [17] OG GO AVOCADO
https://www.youtube.com/watch?v=tpjvQ3MqcFQ&list=PLqU_4ysqg2Ql8oRs5pa0Ar3zca56c2QyM&index=5
- [18] Agroclimatic map <https://goaguacatespain.com/mapa/>
- [19] Zones recommended for avocado cultivation (Spain)
<https://goaguacatespain.com/wp-content/uploads/2021/09/tema-9.pdf>