Technical Article Nº 6

CLIMED-FRUIT

Innovative practices for water stress management and dry farming in perennial crops

The Mediterranean region is known for its warm climate and limited water resources, making it vulnerable to water stress and the impacts of climate change. Various innovative practices have been developed and implemented in the region to address these challenges for water stress management and dry farming. Dry farming relies on the natural moisture retained in the soil and specific farming techniques to ensure crops receive enough water to grow and produce. However, it requires a high level of skills and experience, as farmers must be able to evaluate the soil status and adapt the techniques to changing weather conditions. Key strategies include regulated deficit irrigation (RDI) and partial root-zone drying (PRD), which optimise water use by targeting critical growth stages or alternating root-zone hydration. Soil management techniques, such as mulching, adding organic matter and planting cover crops, enhance soil moisture retention and structure. Advanced technologies such as soil moisture sensors, remote sensing and real-time monitoring systems improve precision in water application.

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 groups 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 CLIMED-FRUIT project.

Setting up a traditional water-efficient irrigation system

There are various ways of improving irrigation water efficiency. Firstly, the choice of irrigation system is a critical factor: choosing a localised drip or 'micro-jet' system distributes water as close as possible to the roots, avoiding excessive evaporation and limiting the development of weeds. However, very localised water distribution does not stimulate the development of root systems in terms of their depth and on a large horizon, thus increasing the plants' dependence on irrigation. Therefore, the choice of irrigation system, its positioning and the timing of inputs are all factors that go into improving water use efficiency.

Drip irrigation

It is one of the most widespread systems for growing perennial crops (Fig. 1). In this system, a reduced quantity of water is applied to the roots of plants in the form of continuous or discrete drops, tiny streams or pulse systems. Between 2 and 20 litres are delivered per hour from a narrow tube with several orifices known as emitters [2]. Drip irrigation is widely

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known to increase water use efficiency by having 50% less water demand than furrow irrigation and reducing waterlogging.

Fig. 1. Aerial drip irrigation system in viticulture (photo credit: IFV Sud-Ouest)

Deficit irrigation

Deficit irrigation (DI) is a watering strategy where irrigation is only applied during drought-sensitive crop growth stages to reduce water wastage.
There are different types of DI (Fig. 2):

- *Sustained DI:* based on distributing the water deficit uniformly over the whole fruit season, thus avoiding the occurrence of a severe plant water deficit at any crop stage that might affect the marketable yield or fruit quality.
- *Regulated DI:* full irrigation is supplied during fruit trees' critical periods, while it is limited or even unnecessary if a minimum supply of water is provided by rainfall during critical periods.
- *Partial root drying DI:* based on irrigating only one part of the root zone, leaving another part to dry to a certain soil water content before rewetting by shifting irrigation to the dry side.

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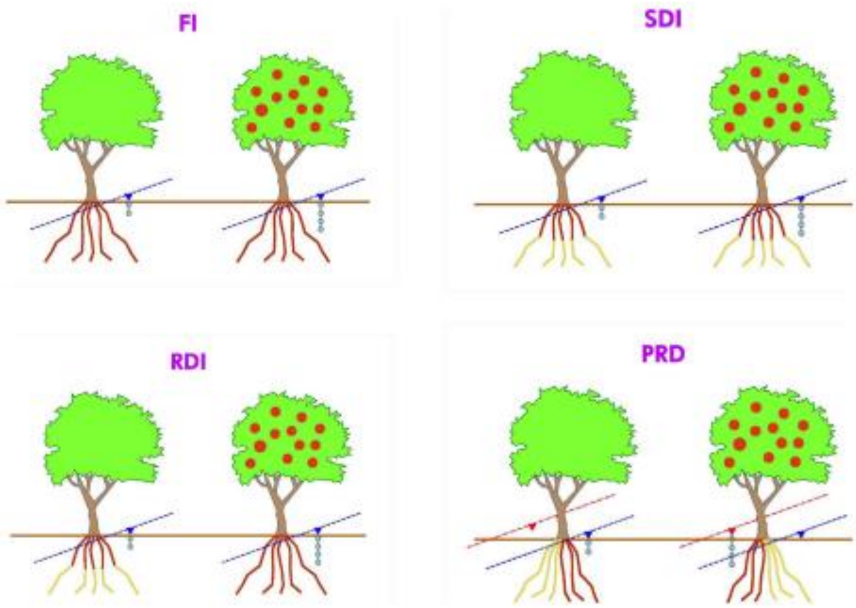

Fig. 2. Graphic pattern of full irrigation (FI), sustained deficit irrigation (SDI), regulated deficit irrigation (RDI) and partial root drying (PRD) strategies in fruit trees [3]

Smart irrigation systems

Avocado orchard

Due to the better economic profitability of avocado and the new climatic conditions, European farmers are turning to it as a substitute for other crops. Avocado is sensitive to drought and root asphyxia, requiring an exact water volume to grow and produce fruit. The shallow roots limit the ability to exploit large volumes of soil and fully use stored rainfall. Many farmers need to familiarise themselves with the most appropriate agronomic techniques adapted to the specific conditions. In this context, OG GO AVOCADO [4] has been leading in the development of new cultivation practices, such as using capacitance probes (Fig. 3) combined with drones and agroclimatic maps [5] (Fig. 4). Before planting, the agroclimatic map must be consulted to determine whether the plot meets the optimum conditions. At the same time, a suitable irrigation system is essential for water efficiency, regardless of the plot location. Capacitance probes can be chosen to determine the irrigation needs at each moment (some are autonomous and work with a small solar panel). These probes can determine soil moisture content, salinity and temperature at different soil depths. The estimation of soil moisture content is based on measuring the soil's electrical constant using electrodes, which can detect oscillations in the constant since the soil is an electrically conductive substrate. These variations in the value of the electrical constant correlate with the soil capacitance or moisture content. The same system is used to estimate soil salinity.

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Fig. 3. Capacitance probe in a citrus plantation, similar to those used in [OG GO AVOCADO]

Fig. 4. Agroclimatic map – [OG GO AVOCADO]

The capacitance probes measure volumetric soil water content (VWC) accurately and in real-time, making it possible to monitor moisture levels in the root zone, detect changes or deviations after irrigations or rainfall and identify drying patterns between irrigations. With this information, the technician can adjust the frequency and duration of irrigations according to the actual needs of the avocado crop. In addition, this avoids excessive irrigation and prevents water stress. Finally, although using capacitance probes for crop water management initially entails an extra cost due to the high price of the technology, it produces significant savings in water, fertiliser and energy by applying only the necessary amounts.

Fig. 5 shows the humidity detected by the probes at four depths (black 10 cm, red 30 cm, blue 50 cm, yellow 70 cm). After each irrigation, the water content of the soil increases to a greater extent in the first centimetres and is practically imperceptible at the deeper levels. The red and black dots show root activity, i.e., the times when the roots take up water.

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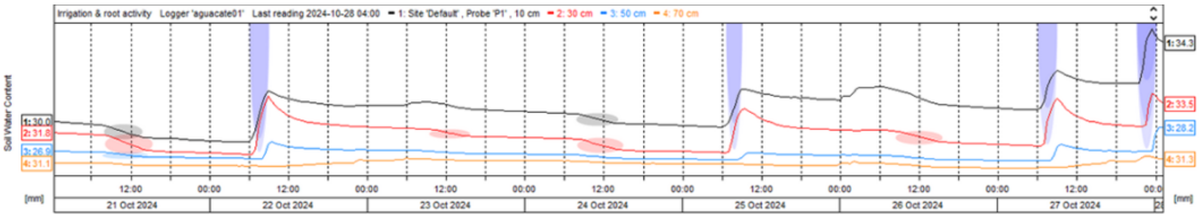

Fig 5. Graph of data from the capacitance probe on the evolution of soil water content at different depths and after irrigations – OG GO AVOCADO

To determine the exact volume of water needed by the avocado crop, the OG GO AVOCADO [4https://climed-fruit.eu/wp-content/uploads/2024/06/8.-EPA-GO-AVOCADO.pdf] monitored instantaneous consumption and adapted the irrigation regime to the real needs of the plant. One hectare of avocado is estimated to consume about 6,300 m3/year (Manual of practical management of avocado cultivation). This crop needs constant humidification in the root zone, with 50% of the roots located within the first 30 cm of soil. Thus, it was observed that increasing the number of irrigation days but applying a smaller volume of water at each irrigation increased yields compared to irrigating on more days with a higher volume of water. This is because short and continual irrigations keep the soil surface constantly wet. It has been observed that installing ultra-low flow drippers (0.6 l/h) arranged in 4 rows of dripper lines generates constant wetting in the first centimetres of the soil.

Citrus orchard

The OG GO CITRICS [6] conducted a pilot test of citrus cultivation using thermographic cameras, drones, satellite information and capacitance sensors to determine the areas with irrigation excesses or deficits to balance this aspect. It was possible to determine the water available in the irrigation system using the data obtained and, by applying the appropriate corrections, the information acquired this way can be transferred to growers for application on their farms. It can be difficult to use this method in some production areas due to the knowledge required to manage these kinds of technology. For this reason, the OG GO CITRICS is working to train farmers to make it easier for them to interpret the valuable information provided by the probes and other monitoring systems. The capacitance probes in the field enable optimal irrigation scheduling based on the optimal time and amount of water needed according to the soil moisture obtained by the sensors (Fig. 6a). In addition, the data obtained from drone flights equipped with a hyperspectral camera (Fig. 6b) and satellite images allowed for detecting failures in the irrigation systems, highlighting areas with both over- and under-irrigation (Fig. 6c). These detections are carried out by monitoring vegetative rates such as the normalised difference vegetation index (NDVI). This parameter is based on detecting infrared wavelengths and provides precious information for preventing crop stresses before the appearance of symptoms in the plant. Stress detection allows for correcting stress early, repairing possible failures and adapting irrigation strategies to crop needs. In addition, a mulch layer of rice straw

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generates benefits in terms of reducing irrigation requirements by 30% and increasing yield by 10% compared to traditional conditions with 100% ETc irrigation and without mulching.

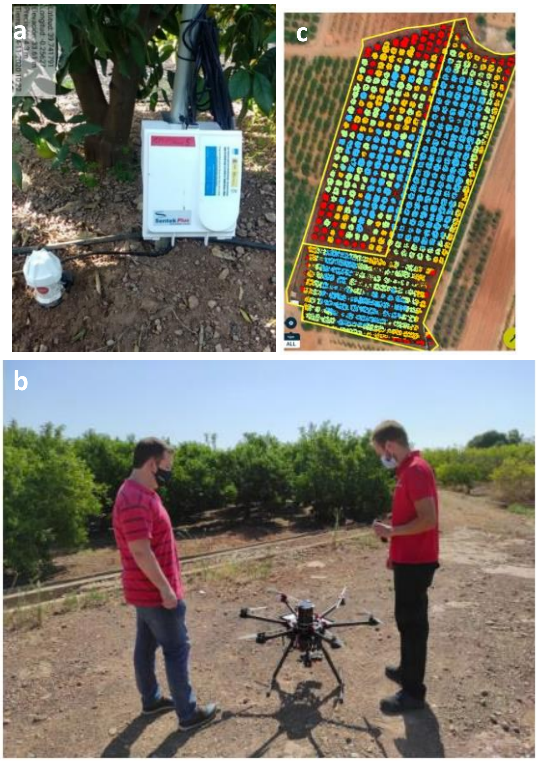

Fig. 6 a) Capacitance sensor; b) digital platform with the hydrological results; c) drone equipped with thermographic cameras – OG GO CITRICS

Olive orchard

Precision irrigation based on daily trunk growth using a dendrometer (Fig. 7), installed 15 cm above the ground on the main trunk of the trees, was applied for three years in a young super high-density olive orchard (Arbequina cultivar) in northeastern Spain [7]. Based on the dendrometer data irrigation in July and August (summer vegetative growth stop) occurred after two consecutive days of decreased trunk diameter. The dendrometer took and sent measurements every 15 minutes via radio to a data logger. The olive oil production increased by 7% and the vegetative variables did not show significant reductions, resulting in 31% water savings compared to the control strategy.

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Fig. 7. Dendrometer

Dry farming

Soil management practices

Sustainable soil management practices are crucial to preserve soil health and mitigate adverse effects on plant performance. The Portuguese OG New Practices in Rainfed Olive Groves [8] assessed the effects of conventional tillage and self-reseeding annual legume cover crops on plant physiological performance and soil properties [9]. Legume cover crops (white lupine, vetch, subterranean clover, red clover, yellow serradella) were seeded in autumn and terminated in spring the following year, after seed maturity. They were then destroyed with a rotary slasher and left on the ground as mulch. This practice reduced soil erosion risk, improved soil fertility, prevented soil water content loss through evaporation and increased water holding capacity. Therefore, the use of leguminous cover crops is a promising strategy for sustainable soil management in rainfed olive orchards, as it can provide numerous ecosystem services such as nitrogen fixation, hosting beneficials and increasing water retention.

More information on other soil management practices is available in chapter SUBTOPIC 2 Improving resilience to climatic hazards: dry farming practices.

Conclusion

Innovative water stress management practices, such as deficit irrigation, and precision technologies, such as capacitance probes and remote sensing, significantly enhance water efficiency and crop resilience in Mediterranean and semi-arid regions. These strategies, exemplified in crops including pistachios, almonds, olives and avocados, optimise irrigation by targeting critical growth stages and leveraging advanced monitoring systems to reduce water use without compromising yield or quality. Integrating sustainable soil management, such as cover crops, further improves water retention, soil health and ecological balance, offering practical solutions for climate adaptation in dry farming systems.

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