Technical Article Nº 4

CLIMED-FRUIT

Improving vineyard resilience: innovative practices for water stress management

The Mediterranean region is known for its warm climate and limited water resources, making vineyards 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.

Regulated deficit and drip irrigation, combined with advanced technologies such as soil moisture sensors, and real-time monitoring systems improve precision in water application and optimise water use by targeting critical growth stages or alternating root zone hydration. Additional innovations, such as remote sensing and water harvesting, further bolster vineyard resilience. These methods reduce water use, improve grape quality, maintain economic viability and promote long-term sustainability in vineyard management.

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 large horizon, thus increasing the plants' dependence on irrigation

Drip irrigation

Drip irrigation is widely used in viticulture (grape cultivation) due to its precision and efficiency in water delivery, helping to optimise grape quality and yield grapevines. 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. Drip irrigation is widely known to increase water use efficiency by having 50% less water demand than furrow irrigation and reducing waterlogging. Aerial drip irrigation (Fig. 1) is an innovative technique with elevated drip lines above the ground, typically suspended along trellis systems or wires in agricultural settings. While less common than traditional ground-based drip irrigation, aerial systems have specific applications and benefits.

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

Subsurface irrigation

The French Operational Group (OG) OFIVO [2] examined the effect of aerial drip and subsurface drip irrigation in a vineyard using soil capacitive probes (wet bulbs, Fig. 2). The application of subsurface irrigation (40 cm depth) in the middle of the row generated larger wet bulb volumes (with vertical and lateral percolation of the water) than the aerial drip irrigation system (Fig. 3). In subsurface irrigation, water reaches the ground surface by capillarity without changing the vines' water status or the yields compared to aerial irrigation.

Fig. 2 Use of capacitive probe to study water behaviour in the soil – OG OFIVO

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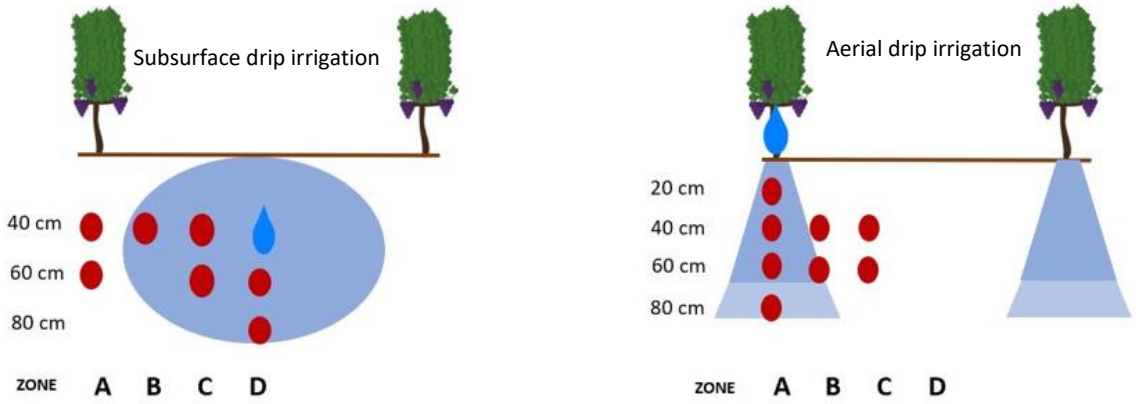

Fig. 3. Capacitive probe positioning in subsurface irrigation and aerial irrigation treatments [3]

Subsurface dripper irrigation facilitates mechanical weeding/weed management and improves root expansion between rows. The main benefit of this irrigation system in the Mediterranean area is water use efficiency, facilitating the establishment of vegetal cover and maintaining viticulture in dry areas. Subsurface drippers improve durability by protecting pipes from pests and machinery damage, enabling more reliable irrigation over time. They facilitate easier mechanical weeding and weed management by eliminating obstructions on the soil surface. Additionally, delivering water directly below the ground encourages better expansion of the vine's root volume between rows, promoting healthier and more robust plant growth. Moreover, the full fertigation strategy was applied, which showed the best ratio between yield and maturity. It significantly reduced inputs (30% fewer fertilisers). However, this system is more expensive to install than an aerial drip system (+20%) and unsuitable for stony soils. Proper filtration and regular network maintenance are crucial for the efficiency and longevity of subsurface drip irrigation systems, as they prevent clogging and ensure consistent water delivery. Installing appropriate drippers is essential; flat drippers resist soil weight to prevent damage, while anti-siphon, anti-root intrusion and self-regulating features safeguard the system from blockages, root intrusion and uneven water distribution. The system's end-of-life must also be considered, and soil contamination with plastic residues must be avoided.

Smart irrigation systems

Wine vineyard

In Northern Italy, the OG VIRECLI [4] applied a precision irrigation system to maintain production and quality standards in grapes used to produce sparkling wine, even in the most challenging vintages. By optimising water use, they achieved higher production with superior quality characteristics compared to on-farm management and non-irrigated systems, despite severe drought. The results were particularly significant in vineyard plots with higher water requirements.

A thorough analysis of soil characteristics and their variability within the vineyard is needed for proper irrigation system design. This can be done using state-of-the-art

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technologies such as those based on acquiring electrical resistivity and strongly correlated with the main soil physicochemical parameters. The indications thus obtained make it possible to divide the vineyard into homogeneous zones, within which the hydrological properties are uniform. Vineyard zones with higher water retention capacity, shown in light blue on the map, require less irrigation water volume, while those where the plants have less vigour, in red on the map, require greater irrigation volumes. Each homogeneous zone is finally characterised through the soil data obtained from the survey that results in a vigour map (Fig. 4). Based on the information gathered, the pitch of the drippers varies within the vineyard to meet the water needs of the defined homogeneous management zones (Fig. 5). It is necessary to use a decision support system (DSS) to guide the irrigation (i.e., a DSS that considers soil water content and plant needs, together with meteorological forecast) to identify the best time to irrigate; the systems tested were Irriframe ANBI, based on a classical water balance, and Manna by Rivulis, integrated with satellite data. Both systems were appropriately calibrated with on-site measurements of the plant's actual water status.

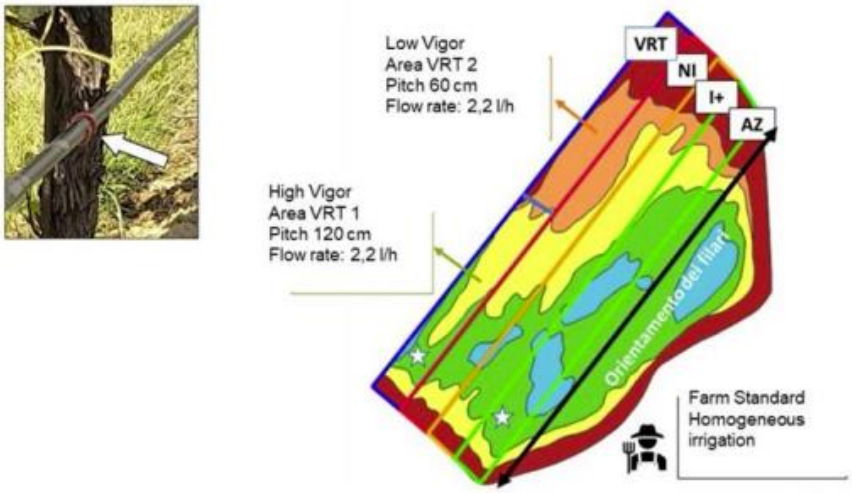

Fig 4. Example of distribution of different irrigation theses and characteristics of a variable rate irrigation system – OG VIRECLI

Fig. 5. Hydro clips applied to the drippers to close them and modulate the pitch and obtain a variable-rate drip system – OG VIRECLI

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In 2021 and 2022, years of severe drought, areas of low vigour produced 15% more grapes per plant with precision irrigation than areas in the same vineyard with similar vigour but irrigated with the standard drip system. Variable-flow irrigation management saved 15% water compared to the non-modular irrigation system while better responding to the needs of individual plants.

Table grape vineyard

The water consumption of a 2-ha table grape vineyard in the Apulia region (southern Italy) can range from 2,000 to 6,000 L per season, depending on the irrigation technique applied and the specific needs of variety, emphasising the importance of resource use efficiency. The OG OLTREBIO [5] implemented interconnected sensors at soil and crop levels on a farm (Fig. 6), which communicated with the decision support system (DSS) for water management in organic table grape vineyards to optimise resources. Water use is registered and managed on a seasonal basis with the help of IoT sensors at various levels (soil and crop) using locally obtained weather data (Fig. 7.). Data is gathered in Blueleaf® software. The DSS system, a key component, is tailored to the table grape vineyard and plays a crucial role in managing water use during critical periods of water scarcity. The benefit for DSS users is the efficient use of water resources, saving water by approximately 30% to 40% depending on the seasonal trends and the grower's work time, without compromising crop production or fruit quality.

Fig. 6. Sensors at soil and crop levels – OG OLTREBIO

Fig. 7. Communication method between the hardware and software – OG OLTREBIO

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Conclusion

Over the past 20 years, rising temperatures have increased evapotranspiration, leading to significant water stress in vines. Precision irrigation offers a sustainable long-term solution for optimising water use. When water is available, this approach ensures consistent grape production and high-quality wine, even in challenging years, by efficiently managing water resources.

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