CLIMED-FRUIT

Adaptation to climate change and mitigation for perennial crops in Mediterranean Area

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Deliverable D4.6_Production of 10 didactic technical sheets for farming students and vocational training

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Nature of the deliverable		
R	Document, report (excluding the periodic and final reports	x
DEM	Demonstrator, pilot, prototype, plan designs,	
DEC	Websites, patents filing, press & media actions, videos, etc.	
OTHER	Software, technical diagram, etc.	

Dissemination Level		
PU	Public, fully open, e.g., web	x
SEN	Sensitive, limited under the conditions of the Grant Agreement	
CO	Confidential, restricted under conditions set our in Model Grant Agreement	
CI	Classified, information as referred to in Commission Decision 2001/844/EC	

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More information on the project can be found at project website.

Project summary

CLIMED-FRUIT aims to share knowledge ready for practice, collected from different Operational Groups (OG) across Europe, for a better adaptation to climate change and mitigation, in perennial crops in the Mediterranean Area (grape vine, olive, fruits). The project builds on the results of a core group of 9 OG coordinated by a multi-actor consortium members (advisors, farmer organisations, research and education institutes, standardisation organisation), covering several Mediterranean crops in 7 different countries (France, Spain, Portugal, Greece, Italy, Croatia, Serbia). Best practices collected and shared range from (i) soil conservation and carbon storage, (ii) improving resilience of crops facing climatic hazards (frost, hail), (iii) innovative practices for adapting water stress management, (iv) adaption of food chain processes to climate change and diversification, and (v) preserving biodiversity for a better resilience to climate change issues and pests. These groups will share their experience through a combination of innovative digital formats, cross-visits and interactive local dissemination events. In addition, new knowledge and practices will be gathered more widely by organising an open contest. Participants from other European projects, other EIP OGs or even international projects from the Mediterranean area will be invited to propose abstracts. The most applicable solutions will be selected and pitched in a broad online conference. Participants will be invited to rank the best presentations according to cost/benefit ratio, which will then be widely disseminated and shared. Social media channels, videos, podcasts, crowd writing contests will be used to spread the knowledge. Specific editorial partnerships will be established with most popular technical reviews. The network will host a forum to capitalise on existing OG experiences and aims to foster new OGs to spread and explore new practical knowledge in relation to adaptation to climate change.

Objective and executive summary

Deliverable 4.6 is the product of the activities done in task 4.5, whose text in GA is here entirely reported:

Task 4.5. Production of material for students and farmer vocational training *(Task Leader: IFV, Participants: all partners): A set of 10 didactic practical sheets will be very explanative and aim to be used by students and vocational training for professionals. They will include links to digital material (videos, interviews) produced during the project. IFV and CIHEAM-IAMB will submit and coordinate these sheets.*

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1. Implementation of the Didactical sheets – Methodology

The development of the didactical sheets aimed to address concrete needs identified within the sector, with the objective of producing concise, practical tools to be disseminated directly in the field. Their content was designed to synthesize key operational knowledge in a clear and accessible format. The selection of practices presented in the sheets was guided by the subtopic review and further refined through consultation with project partners, ensuring alignment with their respective training priorities and maintaining a strong connection to the realities faced by farmers.

To enhance clarity and user engagement, a question-and-answer format was adopted. This approach was chosen to make the sheets more dynamic, readable, and suited to diverse audiences, particularly practitioners. An example of the layout used for these sheets is provided in **Annex 1**.

The topics covered and the partners responsible for drafting each sheet are detailed below:

Partner	Crop	Training provided	Needs for documents/didactical sheet
IFV / VIN	Vine	Emerging pests	Emerging pests in Mediterranean perennial crops
IFV / VIN	Vine	Carbon footprint	Reducing the carbon footprint of winegrowing
IFV / VIN	Vine	Cover crops and green manure	Soil cover management in Mediterranean viticulture
IFV / VIN	Vine	Sol and fertilisation	Set of indicators to diagnose soil quality
IFV / VIN	Vine	Farming systems	Agroforestry in viticulture
APPITAD / HMU	Olive	Organic farming	Boosting biodiversity in olive orchards: the benefits of organic farming and green infrastructure
APPITAD / HMU	Olive /almonds / vine	Workshops on prunning	Pruning and climate-smart residue management in olive orchards
CIHEAM Bari / AVA-ASAJA	Citrus	Emerging pests	Huanglongbing (HLB) in the Mediterranean Citrus-Growing Region
CIHEAM Bari	Grapes/cherries	Organic farming	The Power of Compost and Compost Tea in Sustainable Organic Vineyards and Cherry Orchards Farming
AVA ASAJA	Citrus	Managing pest	Invasive pests in citrus crops

2. Didactical sheets

Agroforestry in viticulture

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Agroforestry encompasses all farming practices that combine trees (in various forms such as hedgerows, rows, groves, etc.) with crops and/or livestock on the same plot. It is based on the complementarity between plants to promote a natural and functional balance within the farming system, through species diversification, staggered cropping, and maximizing interactions between different ecosystem compartments (soil, plants, animals, atmosphere)[1] . According to the international definition proposed by the World Agroforestry Center – ICRAF, agroforestry refers to the interaction between agriculture and trees, including their agricultural use: trees in fields, on farms, or within agricultural landscapes, as well as farming in forests and at forest margins. It also includes tree-based cropping systems such as cocoa, coffee, rubber, and oil palm. These interactions occur at various scales (field, farm, landscape) and contribute to ecosystem service provision"[2]. The tree-vine association is a long-standing marriage: the first references to a "shrubby" vine date back to the Ancient Greeks who pass it to the Etruscans to become a fully established systems within the Roman timesToday, the wild vine Vitis vinifera sylvestris still bears witness to this, relying on the tree for its growth. Besides, few historical remains of cultivated grapes "married" with maples or other trees are visible in the Mediterranean region.

What place for agroforestry in the CAP?

After the Second World War, agriculture intensified under the impetus of the CAP, to the detriment of trees, which were seen as a nuisance. But over the last twenty years or so, agroforestry has been gradually gaining recognition in agricultural policies. There have been several key milestones in this development: recognition of the agricultural status of agroforestry plots (2006), more flexible rules of tree density and installation aid (2010), regulatory adjustments (2015), and new aid under the 2023-2027 CAP (eco-regime, MAEC, "hedge bonus"). Today, agroforestry is fully integrated into public policy, thanks in particular to the advocacy work of players such as EURAF. The "Hedge Pact" (2023-2027) further strengthens this support by financing planting and maintenance.

Why to consider an agroforestry system for winegrowing?

Interesting interactions can be observed between trees and vines, impacting both the soil and climate conditions in the plot and certain agronomic parameters (including biodiversity balance and prevention of pests and diseases). Indeed, the presence of trees and hedges on the plot can be useful for: impacting the plot's microclimate (modifying air and energy flows), developing the plot's biodiversity, improving soil structure and 'buffering' CO_2 emissions on the plot.

[1] Agroforestry definition, French Agroforestry Association.
[2] What is agroforestry? The Center for International Forestry Research and World Agroforestry (CIFOR-ICRAF).

What influence on the plot's microclimate?

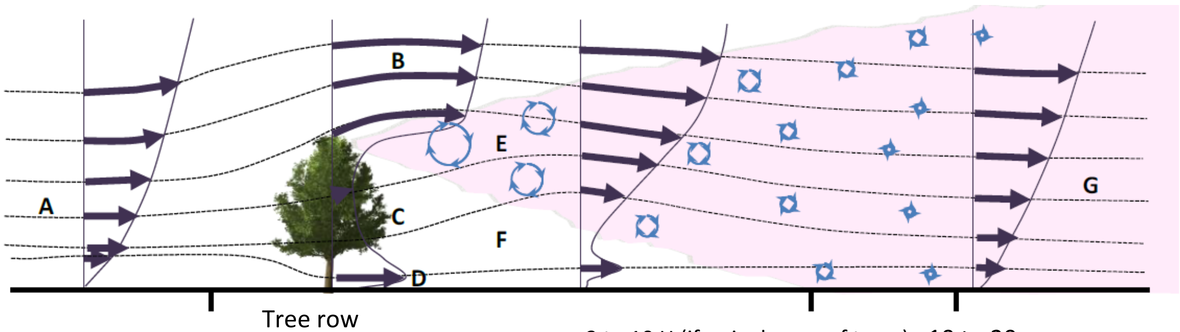
Controlling the microclimate in the vineyard is an essential factor in producing quality grapes. Its presence affects the amount of available radiation (solar and infrared) and turbulent energy. The coupling of radiative and turbulent flows controls air temperature and humidity, which depend on the way in which the system dissipates this energy. This energy is divided between sensible heat flux (which heats the atmosphere), latent heat flux (through evapotranspiration) and air/ground conduction flux (which heats or cools the ground)

Work carried out in France as part of the VITIFOREST project[3] and Juliette Grimaldi's thesis[4] has shown that:

- In terms of light capture, this is less important in the rows of vines located to the north of the trees, reducing the potential for photosynthesis, attenuating the deleterious effects of heat peaks but greatly increasing the duration leaf wetting. Conversely, there is a surplus of energy, and therefore heat, on the vine's rows located south of the trees, increasing production potential but exposing the grapes to the risk of scald. Finally, the trees produce infrared radiation which increases the temperature at ground level, helping to limit the impact of late spring frosts.

- As far as interactions on the water cycle are concerned, trees can modify the presence of water or humidity in their immediate environment: they recycle deep resources and increase the relative humidity of the air by a few percent, making it possible to moderate heat peaks by encouraging the opening of stomata and the extension of evapotranspiratory flows. Trees are excellent water traps, capable of condensing the moisture contained in the air in the form of dew, but also of intercepting rainwater up to a depth of 3-5 mm.

- Turbulence fields in the plot are modified by the presence of trees. Isolated intra-plot trees increase these turbulent flows, attenuating temperature peaks and reducing the duration of leaf wetting. On the other hand, when trees are located at the edge of a plot, particularly in a low topographical position, the circulation of cold air can be slowed. This can increase the risk frost, especially in low-lying areas.



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[3] Emilie Bourgade, Adeline Alonso Ugaglia, Vincent Bustillo, Thierry Dufourcq, Juliette Grimaldi, et al. VITIFOREST: Evaluation of the impact of agroforestry trees in a winegrowing context. Innovations Agronomiques, 2020, 79, pp.471-497. 10.15454/73ry-yq72.

[4] Juliette Grimaldi. Impacts of agroforestry on microclimate for grape and wine production: assessment in Southern France. Life Sciences [q-bio]. Université Toulouse III Paul Sabatier (UT3 Paul Sabatier), 2018. English. ⟨NNT : ⟩.

A: Wind profile upstream of the windbreak
B: Acceleration above the canopy
C: Slowing of air passing through the canopy
D: Acceleration below the canopy
E: turbulent zone
F: Sheltered area
G: Profile restored
H: Height of the tree

Figure 1: Schematic representation of turbulent air flows around a lone tree (source: Grimaldi, 2018).

What influence does this have on soil structure and carbon storage?

By improving microbiological activity, increasing organic matter and providing numerous roots, trees have an impact on soil structure. It increases porosity and limits erosion

About carbon, a distinction must be made between the carbon fixation function (photosynthesis) and the carbon storage function (creation of a carbon stock over time). The tree's large biomass and long life mean that it can fix a large quantity of carbon compared with most other plants in the agro-ecosystem. The carbon is then returned to the soil through its leaves, wood and roots. Soil decomposers transform them into OM, improving fertility and fixing CO2 in the soil. Here is an example of the storage capacity of different types of sustainably managed hedgerows (planted in south-west France) in tonnes of CO2 equivalent stored per km of hedgerow per year:

Table 1: Carbon storage in the above-ground and root biomass of a sustainably managed hedgerow by type in western France (in teqCO2/km/year). Above-ground biomass is divided into biomass remaining on site and biomass used for wood energy. (Source: values from the Carbocage project, hedgerow illustrations from Arbre et Paysage 32 https://ap32.fr/arbres-paysages/)

In teqCO2/km/year	**Multi-purpose hedge** 	**Coppice hedge** 	**High hedge** 	**Shrub hedge** 
Total biomass	5.90	8.90	9.98	1.80
Root biomass	1.8	3.2	2.7	0.4
Above-ground biomass remaining on site	1.89	0	4.85	1.4
Above-ground biomass exploited *(optional if exploited)*	4.41	11.40	4.85	0

What influence does this have on the biodiversity of the plot?

In the short and medium term, the introduction of trees around the perimeter of a plot of land or within a plot of land creates a diversity of landscapes and a variability of vegetation strata, and therefore new ecological niches. Trees and all their components (branches, leaves, flowers, fruit, cracks in the trunk, roots) offer a 'mix' habitats, refuges, food resources, hunting, breeding and wintering areas for a wide variety of species. Within this overall diversity, organisms that are useful to the wine grower can also benefit from these resources, such as mites, lacewings, certain carabid beetles, parasitoids,

Soil biodiversity is also affected. The combination of vines and trees promotes the mycorrhizal network, which plays an important role in the exchange of water and nutrients. Soil earthworms also have a positive impact, as shown in the VITIFOREST project, where a significant impact of the presence of trees on the distribution of earthworms was demonstrated, with a gradient of decreasing frequency observed as the distance from the tree zone increased. The presence of trees on wine-growing plots also has an impact on microbial communities, in particular by providing additional nutrient resources to soil micro-organisms via the rhizosphere and tree litter.

Introducing trees into vineyards should not be considered in isolation, but as part of an overall strategy combining biodiversity-friendly features (such as hedges or late mowing) and reduced inputs, to ensure effective ecological continuity.

What are the main points to bear in mind?

- **Water-nitrogen competition**

The potential competition between trees and vines is a real constraint that needs to be taken into account. In certain experimental plots in a Mediterranean context in the south of France, the rows of vines closest to the trees showed a drop in yield of 9 to 31% compared with the rows distant from the trees. Differences in nitrogen nutrition were also observed, with levels up to 20% lower near the trees[5]. These results need to be interpreted and understood according to site specific soil and climate. In fact, on plots located in south-west France, nine years of co-planting in different arrangements revealed no difference in behaviour, either in terms of biomass production or grape quality, between vines planted in the immediate vicinity of trees (adjacent row) and those located in the heart of the plot, more than two rows apart[2]. It would be useful to repeat this monitoring when the system approaches 20 years of co-cultivation with mature trees that have developed significantly.

Whatever the case, there are various ways of preventing potential competition between trees and vines in agroforestry:

- tree management: Pruning the canopy (in winter or when it is green) reduces shade and water consumption.
- root circling, carried out every 3 years, limits the spread of roots towards the vine. It may also be possible to use a pollard system.
- sowing leguminous cover crops between the rows improves fertility and limits leaching while fixing atmospheric nitrogen.
- localised fertilisation (ground or foliar) and targeted irrigation help to offset the effects of competition, particularly for rows close to trees.

- **Root Rot**

Particular vigilance is required when it comes to root rot disease. A large number of woody species can harbour the fungi responsible for this parasitism (including *Armillaria mellea*, responsible for "agaric root rot"), and the introduction of trees into wine-growing plots runs a significant risk of the disease developing over time. Oaks, peach trees and many other forest and fruit species are particularly susceptible. Root rot develops slowly but persists in the soil, causing recurrent outbreaks of symptoms and mortality in the same place, despite periods of fallow. There is no curative treatment available, and agroforestry may encourage its development. A few prophylactic measures to bear in mind:

- thoroughly clean the plot when planting (debris, old roots).
- leave the soil to rest for 4-5 years if replanting after uprooting.

[5] Juliette Cassagne, Agroforesterie - Les impacts sur la vigne en termes de concurrence, Vitisphère, 2014

- ➢ encourage a living, well-structured, well-drained soil.
- ➢ limit root exchanges between the vine and nearby trees by trying to maintain a minimum distance of at least 3m (empirical recommendation, no proof that this distance will prevent contamination between the trees and the vine).

- **Technical constraints linked to the development of the plot**

Finally, the last point to watch concerns the layout of the agroforestry plot: a number of points need to be taken into account to ensure the success of the project, such as the objectives and scale of the project, the orientation of the plot, mechanisation (particularly the number of rows covered in the case of intra-plot trees), game animals problems, soil condition, etc. In addition, as mentioned above, the presence of trees and hedges influences the microclimate of the plot, and the correct modelling of hedges plays a vital role in ensuring that they do not increase the risk of frost damage (an impermeable hedge at the bottom of a slope does not allow cold air to be evacuated) or dampness (conducive to fungal diseases) but, on the contrary, facilitates air circulation and improve overall vineyard health.

What are the prerequisites for setting up an agroforestry plot?

- **Architecture of agroforestry in vineyard**

There are four types of agroforestry development possible in vineyards:

- ✓ an island of trees in the plot. This is a multi-species grove, preferably multi-strata.
- ✓ intra-parcel trees, in the row of single or multi-species vines;
- ✓ rows of trees (single- or multi-species) in place of one or more rows of vines;
- ✓ hedges at the border of a plot or to divide a plot into several parts.

The final choice depends on production constraints and the winegrower's expectations: is the primary objective to limit the effect of side winds or the drift of phytosanitary products? Or to create resources and habitats for biodiversity? Is the development taking place on an existing plot or one undergoing restructuring?

Twenty years after the first trials carried out in a Mediterranean context in the south of France and following the VITIFOREST project, here are some recommendations to be followed wherever possible:

- ✓ favour north-south orientations to limit and balance the shading of the trees on the vines;
- ✓ leave a minimum distance of 3 metres between the line of trees and the first row of vines, ideally 4 metres;
- ✓ try to aim for a distance of 25 to 30 m between each line trees;
- ✓ the distances between the trees on the line will depend on the target density;
- ✓ define tree density according to local resources and vineyard needs and status. For low density consider about 50 stems/ha, while maximum density could be considered 150 stems/ha;
- ✓ Consider the space needed for mechanical means and tools to move inside and around the vineyard.

- **Choice of species**

Integrating trees into winegrowing requires a site-specific selection of species to ensure the agronomic and ecological coherence of the system. It is essential to choose hardy species adapted to local soil and climate conditions and to take account of the heterogeneity of the plot (soil, humidity, exposure).

Diversity, both in terms of species and genetics, must be sought to strengthen resilience and limit health risks. Depending on the winegrower's objectives, species can be chosen for their production (wood, fruit, flowering), their ecological role (shade, auxiliary biodiversity), or their compatibility with the vine (light foliage, low light competition). When dealing with vineyards, it is worth noting that oaks and pines are very competitive for water and nutrients, and many fruit trees are particularly susceptible to rot. The field maple is an example of a suitable candidate for vines, as it is not very competitive and is not very susceptible to root rot.

Plant material must be certified for health and genetics. The use of young plants is to be preferred to encourage good recovery. A suitable option if planting fruit trees is to plant the rootstock and 2 years later to draft it on site. It allows a better and deeper rooting.

- **Preparing for planting**

Good soil preparation is essential to ensure optimum rooting and development of the young trees that will be planted. Subsoiling, followed by surface refinement, is best carried out in autumn before the trees are planted in winter or early spring. To limit herbaceous competition and conserve soil moisture, a mulch will be laid over an area of $1m^2$ around the young trees. This can be done with straw, chopped wood or biodegradable film. Depending on the area, it may be useful to protect the plants from game animals with shields

- **Tree management**

Tree training, from the first 5 to 8 years, is essential to ensure their proper development. For isolated trees, trunk clearance of at least 2m is recommended, particularly for timber production. Hedges, on the other hand, should be kept horizontally to avoid encroaching on the inter-row space, and can be maintained at the same time as the vines. Depending on the species, shading can be modulated by pruning, particularly pollarding, which limits the leaf area and encourages the creation of cavities, useful as habitats for wildlife.

How much does an agroforestry project cost?

According to the costs listed for 2023 in France by the Réseau Haies France - AFAC Agroforesteries[6] , a one-row hedge planted every metre would cost an average of €18.27 per linear metre, while a two-row hedge planted every 1.5 metres would cost an average of €28.91 per linear metre. You should allow 20 to 40 hours' work for 100 metres of hedge over the first 5 years.[7]

The cost of planting a single tree within a plot would be €27.96 per plant. On average, 25 to 30 hours of work are needed to plant 100 trees[6].

[6] Références coût de plantation agroforestière établies par l'Afac-Agroforesteries, Avril 2023
[7]https://www.vinipole-sud-bourgogne.fr/uploads/mce/docs/Guide agroforesterie en viticulture VITAF.pdf Guide technique de l'agroforesterie en viticulture en bourgogne Franche-Comté, projet VITAF, Décembre 2022

TO FIND OUT MORE

- ✓ Institut Français de la Vigne et du Vin - Agroforestry and viticulture - Itinéraires n°28 - 2018, Available at: https://www.vignevin.com/wp-content/uploads/2019/03/1811_ESOPE_IFV_Brochure_Agroforesterie_web100_DPI_VF-1.pdf
- ✓ Juliette Grimaldi. Impacts of agroforestry on microclimate for grape and wine production: assessment in Southern France. Life Sciences [q-bio]. Université Toulouse III Paul Sabatier (UT3 Paul Sabatier), 2018. English. ⟨NNT : ⟩. ⟨tel-03515990⟩, Available at : https://theses.hal.science/tel-03515990
- ✓ Delinat Consulting and Domaine Emile Grelier - Agroforestry in viticulture, a step forward towards resilience - 2022, Available at: https://www.agroforesterie.fr/wp-content/uploads/2022/09/fr-agroforesterie-en-viticulture-print.pdf
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- ✓ Guide technique de l'agroforesterie en viticulture en Bourgogne Franche-Comté, VITAF-2022 project, Available at: https://www.vinipole-sud-bourgogne.fr/uploads/mce/docs/Guide%20agroforesterie%20en%20viticulture%20VITAF.pdf

Boosting biodiversity in olive orchards: the benefits of organic farming and green infrastructure

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Intensive management of agricultural lands along with intensification of production of farming systems and monocultures, combined with climate change have degraded agroecosystems' functionality and impacted food quality and quantity (Cramer et al., 2018). The establishment of Green Infrastructures (GI) or Ecological Infrastructure in olive orchards and other perennial crops, has been suggested as a promising strategy to improve orchards biodiversity and functionality by enhancing the provision of agroecosystem services to achieve sustainability in food production (Kabourakis, 1999; MAES et al., 2018). Organic farming plays a key role in protecting the environment by promoting biodiversity and supporting green infrastructures.

1 What is organic farming and how does it support biodiversity?

Unlike conventional management, organic farming prohibits the use of synthetic chemicals and promotes the application of farming methods that sustain agroecosystems, by conserving/protecting agroecosystems' biodiversity and enhancing biodiversity-related biological processes and agroecosystem services. By providing habitats and subsequently fostering a variety of plants, animals, and microorganisms, organic farms create balanced habitats that enhance biodiversity and soil health, leading to pest control and increased pollination. GI (including hedgerows, stone and water refugia, and cover crops) further support biodiversity while managing water and soil resources. Together, these practices build resilient farming systems that not only produce high-quality food but also contribute to the mitigation of climate change negative effects, providing adaptation of crops to and long-term sustainability. Organic farms often have more diverse plant species, which attract a variety of insects, birds, and other wildlife (Solomou and Sfougaris, 2021). The absence of harmful synthetic chemicals also means fewer threats to beneficials organisms, such as soil microbial flora and fauna, pollinators and predators and parasitoids of the pests of the olive trees. Examples of increased biodiversity may be multiple crop varieties (not just monocultures), pollinators like bees and butterflies, predators, parasitosis and decomposers like ladybugs (natural pest control) or ants, birds and small mammals in hedgerows and grassy strips.

2 Why does biodiversity matter in farming, and how can it be enhanced?

Greater biodiversity makes olive orchards more resilient to pests, diseases, and climate change. It reduces the need for synthetic chemical inputs and helps maintain long-term productivity and agroecosystem health. Farming practices that enhance biodiversity include the use of:

- crop rotations,
- mixed cropping and intercropping,
- Native vegetation biotopes, hedgerows, spontaneous flora field margins and flowering plants strips,
- minimum tillage,
- proper tree canopy and pruning residues management,
- optimum irrigation and plant protection management,
- ecological nutrient and fertiliser management.

3 Which is the functional biodiversity in an olive orchard?

Functional biodiversity is the biodiversity that offers several benefits to humans and to the environment, including several flora and fauna species related to the provision of agroecosystem services. Examples of fauna species are arthropods of several taxa. Important examples are Hymenoptera species that are parasitoids (*Psytallia concolor*) or predators (Ants and lacewings) of the olive fruit fly (*Bactrocera oleae*), the main pest of olive trees in the Mediterranean area (Figure 1). Other arthropods such as coleoptera (beetles) also serve several important biological processes such as predation and decomposition. Butterflies (Lepidoptera) serve the important service of pollination. Other fauna species such as birds, reptiles and mammals can be important regulators of agroecosystem functions as well as facilitators of biological pests and disease control by predating on several enemies of the olive tree. Examples of mammals that have been found in the LIFE IGIC project are several species of shrews, badger, and hedgehog. Several species of legumes (Family: Fabaceae) grow native in olive orchards of the project. Those can significantly improve soil fertility. In addition, plant species, attracting large numbers of pollinator species (Families: Apiaceae, Asteraceae) and species related to improvement of soil structure (Families: Poaceae, Fabaceae). Moreover, species related to food provision (edible species) are important for agroecosystem services provision.

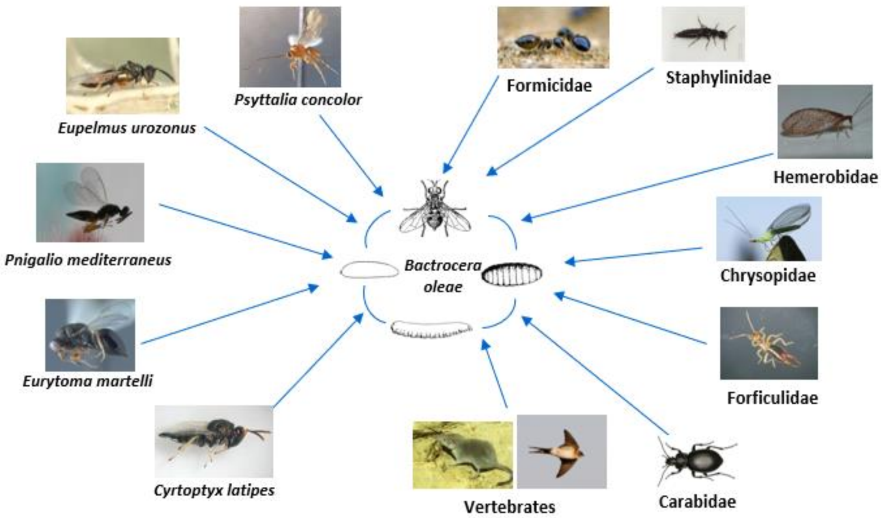

Figure 1. Predators and parasitoids of the olive fruit fly supported by green infrastructure (source LOVAPS lab – HMU).

4 How do green infrastructures support functional biodiversity in agricultural systems?

Green Infrastructures (GI) are defined as “a strategically planned network of natural and semi-natural areas, with other environmental features, designed and managed to deliver a wide range of ecosystem services” (European Commission, 2013). In agricultural systems, particularly in olive orchards, GI include elements such as hedgerows, ponds, stone and brush refuges, cover crops, agroforestry, and buffer strips. These components help manage water, soil, and biodiversity (Figure 2, Figure 3), while supporting sustainable production.

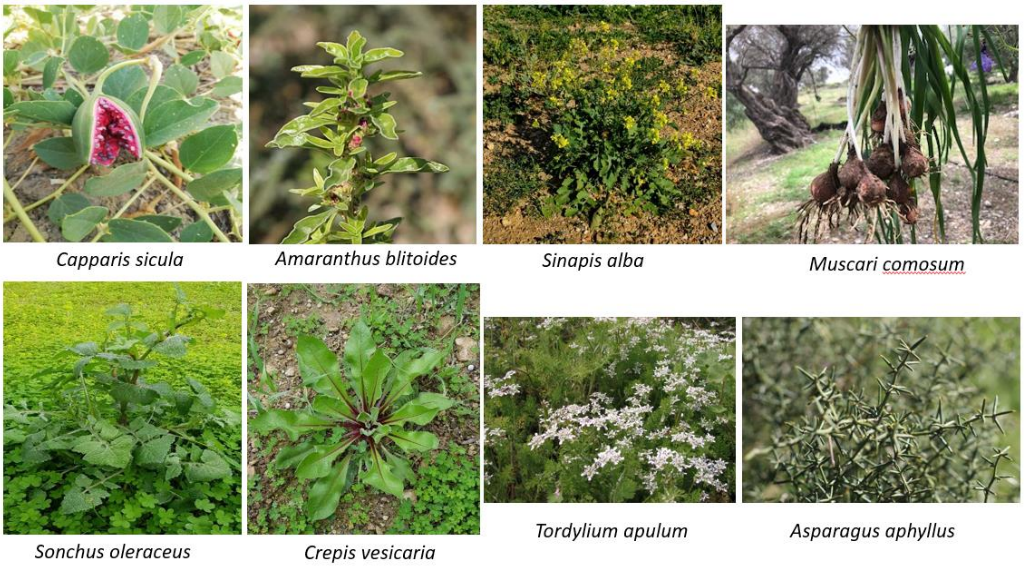

Figure 2. Edible flora of olive orchards (photo LOVAPS lab – HMU)

Figure 3. Fauna diversity supported by green infrastructure in olive orchards (photo LOVAPS lab – HMU)

By enhancing functional biodiversity, GI improve several agroecosystem services. They reduce erosion and runoff, improve soil fertility and structure, support pollination, and promote natural pest control. Planting aromatic, medicinal, and fruiting shrubs and trees provides food and shelter for beneficial insects, birds, reptiles, and small mammals, many of which contribute to pest regulation, including predators of the olive fruit fly (*Bactrocera oleae*).

GI also enhance belowground biodiversity, including soil invertebrates and microorganisms that drive key processes such as assimilation, nitrification, and decomposition, essential for tree nutrition and long-term soil health. These improvements contribute to greater resilience to climate change and environmental stress.

Beyond ecological functions, GI support the production of high-quality olives and additional resources such as wild herbs and contribute to rural development through landscape enhancement and agrotourism. When integrated with sustainable practices, they represent a multifunctional strategy to improve the environmental and economic sustainability of Mediterranean olive farming.

5 Which green infrastructures can be implemented in perennial crops, and what are their main impacts?

As mentioned above, GI in agroecosystems can take the form of plantations of perennials, medicinal, aromatics and fruit-bearing shrubs and trees, brush piles (wooden branches), stone elements, artificial water ponds (Figure 4).


Figure 4. Green infrastructure elements (photo E. Kabourakis, LOVAPS lab – HMU)

Among all these green infrastructures, some are particularly well suited to perennial crops:

- **Cover Crops**: they improve soil fertility, prevent erosion, suppress weeds, and they attract pollinators and beneficial insects. Examples may be legumes (e.g., clover, vetch), grasses (e.g., rye, barley) and wildflowers.
- **Hedgerows and Windbreaks**: they provide habitat for birds/insects, reduce wind erosion and act as buffers. Examples may be native shrubs, aromatic herbs (like rosemary), or nitrogen-fixing trees (like tree medick, carob or acacia).
- **Bioswales and Infiltration Trenches**: they capture runoff, increase groundwater recharge and reduce erosion. An example may be shallow vegetated ditches between rows or at field edges.
- **Pollinator Strips/Windflower Borders**: they support pollinators and beneficial insects. They should be placed along borders, paths or between rows or flat edges.
- **Agroforestry and Intercropping**: They have the purpose of diversity production and improve soil microclimate. Examples may be lavender or thyme (inter)planted in olive orchards
- **Insectary Habitats/Beetle Banks**: they encourage natural pest control agents like ladybugs, lacewings, and ground beetles, hymenopteran parasitoids. In practice, it can be grassy or herbaceous plant strips between fields or specially built shelters for bees, bats and other species.

- **Tree Islands or Scattered Native Trees**: they provide shade, promote biodiversity and wind protection. As a tip, drought-tolerant natives like cypress tree, holm oak or mediterranean pine should be used.

6 How to apply green infrastructure in olive orchards?

Technicalities regarding the establishment of GIs in olive orchards are suggested below. It is important to consider that the technicalities should be adjusted for each area and each olive orchard, as differences on climatic conditions and landscape morphology can impact the effectiveness of the established GIs. A DST support to evaluate green infrastructure in olive orchards, available on https://lovaps.hmu.gr/apps/green-report/index/ and a short demonstration video: https://www.youtube.com/watch?v=IvGDESfrsmI has been created in the content of LIFE IGIC project.

✓ **Regarding GI elements:**

- Suggested number: 100 - 400 aromatics/ha or 30 - 100 trees/ha or a combination of both, 5 brush piles/ha, (minimum 2/ha), 5 stone elements/ha (minimum 2/ha), 2 water ponds/ha (minimum 1/ha)
- Location & construction: Margins of the olive orchards to avoid hinderance of farming practices processes. Stone elements should be meshed to avoid elements destruction by human intervention. For the water ponds, close to irrigation system for easier refilling and cleaning of the pond. Preferably under the canopy of olive trees to avoid water evaporation.

✓ **Regarding sustainable farming practices:**

- Olive tree canopy management: Shredding and incorporation of pruning residues.
- Soil, spontaneous vegetation and field margins management: mowing and minimum tillage, use of green manures, soil covers and cover crops, uncultivated hedge strips of spontaneous flora and GI-plantations.
- Nutrient and fertiliser management: rational use and minimisation of synthetic chemical inputs. Use of organic fertilisers.
- Irrigation water management: efficient and economical irrigation methods according to the requirements of the olive trees and the soil.

Additional material

Green Infrastructure in olive orchards:
www.lifeigic.eu
https://www.youtube.com/watch?v=IvGDESfrsmI
https://www.facebook.com/lifeigic/
Decision Support Tool for assessing green infrastructure in olive orchards:
https://lovaps.hmu.gr/apps/green-report/index/

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Reducing the carbon footprint of winegrowing

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In 2021, the EU adopted its first European climate law as part of the European Green Deal. This law sets Europe's climate neutrality targets by 2050, as well as a target to reduce Greenhouse Gas (GHG) emissions by 55% by 2030, compared to 1990. In accordance with the Climate Act, the Commission also recommended, in February 2024, an additional intermediate target of reducing emissions by 90% by 2040, thus confirming the direction taken[8]. The aim of this strategic vision is to achieve an economy with net zero greenhouse gas emissions[9]. How can the wine sector become part of this carbon-neutral approach? What are the main levers in the technical itinerary for reducing the carbon footprint of vinegrowing? Discover some of the keys in this fact sheet.

What is carbon neutrality?

Carbon neutrality corresponds to a balance between anthropogenic GHG emissions and the sequestration (or storage) of biogenic CO2 (soil, biomass). Carbon neutrality is therefore based on offsetting emissions by sequestering carbon in soils and living biomass through photosynthesis. Sequestration mechanisms are diverse and can only be accounted for if they are long-term: storage in wood (hedges, tree plantations, etc.), storage in the soil via organic matter. However, it should be considered that any increase in the carbon stock in soils or biomass is reversible if practices are stopped, cancelling out the beneficial effect of the storage. Offsetting emissions by sequestration is therefore no substitute for reducing the emissions generated.

Launched at COP 21, the '4 by 1000' initiative is based on the principle that increasing the organic carbon content of soils by 0.4% each year would make it possible to offset global GHG emissions linked to human activities. The idea is to consider GHG emissions linked to human activity. Soil contains around 2,400 Gt of carbon, while annual emissions from human activity amount to 9.4 Gt. However, a collective INRAE study known as the '4 per thousand study'[10] showed that the potential for additional carbon storage in French agricultural soils is limited. Even with the widespread use of agricultural practices that favour carbon storage - assuming a constant climate, atmospheric CO2 concentration and land use - the gain would only be 29.9 Mt CO_2e/year, or 6.5% of national emissions in 2016, which corresponds to an accumulation rate of +1.8 ‰/year. This figure is still well below the global target of +4 ‰/year.

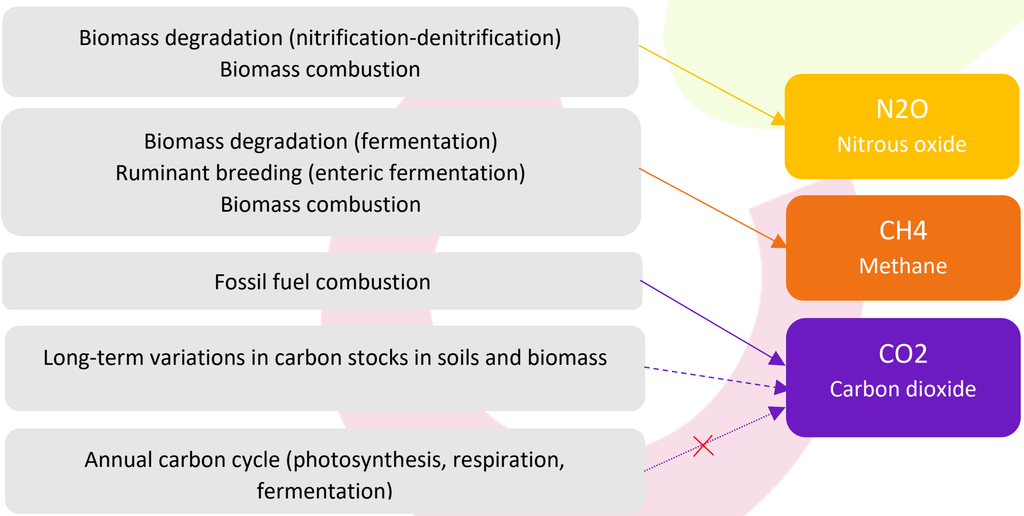
[8] European Commission website, 'The Green Deal for Europe: https://ec.europa.eu/stories/european-green-deal/
[9] Communication from the European Commission, 'A clean planet for all: A strategic long-term European vision for a prosperous, modern, competitive and climate-neutral economy' [COM(2018) 773 final].
[10] Pellerin, Bamière et al., Stocker du carbone dans les sols français, Quel potentiel au regard de l'objectif 4 pour 1000 et à quel coût ? Rapport scientifique de l'étude, INRA (France), 2020, 540 p.

In viticulture, while storing carbon in the soil is an interesting lever, it is not enough on its own. It therefore needs to be part of a wider strategy, combining storage and direct reduction of emissions (energy, inputs, transport, etc.).

What are the main greenhouse gases emitted by the wine industry?

The various greenhouse gases that we count do not all have the same effect on climate change. The warming power of gases depends on whether or not they absorb infrared radiation and on how long they remain in the atmosphere. These two factors are expressed by their 100-year Global Warming Potential (GWP). The 100-year GWP expresses the warming power of a gas emitted into the atmosphere over a period of 100 years. The GWP is constructed as a standard, with CO_2 taking the value of 1. The main greenhouse gases to be found in the viticulture carbon footprint are: carbon dioxide (CO_2) (GWP = 1), nitrogen dioxide (N_2O) (GWP = 273) and methane (CH_4) (GWP = 28).

This means that 1 kg of N_2O emitted into the atmosphere corresponds to 273 kg of CO_2 emitted. The same applies to methane: 1 kg of CH_4 corresponds to 28 kg of CO_2. This is why a carbon footprint is expressed in kg CO_2e[11] ('kg of CO_2 equivalent').



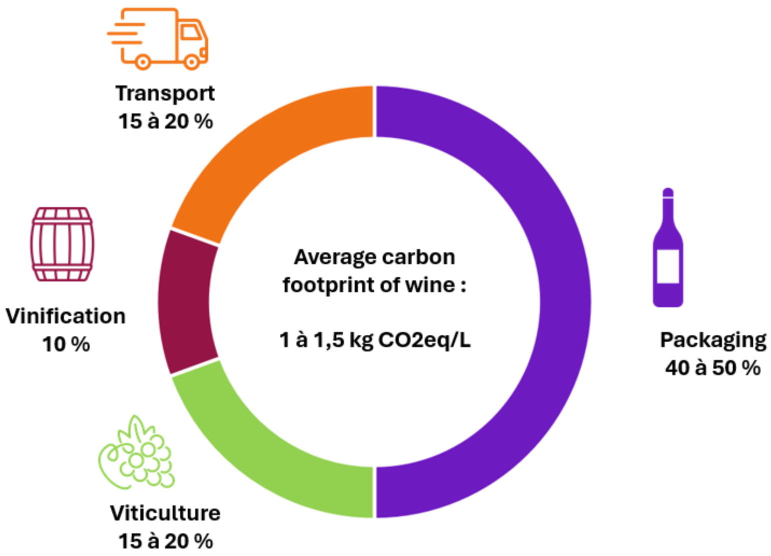
The main greenhouse gases produced by the wine industry and how they are emitted (Adoir et Luzi, 2024)
Solid arrow = emissions, dotted arrow = sequestration, crossed-out arrow = flows not considered in the carbon footprint (zero net balance).

What are the main sources of emissions in the wine sector?

Work carried out in France by the IFV shows that the footprint of the wine industry is structured as follows: packaging 40% to 50% of emissions, viticulture 15% to 20%, transport 15% to 20%, vinification around 10% (IFV, unpublished). Packaging includes indirect emissions linked to the manufacture of dry materials, in particular bottles, which represent the main source of emissions. The carbon footprint of the viticulture phase mainly includes fuel consumption and fertiliser production. As far as transport is concerned, only emissions linked to the use of fuel are taken into account. Finally, winemaking is mainly responsible for electricity consumption, the carbon footprint of which remains relatively low in France. It should be noted that, even if exports are included, the share of transport in the total carbon

[11] Emilie ADOIR, Hugo LUZI, L'empreinte carbone des entreprises du vin, Les Entretiens du Beaujolais et les Assises de l'Agroecologie en Beaujolais- Edition 2024. Le carbone, ça detonne !, 2024.

footprint remains relatively small. The order of magnitude of the carbon footprint of wine over its entire life cycle (from grape to shelf) is 1 kg to 1.5 kg CO2eq/L of wine.



Breakdown of the carbon footprint of wine by major stage in the life cycle (Adoir et Luzi, 2024)

A number of ways of reducing greenhouse gas emissions can be suggested post-harvest: changing the type of glass by avoiding clear glass, reducing the weight of the bottle by refining the glass, setting up deposit systems, using other containers such as aluminium cans or Bag-In-Boxes, transporting the wine in bulk, developing wineries with gravity systems, and so on.

What are the biggest sources of emission at viticulture level?

The order of magnitude of viticulture's carbon footprint is in the order of 1 to 3 tonnes of CO2e/ha/year, as mentioned earlier it represents 15 to 20% of the carbon footprint of the wine life cycle.

Using the GES&Vit tool, IFV has calculated the carbon footprint of a plot of vineyard in a high-yield production context. This calculation takes into account a technical itinerary involving mechanical pruning; high nitrogen inputs of around 80 kg of nitrogen per hectare per year (40 kg applied to the soil in organic form, 40 kg in mineral form applied fractionally by fertirrigation); plant cover on all the inter-rows, with alternating green manures and permanent grass cover; and the use of a decision-making tool for plant protection. In this context, here are the four main emission items identified:

- **fuel**, linked to the manufacture and combustion of the off-road diesel sed on the plot, accounts for around 30% of the plot's emissions. The use of the tractor is a significant item, particularly because of the energy required for the various tasks carried out (tilling the soil, pruning, shredding, etc.).

- **N_2O emissions in the field**, also around 30% of plot emissions: N_2O, known as nitrous oxide or dinitrogen monoxide, is released as a result of nitrogen inputs (nitrogen fertilisers, organic fertilisers and soil improvers, spreading of animal waste, etc.) and through the management of plant cover, such as mowing or termination, which activate nitrification-denitrification reactions. Nitrous oxide is one of the main greenhouse gases produced by agriculture. This is a major source of emissions for vineyards, where yields are high, due to the high level of fertilisation and the regular management of plant cover through plowing.

- **the manufacture of fertilisers/soil improvers** accounts for around 10% of emissions from the plot: like N_2O emissions, this item is even more important for high-yield vines, as is the case in this example.

- **setting up the plot** also accounts for around 10% of emissions from the plot itself, this involves planting and trellising and is amortised over the life of the plot[12].

How to reduce emissions in winegrowing?

For a plot of land that has already been planted, there are a number of relatively simple levers that can be implemented to reduce emissions or increase carbon storage in the short term.

- ✓ **Nitrogen fertilisation** is a particularly interesting area to explore. By reducing mineral nitrogen inputs, we reduce both indirect emissions linked to the manufacture of fertilisers and direct emissions of nitrous oxide. Each unit of mineral nitrogen not used saves around 12 kg CO_2e[13]. Replacing mineral nitrogen with organic nitrogen has the advantage of reducing direct emissions and increasing the carbon stock in the soil, although emissions are also associated with organic fertilisers production. For example, the composting process of some organic fertilisers can generate significant methane and nitrous oxide emissions, which can reduce the expected benefits.

- ✓ **Fuel consumption** is also a significant item, accounting for around a quarter of emissions. Every litre of off-road diesel saved reduces the carbon footprint by 3.14 kg CO_2e[6]. There are a number of ways of optimising this consumption: reducing the number of passes, combining operations, choosing suitable tools and tractors, eco-driving, better organisation of work sites, or bringing equipment closer to the plots. The introduction of measurement protocols also makes it possible to target the most energy-intensive work. Viable alternatives to diesel, such as electricity and, in the longer term, hydrogen and animal traction, are being developed, but full studies of their overall environmental impact are still needed. Electric tractors for some works in the vineyard are already available and particularly cheap when the energy is produced on farm, for example with photovoltaic panels of the cellar roof.

- ✓ **The choice of trellising materials** also has a significant impact: using wooden stakes instead of metal ones saves an average of 100 kg CO_2e/ha/year[6].

- ✓ **Grass cover**, when it replaces mechanical or chemical weeding, may temporarily increase emissions because of the increase in fuel consumption, but in the medium term it allows better carbon sequestration in the soil. A recent study showed that inter-row permanent cover with grass resulted in a net reduction of 300 kg CO_2e/ha/year[6] compared with mechanical weeding.

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[12] Camille Guilbert, Clara Gérardin et Hugo Luzi, Réduction de l'empreinte carbone d'un Vignoble Innovant Ecoresponsable. Scénarii et leviers évalués avec l'outil GES&Vit, 2023

[13] Emilie ADOIR, Hugo LUZI, L'empreinte carbone des entreprises du vin, Les Entretiens du Beaujolais et les Assises de l'Agroecologie en Beaujolais- Edition 2024. Le carbone, ça detonne !, 2024.

- ✓ **Returning vine prunings to the soil**, rather than burning them, is another relevant lever. Despite the need for an extra tractor pass, this practice results in carbon storage that more than offsets the emissions caused, with an estimated environmental gain of around 400 kg CO_2e/ha/year[6], while also reducing fine particle emissions.

- ✓ **Planting hedges:** hedges are one of the most effective ways of storing carbon in the biomass of the hedge, as well as in the soil, which they enrich with organic matter. It is generally difficult to plant a hedgerow because of a lack of space once the vines are in place. One solution is to target small shrub hedges around the edges of the plot. For example, by planting 90 linear metres of hedges per hectare, this would make it possible to store around 200 kg CO2e/ha/year (smoothed over 25 years)[14], i.e. almost 10% of the emissions from the plot in our case study of high-yield vines. It should be remembered, however, that this storage is reversible if the vines are grubbed up.

Viticulture therefore has a wide range of options for reducing its carbon footprint. These must be chosen on the basis of their environmental effectiveness, as well as their agronomic, economic and social feasibility.

[14] Storage values calculated on the basis of « Label Bas Carbone » figures – méthode haies and ADEME Carbocage project.

TO FIND OUT MORE

- Pellerin, Bamière et al., Stocker du carbone dans les sols français, Quel potentiel au regard de l'objectif 4 pour 1000 et à quel coût ? Rapport scientifique de l'étude, INRA (France), 2020, 540 p.: https://www.inrae.fr/sites/default/files/pdf/Rapport%20Etude%204p1000.pdf
- GES&VIT, a tool for GES emissions estimation and reduction in viticulture (video): https://www.youtube.com/watch?v=qbH_yIY_uGM&ab_channel=CLIMED-FRUIT
- Emilie ADOIR, Hugo LUZI, L'empreinte carbone des entreprises du vin, Les Entretiens du Beaujolais et les Assises de l'Agroecologie en Beaujolais- Edition 2024. Le carbone, ça detonne !, 2024 : https://www.vignevin.com/wp-content/uploads/2024/05/Le-Carbone-ca-detone.-Entretiens-du-Beaujolais-et-Assises-de-lAgroecologie-2024.pdf
- Réduction de l'empreinte carbone d'un Vignoble Innovant Ecoresponsable. Scénarii et leviers évalués avec l'outil GES&Vit : https://www.vignevin-occitanie.com/empreinte-carbone-vie/
- 4p1000: https://4p1000.org/discover/?lang=en

The Power of Compost and Compost Tea in Sustainable Organic Vineyards and Cherry Orchards Farming

Every year, farms produce vast amounts of organic waste and residues that often end up being burned or sent to landfills. But what if this "waste" could become a powerhouse for soil health and crop productivity? By composting these residues, farmers can create nutrient-rich humus and compost tea, transforming agricultural byproducts into sustainable solutions. Compost improves soil structure, enhances water retention, and reduces reliance on synthetic fertilisers, while compost tea serves as a natural biostimulant. The application of both leads to higher quality products, allows farmers to cut costs, and contributes to a circular economy.

What are the key benefits of using on-farm residues for compost production?

On-farm residues are often seen as waste but can be valuable when repurposed through composting. Composting is a biological process where biodegradable organic compounds are transformed into compost. As organic amendments, composts are rich in humified organic matter and can be used as a slow-release source of nutrients in contrast to mineral fertilizers. Composts improve physical, chemical and biological properties of soils, in particular by increasing available nutrients mainly in the organic soil fractions. Composts have a high-water retention capacity, which increases soil water content [1]. These modifications positively affect plant cover by improving plant nutrition and growth and help reduce the risk of erosion [1]. Furthermore, composting helps lower greenhouse gas emissions by preventing biodegradable materials from ending up in landfills, where they would produce methane.

Additionally, compost tea can be applied directly to plant roots or foliage, providing a quick boost of beneficial macronutrients, phytohormones, humic acid, with a ready effect that can promote growth plant, help in the biocontrol of fungal pathogens and have positive effects on soil quality and plant health [2, 3].

By utilizing on-farm residues for compost and compost tea, farmers can close the nutrient loop, reduce waste, and enhance the sustainability of their agricultural practices—all while improving yields and soil health over time.

What are the essential steps for composting residues?

According to OG OLTREBIO, the first phase of the process involved preparing the piles after crushing and mixing the raw materials (Fig. 1.), i.e., crop residues mixed with grass cuttings. The pile is then covered with a sheet, and oxygenation is ensured by the aeration system, which is activated at regular intervals (ten minutes every two hours in the first two weeks). The temperature should be measured continuously with probes connected to a data logger, while the humidity should be checked weekly (40–70%). To allow the homogenisation and fermentation of the materials, the pile was turned weekly twice in the first two weeks and then once again before the end of the process.

Fig. 1. On-farm composting at the CREA-AA experimental farm: 1. collection of farm waste; 2. shredding and mixing; 3. preparing and oxygenating the pile; 4. checking the temperature and humidity; 5. storing the mature compost; 6. application in the field [4]

Table 1 presents the main characteristics of the compost produced within the OG. The parameters comply with Italian legislation and indicate a good level of maturity and quality of the compost.

Table 1. OG OLTREBIO compost characterisation [4]:

Parameters	Value
Dry matter (%)	76.2
pH	8.09
Total organic carbon (%)	20.85
Total nitrogen (%)	2.43
Carbon to nitrogen ratio (C:N)	8.58

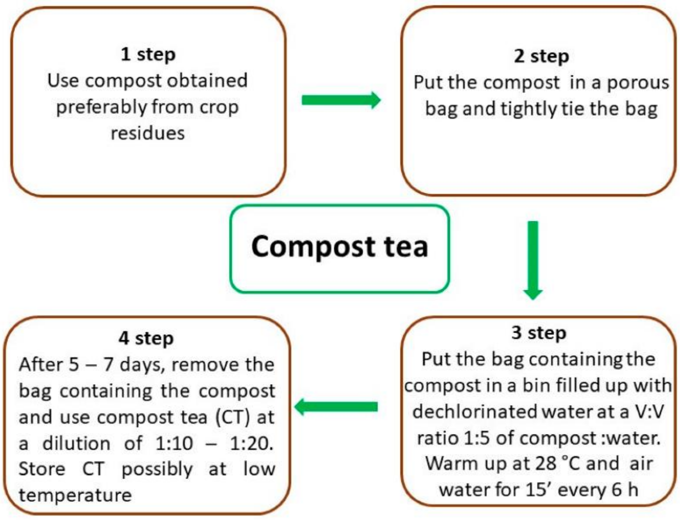
How does compost tea differ from traditional compost, and what are its advantages?

In recent years, compost-derived products like compost tea have gained popularity in agriculture for their positive effects on crops. Compost tea is a liquid organic formulation made by extracting compost materials in water under controlled conditions. Unlike traditional compost, which is applied directly to soil in solid form, compost tea provides a rich microbial and nutrient infusion that is immediately bioavailable to both plants and soil microbiota. Traditional compost improves soil structure and nutrient reserves over several months, whereas compost tea acts quickly, enhancing plant health through increased foliar nutrient uptake—especially nitrogen—and promoting stronger root development. Additionally, compost tea can be produced rapidly (24–48 hours) and used immediately. Essentially, compost tea enhances the benefits of compost by utilising its living components in a dynamic and targeted manner. Compost teas contain essential macronutrients (nitrogen, phosphorus, potassium), micronutrients (copper, zinc, iron, manganese), phytohormones (IAA, cytokinins, salicylic acid), and humic acids, all dissolved in water for immediate availability. They also host diverse microbial communities, including fungi, bacteria, and protists, which support plant growth and help control fungal pathogens [2, 5, 6]. These microorganisms contribute to compost tea's properties by providing biological control of diseases and stimulating plant development. Many bacterial strains in compost tea act as plant growth–promoting rhizobacteria (PGPR), enhancing plant resistance to stresses and improving growth [7, 8]. Various studies have reported successful biostimulation outcomes across different crops, making compost tea a valuable tool for sustainable agriculture [9, 10].

How is the compost tea produced?

The most common compost teas are aerated compost teas (ACTs), produced by continuously or intermittently aerating dechlorinated water for a period ranging from 24 hours to a week to promote microorganism growth [2]. Filtration is typically achieved with a porous bag or screen. Practitioners often add nutrients or adjuvants to ACTS during or after preparation [2]. The amount of compost used depends largely on the size and type of the brewing vessel and equipment used [11]. The size of the brewing vessel varies from small (a few litres) to several hundred litres. Optimal conditions for producing quality CTs, as reported by Zaccardelli et al. [12] and adopted by OG OLTREBIO, include a compost:water ratio of 1:5; high-quality compost, especially if derived from plant residues rich in aromatic compounds, such as artichoke, fennel, walnuts, and aromatic plants; a temperature of 28 °C during production; oxygenation for 5 minutes every 3 hours or 15 minutes every 6 hours; and a brewing period of 7 days [2], see Figure 2. Generally, different additives such as molasses, sugar, fish meals, whey, etc., can be added to compost tea, but their addition does not always improve the quality and biological effects. To achieve higher quality CTS, it is crucial to use good-quality compost.

Fig 2. Steps in compost tea production [2]



Different types of Compost Tea:

There are two types of compost tea depending on whether the maceration liquid is aerated or not.

- **Aerated Compost Teas (ACTs):** Produced by continuously or intermittently aerating dechlorinated water mixed with compost for 24 hours up to 1 week. Aeration promotes growth of aerobic microorganisms. Filtration uses porous bags or screens.
- **Non-Aerated Compost Teas (NCTs):** Made without aeration, incubated for 7 to 14 days. They rely on natural fermentation, dominated by anaerobic microbes. NCTs require less energy and are preferred where electricity is limited.

Oxygen and Microbial Communities:

- ACTs typically have aerobic microbes; NCTs have anaerobes.
- However, there is no clear scientific consensus on oxygen levels distinguishing these types.
- Dissolved oxygen (DO) above 5.5 mg/L is recommended for ACTs but often not measured.

What challenges might farmers face when composting farm residues, and how can they overcome them?

Farmers may encounter several challenges when composting on-farm residues:

1. **Slow Decomposition:**
   - Woody materials (e.g., vine branches) decompose slowly.

     ➤ **Solution:** Chip or shred residues before composting
2. **Imbalanced Carbon-to-Nitrogen (C:N) Ratio:**
   - Excess carbon slows decomposition.
   - Excess nitrogen causes odors and leachate.
     ➤ **Solution:** Aim for a C:N ratio of 25–30:1 by mixing dry (straw, leaves) and wet (manure, green waste) materials.
3. **Poor Moisture and Aeration:**
   - Too much moisture causes anaerobic conditions.
   - Too little dries out microbes.
     ➤ **Solution:** Maintain 50–60% moisture (like a wrung-out sponge). Turn piles regularly to introduce oxygen.
4. **Temperature Control:**
   - Compost must reach 55–65 °C to destroy pathogens and weed seeds.
     ➤ **Solution:** Monitor with a compost thermometer and insulate piles during cold weather.
5. **Odors**:
   - Anaerobic conditions cause foul smells.

     ➤ **Solution:** Turn the pile regularly and maintain proper moisture levels.
6. **Labor and Time Demands:**
   ➤ **Solution:** Use simple compost turners or collaborate in cooperatives to share labor and equipment.
7. **Space Constraints:**
   - Large-scale composting requires ample space.

     ➤ **Solution:** Use windrows or modular bins to optimize area.

8. **Pest Attraction:**

    - Fruit waste and improper composting can attract rodents or insects.
    ➤ **Solution:** Avoid meat or dairy. Bury fruit waste deep in the pile and cover piles to deter pests.

By addressing these challenges proactively, farmers can ensure efficient composting and high-quality outputs for their vineyards and orchards

What are the best practices for applying compost and compost tea in vineyards and orchards?

Applying compost and compost tea supports soil fertility, microbial activity, and plant health in vineyards and orchards. **Compost** should be applied in early spring or during dormancy in a 2–5 cm layer along tree or vine rows, avoiding direct trunk contact to prevent disease. However, **Compost tea** is best applied during the growing season. It can be used as a **foliar spray** to improve nutrient uptake and disease resistance, or as a **soil drench** for root health. Freshly brewed tea should be used within hours to maintain microbial viability [2, 13]. Applications every 2–4 weeks, especially after rain or irrigation, are effective.

Combining compost with compost tea offers long-term benefits, improving biodiversity and disease suppression. OG OLTREBIO applied the mature compost for three years as fertiliser in organic table grape vineyards (Sofia and Crimson Seedless varieties) in doses of 2.1 tons/ha in combination with compost tea as soil drench in the dose of 1.5 L/vine at a shoot length of approximately 15 cm and in the post-fruit setting and veraison stages [14]. These applications allowed the farm to maintain the quality of table grapes and reduced the inputs and fuel used by the farm by 70% and 10%, respectively [4]. Moreover, OG OLTREBIO applied in an organic cherry orchard as soil treatment (3 L/tree) and foliar treatment (250 mL/tree) at the pink bud, post-fruit setting and veraison stages. The application of compost and compost tea significantly increased the fruit sugar content in table grapes, Sophia Seedless variety (17.40 °Brix) and cherries, Lapins variety (22.81 °Brix), compared to the control (15.67 and 20.63 °Brix, respectively) and contributed to improving the water condition of the plants compared to the control under severe water stress conditions (< -1.5 MPa).

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Emerging pests in Mediterranean perennial crops

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Mediterranean perennial crops, such as vines, olives and citrus, are facing an increase in phytosanitary threats due to the emergence of exotic pests or the resurgence of certain pests that were previously not particularly worrying. Some of these pests are direct pests of crops, while others are vectors of viruses or diseases that can cause serious problems for the crops they affect. These introductions are often facilitated by international trade and climate change, which create favorable conditions for the establishment of these harmful organisms.

PART 1 – Direct pests

1. Polyphagous

1.1 *Popillia japonica* (Japanese beetle)

David Cappaert, bugwood.org

Popillia japonica is an invasive Asian beetle, classified as a priority quarantine pest in Europe. As an adult, it measures around 10 mm, has a metallic green carapace and coppery-brown elytra with ten characteristic tufts of white bristles. It can be confused with other beetles but can be distinguished by these tufts. Its life cycle lasts one year. In winter, they remain in the soil as larvae. In spring, the larvae emerge from hibernation, feed on roots and then transform into adults between mid-May and the end of July. Females lay up to 60 eggs in moist soil. Adults live for around 35 days.

Originating from Asia, it has been detected in Europe since 2014, first in Italy, then in Switzerland as far as the French border. Its spread is facilitated by transport (planes, trains, etc.).

This polyphagous beetle attacks over 400 plant species. It causes major damage to vines, devouring the leaves and leaving a lacy appearance, leading to defoliation and under-ripening of the grapes. The larvae damage grass roots, causing wilting and yellowing. Early detection and monitoring are crucial to prevent its establishment in France and in Iberian Peninsula.

Find out more

1.2 *Bactrocera dorsalis* (oriental fruit fly)

Bactrocera dorsalis originated in South-East Asia, then spread to sub-Saharan Africa in the early 2000s. It was detected in Réunion in 2017 and reported for the first time in Europe in 2018, particularly in southern Italy. In 2018, the first adults were caught in France.

A. Franck, CIRAD

The adult is about 8 mm long, with a dark brown to orange thorax and abdomen with a dark "T"-shaped band. The wings are transparent with characteristic patterns. Females have a prominent ovipositor.

B. dorsalis is extremely polyphagous, attacking the fruit of 539 plants, the major host plants being mango, papaya, grapefruit, mandarin and peach. Secondary host plants include chilies, peppers, cucumbers, apples, pears, tomatoes and grapes. The oriental fruit fly is at high risk of becoming established over the long term in low-lying Mediterranean regions. The larvae develops by feeding on the pulp of the fruit, causing sagging tissue, runs and lesions. Infested fruits ripen more quickly, drop prematurely and become unmarketable. This damage also facilitates the entry of secondary pathogens.
Control of *B. dorsalis* is based on monitoring by trapping, biological control using parasitoids, chemical control and cultivation methods involving collecting and destroying infested fruit to interrupt the development cycle.

[Find out more]

1.3 *Aleurocanthus spiniferus* (lemon whitefly)

Aleurocanthus spiniferus is a hemipteran, belonging to the Aleyrodidae family and originating from south-east Asia. It is considered a citrus pest and has been present in Italy (since 2008, when it was first detected), Greece, Croatia and Albania, and in France since 2023. It is classified as a quarantine pest by the EU and is subject to compulsory control. Its main hosts are citrus fruits and roses. Highly polyphagous, it attacks over 90 species, including vines, apples, pears, figs and ivy.

Aleurocanthus spiniferus on vines (source: FREDON Occitanie)

Adults measure no more than 1.7 mm and have metallic blue-grey wings with white spots. The larvae are black with a white margin made up of wax filaments. The larva develops in 4 stages. The larvae gather in immobile colonies on the underside of the leaves. *Aleurocanthus spiniferus* weakens plants by sucking sap. Symptoms include yellowing, deformation of young shoots and premature leaf drops. In addition, *Aleurocanthus spiniferus* excretes honeydew, which leads to the development of fumagine (an ascomycete fungus) preventing photosynthesis and plant respiration.

Control methods are essentially chemical, using insecticide treatments or the application of mineral, paraffinic or essential orange oils with a physical action that suffocates the larvae (only in cases of low infestation and without the development of fumagine).

2. VINE'S PESTS

2.1 *Jacobiasca lybica* (African leafhopper)

It is an invasive species first described in Libya on cotton in the early 20th century, then on grapevines in the vineyards of the Maghreb; it is thus nicknamed the African grapevine leafhopper. It is already present in the vineyards of southern Europe: first spotted in Italy (Sicily and Sardinia, 1962), then in Spain, Greece and Portugal, it has been observed in Corsica (2023) and in the French littoral (2024). It is a species that cohabits with *Empoasca vitis* in southern vineyards and it is very difficult to distinguish the two species with the naked eye. The adults leave the attacked vines at the end of the vegetative period, in autumn. They overwinter on a wide range of plants, including alders, fig trees, apples and oaks, before returning to the vines in May of the following year to lay their eggs, giving rise to the 1st generation. Most of the time, 5 generations follow one another during the year, partly overlapping.

Damage *caused by J.lybica* on vines.
Photo by Guilles Salva (CRVI)

Jacobiasca lybica is a sucking-biting insect that feeds on all leaves (young and adult) by puncturing the veins. Attacked leaves quickly become discolored and dry out as the sap no longer circulates, and curling is sometimes observed at the start of the symptoms. The leaves are no longer functional, slowing down the ripening of the grapes. In the event of a heavy attack, the leaves fall off, exposing the bunches to the sun and scalding.

2.2 *Cryptoblabes gnidiella* (Daphne moth)

Cryptoblabes gnidiella is a species of lepidopteran insect in the Pyralidae family, native to the Mediterranean basin. It is a growing pest in vineyards around the Mediterranean. Initially present in coastal areas, it has recently been identified in more continental regions, notably in Greece, where infestations were reported in 2024 in organic vineyards in the Drama region. In France, *Cryptoblabes gnidiella* is well established in many southern costal departments but has gradually extended its range inland. This polyphagous lepidopteran feeds on a wide variety of species and can produce up to 4 or 5 generations a year. It is often associated with other pests such as citrus mealybugs (*Planococcus citri* and *Pseudococcus citriculus*) and grapevine moth (*Lobesia botrana).* The larvae attack sweet fruit that has already been damaged, causing crop losses. These losses have been estimated at 5% a year in French winegrowing. Control methods are based on trapping the insects to determine the need for chemical intervention (on average two per year), or biological control using *trichogramma* or mating disruption. Early detection is difficult, which complicates the management of infestations.

3. Olive tree's pests

3.1 *Melanaspis corticosa* (olive corticolous scale-insect)

Melanaspis corticosa, a scale insect originating from South Africa, was first detected in Europe in 2016, infesting olive trees in the Algarve region of Portugal. Its identification was confirmed by morphological and molecular analyses in 2022. Previously, this species had only been known in a few African countries or in the Middle East. This scale-insect is considered to be a potential pest of olive trees in Europe, although information on this species is still limited. *M. corticosa* is small, oval-shaped and dark in colour, difficult to distinguish with the naked eye. The host plants are mainly olive trees, but the scale-insect can infect other woody species.

Melanaspis corticosa infests branches and shoots, causing a general weakening of the tree. Its presence can lead to a reduction in tree vigour and lower production. Implementing a control strategy is difficult, as the insect has proved to be resistant to insecticides, the number of natural predators is limited and there is a lack of knowledge about the insect itself.

3.2 Dasineura oleae (Olive leaf midge)

Dasineura oleae, a specific olive midge, has historically been considered a secondary pest. However, since 2010, severe infestations have been reported in several Mediterranean regions, particularly in central Italy from 2016. It is a small fly whose larvae cause galls on the leaves, young branches and flower buds of olive trees, disrupting photosynthesis and reducing tree growth and production. Severe infestations can cause significant economic losses. The fight against this pest is based on regular monitoring, the use of traps, targeted insecticide treatments and the encouragement of natural parasitoids to control populations.


Symptoms on olive trees

4. Other secondary pests

Other pests deserve particular attention because of the risks they represent for certain agricultural sectors.

Xylotrechus chinensis, known as the tiger longhorn beetle, is a beetle native to Asia that mainly attacks mulberry trees (*Morus* spp.), but its presence is a threat to other species; it has already been found on apple, pear and grapevine. The adult lays its eggs under the bark, and the larvae dig galleries in the wood, causing the trees to gradually decline or even die. Although still localised, its rapid establishment in several regions of Europe (Spain since 2013, then Greece and France, where it is classified as a quarantine pest) indicates a worrying potential for spread.

Halyomorpha halys, the devil bug, is a polyphagous hemipteran native to East Asia. It affects a wide range of crops, including vines, fruit trees and vegetables. It causes fruit deformation, reduced commercial quality and significant yield losses. Its gregarious behavior and adaptability make it a difficult pest to manage.

Pochazia shantungensis is a leafhopper originating from China and classified as a quarantine pest in Europe. It was detected in France for the first time in 2018 on the Mediterranean coast. It is a pest of many fruit crops (olive trees, peach trees, apple trees, chestnut trees, etc.), forest trees (ash trees) and shrubby ornamental plants (laurel, ornamental pomegranate, camphor trees). Adults can be seen from July to the end of November. They range in size from 7 to 17 mm, are dark brown to black in color and lay eggs in a zigzag pattern covered with white wax filaments. Egg-laying takes place between mid-August and November on the stems. There are 5 larval stages, also covered in wax filaments. *Pochazia shantungensis* weakens plants and in the event of heavy attack leads to the death of twigs, branches and trees. P. *shantungensis* also secretes honeydew on which fumagine develops on leaves and stems, reducing photosynthesis .

Lycorma delicatula, the spotted fulgore, is a hemipteran in the Fulgore family. It originates from China. It was introduced into the USA in 2014 (where it is known as the "Spotted Lanternfly") and has since caused major problems in the agricultural and forestry sectors. Its presence has not yet been detected in Europe. This insect feeds on more than 70 species of ornamental plants, fruit and nut trees and vines. Adults and larvae take sap from leaves and stems. When several specimens feed on the same plant, it dies. When feeding, *Lycorma delicatula* produces a honey-like substance that causes the appearance of fumagine, a mould that prevents photosynthesis. The adults lay their eggs on flat surfaces, which can then be transported and infest new areas. Its spread is facilitated by human activity.

[Phlyctinus callosus](), a weevil native to South Africa, is a pest of vineyards and fruit trees. It is not present in Europe but is on the alert list. *P. callosus* is a polyphagous species that feeds on a wide range of monocotyledonous and dicotyledonous species. Adults spend the day in the leaf litter on the ground near the host plant and climb on its aerial parts at night to feed and mate. It is considered a major pest of grapevines and fruit trees in South Africa, Australia and New Zealand. It also damages a number of ornamental plants. On vines, damage mainly affects leaves and stems (as well as the peduncles of bunches or the pedicels of berries). Damage to fruit renders it unfit for sale, and infestations lead to its rejection for export. Young fruit trees can be completely defoliated when adult populations are dense. Larvae cause root damage, which can be severe on root vegetables or young vines and trees

Acanalonia conica is a hemipteran native to North America. It is highly polyphagous and feeds on vines and olive trees. First observed in Italy in 2003, it has also been present in Austria, Hungary and France since 2020. No significant damage has been reported since its introduction. On the other hand, *A. conica* is often accompanied by *Metcalfa pruinosa*, which is recognised as a pest on a large number of host plants.

Zygina rhamni, also known as the Italian leafhopper, is native to Europe and can be found in southern Europe (south-west France, Switzerland, Sicily, Slovenia, Cyprus, etc.). The larvae are yellowish-white in colour and closely resemble those of *E. vitis*, but are less mobile. The adult measures 3 to 3.5 mm, is yellow-ochre in colour with reddish stripes, more evident in males, and moves in a straight line. *Z. rhamni* feeds on parenchyma cells, producing silvery-white discolourations on the leaf surface which then turn red. Z. rhamni colonises vines late in the spring. For the time being, it is not a major problem in vineyards.

Damage to vine leaf caused by *Z. rhamni* *(Source : ephytia)*

Arboridia kakogawana, or Japanese leafhopper. Native to Japan, then found in Korea, the Russian Far East and China. In 1999, identified in southern European Russia, then in Ukraine, Romania, Bulgaria, Serbia and Moldavia. This insect could become established in most French vineyards due to climatic conditions that are favourable to its development. The adults overwinter in deciduous and mixed forests, moving into vineyards in the spring where there can be up to four generations, before returning to the forests in late summer or early autumn to overwinter. It can spread via host plants. Wood with bark may carry the leafhopper, as the insect overwinters under the bark of trees

Nysius graminicola is a bedbug already present in Europe in small populations. It likes hot, dry climates and prefers to come out at night, which makes it difficult to observe. In the event of an outbreak, significant damage can be observed, particularly to young vine plants.

Erasmoneura vulnerata is a grapevine leafhopper that is widespread in North America. In 2004, it was detected for the first time in Europe, more specifically in north-eastern Italy, where it remained a minor pest of vineyards for a long time. In 2016, the first infestations *of E. vulnerata* were reported in several vineyards in the Veneto region. It is gradually colonising other European wine-growing regions (Switzerland, Germany, Hungary). It has not yet been detected in France. *E vulnerata* feeds on the leaves, causing speckled white lesions on the leaf surface. In the event of severe damage, the lesions may coalesce and the leaf may fall prematurely. It has been recorded on many other host plants such as horse chestnuts, willows and brambles, although the frequency of collection on these plants is much lower than that observed on species of the *Vitis* genus.

PART 2 - Virus-carrying pests

1. *Philaenus spumarius* (vector of *X. fastidiosa*)

Philaenius spumarius (source: ANSES recognition sheet, Germain 2015)

Philaenus spumarius is an insect belonging to the Aphrophoridae family (cicadas, bugs, aphids and scale insects). The adults are small, between 5.3 and 6 mm in size for the males and 5.4 to 6.9 mm for the females. This species is polymorphic in color, making it difficult to identify, with shades of light grey to blackish. The most typical form is yellow-green with indistinct dark lines. Adults are present from April. Not very active, they display saltatory behavior if disturbed. Egg-laying takes place in late summer, in the stems of plants. They hatch in spring. The larvae, which are not very mobile, feed on the sap present in the xylem by digging their stylets into the plant. The larvae go through five stages, which are difficult to identify. The larvae protect themselves with a foamy secretion called "cuckoo spit", which can be seen in the leaf axils. *Philaenus spumarius* is native to Europe, where it has a very wide distribution and also extends to certain parts of western Asia. It has been accidentally introduced into other parts of the world over the last few centuries, particularly in the temperate regions of North America, South America, Asia, Australia and New Zealand

Philaenus spumarius is known to be one of the vectors of the Xylella *fastidiosa* bacterium (6 subspecies) on olive trees. *X. fastidiosa* is a quarantine organism in the European Union and is subject to official surveillance. The bacterium is present on a large number of plant species and can cause diseases such as CoDiRO (rapid desiccation complex of olive trees) on olive trees or Pierce's disease on vines, which has been observed several times in Europe, but has been eradicated or contained to date (Balearic Islands 2016, Portugal 2023, Italy 2024).

More information on the insect . More information on Xylella fastidiosa

2. *Trioza erytreae* (African citrus psyllid)

The African citrus psyllid, *Trioza erytreae*, is the most recent citrus pest to be introduced to mainland Europe. It was detected in north-west Spain in 2014, and has since spread along the Portuguese coast. The adults are light brown in colour, the female is larger than the male and has a very pointed abdomen. It is a biting-sucking insect, preferentially attacking lemon and lime trees. It is sensitive to hot, dry conditions and favours cool, damp areas above 500 m altitude.

Damage caused by Trioza erytreae on orange leaves

Females lay their eggs on the margins of young leaves, on shoots or on the main veins of leaves. They can lay up to 800 eggs. The larvae are sedentary and pupate in open galls at the 5th larval stage.

Leaves are deformed, with galls and often chlorotic spots visible at feeding points. This psyllid transmits citrus greening or huanglongbing (HLB), one of the most devastating citrus diseases in the world. HLB is expressed as a degeneration caused by an endocellular bacterium in the phloem.

Control methods include preventive measures using hedges to encourage beneficial insects, and biological control using *Tamarixia dryi*, which has proved effective as a predator of *Trioza erytreae*.

3. Other secondary pests

Diaphorina citri, the Asian citrus psyllid, is an insect native to South Asia. It is widespread on the Asian continent and is also present in America and certain African countries. It poses a serious threat to Mediterranean citrus-growing areas. A biting-sucking insect, it attacks citrus fruit as well as various rutaceous plants. The species is mainly found in warm coastal areas. *Diaphornia Citri* is one of the main vectors of Greening , or Huanglongbing or HLB or Yellow Dragon disease, a diseaseserious citrus degeneration disease caused by an endocellular phloem bacterium. For the moment, the species has not yet been detected in Europe.

Aphis illinoisensis, the American vine aphid, is native to North America. It attacks vines exclusively, weakening plants and reducing production. Its presence in parts of the Mediterranean region, although limited, requires careful monitoring to prevent its spread. It is known in the United States as a vector of the *Vein clearing virus*, with the potential for this aphid to transmit other problematic viruses probably constituting the greatest danger if it spreads.

The information contained in this sheet comes from the EPPO global database, EFSA, FREDON, ANSES and the ephytia platform.

Pruning and climate-smart residue management in olive orchards

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Pruning is a vital agricultural practice that enhances plant health, productivity, and sustainability in crops like olive, citrus, almond trees, and vines. It controls growth, optimizes sunlight, and improves fruit quality. Amidst climate change, with rising temperatures and erratic rainfall, adaptive pruning is essential to maintain yields and reduce stress. Additionally, pruning residues in olive orchards—such as branches and leaves—can be shredded and spread across the soil to retain moisture, suppress weeds, and boost fertility. As they decompose, they release nutrients like nitrogen and potassium, improving soil health and reducing fertilizer needs, according to guidelines by LOVAPS at HMU, CITAB at UTAD, and CIMO at IPB.

What is Pruning and Why is it Important?

Pruning is the selective removal of certain parts of a plant (like branches, shoots, or leaves) with the purpose of reducing excessive vegetation to improve structure, health, and productivity. In fruit crops, it helps to control the plant's shape, encourages airflow and light penetration, and stimulates better fruit quality. Pruning opens the plant so sunlight can reach all the leaves and air can flow through. This helps the plant grow stronger and healthier, like getting fresh air. Pruning of olive trees should be adapted to the climatic conditions (soil, temperature, humidity, solar radiation) of the area, especially in areas vulnerable to climate change. It is important for the:

- Regular fruiting and longevity of the olive tree.
- Better balance between vegetation and fruiting.
- Saving water and moisture (reducing canopy evapotranspiration).
- Optimizing tree nutrient requirements by regulating the olive tree canopy and growth.
- Preventing olive tree pests, leading to improved pest management and reduced pesticide requirements.
- Optimising harvesting.

How to conduct fruiting pruning in an olive orchard?

The cultivar growth habit and vigour and canopy density as well as the fruit load should be considered for proper fruiting pruning. Pruning focuses on maintaining an open canopy to let light into the centre of the tree for good fruit production and making harvesting easier. Olive trees can live for a very long time, so pruning also helps maintain their shape and productivity over many years. The best time to control the canopy through pruning, is late winter to early spring (before new growth starts). Currently there are three main techniques described as follows, and Figure 1 compares the olive production over 3 years of different pruning regimes:

- **Classical pruning:** Trees are severely pruned every 3 or 4 years. This practice is conducted removing large branches and leaving about 25 to 50% of the canopy. It may be interpreted as renewal pruning with a major impact in production. It increases the risk of loss of production when there are adverse weather conditions due to climate change.
- **Annual light pruning:** In this approach an average of 10 to 20% of the canopy is yearly removed. Shoots that produce fruits are removed as well as branches that alter the tree canopy optimum shape. This technique prevents production variability and reduces the risk of climate change adverse effects on production, but it requires skills and carefull consideration, to draw the line to when to stop cutting.
- **3-cut pruning:** An annual practice that obeys to the rule of 3 cuts. In this approach 3 strategically chosen branches are removed, the strategy is to look at the tree and choose 3 branches that may be removed considering their position in the tree, their size, the overall canopy balance, crossed branches, etc. The important thing is never to remove more than 3 branches. This way the tree will always have a reasonable volume, and the production will not be affected, i.e., the production is stable throughout the years.

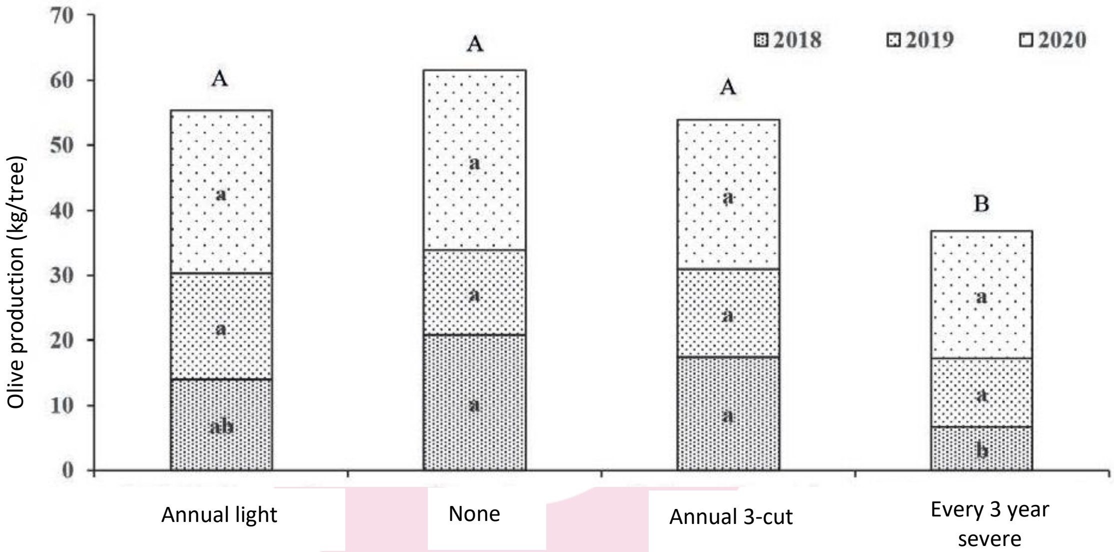

Figure 1. Olive production in four different pruning regimes[1].

Olive trees, following a year of heavy fruiting and trees that have not been pruned for an extended period, should be pruned. Finally, all infected, dry etc. shoots should be removed. For olive varieties with erect growth habit and for olive trees with sparse and medium canopy density, a moderate to light pruning of the centre of the canopy as well as clearing of infected or dead shoots should be performed.

Common mistakes to avoid are cutting too much or too little, pruning during frost-prone periods, leaving stubs or tearing branches and not disinfecting tools between trees.

How are pruning residues managed?

After pruning, there are a lot of branches and twigs l on the ground. These leftover branches and twigs are called residues and traditionally farmers would just pile them up and burn them however, this is not a climate-friendly practice. Moreover, this practice represents a waste of raw material and nutrients that may be of great service to the soil and the olive tree. Next is a list of possible management solutions that can contribute to a better environment:

- **Shredding and Mulching:** The branches can be placed in between rows (Figure 2-left) and mechanically managed, so they became small woodchips or mulch (Figure 2-right). This mulch can then be spread around the base of the olive tree or left on the ground between the olive tree rows. Mulch helps to keep the soil moist; it also helps prevent weeds from growing. As the mulch decomposes it adds nutrients back into the soil, making it more fertile and healthier. Healthy soil can also store more carbon from the atmosphere, which helps fight climate change.
- **Composting:** Smaller branches and leaves can be added to a compost pile. Over time, they break down into a rich, soil-like material called compost. Compost is a natural fertilizer and using it, means farmers might not need to use as many fertiliser inputs reducing greenhouse gases. Compost also helps the soil hold more water and carbon.
- **Bioenergy:** In some cases, larger branches can be used to produce energy. If done correctly and sustainably, using pruning residues for bioenergy can be an energy source reducing reliance on fossil fuels like coal and oil.
- **Creating Biochar:** Heating the pruning residues under specific conditions can create a charcoal-like material called biochar which can be added to the soil and store carbon.

Figure 2. Left - Aligned pruned branches in between olive rows (photo by M. Â. Rodrigues, CIMO - IPB); right - Shredded and mulched pruning residues (photo by E. Kabourakis, LOVAPS lab – HMU)

The practice of burning pruning residues constitutes a waste of valuable nutrients, it leads to the emission of atmospheric pollutants that pollute and lower the quality of the olives that are not harvested and contributes to increased carbon emissions (carbon footprint) in the atmosphere and to climate change (environmental pollution). Instead, pruning residues may be used to create temporary brush piles (Figure 3). The establishment brush piles create complementary microhabitats and nesting places as stepping stones and patches for functional biodiversity.

Figure 3. Pruning residues used as a brush pile to harbour fauna (photo by E. Kabourakis, LOVAPS lab – HMU)

What are the benefits of smart management of pruning residues in tree nutrition, olive orchard biodiversity and climate change?

Even though pruning might seem like a small thing, how we manage the residues can have a big impact on the planet through:

- **Reducing greenhouse gas emissions:** instead of burning, using residues for mulching, composting, or bioenergy reduces carbon and methane. These methods also enhance soil health, supporting climate resilience and reducing the environmental footprint of the olive orchards.
- **Using resources wisely:** reusing pruning residues helps to reduce waste and conserves water by shading the soil, which lowers evaporation and retains moisture.
- **Supporting biodiversity:** avoiding synthetic fertilizers and enriching soil with organic matter from residues supports diverse soil organisms. This promotes processes like nutrient cycling and decomposition and provides food for higher level species such as birds and mammals that can help control pests. Small brush piles left in the orchard provide great shelter for small mammals.
- **Heathier soil:** Mulching and composting improve soil fertility and structure (their decomposition releases nutrients – nitrogen, N, phosphorus, P, potassium, K, etc back into the soil), reduce erosion and nutrient loss, and support beneficial microbes and invertebrates like earthworms, which further enhance soil quality and tree nutrition.

TO FIND OUT MORE

Related links and material

[1] M. Ângelo Rodrigues, Carlos Lopes, Margarida Arrobas and Carlos Correia, "Poda do olival tradicional em três cortes: um novo conceito de poda que reduz os custos e assegura a produtividade", Vida Rural, outubro 2021, 76-82.

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LIFE IGIC video https://www.youtube.com/watch?v=IvGDESfrsmI

Set of soil quality indicators

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[2]VINIDEA, Piazza 1° Maggio, 2029028, Ponte dell'Olio (PC), Italia

Soil quality is its ability to function as a living ecosystem, supporting agricultural production while preserving the biological functions and ecosystem services. Several biological and agronomic indicators can be used to assess the impact of farming practices on soil life and their impact on the sustainability.

what are the relevant bioindicators to assess the biological quality of the soil?

A biological indicator is a tool that reflects the activity, diversity or functionality of living organisms in the soil. These indicators make it possible to:

- ✓ measure the impact of farming practices on soil life;
- ✓ assess the soil's capacity to provide ecosystem services (fertility, carbon storage, water regulation, etc.);
- ✓ identify biological misfunctions or risks.

The biological quality of a soil can be assessed using biological and agronomic indicators, such as (i) soil physico-chemistry and structure, to characterise habitat quality; (ii) organic matter decomposition rate, to assess biological activity; (iii) microbial abundance and diversity, (iv) nematode abundance and diversity and (v) earthworm abundance and diversity, to characterise the state of living organisms present in the soil.

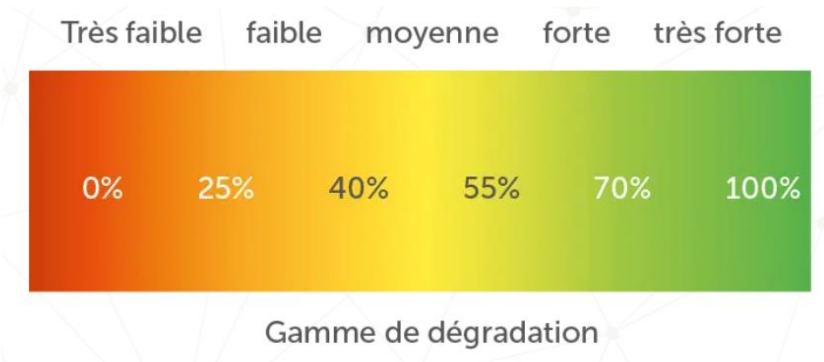
The following parts are explaining the main indicators.

How to measure soil biological activity?

The biological activity of the soil, in particular its capacity to decompose organic matter, can be assessed using a simple field test: the LEVAbag® test. Other methods exist, as tea bag or "undies test" giving the same result but are less scientifical because not standardized.

It is used to measure the rate of degradation of a reference organic matter in agricultural soil. Evaluation of the degradation of litter (above or below ground) in a cultivated environment has shown that the litterbag method, on which the indicator is based, is relevant for measuring the decomposition of crop residues and the impact of agricultural practices. Bags of a given size and mesh (pores that allow organisms smaller than 1 mm to pass through) filled with standardised organic matter (organic straw) are buried (in February-March) at a depth of 10 cm for 4 months, then they are dug up and the loss of mass is measured: the higher the loss of mass, the greater the biological activity (the soil organisms have 'digested' the contents).

AVERAGE DEGRADATION
(Loss in mass)



How do you assess the microbiological quality of soil?

Analysis of the microbiological populations provides information on the biological state of the soil and its functional potential, which is directly linked to the quality and sustainability of production systems. Several indicators provide information on this quality:

- **microbial molecular biomass**, it corresponds to the total abundance of soil micro-organisms. It is measured by the quantity of microbial DNA extracted from the sample. It is an indicator of the impact of soil use;
- **microbial balance**, it is the ratio between the density of fungi and the density of bacteria. It can reflect disturbances in the soil caused by certain uses or cultivation practices. An imbalance in this ratio reflects a sub-optimal state of biological functioning in the soil. Diversified crop rotations, intermediate crops, organic fertilisation and reduced tillage are practices that favour this balance. Fungi and bacteria are quantified by quantitative PCR;
- **microbial diversity**, it is an indicator of the richness of bacteria and fungi (in terms of the number of taxa), which provides information about the biological functioning of the soil and its resilience. For example, it has been shown that a 30% drop in diversity results in a 15-50% reduction in most of the major soil functions (Novasol Experts).

Micro-organisms have a very short lifespan and their genome is plastic, so they are the quickest to respond to changes (in climate, land use, etc).

In France, there is a national reference system (INRAe) that can be used to predict a critical threshold and reference values for each indicator (based on 2,200 soils).

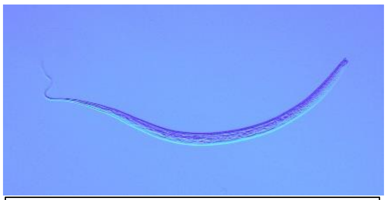
What information do nematodes give us?

Soil is a habitat for a wide variety of organisms, including nematodes, microscopic metazoans generally measuring a few millimetres in length and tens of micrometres in diameter. As bio-indicators, nematodes are particularly relevant for assessing the biological functioning of soils, due to:

- their high abundance in a wide variety of ecosystems (between 200 and 20,000 individuals per kilogram of "ordinary" soil).
- their taxonomic and functional diversity.
- their sensitivity to physical or chemical changes.

In the agricultural context, nematodes are often perceived in a negative aspect, due to the presence of plant-parasitic species that can cause significant damage to crop. However, parasitic species represent only a fraction of the soil nematofauna, the majority being made up of so-called 'free-living', i.e. non-parasitic, nematodes. The functional classification of nematodes according to their trophic group can be used to infer information about soil ecosystem processes. A distinction is made between :

- **plant-feeding nematodes** (obligatory or facultative), indicators of the state of the plant cover and the risk of agronomic losses.
- **bacterivorous and fungivorous nematodes**, which reveal microbial activity, the dynamics of organic matter and nutrient recycling.
- **higher trophic level nematodes** (omnivores and carnivores), which reflect the ecological integrity of the soil in the face of human disturbance.



Nematode (source: Elisol Environnement)

What's more, their small size means that entire communities can be analysed from small quantities of soil (generally less than 500g), making them easier to sample and study in the laboratory.

Find out more

What about earthworms?

Earthworms are also indicators of soil quality, and are often referred to as "soil engineers". They play an important role in the degradation and recycling of organic residues in the soil. They create a network of galleries between the surface and the depths of the soil, helping to aerate the soil and facilitating the development and progress of roots.

Around a hundred species have been listed and are classified into 3 ecological categories:

Adult spadefoot (*Satchellius mammalis)*

- **epigeics**: Small (1-5 cm) and dark (red, brown). They live on the surface (top 1 cm) and in piles of dead organic matter (forest litter, manure, compost, green waste, sewage sludge, etc.). They dig few or no galleries in the soil. They have a high reproductive capacity and feed on organic waste, helping to break down this dead organic matter (diet: saprophagous). Epigeids are the most exposed to surface action.

Adult red-headed beetle (*Lumbricus terrestris*)

Juvenile black-headed anteater (*Aporrectodea giardi*)

- **Anectic**: large species, between 10 and 110 cm. Their colours vary from red to brown, with a common gradient of colour from head to tail. They live on the entire soil profile (galleries up to 5 m long). They dig permanent galleries vertical to sub-vertical and open at the surface, allowing water to infiltrate. They deposit their droppings on the surface of the soil (castings), increasing the roughness of the surface and limiting erosion. They return to the surface to feed, breaking up organic matter, burying it and mixing it with the ingested soil (diet: saprogeophagous). Anecia are more sensitive to chemical action (weeding) than mechanical action (tillage). There are two main genera of anechoids. Redheads (of the genus Lumbricus) or epi-anecium at the juvenile stage. They are very reactive to changes in temperature and humidity, and resume their activity when soil moisture conditions are favourable. Their gallery network is not very branched. Epi-anecium need organic matter that is easy to consume (leaves, for example). Blackheads(of the genus Aporrectodea) systematically have a period of inactivity between June and August and create a highly branched network of galleries.

- **endogeic**: species varying in size from 1 to 20 cm. They are very lightly coloured to apigmented (grey, pink or green). They live mainly in the top thirty centimetres of soil. They dig temporary horizontal to sub-horizontal galleries. They help to create a "lumpy structure", influencing water retention and infiltration in the soil (diet: geophagous)

Learn more about earthworms

Juvenile endo (*Allolobophora icterica)*

TO FIND OUT MORE

Related links and material

- *Earthworms – architects of fertile soils,* Technical guide FiBL No 1629, 2022. Available at https://www.fibl.org/fileadmin/documents/shop/1629-earthworms.pdf
- *Why use nematofauna as a bioindicator of soil biological functioning?* ELISOL Environnement. Available at : https://www.elisol.fr/services/pourquoi-la-nematofaune-comme-bio-indicateur-du-fonctionnement-biologique-du-sol/
- *Learning more about earthworms,* EcoBioSoil. Available at: https://projets.ecobio.univ-rennes.fr/opvt/node/4

Soil cover management in Mediterranean viticulture

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Cover crops are used as intercrops in perennial systems such as vineyards and orchards. They are referred to by various terms: service crops, green manures, or catch crops (e.g., Cover Crops for Nitrate Trapping – "CIPAN" in French). These crops are not grown for direct harvest, but rather to promote and enhance ecosystem services within the agricultural system. Although increasingly present in vineyards, cover crops require careful management, particularly in Mediterranean climates where the risk of competition with the vine is heightened. This competition can threaten both yield targets and economic viability. Therefore, cover crop management must be tailored to the specific pedoclimatic conditions, production goals, and the ecosystem services sought.

Soil Cover Strategies in Viticulture

Various types of soil cover are used in viticulture, mainly in the inter-row area, but also under the vine row, depending on production objectives and constraints. Four main soil cover strategies can be identified[15]:

- **Spontaneous permanent cover cropping**: development of naturally occurring species already adapted to the plots. This strategy involves low costs (limited to cover maintenance), but no control over the species established: previous weed management may have selected invasive species that compete strongly with the vine.
- **Sown permanent cover cropping**: long-term establishment of a mixture of selected species adapted to local conditions and with low competitiveness toward the vine. This allows better control of species composition and the ecosystem services delivered. However, sowing costs must be considered, as re-sowing may be needed periodically depending on species persistence.
- **Spontaneous temporary cover cropping**: establishment of a spontaneous cover, offering greater flexibility in managing competition for water or nitrogen since the cover can be selectively destroyed. No sowing costs, but requires close monitoring to ensure timely intervention.
- **Sown temporary cover cropping**: establishment for a few months of selected plant species based on the ecosystem services targeted (e.g., leguminous green manures for their potential nitrogen contribution to the soil). Sowing must be planned in advance to ensure successful emergence and biomass production. Similarly, the destruction method must be carefully chosen to maximize agronomic benefits without harming the vine

[15] Pierre-Antoine Noceto, Hériché, Mathilde, Laure Gontier, Daniel Wipf, Benoît Bazerolle, et al.. Les couverts végétaux. Partie 1/2 : Une pratique agroécologique au service de la vigne. La revue des œnologues et des techniques vitivinicoles et œnologiques, 2021, 178, pp.24-26. ⟨hal-03130035⟩

Cover Crops Supporting the Vine

Cover crops can provide numerous ecosystem services that benefit the vine[16], particularly in the following areas:

- **Soil physical properties and water balance**: protection against erosion, improved soil structure (reduced compaction, better load-bearing capacity, increased porosity), enhanced water infiltration and retention, helping to reduce runoff and evaporation.
- **Soil organic matter status**: increased organic matter content, carbon sequestration.
- **Soil chemical fertility**: nitrogen input (depending on the C/N ratio, type of cover, biomass produced, and destruction method), reduced nitrogen losses through leaching.
- **Soil biodiversity and biological activity**[17]: increased abundance of soil fauna (earthworms, nematodes) and mycorrhizae, stimulation of microbial activity.
- **Microclimate and fungal disease regulation**: reduced vine vigor and increased potential evapotranspiration, thereby limiting fungal development; mitigation of heat stress by reducing ground reflectance.
- **Pest regulation**: diversification of habitats for natural enemies of pests, such as predatory mites (Phytoseiidae)[18].
- **Weed control**: reduced germination through competition for light, water, and nutrients; rapid, dense ground cover with high biomass production.

More broadly, cover crops also benefit the wider environment, notably through water purification and pollution mitigation, carbon sequestration, biodiversity and wildlife conservation, and enhancement of landscape aesthetics, which can be an asset for agritourism.

However, despite their many benefits, cover crops may also introduce certain disservices across nearly all the above categories. Key points of caution include strong competition for water and nitrogen, and a potential increase in canopy humidity, which may raise the risk of frost and fungal diseases.

[16] Léo Garcia et al., Management of service crops for the provision of ecosystem services in vineyards: A review, Agriculture, Ecosystems & Environment, Volume 251, 2018, Pages 158-170, ISSN 0167-8809, https://doi.org/10.1016/j.agee.2017.09.030

[17] Karimi, B., Cahurel, J. Y., Gontier, L., Charlier, L., Chovelon, M., Mahé, H., & Ranjard, L. (2020). A meta-analysis of the ecotoxicological impact of viticultural practices on soil biodiversity. *Environmental Chemistry Letters*, *18*, 1947-1966.

[18] Lou Tabary, Denise Navia, Léo Garcia, Elena Kazakou, Marie-Stéphane Tixier. Diversité des acariens prédateurs dans un vignoble agroécologique méditerranéen : effet des couverts végétaux et de l'agroforesterie. VEGÉPHYL – 13ème conférence Internationale sur les ravageurs et auxiliaires en agriculture, Institut Agro Montpellier, Oct 2024, Montpellier, France. ⟨hal-04956307⟩

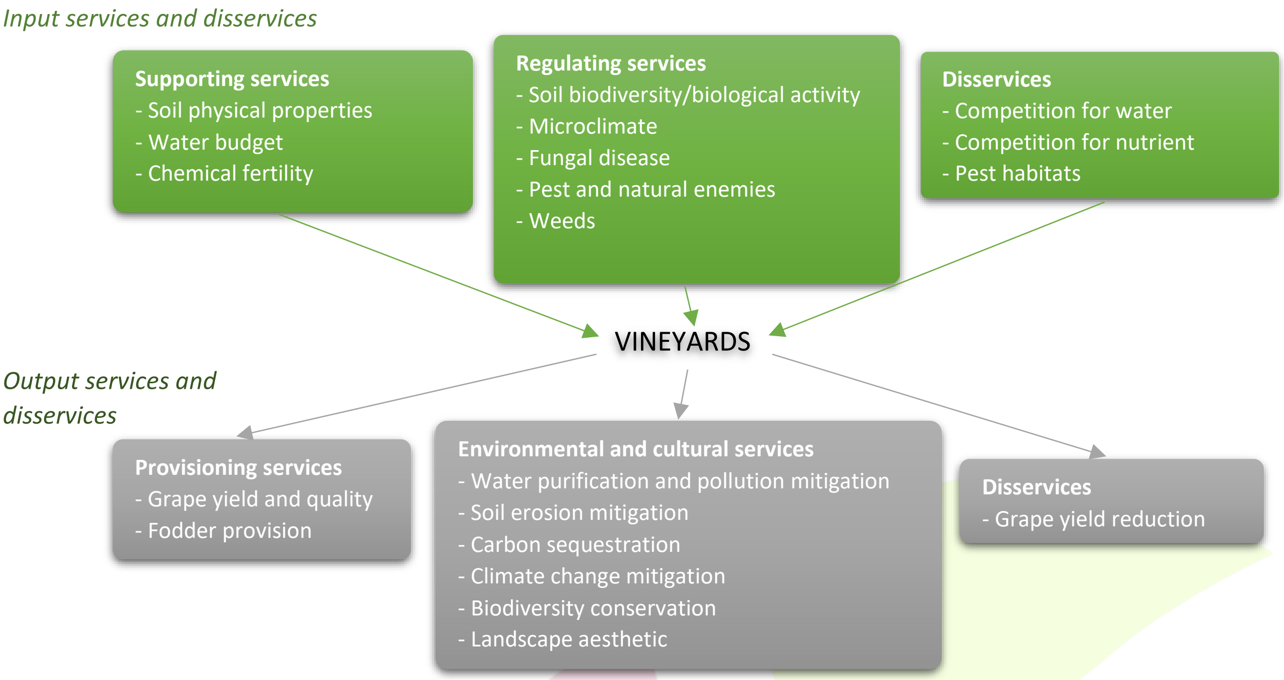

Figure 1: Ecosystem services and disservices expected from service crops in vineyards (L. Garcia et al., 2018)

Temporary Cover Crops: Which Species to Sow?

Species selection should prioritize the primary agronomic objective and local soil and climate conditions. In Mediterranean areas, early sowing (late August to early September) is recommended to ensure good cover development. This helps reduce erosion during heavy autumn rains and prevents vine leaves from being blown away—these leaves serve as an additional source of soil nutrients.

Overseeding (increased seed rates for all species) is also advised, along with choosing a well-diversified mix (legumes, grasses, cereals, brassicas) to ensure the long-term sustainability of the cover through the rotation of dominant species. Below is a selection of species recommended for Mediterranean viticulture, drawn from the *Green Manure Fact Sheets*[19] by the French Vine and Wine Institute (IFV):

[19] Fiches Pratiques - Engrais vert en viticulture de l'Institut Français de la Vigne et du Vin, disponible sur : https://www.vignevin-occitanie.com/wp-content/uploads/2019/02/Fiches-engrais-verts.pdf

Characteristics	Faba bean (*Vicia faba*)	Oat (*Avena sativa*)	Barley (*Hordeum vulgare*)	White mustard (*Sinapis alba*)
Family	Fabaceae (legume)	Poaceae (grass)	Poaceae (grass)	Brassicaceae (crucifer)
Average dry matter yield (t/ha)	4–6	3–6	3–6	4–5
Atmospheric nitrogen fixation	Yes	No	No	No
Potential nitrogen return for 2 t DM/ha	47 kg/ha	24 kg/ha	22 kg/ha	26 kg/ha
C/N ratio	12	18	19	17
Soil coverage	Medium to low	Good	Good	Good
Competitiveness against weeds	Low	Good to moderate	Good to moderate	Good

Figure 2: Medicago lupulina

A study was conducted to optimize species selection in order to reduce runoff and limit water competition between cover crops and vines. The goal was to find the best trade-off between ground cover rate (used as an indicator of runoff and erosion control) and impact on soil water reserves (water supply/retention)[20].

Analysis of species traits showed that aboveground dry matter content is positively correlated with soil water stock but negatively with ground cover rate. Additionally, several root traits significantly influence soil water retention, particularly the proportion of very fine roots, specific root length, and average root diameter.

Under Mediterranean conditions, *Medicago lupulina* (Fabaceae) emerged as a particularly promising species. It combines high dry matter content, shallow rooting, strong soil water retention capacity, and good ground cover performance.

Temporary Cover Crops: Influence of Termination Date and Method

As previously mentioned, cover crops require precise management, with key levers being the **termination date** and **termination method**. Depending on the chosen strategy, these factors have

[20] Léo Garcia, Aurelie Metay, Elena Kazakou, Jonathan Storkey, Christian Gary, et al.. Optimizing the choice of service crops in vineyards to achieve both runoff mitigation and water provisioning for grapevine: a trait-based approach. Plant and Soil, 2020, 452 (1-2), pp.87-104. 10.1007/s11104-020-04543-y. hal-02619383

varying impacts on both the cover crop and the vine. A recent study[21] compared two different termination dates (early termination vs. at budburst) and three termination methods (tillage, rolling, mowing). Below are the main effects of these decisions:

Effects on Cover Crop Management

Allowing cover crops to grow until vine budburst resulted in double or triple the biomass compared to early termination. The method of termination also influenced regrowth: tillage was the most effective at eliminating covers and limiting weed pressure at flowering (a critical stage for the vine). In contrast, rolling was less effective, particularly on grasses, but generated the most surface residue, making it a good option for in situ mulching.

Effects on Soil Organic Matter and Microbial Biomass

After three years of monitoring, no significant change in soil organic matter was observed. Building up organic matter typically requires several years of continuous cover. Soil carbon accumulation is largely determined by the biomass produced and its characteristics (e.g., C/N ratio). Microbial biomass, however, was significantly influenced by the timing and method of cover crop destruction: late termination (at budburst) without tillage led to higher microbial biomass levels, likely due to greater biomass return and extended root activity.

Effects on Soil Water Reserves and Vine Water Status

Cover crops improve water infiltration and soil water storage. In this study, only the method of termination significantly affected soil moisture and vine water stress. Tillage rapidly stopped cover transpiration, leading to higher water reserves and lower vine water stress, compared to mowing or rolling. However, the relative effectiveness of different termination methods is still debated in the literature. The roller-crimper, for example, has been shown to enhance soil moisture conservation and reduce soil temperature compared to residue incorporation, while also reducing energy costs—an important environmental consideration in Mediterranean regions[22]. Lastly, year-to-year climatic variability—especially spring rainfall—has a dominant effect on soil water reserves and vine stress levels.

Effects on Soil Mineral Nitrogen and Nitrogen in Grapes

Tillage-based cover termination led to much higher levels of mineral nitrogen in the soil (up to 61 kg/ha) compared to rolling and mowing (16.25 kg/ha). This can be attributed to several combined factors: accelerated mineralization of incorporated residues and reduced competition from the destroyed cover[23]. Conversely, no-till methods allowed regrowth of the cover crop, which absorbed available nitrogen. Seasonal effects were also notable: low biomass and high C/N ratios slowed mineralization. Nitrogen content in the grape must followed the same trend, with higher assimilable nitrogen levels in the tilled treatments—confirming a "green manure effect."

[21] Léo Garcia et al., Adapting service crop termination strategy in viticulture to increase soil ecosystem functions and limit competition with grapevine, European Journal of Agronomy, Volume 156, 2024, 127161, ISSN 1161-0301, https://doi.org/10.1016/j.eja.2024.127161.

[22] Alonso-Ayuso, M., Gabriel, J.L., Hontoria, C., Ib´a˜nez, M.´A., Quemada, M., 2020. The cover crop termination choice to designing sustainable cropping systems. Eur. J. Agron. 114, 126000 https://doi.org/10.1016/j.eja.2020.126000.

[23] L. Gontier, Engrais verts en viticulture : incidence du type de couvert végétal et de son mode de destruction sur l'alimentation azotée de la vigne, 2013

Effects on Vine Vigor and Yield

The method of cover crop termination significantly influenced vine vigor and yield. Tillage-based destruction led to greater vine vigor (higher pruning weights) and stable or even increasing yields over the three-year study period. In contrast, mowing and rolling produced lower pruning weights, which could compromise long-term sustainability in the case of repeated drought. Observed yields (7.25 to 13.7 t/ha, depending on termination strategy)[4] were acceptable for some AOPs (PDOs), but could be limiting for other types of production (PGI, table wines). Cluster number, the main yield determinant, was significantly higher in the tillage treatment—likely linked to reduced water and nitrogen stress.

Mediterranean context: the need for precise management

In Mediterranean regions, increasingly characterized by dry winters and a higher frequency of drought events due to climate change, the management of cover crops must be strategicly and finely tuned to the climatic conditions of each growing season.

To best adjust the timing and method of cover crop termination, several indicators must be taken into account: autumn–winter rainfall balance, access to irrigation, soil depth and available water capacity, and the vine's vegetative status during the previous year (signs of reduced vigour, low yield, etc.). Tillage-based termination appears to be the most secure strategy to preserve vine vigour and maintain production in Mediterranean areas. However, this choice must be considered in light of production objectives and the economic value of the wines produced.

An adaptive approach seems particularly relevant. When autumn and winter rainfall have ensured good soil water recharge, the risk of competition is limited. In such cases, it is possible to extend cover crop growth into spring to maximize biomass production and associated ecosystem services. Termination using a roller-crimper can be considered in this context. Conversely, in years marked by winter drought or a lack of irrigation, prolonged cover crop development may increase vine water and nutrient stress, to the detriment of its vigour and yield, particularly in shallow or drought-sensitive plots. Tillage is therefore recommended for cover crop termination during dry years.

This adaptive strategy can be reinforced by choosing cover crop species that are easy to terminate mechanically, have minimal impact on soil water reserves, and provide high ground cover. Finally, differentiated management at the plot scale can help fine-tune the balance between soil biological activity and vine performance. For example, alternating practices between rows (tillage every other row, roller-crimper on the others, switching from year to year…) or adjusting the level of ground cover based on intra-plot variability[5] can be effective.

TO FIND OUT MORE

- Fiches engrais verts, Institut Français de la Vigne et du Vin, disponible sur : https://www.vignevin-occitanie.com/wp-content/uploads/2019/02/Fiches-engrais-verts.pdf
- Léo Garcia et al., Management of service crops for the provision of ecosystem services in vineyards: A review, Agriculture, Ecosystems & Environment, Volume 251, 2018, Pages 158-170, ISSN 0167-8809, https://doi.org/10.1016/j.agee.2017.09.030.
- Karimi, B., Cahurel, J. Y., Gontier, L., Charlier, L., Chovelon, M., Mahé, H., & Ranjard, L. (2020). A meta-analysis of the ecotoxicological impact of viticultural practices on soil biodiversity. *Environmental Chemistry Letters*, *18*, 1947-1966.
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- L. Gontier, Engrais verts en viticulture : incidence du type de couvert végétal et de son mode de destruction sur l'alimentation azotée de la vigne, 2013
- Léo Garcia, Aurelie Metay, Elena Kazakou, Jonathan Storkey, Christian Gary, et al.. Optimizing the choice of service crops in vineyards to achieve both runoff mitigation and water provisioning for grapevine: a trait-based approach. Plant and Soil, 2020, 452 (1-2), pp.87-104. 10.1007/s11104-020-04543-y. hal-02619383

Huanglongbing (HLB) in the Mediterranean Citrus-Growing Region

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Huanglongbing (HLB) is a citrus disease that causes severe damage in the production areas where it is present. It is associated with bacteria of the genus *Candidatus Liberibacter*, which are primarily transmitted by two insect vectors: the psyllids *Trioza erytreae* and *Diaphorina citri*. The former has already been detected in the Iberian Peninsula, while the latter, which is of even greater concern, has been reported in Israel. Although the disease has not yet reached Europe, its potential arrival and subsequent impact on citrus crops would have catastrophic consequences for the sector. Current research efforts focus on preventing the introduction of the disease and identifying tolerant plant material that would allow coexistence with the bacterium without compromising the productivity of citrus cultivars in the Mediterranean region.

What is the current disease status?

At present, Mediterranean citrus production in Spain remains free from both the aforementioned vectors and HLB. However, the outlook is far from encouraging. The vector *T.erytreae* was detected in Galicia in 2014 and has since spread along the Cantabrian coast and the Portuguese Atlantic coastline. It is now present in the Algarve region of Portugal, only about 120 km from the citrus-producing area of Huelva in southern Spain. Meanwhile, *D.citri* was first detected in the Mediterranean basin in July 2021, in Israel, where citrus plantations are abundant. The failure to eradicate this initial outbreak has led to the pest spreading to other citrus regions, such as the Jordan Valley. The biological potential of *D.citri*, as well as its rapid multiplication on the main citrus varieties and species cultivated in the Mediterranean, is much greater than that of *T.erytreae*. Given this concerning situation, research institutes across the Mediterranean are intensifying their efforts to control both the vectors and the HLB disease. The search for HLB-tolerant plant material and the use of defense inducers have emerged as key strategies to combat the disease.

What are this disease's biological and symptomatic features?

Bacteria of the genus *Candidatus liberibacter* colonize the phloem of citrus plants, interfering with nutrient transport. Initial symptoms include asymmetric leaf mottling, shoot yellowing, premature fruit drop, and fruit malformations. Additionally, affected fruits fail to fully change color, remaining green and yellow, which is why the disease is commonly known as "Yellow Dragon." As the infection progresses, plants exhibit general weakening, drastic yield reduction, and ultimately, death. Transmission occurs mainly via the psyllids *T.erytreae* and *D.citri*, which acquire the bacterium while feeding on infected plants and subsequently spread it to healthy ones. These vectors are highly polyphagous, feeding on a wide range of cultivated and wild species, which greatly complicates control efforts once an outbreak occurs. Management is further hindered by symptom similarity to other deficiencies and the lack of a cure, necessitating the removal of affected plants to prevent further spread.

What is the impact of HLB disease in countries where it is present?

The impact of HLB in countries where the disease is present has been devastating. In Brazil, since its emergence in 2004, HLB has caused the death of 43 million citrus plants in just a decade. In Florida, USA, where it was detected in 2005, the disease has affected 66,000 hectares and led to a 70% decline in the state's total citrus production. These examples illustrate the enormous destructive power of HLB and its capacity to radically alter the economy and agricultural landscape of entire regions. Furthermore, the difficulty in eradicating the vectors and the absence of curative treatments have led to HLB being defined as the most serious and complex disease for global citrus production. It is also noteworthy that these countries possess greater phytosanitary resources than the European Union to combat these insects.

What preventive measures need to be deployed?

Prevention strategies against HLB focus on excluding both the vectors and the disease, intensive monitoring, and rapid eradication of initial outbreaks. In Spain, biological control programs have been implemented, such as the introduction of the parasitoid *Tamarixia dryi* to control *T.erytreae* populations. Research is also underway to identify more tolerant citrus genotypes and to evaluate the use of plant defense inducers, such as volatile compounds that activate defense mechanisms in plants and repel vectors. European legislation designates HLB as a priority pathogen, establishing epidemiological surveillance, contingency plans, and simulation exercises to prepare for a rapid and coordinated response in the event of detection. Thus, all citrus-producing countries are working together to implement contingency plans, recognizing that HLB is the main threat to citrus cultivation

How to identify HLB?

Early detection of HLB is essential for its management. Due to current limitations in time and specialized field detection equipment, the Valencian Institute of Agricultural Research (IVIA) has developed a rapid detection kit for field use. This kit can identify the presence of HLB-associated bacteria within approximately 30 minutes, with sensitivity and specificity comparable to current PCR techniques. The kit has been validated on samples from various geographical origins and can be applied to both plants and insect vectors (For more information, see this link). Additionally, epidemiological models have been developed to optimize surveillance and delineate treatment areas, as well as sampling and diagnostic protocols in collaboration with international laboratories. This allows for effective discrimination between positive and negative samples and integration of detection into management and contingency programs. This prototype represents a highly useful tool for in situ diagnosis of this serious citrus disease.

What are the mechanisms underlying defense induction and volatile-mediated control?

IVIA has developed innovative strategies for HLB control based on activating the natural defense mechanisms of citrus plants. One of the most promising approaches is the use of volatile compounds emitted by the plants themselves to induce defensive responses. The volatile compound (Z)-3-hexenyl propanoate has proven particularly effective: exposure of plants to this compound triggers the production of defensive proteins such as protease inhibitors, catalases, and chitinases, which reduce the survival of the psyllid vectors (*T. erytreae* and *D. citri*) on treated plants. In addition to strengthening internal defenses, this method has a dual impact:

- Repellent effect: Treated plants become less attractive to psyllids, hindering their feeding and reducing transmission of *Candidatus liberibacter*.
- Attraction of natural enemies: The released volatiles attract specific parasitoids of the vectors, such as *Tamarixia radiata* (for *D.citri*) and *Tamarixia dryi* (for *T.erytreae*), enhancing biological control.

Parallel research is being conducted on the use of plant hormones and antioxidant inducers to improve citrus tolerance to HLB. Preliminary studies suggest that increasing antioxidant levels in plant tissues may mitigate the oxidative stress caused by the bacterium, delaying disease progression. These strategies are integrated with other measures, such as classical biological control through the release of *T.dryi* (a specific parasitoid of *T.erytreae*), which has significantly reduced vector populations in regions such as Galicia and the Canary Islands. The combination of defense inducers and natural enemies offers a sustainable approach to slowing HLB spread without relying exclusively on chemical pesticides.

While these methods do not cure the disease, they represent key tools for strengthening citrus resilience and buying time in the face of a potential HLB introduction in Europe. Their effectiveness depends on early and coordinated application, integrated into surveillance and integrated pest management programs.

TO FIND OUT MORE

- Nueva herramienta de diagnóstico para la detección rápida de las tres especies de \`Candidatus Liberibacter´ asociadas al HLB: RPA-universal-HLB http://hdl.handle.net/20.500.11939/8447
- Huanglongbing (HLB) y otras enfermedades bacterianas de los cítricos ('Citrus HLB and other bacterial diseases') http://hdl.handle.net/20.500.11939/7444
- Nuevas estrategias de lucha frente al HLB: Material vegetal tolerante e inducción de defensas http://hdl.handle.net/20.500.11939/7203
- La expansión de psílidos transmisores de HLB en la cuenca del Mediterráneo https://hdl.handle.net/20.500.11939/8586
- Últimos resultados en la prevención y lucha frente al HLB y sus vectores https://hdl.handle.net/20.500.11939/8652

Invasive pests in citrus crops

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The Mediterranean citrus sector is constantly threatened by the arrival of new invasive pests and by the increased incidence of others that, although already present in our territory, did not suppose a danger to the crops. The globalization of the fruit trade, imports of plant material, climate change and the reduction in the efficacy of phytosanitary products make it increasingly difficult to control phytophagous pests in citrus fields. The application of integrated production systems where the use of auxiliary fauna-friendly products prevails is a strategy that may not be effective in southern European countries, where the climatic variable increases the severity of attacks by new pests.

What are the causes of the arrival of new pests?

The presence of new invasive pests has increased in the Mediterranean region favored by the growth of international trade in plant material and food products that cross continents with a very lax control for the risk involved. Europe is an importing continent, which imports fruit from different parts of the world throughout the year to meet the demands of consumers. These imports are subject to a series of controls that only allow monitoring a small part of all fruit entering the European Union. These fruits may have inoculums of different pests that, in their area of origin, are well controlled but in other climatic conditions may pose a real risk. In addition, countries in other latitudes have active substances and phytosanitary products available to control these pests. On the other hand, in Europe, legislation greatly limits the use of phytosanitary products, so that the arrival of a new pest can mean a complete alteration of the citrus ecosystem.

How does climate change influence the installation of new pests?

In general, pests exhibit zonal behavior, they are acclimatized to a particular area. When a new pest enters a region from a different climatic zone, its establishment and survival depends largely on the similarity in climatic conditions between the country of origin and destination. In this sense, climate change is favoring the establishment of these tropical and subtropical pests that a few years ago were limited by cold winters. In general, current winters do not interrupt the development of pests such as the South African cotonet or citrus thrips, pests that would have been much more restricted under the climatic conditions of two decades ago. Another example is the oriental mite, a pest that affects citrus late in the cycle and that, with low temperatures, slows down its development. On the other hand, winter temperatures above 18 degrees Celsius mean that the pest continues to reproduce in the middle of the citrus harvesting period, so that the active substances to be used for its control are very scarce. The same problem is encountered with the spread of the worst citrus disease, HLB. One of its vectors, Diaphorina citri, is acclimatized to temperate zones typical of the Mediterranean region. It has already been localized in Israel and Cyprus and the Mediterranean side of producing countries such as Spain, Italy and Morocco is seriously threatened.

What can biological control bring us?

Biological pest control is defined as the action generated by the natural predators and parasitoids of the pest to prevent them from exceeding the threshold of economic damage. It should be noted that many of the invasive pests that have appeared in recent years do not have effective biological control agents in the Mediterranean citrus region, contrary to what happens in their places of origin. This causes the need to find such agents in their area of origin and import them to try to establish a new balance in our citrus fields. This process involves some problems and risks, the main one being the legal impediments to such introductions, which sometimes go far beyond the principles of proportionality and prudence in an exercise of self-protection on the part of those responsible for the administration. An example can be found in the introduction of the parasitoid *Tamarixia dryi* in the Iberian Peninsula for the control of *Trioza erytreae*: The parasitoid was released experimentally in three locations in northern Spain in autumn 2019 and spring 2020. Sampling showed that T.dryi has become established, shows high levels of parasitism at the release sites and is dispersing without affecting other psyllid species present in Galicia.

What are the current pests present in citrus cultivation?

In general, citrus crops are affected by pests such as thrips, spider mites, coccinellids, and diaspids. Although with marked differences between varieties (lemons, oranges and mandarins) and climatic zones throughout the Mediterranean region, the pests described in this paragraph represent a generalized problem in terms of plant health:

- ***Eutetranychus banksi*** (McGregor). It was detected in 2013 and since then it has invaded the entire citrus growing area, becoming the most frequent mite species in citrus cultivation in the Valencian Community since it does not present a good biological control, even displacing *Panonychus citri*. and *Eutetranychus orientalis*, with which it can be confused. It causes relatively important damage to leaves and fruits. It prefers the upper side of the leaves, unlike other tetranychids, and can only be found in fruits with very high populations. The most effective natural enemies are the phytoseiids *Neoseiulus californicus* and *Euseius stipulatus*.

- ***Delottococcus aberiae*** (De Lotto) The South African cotonet, detected for the first time in citrus in Benifairó de les Valls (Valencia) in 2009, has proved to be one of the most damaging invasive pests due to the serious deformations it causes in the fruit, which completely depreciate its commercial value. The identification of the sexual pheromone of this pseudococcidian has allowed the monitoring of the pest and the use of the attract-and-kill technique for its control. The introduction of the exotic parasitoid *Anagyrus aberiae* and the predator *Cryptolaemus montrouzier*i contribute to its control as natural enemies of the pest.

- ***Scirtothrips aurantii*** Faure : *It belongs to the Order Thysanoptera and is native to Africa and Yemen. It is a very polyphagous species that can be found on more than 50 species of plants, both cultivated and wild. In Spain it became established in southwestern Andalusia in 2020 and in 4 years it has been invading new areas along the Mediterranean until it was declared in 2024 in the Valencian Community, where in addition to citrus it is seriously affecting persimmon and pomegranate crops. It is considered a quarantine pest of the European Union. In fruits a superficial gray scar appears on the rind of the fruit that often forms a ring around the* *peduncle. Unlike other thysanoptera, it needs to survive in young plant tissues so its potential for natural spread is relatively limited.*

New threats to citrus management

In addition to the pests presented in the previous section, there are a number of pests that are present in countries with which we have commercial relations and can enter our region, thus affecting citrus crops. Among them, the following stand out:

- ***Paracoccus burnerae*** (Brain) Native to the Afro-tropical region, this pseudococcid has been detected since the 2010s in citrus plots in Andalusia, Murcia and the Valencian Community, although only occasionally. Apart from the typical cotonet damage, the symptoms of its presence are manifested as deformations in leaves, in the form of pinching, and in fruits, forming cracks. Parasitoids of the genus *Anagyrus* (main predator of *D.aberiae*) are not reported to be effective biological control agents against this cotonet.

- ***Thaumatotibia leucotetra*** (Meyrick) The false apple moth is a pest regulated by the EU as a priority quarantine pest. The importance of this tortricid is that it can attack numerous fruit species, both cultivated and wild, including citrus, but also avocado, peach, persimmon and pomegranate, and horticultural species. It is established in Israel, although it has been detected 562 times in other European countries. In Spain, 67 interceptions have been carried out from 2009 to 2020, on orange, grapefruit and mandarin trees from South Africa, Swaziland and Zimbabwe. According to the Spanish Ministry of Agriculture, "fruit may only be imported from pest-free areas or fruit that have undergone an effective cold treatment to ensure freedom from *T. leucotreta* or other post-harvest treatment". Due to its dangerousness, the Ministry has published an eradication plan for this pest that includes the delimitation of areas with confirmed presence and a series of control measures.

How to prevent the entry of new pests into our crop?

To effectively prevent and manage pests in citrus crops, it is essential to combine early detection strategies, preventive measures and specific control methods. The following are the key actions:

- Regular visual inspections: Check leaves, shoots and fruit for signs such as curled leaves, galleries in leaf tissue, presence of adult insects or larvae, and sticky substances (honeydew).
- Use of traps and monitoring: Implement chromatic traps (yellow or blue) to capture insects such as fruit flies (*Ceratitis capitata*) or thrips.
- Place specific "attract and kill" devices to control invasive pests without damaging auxiliary fauna.

✓ **Preventive Measures**

- Cultural practices: Maintain a water balance in the soil to avoid stress in the trees, which makes them more vulnerable to pests. Conversely, excessive irrigation or nitrogen fertilization can increase sprouting, making it more susceptible to pests that attack young shoots.
- Use resistant varieties and prune to promote foliage aeration.

✓ **Application of Integrated Pest Management**

- Use specific insecticides/acaricides against the target pest only when the economic damage threshold has been exceeded.
- Introduce natural predators such as *Euseius stipulatus* (against mites) or *Cryptolaemus montrouzieri* (against mealybugs).
- Avoid broad-spectrum pesticides that harm beneficial fauna.
- Conduct weekly monitoring to detect early outbreaks and act before the pest spreads.
- Apply entomopathogenic fungi (e.g., *Beauveria bassiana*) to control insect populations without chemicals.
- Prune and destroy branches affected by highly localized pests or outbreaks.

TO FIND OUT MORE

- Las nuevas plagas obligan a actualizar el programa de Gestión Integrada en cítricos: https://www.phytoma.com/noticias/noticias-de-actualidad/las-nuevas-plagas-obligan-a-actualizar-el-programa-de-gestion-integrada-en-citricos
- Cítricos: plagas y enfermedades (junio 2024) https://www.phytoma.com/sanidad-vegetal/avisos-de-plagas/citricos-plagas-y-enfermedades-junio-2024
- PHYTOMA MEETS. La explosión de plagas en la citricultura mediterránea https://www.youtube.com/watch?v=YLhuXpyYiYI
- Aumento de la resiliencia frente a plagas y enfermedades en cítricos: Gestión de los recursos naturales https://hdl.handle.net/20.500.11939/8569
  Delottococcus aberiae, nueva plaga de cítricos http://hdl.handle.net/20.500.11939/4028
- Revalorización del complejo de depredadores polífagos en cítricos http://hdl.handle.net/20.500.11939/6658

ANNEX 1 - Sample layout of a didactical sheet

L'agroforesterie englobe toutes les pratiques agricoles qui associent des arbres (sous diverses formes telles que des haies, des alignements, des bosquets, etc.) à des cultures et/ou du bétail sur la même parcelle. Elle est basée sur la complémentarité entre les plantes pour favoriser un équilibre naturel et fonctionnel au sein du système agricole, par la diversification des espèces, l'étalement des cultures et la maximisation des interactions entre les différents compartiments de l'écosystème (sol, plantes, animaux, atmosphère, etc.)[1]. Selon la définition internationale proposée par le Centre mondial d'agroforesterie - ICRAF, l'agroforesterie désigne l'ensemble des interactions entre l'agriculture et les arbres. Ces interactions se produisent à différentes échelles (champ, exploitation, paysage) et contribuent à la fourniture de services écosystémiques[2]. L'association arbre-vigne est un mariage de longue date : les premières références à une vigne « arbustive » remontent à l'Antiquité en zone méditerranéenne. Aujourd'hui la vigne sauvage Vitis vinifera sylvestris en témoigne encore, s'appuyant sur l'arbre pour s'élever.

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QUELLE PLACE POUR L'AGROFORESTERIE DANS LA PAC ?

Après la Seconde Guerre mondiale, l'agriculture s'est intensifiée sous l'impulsion de la PAC, au détriment des arbres, perçus comme gênants. Mais depuis une vingtaine d'années, l'agroforesterie retrouve une reconnaissance progressive dans les politiques agricoles. En France, plusieurs étapes clés ont marqué cette évolution : reconnaissance du statut agricole des parcelles agroforestières (2006), assouplissement des règles de densité d'arbres et aides à l'installation (2010), ajustements réglementaires (2015), et nouvelles aides dans le cadre de la PAC 2023-2027 (écorégime, MAEC, « bonus haie »). Aujourd'hui, l'agroforesterie s'intègre pleinement aux politiques publiques, notamment grâce au travail de plaidoyer d'acteurs comme l'EURAF. Le « Pacte en faveur de la haie » (2023-2027) renforce encore ce soutien en finançant plantation et entretien.

POURQUOI PENSER À UN SYSTÈME AGROFORESTIER EN VITICULTURE ?

D'intéressantes interactions peuvent être observées entre les arbres et la vigne, impactant à la fois les conditions pédoclimatiques de la parcelle et certains paramètres agronomiques (y compris l'équilibre de la biodiversité et la prévention des ravageurs et des maladies). En effet, la présence d'arbres et de haies sur la parcelle peuvent s'avérer utiles pour : impacter le microclimat de la parcelle (modification des flux d'air et d'énergie), développer la biodiversité de la parcelle, améliorer la structure du sol et « tamponner » les émissions de CO_2 sur la parcelle.

QUELLE INFLUENCE SUR LE MICROCLIMAT DE LA PARCELLE ?

La maîtrise du microclimat sur la parcelle de vigne est un facteur essentiel pour produire un raisin de qualité. La présence impacte la quantité de rayonnement disponible (solaire et infrarouge), et d'énergie turbulente. Le couplage des flux radiatifs et turbulents contrôle la température et l'humidité de l'air qui dépendent de la manière dont le système dissipe cette énergie. Cette énergie se partage entre flux de chaleur sensible (qui chauffe l'atmosphère), flux de chaleur latente (par évapotranspiration) et flux de conduction air/sol (qui réchauffe ou refroidit le sol).

Les travaux menés en France dans le cadre du projet VITIFOREST[3] et de la thèse de Juliette Grimaldi[4] ont permis de montrer que :

- Au niveau de la captation de lumière, un déficit est observé pour les rangs de vignes situés au nord des arbres, réduisant le potentiel de photosynthèse, atténuant les effets délétères des pics de chaleur mais augmentant fortement la durée d'humectation des feuilles. A contrario, un excédent d'énergie et donc de chaleur est observé au sud des rangs d'arbres, permettant d'accroître le potentiel de production mais exposant le raisin au risque d'échaudage. Enfin l'arbre produit un rayonnement infrarouge qui augmente la température au niveau du sol, permettant de limiter l'impact des gels tardifs de printemps.

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1. Définition de l'agroforesterie, Association française d'agroforesterie.
2. Qu'est-ce que l'agroforesterie ? The Center for International Forestry Research and World Agroforestry (CIFOR-ICRAF)
3. Emilie Bourgade, Adeline Alonso Ugaglia, Vincent Bustillo, Thierry Dufourcq, Juliette Grimaldi, et al.. VITIFOREST : Evaluation de l'impact de l'arbre agroforestier en contexte viticole. Innovations Agronomiques, 2020, 79, pp.471-497. 10.15454/73ry-yq72. hal-03209987
4. Juliette Grimaldi. Impacts of agroforestry on microclimate for grape and wine production: assessment in Southern France. Life Sciences [q-bio]. Université Toulouse III Paul Sabatier (UT3 Paul Sabatier), 2018. English. (NNT :). (tel-03515990)

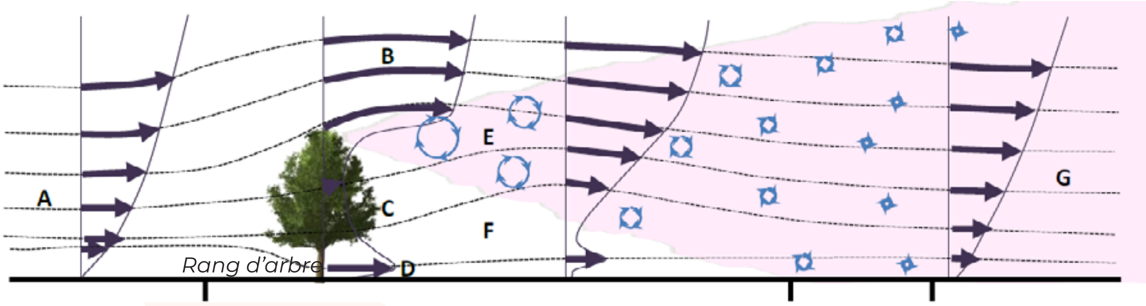

Figure 1 : Représentation schématique des flux d'air turbulents autour d'un arbre isolé (source : Grimaldi, 2018)

A : Profil de vent en amont du brise-vent	*2 à 5 H*
B : Accélération au-dessus de la canopée	*3 à 10 H (si un seul rang d'arbre)*
C : Ralentissement de l'air traversant la canopée	*1.8 H (si multiples rangs d'arbre)*
D : Accélération en dessous de la canopée	*10 à 20 H*
E : zone turbulente	
F : Zone abritée	
G : Profil rétabli	
H : Hauteur de l'arbre	

- Concernant les interactions sur le cycle de l'eau, les arbres peuvent modifier la présence d'eau ou d'humidité dans leur environnement proche : ils recyclent les ressources profondes et augmentent l'humidité relative de l'air de quelques pourcents, permettant de modérer les pics de chaleurs en favorisant l'ouverture des stomates et la prolongation des flux évapotranspiratoires. Les arbres sont d'excellents pièges pour l'eau, capables de condenser l'humidité contenue dans l'air sous forme de rosée, mais aussi d'intercepter l'eau de pluie à hauteur de 3-5 mm.
- Les champs de turbulence sur la parcelle sont modifiés par la présence d'arbre. Les arbres intra-parcellaires isolés accroissent ces flux turbulents, permettant une atténuation des pics de température et une réduction de la durée d'humectation foliaire. Lorsque les arbres sont situés en bordure de parcelle et notamment en position topographique basse, la circulation d'air froid peut être ralentie. Ce phénomène peut majorer les risques liés au gel, surtout dans les zones de bas-fonds.

QUELLE INFLUENCE SUR LA STRUCTURE DU SOL ET LE STOCKAGE DE CARBONE ?

L'arbre, par l'amélioration de l'activité microbiologique, l'accroissement de la matière organique et ses nombreuses racines, impacte la structure du sol. Il permet d'augmenter la porosité et limiter l'érosion.

Concernant le carbone, il faut distinguer d'une part la fonction de fixation de carbone (photosynthèse) et la fonction de stockage de carbone (création d'un stock de carbone dans le temps). La biomasse importante de l'arbre et sa pérennité permettent de fixer une grande quantité de carbone en comparaison à la plupart des autres végétaux de l'agroécosystème. Le carbone est ensuite restitué au sol par l'intermédiaire de ses feuilles, de son bois et de ses racines. Les décomposeurs du sol les transforment en MO améliorant la fertilité et fixant le CO_2 dans les sols. Voici en exemple le stockage de différents types de haies gérées durablement (et implantées dans le Sud-Ouest de la France) en tonnes d'équivalent CO_2 stockées par km de haie par an :

Table 1 : *Stockage de carbone par la biomasse (aérienne et racinaire) d'une haie bocagère gérée durablement selon son type dans l'Ouest de la France (en teqCO2/km/an). La biomasse aérienne est divisée en biomasse restant sur place et biomasse exploitée pour du bois énergie. (Source : valeurs issues du projet Carbocage, illustrations haies Arbre et Paysage 32 https://ap32.fr/arbres-paysages/)*

En teqCO2/km/an	Haie pluristrate 	Haie taillis 	Haie futaie 	Haie arbustive 
Biomasse totale	5.90	8.90	9.98	1.80
Biomasse racinaire	1.8	3.2	2.7	0.4
Biomasse aérienne restant sur place	1.89	0	4.85	1.4
Biomasse aérienne exploitée (en option si exploitation)	4.41	11.40	4.85	0

QUELLE INFLUENCE SUR LA BIODIVERSITÉ DE LA PARCELLE ?

A court et moyen termes, l'introduction d'arbre en pourtour ou au sein de la parcelle apporte une diversité paysagère et une variabilité des strates de végétation, et donc de nouvelles niches écologiques. En effet, l'arbre et tout ce qui le compose (branches, feuilles, fleurs, fruits, fissures du tronc, racines), offrent une «mixité» d'habitats, de refuges, de ressources alimentaires, de zones de chasse, de reproduction et d'hivernage pour une grande diversité d'espèces. Au sein de cette diversité globale, les organismes utiles au viticulteur peuvent aussi bénéficier de ces ressources comme les acariens, chrysope, certains carabes, des parasitoïdes…

La biodiversité du sol est également impactée. La combinaison des vignes et des arbres permet de favoriser le réseau mycorhizien, jouant un rôle important dans les échanges d'eau et de nutriments. Les lombrics du sol sont également impactés positivement, comme montré dans le cadre du projet VITIFOREST où un impact significatif de la présence des arbres sur la distribution des vers de terre a été mis en évidence, un gradient de fréquence décroissante ayant été relevé au fur et à mesure de l'éloignement de la zone arborée. La présence d'arbre sur les parcelles viticoles permet également de jouer sur les communautés microbiennes, notamment en fournissant des ressources nutritives supplémentaires aux micro-organismes du sol par la rhizosphère et la litière des arbres.

L'introduction d'arbres dans les vignes ne doit pas être envisagée isolément, mais intégrée à une stratégie globale alliant aménagements favorables à la biodiversité (comme les haies ou les fauches tardives) et réduction des intrants, afin d'assurer une continuité écologique efficace.

QUELS SONT LES PRINCIPAUX POINTS DE VIGILANCE À PRENDRE EN COMPTE ?

La compétition hydro-azotée

Les compétitions potentielles des arbres par rapport aux vignes sont une réelle contrainte à prendre en compte. Sur certaines parcelles expérimentales en contexte méditerranéen dans le Sud de la France, les rangs de vigne les plus proches des arbres présentent une baisse de rendement de 9 à 31 % par rapport aux rangs les plus éloignés. Des différences en nutrition azotée ont également été observées, avec des teneurs inférieures pouvant aller jusqu' à 20 % à proximité des arbres[5]. Ces résultats sont à nuancer en fonction du contexte pédoclimatique de la parcelle concernée. En effet, sur des parcelles situées dans le Sud-Ouest de la France, neuf années de co-plantation dans différents aménagements n'ont révélé aucune différence de comportement, que ce soit en termes de production de biomasse ou de qualité des raisins, entre les vignes implantées à proximité immédiate des arbres (rang adjacent) et celles situées au cœur de la parcelle, à plus de deux rangs de distance[2]. Il serait pertinent de renouveler ce suivi lorsque le système approchera les 20 ans de co-culture avec des arbres adultes et dont le développement sera important.

Quel que soit le cas de figure, il existe différents leviers permettant de prévenir cette potentielle compétition entre les arbres et la vigne en agroforesterie :

- La gestion des arbres : La taille du houppier (en hiver ou en vert) permet de réduire l'ombrage et la consommation en eau. Le cernage racinaire, réalisé tous les 3 ans, limite l'extension des racines vers la vigne. La conduite en trogne peut aussi être envisagée.
- L'implantation de couverts légumineux entre les rangs améliore la fertilité et limite le lessivage tout en fixant l'azote atmosphérique.
- La fertilisation localisée (au sol ou foliaire) et l'irrigation ciblée permettent de compenser les effets de la concurrence, notamment pour les rangs proches des arbres.

Le pourridié

Une vigilance particulière doit être apportée concernant la maladie du pourridié. En effet, de très nombreuses espèces ligneuses peuvent héberger des champignons responsables de ce parasitisme (dont *Armillaria mellea* responsable du « pourridié agaric »), et l'introduction d'arbres au sein des parcelles viticoles fait courir un risque important de développement de la maladie à terme. Chênes, pêchers et de nombreuses autres essences forestières ou fruitière y étant particulièrement sensibles. Le pourridié évolue lentement mais persiste durablement dans le sol, provoquant des foyers récurrents de symptômes et de mortalité au même endroit, malgré des périodes de jachère. Il n'existe pas de traitement curatif disponible et l'agroforesterie peut dont favoriser son développement. Quelques mesures prophylactiques à prendre en compte :

- Bien nettoyer la parcelle dans le cas d'une plantation (débris, anciennes racines).
- Laisser le sol au repos 4–5 ans si replantation après arrachage.
- Favoriser un sol vivant, bien structuré et drainé.
- Limiter les échanges de racines entre la vigne et les arbres proches en essayant de conserver une distance minimale d'au moins 3m (recommandation empirique, aucune preuve que cette distance évitera les contaminations entre les arbres et la vigne)

Contraintes techniques liées à l'aménagement de la parcelle

Enfin le dernier point de vigilance concerne l'aménagement de la parcelle agroforestière : de nombreux points sont à prendre en compte pour la réussite du projet, comme les objectifs et l'ampleur du projet, l'orientation de la parcelle, la mécanisation (notamment le nombre de rangs couverts en cas d'arbres intra-parcellaires), les problématiques de gibier, l'état du sol… De plus, comme évoqué précédemment, la présence d'arbres et haies influe sur le microclimat de la parcelle et la bonne modélisation des haies joue un rôle primordial pour garantir qu'elles ne risquent pas d'augmenter les dégâts liés au gel (une haie imperméable en bas de coteau ne permet pas à l'air froid d'être évacué) ou à l'humidité (propice aux maladies cryptogamiques).

QUELS PRÉREQUIS POUR LA MISE EN PLACE D'UNE PARCELLE EN AGROFORESTERIE ?

L'aménagement de la parcelle

Concernant d'abord le type de formations arborées, il y a quatre types d'aménagements agroforestiers possibles dans les vignes :

- Un îlot d'arbres dans la parcelle. Il s'agit d'un bosquet multi-essences et de préférence multi-strates.
- Des arbres en intra-parcellaire, dans le rang de vigne en mono-essence ou multi-essences.
- Des rangs d'arbres à la place d'un ou plusieurs rangs de vigne en mono-essence ou multi-essences.
- Des haies en bordure de parcelle ou pour couper une parcelle en plusieurs parties.

5. https://www.vitisphere.com/actualite-68990-les-impacts-sur-la-vigne-en-termes-de-concurrence.html

Le choix final est fonction des contraintes de production et des attentes du viticulteur : l'objectif premier est-il de limiter l'effet de vents latéraux ou la dérive de produits phytosanitaire ? Ou bien de créer des ressources et des habitats pour la biodiversité ? L'aménagement se fait-il sur une parcelle déjà en place ou en cours de restructuration ?

Vingt ans après les premiers essais menés en contexte méditerranéen dans le sud de le France et à la suite du projet VITIFOREST, voici quelques recommandations à suivre dans la mesure du possible:

- Privilégier les orientations Nord-Sud pour limiter et équilibrer l'ombrage des arbres portés sur la vigne.
- Prévoir une distance minimale de 3 mètres entre la ligne d'arbres et le premier rang de vigne, idéalement 4 mètres.
- Essayer de viser une distance de 25 à 30 m entre chaque ligne d'arbres.
- La distance des arbres sur la ligne dépendra de la densité visée.
- Rester sur une faible densité d'arbres: 30-50 tiges/ha.
- Respecter les tournières en bout de rangs pour les manœuvres d'engins.

Le choix des essences

Intégrer des arbres en viticulture nécessite une sélection rigoureuse des essences pour assurer la cohérence agronomique et écologique du système. Il est essentiel de privilégier des espèces rustiques adaptées aux conditions pédoclimatiques locales et de tenir compte de l'hétérogénéité de la parcelle (sols, humidité, exposition).

La diversité, à la fois spécifique et génétique, doit être recherchée pour renforcer la résilience et limiter les risques sanitaires. En lien avec les objectifs du viticulteur, les espèces pourront être choisies pour leur production (bois, fruits, floraison), leur rôle écologique (ombrage, biodiversité auxiliaire), ou leur compatibilité avec la vigne (feuillage léger, faible concurrence lumineuse). Dans le cadre de la viticulture il est intéressant de noter que les chênes et les pins s'avèrent très concurrentiels pour l'eau et les nutriments et les fruitiers sont particulièrement sensibles au pourridié. L'érable champêtre est un exemple de candidat adapté pour la vigne puisqu'il est peu concurrentiel et peu sensible au pourridié.

Le matériel végétal devra être certifié sur les plans sanitaire et génétique. L'utilisation de jeunes plants est à privilégier pour favoriser une bonne reprise.

Préparation de la plantation

Une bonne préparation du sol est primordiale pour assurer un enracinement et développement optimal des jeunes arbres qui seront plantés. Un sous-solage, puis un affinage en surface se feront préférentiellement à l'automne avant la plantation des arbres en hiver ou au début du printemps. Pour limiter la concurrence herbacée et conserver l'humidité du sol, un paillage sera déposé sur une surface de 1m^2 autour des jeunes arbres. Il pourra être constitué de paille, de bois raméal fragmenté ou d'un film biodégradable. De même, chaque arbre sera protégé par une protection contre les cervidés de 1,2 m de hauteur.

Conduite des arbres

La formation des arbres, dès les 5 à 8 premières années, est essentielle pour assurer leur bon développement. Pour les arbres isolés, un dégagement du tronc sur une hauteur minimum de 2m est recommandé, notamment pour la production de bois d'œuvre. Les haies, quant à elles, doivent être contenues horizontalement pour éviter l'empiètement sur l'inter-rang, avec un entretien possible en même temps que la vigne. Selon les essences, l'ombrage peut être modulé par la taille, notamment en têtard, qui permet de limiter la surface foliaire et favorise la création de cavités, utiles comme habitats pour la faune.

QUEL EST LE COÛT D'UN PROJET AGROFORESTIER ?

Selon les coûts répertoriés en 2023 en France par le Réseau Haies France - AFAC Agroforesterie[6], une haie d'un rang avec plantation tous les mètres reviendrait en moyenne à 18.27 € le mètre linéaire, quand une haie de deux rangs avec plantation tous les 1.5m reviendrait en moyenne à 28.91 € le mètre linéaire. Il est conseillé de prévoir 20 à 40h de travail pour 100m de haie sur les 5 premières années[7].

Concernant la plantation d'arbre isolé en intra-parcellaire, le coût reviendrait à 27.96 € par plant. On considère que 25 à 30h de travail sont en moyenne nécessaires pour la plantation de 100 arbres[6].

POUR EN SAVOIR PLUS

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