CIHEAM
IAM BARI

Ministero dell'Ambiente
e della Tutela del Territorio
e del Mare
Direzione Generale per la Protezione della Natura

REGIONE PUGLIA
Assessorato all'Ecologia
Ufficio Parchi e Riserve Naturali

CIHEAM
MAI CHANIA

LIFE+ Cent.Oli.Med. (LIFE 07 NAT/IT/000450)

Identification and conservation of the high nature value of ancient olive groves in the Mediterranean region

GUIDELINES FOR THE SUSTAINABLE MANAGEMENT OF THE CENTURY-OLD OLIVE GROVES

With the contribution of the LIFE
financial instrument
of European Community

GUIDELINES FOR THE MANAGEMENT OF BIODIVERSITY IN CENTURY-OLD OLIVE GROVES

Generosa Calabrese, Gaetano Ladisa, Angelo Proscia, Vito Simeone
CIHEAM - Mediterranean Agronomic Institute of Bari

Panagiotis Kalaitzis, Christos Bazakos, and Sotirios Fragkostefanakis
CIHEAM - Mediterranean Agronomic Institute of Chania

CIHEAM – IAMB
Valenzano 2012

INDEX

INDEX OF PICTURES

INDEX OF TABLES

INDEX OF SHEETS

FOREWORD

The following guidelines fall within the activities promoted by the project LIFE + CENT.OLI.MED "Identification and conservation of the high nature value of ancient olive groves in the Mediterranean region", which is designed to identify and preserve the High Nature Value of century-old olive groves throughout the Mediterranean basin. Following the track of the Convention for the Biological Diversity and of the European Landscape Convention, a number of actions are envisaged for the characterization, protection of biodiversity in the century-old olive groves and for the preservation of the landscape they define.

In order to define the practices hereafter collected, a participatory approach has been developed in order to collaborate with a series of local stakeholders to the definition of management criteria that could be valid and fitting for century old olive orchards in Apulia and Crete.

The proposed methodology, detailed by mean of shared protocols (www.lifecentolimed.iamb.it) was applied in Torre Guaceto (Italy) and Voukolies (Chania, Crete) target areas, accordingly the following steps:

1. Stakeholders were selected on the basis of their role or interest in ancient olive groves management as well on their background (economic, environmental, socio-cultural, institutional).
2. An ad-hoc questionnaire was submitted to these stakeholders in such a way to put in evidence their awareness of the problem, the values that they attribute and the threats they perceive about ancient olive groves and, finally, the main objectives for the biodiversity conservation in the frame of sustainability dimension (economic, social, environmental, institutional).
3. A number of meetings with stakeholders, technicians, institutions aimed to define a list of prioritized specific objectives, results and actions for the sustainable management of Apulian and Cretan target areas, starting from the preliminary objectives identified through the interviews.
4. The so defined management criteria were validated from experts botanist and zoologist in order to make them compatible with the biodiversity conservation/improvement needs in the century-old olive groves. Particularly, the compatibility of some farm practices usually adopted in traditional olive orchards in Apulia and Crete was checked, with the life-cycle of spontaneous vegetation (herbaceous and shrubs) and of fauna (birds, reptiles and mammals).

We kindly acknowledge all the colleagues from MAIB and MAICh that collaborate to the editing of the present Guidelines and all the people that with goodwill and patience participated in the analysis and in writing this document.

INTRODUCTION

Olive growers are by tradition the guardians of our landscape and of the knowledge relating to our olive groves. They do know how to get high-quality productions from century-old olive trees. However, the challenge thrown down by the market along with an increasingly intensive agricultural production imposes changes which are not always compatible with the preservation of our land with its productive, cultural and agricultural values.

The following guidelines intend to make further efforts towards the protection of the landscape, of our environmental, social and cultural heritage. They provide brief suggestions for the sustainable management of our environment inhabited by century-old olive groves scattered across the Mediterranean basin.

The said guidelines intend to reconcile production aspects of century-old olive trees management with the need to protect and preserve the biodiversity peculiar to olive groves.

To this end, it is necessary to take account of the agro ecosystem of century-old olive groves and to perform all the agricultural practices instrumental for a quality production in compliance with some simple rules which help reducing the negative impacts on biodiversity.

Some practices, such as the choice of the planting site, will not be considered since these guidelines refer to century-old olive groves for which a more environment-friendly management may help enhancing the land resources. These actions assign greater value to their specificity thereby including these agricultural areas in a global system enhancing their territorial specificity.

AGROECOSYSTEM

The term agro-ecosystem refers to the part of the landscape which is modified by the humans and where farming is practised. Agro-ecosystems differ from the natural ecosystems since they have been modified by the presence of human beings and by their activities. If one considers the number and the presence of plant and animal species as expression of biodiversity in a territorial system, it is then clear-cut that agricultural areas and cultivated fields have a poorer biodiversity if compared with the natural systems in the same areas. This is justified by the fact that wild animals and plants inhabiting the agro-ecosystems are better adapted to the characteristics of land and species and are also able to live in a system modified by man. This results in a simplified composition (number of species) and structure (interaction among species).

For low-impact farming on the environment (environment-friendly) with good quantity and quality results, it is necessary to create or re-create a balance between crops and the environment so as to reduce or to suppress the application of external inputs.

The equilibrium between production of the agro-ecosystem (crops and farm) and the sustainable use of natural resources implies the in-depth knowledge of the characteristics of our olive groves, the application of some measures which are designed to increase the level of biodiversity and to make the agro-ecosystem more complex, which means making it more similar to the natural systems. These measures shall contribute to creating and/or preserving the conditions for a high biodiversity and may intend to:

- preserving or, if not present, creating areas on the farm such as hedges, tree rows, wet land, pebble walls, etc., where beneficial may shelter, feed and reproduce;
- creating and/or maintaining good levels of soil fertility through a careful management of organic matter, and paying attention to the use of organic substances available on the farm (e.g. crop residues);
- preserving the soil, protecting it against physical degradation agents, such as wind and water, which may raise erosion problems;
- enhancing and selecting cultivated varieties which are better fit for the environment considered;
- using natural resources at best (for example water);
- Carrying out agricultural practices in a sound manner.

Biodiversity may be protected by preserving the level of naturalness and the environmental resources available in the agro-ecosystem. All that will engender a positive impact on farming with a reduction of production costs resulting from a lower application of chemical fertilisers and synthetic plant protection chemicals.

CENTURY-OLD OLIVE TREES, SOIL AND CLIMATE

With their longevity and ability to keep producing centuries after their establishment, century-old olive trees have proved to perfectly fit into the environment in which they thrive with a high resistance to adverse environmental conditions and to be the perfect response to climate changes.

Picture1 – Area of distribution of Olive tree (source: International Olive Council)

Century-old olive trees have been living, characterizing and shaping our landscape from time immemorial. The areas where they have been growing meet the needs of this crop. The environment-plant relationship is already optimized and this eases the application of cultivation methods with a low impact on the environment which allows reducing to the minimum agricultural practices (fertilization, irrigation and pest control treatments); good results are achieved in terms of quantity and quality.

Olive trees have, like every single species, specific soil and climatic needs which may slightly vary according to the variety. As to soil, the best results are obtained with soils medium-textured, sandy, silty, clayey-silty or silty-clayey and a pH from 6.8 to 7.5. These soils confer a good equilibrium in terms of aeration, permeability and water retention capacity. Sandy soils are less able to retain nutrients and water whereas clayey soils do not often enable a suitable aeration; furthermore, in the valleys, they are more exposed to waterlogging to which this species is susceptible. However, olive trees have a high adaptability; they may grow and produce in an acceptable way also in soils with a high limestone content, reduced nutrients, a pH up to 5.5 and 8.5, that is to say saline and/or sodic. If compared to most fruit species, olive trees have a higher tolerance to boron and chloride excess in the soil.

Pertaining to max temperature values, the olive tree can resist even temperatures which exceed 40-45 °C. However, should these high values persist over time, negative effects may impact the vegetative and productive activity of plants especially if they are associated with water scarcity. Late frosts (early spring) and/or early frosts (autumn) are also noxious. About the climate, minimum winter temperatures are the most important limiting factor. Olive trees may be grown up to 600-700 m a.s.l., especially in the milder growing areas (Southern Italy). The temperature impacts the chemical composition of oil and its qualitative characteristics. By way of example, oils from warmer areas usually have higher saturated fatty acid content if compared with those produced in cooler areas.

Olive trees are highly resistant to drought thanks to different forms of anatomic and physiologic adaptations; thus, they may tackle these adverse conditions better than other fruit species and keep producing also with very low rainfall (< 300 mm).
Olive trees may hardly withstand very wet and/or foggy environments since these conditions favour pathogen and/or plant pest attacks. If it rains during blossoming, fruit setting gets reduced.

Although genetically similar to some varieties which are still grown, century-old olive trees are in part different from them. The current varieties result from man-made selections designed to better their pomologic and morphologic characteristics in order to impact the yield or training system of this species in the various growing areas.

GOOD FARMING PRACTICES

These guidelines will take into account only those farming practices which are directly linked to the management of century-old olive groves such as:

1. Pruning
2. Soil management and fertilization
3. Irrigation
4. Management of adverse conditions
    a. Weed management
    b. Pest control
5. Olive harvesting
6. Thickening, replacing dead plants
    a. Choice of varieties
    b. Choice of the training system

The above-said practices will be detailed on the basis of their relevance in the management of century-old olive groves and of biodiversity maintenance.
Some practices, such as the choice of the planting site, shall not be taken into account in that these guidelines refer exclusively to century-old olive groves for which a more environment-friendly management may help including these agricultural areas in a global system enhancing their territorial specificity without disregarding their economic yielding and the sustainability of the agro-ecosystem they contribute to creating.

1. Pruning

In century-old olive groves, common management practices imply production pruning (ordinary and extraordinary) and, sometimes, shape pruning after thickening and replacing dead plants.

Shape pruning

The choice of a training shape intends to achieve one or several aims which respond to a specific operational context. The main aims, which sometimes overlap, are as follows:

- **Balancing the relationship between the vegetative and reproductive system.** A good balance between these two systems allows optimizing production in terms of quality and quantity; in the meanwhile, it provides the necessary nutrients to renew the vegetation and the fruit setting of the following year.
- **Adjusting the plant to the light conditions**. If light is a limiting factor, the training shape helps optimizing the use of light easing its penetration inside the canopy. Should light be excessive with respect to the needs of the species, the training shape is designed to prevent damages (due to sun radiation excess) to the cambium or to the fruits.
- **Providing suitable canopy aeration.** A too dense canopy creates conditions of air stagnation with the development of a humidity gradient which hampers evapotranspiration by limiting the intensity of photosynthesis. Furthermore, an insufficient aeration spurs attacks by fungal diseases. The training shape is instrumental for good ventilation within the canopy.
- **Easing cultivation operations**. The training shape is conceived in order to ease some cultivation operations.
- **Reducing the costs of labour force**. The training shape is conceived in order to aid some operations made by hand or with some machines, mainly pruning and harvest, so as to increase the productivity of labour.
- **Respecting specific aesthetic parameters.** The training shape is also conceived in order to fulfil specific aesthetic needs. This aspect is very important for ornamental plants and for gardening. In the past, it was also taken into account for fruit cropping; at present, this need takes second place.

Shape pruning is carried out during the first years after planting so as to confer to the plant the selected shape, to complete the development of its scaffold and to ensure the start of fruit setting in the shortest time possible. This is obtained by reducing pruning, leaving a higher number of side branches than those needed to create the plant structure, cutting only the too vigorous branches or suckers within the canopy.
For the mechanization of harvesting with trunk shakers for vase-trained trees, plants shall be trained so as to obtain a 1-1.2 m high stem free from any vegetation onto which 3 to 4 primary branches are inserted with a 35° insertion angle; onto these primary branches, secondary branches are trained, numerous, short and without changes in direction; weeping branches are cut off since they do not respond to shaking. At the same time, trees must be allowed to grow in height not to reduce the fruit setting volume of the canopy. In the case of hand harvest or with harvest aids, the tree height shall be limited to 4-5 m and the canopy shall be allowed to develop in a broader way; this is obtained by bending the main branches with respect to the vertical axis (up to 40-45°) with longer secondary branches.

Picture 2 – Century-old olive trees' pruning in Salento (Apulia)

Production pruning

Production pruning is carried out when plants are adult. It is designed to maintain the shape conferred with shape pruning, to balance the growing and reproductive activity, to maintain the production ability over time and to suppress damaged parts of the canopy.
A crucial aspect of production pruning is its intensity. An over-pruning often reduces the production ability of plants. Also a too light pruning may be harmful since it may shade the inner canopy and induce high water consumption, thereby creating favourable conditions for the development of pests and pathogens and of water stress.
Production pruning should be carried out every year. Should that not be feasible (lack of labour force), apply production pruning every two years. In the year in which it is not performed, it is advisable to eliminate at least the sucker shoots in the inner canopy (this can be done also in the summer).
In century-old olive groves, where pruning is executed every 5-6 years, it is advisable to prune suckers every year. This allows to maintain a good equilibrium between vegetation and production and to reduce a too high vegetation density.
This treatment schedule helps complying with the regional decree on cross-compliance issued in 2009 which sets out common rules for direct payment to farmers as established by CAP and compels to prune olive trees at least once every 5 years (see Annex II of the Regional Decree transposing cross-compliance – Ministerial Decree transposing the EC Council Regulation n° 73/2009 of 19 January 2009 establishing common rules for direct payments to farmers following CAP).
In an olive grove whose management has a low impact on the environment, it is crucial to avoid excessive vegetation which may favour attacks by pathogens (peacock's eye) and plant pests (scale insects which induce attacks by sooty mould) mainly in wet areas. To this end, remember that cultivars may display different vigour, vegetation density and susceptibility to pests. Therefore, it is

important to opt for the right pruning intensity and timing in line with the environment, the cultivar characteristics and the effects of this practice on the plant health. Furthermore, it is important not to disturb the birds in the olive groves.
Most of these birds feed on insects and this contributes to maintaining the ecological balance in the olive groves. Thus, they must be preserved, offering them the possibility of nesting and of feeding. Trees with too sparse canopies are not good for nesting. Therefore, plants shall have a good canopy. A good management of pruning schedule could help guaranteeing these conditions. In the case of an olive grove with 50 plants/ha, it would be ideal to prune 15 to 16 plants/year so as to have a complete pruning interval of 3 years and to guarantee a suitable number of plants for nesting. This will also have a positive effect on the typical alternate bearing of the species.

Avifauna and insects
Insect-feeding birds, which are potentially present in the olive groves, are very important for the control of insects if account is taken of the high amount of energy a bird needs to fly. An insect-feeding bird can eat, in one year, an amount of insects which is 100 times its weight. In 1981, Groppali et al. calculated that in Italy 80 million birds of various species were present; 46% of them were insect feeders. This complex is likely to kill annually 275 kg of arthropods, mainly insects. Several birds such as hoopoe (*Upupa epops*), tree creeper (*Certhia brachydactyla*), blackcap (*Sylvia atricapilla*), Sardinian warbler (*Sylvia melanocephala*), mistle thrush (*Turdus viscivorus*), woodchat thrush (*Lanius senator)*, great tit (*Parus major*), blue tit (*Parus caeruleus*), cirl bunting (*Emberiza cirlus*), robin (*Erithacus rubecola*), scops owl *(Otus scops,)* wryneck (*Jinx torquilla* (Farinello et al, 1994)) starling (*Sturnus vulgaris*) nest in the trunks of century-old olive trees and feed on insects.
Other birds which hunt small animals, such as the owl (*Asio otus*), little owl (*Athene noctua*), or which are granivorous, as for song thrush (*Turdus philomelus),* wood pigeon (*Columba palumbus*), turtle dove (*Streptopelia turtur*), shelter in the olive groves and contribute to re-establishing the ecological equilibrium.

Pruning is designed to cut the plant parts which are diseased or attacked by insects so as to reduce inoculum sources. However, as for plants with severe olive knot attacks, infected portions shall be excised gradually not to reduce the leaf surface; in the meanwhile, copper-based treatments shall be made to combat the infection.
In case of olive knot or verticillium wilt, remember to disinfect the pruning shears in a copper-based solution before pruning healthy plants.

Pruning time

Pruning may be performed throughout dormancy. In the areas exposed to cold damages, pruning should be carried out after late frosts (in Puglia and Voukolies region the best pruning period is March) not to make plants susceptible to cold damages. Avoid late pruning which weakens plants since it removes the reserve substances mobilized in the reserve tissues along the canopy direction. Just in the case of vigorous trees, it is advisable to prune later (April) which reduces the growing activity to the benefit of reproduction with a higher equilibrium between both activities. Suckers within the canopy and at the plant base may be cut off in the summer.

2. Soil management and fertilization

Soil management is designed to achieve three main objectives:

1. improving soil fertility;
2. saving non renewable resources;
3. refusing the use of products which may contaminate the agro-ecosystem.

These three objectives yield some good basic practices:

- avoiding the losses of soluble elements;
- using legumes as nitrogen source;
- avoiding the use of synthetic chemical products;
- preserving the activity of soil-inhabiting plants and animals;
- erosion control.

Fertility

Scientists have provided different definitions for soil fertility such as "the ability of a soil to supply essential nutrients for the growth of plants" (American Society of Soil Science, 1966), or as "the condition of a humus-rich soil where growth proceeds rapidly and effectively" (Howard, 1956). In fact, fertility is the soil ability to guarantee good productions on a regular basis. This concept encompasses not only the notion of yield but also the one which refers to the quality of productions and disease resistance. It stands out to reason that the nutrient content is but one of the factors contributing to the soil fertility and not necessarily the most important one. The yield of a crop mostly stems from the development and the status of roots. The root system regulates the plant ability to uptake water and nutrients available in the soil within an area from a few millimetres to some centimetres. It is therefore clear that plant nutrition depends first on the soil volume explored by the roots and second on the availability of assimilable elements in the soil.

It is notorious that this concept is of utmost importance for vegetable and herbaceous crops. However, it deserves attention also in the case of tree crops and century-old olive trees whose roots have long inhabited the soil and are exposed to variable climatic conditions which are not always favourable to the plant well-being. The well-being of plants depends on the conditions in which their roots are, first in physical and then in nutritional and chemical terms.

Several factors may be modified to improve the soil fertility from the physical standpoint; they relate to the improvement of the relationship between air and water at the soil level. Hence, water and the soil structure upon which the soil porosity depends are the two main factors instrumental for improving the soil physical conditions. For the control of the water factor, a preliminary step towards improving the soil fertility is represented by trenches or drainage pipes in the case of water excess. Should water be scarce, it is advisable to install an irrigation plant when possible. Also the supply of organic matter helps improving the porosity and the water retention capacity which favour a better development of roots. The role of the organic matter is essential. Although it does not impact the texture (i.e. the balance between the clayey, sandy and silty fraction of a soil), it has a direct action on water retention, soil temperature, its aeration, soil life, its structure, mechanical resistance, colour, pH, chemical fertility.

Soil micro organisms and fauna are two more crucial factors of chemical and physical fertility. Their activity depends primarily on the above-cited elements: humidity, temperature, aeration and organic matter availability.

The organic matter content impacts the chemical fertility:

- A soil with good organic matter content tends to have an acid reaction (pH), since CO_2 gets released and phosphorus is more available.
- The organic matter effects the cation exchange capacity (C.E.C.), that is to say the quantity (in milliequivalents – meq) of exchangeable cations; for example, in 100g of soil 3-15 meq of exchangeable cations every 100g of phyllosilicates or 500 meq every 100g of humus.

In a low-impact olive growing, soil fertility and biological activity shall be maintained or accrued through the application of sustainable agricultural practices by combining activities such as cover cropping or green manuring through the use of plant or animal residues so as to reduce external inputs. The following techniques may be applied for a sustainable crop management:

- **Cover crops,** permanent or temporary; as for the latter, it is important to consider the cultivation of green manure species, mainly legumes, which may fix the nitrogen and increase the nitrogen content in the soil;
- **Incorporating organic matter in the soil**, possibly composted, coming from the very same farm, or from farms practising low-impact cultivation methods or from farms which do not apply intensive or industrial production protocols, or purchased from the market;
- **Use of off-farm fertilizers** both organic and mineral (of natural origin) only if the above systems do not guarantee a suitable nutrition of the cultivated plants.

Based on these principles**,** the management of the olive grove fertility may envisage the following agricultural practices**.**

Cover crop and tillage

Cover crop refers to the association of olive trees with sown or, as is in most cases, wild herbaceous species (natural cover crop).

Water erosion is a problem in many of our soils. This is not the case for flat soils. The danger of water erosion occurs as the slope increases. In Voukolies and in Puglia, rainfall is concentrated in periods when soils are still bare. Very heavy erratic rainfalls can occur quite often. Water erosion induces undeniable damages although they cannot be quantified. Wind erosion can also occur although its effects are less detrimental. In both cases, the only protection is to maintain the soil covered with vegetation or to associate a winter herbaceous crop, sown in autumn and mown or harvested at early-April, to protect the soil. Cover crop improves the soil physical properties thanks to dense feeder roots which are spread in a uniform and deep manner according to the species. Tap roots eases the deep penetration of water especially in the case of heavy rains.

Such a technique raises problems in conditions of scarce water due to the competition for water between olive trees and cover crop. In the case of annual rainfall below 600 mm, soil tillage is the best technique because it exploits water at most; rain water is stored, losses due to evaporation and weeds drop. However, soil tillage causes higher losses of organic matter by mineralization, erosion in sloping soils and a reduced soil carrying capacity just after heavy rainfalls.

A compromise may be reached with temporary and partial cover crop.

Temporary cover crop keeps the soil covered with herbaceous species; wild plants are allowed to grow or some species are sown in autumn-spring (with a high concentration of rainfall and lower competition for water); soil is tilled in spring-summer.

Partial cover crop consists of cover cropping between rows and tilling along rows; or cover cropping and tillage are made every two rows.

In Puglia and in Chania rainfall is not high and varies according to the areas between 400 and 600 mm/year. In these conditions, it is advisable to cover crop if supplementary irrigation is applicable.

If irrigation is not feasible at least in case of need, temporary or permanent cover crop (repeatedly mown to reduce competition for water to the minimum) is the right solution to preserve the organic matter content in the soil. Recent investigations have shown that water consumption is slightly higher with cover crop. However, thanks to the improved physical characteristics of the soil, higher water storage is obtained in the soil in spring which results in a better management of plants in the warmer period. This practice may be used even when water is not available.
In soils bare from autumn to late spring, nutrients and nitrogen are lost by leaching. This impoverishes the soil and pollutes the water table. In contrast, a covered soil acts in two ways: on the one hand, it hampers water runoff (surface flow) and on the other nutrients are stored in the plant tissues in the organic form and made available after the decay of plant tissues.

Cover cropping has several advantages:

- Maintains or increases the level of organic matter in the soil;
- Favours the presence of beneficials which control insect pests;
- reduces erosion in sloping soils;
- reduces soil compaction due to mechanical means;
- allows the development of olive roots also in the soil shallow layers;
- reduces nitrogen loss by leaching and, consequently, the risks of pollution of the deep layers of soil and water table;
- induces a better availability of phosphorus, potassium and of other nutrients along the soil profile;
- if it includes legumes, it may provide assimilable nitrogen;
- eases harvesting (easier movement of films and machines and reduced risks for olives to get muddy) and pruning.

In a silty soil, nitrates flow down, along the profile, one cm every three mm of rain; in a sandy soil, one cm every two mm of rain. It has been estimated that the "recovery" of this nitrogen may be often enough to pay for the cost of seeds of a green manure crop.

The root mass of a cereal is renewed 2-3 times during the growing season; it gives rise to a continuous release of organic matter, its roots perform a mechanical action of compression of soil particles which favours the creation of stable structural glomerules which improve the soil structure.

Managing cover crop

In the first 2-3 years of cover cropping, in soils with a fewer nutrients, it may be necessary to apply a supplementary fertilization to enhance the growth of the "meadow". Later on, supplies from the decay of mown material and of dead roots are enough for the feeding of the meadow which does not need additional fertilisers.
The turf shall be controlled with 2 to 4 mowings per growing season: the first at the start of spring and the others when the meadow reaches some 20 cm in height. If the grass is allowed to grow up to a greater height, the organic matter production increases along with the competition for water. Therefore, when water resources are available and in order to increase the organic matter supplied through cover cropping, mowing may be postponed. In contrast, when water is scarce, never delay the first mowing. Competition for water may be controlled by shortening the intervals between mowings. In spring-summer, mowing creates a mulching layer which helps reducing the losses of water by evaporation.
The height of mowing from the ground shall equal 5-6 cm, not to reduce the grass sprouting ability.

Every 3-4 years, in winter, it is advisable to grub the grass for air circulation in the soil. Permanent cover crop may supply 3-6 t/ha/year of dry matter which equals 0.6-1.8 t/ha/year of humus.

Green manuring (green fertilisation)

Green manuring is a useful tool for the management of soil fertility in the olive groves. As regards water resource, the same constraints and indications reported for cover cropping apply to green manuring. Green manuring may be total or partial. By total green manuring, we mean the incorporation of an herbaceous plant which is grown for that purpose; by partial sowing, we refer to the incorporation of crop residues grown for other types of production.
Green manuring is very important for the supply of organic matter when animal manure or compost are not applicable (they are not available in the area/ high costs of transport). It contributes up to 4-6 t/ha of dry organic matter which correspond to 0.4-1.2 t/ha of humus.
In southern areas with a long summer and mild winter, green manuring may be carried out with several autumn-spring herbaceous species (pulses, graminae, crucifers, etc.) sown individually or mixed up.

Table 1 – Green manuring: possible main objectives and species choice

Main objective	Choice of the species
Nitrogen fixation	Pulses
Organication of nitrogen residue in the soil (*catch crops*)	Crucifers, Graminae
Clod breaking and aeration of soil	Graminae, pigeon bean
Fast covering of soil	Rapeseed, horse radish, wild mustard
Water saving	Autumn-winter green manuring
Weed control	Crucifers
Flowers for bees in autumn-winter	Clovers, yellow mustard, pigeon bean
Additional production of fodder	Graminae-pulses mixtures

Mixing up several different species for a cover crop that will be buried is better than the use of a single species. By combining tap root pulses with fasciculate root graminae improves chemical and physical fertility (structure/permeability/porosity). In semi-dry environments like in Puglia and in Crete, a good practice implies the cultivation of autumn-spring species to be green-manured in March or April. Medium quantities of nutrients and biomass supplied with green manure depend on the selected species and soil conditions.

Table 2 – Biomass of some herbaceous crops for green manuring

Species	Green biomass (q/ha)
Pigeon bean (*Vicia faba minor* L.)	350-450
Lupin (*Lupinus* spp.)	300-350
Vetch (*Vicia sativa* L.)	250-300
Crimson clover (*Trifolium incarnatum* L.)	150-250

The autumn-spring species mostly used in Puglia are graminae and pulses. Very common are mixtures of barley and pigeon bean or of barley and vetch. The cultivation of pulses alone is advisable if one wants to maximise nitrogen fixation through green manuring crop. Pulses-based green manuring can make 50 to 100 kg/ha of nitrogen available; higher quantities are achieved

when pulses are used alone. These quantities can vary according to the environmental conditions and the season trend. To make most nutrients contained in the herbaceous species promptly available, mowing shall be performed at the time of earing for graminae and at the start of flowering for pulses. Mowing may be delayed to maximise the production of stable humus (conditioning effect) to improve the soil structure (and the soil water retention capacity); in this case, the fertilising effect, that is to say the supply of nutrients, will be slightly reduced.

Use of organic matter of plant or animal origin

To preserve or improve the soil fertility, it is important to supply organic matter. Organic substances of plant or animal origin which may be used for the purposes of fertilization are as follows:

- Cattle, sheep, goat, horse manure;
- compost;
- poultry dung;
- green manure;
- pruning residues;
- residues from olive processing, such as pomace and vegetation water;
- residues from the processing of bones, wool and hairs;
- leather scraps.

The above organic substances release nutrients gradually which are better supplied as the plants need them.

The first two types of substances fall within the group of plant or animal conditioners characterized by a low concentration of nutrients and a high content of organic matter and bacterial flora. Conditioners must be mature when applied to the soil; it means that fermentation processes responsible for their formation must be over and the residual organic fraction must be resistant to microbial attacks. Compost may be of plant origin (Green Composted Conditioner) or mixed (Mixed Composted Conditioner).

The organic material used must be available in the vicinity of the farm especially in consideration of the cost effectiveness of administrations.

For reducing external inputs, it is advisable to resort to a fertilisation technique based on olive chain residues such as pruning debris or pomace and vegetation water from olive processing.

As to the use of pomace and oil mill residues (vegetation waters), it is crucial to comply with the specific regulations establishing limits of acceptability and modes of use. In this respect, the maximum doses of pomace or of vegetation waters which may be administered equal 50 m^3/ha/year if obtained with pressurized oil extraction from olives and 80 m^3/ha/year in the case of continuous extraction systems. The amounts shall be established following the regulations enforced in the olive-growing regions.

Pomace and vegetation waters may be also mixed with other substances to obtain compost which acquires a higher fertilizing effect. To this end, it might be useful to compost pomace and vegetation water with the olive pruning residues, by adding straw, mowed residues, manure and/or poultry dung, etc. possibly directly in the field to reduce the costs of transport.

In general, manure and the other conditioners applied on an annual basis make 60-70% of the nutrients they contain available.

Purchasing off-farm compost depends on its price, which in turn is linked to the type of formula and/or packaging of product. By way of example, some firms sell powdered or pelletted compost in bags or in bulk with considerable price differences. Powdered and/or in-bulk compost may be cheaper than the pelletted or bagged one. This deserves much attention especially when fertilisers are chosen; various types of packages of formulations may call for different modes of transport or of delivery.

Manure or other organic materials, composted or not (pomace), should be made in autumn/winter after harvesting. If soil is tilled in autumn, administration shall be made before tillage. In the case of green manuring, organic fertilisers and phosphorus-potassium fertilisers may be administered when plants are sown (after the first autumn rains) or, in alternative, when the biomass is incorporated after mowing.

Criteria to determine the olive nutritional requirements

A balanced nutrition definitely contributes to achieving a good relationship between the growing and reproductive activity of plants. The olive tree takes up from the soil all the nutrients it requires for its growth. Fertilisation aims at improving or preserving the soil fertility, also through the administration of scarce nutrients by using products with a low impact on the environment (like those allowed in organic farming).
In order to estimate the nutrients to be supplied, it is useful to know the level of soil fertility, the nutritional status of plants and the factors that impact the plant nutritional requirements (plant age, production potential of trees, health status, irrigation, etc.). Useful tools are soil analysis, leaf diagnosis, uptake calculations and plant visual observation.
For a correct fertilisation, it is also expedient to know how the uptake of nutrients varies along the growing season.
For the main nutrients, remember that:

- Nitrogen is absorbed during the whole growing season; intensity is higher from blossoming to stone hardening;
- Phosphorus is absorbed in the first part of the growing season (phosphorus requirement is usually low);
- Potassium, whose uptake begins with the start of growth recovery, is used in high amounts during oil development in fruits.

Nutritional requirements are also based on the status of olive trees: if weak or declining, high doses are needed. For fertilisation, do not resort to the so-called recipes formulated on the basis of mean climate, soil and cultural conditions. The technician or the farmer shall set out the amounts of fertilisers to be used according to the amounts of nutrients in the soil (soil analysis), the plant health status (visual observation and/or leaf diagnosis) and the production level which may be achieved as a function of the environmental and agricultural conditions of the olive grove.
The values obtained from the soil analysis shall be compared with those of reference to detect nutritional deficiencies. In order to evaluate the nutritional status of plants, leaf diagnosis may be performed; it compares the nutrient content of the leaves in a given olive grove with the reference values under ideal conditions. The reference olive groves should be located in nearby areas with structural characteristics (cultivars, training system, etc.) similar to the olive groves under consideration; unfortunately, these data are not always available since leaf diagnosis is expensive and not commonly used apart from cases of nutritional deficiencies, excesses or imbalance. The best sampling time is winter dormancy (December-January).
Another approach to determining the nutritional requirements of the olive grove is calculating the amounts of nutrients which are taken up from the soil and not reintegrated. Uptakes to be considered for the so-called “uptake calculation” are as follows:

- Nutrients taken up from parts taken out of the olive grove;
  - ✓ Fruits, branches and leaves taken out of the olive grove after pruning;
- Nutrients which support the growth of the plant permanent organs:
  - ✓ Big roots, trunk, branches;
- Losses by leaching;

- Immobilizations in the soil.

Table 3 - Calculation of the quantities of taken-up nutrients (calculated on 100 medium-sized plants)

Parts of tree which are removed: fruits, wood and leaves	Loss of dry matter (kg/tree)	Nutrients in the dry matter (%)	Nutrients taken up from soil by 100 olive plants (kg)
Annual mean production: 15 kg olives/tree	8,25	Calcium 0,86 Phosphorus dioxide 1,10 Potassium 2,02 Nitrogen 1,18	Calcium 7,07 Phosphorus dioxide 9,09 Potassium 16,67 Nitrogen 9,74
Pruning material: 20 kg wood/tree	11,06	Calcium 1,44 Phosphorus dioxide 0,41 Potassium 1,94 Nitrogen 1,01	Calcium 16,69 Phosphorus dioxide 4,70 Potassium 22,45 Nitrogen 11,69
Pruning material: 5 kg leaves/tree	2,60	Calcium 2,54 Phosphorus dioxide 0,43 Potassium,73 Nitrogen 1,84	Calcium 6,60 Phosphorus dioxide 1,13 Potassium,09 Nitrogen 4,79
Parts of the tree which are not removed: roots, trunk and branches (quantity comparable to that taken up by 15 kg of wood)	8,07	Calcium 1,44 Phosphorus dioxide 0,41 Potassium,94 Nitrogen 1,01	Calcium 12,52 Phosphorus dioxide 3,52 Potassium6,83 Nitrogen 8,77
Uptakes/total requirements			Calcium 41,80; Phosphorus dioxide 18,10; Potassium1,60; Nitrogen 34,20

Based on the uptakes reported in the table, in an olive grove with plants at a distance of m 6 x 6 (278 plants/ha), the requirement of the most important nutrients may be estimated at about 50 kg/ha of phosphorus, 170 kg/ha of potassium and 95 kg/ha of nitrogen. These amounts refer to an olive grove which produces about 41 q/ha of olives; therefore, they shall be increased in olive groves with higher production potential. As for century-old olive groves, one shall take into account the number of plants/ha and the plant size.

Complementary fertilization

The use of complementary fertilisers, both organic and mineral, should be limited to the cases in which the use of cover crops and organic material of plant or animal origin, is not enough to ensure suitable plant nutrition.

Nitrogen-based fertilisers allowed are those from animal epitheliums, blood meal, hide, skins, hairs and wool, hoof, horn, desiccated manure, castor cake, etc. In general, these organic fertilisers release nitrogen more gradually than the mineral ones used in conventional agriculture. However, some differences exist among fertilisers as to the rate of nutrient release: for example those from blood meals release nitrogen much faster than those from hoof and horn. These differences shall be considered while choosing the period of administration. Fertilisers from blood meals shall be administered just before growth recovery; those from hoof and horn much earlier than growth recovery. Some fertilisers are very expensive (i.e. those from blood meal); this aspect deserves much consideration at the time of choice.

About potassium, organic fertilisers are also available, such as stillage and stillage extract, which have a prompt effect. When phosphorus is needed (which is not really the case in Puglia and in

Voukolies), and the mineral fertilisers used are the same as those for basic dressing, it is important to evaluate the soil reaction; soils with a basic pH immobilize phosphorus making it not available.
Several organic fertilisers are available on the market containing all the main nutrients; the label reports their per cent content (title).
For olive trees, nitrogen and potassium requirements are higher than phosphorus; fertilisers shall have a high titre for nitrogen and potassium and a low titre for phosphorus. This may be achieved by supplying different but complementary fertilisers such as one containing more nitrogen and another more potassium.
Poultry dung is a fertiliser that must be given alone or as a supplement of manure or compost.

Leaf fertilisation and fertigation with complementary fertilisers

Leaf fertilization and fertigation are not common fertilisation practices. They should be considered to overcome transient nutritional crisis (nitrogen deficiency in the period of blossoming-fruit setting when nitrogen is temporarily immobilized by the micro organisms which decay the organic matter with a high C/N ratio or in the first years of cover cropping) or microelements deficiencies, by using fertilisers which may be solubilized. These circumstances are not frequent for century-old olive trees.

Where applying fertilisers

When the canopy projection on the soil covers more than 50% of the surface, fertilisation shall be applied all over the olive-growing surface. In contrast, it is better to apply fertilisers along the margin of the canopy projection on the soil where the younger roots of the plant which absorb nutrients more successfully are located.

Fertilisation strategies

In olive groves without cover crop, producing 30-40 q/ha, fertilisation can be made by incorporating chopped pruning debris and supplying 20-30 t/ha of manure or compost having a comparable composition. In olive groves with higher yields, it is needed to increase the supply of manure/compost and/or supplying complementary fertilisers. It is also possible to alternate the supply of manure/compost and green manuring (with gramineae and pulses or pulses alone). These fertilisers shall be supplemented, when needed, with complementary fertilisers.
As to cover cropped olive groves, fertilisation with manure or compost is less needed. If these fertilisers are not available, nutritional needs of plants may be satisfied with complementary fertilisers.
Pruning debris must be ground in the case of green manuring or cover crop. Pruning debris shall be chopped at the time of green manuring or mowing. This combination, mainly with green manure, counterweights the uptake of nitrogen by microroganisms which decay pruning residues. Nitrogen-based fertilisations which supply ready-to-use nitrogen (20-30 kg/ha of nitrogen) (manure or compost) are expedient. Fertilisers may be turned under by breaking the turf made for air circulation in the soil which could be performed every two years. If soil erosion is a risk, manure/compost may be left on the surface.
All in all, should manure or compost be insufficient to meet the nutritional needs of trees, complementary fertilisers may be supplied.
About young olive trees, nitrogen is the basic fertiliser. Fertilisers shall be supplied in the proximity of plants. Requirements are 50, 80, 120 and 160 g of nitrogen/plant, in the 1st, 2nd, 3rd and 4th year after planting.

Assessing the efficacy of fertilisation plans

The efficacy of quantities and types of fertilisers, chosen based on the environmental and cultivation conditions of the olive grove (i.e. soil management, plant production potential, etc.) shall

be assessed from plant responses in terms of growth and production. If needed, adjustments shall be made.
The quantities and types of fertilisers supplied are suitable when the ideal yield is achieved in a given environment and cultivation conditions with good vegetative renewal with 20-50cm-long shoots which are the basis for the following year's production. If yield and plant growth are poor, the quantity of fertilisers shall be accrued. In contrast, if plant growth is too vigorous with several suckers, reduce the quantity of fertilisers. The ideal fertilisation plan results from the observation of plant response. These adjustments can be operated by taking into account also other practices which impact the plant response (pruning and irrigation). The soil analysis, to be performed at least every 5 years, may provide useful indications.

Tillage management

For a sound and cost-effective management of an olive grove which takes into account the need to preserve and improve the natural resources and the environment, attention shall be paid to soil tillage which may, sometimes, harm the soil structure and biodiversity and become a financial charge.
Tillage for soil management may be necessary if rainfall is scarce and irrigation not feasible.
In such circumstances, the first tillage in the year might be made after harvesting when tillage at a depth of 10-15 cm may be appropriate to turn under organic and mineral fertilisers with a low mobility and favour the penetration of rain water.
In spring-summer, some more 2-4 tillage operations can be made at a depth of 5-10 cm for the control of weeds and evaporation reduction.
To reduce the drawbacks of tillage, autumn tillage may be replaced with the mowing of weeds so as to have a cover crop from autumn to spring; this helps the movement of machines in the field and reduces erosion in sloping soils.

Soil management and water excess disposal

If the soil surface of an olive grove is irregular, it must be levelled so as to ease the movement of machines, to avoid water logging which causes not only asphyxia but also favours the attacks by the crown rot agents and verticillium wilt, plant weakening, and problems of soil erosion. At the time of thickening, in case of water logging, it is advisable to drain the soil down to 50-60 cm since plants are young.

Picture 3 – An intense water logging due to ineffectively surface levelling

On hillsides or steep soils, it is requested to hold in check erosion phenomena resorting to cover crop or digging trenches which interrupt the flow of surface water. Surface water is thus conveyed in trenches which allow for its disposal.

Soil management is often neglected giving rise to water erosion of the soil. In the Mediterranean area, rainfalls are often heavy despite their scarcity and these phenomena are quite common and contribute to worsening the soil structure and fertility. Over the years, it is advisable to resort to soil tillage to level the soil surface also for a better water flow management. These measures shall be applied also in the case of minimum tillage or of soil cover cropping. A good soil management allows reducing water excess, stagnation in the case of very heavy rainfalls; however it also improves water storage in the soil which extends irrigation intervals in dry conditions as is the case in summer time across the Mediterranean basin.

3. Irrigation

Olive trees are very resistant to drought thanks to their anatomic and physiological adaptation. Water requirements of olives trees are estimated at 600 mm/year (ETc = 600 mm). In the Mediterranean area where rainfall equals 600 mm/year, irrigation can definitely contribute to improving production and vegetation. It also helps olive trees overcoming critical periods due to high temperatures and drought in some phenological phases when plants are more susceptible to stress conditions. In environments with lower rainfall, irrigation improves the vegetative activity and yields. However, olive trees may survive and produce in conditions of very low rainfall (< 300mm). Century-old olive trees are well adapted to the environment in which they live. In the past, irrigation was less diffused and applied just in case of real need. These plants, usually large-sized, have big roots thanks to which trees can withstand water deficiency or abrupt flooding due to heavy erratic rainfalls.

Olive trees are more susceptible to water stress in the following periods:

- Pre-blossoming, blossoming and fruit setting;
- fruit growth by cell multiplication (from fruit setting to stone hardening);
- fruit growth by cell enlargement (from the end of stone hardening onwards).

Following the environmental and cultural conditions, seasonal irrigation volumes may even attain 2000 m^3/ha in intensive olive groves. For century-old plants, these volumes are extreme cases for the above-reported reasons. Water amounts shall be set out with great care so as to supply the amount which is really needed to ensure good production and growth without any excess that might create conditions favourable to pest attacks.
Trickle and drip irrigation systems are the best ones because they have a high efficiency and 90 to 95% of water is really used by plants.

Picture 4 – Mini-sprinkle irrigation system in olive grove

Drip systems prevent nutrient leaching; they do not wet the vegetation, do not favour pest attacks or the development of weeds since they wet small areas. For the same reasons, overhead sprinkler irrigation shall be avoided.
Olive trees are also susceptible to waterlogging. An effective irrigation system shall be combined with a water drainage system for the flow of rain water also in the case of heavy rainfall.

4. Pest and pathogen management

The balance between the production units of the agroecosystem (plots and farm) and the sustainable use of natural resources implies a perfect command of the characteristics of the olive groves and the application of a range of measures which can make our farms more “complex”, that is to say more similar to natural systems. This can help creating a certain level of “resilience”, the ability of a system to resist or tolerate some level of disturbance without compromising its ability to reproduce.
A high level of biodiversity in the agro-ecosystem is a basic condition to maintain a good balance between beneficials and insect pests. This is why in low-impact farms, it is important to re-establish and/or maintain a high biodiversity. This is made with natural and semi natural areas, such as woods, water ponds, rows of trees, hedges and through the appropriate management not only of cultivated fields but also of outlet rills and headlands. These are shelters and “production” areas (biofactories) for beneficial insects (predators, parasitoids, alternative preys), mites, birds and other animals (amphibians and small reptiles). These areas may be run by the farmer and provide complementary produce such as Mediterranean medlar trees, strawberry madrones and figs or timber and honey. To create groups of trees, shrubs, or hedges, native species shall be chosen; they are better fit for the environment without aggravating water needs or management.

Table 4 - Trees and shrubs for hedges plantation

type	species	common name	region
Trees	*Ceratonia siliqua*	Carob tree	Puglia
	Punica granatum	Pomegranate tree	Voukolies
	Ficus carica	Fig tree	Voukolies
Shrubs	*Myrtus communis*	Myrtle	Puglia/Voukolies
	Pistacia lentiscus	Lentisc	Puglia
	Rhamnus alaternus	Mediterranean buckthorn	Puglia
	Arbutus unedo	Mediterranean strawberry tree	Puglia
	Paliurus spina-christi	Christ's Thorn	Puglia
	Phillyrea latifolia	Mock Privet	Puglia
	Crataegus azarolus	Azarole hawthorn	Puglia
	Crataegus monogyna	Hawthorn	Puglia
	Pyrus spinosa	Almond Leaved Pear	Puglia
	Rubus ulmifolius	Elm-leaved bramble	Puglia
	Sorbus aucuparia	European rowan	Puglia
	Zizyphus zizyphus	Jujube, Red date	Puglia
	Anagyris foetida	Stinking Bean Trefoil	Puglia
	Calicotome spinosa	Spiny broom	Puglia
	Clematis cirrhosa	Virgin's Bower	Puglia/Voukolies
	Prunus spinosa	Sloe	Puglia
	Viburnum tinus	Laurestine	Puglia
	Scutellaria sieberi	Scutellaria	Voukolies
	Hypericum empetrifolium	St John's worts	Voukolies
	Cistus creticus	Pink Rock-Rose	Voukolies
	Melissa cf. officinalis L.	Lemon Balm	Voukolies
	Erica arborea	Tree heath	Voukolies
	Lavandula stoechas L. subsp. stoechas	Rabbit ears	Voukolies
	Origanum vulgare subsp. hirtum	Oregano	Voukolies
	Calicotome villosa (Poiret) Link	Spiny broom	Voukolies

Among the local species, attention shall be paid to those which improve the presence and/or multiplication of entomofauna and avifauna useful for the crop. Evergreen species will be envisaged as well; they may provide protection and shelter for the olive-grove inhabiting fauna in the wintertime such as Sardinian warbler (*Sylvia melanocephala*),blackcap (*Sylvia atricapilla*), song thrush (*Turdus philomelus*), European robin (*Erithacus rubecola*), wryneck (*Jinx torquilla*) (Farinello et al, 1994), common starling (*Sturnus vulgaris*), common wood pigeon (*Columba palumbus*), turtle dove (*Streptopelia turtur*).
Hedges are very important ecological infrastructure that favour the presence of beneficials and protect the soil from wind and water erosion. This is true especially when they are made of low and dense bushes together with high bushes and trees and have buffer zones 1.5 m wide.
Pebble walls are also very useful because they favour the presence of reptiles, such as lizards which feed on insects, and snakes (harmless) feeding on small rodents.
As to cover crops, a high level of biodiversity may be attained by managing the meadow with periodical mowing in alternate areas. Beneficial insects can thus migrate and a high community of arthropods may be maintained in the olive grove.
Natural and semi natural areas play their role at best if distributed with physical continuity with the ecological infrastructure on and outside the farm.
On the farm, the surface areas for maintaining a high level of biodiversity should never be less than 5% of the total area.
The availability of ecological infrastructure on a farm is important regardless of the farm size. As for small-sized farms, the shortage of shelter areas in the agro-ecosystem must be counterbalanced especially when natural areas are limited all around the farm and the nearby farms are deprived of ecological infrastructure. In the case of larger farms, the importance of ecological infrastructure increases in relation to the farm size in that the distance from cultivated plots is wider and the level of connection with the surroundings rich in biodiversity lower.
The following table reports some plant species native to our environment which enhance the presence of predators and parasitoids of olive insect pests. These plants should be preserved or used for establishing biological infrastructure.

Table 5 – List of useful plants

Plants favouring the presence of beneficial insects	**Beneficial insects**	**Insect pests under control**
Sandalwoods *Osyris alba (*L.*)*	*Chelonus eleaphilus* (parasitoid)	Olive moth
Honeylocust *Gleditschia triacanthos* (L.)	*Eupelmus urozonus* (parasitoid)	Olive fly
Thumbnail *Inula viscosa* (L.)	*Eupelmus urozonus* (parasitoid)	Olive fly
Jujube *Zyziphus sativa* (Gaertn.)	*Psyttalia concolor* (parasitoid)	Olive fly
Caper *Capparis spinosa* (L.)	*Psyttalia concolor* (parasitoid) *Chelonus eleaphilus* (parasitoid)	Olive fly Olive moth
Myrtle *Myrtus communis* (L.)	*Scutellista cyanea* (parasitoid)	Olive black scale
Lentisk *Pistacia lentiscus* (L.)	*Scutellista cyanea* (parasitoid)	Olive black scale
Mock privet *Phillirea angustifolia* (L.)		Olive moth

Hereinafter is a brief description of the plant species reported in the table.

Sheet 1 - Sandalwoods

Family: Santalacee
Scientific name: *Osyris alba* L.
Common name: Sandalwoods
Small-sized shrub of the Mediterranean scrub. 1.5 m high, evergreen, numerous upright twigs. Leaves develop in winter and are absent in summer. Flowers not showy and odorous. Male flowers are gathered in bundles; female flowers solitary, pedunculate and yellowish. Flowering from April to June. The fruit is fleshy (from September to October), bright red when ripe. Santalaceae are semiparasitic plants: although they have chlorophyll and are able to synthesize, they take up water and mineral salts from roots and twigs of other plants. Drupes, although good looking, are unpalatable as witnessed by the name *Osyris* which stems from Oxys = sour. Among beneficial insects it hosts is *Chelonus eleaphilus* which is a parasitoid of the olive moth (*Prays oleae*).

Sheet 2 – Honeylocust

Family: Leguminosae
Scientific name: *Gleditschia triacanthos* L.
Common name: Honeylocust
Honeylocust is not a native species despite its adaptation to the soil and climatic conditions of Puglia. It grows in any type of soil also in the poor ones. It is propagated by seed and flowers in May. Water requirements are very low. It is resistant to atmospheric pollution, tolerant to some shadow and is not damaged by winter frosts. Its twigs are fragile and are easily broken by the wind. Honeylocust is useful in the control of the olive fly (*Bactrocera oleae* Gmelin). This plant is infested by a cecidomyiidae dipteran, the honeylocust gall midge (*Dasyneura gleditchiae*), which produces typical reddish galls on the leaves. Thanks to the presence of this insect, mainly in August-September, a very useful insect is found *Eupelmus urozonus*, which parasitizes the gall midge, attacks the olive fly, in summer-autumn, when the olive fly induces the most severe damages. The honeylocust ensures the survival of *E. urozonus* populations in the olive agro-ecosystem also in the years of low olive bearing.

Sheet 3 – Thumbnail

Family: Compositae
Scientific name: *Dittrichia viscosa* (L.) Grueter
Common name: Thumbnail
This species is scattered throughout Puglia and Crete region both along the coast and inland at altitudes below 800 m. It grows in the ruderal environments, such as along the roads. It is hardy and vigorous and used in the programmes of land recovery, rehabilitation of quarries, escarps, etc.. During flowering from end-August to October, it takes a good-looking aspect due to its white flowers. The thumbnail is attacked by a dipteran, (*Myopites stylata*), which produces galls which contain the insect larvae. *Myopites* is parasitized by *E. urozomus* which grows on various larvae, including the olive fly. Larvae of *B. oleae* are parasitized between July and October. Later on, *E. urozonus* quits the olive and overwinters in the galls of *Inula viscosa*. Consequently, *Inula* ensures the survival of *E. urozonus* in the olive agro-ecosystem..

Sheet 4 – Common Jujube

Family: Rhamnaceae
Scientific name: *Zyziphus sativa* (Gaertn.)
Common name: Common Jujube
This species is not native to Puglia; it was introduced for its edible fruits and peculiar taste. It is now all over Puglia well adapted to its soil and climatic conditions. It can be found along the pebble walls; it is used in the boundary hedges thanks to its hardiness and small thorns which prevent animals from passing through. It is appreciated by pollinating insects for its heavy flowering and its palatable pollen. It flowers in May-July. It is propagated by seed or cutting. It enters dormancy late in autumn. It breaks dormancy in late spring.
In the jujube fruits, the larvae of *Carpomia incompleta*, develop. This fly is parasitized by *Psyttalia concolor*, the parasite of the olive fly. *Carpomya* is one of the few alternative hosts of *P. concolor.* This is why this shrub ensures the presence of the parasite also in the years during which the olive fly is absent. The plant plays an important role since it increases the biological diversity thanks to its fruits appreciated by birds and by numerous insect species.

Sheet 5 – Caper

Family: Capparaceae
Scientific name: *Capparis spinosa* L.
Common name: Caper
Native to Puglia and Crete where it is scattered throughout the region. This plant is usually found in rocky areas or on old walls and in ancient farmhouses where seeds are carried by the birds. Its ability to withstand long-lasting drought is ascribable to the structure of its leaves and to the numerous feeder roots. It blooms in May-July. It is propagated by seed or cutting. Capers may be easily marketed as fresh fruits or semi-processed. This species increases the presence of pollinating insects since its flowers are highly appreciated by these insects. The caper fly (*Capparimyia savastanoi* Mart.) is one of the very few alternative hosts of *Psyttalia con colour*. Thus, the plant ensures its presence. *Chelonus elaphinus*, beneficial against the olive moth, is quite effective against this fly although it may live on other Lepidoptera such as *Cydia capparidana* Zel.. *C. spinosa* may contribute to the presence of this insect beneficial against the control of the olive fly.

Sheet 6 – Myrtle

Family: Myrtaceae
Scientific name: *Myrtus communis* L.
Common name: Myrtle
Shrub typical of the Mediterranean scrub, evergreen, aromatic and highly ramified. Its leaves are leathery, flowers hermaphrodite and solitary. It produces round berries which turn black to bluish at maturity. It blooms in May-July. It likes sunny areas and soils with neutral or alkali pH. Berries and shoots may be used to produce an excellent liqueur. It plays an important role for the benefit of some beneficial insects which control the olive black scale (*Saissetia oleae*). Myrtle hosts *Scutellista cyanea*, which is a parasite of most of Lecanidae scales. In Puglia and Voukolies, this insect is the most active enemy of *S. oleae*, and is able to parasitize up to 70-90% of eggs. Myrtle is also infested by the scales which host *Scutellista*. It also hosts species predated by *Chilocorus bipustulatus* which is a very useful insect for the control of scales.

Sheet 7 – Lentisk

Family: Anacardiaceae
Scientific name: *Pistacia lentiscus* L.
Common name: Lentisk
Shrub or, occasionally, evergreen tree. Species typical of the Mediterranean scrub. Its fruits are small drupes 3-5 mm in diameter, first red and then black when ripe. It blooms in March-June.
It plays an important role for some beneficial insects which control the olive black scale. It hosts *Scutellista cyanea* which is the most active and widespread enemy of *Saissetia oleae*.

Sheet 8 – Phillyrea

Family: Oleacae
Scientific name: *Phillyrea angustifolia* L.
Common name: Phillyrea
Shrub 1-3 m in height, it rarely takes the shape of a tree; evergreen. Its bark is grey, opposite leaves, leathery and shining on the upper blade. Flowers are gathered in small axillary racemes with white-pinkish petals. Fruits are small drupes black to bluish in colour. It blooms in March-May. Phillyrea is spread throughout the Mediterranean basin. It is everywhere in Italy. It attracts the olive moth by which it is attacked (*Prays oleae*).

Weed management

No competition occurs between wild species and century-old olive trees neither for water, nor for light and nutrients. Natural or artificial cover crop exhibits several advantages as described in the paragraph about soil management. In this respect, it shall be specified that the old practice of soil ploughing just before summer was not intended to suppress the weeds as potential competitors for water but to break the capillary continuity and to prevent water losses due to direct evaporation from the soil. The olive roots explore soil areas which are much wider than those exploited by herbaceous species; this is especially true for century-old olive trees which have long been fit for our environments and climatic conditions.

Weeds may be controlled by several methods such as chemical weeding and soil tillage. Chemical weeding is not allowed in the case of low-impact olive groves.
Chemical weeding is based on the use of several types of molecules having different modes of action. Some herbicides are highly selective and attack one group or a few species. Their use can produce undesired mechanisms of resistance with an imbalance in the flora composition with agronomic and ecological problems. Non selective herbicides are more commonly used in the olive groves; their action is performed on all herbaceous plants. Indeed, in some plants the translocation rate of the weed killer is slower in some storage organs which are not completely devitalized. The new plants do not compete with other species and produce unbalanced cover crops. Herbicides and their metabolic products may be toxic to beneficial arthropods or fauna.
As seen before, tillage may further reduce the organic matter in the soil and become additional cost. Should the suppression of the cover crop be needed, it is advisable to make very shallow tillage not deeper than 15 cm not to speed up the mineralization process of the organic matter and the loss of water from the soil as explained in relation to soil fertility management.
Pertaining to weed control, an alternative to soil tillage is weed mowing at a height which slows down the sprouting of vegetation which will take place when the climatic conditions for the crop are more favourable. Mowing shall be done at a height of 5-6 cm from the ground so as to create a mulching layer which reduces the water losses by direct evaporation from the soil.

Weed control in localized areas

Even with low environmental impact management, it is sometimes needed to control individual weed species. In some cases, the prevalence of some wild plant species which turn out to be weeds compromise the biodiversity since they are very competitive against other wild plants which become more and more rare.
This phenomenon may be induced by the following causes:

- Repeated soil tillage which "select" or ease the propagation and dispersal of more resistant species such as Bermuda grass (*Cynodon dactylon* (L.) Pers.), porcellana (*Portulaca oleracea* L. subsp. *oleracea*) in the areas where machines pass and wood sorrel (*Oxalis pes-caprae* L.) and of its bulbs;
- Use and/or wrong distribution of prompt fertilizers, as is the case with several amarantacaee which prevail over the floristic cohort in some areas where nitrogen is abundant;
- Selection by herbicides.

In these circumstances, equilibrium in the community of wild plants may be re-established through different actions.
In some cases, the use of a land clearing machine which remove the vegetation and "deplete" the regeneration ability of some propagation organs may provide good results.
Some farmers resort to a land clearing machine to clear space under olive trees before harvest.

Another system for weed control is solarization. It is based on the use of a transparent polyethylene plastic film (PVC is not allowed in organic agriculture) to exploit the solar energy and rise the temperature of the soil; this action reduces the viability of seeds and of propagation organs in the shallow layers between 0 and 30 cm. This technique enables to suppress also most of the micro-organisms in the soil, pathogens included. Thermo-resistant pathogens are preserved. This technique is quite cheap and easily applicable. The soil to be treated is covered with a thin (0.05 mm) plastic film for at least 40 days in the hottest period of the year. To improve the efficacy of the technique, it is advisable to till the soil and to wet it just before the film is stretched; the presence of water promotes the transmission of heat from shallow to deeper layers. Solarization has proved to be an excellent technique in the warm areas. Sometimes, it is not successful to control Portulaca oleracea since this weed is thermophylic. It gives good results with wood sorrel (*Oxalis pes-caprae* L.) and its bulbs.

Pest control

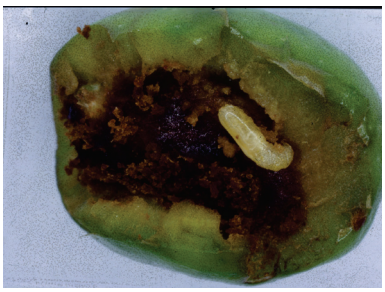
Pest control in low-impact olive groves is based on all factors and techniques made available in compliance with ecological, toxicological and economic principles. These techniques are intended to keep pest populations below the economic thresholds. The said control system implies agricultural, physical, mechanical and/or biological measures; should these methods be inefficient, technical means are applicable.

Thus, in low-impact olive farming, it is essential to create the conditions to reduce the presence of pests. Olive trees may be attacked by numerous pests although just a few of them can jeopardize the economic yield of the crop. The olive grower must be familiar with the pests that can harm his/her farm; this basic knowledge can help him making the best cultivation choice and reducing the damages induced by the key pests.

Hereinafter are some useful tips for the control of the main olive pests and pathogens.

Sheet 9 – Olive fly

Olive fly (*Bactrocera oleae* Gmelin)



Symptoms

On drupes are evident triangular-shaped bites, brown in color with a small hole, made from the female's ovipositor.
Dissecting the pulp there is the presence of a tunnel that can occur of different aspect:

- filiform if caused by first or second age larvae;
- cavernous whether caused by the third age larvae.

The possible presence of an outlet hole is a sign of flickering of the adult and the end of the cycle.
In years when heavy infestation occurs, it is possible to find more bites on same fruit.

Monitoring

Chromotropic (yellow) and/or pheromone traps (2-3/ha) are arranged in the middle of the canopy and controlled weekly to hold in check the evolution of the adult population.

Sampling

As from stone hardening, 100 olives are picked up weekly so as to assess the active infestation.

Limiting factors

Natural	Agronomic	Artificial
Climatic conditions • With summer temperatures above 36°C, death rate of eggs and I-instar larvae may also attain 90%. • Low values of relative humidity (< 50%) are unfavourable to the development of the insect. **Natural enemies** Insects *Psyttalia concolor, Eupelmus urozonus, Pnigalio mediterraneus, Eurytoma martellii, Cyrtoptyx latipes, Lasioptera berlisiana.*	• Choose small-fruited and early ripening varieties. • For soil management, resort, whenever possible, to cover cropping which favours the biocoenosis of beneficials. • Proper management of irrigation to protect olives at the time of high infestation risk. • Do not prune heavily since this reduces production and concentrates attacks on the few olives left which are bigger and more susceptible. • Do not leave fruits on the plants since they favour the continuity of the plant pest generations. • Establishing/managing ecological infrastructure (e.g. hedges, tree rows, etc.) with useful plants such as Acacia spinosa, Enula ceppitoni, Common jujube.	**Biocides** - Pyrethrum (adulticide) - Azadirachtin (larvicide-adulticide) To be applied all over the canopy. Their use is limited by high costs and poor efficacy. - Spinosad It is used at very low doses in olive farming. Excellent selectivity on the crop and on beneficial insects which allow reducing time of application, costs of distribution and water consumption. It can help reducing pollution from drift on the nearby crops; quite odourless, no residues are found in the oil. The olive fly is attracted by the bait on which it starts feeding; feeding takes place *ad libitum*; during feeding the fly does not lay eggs; after one hour, the fly stops feeding and start dying. Complete death occurs in 2-2.5 hours. It may be applied in two different ways either through pump with a single jet and single nozzle forming spots of 30-40 cm (5 litres of solution per hectare); or with pumps carried by a tractor which distributes the product along 15-20 cm –large stripes, single nozzle, single jet (max. 15 litres/ Ha). It suffices to treat 50% of plants (every two rows or every two plants). Treatment may start just after the first captures of adults or when thresholds are exceeded. **Protein baits** A blend of protein baits lured with natural pyrethrins sprayed on part of the canopy of all plants or of 50% of them (in this case treating every two plants or every two rows) based on the level of infestation. Protein baits attract adults which are then killed by the insecticide. This technique is not effective with high infestations. In case of heavy rains, baits are leached and they should be re-introduced. **Repellents**

		-Sulphur -Sodium silicate -Clays (kaolin) -Copper-based products To be applied with the first captures of adults. May be leached by the rain; in this event, repeat the treatment. Kaolin and copper have exhibited a good efficacy. Kaolin is quite expensive. **Biotechnical means** *-Mass trapping* Traps (one per plant or one every two plants) are applied on the south side of the canopy at a height of 2 meters as soon as the first adults are captured. It is always advisable to apply one trap on every single pant along the perimeter of the plot. Mass trapping shall be applied in wide areas (minimum 5 ha), where it gives good results in the first phases of fly infestation or if the pest pressure is not high. The cost of this system is quite high due to the high number of traps. ***Type of traps*** • Chromotropic (yellow) stocky traps covered with glue which attract the fly thanks to their colour and to the ammonium bicarbonate and/or pheromone. • "Mac-Phail" traps which catch flies attracting them with the ammonia produced by the biammonium phosphate; • "Attract & kill" traps, recently introduced, which attract the flies thanks to the action of a special feed and of a pheromone. Insects are killed by the synthetic insecticides (deltamethrin or lambda-cyalothrin) These insecticides are allowed only for traps used for mass trapping. **Biological control** May be applied using *Psyttalia concolor* (Sz.), releasing in the field high amounts of reared insects (inundative methods). Time of releases is established on the basis of weekly samplings of olive so as to identify the presence of larvae (II and III instars) which may be parasitized by *P. concolor*. The application of this technique is limited by poor results and high costs of production of the parasitoid.

Sheet 10 – Olive moth

Olive moth (*Prays oleae* Bern)

Symptoms

Tunnels of different shapes, according with the age of larvae, are visible on the leaves:

- filiform if caused by first age larvae
- C-shaped or circular spots for the larvae of the second age;
- widest spots with different shapes for the other ages.

In the flowering stage, erosions are detected on the flower buds due to young larvae feeding activity.
It is possible to found the exit hole of the larva in the area around the pedicle on drupe and the presence of excrement inside the kernel.
The early fruit drop (September), following the symptoms described herein, is the consequence of an infestation occurring in June.

Monitoring

Pheromone traps (2-3 traps/ha) are arranged in the middle of the canopy to capture the adults. They are inspected weekly so as to check the evolution of the adult population.

Limiting factors

Natural	Agronomic	Artificial
Climatic conditions • Eggs of the carpophagous generation are killed by temperatures above 27-28 °C. • Low values of air relative humidity (< 60%) reduce the percentage of egg hatching. • Numerous days with minimum temperatures equal to or below 0 °C induce a high death rate of overwintering phyllophagous larvae.	• Small-fruit varieties are advisable. • For soil management, resort, whenever possible, to cover cropping which favours the biocoenosis of beneficials. • Do not prune heavily since this reduces production and concentrates olive moth attacks on the few olives left which are bigger and more susceptible.	**Biological control** - *Bacillus thuringiensis* The carpophagous generation is the only potentially harmful one. *B. thuringiensis* efficacy on this generation is limited since the larvae hatched from the eggs on the olives penetrate the fruit rapidly. *B. thuringiensis*-based treatments on the antophagous generation have never given good results.

Sheet 11 – Olive black scale

Olive black scale (*Saissetia oleae* Olivier)

Symptoms

Presence of neanides or adults on vegetation (leaves and young branches).
In the case of massive attack a slight deterioration of the whole vegetation may occur.
As a result of production by the insect of "honeydew", it is possible to have the occurrence of sooty mold in a diffuse way on the tree canopy.

Monitoring

Visual monitoring is made to evaluate the presence of the scale in the canopy. If the scale is present, infestation is monitored on samples of 100 leaves at very short intervals (one week or less) when it is advisable to make treatments for the control of the insect.

Limiting factors

Natural	Agronomic	Artificial
Climatic conditions • The insect is controlled by cold winters which cause the death of eggs and of I, II or III instar crawlers. • High summer temperatures kill I instar crawlers. **Natural enemies** **Insects** *Chilocorus bipustulatus, Exochomus quadripustulatu, Scutellista cyanea, Moranila californica, Eublemma scitula, Coccophagus* spp., *Diversinervus* spp., *Metaphycus* spp., in particular *M. swirskii*, *M. bartletti, M. helvolus and M. lounburyi.* **Fungi** *Cephalosporium lecanii* and species of the genus *Isaria.*	• When new plantings are established, it is convenient to have wide distance which improves light and air penetration within the canopy. These conditions are not favourable to the scale development. • A sound annual pruning betters light and air penetration within the canopy which hampers the scale development. In contrast, biennial or polyannual pruning makes the vegetation dense which favours the scale development. • Remove by pruning and destroy attacked organs. • Proper management of fertilisation (mainly nitrogen) and irrigation so as to avoid excessive vegetation which creates conditions favourable to the scale development.	**Biocides** - Mineral oil When the scale is present, it is advisable to treat only if the number of living crawlers is above 4-5/leaf out of a sample of 100 leaves. The mineral oil is effective if directed against the I-instar crawlers. Therefore, in July-August, when eggs hatch crawlers under the body of the adult scales, it is advisable to perform monitoring weekly. When 70-80% of crawlers have hatched, a treatment is made. It shall be repeated after the complete egg hatching. While treating, be sure that the canopy is evenly wet. If the infestation is concentrated on a few plants, treat only the infested plants. A stereomicroscope is needed to evaluate the rate of egg hatching.

Sheet 12 – Otiorhynchus

Otiorhynchus, Cribrate Weevil (*Otiorrhynchus cribricollis* Gyll.)

Symptoms

Typical semi-circular notches cut out of the leaf margin. On young leaves these notches can occurs on the whole leaf surface, having relevant damages on the plant growing especially in nurseries and on young plants

Monitoring

In the period from May-June to the end of July and from September to November, to check the feeding actions of adults on the budleaves especially the younger. The absence of notches on young leaves indicates the good functionality of the physical means in preventing the upward movement of adults.

Limiting factors

Natural	Agronomic	Artificial
Natural enemies **Insects** *Forficula* spp.. **Entomopathogenic nematodes.** **Fungi** *Beauveria bassiana*.	• Leave some suckers at the trunk base. Otyorrhynchus will feed on the suckers' leaves and not attack the plant canopy.	**Mechanical means** *- Barriers or protective bands*. The adults attack the olive tree during the cool hours of the day and at night. In the peak of the day they shelter in the soil under the tree. For the control, barriers or protective bands are applied around the trunk or, in bigger plants, around the main branches. These barriers are of synthetic wool or wool resinate which trap the climbing insects. For better results, bands of 20 cm in height shall be used tied with elastic ties in the upper part so as to form a tunnel with its lager side downwards. Bands shall be applied also around the stakes; if a trickle irrigation system is available in the olive grove, bands shall be applied around the pipes. Synthetic wool bands last 2 to 3 years. In the past, plastic barriers (the insect slides) or sticky bands (the insect sticks on them) were used. Remember that the first are successful if applied on very smooth bark which creates a warm-wet microclimate under the band able to modify the plant cortical tissues. In sticky bands, the glue can cause phytotoxicity if it gets in touch with the trunk of the plant especially when young. The glue applied on the stake dries more rapidly than that on the plants. Therefore, it must be renewed more often. The glue may trap several beneficial insects such as syrphids, ladybirds and crisopae. **Biological control** It may be applied only against larvae using entomopathogenic nematodes or the fungus *Beauveria bassiana*. The application of these biological means is not convenient due to their higher costs and lower efficacy if compared with the above-cited mechanical means.

Sheet 13 – Margaronia

Margaronia, Olive fruit leaf moth (*Palpita unionalis* Hb.)	
Symptoms The young larva coming out from the egg – sited on leaves or on other parts of the plant – moves upward toward the apex of the shoot. Among leaves it prepare a cocoon made of silken filaments; in the case that young leaves are attacked, these are completely eroded. Final larval stages of this insect could feed on leaf and its central midrib; when a massive attack occurs, they can feeding on young olive fruits. Heavy damages are noted on nursery plants and grafted plants, but rarely also on adult plants with high level of young shoots attacked. **Monitoring** Pheromone traps are available. However, they are not used since the duration of the pheromone is limited (max. one week) and dispensers should be replaced very often with a rise in the costs. This is why it is advisable to monitor through direct visual observations of plants. In the period from April-May to July and from September to November-December, to check on the presence of new shoots and leaves eroded as well as of leaves connected by silken filaments with the presence of the larvae.	

Limiting factors		
Natural	**Agronomic**	**Artificial**
Climatic conditions • The insect is not able to grow with temperatures below 9-10°C. **Natural enemies** **Insects** *Syrphus corollae*, *Apanteles xanthostigmus, Nemorilla maculosa,* **Dipterans** **Neuropterans crisopae,** **Spiders.**		**Controllo biologico** - *Bacillus thuringiensis*. In genere, l'insetto non provoca danni significativi su piante adulte, mentre invece può essere pericoloso su quelle giovani. Su quest'ultime, al manifestarsi dell'attacco, per evitare il blocco dello sviluppo delle piante in altezza, si deve effettuare un trattamento con B. *thuringiensis* che, in caso di forte attacco, può essere necessario ripetere dopo circa 2 settimane. I periodi di maggiore pericolosità dell'insetto sono la primavera e il fine estate – autunno; pertanto, in tali periodi bisogna tenere sotto controllo le piante.

Sheet 14 – Wood borer

Wood borer, Leopard moth (*Zeuzera pyrina* L.)

Symptoms

The presence of the larvae is indicated by the yellowing of the foliage on the whole canopy or on a part of it as well as the presence of dead branches. On twigs and branches it is possible to find the exit holes made by adult, accompanied by sap outflows. In estreme events the entire tree dies, especially if it is a young plant

Monitoring

To monitor diffuse or localized yellowing of the canopy, as well as the presence of the entry/exit holes of the insect.
Before the start of pupations, (April), 2-3 pheromone traps/ha are arranged just above the tree canopy to monitor the insect.

Limiting factors

Natural	Agronomic	Artificial
Climatic conditions • The insect does not grow with temperatures below 9-10 °C. **Natural enemies** **Insects** *Apanteles* spp., *Microdus conspicuus, Pristomerus vulnerator, Rhaphitelus maculatus*. **Fungi** *Verticillium lecanii, Beauveria bassiana*.	• Attacked branches must be pruned and destroyed. • Irrigated and fertilised plants can withstand the insect better. • Vigorous plants may respond to the attacks producing exudates in the larva entry hole. These exudates dry, turn crystalline and may enclose the young larva killing it.	**Biotechnical means** *- Mass trapping* Before the start of pupation (April), 8-10 pheromone traps/ha are applied just above the tree canopy. Pheromone dispensers shall be replaced periodically. Limiting factors for the application of this system are the high costs of traps and its use over wide surface areas. **Biological control** The use of endoparasitic nematodes *Steinernema feltiae* and *biblionis* and of the fungus *Beauveria bassiana*, introduced in the gallery through cotton flocks, may effectively control the larvae. However, the method is expensive. **Mechanical means** At the start of pupations, as detected by the traps for the insect monitoring, check the plants frequently to identify entry holes of larvae. After this operation, a thin iron wire with a hooked tip is introduced in the hole to reach and kill the larva; if the larva is extracted, the success of the operation is guaranteed.

Sheet 15 – Olive knot

<table>
<tr><td colspan="2">Olive knot (Pseudomonas syringae sp. savastanoi Van Hall)</td><td rowspan="2">  </td></tr>
<tr><td colspan="2">Symptoms

Symptoms are the presence of “knots” or galls generally on branches, but also on leaves and trunk. Knots initially appear smooth and green; later on they become gray, increase in dimension with a rough surface. At early stages they appear isolated and then, as the disease proceed, they converge to affect the entire branch.
On the knot surface, several breaks are opened, through which bacteria can go outside during rainy days or when high air humidity occurs.
Heavy infections are able to determine defoliation, damage to upper stems that can lead to reduced fruit fill and total yield.

Monitoring

Check for the presence of the disease on the plant in order to assess the severity of infection; it is of utmost importance to verify the presence of tubercles on the young productive branches.</td></tr>
<tr><td colspan="3">Limiting factors</td></tr>
<tr><td>Natural</td><td>Agronomic</td><td>Artificial</td></tr>
<tr><td></td><td>• Choose olive knot-resistant varieties.
• The organs attacked by the bacterium shall be removed with pruning. Prune in dry periods by limiting large cuts.
• During harvesting, reduce lesions on plants.
• Keep plants in the best growing conditions by means of balanced fertilisations.
• After pruning infected plants, disinfect pruning shears before the operation is repeated on another plant. Infected plants shall be the last to be pruned.</td><td>Biocides
- Copper-based products (oxychloride, Bordeaux mixture, oxide or hydroxide).
Curative treatments are not applicable; the control of the olive knot is based on preventive treatments.
The bacterium penetrates through the wounds. Therefore, in case of frosts or hail, which damage plants, it is necessary to make a copper-based treatment especially when olive cultivars are very susceptible to this disease. About susceptible varieties, if harvest is made with machines or mechanical beaters, which are likely to damage branches more severely than in the case of manual harvest, it is advisable to carry out a copper-based treatment after harvest and in a short lapse of time mainly when temperatures are mild and the air relative humidity high.
In very infected plants, a copper-based treatment may be needed just after pruning.</td></tr>
</table>

Sheet 16 – Peacock's eye

Peacock's eye (*Spilocea oleagina* Cast. Hugh)

Symptoms

Appearance of dark-brown spots on the upper surface of the leaves; during the summer they appear surrounded by a yellow halo. In older infections it is possible to see concentric zones accordingly with the different stages of development of the fungus. These symptoms are usually followed by a yellowing of the leaves and their early fall.
On the fruits next to the maturation brownish markings of a few millimeters occur

Monitoring

Pick from the olive trees 10-20 branches representative of the whole plot, then remove all the leaves and form a single sample from which 100 leaves will be drawn. During early stages of the vegetative period, in early spring or late autumn can be easily detected with the presence of spots of Peacock's eye on the leaves.
.It is Important to identify in a timely way the presence of infections in spring when they are still under incubation, using the method of early diagnosis and determining the percentage of infected leaves.
The diagnosis is made in late summer (July, August) dipping the leaves for 1-2 minutes in a solution of 5% NaOH heated to a temperature of 50°C. In the case that young leaves have to be analyzed, it is possible to use the solution at room temperature.
This monitoring can be carried out also in the spring period, to verify the percentage of infection already present in the olive grove.

Limiting factors

Natural	Agronomic	Artificial
Climatic conditions • Temperatures above 30 °C or below 5-10°C limit the start of infections.	• Do not plant susceptible varieties in wet areas (ex. Valleys, near lakes, etc.). • When a new olive grove is to be established, avoid too narrow planting distance in that, when plants become adult, it promotes shadowing and a wet microclimate within the canopy favourable for the pathogen. • A sound annual pruning increases light and air penetration in the canopy and hampers the development of the peacock's eye. Biannual or polyannual pruning make the vegetation denser which favours the pathogen development. • Do not apply overhead sprinkler irrigation.	**Biocides** - Copper-based products (oxychloride, Bordeaux mixture, oxide or hydroxide). In case of severe attacks from the previous year, shown by defoliations in the lower half of the canopy, make a copper-based treatment before growth recovery to reduce the inoculum. Make another treatment to protect the new vegetation from the pathogen attack using copper-based products before blossoming (15-20 days before blossoming), when the first 3-4 leaf knots have formed in the shoots. In July-August, it is appropriate to make an early diagnosis to identify new infections. If the test is positive, plan another treatment to be made at end-summer, early-autumn when the typical spots by the peacock's eye appear on the upper leaf blade. Early diagnosis is made by dipping a sample of 100 leaves in a 5% sodium or potassium hydrate solution, for 2-3 minutes at a temperature of 50-60°C for mature leaves and of 20°C for young leaves. In the infected leaves small dark spots appear.

5. Olive harvesting

Harvesting time

Harvesting time must be chosen considering the evolution of the olive oil quantity (oil yield) and quality that is to say its fatty acid composition which varies with the ripening of olives. Olive resistance to removal drops during ripening making the fall of fruits easier.
In the choice of the harvesting time, we may consider the efficiency in terms of yield (% of detached products) and the harvesting efficiency of machines with the same level of ripening and variety.
In general, an early harvesting produces oil which is green in colour, herbaceous-fruity, high levels of bitterness and pungency due to its high phenol content. During ripening, phenol substances (important antioxidants both in the oil and in the olives) increase first and then drop. Late harvesting results in oil less green or turning to yellow, with fruity but less bitter taste and strong flavour. Oils with intermediate characteristics are obtained harvesting olives at an intermediate stage.
By and large, the oil sensory characteristics are of high level until the pigmentation of olives covers just the surface (skin), and tend to decay when the colour extends to the pulp (sensory levelling). During ripening, olives become progressively soft and more susceptible to mechanical damages. They can get wounded after harvesting operations, transport and storage prior to processing. The bruise can cause the onset of oil alteration (souring and oxidation) inside the fruits.
The amount of oil that may be obtained from an olive grove increases during ripening as it results from the oil content increase in the olives. However, as ripening goes on, some product is lost due to fruit drop.
At an early stage of harvesting, oils are more characterized from the sensory viewpoint but the quantity obtained is not very high. In an intermediate stage, quantity and quality of oil are satisfactory; in a later stage, oils may be flat from the sensory viewpoint and the quantity may be low due to heavy drop.
As to PDO or PGI area and the oil is to be certified, the harvesting time shall be chosen in consideration of the production specifications on the time of harvesting and the analytical and sensory characteristics of oil.
The evolution of fruit ripening and of oil quality is influenced by the climatic pattern and by the fruit bearing. A heavy bearing slows down the ripening of olives whereas in plants with a low bearing, the same process is speeded up.
In the case of late attacks by the olive fly, it is advisable to anticipate harvesting in order to minimize damages which reduce both oil quantity and quality; this is very important for organic crops.
The harvesting time shall be chosen according to the evolution of quantity and to the primary objective of the farm: an early harvesting to obtain an oil which is strongly characterized in sensory terms and rich in antioxidants such as phenols (novel oil or oil with a high nutritional value), intermediate stage and in some cases medium-late, for cultivars with a limited drop, to get a standard extra virgin olive oil for the retail market (this period meets the indications provided by the production specification of PDO and PGI oils).
It shall be specified that there are cultivars which allow to obtain strongly characterized oils with a high antioxidants content (phenols) also in medium and medium-late harvesting time (for example, Coratina).

Early or medium-early harvesting is advisable for the production of organic oil, since the consumer of this product pays attention to safety, healthiness but also to the quality of the product. Therefore, an early harvest reduces the risks resulting from late attacks of the olive fly.

Harvesting methods

The oil quality is strongly impacted by the olive integrity; that is why, it is important to limit the damages on fruits while harvesting. Bruise and wounds on olives can put the oil inside the fruits in contact with enzymes which catalyze alteration processes (souring and oxidation) and that may speed up the development of microorganisms (moulds) if olives are not immediately processed.
Olives shall not be picked up from the ground or nets under the plants; these systems worsen the quality of oil.

Picture 5 – Hand-made harvesting of olive

Olives must be picked up from the plant as follows:

- **By hand** with manual combs and nets laid under plants to collect the product;
- **With harvest tools** that ease fruit removal, such as rods/whips, combing units, shakers, ecc. and with the aid of nets laid under the trees;
- **With shakers** clamping the trunk or branches, according to the size of plants; in case of application to the trunk, they can be equipped with catching films (reversed umbrella) which allows to mechanize the operations following fruit removal;
- **With mechanical beaters** mounted on tractors for the removal of olives with nets on the ground.

Picture 6 – Olive harvest made with a vibrating shaker

The use of machines is suggested whenever possible. In case of mechanical damages to plants, the use of machines shall be reduced. These conditions are not frequent and may be as follows:

- **debarking** as in the case of shakers of the trunk if plants are still in full vegetation at the time of harvesting;
- **lesions affecting the vegetation,** in the case of harvest aids and mechanical beaters, if harvesting is carried out very early mainly in varieties with small fruits highly resistant to detachment which call for a longer mechanical action.

In both cases, the above drawbacks may be reduced by postponing harvesting.
In case of mechanical lesions on the vegetation and with cultivars susceptible to the olive knot, it is advisable to perform a copper-based treatment.
When aiding machines are used, do not step on the olives on the films. Mechanical beaters induce more damages than other harvesting systems; if processing occurs immediately after harvesting, these damages have no impact on the oil quality. The use of machines and of shakers in particular, allows to concentrate harvesting in the selected period and to have suitable amounts to be carried to the mill in a short lapse of time. In this way, it is possible to get oils of high quality.

6. Thickening and replacing dead plants

Century-old olive groves often have a number of plants/hectare lower than that of more recent olive groves. The number of plants/hectare is often low, sometimes even 48-50 plants/ha or less; therefore, to increase the economic yielding of an olive grove, the farmer may decide to thicken the olive grove by planting new young trees.
As to century-old olive groves, it is not advisable to have a plant density higher than 120 plants/ha especially in rain-fed areas. This choice is justified by agronomic, or landscape reasons or by the need to protect biodiversity.

From the agronomic point of view, the distance between trees depends on the variety (which impacts the vigour), the training system, the soil and climatic characteristics and on the cropping technique. Remember that canopies of olive trees must not get in touch when olive groves are thickened; an excessive density can create shadow and canopies tend to grow upwards which needs pruning operations, may unbalance the ratio between vegetation and production and reduce the olive grove productivity. Shadowing phenomena reduce the vegetation aeration thereby creating conditions more favourable to the attacks by pathogens and plant pests; the application of low-impact production methods becomes harder.

From the ecological viewpoint, the fauna that may be found in the olive groves is highly variable and takes its shelter in the olive canopies, in the part of the soil covered by the vegetation or in the ecological infrastructure which usually occurs in these olive groves. About the protection and preservation of biodiversity in the century-old olive groves, a moderate thickening can be advantageous for the following reasons:

- A wide and usually irregular planting distance eases a good equilibrium between the tree and herbaceous vegetation. We shall not forget that these farming areas exhibit a good level of biodiversity by virtue of the equilibrium between trees and natural or artificial cover crops.
- A wide planting distance implies a low level of disturbance of the environmental conditions of the century-old olive grove. With a low number of plants/ha, it is possible to carry out most of the practices for the management of an olive grove and to get a quality produce with little impact on the wildlife. Fertilisation, pest management, clearing space under trees are operations which regard the part of soil corresponding to the tree canopy. Wide planting distance guarantees areas which are undisturbed, where small animals, birds, arthropods may keep living. With higher planting density, every single type of agricultural practices covers the whole surface area thereby disturbing the fauna and causing a deep impact on the environment.

It may be stated that the number of plants/ha impacts the intensity of cropping operations and the impact of agricultural practices on the surrounding environment.

The conditions and levels of diversity of populations and community living in the century-old olive groves may be protected by thickenings which do not modify the equilibrium. This means that the planting distance must be maintained equal to **10x10m or maximum 8x8m**.

A more reduced planting distance, such as 6x6m, with a number of about 278 plants/ha, does not meet the need to protect biodiversity and the environment.

Another reason why it is important not to exceed a certain number of plants/ha with thickenings is the protection of the landscape. The agricultural landscape of century-old olive groves is characterized by about 100-120 plants/ha. Our olive groves are well balanced in the relation between herbaceous plants and trees; they are good looking which is at the basis of their landscape value; this shows that the human print on the landscape does not always compromise the environment.

A higher number of plants per hectare imply a change in the olive grove aspect. This transforms the original century-old olive grove into a common grove or even in an intensive one whose aspect is definitely different from that of a century-old one.

To avoid the loss of such a landscape heritage, it would be advisable not to have a number of young plants higher than 40% of the total number of plants.

Century-old monumental olive trees and olive groves (Regional Law n. 14 of 4 June 2007)

In Puglia Region where several olive plants exhibit a monumental character, a regional law rules the criteria by which the monumental character is assigned to both olive trees and olive groves. Paragraph 3 of art. 2 of the regional law n. 14 dated 4 June 2007, "Protection and enhancement of monumental olive grove landscape in Puglia" ("Tutela e valorizzazione del paesaggio degli olivi monumentali della Puglia"), rules that the monumental character may be assigned to olive groves having at least 60% of monumental plants within the unit identified in the related cadastral parcel.

As to olive trees, the monumental character is assigned as follows:

Art. 2

(Definitions)

1. The monumental character is assigned when the olive plant is several centuries old as inferable from:

a) size of the plant trunk, with a diameter equal or higher than 100 cm, measured at 130 cm above the ground; in the case of trees having a fragmented trunk, the diameter will refer to the one obtained by reconstructing the theoretical shape of the whole trunk;
b) historical-anthropological value as assessed by documents or iconic-historic representations.

2. It may disregard the characters set out in paragraph 1 in the case of trees having a diameter between 70 and 100 cm measured reconstructing, when the trunk is fragmented, the theoretical shape of a whole trunk in the following cases:

a) sculptural shape of the trunk (spiral-like, honeycomb, hollow, flag-like habit, mamillary formations);
b) recognized symbolical value assigned by a community;
c) located close to historic-artistic, architectural, archaeological sites recognized in the meaning of the legislative decree 22 January 2004, n. 42 (Code of cultural heritage, in the meaning of article 10 law dated 6 July 2002, n. 137).

Choice of varieties

Despite their genetic similarities with varieties that are still grown, century-old olive groves show some differences. Century-old varieties differ form the ones on the market since the varieties now available result from man-made selections intended to improve some pomological, morphological traits which could better their productivity or modify the training mode of this species in various growing environment. Century-old trees have a germplasm which has survived over the centuries able to adapt to different growing conditions.
The longevity and productive ability of century-old olive trees witness to their adaptation to our environment, to their ability to resist adverse conditions making them a real response to the challenge thrown down by the climate change.
When deciding to thicken a century-old olive grove, especially in the case of monumental groves, it would be better to use plants whose genetic resources derive directly from those of century-old plants in the area. This may guarantee a successful crop but also maintain and preserve the genetic resources of century-old plants thereby preventing the risk of extinction.

Whatever the variety selected for the thickening of the century-old olive grove, to apply the low-impact method in a given environment, the olive grower shall evaluate the adaptability of varieties available, and work out the better cropping schemes based on their characteristics.
Puglia Region is one of the most important olive-growing areas with the highest number of cultivated varieties, about 50, mostly autochthonous; out of them, 4-5 cultivars (Ogliarola salentina, Coratina, Cellina di Nardò, Ogliarola barese and Ogliarola garganica) are widespread over several thousand hectares and are economically relevant for the regional agricultural economy.
In Crete region, 3 out of 60 Greek cultivars are widespread cultivated, Koroneiki, Tsounati and Throumbolia.
Hereinafter are the main characteristics to be considered to evaluate the conformity of cultivars to the low-impact farming method.

Table 6 – Main characteristics in cultivars' choice

Varieties	Justifications
With low susceptibility to adverse biotic events	In a low-impact olive farming, the management of pathogens (ex. Peacock's eye, knot, etc.) and pests (ex. fly, scale, etc.) is harder; therefore, the use of resistant varieties plays a major role.
Hardy, with good resistance to abiotic adverse events	They are more tolerant to stress conditions due to environmental factors (ex. low or high temperatures, drought, high windiness, salinity, low soil fertility, etc.), which weaken plants; they are less susceptible to biotic adversities. Hardiness allows obtaining satisfactory productions without the need for high nutritional and water supplies.
Small fruit	Among abiotic adversities, the olive fly brings up great difficulty for the application of low-impact control methods. Furthermore, it lays eggs on the lager-sized olives. Moreover, in the small fruits, high or low temperatures can kill more easily the larvae in the pulp.
Early colour breaking	They allow reducing the impact of late attacks by the fly.
Early ripening	Olives may be picked up earlier thereby avoiding late fly attacks.

Main characteristics of the olive cultivars grown in Puglia and Crete.
Here you find the main characteristics of century-old olive cultivars grown in Puglia and Crete for the production of oil.

Table 7 – Vegetative, productive and biological characteristics, susceptibility to abiotic and biotic adversities and quality of the oil from the main cultivars grown in Puglia and Crete for oil production (source: Pannelli and Alfei, 2008; Therios, 2009)

Variety	Vigour	Habit	Fertility	Entry into bearing	Production potential	Weight per fruit unit	Oil yield
Koroneiki (Crete)	M	Br	Self-sterile	E	H	Lo	H
Tsounati (Crete)	M	Br	Self-sterile	E	H	Lo	H
Throumbolia (Crete)	M	U	Self-sterile	E	Lo	M	M
Cellina di Nardò	H	Br	Self-sterile	E	H	Lo	M
Cima di Mola	H	Br	Self-sterile	E	H	Lo	H
Coratina	M	Br	Partially self-sterile	E	H	M	H
Ogliarola Barese	H	W	Partially self-fertile	M	H	M	M
Ogliarola Garganica	H	W	Partially self-fertile	M	H	M	M
Ogliarola Salentina	H	Br	Self-sterile	E	H	Lo	H

Variety	Time of pigmentation	Pulp firmness	Oleic/ (Palmitic + Linoleic)	Total phenol content	Susceptibility to pests and adverse environmental conditions			
					Frost	Peacock's eye	Knot	Fly
Koroneiki (Crete)	M	M	M	M	M	M	M	Lo
Tsounati (Crete)	L	M	M	M	H	M	M	Lo
Throumbolia (Crete)	M	M	M	M	Lo	Lo	M	M
Cellina di Nardò	M	M	M	H	M	Lo	H	Lo
Cima di Mola	E	Lo	M	H	Lo	Lo	Lo	Lo
Coratina	L	H	H	H	H	M	M	M
Ogliarola Barese	L	H	M	M	M	M	H	M
Ogliarola Garganica	L	H	M	M	M	M	H	M
Ogliarola Salentina	E	Lo	Lo	H	Lo	Lo	Lo	Lo

Legend: H = High; M = Medium; Lo = Low; E = Early; L = Late; U= Upright; Br= Broad; W = Weeping.

Choice of the training system

For thickening an olive grove, the training systems shall allow

- Rapid growth and early entry into bearing of plants;
- Good light penetration in the whole canopy;
- High and constant production;
- A microclimate within the canopy which does not aid the development of fungi and of insect pests;
- Easier cultivation operations, with special reference to pruning and harvesting.

The following table reports the main advantages and drawbacks of the training systems for olive trees.

Table 8 – Main characteristics of typical training systems

Training system	Advantages	Drawbacks
Vase	Excellent light and air penetration in the canopy (high photosynthesis and conditions unfavourable to the development of plant pests and pathogens); if grown with a single trunk at least 1-1,2 m high and with main branches having a relatively narrow inclination angle, this system is fit for mechanical harvest with trunk shaker and catching film..	Not fit for mechanical pruning for which espalier training system is advisable.
Monocone	Shape pruning is simple; it allows mechanizing harvest operations with trunk shaker; fit for mechanical harvesting.	Especially with vigorous varieties, an excessive upward and side (in the lower canopy) development occurs for vegetation); this calls for severe pruning which may cause a vegetative-productive imbalance.
Globe	Early fruit setting; the vegetation protects the main wood structures from sun excess.	The inner canopy is often shadowed; plant protection products can hardly penetrate the innermost canopy; due to its structure, harvesting may become more difficult.

For thickening, the vase training system is advisable in most conditions since it allows for good production levels, mechanical harvesting and an excellent light and air penetration in the canopy. The vase training system also responds to the landscape and aesthetic characteristics of century-old olive trees.

LIFE+ Cent.Oli.Med. (LIFE 07 NAT/IT/000450)
Identification and conservation of
the high nature value of ancient olive groves
in the Mediterranean region

LIFE+ "CENT.OLI.MED." (LIFE07 NAT/IT/000450)
PROJECT SECRETARIAT
CIHEAM - Mediterranean Agronomic Institute of Bari
via Ceglie, 9 - 70010 Valenzano (Bari) - Italy
tel/fax (+39) 080 4606304 - lifecentolimed@iamb.it
www.lifecentolimed.iamb.it

CIHEAM IAM BARI

Ministero dell'Ambiente e della Tutela del Territorio e del Mare
Direzione Generale per la Protezione della Natura

REGIONE PUGLIA
Assessorato all'Ecologia
Ufficio Parchi e Riserve Naturali

CIHEAM MAI CHANIA