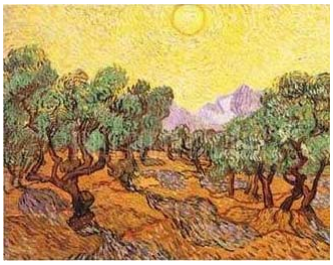
"Setting up a network of Technology Dissemination Centres to optimise SMEs in the olive and olive oil sector".



OLIVE TREE CULTIVATION

Index

Introduction

Orchard planting

Pruning

Irrigation

Fertilization

Weed control

Fruit harvest

Pests

Diseases

Web Links

This booklet has been written to help the non-producing / consumers of olives and olive oil across Europe. Focusing towards the variety of consumers in mind, including small business owners, entrepreneurs, managers and the home user.

"The olive encyclopaedia is a collection of 12 publications part of the project **TDC-OLIVE** which aim is to collect the information related to the olive sector and make it accessible to the interested public".

"This publication has been carried out with support from the European Commission, Priority 5 on Food Quality and Safety (Contract number FOOD-CT-2004-505524 Specific Targeted Project), 'Setting up a network of Technology Dissemination Centres to optimise SMEs in the olive and olive oil sector'. It does not necessarily reflect its views and in no way anticipates the Commission's future policy in this area."

TDC OLIVE

Introduction

TDC-OLIVE project is an initiative included in the Sixth Framework Programme of the European Union, aimed to table olive and olive oil SMEs. Its main target is the creation of a physical and virtual network of Technology Dissemination Centres (TDC) as means of support to enterprises of this sector, as well as a bridge between them and Research and Development institutions. We pretend to:

Achieve a modern SME, with qualified staff, that employs new technologies in order to access information and, in general, to implement technological innovation systems

Achieve an SME committed to the optimisation of the product quality and to the treatment, recycling and reuse of all the wastes generated in its activity

Since Mediterranean olive oil and table olive producers (particularly SMEs ones) need to modernize and to increase their competitiveness, TDCs aim to accelerate the necessary technology innovation process of SMEs by establishing a training program and by providing updated information in those topics of interest for SMEs. Simultaneously, TDCs will carry out a series of actions and promotion activities in order to achieve a certain change of mentality in central and northern European consumers, thus an increase in the consumption of olive oil and table olives.

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This Booklet was designed and developed by Improtechnology Limited for inclusion in the TDC Olive Encyclopaedia.

Orchard Planting

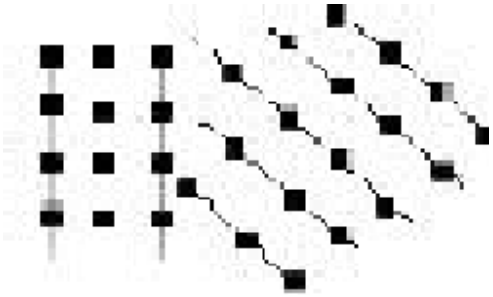
Choosing the area

Olive trees can grow in nutrient-poor, but well-drained soils. They need full sun for fruit production and slight winter chill for the fruits to set. Olive trees should not be planted in areas where temperature falls below -5°C because they do not tolerate very low temperatures and get seriously damaged by winter and spring frosts. A safe criterion for choosing an area is the presence of undamaged olive trees for at least twenty years in the vicinity. Olive trees are also damaged from hot and dry air, particularly during flowering and fruit setting. Also, in areas with low air circulation and high humidity, diseases such as leaf spot appear more easily.

Another criterion for the selection of the planting area is the availability of manpower, especially during the harvesting period, as well as the presence of processing units nearby. The decision must also take into account the annual rainfall. Thus, in low rainfall areas (200-300 mm), olive yield is satisfactory in soils with good water retaining capacity, unless irrigation is applied. In high rainfall areas (400-600 mm) olive yield is good on condition that adequate drainage is provided. In fields with steep slopes, contour cultivation on terraces must be employed. In this case, specialized tractors (caterpillar or crawler tractors) and other vehicles should be used to minimize the danger of overturn.

Planting layout

Olive tree planting scheme is decided according to the cultivation system applied (intensive/non-intensive). For intensive cultivation, in areas with fertile soil and sufficient rainfall or irrigation, trees are planted densely. A planting density of 200-300 trees/ha is not unusual, depending on variety. Often trees are planted very densely (400-500 trees/ha), but later as they grow, half of them are removed, especially those planted in the intermediate rows. In areas with less fertile soils and low rainfall, planting density is reduced accordingly.



(A) **(B)**

Tree planting in square (A) and diamond (B) layout.

In general, two are the main planting layouts:

- The traditional, where planting distances are 7 x 7 m., 6 x 8 m, 8 x 8 m, 10 x 10 m, depending on the area (less than 2000 trees/ha).
- The dynamic, where trees are planted densely at 5 x 6 m, 6 x 6 m, (about 2700-3000 trees/ha).

Preparing the site

Before planting, some necessary cultivation tasks must be carried out, such as uprooting (other trees and bushes), leveling the soil, construction of terraces, etc. If the field is uprooted, it is advised to cultivate grains or legumes for a period of 1-2 years, in order to remove all remaining roots from previous crops and minimize the incidence of root decay in the new trees. Deep ploughing may also be necessary to destroy weeds in combination with/without herbicides. Afterwards, the field is ploughed to facilitate the growth of the root system of the new trees. Finally, phosphate and potash fertilizers are added with the last ploughing, that will be used by the trees during the first years of growth. Before adding any fertilizer, it is strongly recommended to perform soil analysis by taking samples from different spots and depths in the field (30, 60, 90 cm).

Planting new trees

In areas with mild climate, planting takes place in November-December. In colder areas, it is advised to plant the trees in February-March, to avoid the hazard of spring frosts and by all means before the new vegetative cycle. Planting is made into holes that can

be dug manually or mechanically, in dimensions of about 60 x 40 cm (manual digging) or 20 x 30 cm (mechanical digging). Planting depth should be the same as in the nursery. In dry areas, planting holes must be 5-10 cm deeper. Digging holes can raise certain problems. In light (sandy) soils, the walls of the hole fall in, while in heavy (clay) soils the walls are compacted. In this case, the root system takes more time to grow beyond these walls. The trees are planted together with the root ball and the hole is then filled with soil. Special care must be given not to damage the roots when pressing the earth down to firm the plants. After planting, the surrounding earth could be covered with straw to minimize water loss from the soil.

Young trees should be irrigated regularly during the first 2-3 years and fertilized with nitrogen every year. In addition, it is necessary to control weeds in time and take plant protection measures against pests and other diseases.

If another annual crop is cultivated in the field (e.g. cotton, tomato, potato, pumpkins, etc) at the same time (co-culture), it should be restricted among the rows of the olive trees to minimize competition among the plants. As olive trees grow, the area of co-culture should be reduced gradually.

Fertilization of the new orchard

As already mentioned, soil analysis must be preceded before planting in order to determine the necessary amounts of phosphate and potash fertilizers. Additionally, soil analysis will indicate if calcium is necessary. Otherwise, in case where no phosphate and potash have been applied in the last years, the following amounts of fertilizers are recommended:

- 1000-1500 kg/ha 0-20-0 and
- 500-800 kg/ha 0-0-50.

These amounts are sufficient to cover the needs in phosphate and potash for the next 5-8 years. In the next year, after the beginning of the new vegetation, 3-4 fertilizations with ammonium nitrate (20-30 g/tree every time) are necessary followed by irrigation. The same is applied in subsequent years until the trees enter the productive stage, increasing gradually the quantity of fertilizer.

Pruning

Pruning is necessary to adjust the trees to the climatic conditions of the area and increase plantation's productivity. The aims of pruning are: (1) to balance vegetation with fruit yield, (2) to minimize the non productive period, (3) to prolong the productivity of the trees, (4) to delay senescence, and (5) to save soil water, a critical factor in non-irrigated orchards.

There are three main types of pruning:

- **Regulated pruning.** It aims to develop the tree's frame and is of great importance in the first years of the tree's life.
- **Pruning for fruiting.** The aim of this pruning is to induce productive branches to form fruits leaving the structural branches unaffected. Additionally, it maintains uniform production in terms of yield and quality, a feature that is particularly important in table olive varieties.
- **Renovating pruning.** This aims to stimulate sprouting in order to rejuvenate senescent trees.

Regulated Pruning

This pruning aims to develop a tree shape in the first years of growth to facilitate cultivation, spraying and especially harvesting. At this stage, very severe pruning should be avoided, because it delays trees from entering the fruiting period. The most common shaping system is the "free cup".

Free cup shape

To form this shape, one-year-old trees are cut back to 60-80 cm above the ground when they are planted. In the first year, the main focus is to create side branches around the central axis to a height of 30-60 cm from

the ground. In the following years, pruning is very mild aiming at the removal of broken shoots or shoots that intersect to each other. After the tree has developed well, 3-5 main branches are chosen around the central axis, with 20-30 cm distance among each other. When the tree enters the fruiting period, and if no severe pruning is performed, it gradually takes a free spherical shape.

For intensive cultivation where trees are densely planted, short pruning shapes are desired, namely the "short cup" and the "bush". In the former shape, branching takes place very close to the ground, at a height of 30-40 cm, while in the latter no pruning is done in the first 5-6 years. Afterwards, only weak shoots and top branches exceeding 3 m are removed. The bush shape has certain advantages for intensive cultivation systems, such as:

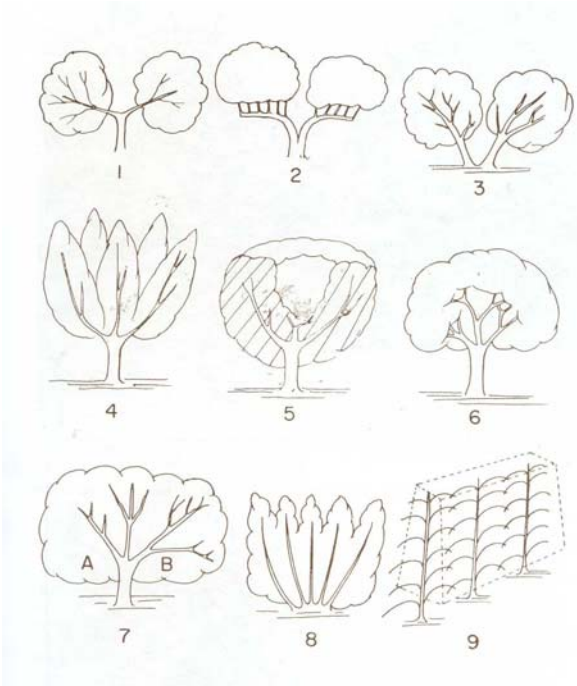
- Earlier fruiting period.
- Higher yields per hectare compared with other pruning shapes.
- Lower labour costs, due to the possibility to harvest from the ground (without using ladders).

Training of young olive trees in free cup (1), short cup (2) and bush (3)

However, both shapes present a major disadvantage because they obstruct mechanical cultivation of the soil. In addition, harvest is difficult particularly for fruits fallen on the ground. An improved short shape without the latter disadvantages is the monoconical pruning. This term means that the tree will have one (mono) central trunk and will be pruned into a Christmas tree type shape (cone).

The main pruning shapes applied in the wider Mediterranean area are the following:

1. The two-branches shape, which is common to Andalusia, Spain, for table olive varieties.
2. The candlestick shape in Tunisia.
3. The double or triple trunk shape in Seville.
4. The multiconical shape, in which every branch has the shape of a cone, found in some regions in Italy.
5. The spherical cup shape in France, Italy and Greece.
6. The spherical shape, which is not so common because it does not provide ample light to the whole tree.
7. The short cylindrical shape.
8. The non-trunk shape in Tunisia.
9. The free palmate. This shape presents some difficulties and it is not widely used, at least for olive oil producing varieties.



Different pruning systems, as explained above.

Pruning for fruiting

Olive trees produce fruits in previous year branches. Very vigorous branches are not productive (they have only vegetative buds) and weak branches produce few fruits. For this reason, the aim of pruning is to induce branches to form fruits, ensure good lighting conditions and maintain the fruiting zone active and vigorous.

The above goals are difficult to be achieved in densely planted trees, due to the reduced lighting of the crown. In this case, the fruiting zone is restricted on the top

branches and in certain areas of the south part of the canopy, where there is more light. The productivity of these trees is greatly reduced when their tops are pruned to give a shorter shape because a significant part of their canopy is removed.

In the productive stage, it is suggested to perform a mild pruning every year to remove dead and dense branches from the fruiting zone. This is necessary because the fruiting zone has the tendency to produce short and dense shoots with time. The aim of this mild pruning is to improve the length of the shoots and ensure good lighting throughout the fruiting zone. It must be noted that this pruning must be severe for trees growing in arid and infertile soils to reduce the surface area of the canopy, saving thus nutrients and water for the new fruiting growth. On the contrary, trees growing in fertile soils with good fertilization and irrigation, must be subjected to less severe pruning because there is adequacy of nutrients and water for both the present vegetation and the development of new fruiting growth. In this case, severe pruning results in the development of sucker shoots.

In the case of table olive varieties, pruning must also improve the size of the fruits. For this reason, it is suggested to thin off excessive fruits right after fruit-setting, especially in high yield years.

Proper pruning can also improve alternate bearing. In this case, a severe pruning is suggested in the winter preceding the year of high yield, by cutting off low vigour shoots.

Renovating Pruning

The main characteristic of olive tree is its longevity because it has the ability to produce new shoots from almost any part of its wood, making thus possible to renovate senescent or frost-damaged trees. Old or low yield trees can be rejuvenated by cutting off their trunk at a low height or at the point of ramification. For partial renewal or reduction of canopy surface in densely planted trees, pruning is performed at the branches or their first ramifications at a desirable height. New vivid shoots will develop from the cutting points, the most appropriate of which are chosen for the new shape of the tree. The new tree enters again the fruiting period after 3-5 years. When damage by frost occurs, trees are left unattended for one year to estimate the real extension of the damage. From the new developed shoots, the new branches will be formed and all the damaged parts will de cut off.

When and how severe will the pruning be?

Before answering this, the following parameters must be taken into account:

- The level of rainfall in autumn and winter.
- The yield of the previous year.
- The vegetative condition (vigour) of the tree when pruning.
- The end product (table olives or olive oil).
- Planting density and the pruning system applied.

Pruning Period

Pruning of olive trees can be done right after harvest. For table olive varieties, pruning begins in November-December for green olives or February-March for black olives. In general, pruning can be performed from autumn to the first months of spring, but it should be delayed in areas with high risk of frosts.

Irrigation

To be able to survive in hot and dry climate, olive trees have small leaves with a protective coating and hairy undersides that slows transpiration. This facilitates cultivation in areas where no other tree can survive. However, this defense system is at the expense of growth and productivity of the tree. Thus, olive yield is greatly increased by applying small amounts of water. However, if maximum yields are desired, greater amounts of water will be needed, on condition that soil humidity does not become excessive.

Irrigation is essential in the following cases:

- When the rainfall in the area is inadequate.
- When there is enough rainfall distributed only during the winter, leaving the soil without humidity in the critical periods of spring and autumn.
- When the soil is sandy or gravelly with low water retaining capacity.

Irrigation is recommended especially in table olive varieties where large fruit size is sought. It is also necessary in intensive plantations with densely planted trees for maximum production. Irrigation also enhances the effectiveness of fertilization and pruning. Finally, it may minimize the phenomenon of alternate bearing.

The critical periods for water stress of olive trees are given in the following table:

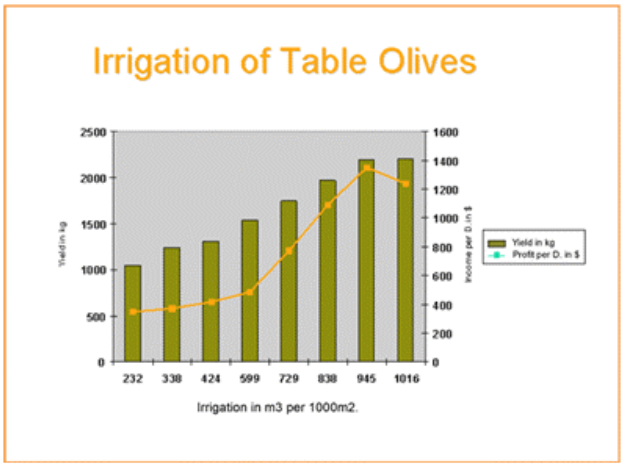
Growth stage	Effect of low soil moisture
- Flower bud development - Bloom - Fruit set - Shoot growth	Reduced flower formation Incomplete flowering Poor fruit-set Increased alternate bearing Decreased shoot growth
1st stage of fruit growth due to cell division shoot growth	Small fruit size due to decreased cell division Fruit shrivel Decreased shoot growth
3rd stage of fruit growth due to cell enlargement of shoot growth	Small fruit size due to reduced cell expansion Fruit shrivel Decreased shoot growth

Shriveled fruits may obtain again their turgidity after irrigation. For this reason, it is recommended to irrigate table olive varieties, especially during the last period of fruit development, to improve their size and quality. However, over irrigation may have negative effects in the case of black olives resulting in delayed maturity. Late irrigation may also lead to new vegetative growth that is susceptible to winter frosts. Many olive orchards around the Mediterranean are not irrigated. In those where irrigation is applied, a variety of methods is employed including, flood, furrow, sprinklers, hanging drippers, surface drip irrigation, and during the last years also sub-surface drip irrigation.

Irrigation by drip system, springlers, hanging dripline and hanging drippers.

In surface drip irrigated orchards, different practices are followed. In most cases, one dripline per row of trees will be placed on the ground. Usage of two driplines per row is also applied. In some orchards, the dripline is hung on the trees to enable criss-cross cultivation.

Irrigation frequency depends on water availability so as to ensure sufficient soil moisture at the critical stages of the crop. The amount of water is different every time and depends on soil type, age and size of the trees and other factors. For traditional low tree densities, the application of a constant amount of water, 80-120 liters/day/tree (in heavy soils), will provide good results.



Effect of irrigation on table olive yield.

Olive trees are very sensitive to over irrigation and will not perform well in waterlogged soils. Waterlogged soil, often a result of poor drainage, causes poor soil aeration and root deterioration and can lead to the death of the trees. Trees cultivated in saturated soils are more susceptible to varying weather conditions and soil borne pathogens such as phytophthora and verticillium.

Fertilization

General Rules

Nitrogen

Nitrogen is the most essential element influencing both vegetative and fruit production. It can also affect, in an indirect manner, the extent of alternate bearing. The response of olive trees to nitrogen is more obvious in

low fertility soils, when soil moisture is not a restrictive factor. Depending on soil fertility and humidity, it is recommended to apply 500-1500 g/tree nitrogen or 50-150 kg/ha (1kg N = 5 kgr approximately of ammonium sulfate, 3 kg ammonium nitrate, 4 kg calcium nitrate or 2 kg urea). The above-mentioned amount of nitrogen per tree is suggested for low tree densities, while the amount per hectare for high trees densities (more than 100 trees/ha).

In dry farming conditions, the amount of nitrogen fertilizer depends on the annual rainfall and the available soil moisture. Hence:

a) In areas with mean annual rainfall less than 400 mm, the addition of nitrogen should be made with extra care. In these areas it is suggested to add 100 g/tree/100 mm of rainfall (or 10 kg/ha/100 mm of rainfall).
b) In areas with mean annual rainfall 400-700 mm, the amount of nitrogen could be increased proportionally to 1500 g/tree.
c) In areas with mean annual rainfall over 700 mm, or in irrigated olive orchards, nitrogen is added depending on soil fertility, up to 1500 g/tree.

The farmer can assess the effectiveness of nitrogen fertilization and amend it, if necessary, by checking:

- *The length of the new vegetation.* If the length of the new vegetation is not sufficient, the amount of nitrogen must be increased, provided that no other critical factors exist (diseases, root damage, etc.).
- *Leaf analysis.* Nitrogen fertilization is adjusted so that the amount of nitrogen in leafs ranges between 1.6-1.8% during winter.

A critical period, in which trees should have available nitrogen, is floral induction, from the beginning of March to June. In dry farming orchards, nitrogen fertilizer is added to the soil in December – February in order to have available nitrogen during the critical period. In eastern Greece, where low rainfall prevails, nitrogen should be applied in the beginning of floral induction period, while in western Greece, it is common practice to apply nitrogen in the end of this period.

Excessive amounts of nitrogen before fruit setting may lead to high fruit load resulting in small size fruits and alternate bearing. On the contrary, sufficient nitrogen amounts after fruit setting contribute to vegetation and high yield in the next year.

Nitrogen application in the critical stages can be done with foliar fertilization. Urea gives good results at a dilution up to 3-4%. Foliar fertilization is effective in dry farming orchards where the absorption of nitrogen through the root system is very restricted.

Phosphorus

The absence of this nutrient is not common and phosphate fertilization is not really necessary, especially when 11-15-15 compound fertilizers have been used for several years in the field.

Phosphorus is not really necessary in the following cases:

1) In olive orchards where abundant phosphate fertilizers have been used repeatedly in the previous years (either in olive trees or other crops).
2) In olive orchards, in which only small amounts of phosphate is added due to low soil humidity.

Phosphate fertilization can be necessary in acid soils or soils containing high amounts of calcium carbonate. The same applies for orchards planted in shallow, infertile soils or in new irrigated olive orchards (1-10 years old) in which ample nitrogen is used every year. Phosphate deficiency is easily determined by leaf analysis. Phosphate addition is necessary when the concentration of the nutrient in the leaves ranges from 0.09-0.10 % in the winter and the ratio N/P is around 20. Higher concentrations in the leaves or higher N/P ratios indicate that phosphate fertilization is necessary.

When phosphate fertilization is necessary, it should not exceed 1/3-1/5 of the amount of nitrogen added. So, if 1 kg N/tree (i.e. 5 kg ammonium sulfate) is added, the corresponding amount of phosphate should not exceed 200-350 g P_2O_5/tree (i.e. 1.0-1.7 kg 0-20-0). As a rule of thumb, it is suggested to add 500 g P_2O_5/tree (i.e. 2.5 kg 0-20-0) in a two-year period.

In the case of severe phosphate deficiency, an amount of 4-5 kg P_2O_5/tree (i.e. 20-25 kg 0-20-0) is added in trees at the stage of full production. For younger trees, smaller amounts (1-8 kg 0-20-0) are added, depending on age and development stage.

The characteristic symptom of phosphate deficiency is widespread chlorosis of the leaves. However, it is not a safe diagnostic criterion because it is often confused with other causes (e.g. nitrogen deficiency). Safe diagnosis can be done with leaf analysis.

Potassium

Olive trees are demanding in this nutrient. High amounts of potassium are removed from the soil with fruit harvest and pruning, particularly in high yield seasons. Regular potassium fertilization is required in order to maximize yield and quality, especially in orchards where no potassium fertilizer has been added for several years.

The amount of potassium should be determined in combination with nitrogen. In olive orchards, in which no potassium has been used in the past, it is preferable to add twice as much potassium as nitrogen. For example, if 0.5 kg N/tree (i.e. 2.5 kg ammonium sulfate) is applied, then 1 kg potassium/tree (i.e. 2 kg potassium sulfate) must be added. In time, potassium dosage is adjusted to be equal to nitrogen. After high yield seasons, it is preferable to increase potassium to supplement the amount that is being removed. Leaf analysis, wherever it is possible, may give better direction for potassium fertilization.

Deficiencies of nutrient elements

Boron deficiency

It is one of the most common deficiencies in both young and older trees. Boron is not very mobile and so deficiency appears in the young leaves. The main symptom is that leaves around the terminal bud turn light green at their base and eventually fall off. Gradually, the same symptom appears to leaves near the base of the shoots, which appear dry at their edges. Later growth shows small and distorted leaves that are stunted, fragile and finally drop off. If a small piece of the stem is cut off with a sharp knife, a brown discoloration appears due to necrosis of the cambium.

Trees suffering from boron deficiency appear chlorotic from a distance and delay entering the vegetative stage. Leaves with deficiency contain less than 20 ppm boron, while those from healthy trees have more than 20 ppm (on dry basis). In full production trees, 300-500 g sodium pyroborate is added in the soil to control deficiency, while for younger trees fewer amount is used (10 g for each year of the tree from the moment of planting). For faster response, soluble sodium pyroborate can be applied by foliar fertilization or through the irrigation system.

Potassium deficiency

Potassium is a mobile nutrient and thus deficiency is most clearly shown in older leaves. They present pale chlorotic patches with the appearance of “burns” (necrosis) at the leaf tips and edges. These areas of dead tissue progress from the tip to the base, and from the leaf margin towards the intervein area. The leaf tip tends to curve downwards.

Potassium deficiency diagnosis is not safe on the basis of these symptoms, and must be further confirmed by leaf analysis. Deficient leaves contain about 0.1-0.3% potassium (on dry basis), whereas the content of well-supplied leaves ranges from 0.4 –1.7%.

Many times, potassium deficiency is due to low soil moisture (drought); potassium is adsorbed by clay and thus trees cannot take it from the soil. The problem can be relieved by selecting cultivating techniques that enhance the growth of the root system and ensure adequate soil moisture. In this case larger amounts of fertilizer are added, usually 10-15 kg of potassium per tree. Alternatively, half of the above mentioned amount can be added in the winter in the form of potassium sulfate, and the remaining amount in the form of potassium nitrate through the irrigation system. Potassium nitrate is applied through the irrigation system at a dose of 300-500 g/tree after fruit-setting.

Calcium and Magnesium deficiencies

The main symptoms of calcium deficiency is the chlorosis of the top part of the leaves, like in boron deficiency, but in this case the veins in the chlorotic area of older leaves become white. The main symptom of magnesium deficiency is the chlorosis of leaves that begins from the top or the edges of the leaf and spreads gradually in the whole leaf area. Other symptoms include severe leaf shedding and the poor vegetative cycle.

Calcium deficiency is corrected rather easily by adding 5-10 kg of calcium oxide per tree. To avoid calcium deficiency, soil pH must be determined before planting a new orchard. The amount of calcium added must be determined after soil analysis.

To correct magnesium deficiency, 300-500 g of magnesium oxide (e.g. 3.0-5.0 kg/tree potassium-magnesium sulfate, providing also potassium for simultaneous fertilization with this nutrient) are used. Alternatively, foliar sprays are applied with 2-4% soluble magnesium sulfate dilution.

Nitrogen Fertilizers

The most common nitrogen fertilizers for olive tree growing are the following:

Ammonium sulfate. It is available in two forms:
- Crystallized (21-0-0)
- Granular (20.5-0-0)

Ammonium sulfate contains also 23-24% sulphur, which is normally an additional benefit. This fertilizer makes the soil slightly more acidic and can be used in soils with high (alkaline) pHs. The granular form is ideal for mechanical application e.g. with centrifugal fertilizer distributor. To minimize losses, due to ammonium evaporation, it is recommended to incorporate the fertilizer into the soil. Ammonium sulfate is available within a few weeks, after nitrification by microorganisms into nitrate. It is preferred when fertilization takes place early in the cultivating period.

Ammonium nitrate. It is available in granular form and contains 33-34% nitrogen. It is very soluble into the soil, where with little humidity offers nitrogen to trees in both nitrate and ammonium forms. Plants readily absorb nitrates; however, excessive amounts are not absorbed by the roots, leaching thus to the underground table water and polluting the environment. Ammonium nitrate becomes available to the trees in a few weeks. It has less residual activity than ammonium sulfate. This fertilizer may acidify the soil, so it should not be applied in acid soils, even in neutral ones.

Ammonium calcium nitrate. It is a compound granulated fertilizer containing 26-28% nitrogen as ammonium nitrate and also calcium carbonate. It can substitute ammonium sulfate and ammonium nitrate in acid soils as well as in humid areas to minimize risk of soil acidification.

Urea. It is water-soluble containing 45-46% nitrogen by weight. It provides nitrogen in ammonium form, which is then nitrified. Nitrogen in the form of ammonia is slightly volatile, and because urea is converted to ammonia before being nitrified, it is worth burying this fertilizer slightly below the surface of the soil to minimize losses. Urea causes soil acidification, whereas in calcareous and alkaline soils a part is lost due to evaporation of ammonia. Due to its high solubility in water, urea can be applied as foliar feeding. To avoid toxicity effects to the trees, the amount of di-urea impurities should not exceed 2% for soil application and 0.25% for foliar sprays.

Potassium fertilizers

The following fertilizers are usually applied in olive trees.

Potassium sulfate. It is available in powder and granulated form for soil application, as well as in water-soluble form for foliar feeding and application with irrigation. It contains the equivalent of 48-50% K_2O and also 17% sulfur. It has low salinity index and it is preferable in alkaline soils. The solubility of water soluble potassium fertilizers decreases with temperatures below 20°C, a fact that must be taken into account when potassium fertilizers are applied with irrigation.

Potassium nitrate. It is available in water-soluble (crystallized) and granulated form. It contains 46% K_2O and 13% nitrogen in the form of nitrates. It is recommended for foliar sprays and application through the irrigation system.

Patentkali®. It is a mixed fertilizer of potassium sulfate and magnesium sulfate. It contains the equivalent of 28% K_2O, 8% Mg and 18% S. It is a registered trademark of BASF, recommended for crops that require a lot of magnesium and which are sensitive to chloride.

Phosphate fertilizers

For soil application it is suggested to use:
1) The simple superphosphate (0-20-0)
2) The triple superphosphate (0-46-0)

For application through the irrigation system, crystal soluble fertilizers are suggested such as:
1) Mono-ammonium phosphate (12-61-0)
2) Bi-ammonium phosphate (21-53-0)

Boron fertilizers

For boron deficiency treatment, sodium pyroborate can be added in the soil. For foliar application or through irrigation, water-soluble boron can also be used.

Weed control

The olive tree can survive in low fertility soils under semi-arid conditions. Unfortunately, many weed species are adaptable to the same conditions and grow faster than olive trees, exercising strong competition for moisture and nutrients.

Weeds, especially perennial species, have almost the same growth pattern as olive trees. However, their adaptability and greater efficiency ensure earlier and larger growth than that of olive. For this reason, weed control must be applied four to six weeks before visible spring growth in olive trees.

Active ingredient	Comments
Pre-emergence	
Simazine Diuron	Apply 3-4 years after tree planting
Oxyfluorfen EPTC	Recommended also for young trees
Chlorthal dimethyl	For olive tree nurseries
Post-emergence	
Paraquat Diquat Paraquat and diquat	Contact herbicides
Glufosinate ammonium	Exert slight systemic activity
Glyphosate Glyphosate trimensium Aminotriazole (amitrole)	Systemic herbicides
Mixture of pre- and post-emergence	
Simazine and paraquat Simazine and aminotriazole Diuron and amonotriazole Terbuthylazine and glyphosate	Effective on germinated weeds

Main herbicides recommended for olive trees

Orchard floor management decisions are significantly influenced by location, climatic conditions, soil, irrigation practices, topography, and grower preferences. Weeds are commonly controlled either chemically or mechanically. The area between tree rows may also be chemically treated or mechanically mowed or tilled. Alternatively, mulches, subsurface irrigation, and flamers can be used. Often several weed management techniques are combined.

Weed control in new orchards

Trees are most sensitive to weed competition during the first few years of growth and where soil depth is limited. Weedy orchards may require several more years to become economically productive than weed-free orchards. Regardless of the method used to control weeds, special attention must be paid not to injure trees with chemicals, or to mechanically damage the trunk or roots. As trees become established, competition from weeds is lessened as shade from the tree canopy reduces weed growth. Some of the most common ways to control weeds in new orchards are the following:

Cultivation. Some growers prefer to manage weeds without herbicides for the first year or two after planting. This usually requires hoeing, cultivating, or using weed knives around trees several times during spring and summer, as well as cultivating or mowing between tree rows. This is best accomplished when weeds are still in the seedling stage, but it becomes more difficult when weeds are allowed to get large. Hand tools are generally used close to the tree to minimize injury from mechanical cultivators, particularly when the trees are young. Mechanical cultivators available for use in the tree row include: weed knives, spider cultivators, and rotary tillers. Rotary tillers are most effective if used on loose soil that is not rocky. Hand-held mechanical flails may be used, but can injure tree trunks. Disks, tillers, or mowers can be used between the rows. Mechanical control of weeds must be done repeatedly when weeds are immature. The equipment should be set to cut shallowly, to minimize damage to tree roots. As weeds mature, they are difficult to control, may clog equipment, and produce seed.

Cover Crops. Planted cover crops can also be used to reduce weed populations between tree rows. With cover crops, the species selected and management will differ from one area to another. The selected cover crop should not be competitive with young olive trees. Examples of cover crops include wheat, oat, cereal rye, or barley. Cultivation in preparation for planting a winter annual cover crop will also reduce weed growth. To preserve surface cover, mow the cover crop to the correct height recommended for that crop.

Mulches. Weeds in the tree row can also be controlled using mulches. Organic mulches (cereal straw, green waste, composted wood chips) or synthetic mulches of polyethylene, polypropylene, or polyester can be used around young trees. Shredded tree prunings also make good mulch. Mulches must be applied when the soil

surface is free of weeds. Mulches prevent the growth of weed seedlings by blocking light and preventing it from reaching the soil surface. They create more uniform moisture conditions, which in turn promote young tree growth. Mulches do not control perennial weed growth unless all light can be excluded. Some woven fabric mulches offer excellent weed control for several years, but the initial cost of purchase and installation is high.

Herbicides. To control weeds with herbicides after trees are planted and before fruiting, apply a pre-emergence herbicide to either a square or circle around each tree or as a band down the tree row. Herbicides can also be applied to control weeds after they emerge. Selective herbicides are available for annual grass control and suppression of perennial grasses. Paraquat can be used to control weeds near young trees protected with shields or wraps. The non-selective herbicide glyphosate can control broadleaf weeds after emergence, but it should be used only around mature trees with brown bark and should not be allowed to contact tree leaves.

Weed control in established orchards

It takes 3 to 4 years for an orchard to become established under normal growing conditions. Established trees are more tolerant to many herbicides than newly planted trees, increasing thus the options available for weed control. Generally weeds are controlled between tree rows by discing or mowing and a basal treatment of herbicide is applied around each tree or in a strip application down the tree row.

Cultivation. Cultivation can be used in established orchards to control annual and biennial weeds and seedlings of perennial weeds. Cultivation also cuts and damages the roots of trees, reducing the ability of the tree to take up nutrients and allowing access to the tree of soil pathogens. For this reason, special attention must be given when this method is applied for weed control.

Flaming. Flaming is a method that can be used to control very young weed seedlings in established orchards. A single flame that is directed to the base of the tree can be used or several burners on a boom to flame the weeds between the tree rows. Flaming is effective only on newly emerged weed seedlings. This method is not recommended for young trees because it may damage the thin, green bark. In mature orchards annual broadleaf weeds can be controlled with flaming but grasses are more tolerant. Flaming is not intended to burn the weeds, but rather to kill the tiny seedling with heat. The method is not recommended where there is dry, dead vegetation, leaves, or duff around the base of the tree. This material may ignite, causing a fire that will damage the trees.

Mulches. Mulches can also be used for weed control but they must be replenished regularly due to degradation. Degraded mulches become a perfect growth medium for weed species.

Herbicides. Pre-emergence herbicides can be applied either alone, in combinations of herbicides in autumn after harvest, split into two applications (autumn and spring), or in winter with a post-emergence (foliar) herbicide. It may be most beneficial to delay the pre-emergent application in winter until most weeds have germinated. Afterwards, a post-emergence herbicide can be used. This allows longer weed control during the summer and does not allow much competition from weeds to the tree. For greatest safety, direct herbicide sprays only at the soil or at weed foliage, not at the tree leaves.

Fruit harvest

Olive fruit harvest is usually carried out manually or mechanically. The traditional manual system consists of knocking the branches with long poles of wood. The olives fall on synthetic nets extended around the trees and then picked directly from the ground. This method is not recommended as both olives, with consequent oil production of very bad quality, and branches, particularly young shoots, are damaged.

Harvesting olives directly from the tree

Another method is the so-called “natural drop”, in which the fruits are harvested directly from the ground after their natural fall on nets. This method is preferred when the trees are of remarkable height and there is little labour availability. The fruits are harvested gradually (at least once every two weeks), otherwise the quality of olive oil is greatly reduced. Another disadvantage is the prolonged harvest period (3-5 months). The above methods have been replaced by the manual “milking” of the branches, drawing the fruits out and leaving them to fall into small baskets, which are suspended from workers at waist level. This method is very good at avoiding fruit injury but presents the drawback of high labour costs. Manual harvest can be improved using hand held pneumatic combs. They consist of a pneumatic comb assembled on variable length telescopic rods (from 2.50 m to 3 m). Rake teeth in two sizes facilitate penetration into the crown of the tree and detachment of the fruits. The system operates by a compressor that is applied to the three points of a tractor or to a motor cultivator. The combining action of the fingers harvests without damaging the fruits or trees.

A variation of this kind of picking machine is the hand-held pneumatic shaker. The shaker is attached to a standard compressor unit, as used for spraying. A hook attaches to large limbs and shakes the olives loose, similar to the combs above.

Hand-held pneumatic comb pickers

Mechanical harvesting systems have considerable economic advantages compared with traditional manual picking procedures, mainly due to great reduction in labour costs and harvesting time. The most common mechanical picker is the tractor-mounted shaker. The shaker is attached to a 70-80 HP tractor and utilizes a hydraulic pump to transfer power to the vibrating head. Harvesting nets are first placed under the tree.

Tractor mounted shaker

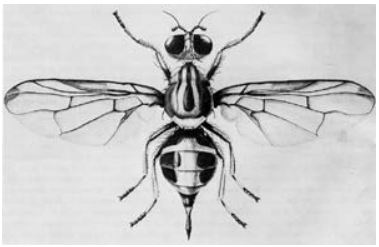
The shakers are hooked to the plants by different types and forms of pliers or rubber rolls and they engrave to the plants and to the fruits pendulum-like or rotary movements. The movements are brief and violent, so much that the drupes are easily detached from the trees and fall in underlying nets.

Pests

The major insects of olive trees are the olive fruit fly (*Bactrocera oleae*), the olive-kernel borer or olive moth (*Prays oleae*) and the black scale (*Saissetia oleae*). Although *B. oleae* is considered the most serious insect, all three are widely distributed in the Mediterranean region and occur on olives at population densities causing important economic losses.

Of the less important insect pests, some occur in particular areas or conditions at population levels that cause serious damage, e.g. *Euphyllura olivina, Zeuzera pyrina, Aspidiotus nerii, Resseliella oleisuga*. Others, although occurring only occasionally, cause serious problems by disrupting the biological balance of the ecosystem, e.g. *Parlatoria oleae, Leucaspis riccae, Philippia follicularis*.

Bactrocera (Dacus) oleae (Diptera: Tephritidae)
It can be found in all Mediterranean olive-growing countries. To the east, it extends as far as India; to the west as far as the Canary Islands. However, it has not been found in regions where the olive is an introduced species, such as North and Central America (California, Arizona, Mexico, El Salvador), SouthAmerica (Argentina, Chile, Peru, Uruguay), Central Asia (China) and Australia.



Adult female olive fruit fly

In northern Italy and southern France infestations may begin in late June, July or even August. Populations gradually increase to a maximum by September-October. At most, three generations may be completed during the year in such regions. In southern Italy, Spain and central Greece, infestations start in June-July, but after the development of the first generation, the population decreases due to high summer temperatures (exceeding 33°C) coupled with low relative humidity. Populations begin to increase again from September until November-December. In the southernmost distribution areas of olives trees, such as Crete and North Africa, infestations begin by the end of May.

Adults are able to live for several months. The maximum longevity is found in adults that emerge in autumn, increasing from September to November. They can survive for a short time at temperatures slightly below 0°C, but they die if they stay for days under these conditions. Temperatures from 0 to 5°C are tolerated for about a month by some individuals, but the mortality rate is generally high.

In the olive tree itself, most *B. oleae* are seen flying within the canopy, since this is the location where olive fruits can be found. However, the olive fruit fly has the potential of long-distance dispersal. Displacements of 4 to 10 km have been observed in the field, depending on climatic conditions, topography and olive fruit availability. Under normal environmental conditions, however, the movements are of short range.

The insect spends the winter in the pupal stage several cm below the soil and leaf litter. Under summer conditions, a preoviposition period of six to ten days elapses before mating, with longer time required earlier when temperatures are not as high.

During the preoviposition period the female is maturing the ovary and a first set of eggs. Beginning in June females actively seek and oviposit in early maturing olive fruits. From 10 to 12 eggs may be laid daily, usually one per olive fruit, and about 200 to 250 are laid in a lifetime. The female punctures the fruit with the ovipositor and deposits an egg beneath the skin. The legless larva (maggot) feeds upon the fruit tissue, causing the fruit to drop off the tree.

Damaged olive fruit

Duration of the life cycle varies from one to six or seven months. Male flies produce an auditory stimulatory sound or signal during courtship. Courtship and mating occur at dusk, near the end of the daylight period. Females of the olive fruit fly produce a multi-component pheromone, and are the only tephritid females known to produce a pheromone; males produce the pheromone in other tephritids that have been studied. The major component of the pheromone is 1,7-dioxaspiro[5.5]undecane and it is a relatively long-range attractant for males. Male flies also produce this compound, and attract males, but females are not attracted to the compound from either sex.

Insect control management includes bait sprays, trapping of adult flies, harvest timing, fruit sanitation after harvest, and biological control. Additionally, insecticides are used in bait-sprays or as sprays from the air to control the olive fruit fly.

McPhail trap

More environmentally friendly techniques that are being tested or used in limited areas use sterilized males by radiation and pheromones. Both sexes can be sterilized with 8 to 12 krad (80 to 120 Gy radiation), when late pupae are exposed to this level of irradiation. Synthesis of 1,5,7-trioxaspiro[5.5]undecane, an analogue of the major pheromone component, has been synthesized and tested, and under optimal conditions it was as attractive as the natural compound, but it did not last as long in traps as the natural material. Small plywood rectangles dipped in 0.1% aqueous solution of deltamethrin for 15 minutes and added to bait stations containing either sex pheromone or ammonium bicarbonate, a food attractant, gave cost-effective control in a large test orchard.

Prays oleae (Lepidoptera: Hyponomeutidae)
The olive-kernel borer or olive moth seems to have had the same origin as the olive tree. It was known as a pest of the olive in very early times, as is evident from descriptions in ancient Greek and Roman documents. *P. oleae* exists in all Mediterranean olive-growing countries. To the east, it has been found in areas around the Black Sea, such as the Crimea and Georgia. Its presence has not been reported in Central Asia (Iran, Pakistan, Afghanistan), East Africa (Eritrea), Southern Africa or America (North and South).

Adult olive-kernel borer or olive moth

P. oleae feeds and develops on olive flowers, fruits and leaves. Its yearly life cycle comprises three distinct generations. The first larval generation leaves on floral buds causing light to moderate flower damage. The second generation appears in the stone of the olive fruit where it eats the kernel. This is the most troublesome stage. It can cause massive fruit drop and damages the fruit for canning and oil making. Olive Oil affected by the moth will have an oxidized and rancid taste.

The third generation leaves on leaves and young shoots. Larvae are leaf miners that use silk to roll the leaf into a protective shape. The leaf larvae can live for months during the autumn and winter months, with the pupae over wintering on the leaf or bark to start the cycle over. In Southern Mediterranean regions, moths start emerging in early March, peaking in April and ending at about the beginning of May. The moths have twilight and nocturnal habits. They usually stay still on the lower surfaces of the leaves during the day and start to be active at twilight.

Flower damage by first generation larvae

Climatic conditions greatly affect the occurrence of *P. oleae*. Eggs and newly hatched larvae are especially vulnerable in conditions of low relative humidity and high temperatures. With a relative humidity of less than 60%, eggs dry out within a few hours regardless of temperature. In the case of newly hatched larvae, they do not survive at temperatures above 30°C. This can explain why *P. oleae* is relatively scarce in hot and dry continental zones.

Control of first generation olive moths can be done using biological insecticides based on *Bacillus thuringiensis* (e.g. Thuricide, Bactospeine). Second generation individuals must be sprayed with selective insecticides such as triflumuron (Alsystin) and teflubenzuron (Nomolt) that suppress chitin synthesis. Other conventional insecticides comprise fenthion (Lebaycid), methidathion (Ultracide), dimethoate, etc.

Saissetia oleae (Homoptera: Coccidae)
S. oleae is widely distributed, extending from Central Asia to Africa. The olive tree is one of a large number of host plants on which *S. oleae* has been found. In general, it completes one generation per year in the Mediterranean although, in some areas and under favourable conditions, a second autumn generation may develop. The preferred habitat is the lower surfaces of olive trees. *S. oleae* damages the olive tree directly by sucking the sap, and indirectly by releasing honeydew onto the leaves. This honeydew is a substrate for the development of different fungi and is

thus responsible for the spread of a sooty mould. By coating the leaves, this sooty mould impedes photosynthesis and respiration and finally induces more or less serious leaf drop.

Black scale (S. oleae)

Adult females are dark brown or black with a prominent H-shaped ridge on the back. Young scales are yellow to orange crawlers and are found on leaves and twigs of trees. High relative humidity and mild seasonal temperatures tend to favour *S. oleae*. For this reason, the density of the olive tree canopy and microclimatic conditions beneath it, related to cultural practices (grove density, soil depth, presence of water, fertilizers, pruning, etc.) have an important influence on scale development. In addition, moderate use of nitrogen fertlizers and irrigation helps to avoid the increase of amino acid and sap circulation within the tree, which would otherwise provide a rich nutrient substrate for *S. oleae* development.

Black scale with exit holes of Scutellista cyanea.

Pruning to provide open, airy trees discourages black scale infestation and is preferred to chemical treatment. In addition, biological control is effective, since a number of natural enemies, including both parasites and predators attack black scale.

The most frequently encountered parasites are the native *Metaphycus flavus* and the exotic *Metaphycus helvolus and M. bartletti.*

Exit holes on black scale from Metaphycus helvolus

Regarding predators, the most frequently found is *Scutellista cyanea* that is an egg predator. These parasites, combined with proper pruning, provide sufficient control in northern and coastal orchards. In other regions, biological control is often ineffective because black scale's development pattern hampers parasite establishment.

Diseases

The most important olive tree diseases are verticillium wilt, olive knot, leaf spot and fruit mummification.

Verticillium wilt

The disease exists in almost all olive-growing countries. It is caused by the fungus *Verticillium dahliae*. The fungus can survive in the soil for years embedded in infected tissues or in the form of sclerotia. It is spread by soil movements during tillage, irrigation water and infected tools used for pruning. Symptoms of the disease appear when leaves on one or more branches of the tree suddenly wilt early in the growing season; this process intensifies as the season progresses. Death of mature trees infected with Verticillium is also possible. Darkening of xylem tissue, a key symptom for distinguishing Verticillium wilt in many crops, is frequently not apparent in olives.

The most effective management strategies to protect trees from Verticillium wilt are those taken before planting. When considering a new site for an olive orchard, it is not recommended to use land that has been planted for a number of years with crops that are highly susceptible to the disease, such as cotton, eggplant, peppers, potato, or tomato.
Inoculum levels can be reduced before planting by soil fumigation, soil solarization, flooding the fields during summer, growing several seasons of grass cover crops or a combination of these treatments. A resistant rootstock is not available, although some tolerance has been reported in the cultivar Ascolano.

In established orcahrds, no reliable method of control has been developed. Soil fumigation and soil solarization have provided inconsistent control in these cases.

Olive knot
This is the only bacterial disease of the olive tree. It is caused by *Pseudomonas syringae* pv *savastanoi*. On infected parts of the tree (mainly primary and secondary branches) irregularly shaped proliferations (knots) develop. Bacteria are transmitted by way of tree wounds resulting from harvesting practices. Within the host plant, the bacterium synthesises indoleacetic acid inducing cell proliferation and tumour formation. There are various strains of the bacterium differing from each other to virulence. Various olive cultivars show different degrees of sensitivity to *P. savastanoi*. In general, older branches and trees are more susceptible to the disease.

Olive knot control measures are usually preventive. Attention must be paid to cultural practices as the pruning and destroying of infected plant material and the use of harvesting methods that do not harm the tree. Treatments with fungicides based on copper may reduce the disease but do not eliminate the bacterial population, which soon multiplies back to previous levels. It is also important to cover wounds after pruning such as galls on limbs or trunks with Bordeaux mixture.

Leaf spot
This disease is caused by the fungus *Cycloconium oleaginum* which is found in all Mediterranean countries and in California. It is pathogenic only to the cultivated olive tree. Although it is of minor importance in arid and hot regions, irrigated olive orchards as well as areas with high relative humidity are highly susceptible. Infectious conidia can survive throughout the year with peak periods in October-November and March-April. The pathogen is scarce during the summer months.

Dissemination takes place mainly by rainfall, since germination of conidia occurs only when enough water is available. Leaf spot causes the leaves to appear slightly chlorotic (some varieties show more chlorosis than others). The undersides of some leaves become discoloured with the conidial stage of the fungus, which appear to be covered with black dust. These leaves may fall, causing some defoliation in some cases. Fruit can also develop small, brown lesion spots and not mature uniformly.
Infections developing between late November and February do not show any symptoms until early spring when lesions appear, producing spores in abundance. The high susceptibility of the olive tree to infection in spring is explained by both the increased availability of inoculum and by the rainfall. Under the normal temperatures of this season, lesions appear within a few weeks.

Measures for control of the disease include cultural practices (such as selective pruning to reduce relative humidity within the tree canopy) and treatment with protective fungicides (e.g. Bordeaux mixture) at the beginning of autumn before the first infection occurs, or in the early spring. In addition, highly susceptible olive tree cultivars to the disease must be avoided (e.g. Manzanilla, Frantoio, Arbequina, Moroccan Picholine).

Fruit mummification
This disease is caused by the fungus *Gleosporium olivarum*. The fungus can penetrate healthy fruit skin, although existing lesions may facilitate the process. Infected fruits display brownish round spots, which expand in size. Usually, infection begins at the distal end of the olive fruit, where water droplets rest after dew or rainfall. Dissemination of the inoculum is facilitated by rain, since germination occurs only in the presence of water. Fungal conidia may survive for one year in mummified fruit at low temperatures.

The disease is common in Mediterranean olive-growing countries, particularly in Portugal, Greece and Lebanon. First attacks appear in September while olive fruits are still green. The combination of rainfall and high relative humidity results in the development of pouches and conidia on the infected fruits creating secondary infections that lead to fruit drop and increase in acidity of the extracted olive oil. Occasionally, the infection may also spread to vegetal parts causing leaf drop, shoot death and the overall weakening of the infected tree.

For the control of the disease, preventive fungicide treatment is recommended at the beginning of September before the rainy period. Application must be repeated later if secondary infections are noticed.

WEB LINKS

IOOC (INTERNATIONAL OLIVE OIL COUNCIL):
http://www.internationaloliveoil.org

FAO (FOOD AND AGRICULTURE ORGANISATION):
http://www.fao.org

NAOOA (NORTH AMERICAN OLIVE OIL ASSOCIATION):
http://www.naooa.org

AUSTRALIAN OLIVE ASSOCIATION:
http://www.australianolives.com.au

ASOLIVA (SPANISH OLIVE OIL EXPORTERS ASSOCIATION):
http://www.asoliva.com

ASSITOL (ACCOCIAZIONE ITALIANA DELL' INDUSTRIA OLEARIA):
http://www.federalimentare.it

CONSORZIO NAZIONALE DEGLI OLIVICOLTORI:
http://www.cno.it

TUNISIAN OLIVE OIL OFFICE:
http://www.onh.com.tn

SEVITEL (GREEK ASSOCIATION OF INDUSTRIES AND PROCESSORS OF OLIVE OIL):
http://www.oliveoil.gr

ELOT (GREEK STANDARDISATION ORGANISATION): http://www.elot.gr

PEMETE (GREEK ASSOCIATION OF TABLE OLIVES PROCESSORS, PACKERS AND EXPORTERS):
http://www.elia-info.gr

MESSINIA CHAMBER OF COMMERCE & INDUSTRY:
http://www.olivetreeroute.gr

GREEK MINISTRY FOR RURAL DEVELOPMENT AND FOOD:
http://www.minagric.gr

ORGANISATION FOR CERTIFICATION AND INSPECTION OF AGRICULTURAL PRODUCTS (GREECE):
http://www.agrocert.gr

PAYMENT AND CONTROL AGENCY FOR GUIDANCE AND QUARANTEE OF COMMUNITY AID (GREECE):
http://www.opekepe.gr

GREEK INTERPROFESSIONAL ASSOCIATION FOR OLIVE OIL AND TABLE OLIVES:
http://www.edoee.gr

DIO (ORGANISATION FOR INSPECTION AND CERTIFICATION OF ORGANIC PRODUCTS):
http://www.dionet.gr