Cranfield University

Attribute analysis and quality assessment of extra virgin olive oil produced in Sitia, Crete, Greece

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The experimental work was carried out in the Laboratories of the

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Abstract

In this study, extra virgin olive oil produced in the mountainous organic semi- intensive production systems of Krya (Sitia, Crete, Greece) was under investigation in different stages of production. The region is characterized by high altitude, sloping and difficulty to access systems that are considered as high risk of abandonment but its sustainability has extreme survival importance for the local population that consists of producers and suppliers that strive daily to improve this product. The study focuses in principles of cultivation, quality control and marketing in order to assess the production systems of Krya in comparison with other regions. Data suggest that dominant crop practices in the area is harvesting with hand–held mechanical harvesters (100%) and soil cultivation with ploughshares attached to different sizes of tractors, irrigation is applied in most systems in Krya, Pruning and fertilization is also practiced in variable degrees. Temperature measured during different stages of processing seems to have reached 27^{o}C to 35 ^{o}C suggesting a drop in quality because of high temperature effect to phenolic content. Samples obtained from Krya groves have produced olive oil that was classified as Extra virgin olive oil based in sensory and chemical tests, with average free acidity scores lower than 0.4 %, with average peroxide scores lower than 12 meq/L and K_{270} index scores lower than 0,15. Sensory results suggest olive oils with high medium fruitiness (< 6) and light sense of bitterness and pungency (< 3) with no defects (0). Several tools are proposed for better evaluation of the standard cultivation practices, sensory characteristics are displayed in specific graph models and the total quality of olive oil is calculated based in specified formula that combined both chemical and sensory results. Based in the Total quality index score formula twenty-four samples obtained from Krya and comparative organic systems are compared with popular olive oils currently dominating the Greek and Cretan market. Finally this study suggests options for improvement of the production stages of cultivation, process and post harvest management that may increase the success of the product and maintain the productivity in the region aiming to become competitive in the global market.

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CHAPTER 1: INTRODUCTION AND LITERATURE REVIEW

1.1 General Introduction

The quality of olive oil is a very interesting subject which has been very heavily studied in the past and still is. Most studies agree that the quality of olive oil is strongly connected with the regional characteristics of the land where it is produced. Multiple factors during all stage of production influence the chemical and sensory attributes of the oil [Servili et al., 1998][Brescia, 2003][Cosio 2006][Dabbou et al., 2010]. These regional characteristics can be determined independently with various methods (in most cases by agro technologists) which deal with various parameters (productivity, crop protection etc.) affecting olive oil. In a different level olive oil quality can be analyzed without taking in consideration its regional characteristics, only by applying chemical and sensory methods (in most cases used by food technologists) to determine the state to the product. Olive oil quality can also focus on the level of the nutrition (in most cases by the nutrition technologists) by examining the nutritional and secondary characteristics (concentration of poly phenols, vitamin E) in relation with human health.

The Mediterranean countries have the leading production systems of olive oil in EU and export products of both high quality and quantity in the global market. In the Mediterranean, olive oil has directly generated an income for about seven million families and supported indirectly more that 30-35 million families the past decades [Bonazzi, 1997]. Olive oil production is very popular in Greece, the rates of consumption are widely known to be increased compared to other countries. Ancel Keys' studies in Crete suggested that the reasons why Cretans appeared to have so high longevity [Artemis, 2001] are high olive oil consumption, amongst other parameters.

Unfortunately, in the olive oil industry quality and health is not always the priority since management in most cases focuses on the increase of profit which can easily be done by increasing quantity which in most cases is a practice competing with quality. In the olive oil sector this is called ‘intensification’ of olive oil production systems which in some cases has proven to be a non profitable practice, and has led to the phenomenon of

abandonment in some regions, including those that are mountainous (sited at an altitude of 400 meters and above) , and difficult to access [MacDonald et al., 2000].

It is a noticeable fact that the EU's agriculture policies the past years have been encouraging higher quantitative production of olive oil, but this also had several negative impacts. In general, the large intensive flatland production systems benefited from higher support compared to mountainous traditional production systems [de Graaf, 2007]. At the same time other oils such as canola oils seem to be more profitable in quantitative strategies. Especially in traditional mountainous production systems such as those in Greece, Italy, Spain and Portugal this policy has proven to be destructive since it has led to their abandonment since there is less potential to establish competitive intensive agro-systems in high altitudes. Due to the high costs of production compared to flat lowlands these mountainous regions are facing either abandonment or pushed to evolve into something more profitable. In southern Europe this tendency has been exacerbated by EU production subsidies under the Common Agricultural Policy (CAP) regime [Beaufoy, 2000].

This phenomenon has been studied by several projects. The famous “Olivero project” study (2003-2006) researched the reasons behind this abandonment and aimed to create possible conservation scenarios for mountainous systems which are considered as “high risk of abandonment” described as “SMOPS”(sloping and mountainous olive production systems) and suggest profitable strategies to assure the sustainability instead of abandonment in areas in Southern Europe. One of the advantageous scenarios was the alteration of the conventional high-intensive but unsustainable olive oil production systems into semi-intensive organic systems, aiming at products of better quality and higher price in the market which would provide the economic survival of family-type producers who would therefore then keep producing olive oil in such areas. By aiming at producing high quality organic extra virgin olive oil with higher price in the market these regions would therefore aim to produce olive oil of optimum quality rather than maximizing quantity for profit [de Graaff et al. 2007]. This strategy would have a number of positive and negative effects including certified oil products with much better quality but with a requirement for specialized knowledge, and an additional cost for certification. Since then not many studies have been done regarding the socio-

economic or quality evaluation of mountainous olive oil production systems which have evolved into organic producing systems. Especially in Greece, where the extra virgin olive oils in general have a deserved reputation of high quality, there are not many studies characterizing the Greek regions and their olive oil varieties. Studies are even less in olive orchards which produce oil at high altitudes and characterized as mountainous, even less in organic olive oils.

It is very possible that organic farming as viewed from many aspects could represent a ‘panacea’ to solve many problems in semi-mountainous and highland systems since it promises high quality yields with less intensified agricultural methods, adopts eco-friendly farming practices which are increasingly demanded and seems to be a profitable business in areas that are considered “high risk of abandonment” due to inclination and difficulty to access. Olive oil quality seems to be the priority in these systems since most studies suggest there is much difference between ordinary virgin oils and extra virgin oils. Regarding its phenolic status extra olive oil is known to be a source of more than thirty phenolic [Kellie, 2002] compounds including acetoxypinoresinol and pinoresinol that are only present in extra virgin olive oil [Owen et al., 2000] and not in other classes of olive oil (virgin, ordinary etc.) It is known to contain natural phenols, including oleocanthal and oleuropein that benefit human health [Tripoli et al., 2005]. These compounds have potent antioxidant properties and are also known to give extra virgin olive oil its characteristic tastes of pungency and bitterness that are gaining respect. In addition extra virgin olive oil produced in highlands (altitudes around 200 to 600 meters) has been reported to have noticeable higher content of total phenols [Dabbou et al. 2010] compared to lowlands regardless the cultivar. This is a considerable factor which not only agrees with the proposals of the Olivero project about alteration of unsustainable mountainous systems into organic systems but also creates the hypothesis that organic practices in these systems could produce olive oil with very desirable characteristics and of higher quality compared to conventional lowland olive oils. The global market clearly pursues products which combine quality, safety and marketing values. So the current situation creates a pressing need for studies which will assess the quality of organic olive oil produced in highland regions. In Crete such systems can be found in all four municipalities (Chania, Rethymnon, Heraklion,

and Lasithi).

1.2 Mountainous production systems: expansion or abandonment?

EU regulations on oil production promoted the intensification of olive oil production until 2005. This has led to the expansion of olive cultivation with conventional methods of farming that resulted to unsustainable agricultural practices [de Graaff and Eppink, 1999] [Beaufoy, 2001]. In later years, EU recognized the failure of policy and proposed to change the policy in 1997 (CEC, 1997).In addition the project “Olivero” was designed to assist in the identification and development of appropriate policy options in less favorable regions. The full title of the project was: "The future of olive plantation systems on sloping and mountainous areas; Scenarios for production and natural resources conservation". The famous Olivero project (2003-2006) was a collaboration of six institutes in five countries financed by the European Union under the Fifth Framework Program for research [Stroosnijder et al., 2007]. It dealt with the socio-economic and environmental sustainability of “Sloping and Mountainous Olive Production Systems (SMOPS)”. The project produced several scenarios where either SMOPS had to be abandoned or become more profitable agro-ecosystems.

Sloping and Mountainous Olive Production System (‘SMOPS’) are production systems in which olives are produced using similar agro-technological, ecological and socio-economic conditions in mountainous “high risk of abandonment” land characterized with high altitude and an indicative land inclination of 15% or higher [Fleskens, 2007]. One of the objectives of Olivero project was to develop alternative scenarios to improve olive orchards productivity and sustainability in the five Olivero (target) areas of including West Crete. Papers followed suggesting different scenarios for each area. Experts tried to foresee possible changes to avoid the abandonment of these systems and encourage intensification and organic production methods [de Graaf, 2008].Some studies also suggested that the project did not develop a concrete, quantified definition for all these systems [Beaufoy, 2007] therefore it became arguable which systems are under abandonment or what strategies fit better for each case. On the basis of these

assumptions; several scenarios were discussed for the participant countries. Portugal pointed in systems of high probability of abandonment suggesting as the optimum scenario the alteration of conventional high-intensive SMOPS into organic production systems. Spain, aimed in further intensification (Granada and Jaen Olivero study areas) and suggested that orchards with especially high slopes were likely to be fully abandoned [de Graaf, 2008]. Organic production strategy was generally considered and became more popular as an idea. Following studies indicated that Organic farming can be a successful strategy only if oil price pre liter is increased. Finally, studies suggested that the future of organic SMOP systems in the EU will probably be determined by consumers and their willingness to pay organic olive oil [Gomez, 2008].

All of the above suggested that a mountainous agro-ecosystem is a high risk unit which needs to be examined very closely from the scope of economic sustainability which is directly connected with the price of the production which is dependent on its quality which is also connected with the production strategy / cultivation methods practiced by the producer in collaboration with the agro-technologists. These regions are often weakly developed and access is difficult. At the same time other farming sites flourish because they are better accessed, has more potential to be mechanized and are more organized which encourages producers to invest in these lands rather than the mountainous and less productive hills [Beaufoy, 2001]. The producers which remain in the SMOPS are in need of a clear strategy which will result in a successful outcome. To survive they need to evolve, or else perish.

1.3 Public health benefits of regions where olive oil is a basic diet element

Modern nutritional science often addresses the importance of a well balanced diet which consists of macro-nutrients and micro-nutrients. The main micro-nutrients are protein, carbohydrates and fat divided into different percentages and are the basis of a balanced diet. In the Mediterranean diet the percentage of fat consumption per day can reach 25-30% of the total calories. The benefits of unsaturated and mono-saturated fats in health have been proved by modern science and foods such as olive oils are preferred instead

of other vegetable oils. In this chapter olive oil is reviewed as a product with many potential uses in human nutrition and as a food product of high importance for the maintenance of health.

1.3.1 Nutritional properties of olive oil and health benefits

The value of olive oil is indicated by the nutritionists as beneficial to health and a major component to be chosen among most other vegetative oils in the market. Numerous epidemiological studies show that olive oil can reduce cholesterol and lower the incidence of breast cancer in women [Patroni, 1995]. Food technology studies suggest that the antioxidants in the oil can contribute to the stability and longevity of the oil as well as in other products when olive oil is used as a natural additive.

According to the World Health Organization WHO), the adoption of behavior related to a healthy lifestyles such as diet, may increase overall health very largely. People who adopt the Mediterranean diet have a longer life, reduced mortality from all causes and specifically reduced mortality from coronary heart disease and cancer. Olive oil has been found to contain several antioxidant compounds that are not found in other type of oils. The researchers believe that the 'type' of oil is more important in health rather than "quantity". The ability of certain types of oils to prevent lipid peroxidation seems to be a key process in the initiation, progression and complication of many diseases such as liver, kidney, cardiovascular and degenerative neurological diseases and diabetes. [Aguilera et al., 2000]

In general, monounsaturated fatty acids such as oleic and linoleic acid are of particular importance because of the nutritional effects. A diet based on a higher quality olive oil will have a better role in the situation of human health, which is directly related to the work undertaken in this project. Evidence from epidemiologic studies also show that a higher percentage of monounsaturated fats in the diet associated with decreased risk of coronary artery. This is important because the oil is quite rich in monounsaturated fats, especially oleic acid. There is much evidence from clinical data suggest that consumption of olive oil can provide benefits for heart health, such as favorable effects on cholesterol regulation and - oxidation of cholesterol, and exerts anti-inflammatory,

antithrombotic, antihypertensive as well as vasodilatory action in animals and in humans [Covas, 2007].

In particular, olive oil protects against heart disease as it controls the levels of "bad" low-density cholesterol (LDL) and increases levels of "good" cholesterol, high density cholesterol (HDL) [Drummond 2010]. Since it is the least processed forms of olive oil, extra virgin or virgin olive oil have more monounsaturated fatty acids than other olive oils. Some clinical data suggest that it is the phenolic content of the oil is responsible for at least some of the cardio-protective benefits. As a result olive oils with better phenolic content are becoming more popular. Horticultural investigations suggested that olive oil produced in high altitudes can have very high phenolic content especially when certain irrigation strategies are followed compared to lowland, highly irrigated orchards [Berenguer, 2006] [Dabbou et al. 2010].

Extra virgin olive oil generally contains more polyphenols, which may have benefits for the heart. This suggests that lower oil quality can have a lower content of phenolic and minimized impact to the benefit of our health, which again emphasizes the importance of olive oil research. Olive oil contains monounsaturated fatty acid oleic acid; Antioxidants such as vitamin E and carotenoids, and oleuropein, a chemical that can help prevent the oxidation of LDL particles [Conni et al, 2001.].

Olive oil was also found to reduce oxidative damage to DNA and RNA, which maybe a factor for the prevention of cancer [Machowetz et al., 2007]. It is very interesting to note how strong impact oil can have on human health. Most of the modern chronic diseases are the result of changing fundamentals in diet, environment and behavior. One of the strongest fundamental changes is the amount and kind of fats and oils which consume daily. Hydrogenated oils for example have been implicated in cancer and heart disease epidemics. Returning to traditional diets based in high-quality olive oil seems to be an efficient way to safely sustain health, replacing unhealthy, processed fats now consumed so often.

1.3.2 The Cretan diet and olive oil

Olive oil has contributed to the health of the Greek population for generations. One of the uniqueness of olive oil is that it can be consumed in its raw form without further purification. This has the effect of keeping all of the vitamins, essential fatty acids, antioxidants and other nutrients that are necessary for the body. Antioxidants protect olive oil from oxidation and in a similar way protect us from the damage of free radical oxidation. Human cell membranes contain fatty acids, which are particularly susceptible to the creation of free radicals and reacts with the production of lipid peroxides which damage the cell [Hamid 2010]. As a result polyphenols, vitamin E, and many other natural antioxidants present in olive oil are making it a key component of an optimum diet.

The island of Crete has had the attention of researchers since 1948 when the Rockefeller Foundation (in the United States), tried to research the nutrition and health of the inhabitants in the island. Investigations led to the conclusion that the majority of Cretans were nutritionally adequate (all the important micro nutrients where in present in their diet) although the quality of living was very low due to the effects of the Second World War, with a few exceptions in areas with very low incomes. Compared regions of Europe with better quality of living had nutritional misbalances or inadequate intake of important nutrients [Allbaugh, 1953]. The following years in the popular “seven countries study” Crete's population became widely known for their special eating habits. The connection of the low rates of premature mortality and cardio vascular diseases in the region were studied. Comparisons between populations showed that Crete’s population had better health and lower rates of mortality from coronary heart disease or cancer, compared with all other populations studied [Keys, 1970][Keys et al., 1986]. The lower incidences of cancer, coronary heart disease and mortality from all causes observed in the population of Crete were attributed to the specific eating habits that characterized this region [Sofi et al., 2008]. For these reasons Crete was considered to have a special diet which was rooted in the long past traditions.

Traditional, dietary habits of the Greeks consisted of a high intake of olive oil, vegetables, fruits, nuts, cheese, fish, moderate amounts of wine, less meat and milk. In

regard with olive oil, Greeks and especially Cretans were and still are the leading consumers of olive oil [Artemis 2001]. In general Greece appears to have the strongest olive oil-based culinary and there is scope for an expanding consumption of optimum quality olive oils in view of their widely accepted nutritional and health properties. Olive oil was and still is used both in salads and in food preparation, unlike the countries of Northern Europe which consume more animal fat. Initially, the protective effect of the Cretan diet on health has been attributed to high content of monounsaturated fat, the daily use of olive oil, and low content of saturated fat, due to low consumption of red meat and animal fats.

1.4 Olive trees in the Mediterranean basin

The Olive tree is native to the Mediterranean basin and two widespread views exist about olive oil production. The first one suggests due to archaeological evidence that the first cultivation took place on the island of Crete as long ago as 3,500 BC (Early Minoan times). The alternative view maintains that olive oil was produced by Canaanites in present-day Israel by 4,500 BC [Ehud Galili et al., 1997].Olive oil was certainly produced by the Late Minoan period (1500 BC) in Crete [Riley, 2002]. Olive tree cultivation in Crete became more intensive in the post-palatial period (1425 to 1170 BC) and played a very important economic role in the island during this period. Archaeological findings confirm the fact that the great first Cretan civilization, the Minoans, not only was based on agricultural economy, but also had broad commercial relations in the East Mediterranean based on its agricultural products [Treuil et al., 1989].

In the regions of Kolymvari (Chania, West Crete) and Kavousi (Lasithi, East Crete) stand two of the oldest olive trees in the world. These monumental olive trees are considered two of the oldest olive trees in the world with an approximate age of at least 2500 years and 3000 years.

Figure 1.1 (Left) Monumental olive tree of Vouves in Chania. (Right) Monumental olive tree of Kavousi in Lasithi.

1.4.1 Mountainous production systems in Crete – the case of Krya

Crete is the biggest island of Greece and also the fifth most big in all Mediterranean. The morphology of Crete is characterized by three main zones: the low zone relates with areas ranging from sea level to 200 m altitude, the band from 200-400 m (middle) and zone with an altitude of 400 meters or more (high or mountainous).The second and third zones occupy almost 3/5 of the island and form a continuous mountain range from west to east, interrupted by small valleys and mountain peaks above 2,000 meters. For this reasons Crete is considered as highly mountainous. Crete's four counties from the West part to the East are Chania, Rethimnon, Heraklion (capital of the island) and Lasithi as shown in the map of Crete below in Figure 1.2.

Figure 1.2 (Left) Map of Crete showing all four provinces of the island. (Right) The province of Lasithi

The terrain is mostly mountainous, with Mount Dikti (or Lasithi mountains) that dominate the county boundaries of Heraklion and Lasithi, occupying entirely the province of Lasithi and part of Mirabello and Ierapetra. A second mountain range, the mountains of Sitia, is located in the east of the county. Valleys with olive trees are often among the mountains, even in the coastal regions. There are two plateaus, the most famous Lasithi plateau Katharo (Kritsa region belongs to the Municipality of Agios Nikolaos). There are no important rivers or streams and any available surface water is used for water supplies and irrigation. Located 25 km from Sitia on the road from Piskokefalo to Krya are both the higher and lower settlements of Krya. The village owes its name to the cool springs or excessive cold (*Krya*:cold) winter. Its old and historic settlements unfortunately inhabited by few people because of the slow but constant abandonment in mountain areas. The settlements are located at an altitude of 550 to 600 meters. Krya is basically one of the eighteen districts of Sitia and with a first glance has not many differences compared to the hundreds of mountainous settlements of Crete which are mainly engaged in farming, animal production and tourism (mainly in summer). Olive trees are one of the most basic sources of income and play an important role in the survival of the populations of this case of settlements. Krya like most of Crete's production systems used to practices a “traditional” cultivation system which has evolved from generation to generation and currently operates as semi – intensive organic farms.

The key characteristic of Krya comparing with other similar regions is that many producers are full-time operators of their production, and the community is very active towards the continuation of olive-growing which is in contrast to the widespread opinion that olive-growing is being abandoned, they have mobilized themselves to apply organic farming methods which is very heavily regulated. Krya brings Sitia’s “Protected Designation of Origin” (PDO) which is designed to protect the integrity food and drink within European Union by legislating the labelling of olive oils products. The expanse of olive groves in Greece has increased steadily over the last 25 years as a result of the plantation of new high-density olive plantings. Groves of olive oil has been

also extended in many mountainous, hilly and coastal areas (mainly in Crete and the Peloponnese). SMOPS in Crete represent the oldest tradition in the cultivation of olives, as more fertile lowland areas were used for other (annual) crops. The often shallow and rocky soil on steep areas performed well for olive trees compared to other crops. As is shown in Figure1.3 these regions are mountainous, shaped with no specific symmetry, can be highly inclined and are difficult to access due to underdeveloped network of roads.

Figure 1.3 (Left) Sitia: one of the four municipalities of Lasithi, and Krya, South - West of Sitia. (Right) the mountainous valley of Krya

However, these agro-ecosystems are traditionally cultivated over generations and combine several characteristics which indicate the possibility for high quality organic olive oil. Farming practices of conventional agriculture (e.g. use of pesticides, fertilizers etc) have been used in very low scale, and many of the olive oil orchards have adopted the organic olive oil agriculture.

1.5 Standard crop practices in organic semi-intensive systems of Krya

Several main production systems can be recognised in Crete. Based in assumptions made during and after the Olivero project, SMOP types can refer to a) traditional, b) organic, c) intensive, d) semi-intensive (low or high input) [de Graaf et al. 2007]. High intensiveness conventional systems can be found in the lowland areas of Crete while and “traditional” systems are mostly found in the highlands. “Traditional” systems can

be easily altered to organic since there is no actual difference between these two classes besides the fact that organic orchards hold a certification of organic product which forbids the use of chemicals. This study mainly focuses on the assessment of organic olive oil produced from organic semi-intensive systems.

Figure 1.4 Typical semi-intensive organic "Koroneiki" cultivar in mountainous Krya.

Cultivar "Koroneiki" is the primary oil cultivar cultivated in Crete as presented in Figure 1.4, it is generally producing very small fruit but very heavy yield, 24-28% of the fruit is olive oil, with high concentrations of polyphenol [Vossen, 2007]. Olive trees like subtropical climates and perform well in long and dry summers often noticed in Crete. Frost during blooming can damage the harvest. Spacing between olive trees can be close (5 x 5 meters) or distant (10 x 10 meters) or 7 x 7 depending parameters such as, soil type, and climate.

Organic olive farming is in general accepted as a semi-intensive practice which relies on techniques such as green manure, composting of weeds and other plants and use of biological pest control to maintain soil productivity and protect against pests on farm instead of using chemical pesticides or chemical or synthetic fertilizers, which are all commonly used in conventional agriculture to increase the production in demand. This is an eco-friendly approach which is very important for the preservation of the natural health of the world since the problems with intensive farming (for example excess of synthetic nutrients in the eco-system etc.) are well acknowledged in the scientific community. Cretan farmers seem to understand well that it is necessary to either make a circle back from high intensive conventional practices to organic semi-intensive organic

agriculture or they will have to face the difficulties of maintaining low profitable systems which will result in the abandonment as discussed in the Olivero project [Stroosnijder, 2007] and has also been the subject of many other studies later on [Beaufoy, 2001 & Fleskens, 2007]. In Crete, the organic movement is growing year by year; consumers prefer to order olive oil directly from organic farms which is accepted as of higher quality rather that search in the market, which has led to the increase of income for the organic producers. The “rooted in the past” tradition of the island and the close connection with the olive orchards has caused people to have a basic education about the quality of olive oil which seems to be the reason why olive oils from different regions of Europe (Portugal, Spain, Italy etc.) are not widely found in the Cretan market.

Organic agricultural methods are internationally regulated based in large part on the standards set by the International Federation of Organic Agriculture Movements (IFOAM), an international organic farming organization established in 1972 [Paull, 2010]. Standards regulate the production methods for organic farming. In the 1980s, guidelines of organic production were produced from the governments. In1991, European Union Eco-control was developed, which set standards for twelve EU countries, and a 1993 program in the UK. In2005, IFOAM created the «principles of organic agriculture” as an international guideline for certification criteria [IFOAM, 2005].Usually organizations certify certification groups rather than individual farms. For a producer to be able to get organic certification is a rather simple process. The olive tree farm has to meet the criteria (be free from chemical formulations) set by EU and after 3 years a license is given to the producer.

1.5.1 Soil management and irrigation in organic semi intensive systems

Soil cultivation is a standard method used in organic olive agriculture to encourage trees to produced new root system and destroy weeds within the crop. In general, olive trees prefer moderately fine-textured soil including sandy loam or loam, silt loam, clay loam and silt loam clay. Such soils can provide aeration for the development of olive tree roots, are highly permeable and have high water capacity. Olive trees are shallow rooted and do not require very deep soils to produce well. The soil is often annually cultivated around May enabling the olive trees to promote new root growth, usually performed

after the pruning season although this is not absolute. Soil is often cultivated with small tractors or a tractor with ploughshares as it is shown in Figure 1.5. Frequent soil cultivation can weed seed populations in the soil, thus reducing weed growth which is especially important in organic agriculture since use of pesticides is forbidden. Soil cultivation is an especially effective method of weed control in Crete's organic orchards.

Figure 1.5 Tractor cultivating the soil to a depth around 10-20cm

It is well known that the total phenol content of olive oil can be affected by the amount of water applied during irrigation. Olive oil obtained under heavy irrigation is very likely to have lower bitterness [Gomez et al., 2007].Traditionally olive plantations epitomized dry land farming and were not irrigated. Water use can vary considerably according climatic and soil conditions of regions, the irrigation system used by the producers, tree density, etc. In organic production trees are treated with supplemental water during the dry months of summer. Access to irrigation network might be difficult in distant areas. The majority of family -type producers do not follow any systematic water testing unless there is noticed a local phenomenon which is suspected to have connection with problem in the water network. In recent years, drip-irrigation (earth drilling) was introduced on a certain areas of Crete showing successful results. Alternately wells or cisterns store water during rainfall months (December-February) which prove the supplemental water needed during the dry months.

1.5.2 Crop diseases and pests in Organic Cultivation

In general, pests and diseases are one of the key issues in Organic SMOPS therefore protection against crop diseases should be a standard crop practice [de Graaf et al., 2007]. One of the main pests in olive oil production, difficult to control in organic farming (where crop protection using chemical products isn't allowed), is the olive fruit fly (*Bactrocera oleae*) shown in Figure 1.6. This pest is very harmful during September and November and is known to cause problems in organic in all Mediterranean production systems, from Greece to Portugal [Ferreira, 2002]. The olive fly also increases the olive fungal disease - *Colletotrichum gloeosporioides* – which is even more harmful for olive oil quality. A very dangerous bacterium which is widely noticed in Crete's traditional orchards is *Pseudomonas savastanoi* (Figure 1.6). It is a plant pathogenic bacterium that infects a variety of plants including olive trees. It is a pathovar of greatest economical significance which causes the disease known as "olive knot". The infected trees show symptoms of formation of tumours induced by indoleacetic acid biosynthesis by the bacteria.

Figure 1.6 (Left) *Bactrocera oleae* as one of the most hostile fly for olives. (Right) tumour caused by *Pseudomonas savastanoi.*

These diseases are very common in olive orchards; *B.Oleae* is seriously damaging olives oil productivity and quality. The attacks partly depend on the climate conditions of the region. Studies suggest that mass trappings of the fly *B.Oleae* can limit the disease spread of *P. Savastanoi* [Bendo, 1999]. Application of this suggestion in Portugal showed promising results and there is space for improvement of the method [Ferreira, 2002]. This can suggest than a possible protection against the fly in Organic

agriculture can give positive results since the majority of organic farmers seem to not making any plant protection practice so far.

1.5.3 Tree nutrition in organic semi – intensive systems

In general, the olive tree is a very resistant plant and it is possible to grow it in various types of soils. It mostly needs nitrogen (N), phosphorus (P) and potassium (P) as well as micronutrients, (calcium for example) to the soil. These micro- nutrients are not always in abundance in the Cretan soil so in organic semi intense cultivation specific strategy may be followed to prevent malnutrition of tree. In general the pH tolerance of olive trees is large, ranging from about 5 to 8.5 but ideally would be adjusted to approximately 6.5. In organic semi intensive orchards such as those in Krya, producers rely on several techniques for the maintenance of the nutrition needs of their orchards which have been developed through years of empirical implementation.

I) Green manure as source of nitrogen

Also known as ("cover crops") is widely used to provide nitrogen through legume plants (more precisely the Fabaceae family) through a process which is based in the symbiosis with rhizobial bacteria. In Crete many species of the family of Fabaceae are naturally growing which is an important characteristic of the organic farming of olive oils in the region since fertilizers are forbidden. A good example of this legume plant is *V. Sativa* shown in Figure 1.7. Grown Legumes develop a natural balance with olive trees and help the production first by providing nutrients to the olive trees and second by competing with weeds.

Figure 1.7 (Left) *Vicia sativa*: one of the most commonly found legume within Cretan olive tree orchards. (Right)*Oxalis Sp.*: a species of the family Oxalidaceae

which is also very frequently observed within the Cretan flora.

Plants like the legumes are often found within the Cretan orchards to serve as “natural fertilization factors” through a process called “nitrogen fixation”. As a result nitrogen (N_2) in the atmosphere is converted into ammonia (NH3) though various chemical reactions performed by micro-organisms. Bacteria called diazotrophs are known to convert nitrogen to ammonia. Higher plants (like the Fabaceae family) have formed associations (symbioses) with diazotrophs and are benefited from the converted nitrogen. Nitrogen can be used by trees and plants to synthesize basic building blocks (protein etc.) therefore natural nitrogen fixation by Legumes can be considered as a method of fertilization.

II) Pruning residues management as compost

Another important organic source that farmers may use in Easter Crete is the remnants of the pruning season. Every tree can possibly produce a great amount of organic mass which can be used as compost. Some producers are composting the leaves and small branches which are broken into smaller pieces with the use of mechanical branch shredders as shown in Figure 1.8 below. After pruning of olive trees the remains are mostly wooden parts which can be used as fire material or fed to livestock or broken down into smaller parts with mechanical branch shredders and used as similarly to “green manure” within the orchard (Figure 1.9).

Figure 1.8 Pruning residues (small branches, leaves) are broken down into smaller pieces which are used as green manure with the help of a mechanical branch shredder.

The residues are left to be “digested” naturally by micro-organisms and as a result a series of enzymatic reactions take place giving a final product which is called olive leaf compost. Alternatively the producers place this product in the base of the olive tree creating a number of possibly advantageous results at the same time. First of all this compost provides organic compounds to the plant. Secondly the compost is subject to thermophilic reactions and reaches a sterilizing temperature which is believed to practically keep the soil “warm” for the trees during some cold days during the winter period and can also hold an amount of humidity which useful for the tree during the dry seasons of summer. Third, the digestion of the mixture releases a small quantity of CO_2 which the tree uses, and fourth it blocks the weeds from emergence, a technique which is known as “mulching”. The producers who use this practice are giving an example of a ‘smart’ and eco-friendly technique which improves the fertility and makes the olive tree farms in Krya self sustaining by limiting the appliance of any external organic fertilizer.

III) Ley farm practice

Another interesting characteristic of organic farming in Crete is farming with both livestock and crops which operate as lay farms as shown in Figure 1.9. This can also act like a natural mowing and cutting of the weeds by the livestock since lambs for example are removing the top growth of the weeds and restrict their development in the roots of the olive trees.

Figure 1.9 Livestock within orchards feeding with surrounding grass and pruning residues.

Lambs are also fed with the bottom part of the olive tree's leaf system which the same time encourages new tree growth. Production systems with livestock are easier to maintain fertility and may rely less on external inputs such as imported compost, manure and other. Remnants from the pruning season are often used as feedstock in ley farms and as an exchange animal manure is recycled back to the orchard as organic fertilizer.

1.5.4. Pruning of olive trees in semi intensive organic agriculture

Pruning is perhaps one of the most important techniques and is taken very seriously by olive tree producers because it has many and rapid advantages for the olive trees. It does not influence olive oil quality directly but it is used mostly to force productivity. Pruning is widely known to renew olive trees and improve yields. It also helps maintain structure and contain tree size; favours light penetration and air circulation inside the tree canopy. It can permit better control of diseases and pest and eliminates old dead or diseased wood. It creates a shape which will be more manageable during harvest and can help trees recover after damages (e.g. frosts). The nutrient input is different in semi intensive organic agriculture compared to highly intensified production therefore it is expected that the pruning of the trees should be also different because it stimulates new growth which is more likely to success if the nutrient input is abundant.

I) Intensity - frequency

In general the intensity of pruning can depend on plant vigour, the age of the tree, number of damaged branches, soil fertility, water availability, and training systems which are followed. The intensity also depends in the frequency of pruning. It is believed that high intensity cutting encourages a stronger vegetative response. As a result yield is increased. Annual practice is avoided in productive trees and more usually pruning is performed every two years for elimination of damaged shoots or four years to remove damaged shoots, maintain vegetative growth and encourage high yield. If no pruning is practiced for more than six years the yields starts to decline and harvesting becomes more difficult.

II) Pruning methods

Olive trees can be pruned for (i) shape for easier mechanical harvesting and to avoid problems when performing other practices such as cultivation of soil for example if the trees have become too close together and too near to the ground. Trees can also be pruned for (ii) productivity to encourage higher yields and goodqualityoffruitingbyremovingmostlythepeaksoftheperipheralbranches to cause the "bush effect", or by removing downward branches. In some other cases pruning is performed for (iii) plant renewal and restoration of old trees. In these cases old trees are more heavily pruned to stimulate the tree to promote new massive productive growth. In some very heavy pruning cases the tree is left with two or four major branches to return faster to a productive state and all smaller branches and leaves are removed. Pruning for restoration can also practise to restore damage from cold or diseases.

III) Training systems – shapes

A number of training systems has been developed for olive trees giving them shape depending on the objectives set by the producers of the orchard. In Crete it is often used the (i) vase system, the (ii) bush or globe and the (iii) free canopy training systems. In the "vase", the central part of the canopy is pruned to help sunlight penetrate the interior parts. This system is believed to encourage higher yield but also requires skilled labour compared to the other two training systems.

IV) Pruning seasons

Pruning in Sitia is mainly performed between mid-winter and early spring before tree flowering (January to April). It is believed that pruning should be performed when the tree is about to transfer its fluids to the leaves and promote new growth. Farmers may prune after the harvest period in general when the temperature is normally between 7 to 22^{o}C.Latepruning may not harm the tree, but usually is avoided as it will remove the tissues to which nutrients and carbon reserves have been remobilized, resulting in a total net loss for the plant.

V) Description of the Cutting process

The professional pruner rapidly cuts the larger branches in the inside of the top part of the tree and then continues outside of the tree correcting its shape then progressively proceeds to the bottom removing the smaller unnecessary dead and old woods. This is often done with a chainsaw or saw and in some cases hand axes are used. Shaded, old, diseased, downward branches and competing shoots which are less productive are removed. Horizontal branches generally can be more fruitful. Upright branches generally remain more vegetative. Branches with a good combination of the two are desired for the best productivity, the Vase training system for example combines both. After the prune, copper solution or ethanol is used to clean the tools and prevent spreading of diseases (for example *Pseudomonas savastanoi.* and *Verticilium sp.*).Paint is often used for covering the bigger cuts to prevent pests or disease from affecting the tree limbs.

1.5.5. Harvesting olives

The process of harvesting refers to the collection of olive fruits during the harvest period. In most cases it is done when the fruits have reached their optimum productive state. Harvesting date in relation with ripeness is known to affect olive oil quality [Beltran, 2004]. The type of harvester used seems to affect both quality and working productivity.

Olives can harvest with hand held mechanical harvester in Crete regardless if a semi intensive organic or a highly intensive conventional strategy is practiced. Lowland orchards can possibly use harvesting vehicles as shown in figure 1.10 which are faster

compared to hand held mechanical harvesters. The application of harvesting vehicles in declined mountainous orchards can be difficult therefore it is unlikely to be used in such systems in Crete.

Figure1.10 (Left) Vehicle harvesting olives by vibration. (Right) Mechanical hand held beating harvester. Olives drop to the surrounding net and then gathered in sacks

Vehicle harvesting is expected to be less efficient in the highland orchards of Crete since (a) high inclinations do not favor the use of it and (b) the most common cultivar "Koroneiki" produces a great number of small olive fruits which has been reported to drop harder with the vibration method used by vehicles of this type. In the event that the olives are large, as in other varieties commonly grown in Italy, the probability to use the vibration method is more likely. Similarly the collection with hand (hand picked olives) is very difficult in the case of Koroneiki which can't afford this method since the worker productivity with manual harvesting is relatively low. All of the above has led in the adoption of hand held harvesters which beat the olives to the ground as seen in Figure 1.10. Studies in Syria suggested than working productivity with hand held harvesters in can be 4-5 times faster compared to manual harvesting olives [Abdine, 2005].

Olive harvest machines are used to drop the fruits to the ground where a net is spread around the olive tree. Linen or plastic sacks are used for the transportation of the olives to the mill and their storage there until milling. Unfortunately, wounds created during beating of olive fruit seem to affect the formation of free fatty acids which can lower the quality of olive oil if the processing of oil from the fruit is delayed. Improper

harvesting, carriage and storage conditions of the olives can lead in an overall lose of quality [Bosku, 1996] [Kyritsakis, 2001].

The widespread view in Krya is that olive should be harvested when the fruits are turned ¾ dark purple assuming that fruit contains the highest concentration of olive oil-although this needs more investigation since other parameters also influence oil content. Fruit determination of ripeness may involve color – visual quality, fruit firmness and oil content [Agar et al. 1998]. Based in color-visual determination, olives may be classified as (i) Green olives, when they have reached normal expected size prior to coloring. In some cases olive fruits can be harvested in an earlier state to produce “olive oil from unripe olives” which is considered to have increased phenolic index and is widely accepted as even more gourmet product than extra virgin olive oil. (ii) Turning-color olives are before complete ripeness, at color change from green to dark purple. (Iii) Black olives are considered fruits with full ripeness (dark purple or black color).In regard with ripeness, Studies in Tunisia suggested that olives produced at higher altitude can have higher ripeness index and oil content compared to olives cultivated at lower altitude [Dabbou, 2010].Irrigated olives seem also to mature faster compared to less irrigated [Dabbou, 2011]. Furthermore harvesting date seems to be related to ripeness and ripeness is being reported to majorly affect olive oil chemical and sensory characteristics [Beltran, 2004] [Dabbou 2011].

1.6 Processing of olive oil with decanter centrifugation

Process of olive oil refers to all works within the mill from the step of fruit reception to the processing of olive oil from the fruit and bottling of olive oil. The most important stage of production during process is the processing of oil from the fruit. In intensive modern methods of processing factories are equipped with the decanter centrifugation technology that can adjust temperature to the needs of production. Temperature and use of water during processing are two very important factors which affect the final quality of olive oil by having an impact in the concentration of poly-phenols and antioxidant substances of olive oil. In general, malaxation is widely accepted that affects the flavor of the resulting oil [Caponio and Gomes, 2001]. [Servili et al, 1998]. Many oils sold in the market are called “cold processed” describing the temperature at which the oil was processed from olive oil. For an olive oil to be characterized as “cold processed” the processing process must not use temperature higher than 27 °C (80 °F). “Cold processed” olive oils are widely accepted as oils of greater quality compared to heated - processed olive oils. In the EU, designations regarding “cold processed olive oil” are regulated by Article 5 of Commission Regulation (EC) No 1019/2002 of 13 June 2002 on marketing standards for olive oil. Processing of olive can be described with the following steps:

I) Fruit reception – leaf removal and olive washing

The first operation right after the delivery of olive oils to the factory is washing. The olives are transported through the elevator where stems, leaves are removed and then washed with water to remove dirt etc. as it is shown in Figure 1.11.

Figure 1.11 (Left) olives and other debris in the fruit elevator. (Right) olives are

washed with water and then moved to the next stage of processing

II) Olive crushing to form a paste and malaxation

Oil is produced in the mesocarp cells of the olive fruit. Each one of these fruit cells contains a tiny amount of olive oil which during processing is separated. During malaxation olives are crushed to a paste and then mixed for thirty to sixty minutes in order to allow the small olive oil droplets to agglomerate. This process is called malaxation (or kneading) of the olive paste as presented in Figure 1.12.

Figure 1.12 Olive paste during malaxation

The exhausted paste is called pomace and can be furthermore processed to produce oil known as “pomace-oil”. The olive paste can be heated or water added during this process to increase oil yield but these techniques are known to generally result in lowering the quality of the oil due to removing of precious water-soluble compounds (polyphenols, water soluble vitamins etc.) or destroy them by heat.

III) Separating the oil from the vegetable water and solids

After kneading, oil must be separated from the rest of the olive components. The separation is done by centrifugation (Figure 1.13). The three-phase calibration separates the oil, the water, and the solids separately. Water can be added to facilitate the processing process with the paste and centrifuge rotates at about 3000 rpm, the high centrifugal force created allows the phases to be easily separated according to their different densities. After centrifugation is complete, the oil can form a cloudy form because of due minute amounts of humidity which tend to settle out and divided into two stages later.

Figure 1.13 the separation of oil from the paste with decanter centrifugation

IV) Oil storage and bottling

After the processing the oil finally is left in a tank of about $1m^3$. Then olive oil is transferred into multiple tanks with more capacity for storage as it is shown in Figure 1.14 where a final separation occurs through gravity.

Figure 1.14 (Left) Olive oil after the separation ending in tanks of 1 m^3. (Right) multiple tanks used for the storage of olive oil in bulk

Oils are in most cases filtered and bottled or sold in bulk. Premium quality oils are stored in specific conditions to maintain their quality [Mendoza, 2001] [Fernandez et al., 1998)]

Olive oil can be filtered before bottling although this is not mandatory. Filtering contributes in the integrity and stability of the oil but may possibly effect the concentration of vitamins and polyphenols in olive oil although this needs more

investigation. In professional bottling companies an automated infrastructure bottles olive oil in dark green glass bottles as shown in Figure 1.15 below. Otherwise bottling can also be done manually.

Figure 1.15(Left) Infrastructures suitable for bottling of olive oil and labelling and (Right) typical green colour bottle used for bottling of olive oil.

The color of the bottle is important because chlorophyll has been noticed to have a dual effect in olive oil. Chlorophyll from the one hand prolongs shelve life because it preserves the stability of olive oil because it protects it from oxidation [Fakourelis, 1987]. This is the effect in conditions where there is no light presence. In conditions where there is lot of light olive oil is known to react different. Oil which is high in chlorophyll, when in contact with light it is degraded due to a phenomenon which is called “light oxidation”. Therefore it is widely accepted that chlorophyll has a “positive” effect during dark storage (stability of quality) and it has “negative effect when in contact with light (moreover reactions which result in oxidation). To prevent this, olive oil is bottled into dark green glass bottles (to absorb light of the specific wavelength which gives the green color) and protect olive oil from the phenomenon of light oxidation. Light oxidation of olive oil is very usual in cases where the bottle of olive oil is transparent. In these cases olive oil can be degraded due to the continuing reactions of chlorophyll and light. Furthermore, the affect in quality bottling is an important element for the success of Organic olive oil marketing. In fact, it has been reported as one of the key issues in Organic SMOPS [de Graaf et al., 2007].

1.7 Modern assessment methods of olive oil quality and classification

Olive oil quality is verified with chemical and sensory according to the standards set by the International Olive Council (IOC), formerly the International Olive Oil Council (IOOC) [Mailer, 2006, Dabbou et al. 2010]. The International Olive oil Council is an intergovernmental organization responsible for the administration of the International Agreement of Olive oil. This agreement lays down the policy that members should take on the standardization of the market for olive oil involving the adoption of international rules to determine the quality of the products on sale and to monitor international trading [Harwood 1991]. The roles of IOC are a) to modernize olive growing and olive oil processing by encouraging research and development to improve product quality and environmental impact of the olive and olive oil industry b) expand international trade and raise consumption of olive oil monitoring any unfair competition and c) ensure regular international trading in olive oil sand table olives by taking measures to strike a balance between production and consumption and to harmonize national laws. The IOC tries to control the quality of olive oils, and has established a classification system which is based on free fatty acids, super-oxides, and other indexes (EU's rules 1989/2003). This classification system is used to chemically determine the quality of olive oil. Free fatty acidity value, absorption in the ultra-violet (K_{232}, K_{270}) and peroxide index is being determined following the Regulation EEC/ 2568/91 of the Commission Regulation (1991) which is described in Chapter 2 Materials and Methods.

1.7.1 Classification of olive oil based on free fatty acids content

One of the main quality tests used for evaluation of the oil is the free acidity determination. The free fatty acid content is a direct measure of the quality of the oil reflecting the total cares taken during the fruit growth. The free fatty acids are the result of dissociation of triglycerides as shown in Figure 1.16, due to a chemical reaction called hydrolysis or lipolysis. The presence of free fatty acids indicates degradation of olive oil and poor quality. Olive oil ontained by poor quality fruits is more possible to suffer from breakdown of triglycerides into fatty acids. A low content of free fatty acids provides relative assurance that the fruit quality was good during processing [Mailer

2006]. Wounds caused to the fruit during harvest or parasites can promote hydrolysis of triglycerides, resulting in increased plasma concentrations of free fatty acids [Shimizu, 2008].

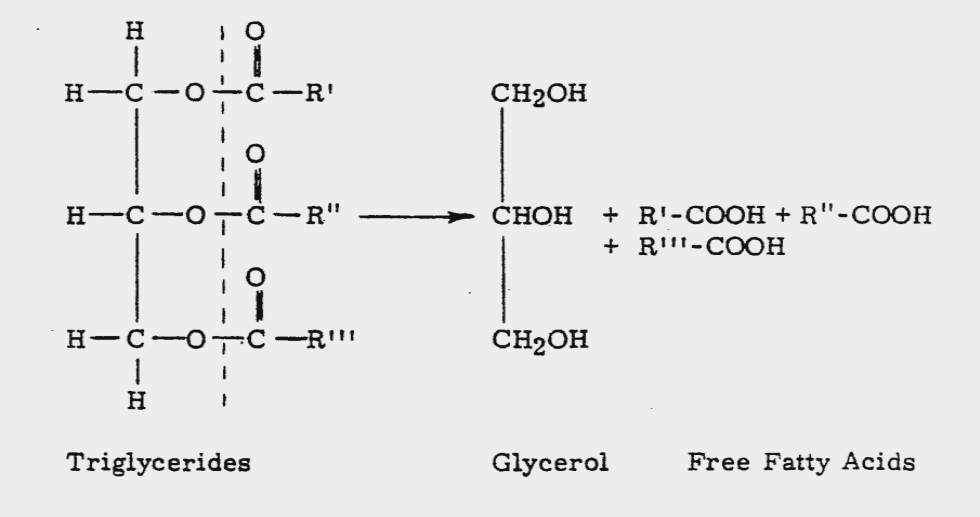

Figure 1.16 Breakdown of triglycerides and release of free fatty acids and glycerol by lipase enzymes

Virgin olive can be classified based in free fatty acidity score as is presented in the following Table 1.1.

Table 1.1 Classification of Virgin olive oils based on free fatty acidity content

Olive oil Virgin Class	**Free fatty acids (%)**
Extra virgin olive oil	<0.8 or 0.8
Virgin olive oil	<2or2
Ordinary virgin olive oil	<3.3or3.3

Both organic Virgin olive oils (created only from organically grown olives) and conventional Virgin olive oils (from conventionally grown olives) follow the same standards. In general there are nine grades of olive oil: accepted as “Virgin” (extra virgin, virgin, ordinary, lampante) or “Refined” (refined olive oil, olive oil, crude pomace, refined pomace, olive pomace) [Mailer 2006]. According to the International

Olive-oil Council [IOC 2012] in countries that adhere to the standards set by the organization show the following oil's grade in stores:

A) Virgin olive oil

I. Extra-virgin olive oil: comes from virgin oil production only, contains no more than 0.8% acidity, expressed as oleic acid, and is judged to have a superior aroma and taste therefore are the optimum quality olive oils.
II. Virgin olive oil: comes from virgin oil production only, has acidity less than 2%, and is judged to have a good taste.
III. Ordinary virgin olive oil: is virgin olive oil which has a free acidity, expressed as oleic acid, of not more than 3.3%

B) Virgin olive oil not fit for consumption

Known also as Lampant oil, *Lampante* comes from olive oil's long-standing use in oil-burning lamps. It is of more than 3.3% of acidity expressed as oleic acid. Lampante oil is mostly used in the industrial market and is not suitable for human consumption.

C) Refined olive oil

Is olive oils obtained by refining methods from virgin olive oils. In most cases is being obtained by virgin olive oils not fit for consumption and has no aroma or flavour.

D) Olive oil

Oil labelled as “Olive oil” is usually a blend of refined and virgin production oil fit for consumption as it is. Blends are accepted as a class of lower quality compared to virgin olive oils. It has a free acidity, expressed as oleic acid, of not more than 1%.

E) Olive Pomace oil: Olive oil processed in this manner is still olive oil but may not be simply called “Olive Oil” because IOC defines Olive Oil as “the oil obtained solely from the fruit of the olive tree, to the exclusion of oils obtained using solvents or re-esterification processes”. Olive pomace oil is generally oil obtained from pomace using solvents (pomace is a residual paste left over from the production of virgin olive oil) such as hexane [Gunstone, 2002]. It still contains a variable proportion of oil depending on the system used to produce the virgin olive oil. It is marketed with the follow in

designations and definitions:

I. Crude olive-pomace oil: is used either for refining or for technical purposes
II. Refined olive-pomace oil: obtained from crude olive-pomace oil by refining methods
III. Olive pomace oil: olive oil often blended with some virgin oil and refined-olive pomace oil fit for consumption as it is, but may not be called "*olive oil"*.

1.7.2 Classification of olive oil based in peroxide value

Oxidation is the change in structure of olive oil due to the contact with O_2. The peroxide value is the index which shows the oxidation of olive oils which may have led to the creation of super-oxides which are formed from the reaction of unsaturated fatty acids with oxygen. These compounds (super oxides) are broken into compounds with smaller molecular weight (ketones, acids) responsible for specific sensory characteristics (negative) found in olive oils such as "rancidness". These oxidized compounds which are present in olive oil are widely accepted as negative substances for the health of cells. It is expressed in milli-equivalents (meq) O_2 / kg usually, and for extra virgin olive oils of higher quality ranges between 5-15 meq O_2.For extra virgin olive oils as well as virgin and ordinary virgin the peroxide value limit is < 20 meq O_2 / kg as set by the IOC.

1.7.3 Classification of olive oil based in the absorption in the ultraviolet light (K indexes)

K_{232}, K_{270} and ΔK (Delta K) are indexes related to the absorption of ultraviolet light in specific wavelengths such as of 232nm and 270nm. It can show of various types of unwanted oxidised substances within the olive oil as well as the possibility of adultery with other types of olive oils. The IOC has set a standard method for the determination of K indexes. The wavelengths at 232nm and 270 are very interesting because they can provide information about state of preservation or the stage of degradation which may have occurred in olive oil.

The K_{270} index score represents the absorption at 270 nm and refers to oxidised materials and practically can show the resistance to oxidation. This score is relative to the freshness of the oil suggesting that olive oils after bottling for example should have the lowest scores compared to older olive oils (2 years after harvest for example) which should have higher scores for K_{270}. The score is constantly rising through time, light and temperature can accelerate the process of oxidisation which will have an obvious rise in the K 270 index score. Extra virgin olive oil's K_{270} index scores usually range between 0.15 and 0.22.

The K_{232}index score represents the absorption in 232 nm and refers to the presence of hydro peroxides. Peroxides are compounds containing oxygen–oxygen single bonds (The O−O group is called peroxide group). Hydrogen peroxide is the simplest peroxide. Practically, peroxides are responsible for the oxidation of olive oil and K indexes give information about the percentage of oxidation of olive oil's compounds which may have occurred in different stages of olive oil production. For example when this value is high it can be related to long periods of olive storage before the milling process or similar cases where olive oil is oxidised. Extra virgin olive oil's K_{232} index scores usually range between 1.5 and 2.5.

The ΔK index score is another indicator of quality used for the quality determination of purity in olive oils. It is calculated with a formula which uses values from other wavelengths around 270 (see Materials and Methods Chapter). The final score can either be negative or positive depending on differences between olive oils. Practically, extra virgin olive oils mixed with other oils (non- extra virgin) can be detected with this index score. The score of extra virgin olive oil is usually negative but can reach the limit of 0, 01 in some cases.

Table 1.2 Limits of olive oils based on K indices

Olive oil Class	K_{232}	K_{270}	ΔK
Extra virgin olive oil	<2.5	<0.20	<0.01
Virgin olive oil	< 2.6	<0.25	<0.01
Ordinary virgin olive oil	< 2.6	<0.25	<0.01

1.7.4 Classification of olive oil based on organoleptic characteristics

Sensory evaluation is one of the most important tests which have to be done to determine the quality of olive oil. In order to assess olive oil by sensory methods, the senses of taste and smell are used. It is known that free acidity alone or any chemical characteristic of olive oil in general cannot guarantee the success of an olive oil in the market since for the consumers the taste is more important, and is how the quality is judged. The most important characteristics are aroma and flavours of fruity, pungency and bitterness [Mailer 2006].

I) Panel team members and booths used for the evaluation

The group leader should be properly trained person with knowledge of the type of oil that he or she will encounter during their work. Panel leaders are responsible for the performance, organization and operation of the panel. The members are carefully selected, trained and monitored by the panel leader, according to their ability to distinguish between similar samples; Accuracy of the members can be improved with training. Panels consist of 8 to 12 testers needed for each test, although additional tasters are trained in reserve to cover possible absences. Sensory trials occur in specially designed rooms as shown in Figure 1.17. Booths should provide the team participating in the sensory tests with a suitable, comfortable, standardized environment that facilitates work and helps to improve the repeatability and reproducibility of results. The IOC protocol indicates that all cabins must be identical to the design and dimensions.

Figure 1.17 Tasting panel during sensory trials of olive oil samples

II) Aroma of olive oil

Testers pick and rotate the glass to wet the inside as much as possible. Once this phase is completed, remove the watch glass and smell the sample for no more than 30 s, taking slow, deep breaths to evaluate the oil. Flavour of virgin olive oil is the sum of perceived sensations generated when the different chemical compounds, which are transported with the air during inhalation and exhalation, reach olfactory receptors in the epithelium. Flavour produced from volatile low molecular weight compounds. Stimulus may be perceived directly (nasal), when the fragrance reaches through the nose and indirectly (retro nasal), wherein the perfume which is volatile at body temperature, it passes through the mouth in the olfactory epithelium. More than one hundred volatile compounds can be identified in virgin olive oil known to contribute to flavour.

III) Sensory score – taste determination of olive oil

The most important feature of olive oil seems to be the organoleptic sensation. The four basic tastes are sweet, salty, sour and bitter. When the olfactory test has taken place, the testers evaluate oral sensations. To do this, they take a sip from about3 ml oil and detect possible positive or negative (unsatisfactory) organoleptic score and its density on a scale1-9 (The method for sensory evaluation of virgin olive oil referred to COI/T.20/Doc.15/RevNo3.IOCProtocol). A professional taster normally distributes the oil throughout the oral cavity, from the front of the mouth and tongue along the sides of the back support and palate and throat, since it is known that the perception of flavors

and tactile sensation vary in intensity depending on the area of the tongue, palate and throat.

III) Colour

It is additional organoleptic characteristics since which normally is not evaluated during the organoleptic trials. It is related to quality parameters such us the percentage of chlorophyll and carotenes in olive oil that are determined with spectrophotometry. The colour of a fresh extra virgin olive oil is between light-gold and green depending on the concentration of chlorophylls which are responsible for the gold-green and the concentration of carotenes which are responsible for the yellow-red colour. The percentage of these concentrations is related to certain parameters such as cultivar, genetics, cultivation practices, production conditions and stage of fruit ripeness.

1.8 Project outline, key issues and objectives

The overall aim of the present research project is to examine all stages of production of olive oil which is produced in Krya, a representative of the mountainous systems of Crete, and assess its organic olive oil production with modern scientific methods in terms of its quality attributes, and suggest methods of optimization. Olive oil quality is strongly connected with its regional characteristics and from this aspect mountainous regions such as those of Crete, have the potential to produce olive oil of excellent quality and higher value in the market which can be marketed as certified organic products with specific characteristics.

This aim leads to the formulation of the following objectives in this research project:

I. Create an inventory of organic productive systems in Krya, its regional interface and mountainous characteristics which make these systems at high risk of abandonment. Also display samples of comparative systems (SMOPS) outside of Krya.
II. Collect descriptive data of standard crop practices which is used in mountainous the organic semi – intensive production systems of Krya
III. Examine the processing process of olive oil and storage conditions of before the

bottling and packaging stage and collect samples which represent the organic orchards of the specific SMOP area which is under examination

IV. Use the samples previously collected and apply the methodology of quality testing and classification which is established by the IOC to determine the quality of olive produced in this region

V. Compare the results with olive oils produced in other regions and olive oils which can be found in the Cretan, Greek, European and global market.

VI. Develop conservation scenarios to optimize the performance of every stage of production in the systems which are studied and discuss the prospect of organic production in Crete.

With regard to the first objective, an inventory will be made mapping the area which surrounds the basin of Krya to have a clear understanding of the origin of the olive oils which are studied. Also mapping of other regions which belong to the category of SMOPS can be reviewed as comparative samples which can also be used as a set of samples comparing chemical and sensory characteristics later on.

The second objective deals with standard crop practices which are used by the producers will be recorded. This creates the necessity to examine the orchard characteristics directly from the field. Data should be able to generate tables which will show the execution rates of practices such as:

- Irrigation, soil cultivation, fertilization etc.
- Pruning systems and management of residues
- Harvesting and residue management
- Pest control and protection against diseases etc.
- Take into consideration which sets of orchards are treated less with standard crop practices described above to generate tables presenting noncompliance rates

The third objective is about examination of the processing processes which takes place in the region of Krya and the management of the olive oil after processing. More specifically:

- To Examine the temperatures during processing inside the mill
- To collect the samples will be used for the following objective.

This leads to the fourth objective which is to assess and determine the quality characteristics of olive oil produced in Krya based in the standard protocols which are proposed by the International olive oil council.

- Free fatty acidity
- Peroxide value
- K indexes
- Chlorophyll determination
- Organoleptic scores

Under the fifth objective the current results from the quality assessment of the samples will be compared with the chemical and sensory scores of olive oils which are currently available in the market.

- Review commercial olive oils currently in the market and their characteristics
- Generate tables for comparison between the marketed olive oils and the set of samples which were studied within this project
- Apply the olive oil total quality index score formula (O.T.Q.I.S) proposed by the IOC for olive oil

The sixth objective concerns the optimization of the respective olive oil production which is at high risk of abandonment areas such as Krya and other areas identified with similar characteristics. Issues noticed within this study which seem to mostly affect the quality of olive oil can therefore be established.

CHAPTER 2: MATERIALS AND METHODS

To accomplish the most urgent challenges [Garcia 2010], various stages of olive oil production in highland regions were researched in this study: (i) agro-technological aspects in high risk of abandonment (due to high altitude, inclination and difficulty of access) orchards were investigated described as SMOPS [Duarte et al., 2007], (ii) processing of olive oil (iii) virgin olive quality determination iv) total quality comparison with other oils was made. The subject of focus was the semi-intensive organic production systems of Krya that represent mountainous orchards often noticed in Crete. Also, to act as a benchmark for comparison other regions of similar geographical and altitude characteristics were included as comparative regions that produce oil. This was to obtain a better overall impression about the quality of the area studied.

For the agro-technological aspects (i), the project focused on the technological applications of producers in the region to determine the differences within this region compared to other regions of Crete. This means that the groves had to be measured and classified as SMOPS based in inclination and altitude, recordings of soil treatments and irrigation methods were made, disease rates and appearance of pests within the orchards was determined, producers were asked about their practices and generally work was carried out to record the cultivation technology of olive trees in the region focusing at all stages of production starting from primary stages (cultivation and care of the olives).

On a different level the processing of olives (processing conditions of olive oil from olives) was researched during olive oil processing in mills. The main area of focus was the processing (ii) of temperature during olive processing which seems to play an important role in the final quality of olive oil. For the determination of the quality characteristics (iii) chemical and sensory analyses were. Chemical tests included determination of free fatty acidity, K indexes and peroxide values. Sensory trials were made to have a complete modern analysis of olive oils as proposed by IOC for the assessment of olive oil.

The total olive oil scores obtained from all tests were used in the calculation of the total quality index score (iv) with a formula proposed by the IOC that combines all scores together and gives a final total quality score. As a result all samples obtained during this study were compared with additional sets of popular olive oils which are currently on the Greek market with this total quality index score formula.

2.1 Agro-technological information about olive oil orchards

2.1.1 Classification as SMOPS

Crete is generally very mountainous, and sloping and mountainous production systems are operating at high altitude, often greater than 400 meters (see also section 1.4.1) with an inclination of more than 15%. To be able to classify the production systems that were studied as SMOPS it was necessary to determine if they met the two criteria of altitude and inclination [Fleskens, 2007]. It is important to know if the systems are heavily or lightly inclined because this can be the largest factor affecting the manageability of the orchard. Flat but mountainous orchards operate differently than inclined ones because it is easier to access, transport, practice soil cultivation, and harvest.

I) Altitude of orchards

Altitude or height is defined based on the context in which it is used, as a distance measurement, and is commonly used to mean the height above sea level of a location (therefore expressed in m and Km). In this study, the altitude of the selected orchards was measured and defined as the height above sea level of the orchards (for example of Krya) and the measurements were made using the **Global Positioning System** (**GPS).** GPS refers to satellite navigation technology that can provide details about location and altitude theoretically anywhere on the Earth

II) Inclination of land

Inclination of land can be measured if the distance and the altitude of two positions are known. As shown in Figure 2.1,

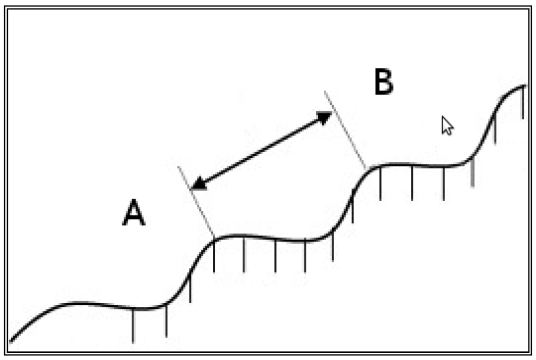

Figure 2.1 Illustration of positions A and B needed for the calculation of percentage (%) of inclination of an orchard

A and B equals the distance of the lowest and highest spot within an orchard and when the altitude difference between A and B is known then inclination can be expressed by dividing the distance towards the relative altitude (inclination = distance / relative altitude). For example, if we know A and B height is 100 meters and the altitude difference between A and B is 10 meters then the inclination is 10%.

Therefore if A and B equals 100 meters and the difference of altitude between A and B is 10 meters then 100 / 10 = 10 %

Since inclination can vary in different sites of each orchard the final calculation of each orchard's inclination was measured from the lowest (A) site of each orchard and the highest (B).

2.1.2 Sub-regions and local names

Sitia's region of Krya is divided in sub-regions which are not all olive oil producing and also are divided into smaller parts with different local names which are used for the identification within the society of the settlement. For the purpose of this research the

orchards were classified by the local name which is used by the producers. Certain codes have been created which represent the local identities of the orchards and were used for the statistical calculation. These codes will represent the orchards in the results chapter as well.

Twelve sub-regional orchards were being examined in total representing the wider region of Krya and its production systems. These systems were divided in four groups which represent four major areas:

- Semi-intensive organic olive oil production systems located in the South parts of "Lower Krya", (A1, A2, A3) with more that 15% inclination
- Orchards with access to the West road of Krya (B4, B5, B6) with more that 15% inclination
- Semi-intensive organic olive oil production systems with access to the East (C7, C8, C9) road of Krya, with more that 15% inclination
- Hard to reach semi-intensive organic production systems, with difficult access and very high inclination (D10, D11, D12), more that 35%

In additional four more sets (twelve sub-regional orchards) were also researched:

- Semi- intensive organic olive oil production systems located in the neighbour settlement called "Dafne" (F16, F17, F18) south-west of Krya with more that 15% inclination
- High-intense organic production systems located in the flatland area of Sitia (E13, E14, E15) with no inclination
- Semi-intensive organic production systems located in the sub-region of Dories (5 Km north east of Neapoli) which belongs to municipality of Agios Nicolaos (G19, G20, G21), a region with similar characteristics (altitude, inclination, high risk of abandonment) compared to Krya.
- Damaged or "poor quality" olive oils: These are samples obtained various

regions by poor quality olives: in Krya (H22), olives were collected and let several days into sacks before processing. Such delays are known to cause increase in peroxides and lower quality olive oil [Kiritsakis, 1998]. H23 refers to olive oil obtained from Messara (located in the county of Heraklio); olives were damaged by an unexpected frost which harmed the olives right before harvesting. Such damages are expected to have sensory defects. H24 refers to olive oil produced in Palaikastro (flatland area close to Sitia), olives seemed to have a general lower quality due to wounds caused by *Bactrocera Oleae* fly. Such wounds are known to cause increase in peroxide and free fatty acids.

All of the above have led to the formulation of the following Table representing 24 olive tree groves that were studied for their crop practices and were also used for the collection of 24 samples that are chemically and sensory tested later on:

Table 2.1 Orchard identifications and coding used within the project

Local Identity (Krya)	Location and Municipality	Orchard Code	Local identity (Comparison areas)	Location and Municipality	Orchard Code
ByzaTrigona	Krya (Sitia)	A1	Rema 1	Rema (Sitia)	E13
ByzasGadana	Krya (Sitia)	A2	Rema 2	Rema (Sitia)	E14
ByzaSterna	Krya (Sitia)	A3	Rema 3	Rema (Sitia)	E15
Minas1	Krya (Sitia)	B4	Dafne 1	Dafne (sitia)	F16
Minas2	Krya (Sitia)	B5	Dafne 2	Dafne (sitia)	F17
Spilios	Krya (Sitia)	B6	Dafne 3	Dafne (sitia)	F18
B.Ntaliana	Krya (Sitia)	C7	Tsourla	Dories (Neapoli)	G19
B.Diamadis	Krya (Sitia)	C8	Koka	Dories (Neapoli)	G20
B.Skourafi	Krya (Sitia)	C9	Ktenas	Dories (Neapoli)	G21
Riza Syntreto	Krya (Sitia)	D10	Lakos Krya	Krya (Sitia)	H22
Krya Spyru	Krya (Sitia)	D11	Messara	Messara (Herakl)	H23
Potamisia	Krya (Sitia)	D12	Palaik	Palaikastro (Sitia)	H24

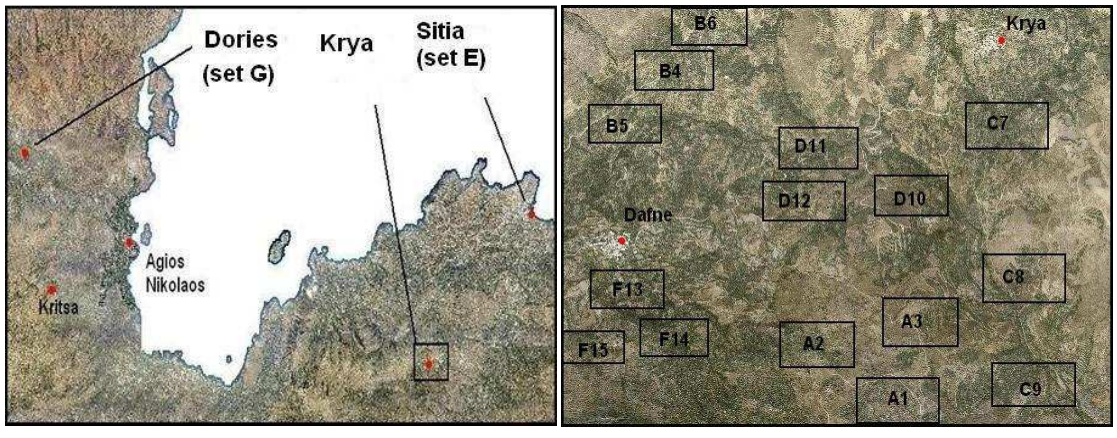

Figure 2.2 (Left) Locations of Neapoly (Set G), Krya (Sets A, B, C, D and F) and Sitia (Set E). (Right) Map and locations of Krya's and Dafne's organic orchards.

2.1.3 Standard crop practices in organic semi intensive production systems

The compliance rates (%) to standard crop practices used in organic production systems give information about the overall care of orchards and can also indicate differences between regions. The type of practices is important to estimate the quality of technology which is used and along with the rates of execution can give information about the strategy of production and the consequences of these treatments in the near future. Different regions may have different compliance rates to standard crop practices and may use alternative practices characterizing the regional strategy of production.

By recording the total standard crop practices which are used in a region it is possible to understand a) the type of practices which are used from the producers b) to degree these standard crop practices are followed or not followed. If the majority of local production systems consider that a certain strategy is standard for the region then noncompliance to this strategy shows that producers are less active, and are unlikely to have a production result similar to the majority of the production systems in the area. Calculation of total non-compliance is a tool which may therefore be used to determine if a region is following a specific strategy.

For example if a production systemhas100 olive trees and 80 are receiving a standard crop practice then the execution/compliance is 80%. If 20 trees received no standard treatment then on compliance is 20%. This tool is very useful since each region has different climate, crop cultivar and scope of production and follows different “standard crop practices”. As a result, each region’s standard crop practice may positively influence that specific region where it was developed but it have negative influence in other area, due to the local conditions.

In this study specific practices are reviewed to determine a) what type of practices are performed in the region of Krya b) to what degree and c) which groves are less compliant with these standard crop practices and d) how noncompliance to standard practices is influencing these groves.

All these treatments that are considered as “standard crop practices” for organic olive

production systems are used thoroughly in this study to describe treatments rates of (a) soil cultivation, (b) irrigation, (c) fertilization, (d) pruning and crop protection against (e) *B.Oleae* and (f) *P.Savastanoi*. Other practices are also reviewed but may not include in the final calculation of compliance/noncompliance because may not represent a standard practice, may be arguable if it represent a standard crop practice or may be performed in a maximum rate at all orchards.

As a result, sets that did not apply these standard crop practices were recorded as "no treatment or other treatment" and were used to calculate their total non-compliance to standard practices.

Total non-compliance scores can be therefore proposed as an objective tool to evaluate olive production systems since different agricultural practices and treatments in general are known to affect olive oil quality [Gutierrez, 1999][Cosio, 2006][Dabbou et al., 2010].. This tool is based on the assumption that systems with maximum compliance to standard crop methods will produce optimum olive oil compared to systems that receive less treatment of standard crop practices which expected to show lower quality olive oil.

I) Soil cultivation rates (tillage)/ compliance to soil cultivation in organic semi – intensive orchards

Soils can be cultivated by many ways and for several reasons depending on the orchard and the producer. Data about the soil cultivation was gathered during the months of April - May when olive trees are normally treated in most parts of Crete, directly from the field in collaboration with the producers. The area of focus was the types of machinery used by the producers to tillage the organic systems of the regions under study and the determination of execution rates. Tillage in olive tree orchards is normally done using sharp steel wedges that cut loose the top layer of soil called "Ploughshares". The machinery which is used for tillage can therefore determine the percentage of mechanisation. Practices of interest during the study were:

- Use of heavy tractor attached with ploughshares
- Small manually controlled tractors

- Other, non-standard treatments / no treatments

The execution rates (%) of each set were calculated by counting the number of trees which received soil cultivation treatment (i.e. the first two in the list) by the producers compared to the total number of the set. Rates and types of soil cultivation give information about the level of mechanization and the degree of the practice used. Soil cultivation is considered a standard crop practice and compliance to this practice gives information about the overall compliance of producers to standard crop practices.

II) Fertilization execution/compliance rates in organic semi – intensive orchards

This refers to the method which is adopted by the producers and the kind of compound used for the improvement of the fertility of the orchards. Fertilization of organic systems in mountainous systems can be more difficult compared to conventional systems because chemical fertilizers are forbidden and producers must rely only on approved methods for organic systems. Data were retrieved in collaboration with the producers with the use of questionnaires. The area of focus was the different type of practices and the execution rates in these systems. The most common practices for fertilization were:

- green manure (as a cover crop grown to add nutrients and organic matter to the soil with the use of legume plants)
- Organic, commercial product (spread onto the soil surrounding the olive tree)
- Compost (commercial or produced by the organic farmers with the use of plant residues)
- Animal manure
- Other / Non standard treatment

The executions rates (%) were calculated by counting the number of trees which received fertilization with one of these types (i.e. the first four in the list) compared to the total number of the set. Fertilization is generally considered a standard crop practice because it offers all valuable compounds necessary for the sustainability of the

production. Orchards that receive no treatment will eventually notice declined productivity.

III) Irrigation sources and compliance to irrigation

This refers to the method which is used by the producers to provide enough water to their olive trees and can be a qualitative characteristic when the method is examined or quantitative when the amount of watered is examined. In this study the orchards were researched to identify the irrigation source which is used by the producers to provide water to the systems. The methods of irrigation under question were:

- Private earth drills (drilling ground for water)
- Wells (public or private storage of water collected during the months of rainfall)
- Network irrigation (public network providing water for agricultural purposes)
- Cistern / tanks (private establishments of water storage obtained either from the network or by other methods to provide water during the dry months)
- Nonstandard crop treatment (only rainfall)

Irrigation executions rates (%) were calculated by counting the number of trees which received watering with one of these sources ((i.e. the first four in the list, besides rainfall) compared to the total number of the set. Irrigation is considered a standard crop practice regardless the amount of water provided and compliance to this practice gives information about the overall compliance of producers to standard crop practices. In addition, systems that do not have access to the public network or privet earth drill may have difficulties in adopting certain irrigation strategies where intensive irrigation is required. Groves that received no standard method of irrigation and relied only in rainfall were considered as “nonstandard”.

IV) Harvesting execution rates and types of harvester

This section deals with the method which is practiced for olive harvesting, by the producers depending on the technology which is used. It is important to determine

which methods are adopted to harvest olives in difficult to access mountainous systems which are identified as semi-intensive organic, with different percentages of inclination. In recent years many type of harvesters have been introduced to the market, most popular practices under examination were the following:

- Hand held harvesters
- Heavy vehicles vibration harvesters
- Manual harvesting of olives
- Rods / sticks (used to drop olives by hitting olive branches)
- (other /nonstandard treatment)

The executions rates (%) were calculated by counting the number of trees which were harvested with one of these types (i.e. the first four in the list) compared to the total number of the set.

V) Pruning execution/compliance rates in organic semi - intensive orchards

This refers to the system (production, shape or renewal) and style (vase, apple etc.) used by the producers to train their olive trees. The systems and style were studied within the orchards during and after the period of pruning. It is an important parameter which gives information about the care of olive trees which can affect the productivity. It is an important indicator of the level of professionalism of producers since it requires specialized workers and constant care. It also gives information about the specific regional characteristics of production which are not necessarily practiced in all systems since every region has its own characteristics. The most important pruning practices were:

- Shape (semi- intense pruning, applied in trees which have lost shape during years for several reasons such as carelessness, limitation of pruning costs or unavailability of specialized pruners etc)
- Renewal (heavy pruning, performed in old, damaged or diseases trees by removing all unnecessary parts

- Productivity (specialized cuts to promote growth and production in trees which already have correct shape and do not suffer from any damage or other conditions.
- Other/ non standard treatment

The compliance rates (%) were calculated by counting the number of trees which where treated with one of the above practices compared to the total number of the set. Pruning is generally considered a standard crop practice regardless of the training system or the type of cultivation. For this reason is also used as a parameter for the calculation of the total compliance to standard crop practices.

V) Management of pruning residues

After pruning the residues are a problem because they can develop and harbour diseases. Practically all options available are likely to be seen practised to varying degrees. For example some producers prefer to burn a percentage of the diseased residues and compost the leaves and small branches or perhaps use as food for livestock and keep larger pieces of wood for burning material (wood-stoves). Information about this method was collected by questioning the producers and directly from the orchards by examining the management of the residues by visiting during and after the months of pruning. Abandonment of pruning residues within the orchards can host several diseases therefore current policies forbid it. The most common practices were:

- Compost. Refers to organic matter that can be decomposed and used as a fertilizer in crops. Pruning residues are broken into small pieces with mechanical shredders and receive treatments to product compost.
- Burning material – firewood. Residues are either burned within the orchards or cut for use as firewood (firewood is also sold for additional income)
- Fed to livestock. Parts of the residues are fed to livestock within the orchards or transferred to livestock farms. This practice usually generates animal manure which is returned to the system as a source of organic matter.
- Other treatment (no treatment here is not used, since no treatment of pruning

residues is illegal, because the remnants can host diseases, and pests and is unlikely that no treatment is applied)

The execution rates (%) were calculated by counting the number of tree residues which where treated with one of the above practices compared to the total number of the set.

VI) Disease and crop pest appearance rate in organic semi-intensive production system

This section deals with the identification of crop enemies within the orchards. Most common symptoms which were examined were those caused by the enemies in Figure 2.3.

- *Bactorcera oleae*
- *Cycloconium oleaginum*
- *Euphyllura olivina*
- *Pseudomonas savastanoi*

Figure 2.3(From left to right) i) bite caused by *B.Oleae* olive fly ii) symptom of "spot" caused *C.Oleaginum* fungus iii) symptom of "cotton" caused by insect *E.Olivina* and iv) tumour caused by *P.Savastanoi* bacterium

The appearance rates (%) were calculated by counting the number of trees which were identified with these symptoms compared to the total number of the set.

VII) Crop protection compliance against *P.Savastanoi* and *B.Oleae*

Crop protection is one of the key issues in organic practice. Crop enemies such as *P.Savastanoi* (bacteria) and *B.Oleae* (olive fly) represent two dangerous cases which widely spread within the Cretan orchards. In organic systems where the use of non-organic pesticides is forbidden *B.Oleae* can cause serious problems because it reduces the production, and can affect the quality of the olive oil because it damages olive quality and quantity. Fruits seem to be more susceptible when the fruit ripeness and the skin becomes softer in later months compared to unripe olives in early months of harvesting [Tamendjari et al., 2004].

Several studies suggest that mass trappings (Eco-traps) can prove to be a successful practice against *B.Oleae* [Ferreira 2002]. *P.Savastanoi*is difficult to control once established because there is no actual treatment against it once the tree has been diseased. It is known to spread through wounds caused during harvesting or pruning. Prevention seems to be the only reliable strategy which is performed by disinfecting harvesting or pruning tools with alcoholic solutions. Strategies against crop enemies can give interesting information about the compliance of producers and the future of these systems. Data regarding the compliance rates of producers were retrieved with questionnaires and the final compliance rates (%) were calculated by counting the number of trees which where treated with either mass trappings or tool disinfection compared to the total number of the set. Crop protection in general is considered a standard crop practice and can be performed as a prevention strategy. No treatment to crop diseases can also used to determine the total non-compliance to standard crop practices.

2.2 Olive oil extraction conditions and collection of samples

The next stage after cultivation and harvesting of olives was also studied in this project. This stage includes olive oil processing from olives in the mill.

2.2.1 Collection of samples processed in Krya mill

Olives produced from the systems described in chapter 2.1.2 were monitored during the post harvest stages for better control of the samples. The following parameters were taken into consideration:

- Olive oils used as samples for the termination of quality were obtained from olive tree grove sets (A-D for Krya and comparative areas) presented in Table 2.1 and illustrated in Figure 2.2. From each grove, 3 litres of olive oil were obtained for all purposes of this study. As a result sample A1 represents 3 litre of olive oil obtained grove A1, sample A2 represents 3 litre of olive oil obtained grove A2 etc.
- Olives from Krya were harvested in the second half of December (15th Dec to 1 January) starting from set A (south Krya), following with set B (east Krya) then set C (west Krya) and finally with set D (highly SMOPS with inclination more than 35%). Olive sets acting as a benchmark for comparison such as those obtained from the flatland area of Sitia (set E) and the settlement of Dafne (set F) were gathered during the same period with Krya (second half of December), samples from Dories were harvested in the end of November to the first week of December (around 25th Nov to 5 Dec).
- Set E olives were more ripened (dark-purple to black olives) compared to Krya, highly irrigated orchards are widely known to mature faster. Set G olives were less ripened (green olives) compared to Krya. Olive obtained from non- irrigated orchards (dry) are widely known to ripe slower. Krya olives were in an intermediate state (turning from green to dark-purple)
- After harvest olives were gathered within linen sacks and piled (as used in these systems) therefore pressures during transportation and storage leading in fluid secretions harming olive oil quality can be expected [Olias & Garcia 1997]. This process represents the dominant method of transportation of olives in the systems under study and no changes were applied during study.

- All olives, in all sets were delivered to the mill not more than 48 hours after harvest. Olive oil was processed with commercial configuration used for organic production and no changes were made during the study in any mill. Temperatures during milling were a separate objective targeting to determine the exact conditions of processing for each mill used.
- The mill used for the olive oil processing of sets A, B, C, D and F was the mill of Krya, managed by elected personnel in favour of the organic producers of the region. The mill of Acladia (flatland Sitia) was used for the processing of samples obtained from flatland area of Sitia (set E). The mill of Furni (Neapoly area) was used for the processing of olive oils obtained from Dories (set G).
- After the centrifugation stage of process, olive oil drops in tanks where it remains for some minutes. Transfer of olive oil is normally made with the use of a valve located in the lower parts of the tanks. Dark green bottles as described in the first chapter (section 1.6 - Figure 1.16) were used for the collection of olive oil. After the processing 3 litres of olive oil were collected directly from the tank for each sample from A1 to H24, totally 24 samples.
- All olive oils samples were properly stored in cabinet at 15 ^{o}C until the chemical and sensory tests were performed.

2.2.2 Measuring temperatures of processing

It is important to note that different mills may follow different processing method, or use another type of equipment or machinery, the amount of water used may be varied during certain stages or may not used at all. One of the most important parameters is heat.

Carefully grown olive oil is known to lose quality if high temperatures are used during processing. Within this project temperatures during different stages of processing of olive oil were recorded. The main object were to determine if the processing which is normally done in the mill of Krya for semi-intensive organic systems can be

characterized as “cold” pressed” (<27^{o}C) or not determine the temperature of processings which is used in this system.

To act as a benchmark for comparison, other mills in the county of Lasithi were included as comparative mills that extract olive oil. This was to obtain a better overall impression about the quality of the area studied. In total, the following three mills were investigated:

- Krya’s mill (operates in the highland region of Krya)
- Furni’s mill (operates near Neapoly, in the highland region of Furni-Dories)
- Achladia’s mill (operate in flatland Sitia, in the lowland region of Achladia)

Investigation was divided into sessions. Each session had five main focusing areas which were the following:

First, the outdoor (outside of the mill) temperatures were measured where the olives were stored before the processing. Storage of olives outside the mill is the normal practice which is followed and it is an important parameter because it is the temperature of the olives before milling but also might affect the indoor temperature as well.

The second area of focus was the room temperature inside the mill which can possibly affect all later processes.

The next area of focus was the malaxation chambers where the olive paste is mixed . Temperature in this chamber is applied from the sides and it is expected to show a relative difference if measured in several positions. The measurement in this study was taken from the middle/core part of the pulp. The malaxation process can last for 30 to 50 minutes which depends in the mill configuration therefore temperature was measured twice for this process, once during mixing in the start and again at the end of malaxation.

The next area was the centrifugation champers, however, it is a closed system and it was not possible to measure olive oil directly so the temperature after centrifugation was recorded by measuring the liquid residue which comes from the centrifugation.

Finally, the last area of focus is the tank where oil collects after processing. All of the above have led to the formulation of the following Table which shows the stage of the olives processing during temperature measurement and the specific area of focus where the thermometer was implied.

Table 2.2 Stages of process in relation with period of time

Stageofprocess	**Area of focus**
Storage of Olives	Atmospheric temperature outdoors
During indoor processing	Atmospheric temp. inside the mill
Malaxation Chamber	Olive pulp temperature during mixing at the start
Malaxation Chamber	Olive pulp temperature during mixing at the end
After centrifugation	Liquid residue temperature
Tank	Olive oil temperature after processing

The temperatures were measured over a period of three months starting from December since these months are the most productive and represent a full harvesting season of olives. For the temperature determination three measurements were carried out for each stage every ten days to examine possible differences. Ten sessions were covered in total for each mill.

2.2.3 Low temperature “cold” processing

Cold processed oils are processed without using external heat, although there may be some heat due to mechanical friction. For olive oil to be characterized as “cold” processed it is widely accepted that the temperature during process should not by higher than 27^{o}C. As a benchmark for comparison with temperature results investigated in 2.2.2, a “cold” press – processing was performed in Krya’s mill to measure the temperatures without the use of heat. The mill’s manager was asked to operate the processing process with the same calibration used for commercial purposes but without using any heat during the different stages of oil processing. This experiment was

repeated for two more times (three in total) focusing in the same areas like in the previous section (2.2.2.)

Different graphs were generated based in these measurements and all results are presented in the following chapter.

2.3 Chemical determination of olive oil quality characteristics

In this section the quality of olive oil which was produced from the orchards was determined based on the protocols of IOC, related to quality determination. The determination of olive oil samples started with the collection of the samples and their storage in appropriate conditions, then followed the application of the test protocol. The results are presented regarding the sets of orchards which were studied and the comparison includes the quality charts which are used for the classification of olive oil as we can see in the following Table.

Table 2.3 Classification of virgin olive oils based on chemical scores of free fatty acids, peroxide value, and K indexes

Code	**Free acidity (%)**	**Peroxide (meq/L)**	**K232**	**K270**	**ΔK value**
Extra Virgin	<0,8	<20	<2,5	<0,20	<0,01
Virgin	<2,0	<20	< 2,6	<0,25	<0,01
Ordinary Virgin	<3,3	<20	< 2,6	<0,25	<0,01

The values from the results were compared with the quality Table above to classify the olive oil samples in the categories above. An “extra category” is widely accepted to be olive oils with very special characteristics, very low free acidity score <0,3 % which are called “extrissima” olive oils and are marketed at a higher price even than extra virgin olive oils.

2.3.1 Collection of olive oil samples

Olives were transported to the mill for processing of olive oil during the months of December and January. Samples were collected directly from the tank in compliance with ISO 5555-2001 protocol. Olive oil samples were bottled in commercial bottles of 1 Litre designed for optimum storage longevity, with green coating for the following chemical tests.

2.3.2 Olive oil free acidity determination and classification

Olive orchards of Krya were assessed based on the parameter of free fatty acid content. The collected samples were chemically tested according the IOC standard method for acidity determination and olive oils were classified based in IOC's standards.

I) Reagents and apparatus used for measurement of free fatty acids concentration (FFA %)

- Digital precision scale (iBALANCE i211)
- Erlenmeyer / Conical flasks of250ml
- Mixed solution of ethanol (Honeywell: Burdick & Jackson),CH_3CH_2OH and diethylether (Honeywell: Burdick & Jackson), $C_4H_{10}O$,1:1(v/v)
- phenolphthalein indicator 1% solution, (ReAgent Chemical Services Ltd) in distilled water as an chemical indicator, $C_{20}H_{14}O_4$
- Sodium hydroxide (ReAgent Chemical Services Ltd), NaOH

II) Preparation of samples and titration process

A conical flask was placed in a previously zeroed digital precision scale to measure the olive oil which is injected and control the weight of the sample to be 1g. Then ethanol

and diethylether in a 1:1 (v/v) ratio was mixed inside the conical flask with the sample. Finally methanolofthalein solution was added as indicator and titration using NaOH solution took place. The reaction was completed when the colour was altered into light pink and the amount of NaOH used was recorded to be used in the formula of free fatty acid acidity calculation.

$$\text{Acidity (\%)} = \frac{\text{V NaOH (ml)} * \text{Normality NaOH} * 0.282 * 100}{\text{Sample's weight (g)}}$$

Where: 0.282 is the milli-equivalents of oleic acid

The results were presented as grams (g) of oleic acid per 100 grams oil, commonly known as the free fatty acidity of the oil in percent. Statistical analysis and design was carried out using Linux Libre Office Calculator and Microsoft Office Excel software.

2.3.3 Peroxide determination

I) Reagents and apparatus used for measurement of peroxide value

- Erlenmeyer / conical flasks of250ml
- Mixture of acetic acid (Honeywell: Burdick & Jackson), CH_3CO_2H – chloroform (Honeywell: Burdick & Jackson), CHC_3,3:2(v/v)
- Saturated solution of potassium iodide (ReAgent Chemical Services Ltd), KI
- Sodium thiosulphate (ReAgent Chemical Services Ltd), $Na_2S_2O_3$,0.05N
- Starchsolution1% (Ricca chemicals), in distilled water as an chemical indicator

II) Peroxide determination process

A sampleof2goliveoil was injected inside the conical flask. A prepared solutionof25mlaceticacid – chloroform, in a ratio of 3:2(v/v) was added. A saturated solution of 1 ml potassium iodide (KI) was added next. The mixture is shaken for 1 minute and left for 5 minutes in a dark place. T hen 75ml of distilled water and 2 ml starch indicator was added. To prepare starch indicator solution, 1 gram of starch added into 10 mL of distilled water and poured into 100 mL of boiling, distilled water for a 1 minute. The mixture was left to cool down.

Titration followed by recording the amount of sodium thiosulphate solution used. Starch indicator formed a very dark blue-black at the end of the reaction and the peroxide value was calculated with the given formula:

$$\text{Peroxide (meq } O_2 \text{ / Kg of oil)} = \frac{\text{Sodium Thiosulfate (ml)} * \text{Normality} * 1000}{\text{Sample's Weight (g)}}$$

Where: 0.282 is the milli-equivalents of oleic acid

Statistical analysis and design was carried out using Linux Libre Office Calculator and Microsoft Office Excel software.

2.3.4 Light absorbency in the ultraviolet

Spectrophotometric absorbency in the ultraviolet is a very useful technology that gives information about the quality of olive oil and its preservation state. For the absorbency determination in the ultraviolet and the determination of the K_{232} and K_{270} indexes the suggested IOC protocol was followed (COI/T20/Doc. no. 19/Rev. 2 2008). The fat in

question is dissolved in the required solvent (iso-octane – Fig. 2.4) and the solution is then analyzed at the specified wavelengths (232nm and 270nm) compared to pure solvent used as reference. Specific extinctions can be calculated directly from the spectrophotometer readings as it is shown in Figure 2.4.

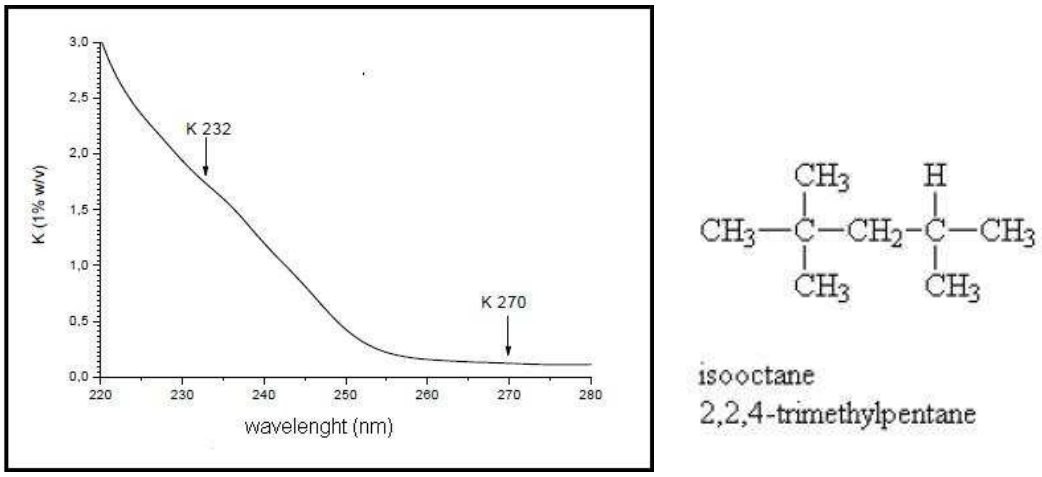

Figure 2.4 (Left) Typical UV absorption spectrum for olive oil. (Right) The structure of iso-octane

I) Reagents and apparatus used for light absorbency in the ultraviolet

- Spectrophotometer (model Jasco V–530) for measuring extinction in the ultraviolet between 200 and 400 nm as shown below in figure 2.3, with the possibility of reading individual nanometric units.
- Rectangular quartz cuvettes with specific known optical length (1cm), preferably with covers. Cuvettes filled with suitable solvent should not show differences if compared between them of more than 0.01 extinction units.
- Iso-octane,$(CH_3)_3CCH_2CH(CH_3)_2$ as solvent (Honeywell: Burdick & Jackson) to dissolve olive oil sample under examination
- 25 ml graduated conical flasks.

Figure 2.5 (Left) Jasco V-530, UV-VIS spectrophotometer used for the determination of UV (K indexes) absorbency. (Right) rectangular quartz cuvette of 1cm thickness used in spectroscopy of olive oil.

II) Preparation of samples

The sample in question must normally be perfectly homogeneous and without suspended impurities therefore it was filtered first through paper at a temperature of approximately 30 ^{o}C (hard fats are to be homogenized and filtered at a temperature of not more than 10oC above the melting point) to prevent light scattering effects. Olive oil sample of 0.25 g was accurately weighted and injected into a 25 ml graduated flask (The resulting solution must be perfectly clear). Solvent was filled until the line of the flask and the solution was mixed very well. The weight of the olive oil was recorded for later correction.

III) Procedure of sample analysis in the spectrophotometer

Spectrophotometer was calibrated and set ready for the test. The cuvette was filled with the solution obtained and the extinctions were measured at the appropriate wavelength between 232 and 276 nm, using iso-octane solvent as a reference. To set the reference two cuvettes filled with iso-octane solvent were first placed to the spectrophotometer to compare the homogeneity and check for possible flaws. Then one of the two was replaced with the prepared sample and the test started. As a result the light response curve was produced showing the absorbency values in different visible wavelengths. A

full spectrum graph of the olive oil will was displayed. The graph was reviewed to identify the peak absorbance values. The specific extinctions (extinction coefficients) were recorded and the various wavelengths were calculated as follows:

$$K\lambda = \frac{E\lambda}{C * s}$$

Where:

Kλ : specific extinction at wavelength λ ;

Eλ : extinction measured at wavelength λ ;

c : concentration of the solution in g/100 ml;

s : thickness of the cuvette in cm.

Olive oil analysis using spectrophotometer is performed in accordance with the official method. Determination of the specific extinction is done with isooctane solution at wavelengths of 232 and 270 nm. Other wavelengths are also used for the determination of ΔK indexes that is calculated by the following formula:

$$\Delta K = Km - \frac{Km - 4 + Km + 4}{2}$$

Where: Km is the specific extinction at wavelength m, the wavelength for maximum absorption around 270 nm.

Statistical analysis and design was carried out using Linux Libre Office Calculator and Microsoft Office Excel software.

2.3.5 Absorbency in the visible, mainly due to chlorophyll

Chlorophyll is a pigment known also as a chelate compound. The two types of chlorophyll in plants complement absorb sunlight. Plants are able to meet their energy needs by absorbing light from the blue and red parts of the spectrum. However, there is still a large spectral range between 500 and600 nm, wherein the chlorophyll absorbs very little light, and plants appear green because this light is reflected. With spectroscopy is possible to see that light with a wavelength of 460 nm is not significantly absorbed by chlorophyll a (Figure 2.6), but will instead be captured by chlorophyll b, which is strongly absorbed.

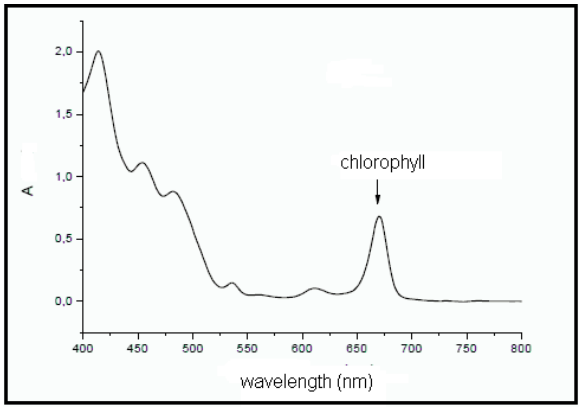

Figure 2.6 A typical absorption spectrum (VIS) for olive oil chlorophyll determination

I) Reagents and apparatus for the chlorophyll determination

For the chlorophyll determination the following apparatus was used:

- VIS(visible light) Spectrophotometer(Jasco V-530)
- Disposable plastic cuvette, 1cmx1cm
- Olive oil samples

II) Procedure for the chlorophyll determination

Two blank (references) were first prepared by filling two empty cuvettes ¾ with tetrachloride. The Spectrophotometer was calibrated and set ready for the test. After the sample cuvette was checked an olive oil sample was added for measuring the absorbency in the specified wavelength which was setup during preparation. As a result the light response curve was produced showing the absorbency values in different visible wavelengths. A full spectrum graph of the olive oil was displayed. The graph was reviewed to identify the peak absorbance values.

Calculation of chlorophyll amount expressed in mg/Kg:

$$\text{Chlorophyll (mg/Kg)} = A670 - \frac{\frac{(A630 + A710)}{2}}{0{,}101\ L}$$

Where:

A=absorbency in specific wavelength

L=cuvette's thickness in cm (1cm)

2.4 Organoleptic determination of sensory index

For the determination of the sensory index the regulation systems proposed by the European Commission Regulation (n° 796/2002) were used. The olive oil samples were

graded based in the median of possible defects and the median for “fruity”. Other positive characteristics like pungency and bitterness are also detected but the final score is based only on the intensity of fruitiness according to the protocol.

Sensory analysis was carried out by an analytical panel of the Agricultural Union of Rethymno made up of 12 specialists according to European Official Methods of Analysis EEC/2568/91 and a certified sensory laboratory was used. Statistical analysis and design was carried out using Linux Libre Office Calculator and Microsoft Office Excel software.

2.4.1 Process of sensory testing of olive oil

The testers evaluated the oil by lifting the sample covered with glass (to limit the release of the aroma) then rotated the glass to wet the inside as much as possible (encourage the release of the aroma). The next steps involved taking slow, deep breaths and smelling the sample for no more than 30 seconds and then consume small sip ofapproximately3 ml oil. The oil during this step is being distributed in the oral cavity as much as possible for better evaluation. To eliminate the residual taste of olive oil a small slice of apple was chewed by the tasters and at least15 minutes elapsed between the end of one session and the beginning of another to restore fatigue or loss of sensitivity caused by continuing tastings and a maximum of four samples per three sessions per day were made.

2.4.2 Use of the profile sheet by panel member and use of the data by the panel leaders

Each member of the panel evaluates both smell and taste of the oil under consideration. Intensity scores of the positive flavors and defects were evaluated on the 10-cm scale as shown in Figure 2.7. Tasters perceived all attributes and recorded them using the term that most accurately describes the attributes. Tasters normally avoid tasting oil that seems to be extremely defective. After the sensory trial the panel leader collected the profile sheets completed by each taster and reviewed the intensities assigned to the different attributes. The assessment data were statistically processed with computer software used in certified panels.

PERCEPTION OF DEFECTS:

Fusty

Musty

Winey – Vinegary
Acid – Sour

Muddy sediment

Metallic

Rancid

Others (specify)

PERCEPTION OF POSITIVE ATTRIBUTES:

Fruity

Bitter

Pungent

Name of taster:

Sample code:
Date:

Figure 2.7 Sheet used by sensory trials to evaluate olive oil attributes in the scale from 0 to 9

A) Terminology for positive organoleptic characteristics:

I) Fruity: characteristic fruity flavour of oil from healthy olives and fresh-picked at optimum maturity. This feature is very important for the organoleptic evaluation method because it is used to classify olive oil

II) Bitter: characteristic flavour of oil from green unripe olives. Can be enjoyable or not, depending on its intensity. However, in no case can be considered as a defect.

III) Pungent: strong tactile characteristic of oils produced at the beginning of

the season mainly from olives that are still green. The intensity of pungency decreases as the oil matures. Pungency is noticed by the fact that it is spread over the entire oral cavity and disappears after a few seconds after the test.

B) Terminology for negative organoleptic characteristics:

The main six defects detected in olive oil that are recorded during organoleptic trials are:

I) Fusty: caused to olives stored in piles that have undergone an advanced stage of anaerobic fermentation.

II) Musty-humid: Caused by fungi and yeasts that has developed during improper in humid conditions

III) Winey – vinegary: caused to olives that have undergone a process of fermentation leading to the formation of ethyl acetate, acetic acid, and ethanol.

IV) Muddy sediment: caused to olives that haven' earth or mud and has not been washed out.

V) Metallic: caused to olives which has been in prolonged contact with metallic surfaces

VI) Rancid: caused to olive that undergone a process of oxidation due to a prolonged contact with atmospheric air.

Other negative characteristics can be: a) heated or burnt, (prolonged heating during production), b) hay or wood (ontained from dried olives), c) rough and pasty mouth, d) greasy taste of diesel oil, grease or mineral oil), e)vegetable taste, f) brine, caused to olives that have been preserved in brine, g) cucumber, h) grubby : caused to olives that were heavily attacked by olive fly (*B. Oleae*).

2.4.3 Classification of olive oil and display of attribute scores

Olive oil samples were classified as extra virgin olive oil were if the median of defects and fruitiness are equal to 0 as presented in Table 2.4 below. The samples were

classified as virgin olive oils if the median of the defects was between 0 and 3.5 and the median of the fruity attribute was above 0. Samples with a median of the defects between 3.5 and 6.0 and the median of the fruity at 0 were classified as ordinary. Finally "Lampante" virgin olive oils were classified as olive oils with a median of the defects above 6.0.

Table 2.4 Classification of olive oils based in their organoleptic score

Classification	**Fruity (median)**	**Defects (median)**
Extra virgin olive oil	>0	0
Virgin olive oil	>0	<3,5
Ordinary virgin olive oil	0	3,5 - 6
Lampante virgin olive oil	0	<6

According the IOC the final sensory score of olive oil is based on fruitiness. Other characteristics like pungency and bitterness are secondary positive characteristics which do not affect the final score. From the scope of research, pungency and bitterness can be attributes connected to regional characteristics or might be related to farming practices. For example some studies suggest that pungency in olive oil is increased in orchards is increased to dry regions. Therefore all 3 positive attributes were taken into consideration. Although there is no established model for the display of these attributes, a model is proposed which shows all positive characteristics in a triangle shaped diagram where fruitiness is the top characteristics and the two side angles or "wings" are formed by the scores of bitterness and pungency. Theoretically, the maximum positive value off fruitiness, bitterness and pungency is 9 and can generate an isosceles triangle (two sides are equal in length) as shown in figure 2.8

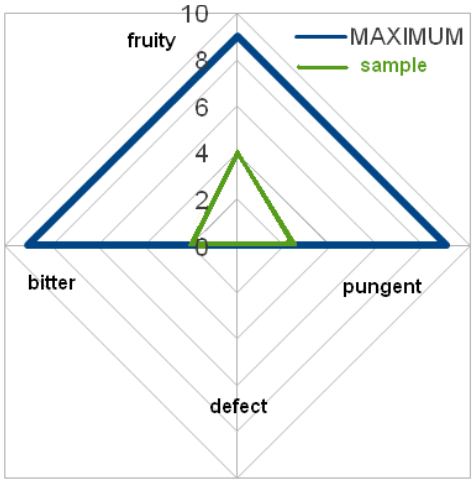

Figure 2.8 Typical sensory scores of extra virgin olive oil expressed as diagram as used in this study. Overall fruitiness score is 4 with no defects which therefore represents the overall quality score.

2.5 Calculating olive-oil total quality index scores and comparing with popular olive oils currently in the market

The Olive-oil Total Quality Index Score (OTQIS) is a formula originally proposed by the IOC which represents an overall score of quality which takes into consideration both chemical and sensory scores and gives an absolute result. Although it is not very widely used it can be a very useful tool for technological studies regarding olive oil and can provide a simplified overall score of quality which can be a method exclusively used for "premium" quality (alternatively called "extrissima") olive oils.

2.5.1 Calculation of live-oil total quality index score

The OTQIS is calculated with the following formula:

OTQIS =

2.55 + (0.91 * Sensory Score)

- 0.780 * FFA Score

- 7.350 * K_{270} Score

- 0.066 * Peroxide Score

Where:

Sensory score is the result obtained from the organoleptic test

FFA score is the result obtained from the free fatty acid chemical determination

K_{270} score is the result obtained from the spectrophotometric test

Peroxide score is the result obtained from the peroxide determination.

Statistical analysis and design was carried out using Linux Libre Office Calculator and Microsoft Office Excel software.

2.5.2 Comparison with typical and popular olive oils currently on the market

In this study the OTQIS formula is used to compare the scores of the olive oils produced in Krya with commercial olive oils which are currently on the market. Olive oil chemical and sensory attributes of these oils were obtained from certified labs that followed the same specifications proposed by the International Olive oil Council (IOC) as described above.

The information from this objective was used to generate tables for the comparison of

olive oils researched in this study as presented in the results and discussion chapter below. For the purposes of this study the samples where named after the same coding and two sets were created.

Set I includes I25 (Kritsa), I26 (Neapoly), I27 (Sitia) that are popular commercial olive oils found in the Cretan market produced in similar mountainous regions of Lasithi of Crete, holding PDO certification and are well respected for their chemical and sensory characteristics.

Set K includes K28 (Argolidas), K29 (Lakonias) , K30 (Messinias) olive oils that are popular olive oils found in the Greek market which and are produced in 3 different Peloponnesian counties as shown in Figure 2.8 with a PDO certification and high recognition in the Greek market for their quality and success.

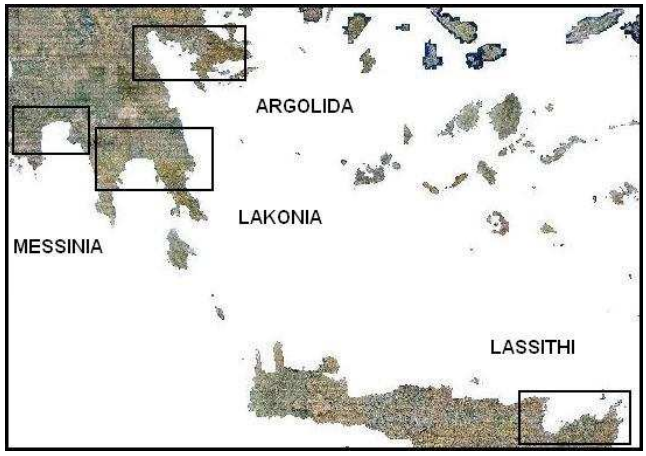

Figure 2.8 Locations (Peloponnesian counties) of olive oil produced in Argolida (K28), Lakonia (K29), Messinia (K30) and Crete's Lasithi.

Sets I and K are produced in mountainous flatlands (plateau areas). These two commercialized sets represent the epitome of mountainous production systems because they combine the positive characteristics of mountainous production systems (regional characteristics, altitude effects) and flatland (mechanized, easy access and manageable practice because of no inclination).

Finally, a set of typical extra virgin oils obtained from grocery stores (set L) and markets was used to act as benchmark for further comparison.

CHAPTER 3: RESULTS AND DISCUSSION

3.1 Standard crop practices in organic semi-intensive production systems

3.1.1 Soil cultivation

Table 3.1 Soil cultivation type and rates in Krya and other regions compared

Practice	Execution rate (%)							
Soil Cultivation:	**Set A**	**Set B**	**Set C**	**Set D**	**Set E**	**Set F**	**Set G**	**Set H**
Ploughshares	97.9	76.1	73.4	35.3	100	72.6	0	0
Small tractor	0	20.2	24.6	24.4	0	27.4	0	33.8
Other treatments	0	0	0	0	0	0	0	0
No treatments	2.1	3.6	2.0	40.4	0	0	100	66.2

Organic producers in Sitia use in majority the ploughshare cultivation method (tractor attached with ploughshares) as is presented in Table 3.1. This is noticed particularly in set A of orchards which belong to the south semi-intensive organic production systems of Krya and Set F which belong to the lowland high-intensive organic production systems of Sitia where the access for a tractor is even easier due to the flat landscape. 2.1%, 3.6% and 2.0% in sets A, B, C refer to hard to access olive trees (which receive no cultivation). In sets B, C, D, F there was use of small tractors owned and used by the producers themselves at 20.2%, 24.6%, 24.4% and 27.4% respectively. This is often noticed in orchards with several characteristics which do not favor use of big tractors with attached ploughshares. This includes orchards with unusual shape or trees planted very close together, or wherever the space is limited in general.

In set D of orchards, some trees where not cultivated either by small tractor, neither by a tractor attached with ploughshares (at 40%) because of high inclination (>35 %). In these orchards leguminous plants were deliberately planted in the soil to prevent weeds instead. As a consequence these legume plants will provide necessary nutrients to olive trees and is known to increase yields as described in previous chapters.

In contrast, Set G refers to the semi intensive organic production systems of Dories (located 5 km north east of Neapoly, acting as a benchmark for comparison) which was left without any treatment at all. This seems to be a characteristics practice of the region where soil cultivation is replaced with mowing of the wild weeds later on to reduce costs (soil cultivation costs more). Dories in Neapoly are generally a region which operates olive orchards as lay farms. As a consequence, soil might not being cultivated but the weeds are being grazed by livestock or mowed and used as feedstock. This is characteristic of the region of Dories (Neapoly) which represents the overall strategy followed in this region of Crete.

In set H 66.2% of trees were left without cultivation of any kind probably to limit the costs. Alternatively, no soil treatment might also represent a deliberate practice of the region which is done in purpose or may be simply due to indifference.

It is widely accepted that soil cultivation has several effects on olive trees. First it promotes new root growth which is necessary for absorption of nutrients from the soil and secondly it is an effective practice against weeds, especially in organic agro systems where no chemicals are allowed. Soil cultivation is generally performed on a yearly basis in Crete after the pruning period. If soil is not cultivated for a couple of years then weeds (and nutrient competition) are increased and production starts to decline.

Ideally all producers in Krya must cultivate soil after pruning to eliminate further residues dropped in the ground. The most accurate months seems to be April when the soil is les humid and can be worked easier. Legume plants can be deliberately replanted to dominate weeds and soil cultivation can be repeated the next year under the same manner.

3.1.2 Fertilization

Table 3.2 Fertilization type and rates in Krya and other regions compared

Practice	Execution rate (%)							
Fertilization:	**Set A**	**Set B**	**Set C**	**Set D**	**Set E**	**Set F**	**Set G**	**Set H**
Green manure	97.9	43.7	75.4	59.6	0	100	28.1	0
Organic fertilizer	0	36.1	0	0	61.1	0	0	38.1
Compost	0	0	24.6	40.4	0	0	0	33.8
Animal manure	0	20.2	0	0	38.9	0	69.3	0
Other treatments	0	0	0	0	0	0	0	0
No treatments	2.1	0	0	0	0	0	30.7	28.1

Besides the soil cultivation, ploughshares have a second role in the olive oil producing systems of Krya. By cultivating the soil, most grown weeds or previously planted legumes are broken in smaller parts within the orchards providing a form of green manure which will provide organic compounds to the orchards necessary for the development of new growth. Some orchards might have been supplemented with additional legume seeds and some orchards might contain seeds from previous seasons, but in both cases all plant growth which is broken down is considered green manure. Either by tractors or in some cases by cutting machinery, all unwanted plants surrounding the tree are mowed and shredded for this purpose.

In combination with Table 3.1 it is noticeable in Table 3.2 that most trees from set A and F were actually both cultivated and provided with green manure at the same time at 97.0 % and 100% respectively. When these weeds die in the field all of their remaining nitrogen, incorporated into amino acids inside the remaining plant parts, are released back into the soil. In the soil, the amino acids are converted to nitrate (NO_3^-), making the nitrogen available to other plants such as the olive trees, thereby serving as fertilizer for future crops [Postgate, 1998]. As a consequence systems which deliberately cultivate legumes along with olive trees will be more sustainable and will not depend on alternative sources of fertilization such as commercial fertilizers used in organic

agriculture.

The practice of cultivating legumes with the orchards did not apply in all cases since 36.1% of trees from set B were supplemented with organic fertilizers and 20.2% of the trees with animal manure. The difference between organic fertilizers and animal manure is mostly the concentrations of nutrients such as nitrogen phosphorus and potassium. Organic fertilizers for olive trees are designed to have higher concentrations of nitrogen because olive trees use it to develop more growth especially after the pruning season where it is mostly needed. Potassium is also essential for the natural development of fruit and soils with low amounts of this nutrient may suffer from low productivity. Likewise, trees from set C and D were fertilized at 75% and 59.6 % by green manure and in 24.6% and 40.4 % by compost products. Compost and animal manure are mostly offering organic compounds which are necessary for all tree functions. Orchards without legumes need an alternative source of nitrogen which in the majority is being offered by commercial fertilizers. Unfortunately, organic orchards rely only on certified products which cost much more than those offered in conventional agriculture. From this aspect, costs in organic agriculture can dramatically increased if no alternative strategy for fertilization is adopted. It is often noticed that trees grown in the orchard are treated with animal manure or compost from the local farmers or animal growers. Lowland areas such as those from set E tend to use commercial fertilizers at 61.1% as recorded in this study, and animal manure (38.9%) as a cheap option. Producers in Dories (Neapoly) with a tradition in animal production seem to either apply animal manure (69.3%) in their olive tree orchards or apply no treatment at all mostly because of indifference.

Set H producers applied organic fertilizers (38.9%), compost (33.8 %) or practiced no treatment at all to reduce costs. In systems with no fertilization, olive tree productivity will eventually decline, often after a period of 2 to 3 years and the profit may be minimized. This is more noticeable in low fertilization input – high intensive systems where trees constantly need external sources of nutrients to sustain production. From this aspect, mountainous semi-intense organic systems can therefore aim towards the production of carefully grown quality olive oils with no special demands for increased production but counterbalanced by a higher price in the market due to the optimisation

of quality. A strategy aiming at mass production of olive oil (which has been largely followed in the past) has generally led in the exhaustion of the soils and the gradual decline of production, with the additional burden from the costs for commercial fertilizers leading to an overall unprofitable strategy, as was reported during the Olivero project (2003-2006).

Ideally all producers must find sources of fertilization in order to achieve productivity sustainability over the years. Various weeds, or legume plants can be used as green manure but producers should not rely only to these sources. Additional organic matter will not cause any damages but lack or fertilization lead to nutrient deficits affecting the overall heath and productivity of the orchards.

3.1.3 Irrigation

Table 3.3 Irrigation type and rates in Krya and other regions compared

Practice	**Execution rate (%)**							
Irrigation source:	**Set A**	**Set B**	**Set C**	**Set D**	**Set E**	**Set F**	**Set G**	**Set H**
Private earth drill	0	60.1	0	21.4	0	35.3	0	38.1
Wells	0	0	0	40.4	0	26.5	19.2	0
Network irrigation	94	18.2	73.2	32.1	98.7	24.7	0	55.6
Cistern/tanks	0	0	22.7	0	0	0	0	0
No treatment (only rainfall)	6	21.7	4.1	6.2	1.3	13.4	80.8	6.3

Regarding irrigation, Table 3.2 shows the different type of irrigation sources used in Krya. Producers are mainly providing water to their orchards through the agricultural irrigation network which is the major source of water in set A production system. Set C orchards which are located closer to set A do follow a similar pattern but 22.7% of the trees are watered through the use of tanks which hold the water for the dry months of summer. Although olive trees are generally perceived as drought tolerant, additional watering during the dry months of summer may dramatically increase the productivity. From this point, tanks for storage of water are particularly useful and are often used in Crete since water from the (public) network provided for agricultural purposed has an

increased price during summer because water availability is generally reduced in the island. Producers may store water during months of rainfall which can used later on during Summer to provide the additional watering which is much more needed during the dry months. Another reason is that the network is not providing water every single day of the week and some producers follow an irrigation plan which does not comply with the days where water is provided by the network. For example in some areas where water is being provided only once a week, a lost watering may result in damaging productivity especially in the dry months of summer when the fruit is under development.

Alternative methods of water storage in these systems is the use of wells as was noticed in orchards from set D where 40.5% of the trees are using water from underground wells. The use of wells as sources of water is rooted in the past, more developed (public) wells for irrigation purposes were constructed in the 1960's that are still used for agricultural purposes.

Orchards from set B have managed to get some required water from a private earth drill (owned and managed by producers) and 60% of the olives trees are irrigated exclusively in this way, 18.2 % of the total trees are irrigated from the network while 21% of the trees receive no treatment at all. Lowland areas use mostly the network, 98.7% of the trees from the F set are irrigated in this way. Set F which represents olive orchards from the neighboring settlement seem to follow the same pattern as Set D but at different percentages.

Finally from the set H samples it was noticed that trees are normally irrigated 38.1 % of the trees use water from private earth drills and 55.6% from the network while 6.3% is left without treatment. Private earth drills as a source of water is a technology introduced in the last two decades which seems to be very successful especially in islands suffering from summer droughts. In areas where underground water is being detected the upper crust of earth can be drilled and specialized mechanisms can make water available for irrigation purposes.

It is very interesting to notice that other areas in Crete follow completely different methods of irrigation, for example, producers from Dories (5 Km north-east of Neapoly) are not providing any irrigation to their orchards, with 80.2% of the trees relying only on rainfall during winter months although there are no significant differences between Dories and Krya regarding rainfall. Trees without irrigation normally have a decrease in productivity. From the other hand, regions such as Krya and Dories that are located within a basin surrounded by mountains may be favored by different microclimates which can positively affect productivity and quality as well. For example higher relative humidity is being noticed in such areas especially in higher altitudes compared to lowland orchards. From a different aspect olives in systems with no irrigation may produce olive oil of higher quality. Droughts seem to result in higher phenolic content in certain compounds which are responsible for the characteristic taste of bitterness in olive oils but low yields in these systems remain a problem.

Irrigation generally affects the performance of olive trees by i) stimulating the assimilation rate of nutrients and ii) creates turgor and expansive growth to the olive tree tissues [Naor, 2006].

Traditionally, before the introduction of earth drills, irrigation was not performed in olive trees. In some cases small amounts of supplemental water was often obtained from wells or cistern/tanks and used to provide water to olive trees during the dry months of summer keeping them sustained (this is called “supplementary irrigation”).

Different irrigation strategies have been used to influence olive tree productivity the past decades. “Sustained deficit irrigation” for example is when reduced amounts of water are used throughout the irrigation season. Deficit strategies have been very popular and their influence to olive productivity is acknowledged. “Regulated irrigation deficiencies” is when 100% of irrigation is applied when the tree is less tolerant to water stress and then irrigation is reduced to 30% for the rest of the season [Girona, 2001]. As a result oil content can be increased (per amount of fruits) without affecting chemical composition of olive oil [Motilva, 2000].

A project was conducted in 2002-2003 focused to determine the irrigation levels for optimum chemical and sensory properties in Arbequina cultivar. Trees were administered to seven different irrigation intensities and oils were evaluated according tithe IOC protocol. As a result the best olive oil was produced in the least and moderately irrigated olive trees. Olive oils with the least irrigation were characterized as extremely, pungent and bitter with the highest polyphenol content. As irrigation intensiveness was increased the phenolic content was declined but olive oils were identified as more fruity. Trees that received the most water were sensory characterized as lightly fruity with almost no pungent or bitter flavors and with decreased phenolic content [Berenguer, 2006].

All of the above suggest that highly irrigated olive orchards (such as flatland set E) do not produce olive oil of higher quality (this is also discussed later on) therefore semi-intensive production systems such as Krya should not necessarily aim to improve irrigation type furthermore since most orchards in Krya are already receive irrigation in some extent. In regard with this assumption priority should be given in the determination of the optimum irrigation intensiveness that fist to the area and cultivar therefore further investigation is needed.

3.1.4 Harvesting

Table 3.4 Harvesting type and rates in Krya and other regions compared

Practice	**Execution rate (%)**							
Harvest:	**Set A**	**Set B**	**Set C**	**Set D**	**Set E**	**Set F**	**Set G**	**Set H**
Hand harvesters	100	100	100	100	100	100	73.9	100
Vehicle vibrators	0	0	0	0	0	0	0	0
Manual harvest	0	0	0	0	0	0	3.2	0
Wooden sticks	0	0	0	0	0	0	26.1	0
Other	0	0	0	0	0	0	0	0

In Krya, as in most systems in Crete, harvesting of olive oils is done from November to February according the maturity of the fruit. Fruit quality determination is used to

define the optimum fruit harvesting and may involve color – visual quality, fruit firmness and oil content [Agar et al. 1998]. This is often performed by the growers empirically.

During harvest, there were no different methods or equipment noted besides the established one (hand held mechanical harvests presented in Figure 1.10 Introduction chapter), which was used by most producers. This suggests that hand-held mechanical harvesters in Crete are considered the optimal option which offers a variety of advantages in local production such as the flexibility to be used in mountainous inclined land.

It is noticeable that producers in Set G use also old fashioned sticks at 26.1%. Very high branches may not be accessibly with hand held mechanical harvesters and for this reason long old-fashioned wooden sticks (non-mechanical) may be used to drop olives down. Alternatively these branches are cut (pruned) during the harvest and are hit by the workers using shorter sticks on the ground. It is widely known that before the introduction of mechanical hand held harvesters in Greece wooden sticks/rods was the established practice for Koroneiki harvesting, still practiced in several undeveloped areas of Crete. Similar hand-held mechanical harvesters have been experimentally introduced this decade in Kenya showing promising results [Abdine et al, 2005]. In Table 3.4 it is seen noticed that 3.2 % of olives in set G which are considered good for table purposes are gathered manually during harvest.

Harvesting method and date are generally important because both can directly affect olive oil quality. Ripeness index is generally know to affect fatty acid composition [Beltran, 2004] and wounds created during beating of olive fruit seem to affect the formation of free fatty acids which can lower the quality of olive oil [Shimizu, 2008]. Wounds can be responsible for further degradation of quality especially if the processing of oil from the fruit is delayed [Kiritsakis, 1998] or olives are pressed during the various stages of production [Olias & Garcia, 1997]. For this reason several alternative harvesters have being introduced like hand-held mechanical vibrators (vibrate the branches to drop olives) but they do not seem to work well in the

“Koroneiki” cultivar compared to hand held mechanical harvesters that drop olive by hitting although further investigation is needed.

Hand held mechanical vibrators are expected to perform better in big-size olive fruit varieties rather than Koroneiki (small and many olive fruits). Most regions in Crete produce the cultivar Koroneiki which is characterized by the production of small olive fruits therefore it seems unlikely that vibration harvesters would be more efficient compared. Similarly the collection by hand (hand picked olives) can be very affordable since the worker productivity with manual harvesting is relatively low [Abdine, 2005].

Olives harvested in unripe stages might be less susceptible to wounds since fruit skin will be harder and tougher compared to mature olives [Tamendjari et al., 2004]. Ideally when olives have reached their full size can be harvested before it start to change color (color changing indicates the start of maturity process). As a result olive wounds may be minimized although these assumptions need further investigation.

3.1.5 Pruning

Table 3.5 Pruning type and rates in Krya and other regions compared

Practice	**Execution rate (%)**							
Pruning:	**Set A**	**Set B**	**Set C**	**Set D**	**Set E**	**Set F**	**Set G**	**Set H**
Shape	26	9.3	25.6	22.4	89.1	22.1	0	0
Renewal	8.3	7.3	6.1	8.5	0	7.1	21.6	28.1
Productivity	52.1	45.5	48.2	50.2	0	45.9	0	0
Other treatments	0	0	0	0	0	0	47.7	33.8
No treatments	13.5	37.9	20.1	18.8	10.9	24.9	30.7	38.1

The most popular training system which is adopted byKrya's producers is a type of vase shaping (a style widely followed in the broader region of Sitia and therefore the sub-region of Krya). This shape was applied in all broader regions of Krya from set A, Set B, Set C, Set D at 26%, 9.3%, 25.6%, and 22.4%. Only 8.3%, 7.3%, 6.1%, 8.5% needed renewal (very heavy cutting) while most trees where pruned for productivity at 52.1%,

45.5%, 48.2%, and 50.2%. The “vase” adopts an opening in the canopy of the tree which increases the surface and lowers the height of the tree making it more manageable for harvesting. Productivity priming refers to the practices which result in an overall increase of productivity (specialized cuts performed by experiences runners). As a consequence olive trees in these sets will have an increased demand for nutrients to support the new growth which is given by several sources as described in the previous section 3.1.2 about fertilization.

No treatment in these cases refers to fully productive and well cared for trees without any need to any specific treatment. 30.7% of G set received no treatment. It is widely accepted that trees which receive no treatments will gradually lose productivity and shape compared to pruned ones. This will make harvesting less easy because branches can grow very tall, up to 1 meter per year. The neighbouring settlement of Dafne (set F) seems to have similar activity as Krya.

It is noticeable that most trees from set E received shape pruning which suggests that these orchards were left without treatment for some years and have lost their basic shape. In case of set E, olive trees which received no treatment refer to trees which where of younger age and needed no pruning.

An unusual method of pruning takes place in Set G of Dories. Traditional animal producers and semi-olive oil farmers tend to operate their orchards as lay farms and selectively cut branches (47.7% were treated this way) which are gathered to feed livestock. This practice was perceived as “other treatment” during this study because it is a rare technique which characterizes the region. Another parameter which might have led to this practice is that the region of Dories is having different local climate than Sitia, which often suffers from heavy frosts, thus increasing the possibility for damage from frost wherever the trees are too severely pruned since higher branches offer protection to the lower parts of the trees. Perhaps that is the reason why the vase is less popular in these areas.

Set H orchards received renewal pruning at 28.1% because of several reasons (high cost of pruning, difficulty to find specialized pruners, carelessness etc.) they have been left abandoned and developed unwanted growth which resulted in loss of shape, in another

case 33.8% of the trees had suffered from frosts which were noticed this season (similarly with Dories other sub-regions might suffer from frosts too), and 38.1 % of trees were left without treatment to limit costs and expenses.

Olive oils obtained from olives suffering from frosts (like sample H23) are expected to have degraded olive oil quality which may be seen in the chemical and sensory results. “No treatments” noticed in all sets are rates which also show that producers have not complied with the pruning needs of the trees. This is more increased in sets B, G; H. Olive trees which receive no pruning at all will eventually lose shape- and productivity, and will become more difficult to harvest. Some studies also suggest that vigorously grown olive trees where lower branches are shaded may be more susceptible to crop pests. This may be more increased in old, damaged branches which can harbour pests and other diseases.

Ideally, olive trees in Krya should be trained in the “vase” system, and pruned for productivity each year. This includes specialized cut performed by expert pruners that are not analysed in present study. Priority is normally given to the removal of broken, old or diseased branches (this is also “renewal pruning”). These cuts might not directly effect olive oil quality but have indirect influences in olive productivity. Harvesting management is directly affected by pruning for shape since trees that have lost shape are difficult to harvest. In Table 3.1.4 it is noticed that not all tress have been treated with pruning. This suggests that producers are not fully in compliance with standard pruning practices of the region therefore is suggested that pruning should be set as a priority in this systems. More details about pruning are in chapter – section 1.5.4.

3.1.6 Pruning residues

Table 3.6 Pruning residue management type and rates in Krya and other regions compared

Practice	Execution rate (%)							
Residue manage:	**Set A**	**Set B**	**Set C**	**Set D**	**Set E**	**Set F**	**Set G**	**Set H**
Compost	0	20.2	0	36.3	0	0	0	33.8
Burning material	80.2	43.7	84	45.7	100	83.3	0	66.2
Fed to livestock	19.8	36.1	16	18.2	0	16.1	100	0
Other treatments	0	0	0	0	0	0	0	0

The management of residues is an important part in organic olive tree farming because it is a high source of organic compounds produce within the system. After pruning there is possibility for the residues to be used as an additional source of organic compounds, which as a practice might seem to be the optimum one but it can increase the costs (because it require extra labour and because shredders use gasoline which increases costs) and some producers are therefore discouraged from practicing it. From the other hand, the use of residues as compost (cut with the help of mechanical shredders) can provide organic compounds which might replace other sources (for example: animal manure or commercial compost). As with green manure, pruning residues which are left in the field may release all their nutrients back into the soil which will be available to other olive trees, thereby serving as fertilizer. Shredding residues was introduced in the last decade as a method to generate compost by the produces themselves. In sets B, D, H, 20.2%, 36.3%, 33.8% of smaller branches where cut into smaller pieces with the help of a branch shredder (Figure 1.8 - Introduction) to produce compost.

Smaller and thinner branches are often destroyed within the orchards by burning, mostly to minimize cost or work, instead of used as fuel in stoves or feedstock (set G Dories). This practice may cost less but great amounts of organic mass are wasted instead of used as a source for fertilization of the soil. Burning residues directly in the orchard can be cheaper but the need for organic compounds has to be covered by other sources such

as commercial compost or animal manure, which may increase the overall costs of production. Most residues in sets A,C, E and F (and in lower rate in other orchards) were used as burning material to reduce cost; heavy branches were either cut or sold for wood stoves generating extra income while smaller branches were burned directly inside the orchard. All tree residues from set G were carried away and fed to livestock. This is part of a general strategy which has been rooted in past traditions. All cut branches were traditionally transferred and fed to livestock. To counterbalance, all animal manure was transferred back to the orchards as a fertilizer.

Certain methods as the use of pruning residues as feedstock (set G) will likely be abandoned in the near future, especially when producers become more focused on olive oil production. The uses of mechanical shredders will likely increase as long as the cost of fuel used for the transfer and operation of mechanical shredders remains low (shredders are high maintenance). Larger wood pieces obtained during the pruning of olive trees will likely be a source of extra income as long as wood stoves continue to be are used in the island. An alternative proposal however suggests that these systems could sustain the traditional practices of the past and operate as agro-touristic lay farms, producing high quality organic olive oil, in an environment simulating the traditional practices of husbandry and agriculture combined. This would likely be more successful in set G for example where producers currently still deal with olive oil and animal production.

Ideally all pruning residues should either i) shredded and become compost acting as natural organic fertilizer or ii) fed to livestock in order to produce animal manure that will be recycled back into the orchard as natural fertilizer. Lesser remnants should be left in the farm to be included in the annual soil tillage as discussed in 3.1.1. No remnants should be destroyed with fire within the orchards since a) organic matter that can be used by the trees is wasted b) this practice is not environmentally friendly since burning increasing CO_2 emissions and c) both larger and smaller pieces of wood can be used as woody by-products known as “wood pellets” that are used in certain agro-industrial activities as fuel for stoves [Giacomo, 2008]. As a result either extra income can be generated from the accurate managements of pruning remnants or organic composts that can be used in the same systems to increase nutrient input in the orchard.

3.1.7 Crop pests

Table 3.7 Crop pest type and rates in Krya and other regions

Practice	Disease rate (%)							
Crop pest:	**Set A**	**Set B**	**Set C**	**Set D**	**Set E**	**Set F**	**Set G**	**Set H**
B.Oleae	28.8	31.5	34.4	35.9	70.7	29.7	70.2	59.4
C. Oleaginum	4.6	4.2	5.7	5.1	17.6	4.4	17.9	8.3
E. Olivina	1.9	1.6	1.8	1.9	11.3	1.6	5	0
P. Savastanoi	17.1	12.8	21.7	14.3	41.7	12	57	40.4

A variety of diseases and plant enemies can be found in every system of production. In olive tree orchards the most dangerous enemy can be *Bactrocera Oleae* known as the "olive fly" because it affects directly the quality (and quantity) of the fruit and olive oil. As is noticed in Table 3.7 all orchards suffer from *Bactrocera* to different degrees of severity. The females lay their eggs to olives in the summer when the fruit is developing. Climate is known to affect the life circle, especially temperature and relative humidity. Temperatures above 30°C can reducing the fecundity of females; a female lays two to four eggs on average per day in summer and 10-20 eggs in autumn. Persistent temperatures above 32°C for several hours a day also cause mortality of over 80% of the eggs and larvae of that age.

Olives wounded by olive fly tend to fall to the ground creating a "ring" of damaged olives around the tree. By looking for these 'rings' it was possible to estimate that 28.8 % of the trees from set A were damaged by the insect while similar rates where noticed in all trees grown in this region. In set E the damage from *Bactrocera Oleae* was noticed at 70.7% of the trees similarly in set G and H which shows that precautions were probably not taken against the fly in the past season. Lowland production systems (set E) are often highly irrigated. In this case, fruit skin can be softer and can be easier to pierce by the fly. If fruits are unripe (for example in regions where irrigation is less), females have difficulty penetrating the outer part of the fruit because it is harder compared to more ripened fruits [Tamendjari et al., 2004]. Therefore *B.Oleae* prefers to lay eggs in olives where the skin of the fruit appears softer. This is done during the months of summer when the female lays eggs.

In Dories (Neapoly) semi- intensive organic production systems (set G) olives might not be in the same ripeness compared to lowland regions during summer. It seems that the microclimate of the Dories region is the most important parameter for the observed increase in *B.Oleae* attacks since olive fly may flourishes in humid climates where temperature does not exceed 32-34°C (such as in the basin of Dories).

Other diseases such as *Cycloconium* also appear at greater rates in sets E and G. Since this can be a secondary disease affecting wounded fruits and leaves it often accompanies the damage from *B.Oleae*. *Cycloconium* flourishes in regions with high relative humidity (such as the basin of Dories and the heavily irrigated flatland of Sitia). Diseased plants seem to appear weaker and their leaves gradually dry and fall. The best protection against *Cycloconium* seems to be pruning which appears to be less practiced in Dories explaining perhaps the increased rate of the specific disease. As described in the earlier section (3.1.5), training systems such as "the vase" may open the tree canopy and encourage the penetration of sunlight in the inner (previously shaded) parts of the tree preventing the spread of the fungus in olive trees. Copper spray may be a successful practice against this fungus as also for the protection against *Pseudomonas* which is widely used and permitted in organic farming practices as it is a natural pesticide [Simeone et al, 2009].

Although some trees were noticed to have *Euphyllura olivine, the* rates were very low and appeared sporadically, with the exception set E at 11.3% which was increased compared to other sets. As a crop pest, it is an insect associated with the new flowering and fruiting olive branches. It can feed directly on the leaves and is known to reduce the yield but also has an indirect action by producing waxy secretions that induce many of the flowers to abort, even those not attacked directly. *Euphyllura* flourishes in temperatures between 20-21 °C during February to April. Females lay eggs in new shoots especially after pruning when new growth is promoted (like in set E were 89.1% of the trees were pruned for shape). Mountainous regions may have lower temperatures in these months which may also explain the lower appearance rate of this pest in highland systems.

It is noticeable that after *B.Oleae* the second most prevalent disease (bacteria) found in these systems is the bacteria *Psaudomonas savastanoi.* Although it does not directly affect the quality of olive oil, it plays an important role in the health of the tree and the productivity.

It can be seen in Table 3.8 that this bacterium shows an increased rate in systems E, G, H. This suggests that *Pseudomonas* can easily spread in systems where precautions are not taken and the disease is not addressed. The bacteria cause tumors about 0.5 to 2 inches in diameter on twigs, branches, trunks, roots, leaves, or fruit stems which may break during harvesting or pruning and contaminate the tools. The bacteria can be easily spread during harvesting in rainfall conditions and during pruning when saws contact the tumors and no disinfection measures are taken (alcoholic disinfection). It is difficult to determine exactly why systems of Krya (sets A to D) and Dafne (Set F) have the least disease rate compared to the other regions. This is mostly attributed to climate conditions of the region, the careful management of olive orchards by the organic producers of the region (for example avoiding harvesting during rainfall) and constant pruning of olive trees.

3.1.8 Crop protection against *B.Oleae*

Table 3.8 Crop protection type and compliance rates against *B. Oleae* in Krya and other regions compared

Practice	**Execution rate (%)**							
Crop protection:	**Set A**	**Set B**	**Set C**	**Set D**	**Set E**	**Set F**	**Set G**	**Set H**
Mass trapping	28.8	20.2	60.7	40.4	100	62.7	0	6.3
Other treatments	0	0	0	0	0	0	0	0
No treatments	71.3	79.8	39.3	59.6	0	37.3	100	93.7

While trapping may include a variety of traps (yellow traps, attract and kill traps etc.) the recorded traps used for *Bactrocera oleae* (olive fly) in the sub-region of Krya are known as “attract and kill” traps [Ferreira, 2002]. “Mass trappings” in Table 3.8

represent the use of traps against *B.Oleae* used in areas under study. Sets A and B seem to have the lowest treatment/compliance rates against *B.Oleae* in Krya since the disease rates were also low. Set C had a disease rate at 34.4% (Table 3.7) and complied with the protection specifications by using mass trappings at 40.4% of the trees.

Sets C and F may also have low disease rates (see previous section 3.1.7) but the compliance rates of protection against the fly where higher (60.7 and 62.7%) compared to sets A and B. Producers seem to have applied mass trappings even if the practice increases costs. All of the above may suggest that producers do not neglect the use of mass trappings as a method of protection against *B.Oleae* in the region of Krya and the neighbouring settlement of Dafne. In the same way, set F applied mass trappings at 100% execution rate since this region suffered form fly attacks at 70.7% (Table 3.7) the previous season

Hypothetically, the introduction of new predators as a biological control method against *B.Oleae* or the control of natural enemies found in Crete can be used as a successful practice to protect against the fly. Unfortunately, in set E seems unlikely to success when neighboring orchards (conventional agriculture is often practiced in nearby orchards) use pesticides for crop protection. Krya, on the other hand does not face the same problem and most sets (A to D and F) are at a significant distance from conventional practices (pesticides) used in the lowlands. For Krya it may be possible to employ the use of biological control agents (natural enemies of *B.Oleae* which can be purposely controlled or new species can be introduced) in the near future.

Set G (and H) seems to do nothing about the infections from *B.Oleae*. Producers in Dories claimed that mass trappings haven’t been successfully introduced in these systems yet. This is a perhaps because up until now, they have little experience in organic methods. In Dories where organic systems have only recently received their certification, it is to be expected that producers may have less experience about organic agriculture compared to other regions (such as Krya) that have adopted organic practices earlier. If no precautions are taken against *B.Oleae* in Dories then this may lead to serious consequences in the productivity and quality of olive oil in later years. In addition if crop protection in regions such as Dories is not adequately controlled this

will lead in the fluctuation of olive oil chemical and sensory scores from year to year. This lack of stability in quality may have a negative impact on the image of this product in terms of marketing. Olive oil in Dories is sold only in bulk state. For this reason, producers are not yet encouraged to produce olive oil of optimum quality because the differences in price per litre when olive oil is sold in bulk are relative low. Producers from set G (and H) generally present indifferent behaviours compared to Krya.

Besides using mass trappings to counterbalance the damages from *B.Oleae*, producers can harvest olives at an earlier stage of development. As a result the various biochemical reactions which lead in the increase of free fatty acidity in olive fruits are limited, which affects the quality of the oil. It is widely accepted that olives damaged from olive fly must be harvested and processed as soon as possible.

“Other treatments” in table 3.8 refer as well to a variety of other methods (Cultural controls, the use of GF-120, sprays of kaolin clay) but no such practices were actually recorded during this study. This in general may suggest that no serious efforts have been made for the introduction of these crop protection methods in Krya (or any other system in the county of Lassithi) and that there is scope for research focusing on cultural controls with predators and parasites.

Ideally, all orchards should follow the example of set E, applying massive trapping as a preventive strategy regardless if olive fly is detected. This is generally avoided since traps cost and as a result *B.Oleae* is usually spread damaging olive fruits but growers will eventually need to adopt an annual preventive strategy to control olive fly. Olives wounded from flies decrease in quality since defects and increased acidity may be noticed in olive oil [Tamendjari, 2009].

It seems that damages from *B.Oleae* can increase in heavily irrigated orchards (set E) because olives are more ripened and the skin softer when the insect is active (summer). Non-irrigated orchards seem to perform better against the fly because fruits are unripe when mature flies are most active (also discussed in section 3.1.8). As a result olive suffers less from olive oil attacks [Tamendjari et al., 2004].

In conventional farming, the use of chemical formulations may reduce the problem but in biological agriculture where chemicals are not permitted the problem remains.

Controlling olive fly with mass trappings seems to be promising. Some studies done in Portugal suggest there is space for improvement [Ferreira, 2002].Flatland area of Sitia (set E) showed the highest compliance to this method but olives were highly diseased (70.7%). This suggests that more biological crop protection practices should be introduced. The efficiency of newer traps in Krya is under question. These new devices containing reduced amount of pheromones promise better protection with lower cost [Noce, 2009]

3.1.9 Crop protection against *P. Savastanoi*

Table 3.9 Crop protection execution type and rates for *Pseudomonas* in Krya and other regions compared

Practice	**Execution rate (%)**							
Crop protection	**Set A**	**Set B**	**Set C**	**Set D**	**Set E**	**Set F**	**Set G**	**Set H**
Copper / bactericides	0	24.2	0	24.5	0	0	0	28.1
Tool disinfection	0	0	0	0	100	0	0	0
Other treatments	0	0	0	0	0	0	0	0
No treatments	100	79.8	100	75.6	0	100	100	71.9

Pseudomonas savastanoi (olive knot) is difficult to control once established. Prevention seems to be the only reliable strategy [Smith 1988].

As can be seen in Table 3.9, no applications of copper containing bactericides or other treatment to protect the trees for sets A, C, F. In combination with Table 3.7 this can be understood that for sets A, C, F the need for treatment of injuries is low. The disease can gradually increase by the years and become serious problem in the near future if no treatments are done in these systems. The most possible reason for noncompliance against the disease seems to be indifference and lack of knowledge about the threat from *Pseudomonas savastanoi.*

Combining Table 3.8 and 3.9 it can be noticed that producers from set C have focused on the protection against *B.Oleae* while have taken no measures against *Pseudomonas.* This can be seen as an example, showing that producers might not take the bacterial

damages seriously enough (lack of knowledge about the consequences). High disease rates of *Pseudomonas* are gradually weakening the tree, reducing productivity and may also eventually cause total death of the tree (especially in humid regions).

Some producers seem not to understand the possible dangers from neglecting the disease. In Sets B and D the compliance rate to crop protection against olive fly is 24.2% and 24.5% while producers from Set H seem to make an effort to use copper (28.1%) as a precaution against the disease but the disease rate was in general higher (40.4% - table 3.7). Costs for tool disinfection and application of copper and other bactericides are not very high, 5 litres of alcoholic solution may be used for up to 500 trees if used correctly. Two applications of copper can be made, one in the autumn before the rain starts and one in the spring when most leaves have been shed. The systematic application of copper in previous years might be the reason why sets B and D have a lower appearance rate of the specific disease compared to other sets of Krya which were studied. Information from specialized agronomists in olive farming can be very useful in these systems.

Producers from Sitia's lowland areas (set E) have taken precautions by eliminating the disease during pruning by tool disinfection (because the bacteria may be carried on pruning shears or chainsaws) at 100%. As can be seen all trees were pruned with disinfected tools in Set E example. The next step should be the control of disease with sprays of copper or other bactericides certified for organic agriculture. As a consequence these systems may notice improved health conditions in olive trees and increased productivity compared to the other systems.

In Set G (Dories in Neapoly), producers mostly focus on the removal of diseased branches (the removal of tumours caused by *P. Savastanoi* during summer has also been reported to control the bacteria). From Table 3.6 on pruning residues it is understood that this region uses pruning residues as feedstock which probably is practiced during all months of the year. As a consequence new tree growth does not suffer from the disease (at least not in the first years) and gives production while older and diseased branches are gradually removed. Controlling the disease by removing diseased branches may be a characteristic behaviour of the region although it may not be identified as a

protective practice against the disease. As a consequence the overall health and productivity of olive trees in Dories may be lowered because of the weakness caused by *P.Savastanoi* in the near future. Other regions that follow systematic protection against *Pseudomonas savastanoi* should aim to control it as well. Cooper use and disinfection of tools is widely accepted to successfully control the disease in olive oil production systems.

3.1.10 Summary – Total noncompliance rates to standard crop practices

Table 3.10 Noncompliance rates (%) to standard crop practices in organic semi intensive production systems compared

Practice	Noncompliance rate (%)								
	Set A	Set B	Set C	Set D	Set E	Set F	Set G	Set H	Ref.
Soil cultivation	2.1	3.6	2	40.4	0	0	100	66.2	100
Fertilization	2.1	0	0	0	0	0	30.7	28.1	100
Irrigation	6	21.7	4.1	6.2	1.3	13.4	80.8	6.3	100
Pruning	13.5	37.9	20.1	18.8	10.9	24.9	30.7	38.1	100
Pr. (*B.Oleae*)	71.3	79.8	39.3	59.6	0	37.3	100	93.7	100
Pr. (*P. Savast.*)	100	79.8	100	75.6	0	100	100	71.9	100

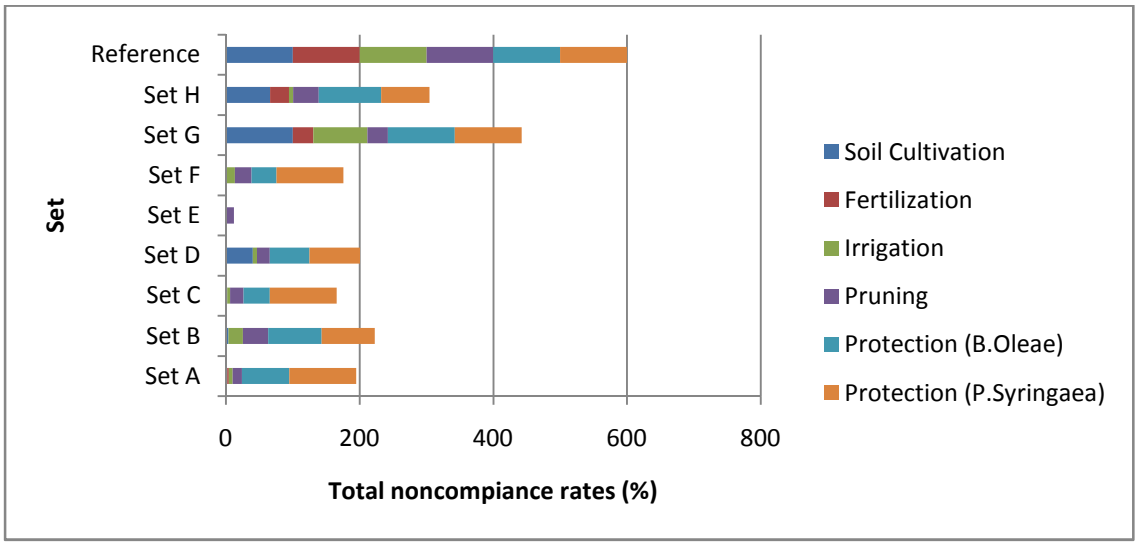

Figure 3.1 Total noncompliance rates (%) to standard crop practices in organic semi-intensive systems compared

I) Total noncompliance rates to standard crop practices used in organic semi intensive production systems

Certain crop practices (also described in section 2.1.4) are considered standard in organic olive tree growing. Total noncompliance rate scores operate as an objective tool for assessing the degree of compliance with the standard crop requirements used in organic olive production systems. For organic semi intensive production systems the general crop practices are also described in the first chapter (section 1.5). Table 3.10 summarizes the "no – treatment or other" that represent the noncompliance rates to standard practices such as soil cultivation (Table 3.1), fertilization (Table 3.2), irrigation (Table 3.3), pruning (Table 3.5), protection against crop enemies such as *B.Oleae* (Table 3.8) and protection against *P. Savastanoi* (Table 3.8.). Harvesting is not included because the majority of production systems and 100% of Krya systems are using the same method. Pruning residues is also not added because all residues are managed, since it is illegal to be left in the orchards as they can host diseases and crop enemies. The total noncompliance rates in Figure 3.1 summarize all no-treatment rates regarding the farming practices under study generating a graph representing the overall non-compliance of all sets compared (absolute non-compliance is referred as reference). Total non-compliance rates to standard crop practices can be a useful tool to objectively evaluate similar organic olive oil production systems since agricultural practices in general are known to affect olive oil quality [Gutierrez, 1999]. In general, a variety of practices can be recognized in the organic semi – intensive mountainous systems, and a balance of different methods has developed amongst different regions and producers that are also influenced by agricultural specifications given by agro-technologists and experts in the olive oil sector. These regional methods of production can be compared with the total compliance to standard crop practices to determine if focusing in olive growing practices will improve quality. For example set E has maximized its potential since it has the highest compliance rate to standard crop practices and may focus to other stages of production to improve such as introducing more efficient methods. From the other had set G has very low compliance rates and this fact suggests that there is space for improvements in this set since the standard crop practices are not fully applied yet. As a result these differences between regions are characteristic and can be

determined with the use of the total non-compliance rates which is a tool from objective evaluation of olive production systems proposed in this study.

For set H and set G the total compliance rates to standard crop practices were lower compared to production systems of Krya (set A to D). Set H represented a group of samples from different regions with expected low quality olive oil because of the overall low quality of olives before processing. Data in Figure 3.1 may suggest olive oil produced in orchards with low compliance rate (set H for example) to standard crop practices might also produce lower quality olive oil. Regions such as set G, representing neighboring systems with different scope of production, seemed to have a different strategy which characterizes the region and therefore the compliance rates to standard crop practices might be connected with the overall strategy which is followed by the local producers. The flatland area of Sitia (set E) represented high-intensive organic systems and was also characterized with high rates of compliance towards all standard crop practices.

The neighboring settlement of Dafne represented a semi – intensive organic system which exemplified Krya. It s noticeable that Dafne (set F) follows a similar overall strategy to Krya (sets A to D) compared to Dories (set G) that is characterized with its own regional practices.

II) Crop practices summary in Krya

Regarding soil cultivating in Krya, the use of heavy tractors (hired services) attached with ploughshares during the months of April – May seem to be typical while some producers prefer to use their own small tractors to reduce additional work costs. This trend is most popular in flatlands, but wide differences may be seen in other regions such us Dories (Neapoly) which are not characterized by this practice. Total compliance rates (Figure 3.1) to standard crop practices (soil cultivation, fertilization etc.) in Krya (sets A to D) and Dafne (set F) seem to be higher compared to other sets except the flatland area of Sitia (set E)which is the most compliant to standard agricultural practices.

On fertilization in semi- intensive organic production systems, it seems that the use of green manure to sustain soils with nutrients is the usual practice, but a variety of materials are being used (animal manure, compost) in general. Commercial fertilizers are applied mostly when nutrients seem to be missing. Areas that have alternative occupations (such as animal production) may have additional sources of organic matter (such as compost) but a general use of branch shredders to cut weed remnants and residues from the pruning season to produce organic compost is also used. Most regions seem to comply with fertilization, although more investigation comparing these varying methods is necessary to determine which is more productive.

With regard to irrigation, Krya seems to rely on public network irrigation used for agricultural purposes, and some may apply additional watering during the dry months of summer to sustain the fruiting. Highland regions (Krya, Dafne and Dories) located within basins seem to be more favored with increased humidity which might be helpful during general droughts. In a recent study held in Tunisia, Koroneiki olives were treated with different amounts of water provided with earth drill irrigation (similarly to Krya) to determine differences in quality in various ripeness stages. Chemical quality indexes were less affected by the irrigation [Dabbou 2011]. Past studies suggested that a regulated deficit irrigation strategy can increase oil yield per amount of fruits without affecting chemical composition of olive oil [Motilva, 2000]. Olive oil obtained under low irrigation is very likely to be characterized by increased bitterness [Gomez et al., 2007]. Other studies suggest that low crop loads in individual trees may produce olives with more oil content [Barone, 1994]. All of the above may lead to the hypothesis that minimum irrigation noticed in Krya does not cause a reduction in production.

The main method of harvesting in highland, inclined systems seems to be hand held mechanical harvesters due to their flexibility and the lack of alternative methods.

Pruning seems to be an important practice in organic semi-intensive systems. Several training systems may have been developed but the most common shape in Krya is the “vase” which puts emphasis on the opening of the tree canopy and the lowering of the tree to become more manageable during harvest. The cost of this practice remains high but in some cases the producers are carrying out the pruning themselves or it may be

done by close members of the community of organic producers, and costs may be reduced in this way.

Organic semi –intensive production systems may use pruning residues for several purposes. In some cases residues are used to generate extra income (firewood) while in some other cases they are processed to generate compost which is used to fertilize the land. The burning of tree residues remains a cheap option but does not offer additional nutrition to the orchards which may then be needed from other sources (such as commercial products). This practice may also have a negative ecological impact (CO_2 emissions).

Organic semi-intensive production systems may suffer from various diseases and pests. Crop pests seem to be a key issue in organic systems where implementation of chemical pesticides is forbidden. The low rates of *B.Oleae* suggest lower damage levels caused by the insect compared to other regions such as the flatlands of Sitia or Dories (of Neapoly) that deal with higher rates of appearance, which need to be controlled. The use of mass trappings seems promising while the introduction of biological control agents is an area which needs further investigation. Producer compliance against *Psaudomonas* seems low; perhaps more information about the consequences must be given because producers (in Krya for example) do not follow a systematic tool disinfection strategy probably due to ignorance of this problem (*Pseudomonas* does not have an immediate impact in fruit quantity or quality). The general compliance of producers against diseases seems to be low in Krya and Dafne because disease incidence is lower compared to regions such as Dories. It seems possible that local climate is influencing *B.Oleae* since climate is known to affect the life circle of olive flies, especially temperature and relative humidity. Decreased temperatures during winter and increased humidity during spring compared to other regions (flatland Sitia) characterize the region and may be negativity influence the reproduction of the insect. As a result, oil produced in Krya and Dafne may be less affected by pests compared to other regions and may require less crop protection costs suggesting that this is a unique regional advantage. For the same reasons ccompliance against diseases is very high in the lowland high-intensive production systems of Sitia (set E) since the disease incidence is higher

compared to other sets. *B.Oleae* is known to flourish in warm temperatures during autumn (not above 30°C) during the stage when females lay eggs. Such temperatures are most likely noticed in Crete's lowland systems during autumn while highland regions have noticeable lower temperature and higher humidity. In addition, olive fruit also grows significantly in autumn and if olives are irrigated (like in set E – Sitia) then ripen faster [Dabbou et al., 2011] as a result become more susceptible to *B.Oleae* damages [Tamendjari et al, 2004].

Dories (set F) seem to have lower compliance rates against crop enemies although the disease rates are higher compared to Krya. The main differences between Dories and the other regions seem to the level of experience in organic crops since Dories have been only recently turned to organic agriculture. The total noncompliance rate to standard crop practices seems also to be a consequence of strategy and encouragement. In many productive systems of Crete (Dories for example) producers are practicing traditional methods which are associated with social-cultural habits rather that economic-productive. This acts as a factor influencing the overall strategy followed in Dories which was expressed as low compliance rate to standard crop practices in this study.

In general, two possible ways to marketing of olive oil can be recognized in the systems investigated here. Olive oil can be either bottled and marketed by the producers or sold in bulk to the mill. Producers that market olive oil independently may be more encouraged to produce olive oil of higher quality since sells and price can be raised for quality olive oils. From the other point of view, producers sell olive oil in bulk to the mill will be less encouraged to follow a "strategy of quality" since quality does not majorly affect price per liter when olive oil is sold in bulk. If there is no motivation for quality production counterbalanced with higher price of olive oil per liter in the market then space for improvement is limited. From this point of view, correct marketing of optimum olive oil at higher prices seems to be the key parameter for the encouragement of producers to comply with standard crop practices.

Another issue noticed is that olive oils produced in lowland regions may have the same price as olive oils produced in highland regions regardless of their sensory score or

phenolic content when sold in bulk. The situation in Krya is different since olive producers are bottling and market olive oil and final price is formulated based on demand. Further economic analysis is needed to support the assumption that optimum quality olive oil will be more successful in the market thought since in the end; the willingness of certain target group of consumers to pay more is what determines the commercial success of the oil. From this scope, Dories production systems that have only recently introduced to organic agricultural methods must focus to develop towards the most positive scenario. That is optimization of agricultural practices, post-harvest conditions and investing in efficient bottling and marketing.

3.2 Temperatures during milling (processing of olive oil)

Table 3.11Temperatures during the different stages of olive oil processing in mills located in Krya, Furni (Dories - Neapoly) and lowland Sitia (Acladia).

	Krya (Highland, Sitia)			Furni (Highland, Neapoly)			Achladia (Lowland, Sitia)			"Cold" Press (Krya)		
Stage of process	**Temp. (°C)**	Variable	St. Error	**Temp. (°C)**	Variable	St. Error	**Temp. (°C)**	Variable	St. Error	**Temp. (°C)**	Variable	St. Error
Outdoor	**10.4**	2.5	1.6	**11.0**	5.3	2.3	**12.2**	6.0	2.4	**12.2**	0.6	0.8
Malaxation(1st)	**26.8**	0.7	0.8	**29.4**	3.9	2.0	**30.4**	4.8	2.2	**22.5**	1.3	1.1
Malaxation(2nd)	**31.0**	0.6	0.8	**33.4**	3.1	1.8	**34.3**	4.4	2.1	**24.5**	1.8	1.3
Centrifugation	**32.9**	0.8	0.9	**36.3**	2.4	1.5	**36.1**	4.1	2.0	**25.3**	1.4	1.2
Within the tank	**31.1**	1.1	1.1	**33.8**	4.2	2.1	**34.8**	2.0	1.9	**23.7**	1.1	1.1
Room Temp.	**18.7**	2.4	1.5	**21.3**	1.6	1.3	**22.0**	1.9	1.4	**22.0**	0.9	1.0

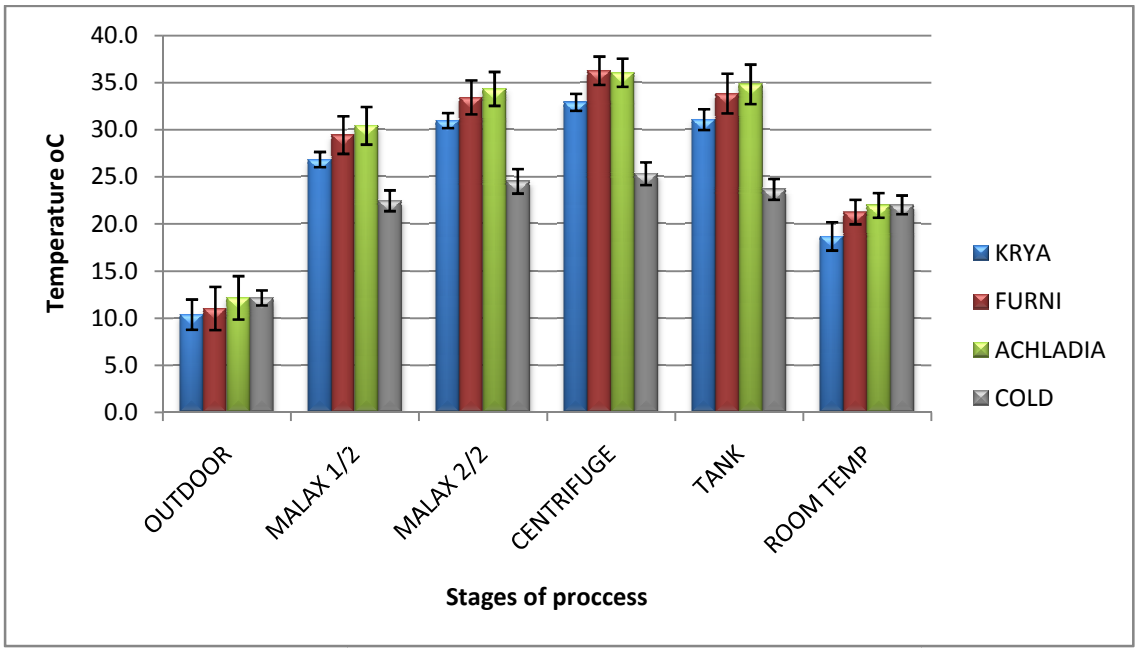

Figure 3.1 Temperature scores and standard errors during different olive oil

processing stages in 3 mills compared to “cold” press processing temperatures

As presented in Figure 3.1, Krya (mill stationed in the mountainous settlement of Krya), Furni (mill stationed 2.5 Km north east of Neapoly), and Achladia (stationed in the lowland Sitia) may reach high temperatures during different stages of processing. The additional “cold” press bar represented processing in Krya mill without the use of heat (processed at room temperature). Although there is no established configuration for “cold” pressed olive oils IOC regulations suggest that all olives produced below 27^{o}C are considered unheated. Since the use of heat is optional it is in the decision of the olive oil producer in agreement to the mill manager to adjust the temperature either for commercial purposes or not. Since the use of temperature may in olive oil it is most often noticed that producers choose to use higher temperatures to extract more olive oil (heat is widely known to increase yield) which is more profitable decision but in the cost of quality. “Cold processed” olive oil seems to be commercially used exclusively for the production of higher quality olive oils in the market so far.

All measurements where taken during the productive months (November – February), “Cold” processing was taken afterwards in February and small differences in outdoor temperature are reasonable. The overall outdoor temperature as shown in table 3.11 was in all cases between 10.4 °C to 12.2 °C. Krya and Furni (Neapoly) are located in highlands, where temperature is normally 1-2 degrees lower than flatland neighbouring regions.

As shown in Figure 3.1 the temperature of “cold” press processing was 22.5°C and 24.5°C during the first and second stages of malaxation. The mill was operating at room temperature at 22°C which suggests that temperature has risen because of mechanical action with a maximum temperature of 25.3 °C during centrifugation (by measuring wastewater). Olive oil after processing was at 23.7 °C within the tank, gradually reducing to room temperature.

The temperature of processing was increased in all mills; Krya’s olive paste reached temperatures of 26.8 °C and 31 °C during the first and second stages of malaxation. Furni’s (Neapoly) olive paste reached 29.4 °C and 33.4 °C and Achladia’s reached 30.4 °C and 34.3 °C in these stages.

Malaxation is a process that takes almost about an hour which is likely to be sufficient for precious compounds to be destroyed at the high temperatures which were recorded. According to IOC regulations olive oil is still considered "cold processed" if the paste is warmed to room temperature during the malaxation. Regulation 1019 of 2002 determines the use of the term "Cold processed" in the EU. According to this IOC regulation, all olive oils obtained from the mills in Krya (Sitia), Achladia (Sitia) and Furni (Neapoly) including the samples tested in this study are not considered “cold processed” since were processed with the use of heat, at more than 27ºC.

During malaxation the olive paste must be kept under 27ºC (81ºF) for an oil to be considered as non-heated. Heating the paste excessively increases yield but is known to degrade quality and flavours. Again, the management of heat must become part of the broader qualitative strategy. Carefully grown organic olive oil (like that which is produced in systems of Krya) has to be controlled in this stage of the process. Olive oil which is sold in bulk (like systems of Dories) may be more encouraged to use heat during processings to increase the yield since quality does not affect the price per litre.

The temperatures of waste water coming from the centrifugation process were increased compared to malaxation in all mills In Krya, Achladia and Dories temperatures reached 32.9 °C , 36.1 °C and 36.3 °C respectively . After all processing of olive oil it is noticeable that olive oil which comes into the tank after centrifugation had temperatures at 31.1°C, 33.8°C, 35.8°C for Krya, Furni and Achladia respectively. These temperatures are 8 to 12 °C higher than the “cold” pressed processing (23.7°C in the tank) which suggests that the effects of temperature might lower the quality of carefully grown olive oil in the Region of Krya. Temperature can affect the aromas and taste of olive oil lowering dramatically its sensory intensity which seems to be connected with the phenoloc content [Caponio and Gomes, 2001]. Alteration into low temperatures during kneading requires is in the decision of the mill management since current centrifuge systems are adjustable to the needs of the production. Cold processed olive oil can be experimentally produced in the first years and if this practice proves to be efficient then producers may decide to invest in specialized systems that produce olive oil without heat. This suggests that if carefully grown organic olive oil does in fact deteriorate due to high temperatures during milling then perhaps this is a practice that

should be altered, and lower temperatures during processing should become standard strategy demanding optimum quality “cold” pressed olive oil. As a result, yield might be lowered compared to heated olive oils processing but the flavors and aromas of olive oil will be increased as also individual phenolic substances [Kotsifakis et al., 1999][Caponio and Gomes, 2001]. The benefit of increased quality from cold processed organic olive oils can theoretically increase the price of the product on the market but this remains a key issue in organic production dependant on marketing management.

3.3 Chemical and sensory quality test results

Olive oil quality characteristics can be assessed with various chemical and sensory tests. IOC has established a protocol which evaluates free fatty acids (%) and concentration of peroxides (meq/L) with titration methods and determination of indexes (K_{232}, K_{270}, ΔK) based on absorption in the ultraviolet measured with a spectrophotometer, and the overall assessment is completed with sensory tests which are used for the determination of aroma and taste. IOC made a proposal for a 'Total Quality Index' score formula to be used which can combine all these scores and give a final value which will represent the overall quality of olive oil. In this section, chemical and sensory results of all sets and samples tested in the study are presented, discussed and finally the overall quality is calculated. Totally 24 Samples from A1 to H24 represent olive groves from A1 to H24 (also see chapter Material and Methods – Table 2.2)

3.3.1 Free fatty acid (FFA)

Table 3.12 Free fatty acid (FFA) scores of samples collected from organic semi-intensive production systems

Code	FFA (%)	Variability	Standard Error	Code	FFA (%)	Variability	Standard Error
A1	0.26	0.0000	0.001	**E13**	0.45	0.0000	0.003
A2	0.26	0.0001	0.011	**E14**	0.41	0.0001	0.007
A3	0.36	0.0000	0.004	**E15**	0.38	0.0000	0.005
B4	0.39	0.0001	0.011	**F16**	0.39	0.0000	0.006
B5	0.24	0.0000	0.007	**F17**	0.35	0.0001	0.012
B6	0.30	0.0001	0.011	**F18**	0.37	0.0000	0.006
C7	0.34	0.0001	0.009	**G19**	0.32	0.0000	0.006
C8	0.39	0.0001	0.011	**G20**	0.33	0.0001	0.008
C9	0.29	0.0001	0.008	**G21**	0.50	0.0001	0.008
D10	0.30	0.0001	0.008	**H22**	0.43	0.0002	0.012
D11	0.45	0.0001	0.010	**H23**	0.69	0.0001	0.007
D12	0.47	0.0001	0.007	**H24**	0.80	0.0002	0.013

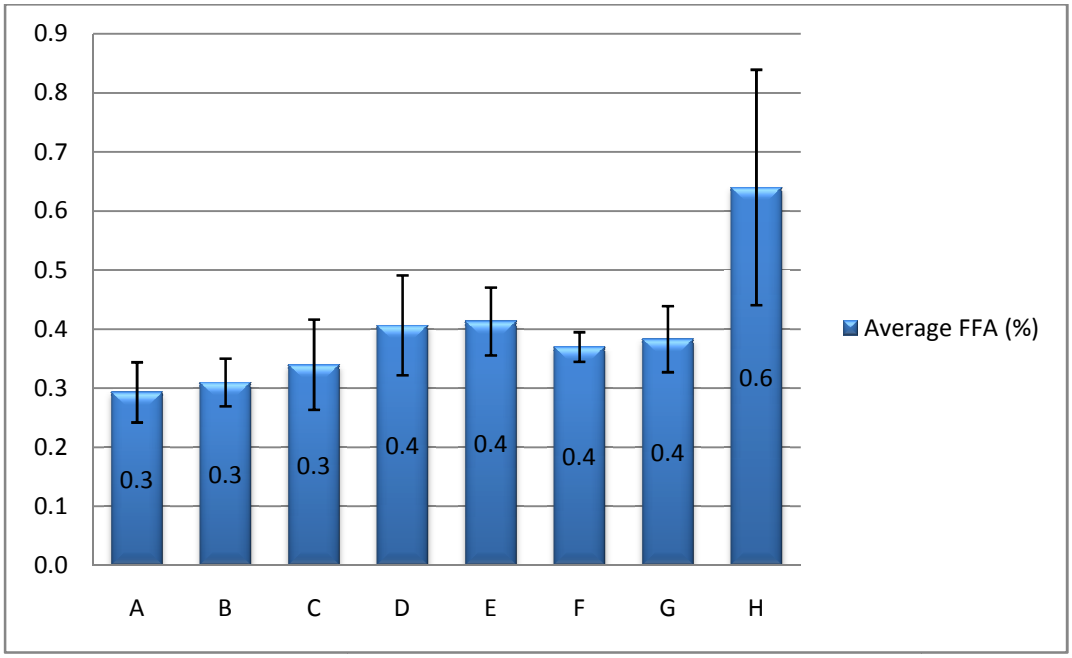

Figure 3.2 Diagram of average free fatty acid (%) scores of all sets compared

Free fatty acidity measures directly the quality of the oil and reflects the care taken during the development of the fruit. The chemical reaction called hydrolysis is responsible of the degree of breakdown of the triglycerides which forms free fatty acids. In general, oil obtained from poor quality fruit suffers from increased free fatty acids. Most studies widely agree that wounds caused to the fruit during the various stages of production (Crop pests, harvesting, transportation etc) can favor the hydrolysis producing olive oil with high free fatty acidity content [Shimizu, 2008] [Yousfi, 2012]. Harvesting time can also affect fatty acid composition [Beltran, 2004].

The results regarding acidity as displayed in Table 3.12 show that all samples from Krya (sets A to D) can be classified as extra virgin olive oils between an acidity score of 0.24 (sample B5) to 0.47 (sample D12) since all olive oils with an FFA score lower than 0.8% are considered extra virgin according to IOC classification system. In general, lower scores of free fatty acidity are indicative of the highest quality oil. Especially olive oils with free acidity score below 0.3 % like samples A1, A2, B5, and C9, which can be characterised as “extrissima. This term refers to extra virgin olive oils which have very low acidity score (lower than 0.3%) and can have a higher price in the market

compared to other olive oils with higher acidity score (lower quality). All comparative regions (Sets E to H) are also classified as -virgin, only sample H24 may be classified as Virgin oil based on acidity.

It is noticeable that sample A1 and sample A2 have similar acidity scores. Although 0.10% difference in FFA may be normal, it seems that the most probable parameter which affected the FFA score in orchard A3 was increased disease caused by *B.Oleae*. As was discussed in section 3.1.8 about disease rates (Table 3.8) 28.8% of trees where attacked by olive fly which may suggest that the difference is related to wounds caused by the olive fly. Olive fly in general is known to cause qualitative damages which refer to higher acidity and peroxide scores [Tamendjari, 2009].

Regarding samples B4, B5, B6, it seems that the differences are wide (difference between minimum and maxim score is 0.15%). This may be explained by the wide differences in cultivation methods (soil, irrigation, pruning and fertilization) and disease rates (mostly attacks form *B.Oleae*).

Regarding set C it can be seen that that the minimum FFA score is 0.29% (C9) while the maximum is 0.39% (C8). Different cultivation methods as well as wounds caused by olive flies can explain these differences.

The FFA difference in orchards of set D seems wide (0.17%) also. It seems that set B and D have wider differences compared to sets A and B. By checking the total noncompliance rates to standard crop practices in Figure 3.1 about irrigation, soil cultivation, pruning and fertilization it can be seen that sets B and D have higher noncompliance rate compared to sets A and C. It seems reasonable that these wide differences in acidity between orchards of the same set are related to compliance towards standard crop practices. By reviewing the pruning residue management it is notable that sets B and D have used shredders to break pruning residues within the orchards. Perhaps this may suggest that broken residues within the orchard can somehow affect the fruit indirectly perhaps by hosting diseases and pests, although deeper investigation is needed to confirm these assumptions. Also, the average acidity score of set D compared to the other sets from Krya seems also to be higher. Since orchard D10 produced olive oil with 0.30% acidity it seems more likely that compliance

to standard crop practices is the parameter which particularly affected acidity. In addition to these standard practices there are also certain other secondary post harvest parameters such as pressures damaging olives [Olias & Garcia 1997] or wounds caused by *B.Oleae* [Tamendjari, 2009] which can also affect acidity scores.

In set E located in the lowland region of Sitia, which is following specifications towards farming practices (soil cultivation, irrigation, pruning etc.) with more zeal (since it has the highest compliance rate), it seems that the minimum FFA score is 0.38 which represents the finest quality in this set. Orchard E13 produced olive oil with acidity score at 0.45 which can be a reasonable difference (0.07%). The average FFA score seems high; this can be explained by high disease rates caused by *B.Oleae.* Protection against crop enemies seems to be a key issue in these systems.

Set F from the neighbouring settlement of Krya has the minimum differences between lowest and highest olive oil acidity scores (0.04%) compared to other sets, followed by an average acidity score between sets C and D.

Regarding the semi-intensive organic production systems of set G, which are located in Dories (Neapoly), the acidity score was generally low. Orchard G19 and G20 produced olive oil of 0.32% and 0.33% FFA score which is very close to “extrissima” quality (<0.30%). The average FFA score is relatively low (lower than set’s D of Krya) which suggests that the region has the dynamic to produce optimum quality olive oil as well. By comparing the previous two samples from G set with G21’s FFA score, it seems that wide differences in cultivation methods between producers may be responsible. It is noticed that the average FFA score is relatively low compared to Krya’s sets. The main difference between set G and set E compared to olive fly attacks seems to be the ripeness stage of olives during harvest. In Dories, olives are mostly not irrigated (rely on rainfall) and as a consequence remain less ripened during harvesting compared to olives grown in Sitia’s flatland areas which are irrigated and left to ripen more. Some reports suggest that crop load between orchards can also be related with olive ripening and low yields seem to produce more olive oil per kilo of fruit [Barone, 1994]. Well ripened olives are also known to produce more olive oil [Dabbou, 2011] but if attacks from *B.Oleae* are at a high rate then olive oil will have higher FFA scores (lower

quality) [Tamendjari, 2009]. Again, it is a matter of strategy which has to either be focused on quality or quantity. As a conclusion, in Dories, the harm from olive fly was controlled by the producers by harvesting at an earlier state, which led to lower FFA overall.

In regard to set H, as a group of samples with expected poor quality (used as a reference for comparison), the increased average FFA score is reasonable since sample H22 was obtained from very poor quality olive oils due to delayed processing after harvest. Sample H23 was obtained from damage olives due to frosts and finally H24 was obtained from olives damage from *B.Oleae*. All these factors in general are known to increase free fatty acidity content as seen also in Figure 3.2 [Kiritsakis, 1998].

3.3.2 Peroxide

Table 3.12 Peroxide scores of samples collected from organic semi-intensive production systems

Code	Peroxide meq O_2/Kg	Varia bility	Standard Error	Code	Peroxide (meq O_2/Kg)	Varia bility	Standard Error
A1	8.4	0.05	0.23	**E13**	12.7	0.09	0.29
A2	8.9	0.02	0.14	**E14**	10.6	0.03	0.17
A3	8.7	0.01	0.11	**E15**	9.8	0.02	0.13
B4	9.9	0.00	0.06	**F16**	13.0	0.03	0.18
B5	10.9	0.05	0.22	**F17**	9.9	0.05	0.23
B6	11.2	0.02	0.12	**F18**	11.7	0.04	0.18
C7	8.7	0.12	0.34	**G19**	7.9	0.01	0.23
C8	14.6	0.01	0.09	**G20**	8.7	0.08	0.19
C9	10.8	0.10	0.32	**G21**	14.6	0.04	0.17
D10	7.1	0.05	0.23	**H22**	9.9	0.00	0.05
D11	14.8	0.05	0.22	**H23**	23.5	0.04	0.20
D12	13.1	0.00	0.06	**H24**	23.2	0.07	0.26

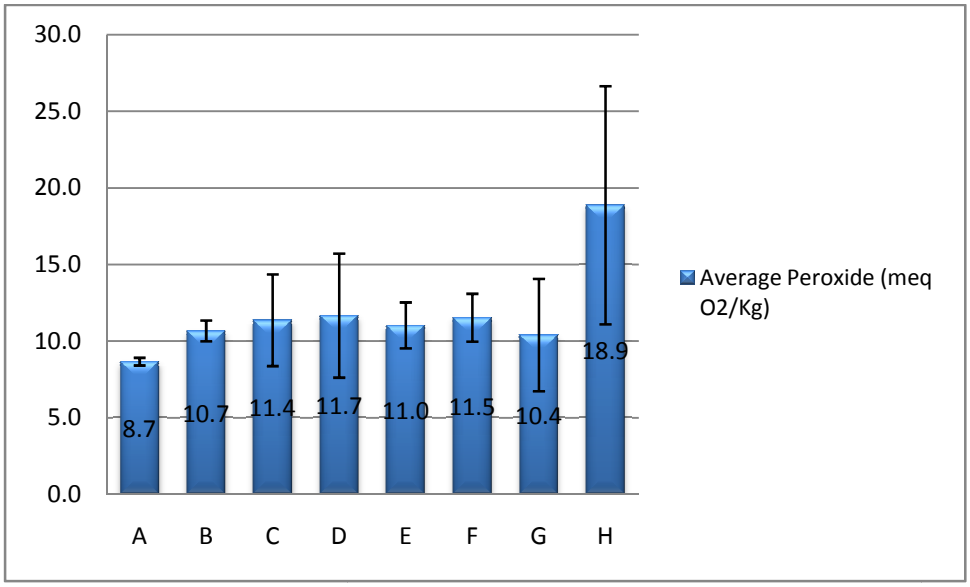

Figure 3.3 Diagram of average peroxide value (meq O_2/Kg) of all sets compared

The peroxide score is the index which shows the oxidation of olive oils which may have led to the creation of peroxides. These are formed from the reaction of unsaturated fatty acids with oxygen. For extra virgin, virgin and ordinary virgin olive oils the peroxide value limit is < 20 meq O_2 / kg as set by the IOC. Very high scores of peroxide such as sample's C8 (14.6 meq O_2/Kg), D11 (14.8 meq O_2/Kg L) and G21 (14.6 meq O_2/Kg) can play an important role in the overall image of an olive oil in the market because peroxides indicate the level of rancidness of olive oil, which is an unwanted attribute.

With regard with set A, from Table 3.12 it is seen that samples were of similar peroxide score, and from Figure 3.3 it is noticeable that the average peroxide score is lower compared to all other sets. This result suggests that the overall quality of the fruit before processing was better, with less wounds and harvesting in the optimum ripeness stage.

Similarly, set B has peroxides values with small differences (between 9.9 meq O_2/Kg to 11.2 meq O_2/Kg) within the set. The wider differences detected between FFA scores are not similarly present in these peroxide results. Sample B5 has a higher peroxide value than B4. In FFA results B5 had lower FFA score compared to sample B4.

Samples C7 and D10 had generally lower peroxide score (8.7 meq O_2/Kg and 7.1 meq O_2/Kg) compared to the other two samples of each set. This may suggest that the overall quality of the fruits was better during processing. In contrast, C8 and D10 had an

increased peroxide score (14.6 meq O_2/Kg and 14.8 meq O_2/Kg) which suggests that the overall quality of the fruits in each set was not so good compared to the others before processing. Wounds caused during harvesting, attacks from *B.Oleae* (also affected FFA) and delays before milling are the most possible reasons for this result since all these parameters are well known to affect quality of olive oil [Shimizu, 2008] [Yousfi, 2012]. Set F of the neighbouring settlement of Dafne seems to have similar results.

Regarding set E, the average peroxide score is higher that sets A, B, C of Krya but lower than set D. In general, wounds caused by *B.Oleae* responsible for lowering quality in set E may be prevented with successful crop protection during the year [Tamendjari, 2009].

In set G it is noticeable that samples obtained from G21 orchards, had increased peroxide values (14.6 meq O_2/Kg) compared to the other two samples (7.9 meq O_2/Kg and 9.7 meq O_2/Kg). In comparison with FFA results it is noticed that sample G21 had gained a much higher FFA score compared to the other two samples. This may suggest that the quality of the fruit was poor compared to G19 and G20 which affected both FFA and peroxide score. This is normal in fruits damaged by olive fly [Tamendjari, 2009), especially when sacks contained olives are piled and pressed too much after harvest [Olias & Garcia 1997].

Regarding set H it can be noticed that the peroxide score of samples H23 and H24 does not meet the criteria to be classified as -virgin (-virgin <20 meq O_2/Kg). This is characteristic of olive oil obtained from very poor quality fruits. Unexpected factors, such as high temperatures favouring *B.Oleae*(sample H24) during summer or frosts during harvesting (sample H23) may be significant for these results (discussed in Materials and Methods – 2.1.2) As also shown in table 3.11 the FFA was increased and sensory scores may be seriously affected too. However, the sample obtained from H22 gave a good peroxide score, and its FFA score wasn’t so high compared to other sets, therefore it represents a more optimistic result compared to other samples of the set.

3.3.3 Absorption in ultraviolet (K indexes)

Table 3.13 K index scores of the organic olive oil samples collected from Krya

Code	Average K_{232}	Variability	Standard Error	Average K_{270}	Variability	Standard Error	ΔK value
A1	2.2	0.003	0.051	0.13	0.00000	0.001	-0.009
A2	1.8	0.003	0.058	0.13	0.00000	0.001	-0.006
A3	2.2	0.006	0.076	0.12	0.00000	0.001	-0.009
B4	2.4	0.003	0.051	0.14	0.00000	0.003	-0.008
B5	2.3	0.007	0.086	0.11	0.00000	0.004	-0.012
B6	2.2	0.001	0.024	0.15	0.00001	0.001	-0.010
C7	2.0	0.001	0.025	0.11	0.00001	0.005	-0.008
C8	2.2	0.001	0.029	0.14	0.00005	0.007	-0.009
C9	2.1	0.002	0.040	0.11	0.00001	0.003	-0.008
D10	1.9	0.004	0.065	0.13	0.00003	0.005	-0.008
D11	2.8	0.003	0.059	0.13	0.00000	0.002	-0.011
D12	2.5	0.010	0.098	0.15	0.00000	0.000	-0.009
E13	2.3	0.001	0.032	0.15	0.00002	0.005	-0.006
E14	2.6	0.008	0.091	0.17	0.00003	0.006	-0.006
E15	2.3	0.000	0.018	0.14	0.00001	0.002	-0.008
F16	1.9	0.005	0.068	0.11	0.00001	0.004	-0.009
F17	2.0	0.007	0.082	0.12	0.00002	0.004	-0.012
F18	2.3	0.001	0.030	0.13	0.00004	0.006	-0.010
G19	2.5	0.001	0.033	0.14	0.00003	0.006	-0.010
G20	2.1	0.003	0.055	0.14	0.00004	0.006	-0.010
G21	2.8	0.005	0.069	0.19	0.00002	0.004	-0.007
H22	2.1	0.002	0.043	0.14	0.00000	0.002	-0.004
H23	2.8	0.000	0.011	0.19	0.00002	0.005	-0.003
H24	3.0	0.002	0.042	0.20	0.00002	0.005	-0.002

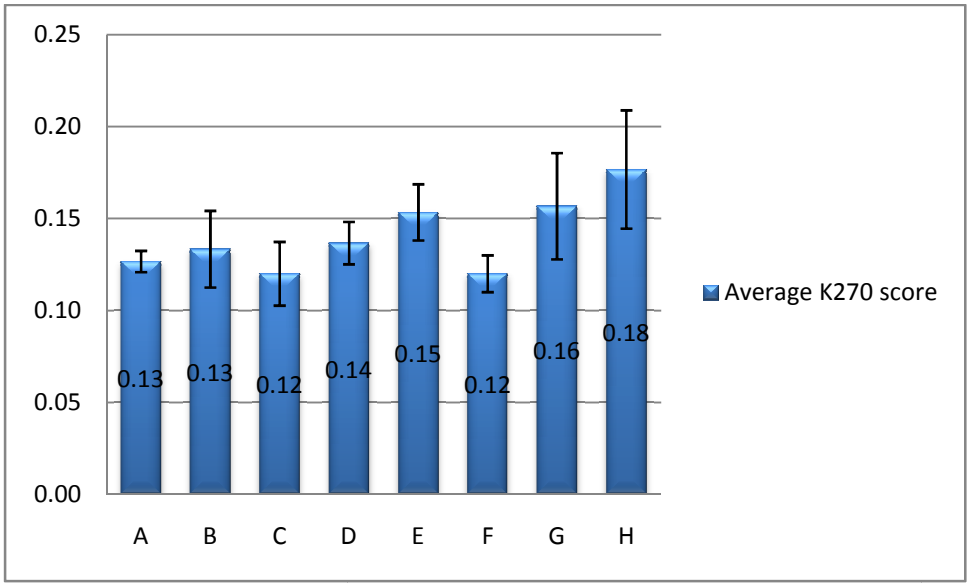

Figure 3.4 Average K_{270} index score of olive oils obtained from organic semi-intensive production systems compared

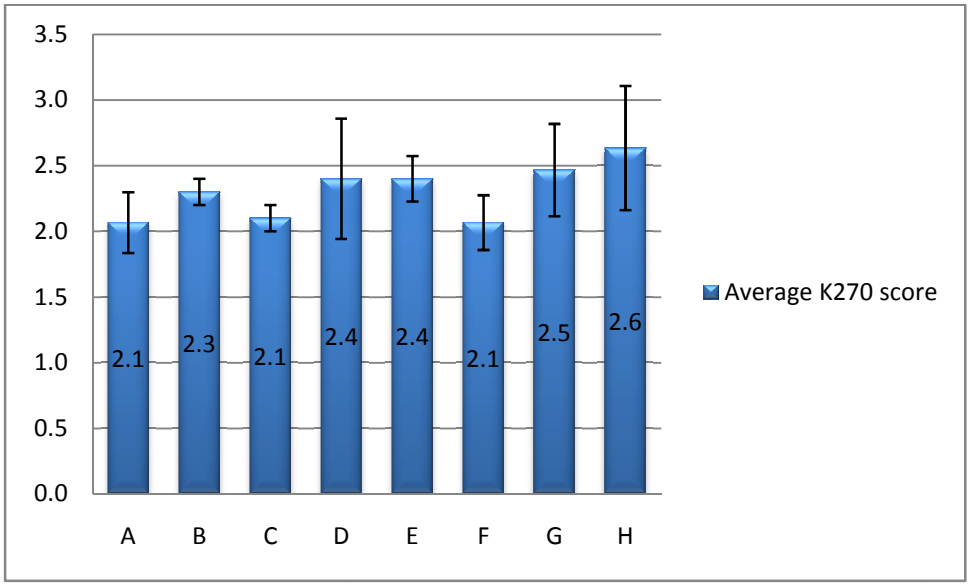

Figure 3.5 Average K_{270} index score of olive oils obtained from organic semi-intensive production systems compared

The wavelengths at 232nm (presence of organic hydro-peroxides) and 270nm (freshness of fruit) are very interesting because they can provide information on the quality of an oil, its state of preservation or the stage of degradation which may have occurred during and after harvest. K_{232}, K_{270} and ΔK (Delta K) are indexes related to the absorption of

ultraviolet light in specific wavelengths such as of 232nm and 270nm. Especially the K_{270} index score is important because it represents the absorption at 270 nm and refers to oxidised materials and practically can show the resistance to oxidation and it is also used later on in the calculation of the total quality index score. Time, light, and temperature during storage can influence both K_{270} and K_{232} index scores. Organic peroxides (R^1-O-O-R^2) and organic hydro-peroxides (R-O-O-H) that are different type of peroxides. Hydro-peroxides are usually formed when olives are harvested during rain or stored during humid conditions. ΔK index can show if extra virgin olive oils are mixed with other oils (non extra virgin). The score of extra virgin olive oil is usually negative but can reach the limit of 0.01 in some cases. Extra virgin olive oils must have a K_{232} score lower than 2.5, K_{270} score lower than 0.20 and ΔK score lower than 0.01 according to IOC.

At first glance, from Figure 3.4 and Figure 3.5 it is noticed that most samples obtained from Krya can be classified as extra virgin based in their K_{232} (< 2.5) and K_{270} (< 0.20) scores. In combination with results from peroxide and FFA scores, sample A2 seems to have the best chemical characteristics compared to the other two samples of the set. This score also suggests that this sample will have a prolonged storage life compared to other samples. Set A has a general high compliance with standard crop practices (soil cultivation, irrigation, pruning etc) which may be suggest that this has led to good quality fruits in this set. In addition, if the overall post harvest management is good (proper conditions before processing) and olives are delivered in optimum condition then olive oil will likely have optimum quality as A2.

Regarding set B, samples obtained from all orchards show an overall low difference in K_{232} scores similarly to peroxide scores presented in table 3.12. K_{270} scores of B4 (0.14) and B6 (0.15) seem increased compared to B5 (0.11) and set A. Finally, B5 may represent the finest quality (extrissima) of set B with an overall excellent chemical quality profile. B4's K_{270} score (0.11) and ΔK (-0.012) indicated longer storage life (compared to the other samples) and homogeneity which are additional characteristics of quality in olive oil because they ensure the longevity of the product and indicate no mixture with other olive oils.

The differences between K_{232} scores in set C are low, values between 2.0 to 2.2 seem reasonable for extra virgin olive oils. The K_{270} score of C8 (0.14) is higher compared to C7 (0.11) and C9 (0.11) and similar to peroxide results as shown in table 3.12. This sample represents a harvest of lower quality compared to the others of the set probably related with over-ripeness of the fruit compare to other samples of the set. Studies suggest that oil quality can be lowered as fruit ripens influencing all chemical characteristics [Baccuri, 2007]. Oil obtained from C9 orchard represents the optimum quality olive oil of the set and can be classified as “extrissima” extra virgin olive oil.

With regard to set D it can be noticed that K_{232} scores between samples have wide differences, the minimum value is 1.9 (D10) and maximum is 2.8 (D11). This result seems to be similar compared of peroxide and FFA results where D10 (7.1 meq O_2/Kg peroxides and 0.30% acidity) had the lower peroxide and FFA score and D11 (14.8 meq O_2/Kg and 0.45% acidity) the highest peroxide and FFA score. This may suggest that olives harvested from D10 were of good quality (low peroxide and FFA scores) and where processed without unexpected delays. Oil obtained from D11 had higher scores of K232 which indicated increased formation of organic hydro-peroxides (K_{232}). This is most likely to happen in very difficult to access orchards with high inclination (>35%) like set D compared to less inclined systems because pressures during transportation are increased, sacks containing olives are pressed together too much and as a result the fruits can be more damaged [Olias & Garcia 1997]. As stated above, extra virgin olive oils must have a K_{232} score lower than 2.5 and virgin oils not more than 2.6 therefore olive oil obtained from D11 (and marginally D12) is classified as not fit for consumption (K_{232} score >2.6). Olive oils obtained from different orchards are often mixed together in the same tank after processing and these scores are usually balanced. This mix may possibly detected if the ΔK value is higher that 0.01. D10 represents the optimum quality of the set.

By testing samples obtained from E set it is noticed that E14 cannot be classified as extra virgin because it’s K_{232} score is 2.6 (extra virgin olive oils must have lower than 2.5 K_{232} score. Similarly, it’s K_{270} score seems to be higher that the other two samples of the set and also compared to all samples obtained from Krya. Several assumptions can be made for the results regarding this set. Wounds caused by *B.Oleaa* can influence

olive oil K indexes [Tamenjari, 2009]. Olives often stored in piles may cause secretions of fluids affecting the quality of olive oil too [Olias & Garcia 1997]. All of the above seem to be responsible for the increased K_{232} and K_{270} scores of E14 compared to other samples.

Regarding set F, it is noticed that olives obtained from the neighbouring settlement of Dafne are extra virgin, these scores are reasonable, and represent oil obtained from olives with less wounds caused by harvest [Yousfi, 2012], properly transferred and stored to the mill [Kiritsakis, 1998]. F16 has better K index scores; in general it suggests that this sample will have a prolonged storage life compared to other samples. The K index score of F16 conflicts with the peroxide test results (13.0 meq O_2/Kg was higher compared to F15 and F17). Increased peroxide has possibly been caused by *B.Oleae* which also seems to be responsible for the increased FFA [Tamendjari, 2009].

Samples obtained from the neighbouring municipality, in Dories (Neapoly) seem to have increased K index scores. Sample G21 (and marginally sample G19) is not classified as extra virgin, Virgin or Ordinary because its 2.8 K_{232} score is higher that the limits for these classes. Its K_{270} score is also high. This sample may be representative of oil obtain from poor quality olives harvested during rainfall or stored in increased humid conditions. This set has high noncompliance rates to standard crop practices of the region which suggest that poor quality olive oil is connected with compliance described in section 3.1.10. However, samples G19 and G20 represent higher quality oils, especially sample G20 (2.1 K_{232} and 0.14 K_{270} score) which in combination with the other results (FFA and peroxide) represents the optimum quality produced in this set of samples. This may have been a consequence of a more careful production.

With regard to set H which represents oil samples obtained from very poor quality olives, samples H23 (suffered from heavy frosts during winter) and H24 (high damage by *B.Oleae*) have increased K scores and are not classified as extra virgin, virgin or ordinary, if assessed exclusively for their K_{232} scores. H24's K_{270} score is in the limit (marginal) to be classified as Virgin. Unexpected climate conditions, delays between harvest and milling, and olives wounded by *B.Oleae* are parameters affecting the quality of these samples. It is however noticed that H22, H23 and H24 have higher ΔK scores (-

0.004, -0.003 and -0.002 respectively) compared to the other samples, which is actually an indicator of lower quality).Sample H22 collected from poor quality olives, seems to have an overall better K index score, which suggests that the stages of delivery and processing and overall condition is crucial for the K index of olive oil. However, olives severely damaged by unexpected climate conditions such as frosts (sample H23) do not seem to result in good oil after this damage is done. In addition, trees will need time to recover for the following two to three years, which may also affect the quality of these following harvests too.

3.3.4 Chlorophyll content and olive ripeness

Table 3.14 Chlorophyll (mg/kg) results of olive oil samples collected in this study

Code	Chl (mg/Kg)	Code	Chl (mg/Kg)	Code	Chl (mg/Kg)	Code	Chl (mg/Kg)
A1	12.9	**C7**	5.3	**E13**	5.6	**G19**	12.2
A2	2.0	**C8**	7.7	**E14**	7.1	**G20**	11.7
A3	9.5	**C9**	8.9	**E15**	7.3	**G21**	10.9
B4	7.7	**D10**	2.6	**F16**	8.8	**H22**	7.3
B5	8.9	**D11**	6.3	**F17**	11.1	**H23**	6.6
B6	12.3	**D12**	5.5	**F18**	8.7	**H24**	8.1

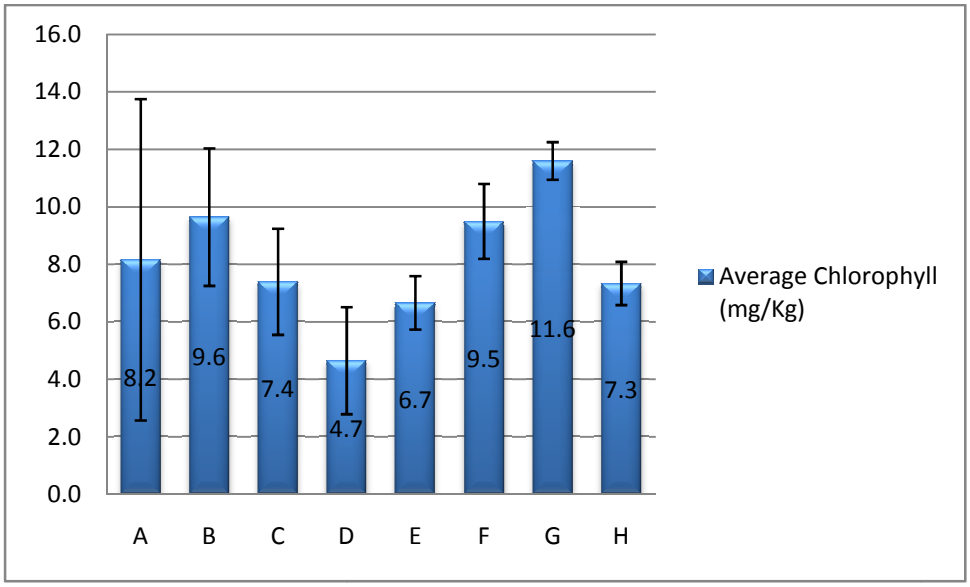

Figure 3.6 Average chlorophyll content (mg/ kg) of olive oils obtained from organic semi-intensive production systems compared

I) Chlorophyll content

Chlorophyll was examined as a parameter which plays an important role in the oxidative stability of olive oil. Olive oils with high chlorophyll play an important role

during storage of olive oil affecting its oxidative stability due to their antioxidant nature during dark conditions and their oxidative effects during light conditions [Queslati et al. 2009]. Chlorophyll content within olive oil can also be affected by the configuration and type of the mill since the last two parameters might determine the amount of olive leafs which pass into the malaxation chambers. In normal conditions no leafs enter the malaxation chamber but in some cases the producers demand a small percent of leaves to pass into the process to increase the phenolic content of olive oil, which also increases the amount of chlorophyll and adds a bitter taste and a dark green colour to olive oil. Recent studies suggest that chlorophyll is a powerful antioxidant and can be a potential cancer preventative agent [Ferruzzi, 2007].

As presented in Table 3.14 samples obtained from A1, has higher chlorophyll at 12.9 meq / kg content compared to A2 and A3. Sample A2 has lower chlorophyll content at 2.0 meq / kg. A1 and A2 represent two extreme cases. Since chlorophyll can influence the oxidative stability and longevity of olive oils this may suggest that A1 olive oil will have longer storage life compared to A2 that has chlorophyll content at 2 mg/kg.

Samples B4 and B5 seem to have a similar content with A3 that represents intermediate chlorophyll content compared to A1 and A2 that represent two extreme cases. B6 has high chlorophyll content like A1. As stated above, olive oils with high chlorophyll content will have longer storage life. Low peroxide - hydro peroxide content also indicates longer shelf life and stability of oil. Although these two parameters (peroxides and chlorophyll) do not seem dependent on each other, they may both contribute to the longevity of the product.

Set C samples seem to have similar chlorophyll content with B4, B5. Also D11 and D12 have approximately the same scores. D10 suggests a similar ripeness level with A2. In general, all samples obtained from Krya (A, B, C, D sets) have a variety of chlorophyll content which is between 2 to 13 (12.9). In Figure 3.6 it is noticeable that the average chlorophyll content gradually decreases from set A to set D, similarly with results from sensory trials which suggest that ripeness of olives may affect the intensity of aromas and taste because of phenolic substances such as oleuropein.

With regard to set E located in the lowland region of Sitia, all samples seem to have an

average higher chlorophyll content compared to set D, but lower compared to other sets of Krya. The average content seems more similar to set C. Several studies suggest that olives wounded by *B.Oleae* can mature faster because of the biochemical reactions occurring after the fruit has been pierced by the fly [Tamendjari, 2009]. This may suggest that impairment of quality can rapidly progress due to olive fly damage. It seems that early harvesting of diseased or wounded olives might prevent further damage in quality.

In set F, olive oil samples obtained from the neighbouring settlement (Dafne) have an average higher chlorophyll content compared to lowland region (set E) or Krya's set D, C and B. Results are lower compared to set A. This may suggest that olive oil obtained from the area of Dafne has been ontained from better quality olives compared to other sets (except A)

Finally, set H average chlorophyll content can be compared with set E. Sample H22 obtained from olives with overall poor quality does not seem to have a wide difference in chlorophyll content. Olives damaged from frosts (H23) do not seem to have a wide difference in chlorophyll content, although all these assumptions need more study. Although set H24 suffered from *B.Oleae* at an increased rate, it has chlorophyll content similar to set E samples, and was collected at approximately the same given time.

Again, in both qualitative and quantitative strategies, control of ripeness level with cultivation practices and correct harvesting timing seems to be the key parameter for olive oil quality.

II) Ripeness and Chlorophyll

Chlorophyll can also be used as to give information about the ripeness of the olive fruit. Ripeness is very important since studies suggest that oil quality can influence all chemical characteristics of olive oil [Baccuri, 2007]. Olive oil colour in Koroneiki olives can appeared green for olive oils with high chlorophyll content (unripe olives), and orange-gold for olive oil obtained from olives with low chlorophyll content (over-ripened olives). Olives collected in an intermediate level of ripeness (50% ripe and 50% unripe) have a golden, lightly green colour.

Olives obtained from A1 were more unripe compared to other olives before processing and this can be seen also from the chlorophyll content. However, in A2, which has lower chlorophyll content, olives were possibly more ripened before processing. Altitude, harvesting date and irrigation seem to be parameters that can affect olive ripeness. Highly irrigated olives are noticed to ripen faster that non-irrigated olives [Dabbou, 2011]. Early pruned olive trees have been noticed to give earlier flowering and earlier production compared to lately pruned olive trees. This suggests that that pruning can be an effective practice for the overall control of production and the ripening of olives in organic systems, although more studies are needed. When olives reach maturity the most effective control method is harvesting, which ultimately determines the ripeness stage of olives. Based on these assumptions, heavily irrigated orchards, early pruned will give production earlier, as a consequence, will ripe faster compared to other orchards with opposite treatments, but this needs more research.

D10 sample also has very low chlorophyll content. This olive oil was produced from the D set that is highly inclined and in a higher altitude (high SMOPS) compared to other sets. In some cases producers may have difficulties to harvest olives because of inclination and difficulty to access and all stages from harvest to transfer to the mill can be delayed. As a consequence olive may by harvest later when they are more ripened. Altitude also seems to play an important role to the ripeness of olive fruits. As a result differences in altitude may be responsible for similar differences in chlorophyll content noticed between Krya set D and other sets.

Set G (Dories) seems to represent a case of early harvesting of mostly unripe olives. Quantitative and qualitative damage caused by *B. Oleae* has been reported to be limited with such practices (also discussed in section 3.1.7 about disease rates and in section 3.1.8 about protection from *B.Oleae*. The overall ripeness level of olives seems to be characteristic of the region since olives produced in Sitia's lowland regions (set E) and Krya's set D were far more ripened at the same period. This is mainly a consequence of non-irrigation, and perhaps other strategies (pruning) followed in the region. As a result, sensory scores were also affected by this practice.

3.3.5 Organoleptic index scores

Table 3.15 Sensory scores, classification and descriptions of samples collected from semi- intensive mountainous production systems

Code	Fruity	Bitter	Pungent	Flaw	Flaw description	Class
A1	4.7	3.15	3.65	0	N/A	E.V.
A2	5	2.5	3.65	0	N/A	E.V.
A3	4	2.4	2.6	0	N/A	E.V.
B4	4	2	2.35	0	N/A	E.V.
B5	4.4	2.4	2.5	0	N/A	E.V.
B6	4.2	2.55	2.10	0	N/A	E.V.
C7	2.9	1.6	1.7	0	N/A	E.V.
C8	3.9	2.2	2.75	0	N/A	E.V.
C9	3.8	2.4	2.2	0	N/A	E.V.
D10	3.9	2.6	2.4	2	N/A	E.V.
D11	1.6	1.4	2.5	0	Winey	V.
D12	2.1	1.9	2	1.5	Fusty	V.
E13	4.0	1.5	2.9	0	N/A	E.V.
E14	1.9	1.5	2.6	1.7	Fusty, grubby	V.
E15	3.5	1.9	2.5	0	N/A	E.V.
F16	4.1	1.9	2.1	0	N/A	E.V.
F17	4.2	2.1	2.4	0	N/A	E.V.
F18	4.0	2.0	2.4	0	N/A	E.V.
G19	2.9	2.4	2.5	2.0	Fusty, grubby	V.
G20	4.0	3.5	3.7	0.0	N/A	E.V.
G21	0	0	0	4.0	Musty	Defective
H22	0	0	0	4	Fusty	Defective
H23	0	0	0	4.0	Burnt, hey	Defective
H24	0	0	0	3.5	Muddy	Defective

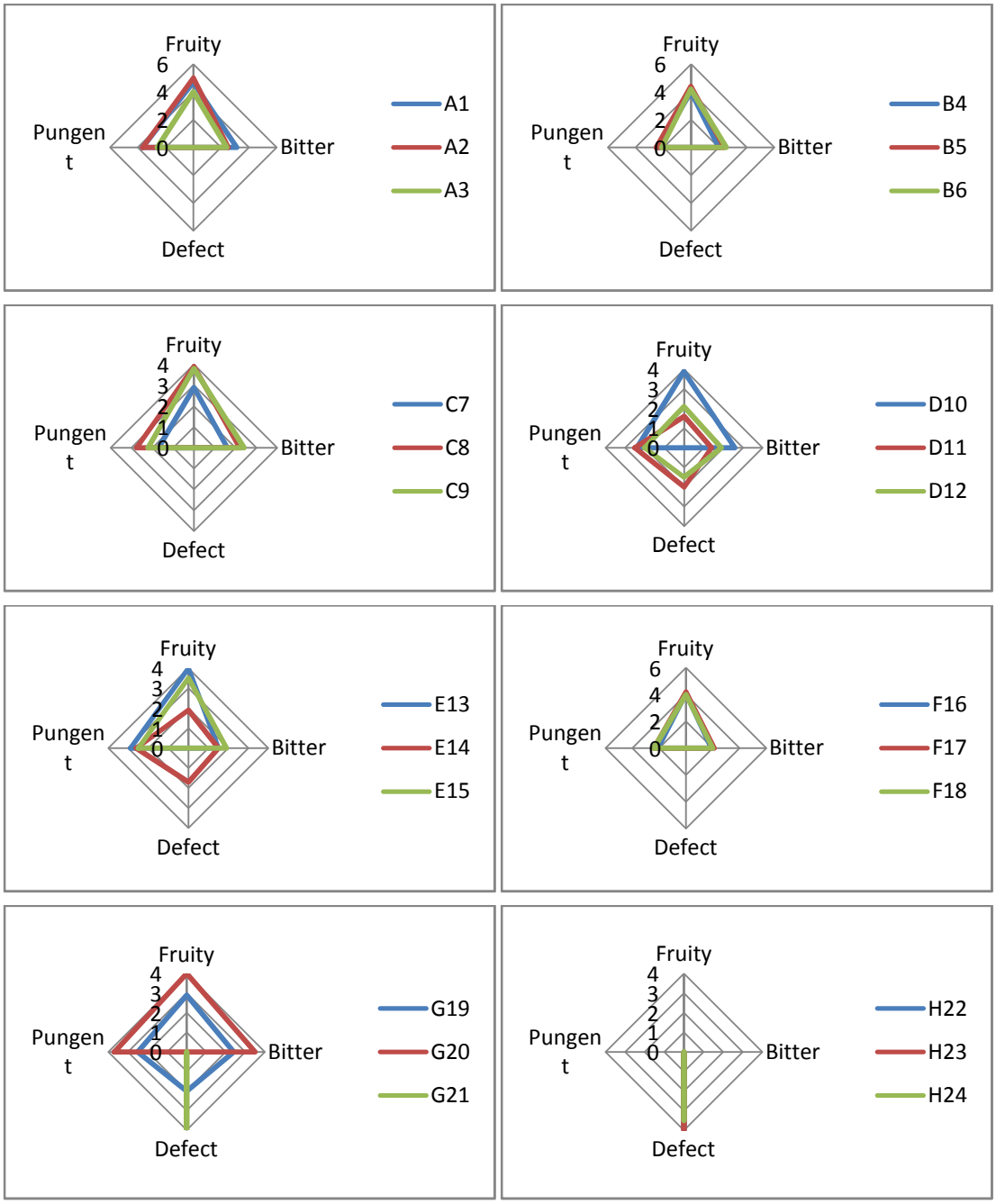

Figure 3.7 Diagrams presenting sensory attributes of olive oils obtained from organic semi-intensive production systems compared

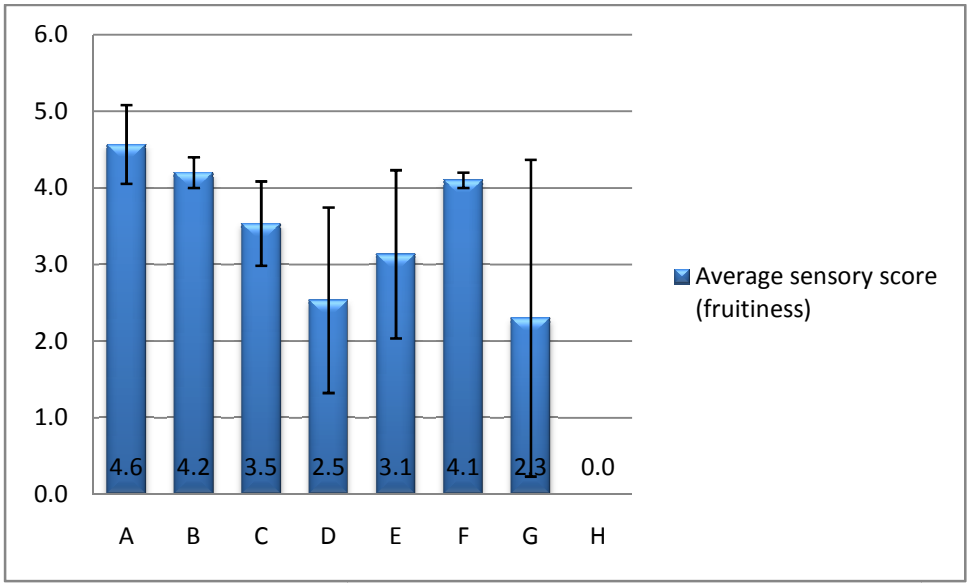

Figure 3.8 Average sensory scores (fruitiness) of olive oils obtained from organic semi-intensive production systems compared

All samples obtained from the orchards under question, were assessed for their positive sensory attributes (fruity, pungent, bitter) and flaws, the results are displayed above in Table 3.15. In the scale from 0 to 9, samples were graded based on the intensity of the aromas and taste. The classification was based on the intensity of fruitiness which represents the overall sensory score. Pungency and bitterness are secondary positive attributes which are not used in the formulation of the final sensory index score.

Extra virgin olive oil must have no flaws, and usually are referred as E.V. olive oils of light (1-3), medium (4-6), or high (7-9) intense flavour and aroma. Virgin olive oils must have a flaw (or defect) below 3.5 (<3.5) and fruitiness above 0, and Ordinary olive oils are classified those with flaw between 3.5 – 6 and fruitiness above 0.

Fruitiness and secondary characteristics such as bitterness and pungency are presented in Figure 3.7. In this project all three positive characteristics are presented in the form of triangles with fruitiness (the most important positive characteristic) at the top, and bitterness and pungency to the left and to the right. The theoretical value of 9 (see Chapter 2 Materials and methods) which was not detected in these samples is generally a rare but possible example of the maximum sensory quality. The formation of the

triangles can change according the scores of the samples, so for example in some samples such as D10 the “fruitiness” peak is higher and a triangle is been generated compared to other two samples D11 and D12 that a quadrilateral shape is generated because of the presence of defects and a lower “peak” is noticed because of low fruitiness. If oils are evaluated as defective (set H) then no triangle or quadrilateral is generated but a vertical column. Olive oils with either high pungent or bitter taste will generate shapes with longer left (E14) or right (D10) “wings” or angles. Olive oils that have balanced fruitiness, bitterness and pungency scores in a 1:1:1 ratio will generate a rectangular isosceles triangle similar to sample G20. The sensory panel’s software may create a variety of different graphs but in general there is not a single specified model used in the oil industry.

From Table 3.15 it can be noticed that samples obtained from set A, have medium flavours (4-6) and are classified as extra virgin olive oils, without any flaws. Sample A1 was bitterer (3.15) and sample A3 was evaluated as less pungent (2.6) compared to the other two. Sample A2 represents the “optimum” of set A and may be characterized as medium fruity and pungently flavoured, with light bitterness taste. Phenolic substances may be responsible for the increased bitterness in A1 such as oleuropein [Servili, 2002] that is affected by the level of ripeness of the olive fruits as also from the conditions during processing process (water and temperature)[Botia, 2001]. Various studies suggest that bitterness caused by oleuropein is often noticed in olive oils collected in warm climates at the beginning of the harvesting season [Visioli, 2002]. Factors responsible for the decreased pungency of A3 compared to A1 and A2 may irrigation and time of harvest. Pungency is often more noticeable when several phenolic substances are present in the olive oil [Dabbou 2011]. Based on this assumption A3 might have a lower concentration of these phenolic substances. From another aspect, olive oil known as unripe oil (produced from unripe olives) is known to have a greater phenolic profile than extra virgin oils and is characterized as highly pungent which suggests that pungency is indeed connected to phenolic substances.

Regarding set B, it can be seen in Table 3.15 that sample B5 has the higher fruitiness (4.4) and pungency score (2.5) while its bitterness (2.4) is between sample B4’s (2) and B6’s (2.55) which represents the optimum quality in this set. In Figure 3.7 it is noticed

that all samples have formed similar diagrams which is characteristic of the general low difference between sensory attributes in this set. All samples were evaluated as extra virgin olive oils without any flaws.

In set C of Krya, sample C7 has a generally lower intensity of aromas and taste which is also displayed in the formation of a smaller diagram compared to samples C8 and C9. All samples in general were classified as extra virgin, and C8 seems to represent the optimum quality olive oil produced in this set with a medium score of fruitiness at 3.9, with light taste of pungency at 2.75 and bitterness at 2.75. The average sensory quality in Figure 3.8 of samples obtained from C set was generally lower compared to set B and set A. By reviewing the other figures displaying average FFA and average peroxide scores in previous sections (3.3.1 - 3.3.2) it can also be noticed that FFA – peroxides scores of set C where higher compared to sets A and B (which indicate poorer quality).

Regarding set D, sample D11 represents the finest quality of this set with scores of medium fruitiness at 3.9, with light bitterness at 2.6 and pungency at 2.4. Samples D10 and D12 seem to have developed defects which were detected as flaws by the sensory panel and were both classified as Virgin olive oils. Specifically, sample D10 developed a “winey” taste. This flavour is mainly due to a process of fermentation in the olive fruits leading to the formation of acetic acid, ethyl acetate and ethanol. It is uncertain what exactly triggered the fermentation but it is most possible that storage conditions before processing may have led to this result. The chemical results (peroxide and acidity) also show a general poor chemical quality profile which agrees with the sensory result. D12 has developed a sense of fustiness which is characteristic flavour of olive oil obtained from olives stored in piles that have undergone an advanced stage of anaerobic fermentation. Studies suggest that pressures caused to olives often stored in piles may cause secretions of fluids affecting the quality of olive oil [Olias & Garcia 1997]. By reviewing the results from other sections (3.3.1, 3.3.2, 3.3.3) it is noticed that sample D12 has also increased scores of peroxides, hydro-peroxides (K_{232}) and acidity compared to other samples. Previous studies suggest that olives attacked from *B.Oleae* may be of poor quality, develop characteristic flavours of “fusty” and “grabby” in olive oils and propose that optimum harvesting is when olives are turning colour from green to purple [Tamendjari et al., 2009]. In Figure 3.7 samples D11 and D12 have given two

asymmetric quadrangles, which characterize virgin (and ordinary) olive oils.

With regard to olive oil obtained from the flatland region of Sitia, it is noticeable from Figure 3.8 that the average sensory quality scores of set E were higher compared to set D of Krya. Sample E13 represent the finest quality of set E, it was classified as extra virgin olive oil with characteristic medium taste of fruitiness at 4, light taste of bitterness at 1.5 and pungency at 2.9. Samples seem to have decreased bitterness which suggests that olives where well matured. Such olives are in general easier to pierce by *B.Oleae* compared to olives which are unripe because the skin of the fruit is softer [Tamendjari et al., 2004]. Sample E13 was characterized with a light presence of "fustiness" and was classified as 'virgin". Wounds caused by Olive flies in sample E14 could be responsible for the development of this defect.

Samples obtained from the neighbouring settlement Dafne (F set) had higher sensory scores of fruitiness on average compared to the flatland area of Sitia and sets C, D of Krya. The average sensory scores were more similar to set B, and had low differences in general. As presented in Figure 3.7, three symmetric triangles were generated from the sensory scores with similar dimensions.

Regarding set G, located in Dories (Neapoly) sample G19 was evaluated as extra virgin olive oil with light taste of fruitiness at 2,9, pungency at 2,4 and bitterness at 2,5. Sample G19 was characterized with a light presence of "fustiness" and was classified as Virgin. Wounds caused by Olive flies in sample G19 may be responsible for the development of this defect similarly to sample E14. Both sets E and G had a high disease appearance of *B.Oleae* indicating that crop protection is a key issue in these organic semi-intensive systems of olive oil production. Sample oil obtained from G20 gave a sensory score of medium fruitiness (4.0) medium pungency (3.7) and medium bitterness (3.5). In Figure 3.7 it is noticeable that sample G20 generated a symmetric triangle with high bitterness and pungency scores compared to other samples. It seems that the fruitiness, bitterness, pungency ratio is almost 1:1:1 (slightly increased fruitiness) which is unique oil compared to the other samples. This ratio shows highly bitter and pungent olive oil that indicates high content of total phenols, presence of eleocanthale and oleuropein that has been reported to be identified in mountainous

systems of olive oil production[Tripoli et al., 2005] [Dabbou et al. 2010]. High bitterness and pungency scores in these samples may be explained by the characteristic cultivation strategy followed in the region since many olives in Dories are not treated with irrigation which seems responsible for the high score of pungency [Gomez et al., 2007]. Also olives were harvested at an early ripe stage to minimize the damage from Olive fly (also discussed in section 3.1.7 about disease rates and section 3.1.8 about crop protection). As a consequence both olive oil samples seem to have similar scores of pungency and bitterness compared to fruitiness which is not detected in other set samples (perhaps only D12). Sample G21 was evaluated as “Musty” with a score about 4 and no fruitiness attributes. This oil was most possibly evaluated only for its aroma since according to the panel this oil is not fit for consumption and cannot be classed in any Virgin class. Mustiness is a flavour in olive oils obtained from fruit in which fungi and yeasts have developed. High noncompliance to standard crop practices in Dories may also be connected (set G). Improper olive storage conditions (high temperatures) before milling is also known to general cause the development of fungus affecting also the sensory attributes of olive oil [Rabiei, 2011].Piling of olive sacks is also known to cause pressures leading to fruit secretions thus providing substrate for fungus to develop that can affect olive oil quality and sensory characteristics [Olias & Garcia 1997].

Similarly to sample G21, all samples obtained from set H orchards had poor sensory quality and were classified as not fit for consumption. Instead of specific shape, the diagram in these samples is shown as a vertical line representing the negative feature of each sample. H22 was described as “fusty” (mainly due to poor quality olive fruits usually damaged during storage in piles and in high temperatures) sample H23 was described as ‘burned hey’ (characteristic of dried out olives which is noticed after damage from frosts) and H24 was described as muddy or earthy. This flavour of olive oil is noticed in olives that have been collected with earth or mud and have not been washed out properly. They may be olives that have been collected from the ground after attack from *B.Oleae*.

3.3.6 Summary - Total quality index score

Table 3.16 Chemical and sensory scores of organic olive oil and their final total quality index scores compared

Code	Sensory (Fruity)	FFA (%)	K270 Score	Peroxide (meq O_2/Kg)	Total Score	Code	Sensory (Fruity)	FFA (%)	K270 Score	Peroxide (meq O_2/Kg)	Total Score
A1	4.7	0.26	0.13	8.4	**5.11**	E13	4.0	0.45	0.15	12.7	**3.89**
A2	5.0	0.26	0.13	8.9	**5.35**	E14	1.9	0.41	0.17	10.6	**2.01**
A3	4.0	0.36	0.12	8.7	**4.45**	E15	3.5	0.38	0.14	9.8	**3.76**
B4	4.0	0.39	0.14	9.9	**4.29**	F16	4.1	0.39	0.11	13.0	**4.31**
B5	4.4	0.24	0.11	10.9	**4.83**	F17	4.2	0.35	0.12	9.9	**4.56**
B6	4.2	0.30	0.15	11.2	**4.29**	F18	4.0	0.37	0.13	11.7	**4.17**
C7	2.9	0.34	0.11	8.7	**3.54**	G19	2.9	0.32	0.14	7.9	**3.38**
C8	3.9	0.39	0.14	14.6	**3.80**	G20	4.0	0.33	0.14	8.7	**4.32**
C9	3,8	0.29	0.11	10.8	**4.26**	G21	0	0.50	0.19	14.6	**-0.20**
D10	3.9	0.30	0.13	7.1	**4.44**	H22	0	0.43	0.14	9.9	**0.53**
D11	1.6	0.45	0.13	14.8	**1.72**	H23	0	0.69	0.19	23.5	**-0.93**
D12	2.1	0.47	0.15	13.1	**2.12**	H24	0	0.80	0.20	23.2	**-1.07**

Table 3.17 Chemical and sensory scores of popular brands and oils found in the Cretan and Greek market and their final total quality index scores compared

Code	Sensory (Fruity)	FFA (%)	K270 Score	Peroxide (meq O_2/Kg)	Total Score
I25	6.0	0.26	0.110	8.5	**6.51**
I26	5.8	0.26	0.150	8.6	**5.95**
I27	6.0	0.27	0.130	8.4	**6.28**
K28	7.0	0.21	0.101	7.1	**7.55**
K29	6.0	0.14	0.119	4.0	**6.75**
K30	5.2	0.17	0.093	6.5	**6.05**
L30	3	0.60	0.170	14.0	**2.63**
L30	3.5	0.63	0.150	16.0	**3.08**
L30	2.7	0.56	0.140	14.8	**2.56**

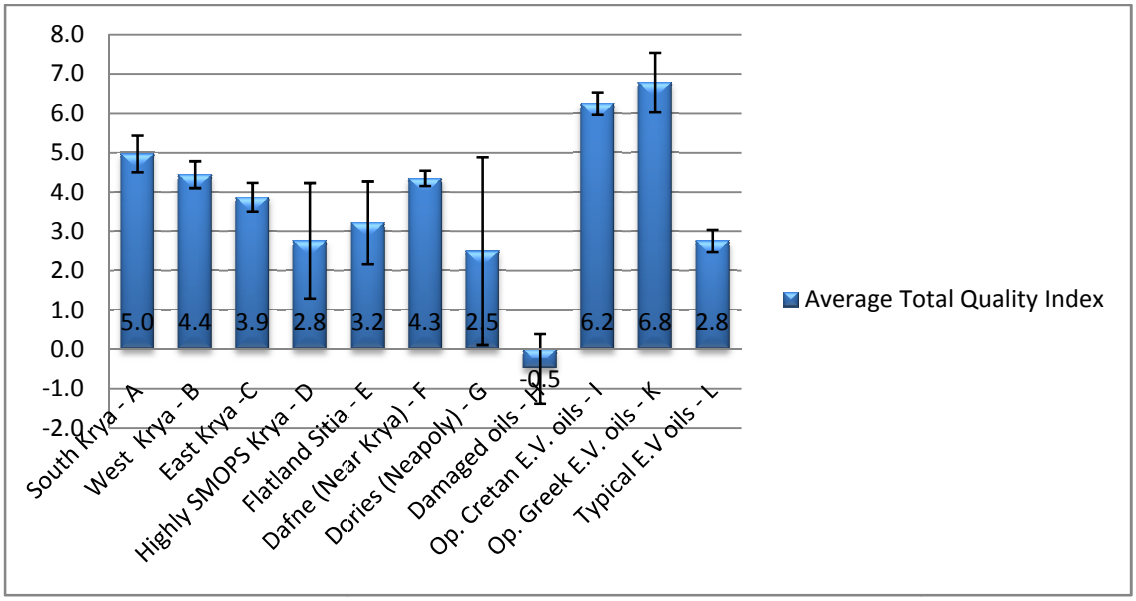

Figure 3.9 Diagram presenting the average total quality index scores of all sets compared

As can been seen in Table 3.16 the olive oil total quality index score (O.T.Q.I.S.) formula can be a very useful tool to compare olive oils because it combines chemical and sensory parameters and give an overall score. Especially for oils which belong in "extrissima" class (or "premium" quality) (Table 3.7) this tool can be very useful to compare the total quality.

Sets I and K represent optimum quality olive oils produced in Crete and Greece (Peloponnesian oils) that have been tested by certified chemical labs and sensory panels and are used as a benchmark for comparison with those olive oils produced in Krya (see also Materials and Methods 2.5.2). Set L represents the typical extra virgin olive oils (Typ. E.V. oil) found in the market as shown in Table 3.17. Most grocery store and market olive oils have an average FFA score around 0.6%, K_{270} at 0.17, a peroxide score around 14 meq O_2/Kg and a sensory score around 3. Chemical and sensory scores are not always written on the label although this has been suggested by IOC and can give lot of information to consumers about the quality of olive oil. Most olive oil labels include only the classification limits (<0.8 acidity %, <20 meq O_2/Kg for peroxides, and the limits for K indexes). Sensory scores are almost never found on the labels of typical

olive oils. It is more likely to be found in optimum quality olive oils either marketed through organic product markets or through electronic markets (internet).

By combining the chemical and sensory scores to calculate the T.Q.I.S. it can be noticed that set A of samples has an average higher T.Q.I. score if compared to the other sets which were under study. In Figure 3.9 set A has an average score of 5. Samples A2 and A1 have the higher scores (5.35 and 5.11) compared to the other samples of the set. A1 seemed to have been harvested in the unripe stage (high chlorophyll content at 12.9 mg/kg) and as a consequence its overall chemical and sensory quality was higher compared to other set samples (unripe olives are widely known to produce oil with less free fatty acid content and peroxides in general but also produce less oil). A2 seemed to have been harvested in more mature levels (low chlorophyll content at 2 mg/kg) compared to A1 and with better overall chemical and sensory quality scores compared not only to the to other samples of the set but also compared to all sets, as its T.Q.I score at 5.35indicates. A2 was described as olive oil of medium flavors of fruitiness and pungency and light bitterness. Carefully grown and harvested olives properly stored and transferred to the mill (as K indexes and peroxide scores indicate) may produce higher quality olive oil such as A1 and A2.

In regard with set B, all oils obtained from these semi- intensive mountainous organic production systems of west Krya, have lower T.Q.I. scores in average compared to set A. Sample B5 has the best T.Q.I. score compared to other samples of the set, also noticed in previous sections (3.3.1, 3.3.2, 3.3.3) when reviewing FFA, peroxide and K indexes separated. These results are suggestive of an olive oil produced with more care that other of the set, harvested at an intermediate level of ripeness (also discussed in section 3.3.4 about ripeness), from olives with low damage from *B.Oleae* which is noticed from the low FFA scores, properly harvested and transferred to the mill, as K indexes indicate. The sensory trials described B5 as medium fruitiness; with light intensity of pungency and bitterness. This olive oil is classified as extra virgin olive oil, and its acidity score can be identified as “extrissima” or “optimum” quality olive oil with a T.Q.I. score of 4.83.

Regarding set C, all oils obtained from these semi- intensive mountainous organic production systems of east Krya, have lower T.Q.I. scores on average compared to set B and A. Sample C9 has the higher T.Q.I. score compared to the other two samples of the set. Its chemical and sensory characteristics are indicative of an olive oil harvested at an intermediate level of ripeness (similar to B5) as chlorophyll scores suggest. The sensory trials described C9 as 'medium fruitiness' ; with light intensity of pungency and bitterness similar to B5, with the same oil classification, also identified as "extrissima", with a T.Q.I. score of 4.26.

The mountainous systems of set D produced olive oil with lower average T.Q.I. score, compared to all other sets of the region of Krya. An overall decrease in quality may be noticed in all chemical and sensory results which seem to be related to the regional characteristics of sloping terrain and difficult access. D10 is representative sample of higher quality compared to the other two of the set, with a T.Q.I score of 4.44. Oils collected from D11 and D12 were classified as "virgin", with light defectives tastes described as winey and fusty, possibly spoiled from careless storage during the period after harvest and with also perhaps a delay before processing. Storage conditions before milling are well known to affect olive oil quality [Kiritsakis, 1998]. Wounds caused from *B.Oleae* and during harvest probably increased the process of fermentation caused the defective flavors to appear in these oils. The total quality of D10 suggests that there is room for improvements for D11 and D12 if the producers comply with improved agricultural techniques. The average quality of set D is still better that the typical olive oil found in the grocery stores (set L).

Regarding olive oil obtained from the high-intensive production systems of the flatland region of Sitia (set E), it is noticeable that the average T.Q.I. score is higher than set D. This set generally had a high compliance rate to standard crop (shown in the compliance rates section 3.1.10), but seems to suffer from crop pests such as *B.Oleae* which has an immediate impact in the quality of olive oil. In addition, high yields often noticed in these systems are more difficult to manage because they require more storage and transportation space, sacks containing olives are often piled during storage before milling and become wounded practices [Olias & Garcia 1997]. Replacing linen sacks

with plastic (well aerated crates) and successful protection against *B.Oleae* may be two keys for improvement of olive oil quality in these systems [Giovacchino, 1997].

The neighboring settlement Dafne, with semi-intensive organic productions systems located close to Krya, has better average T.Q.I. score compared to set C, D, and E with an average T.Q.I. score at 4.3 similar to set B (4.4 points). Although no "optimum" (acidity score lower than 0.3) olive oils were detected in this set, all three samples obtained from Dafne were classified as extra virgin with medium intense of fruitiness and light intense flavor of pungency and bitterness and chemical scores indicating olive oils produced with care similarly to set B.

The semi-intensive organic production systems of Dories (Neapoly) have an overall T.Q.I. score at 2.5 similar to the average oil found in the grocery market (2.6 points). Total noncompliance with standard crop practices was high in this set suggesting that crop practices before harvest may be responsible for these results. As a result wounds from *B.Oleae* followed with additional pressures applied to wounded olives during transportation lead to the overall degradation of quality in this sample's olives which produced poor olive oil in the end.G20 represents the optimum quality of the set with a T.Q.I. score at 4, possible harvested from more unripe olives (as chlorophyll also suggests) compared to other samples described by the panel as olive oil with medium intensity of fruitiness, and pungency and bitterness which seems characteristic of the region (described as a 1:1:1 ratio of the three positive characteristics in section 3.3.5 about sensory attributes). Biochemical reactions caused after the piercing of olives by olive fly is known to favor the formulation of free fatty acids, and harvesting olives early on seemed to limit the damages caused from olive fly in the cases of Dories, although more research is needed to determine exactly the consequences of this practice.

Olive oil obtained from orchards in set H, seems to have serious problems caused by a range of climatic conditions, production carelessness and indifference towards pest control. These oils were evaluated as "not fit for consumption" or "damaged oils" or "defective oils" which gave negative results with T.Q.I score formula as shown in Figure 3.9.

By reviewing set I in Table 3.17, it is noticeable that they represent higher quality olive oils compared to the samples obtained in this study. In general, set I orchards are located in mountainous flatland orchards which suggests that they combine the optimum characteristics of both mountainous and flatland regions. These oils are often winning quality awards for olive oil at a national level, representing the best produce from the county of Lassithi. It seems that the difference in sensory scores is the most important parameter affecting the final total index score between oils. From Tables 3.16 and 3.17 it is seen that sample A2 (highest quality olive obtained from Krya) has 1 point less fruitiness compared to I26 which represents the lowest quality of Set I. The T.Q.I. score of A2 is only 0.6 points lower than I26's. This may suggest that higher compliance to standard crop practices described may result in the production of better quality olive oil in Krya. It is also interesting to speculate on the effect of the alteration from "heated" processing to "cold" during milling to the qualities of samples obtained from Krya. Note that I26 olive oil is produced in Neapoly and represents the optimum quality olive oil of the region. The semi-intensive organic production systems of Dories (close to Neapoly) may be a suitable area to produce oil similar to I26. Olive oil obtained from I27 represents the optimum quality olive oil produced in Sitia, with a sensory score at 6 (1 point more that A2) and an overall T.Q.I. score at 6.28 (0.93 points more than A2). Taste and aroma are key parameters for the success of olive oils in the market and will have to be set as primary targets for any olive oil producer. Similarly to the other oils, I25 was produced in Krista, a region south from Neapoly and west from Agios Nicolaos. Kritsa represents a region with well known and respected olive oils. Kritsa's T.Q.I. score was 6.51, higher compared to Sitia (I27) and Neapoly (I26), which suggests that within the same county other regions also produce high quality olive oil and further study may be necessary to assess such regions.

With Regard to set K; olive oils are produced in 3 different Peloponnesian counties and represent oils with optimum quality at a national level. As seen in Figure 3.9, the average quality of the set is highest compared to all other samples. From the K set, olive oil K28 produced in the county of Argolida (close to Athens), has the highest T.Q.I. score at 7.55, excelling in high intense fruitiness at 7 compared to other olive oils. Olive oils at this level are produced with the best care and all specifications given by agro-

technologists (expressed as compliance to standard crop practices in this study) are followed with the maximum zeal. Oil K29 was produced in the county of Lakonia (close to Sparta), with a T.Q.I. score of 6.75 excelling in low FFA scores of 0.14 and peroxide at 4 meq O_2/Kg which suggests that it was obtained from fresh, unripe olives possibly without any damage from *B.Oleae* or wounds caused during harvesting. Unripe olives usually give such peroxide and acidity scores but quantity of production may be reduced. This is often counterbalanced with an increased price on the market. Finally, sample K30 was produced in the county of Messenia, and represents the optimum quality of this county. It is noticed that its sensory score is only 0.2 points higher compared to A2 olive oil produced in the semi-intensive highland region of Krya. The major difference between these two oils is in the chemical characteristics forming a final T.Q.I. score of 6.05 for K30 and 5.35 for A2 (0.70 points difference).

By comparing the average T.Q.I. scores of K and I sets with olive oil produced in Krya (sets A to D) it is noticed that the differences are wide , set A which represents the optimum case in Krya has an average score at 5 while the average scores of I and K are 6.2 and 6.8 respectively. Typical olive oils found on the market have an average T.Q.I. score around 2.6 which is similar to the highly inclined regions of Krya (>35%) of set D. All of the above can suggest that olive oil production in Krya is above average (grocery oils), producing extra virgin organic olive oils and several organic “extrissima” olive oils (A1, A2, B5, C9) olive oils. By reviewing the total compliance rates (section 3.1.10) to standard crop practices and hypothesize that compliance is influencing the final quality it seems possible that production can be improved since it is not already maximized in these systems. Finally, the olive oil processing method with the use of heat seems to be a key issue which has to be controlled if high quality production is seriously pursued.

Optimum commercial olive oils seem to be sold from separated marketing networks compared to typical olive oils (through organic product markets or electronic markets). Flatland mountainous olive oils (such as sets I and K) are produced in upland flat areas which combine the positive characteristics of mountainous (e.g. high altitude increased phenolic content) and flatland agriculture (e.g. easier management because of no inclination which causes manageability issues). In these locations, all stages of

production can evolve more easily without any unexpected problems that can damage fruit quality (e.g. faster and easier access in the orchards and from there to the mill because of no inclination and better road networks). For these reasons, flatland mountainous regions may have increased compliance rates to standard crop practices (similarly to flatland orchards of set E) and can produce higher yields of high quality olive oil compared to inclined (>15% inclination) and highly inclined (>35%) mountainous organic systems. Areas with difficult access and high altitude were generally noticed to have elevated peroxides in this study such as set D that produced lower quality olive oil compared to other sets of Krya.

3.3.7 Key issues for quality improvement in semi intensive mountainous organic production systems of Krya

In this section a set of practices that can improve quality production and sustainability for the region are discussed. Krya is located in high altitude, sloping land which shows variable degrees of inclination, some orchards deal with difficult access. Perhaps, in some cases, the region needs to adopt practices that have not been considered up until now.

I) Scope of production and marketing

Olive oil production in the semi-intensive mountainous organic production systems of Krya was evaluated with the olive oil total quality index score (O.T.Q.I.S). This tool was used for comparisons between extra virgin olive oils, resulting in an absolute score which is calculated by combining both sensory and chemical attributes. However, evaluation cannot be dependent only on chemical attributes such as free fatty acidity since oils may be classified as extra virgin (when FFA score is lower than 0.8 %) but negative taste characteristics (defects) (D11, D12, E14, G19, G21, H22, H23) may be detected at the same time. Therefore it seems that the most important component influencing total olive oil quality is its sensory attributes. It is likely that olive oils with high sensory score are expected to be more successful in the marketplace and certain groups of consumers are expected to show a preference for these oils (although this

needs more investigation as the reaction of consumers to highly bitter or pungent olive oils (>6 sensory score) may be variable). For the above reasons the scope of production in the systems of Krya should be to maximize the sensory attributes of their oils in combination with efficient marketing.

Marketing would involve designing a label which makes use of the special sensory and chemical characteristics, suggesting that olive oil produced in Krya has superior quality compared to other olive oil products, has specific desired sensory attributes (for example intensive fruit and pungent olive oil with a medium intense of bitterness), and brings all the necessary certifications (organic olive oil etc). The desired target croup of consumers may also be determined in combination with consumer tests in order to see how the specific olive oil produced in Krya is perceived by different groups of people. As a result, olive oil produced from Krya may gradually build a brand that would be acknowledged and well respected in the market for its high quality, allowing the product to become more profitable.

II) Temperature during olive oil processing and sensory characteristics

In order to produced olive oils with high intensity of fruitiness (6 to 9) all parameters influencing the flavors and aromas have to be controlled. The most obvious parameter negatively affecting olive oil sensory scores in Krya and other regions seems to be the temperature during processing. Temperature during malaxation is widely known to affect olive oils quality [Martel, 1983] [Lanzani, 1990] [Giovacchino, 1991] [Botia, 2001]. During this study temperatures started from 26.8 ^{o}C (first half of malaxation-kneading) and ended at 31.1^{o}C within the tanks indicating that all oils produced with this configuration cannot be considered as “cold” pressed (<27 ^{o}C) according the IOC specifications. The use of lower temperatures during kneading will not require any new equipment in Krya since modern centrifuge systems are already used and temperature is adjustable to the needs of the production. As a result, yield might be lowered compared to heated olive oil processing but the flavors and aromas of olive oil will be increased as will levels of individual phenolic substances [Kotsifakis et al., 1999][Caponio and

Gomes, 2001].Finally, lowering of kneading temperature in these systems needs to be further investigated including marketing and economic parameters before it can be widely adopted (regardless of the fact that this practice is already performed in other systems).In terms of milling management, olive producers can be divided into two groups (i) intended for low temperature (more quality – lower yield) processing (<27 ^{o}C) and (ii) intended for higher temperature (>27 ^{o}C) processing (more yield – lower quality).

III) Storage conditions and use of crates

The next parameter after milling temperature is the condition of fruit before processing. Olives intended to produce optimum quality olive oils should be treated with priority to minimize parameters affecting olive quality during storage such as (i) extended storage periods and effects of (ii) temperature - humidity [Nabil, 2011] [Rabiei et al. 2011]. Piling of olives (iii) is also known to negatively affect olive oil quality since pressures caused to the bottom sacks may lead to loss of fruit contents [Olias & Garcia 1997]. The consequences of failure to control storage and transportation conditions was generally noticed in samples of olive oil obtained from B6, C8, D12 that had increased peroxide content and K index scores compared to other samples.

In order to control all the parameters above the use of plastic crates is proposed for Krya's semi-intensive production systems instead of linen sacks that are currently used. Open, well aerated plastic crates have been reported to prevent the harmful heating caused by the catabolic activity of the fruit in other olive varieties. In addition, the design of the crates minimizes pressures when storage in large piles compared to linen sacks [Giovacchino, 1997].Crates can also be used for safer transportation from the orchards to the mill. As a result chemical and sensory scores are expected to be increased compared to present practices although this may need further investigation.

IV) Harvesting method alternatives

In order to ensure that optimum quality olives are delivered to the mill certain parameters during harvesting should be controlled. Damage caused to olives during harvesting is generally known to influence olive oil quality [Bosku, 1996]. Hand-held mechanical beating harvesters seem to be the dominant practice (discussed also in section 3.1.4) in Krya. Alternatively, hand held vibrating harvesters can be used that cause less damage to olives during harvest, although more investigation is needed since vibrations caused to the tree branches may lead to tree damage. Perhaps certain pruning systems can be more efficient in vibration harvesters but this remains questionable.

V) Earlier harvesting

Harvesting date is normally determined in relation with optimum fruit ripeness. "Optimum fruit ripeness" is mostly a term describing the optimum stage for industrial purposes and is still an area of controversy. Ideally the optimum stage is when the fruit oil content and quality are both high. Optimum fruit ripeness in Crete has generally not been comprehensively reviewed and most studies regarding Koroneiki olives are confined to other regions. It is known that olive oil acidity content can be increased as fruit gradually ripens [Dabbou et al., 2010]. Individual phenolic substances such as oleuropein are also lowered as fruit over-ripens [Servili, 2002]. Also olives that remain on the tree have more possibility to be susceptible to crop enemies [Tamendjari, 2009]. In the present study 3 stages were recognized: a) green color olives (set G), b) turning color olives (Krya and Dafne sets) and c) dark purple- black olives (flatland Sitia -set E). If no crop enemies are present then this stage can be extended but this is dependent on crop enemy appearance which is also discussed separated below. It is suggested that olives should be harvested when they have reached their final size and before they start to turn color. As a result, olive oils harvested in early ripeness will:

- Suffer less damage from *B.Oleae* because the skin will be harder to penetrated by the insect and the process of hydrolysis may be limited since the harvesting will be performed earlier
- Have higher intensity of fruitiness, bitterness and pungency that are considered as positive characteristics found in less ripened olives [Dabbou et al., 2011].

- May have increased chlorophyll and oleuropein content which is indicative of olive oil of higher quality and are recently considered as potential cancer preventative agents [Ferruzzi, 2007].

Of course, this strategy will have to be performed in combination with low temperature olive oil processing because otherwise olive quality will be compromised.

VI) Preventive strategy against crop enemies *B.Oleae* and *P.Savastanoi*

B.Oleae is known to affect olive oil quality causing an increase in free fatty acidity content and the development of sensory defects. Wounds caused by olive fly in combination with pressures during transportation and storage in piles may cause fruit leakage and the further development of yeasts and fungus that can dramatically damages olives. Olive fly is generally considered very detrimental (discussed also in section 3.1.7 and 3.1.8) in organic systems [Tamendjari, 2009] and crop protection against it is a key issue for organic cultivation and sustainability of production in Krya. During this study production systems of Krya seem to suffer from olive fly at lower levels compared to other sets but this may change in the future. It seems necessary that effective crop protection is needed in the region. For these reasons:

- Krya cannot exclusively rely on the use of mass traps; other studies also suggest that mass trappings need to improved [Ferreira, 2002]. Until then, application of mass traps as a preventive strategy can at least limit the yearly damage from *B.Oleae.* The efficiency of newer traps in Krya is under question. These new devices containing a reduced amount of pheromones promise better protection with lower cost [Noce, 2009]
- More crop protection methods must be introduced in the future in order to achieve more sustainability and better crop protection. The use of copper sprays for example has been used successfully in organic olive oil cultivation.
- Biological control of predators of *B.Oleae* currently found in the Mediterranean may be successful. Biological control of natural predators (or parasites) in organic olive oil production might be effectively in Crete but more investigation

is needed on this subject. Introduction of alien parasoids such as *Psyttalia concolor* showed promising results in east Europe – Turkey [Hepdurgun et al., 2009]. If there are no legislation limits these parasoids can be introduced in Crete too.

During the study some areas were noticed to have high compliance rate against *P.Savastanoi* (set E) and other seemed to do nothing (set G). Krya represent an intermediate case between those two extremes. Tool disinfection does not cost too much, it is currently the individual decision of the pruner whether or not to disinfect the tools. However, preventing the spread of the disease with tool disinfection is a standard method and it is to be strongly advised that it becomes a habit in Krya similar to the practice in set H. The consequences (are also discussed in section 3.1.9) of increased *P.Savastanoi* disease include overall weakness of the tree resulting in low productivity.

VII) Deliberate use of legume plants

The use of plants belonging in the family of Fabaceae (legumes) is generally used in organic farming. Deliberate cultivation of legume plants seems to have two basic advantages:

- Cultivation of legumes can minimize the appearance of weeds in olive tree orchards because of competition between weeds and legumes. Legumes then are used as green manure when soil is cultivated by heavy tractors attached with ploughshares as practiced in several systems in Krya.
- When legumes die in the field all of their remaining nitrogen, that is incorporated into amino acids is released back into the soil and converted to nitrate (NO_3^-), making the nitrogen available to the olive trees, thereby serving as fertilizer for future crops [Postgate, 1998].

More investigation in needed on the long-term consequences of this practice on the island of Crete. Theoretically this practice can be generally performed after the pruning season especially if pruning residues remain in the field. Organic biomass provided by the combination of these two practices seems to fertilize the orchards increasing the

productivity and is seems to be a very efficient technique although more studies need to be made in this subject.

VIII) ‘Agro-tourism’ farms

An alternative scenario previously suggested by the program Olivero was the conversion of high risk (of abandonment) olive groves into ‘agro-tourism’ farms [Fleskens, 2007]. Although this approach has not yet been appraised, it might prove to be a profitable business. In this case the olive oil production systems can additionally operate within the concept of tourism and receive visitors who are interested to see and learn about the tradition of the cultivation of olives, and they can visit ancient or old fashioned mills used in the past, etc. This can be more successful in areas such as Dories where producers haven’t yet specialized completely in organic olive oil production and still combine husbandry and olive production. In this case they can operate as agro touristic ley farms offering accommodation in the traditional settlements, local dishes etc. As a result olive oil can be marketed as part of the tourist industry.

CHAPTER 4: CONCLUSIONS

There have been several proposals in the past suggesting that the approach of olive oil should be multi-level focusing in aspects that are still the subject of debate and controversy among scientists focused on olive oil. Within this scope, the main issues recognized in this study was noncompliance to standard crop practices, damage done by crop pests, failure to sustain fruit quality during transportation and storage of olive oils, use of high temperatures during processing of olive oil. If producers manage to control all these factors efficiently then quality production may significantly increase.

Krya at Sitia of Crete is a mountainous region that fits into the classification of "SMOPS" as was defined by the Olivero project (2003-2006). Regarding areas identified as "high mountain slopes difficult to access" by the Olivero project, it seems that the definition of orchards with slope greater than 15% (> 15%) as SMOPS is relatively vague and perhaps too general, as during this study areas with (a) inclination more than 35% (> 35%) were recognized (b) production systems near roads and others far more distant from roads were noticed (c) systems producing olive oil at an altitude of over 400 meters or even up to 700 meters were detected. As a result criteria such as altitude, degree of slope or access need to be redefined more accurately.

By examining Krya, it is noticed that organic semi-intensive SMOP systems can operate successfully, although more study is needed to see how this systems will perform in the long term. The main advantage of production systems of Krya seems to be quality of production. Sets A to D and also Dafne (Set F) produced extra virgin olive oils (< 0.8 FFA %) and in some cases "extrissima" (<0.3 FFA %). Areas such Dories seem to be less encouraged producing highest quality olive oil and this is also shown by the low compliance rates to standard practices compared to other regions such as Krya. The main reason responsible for this seems to be the final price per liter between "extrissima" (<0.3 FFA %) and extra virgin olive oils (<0.8 FFA %) since price is not significantly affected if olive oil is sold in bulk. Areas that until now follow their own peculiar mode of production (such as mountain systems of Dories) and deal with similar problems to those mentioned in Olivero Project (vulnerable to abandonment) may seek

alternative practices beyond those discussed in this study. For example the conversion of systems cultivating olives and simultaneously animal production to agro-touristic farms have been proposed in the past but it is uncertain whether this can be sustainable. These conclusions may encourage producers to sustain their efforts to improve further or adopt different strategies of production.

B.Oleae seems to pose a serious problem for growing olives. All sets from Krya investigated in this study suffered from 28% -35% appearance rate of olive fly. *P.Savastanoi* can also threaten productivity in Krya mainly due to lack of measures (tool disinfection during different stages of productions discussed in section 3.1.9). Crop protection and prevention strategies are generally a challenge. Unripe olives collected from Dories (set F) seemed to have less qualitative damages from *B.Oleae*. Especially samples obtained from G20 appeared to have a high total quality index score (4.32) compared to other samples regardless of the fact that disease rates were very high in the set (70.2%). Harvesting in unripe stage may prove to be an efficient practice to limit damages done by B.Oleae in other systems too. In addition, leakage caused by olive piling during transportation and storage may be much lower in unripe compared to more ripened olives. This can be treated as an additional advantage for cultivating unripe olives in Krya although this assumption needs further investigation.

Total compliance rates to standard crop practices (section 3.1.10) varied for each region studied (Krya, Sitia, Dories). Calculation of these rates allowed assessment of which regions adhered most with standard practices and indicated generally that improvement is needed. Perhaps maximization of the compliance rates to the standard crop practices described in this study may lead to increased quality of olive oil but this remains questionable until more improvements are made. Further parameters should be introduced and an improved formula can be designed in order for total compliance rates to be used as a more complete and objective tool for crop practices evaluation. For example, post harvest manageability can play an important role in the increase of peroxides in olive oil and the simultaneous creation of negative organoleptic characteristics such as those that occurred in the samples studied.

Quality results (chemical and organoleptic characteristics) might improve for olive oil produced in Krya production systems if an attempt is made to reduce the processing temperature under 27ºC (81ºF). Low temperature olive oil ("cold") will result in a questionable reduction of the quantity of production which can theoretically compensated mainly by recognition of superior quality and increase the value of the product.

Regarding chemical characteristics of olive oil, the chemical classification based exclusively on free fatty acidity content to separate extra virgin olive oils (> 0.8% FFA) from virgin (2% FFA) etc. seems to be not sufficient for the complete evaluation or classification of oil. As shown by the results, it is likely that oil with low acidity (less than 0.8%) will be classified as extra virgin olive oil (based in this system) and have negative taste characteristics (defects) (D11, D12, E14, G19, G21, H22, H23) at the same time. For this reason olive oil products must include both chemical and sensory scores on their labels, and consumers must be aware that acidity score in olive oil labels does not necessarily prove that an olive oil is extra virgin. If all these details seem too much to be included in a label then perhaps different and simpler tools may be used that will be user-friendly to consumers and be easier to understood and read.

Although the sensory panels usually use several graphs to illustrate the organoleptic results, in this study the triangular diagram was used. As shown by the results, the triangular diagram can be useful and can give as simple presentation of results related to sensory evaluation (extra virgin appears triangular and Virgin olive oils or Ordinary as quadrilaterals). The formation of specific triangular or quadrilateral shapes may be typical per area (more details about this are found in sensory results section 3.3.5). Organoleptic characteristics, although a very important element of olive oil quality does not seem so far to appear on olive oil labels. In many cases, chemical characteristics are also not shown in labels (for example L sets oils) but only the classification despite the repeated instructions given by the IOC (International Olive-oil Council). However the best olive oils (sets I and K) that are currently in Greece which are distinguished for their superior quality seem not to neglect to put both organoleptic and chemical characteristics of olive oil on the product label.

Data in present study suggest that irrigation can affect the sensory attributes of the final product. For example, Dories received the least water treatment and produced more bitter and pungent olive oil (in a 1:1:1 ration) compared to other regions (Krya). From the aspect of consumer preferences, extremely bitter and pungent oils might prove to be less preferred compared to more fruity olive oils but this must be investigated more. Alternately, olive oils with especially high phenolic content may be marketed as pharmaceuticals. Marketing and the willingness of consumers to pay more for optimum quality olive oils seem to be future challenges.

The Total Quality Index score (T.Q.I.) seems to be a very useful tool for the comprehensive quality evaluation of olive oil because it combines both chemical and organoleptic scores received after an oil analysis and gives a final total quality score. It can be a very useful tool not only to assess the oil, but also for the overall record and monitoring of the improvement of production (in qualitative terms) annually. The final score (when using the T.Q.I. formula) seems to be more affected by organoleptic characteristics. The index tool should also be further studied in relation to consumer preferences, for example, do they prefer oils with high or low index? As noticed, chemical characteristics play a minor role in shaping the final index score. Total index score may also have further uses in marketing to distinguish olive oils of optimum quality.

CHAPTER 5: FUTURE WORK

According to several studies the most urgent challenges can be divided into six areas: a) agro-technological issues , (b) processing, byproduct, and environmental issues in olive oil production; c) virgin olive oil chemical and especially sensory quality, purity authentication and traceability of products d) health and nutrition (e) consumers. These areas would increase the understanding of some aspects that are still the subject of controversy among scientists focused on olive oil [Garcia, 2010]

The most important aspect to begin with is the effect of olive oil consumption on human health (for more details see section 1.3). From this aspect olive oil contains antioxidants that seem to influence positive health. Chlorophyll has been recently studied as a potential cancer preventative agent [Ferruzzi, 2007]. Much of olive oil's positive effects to human health seems be connected with phenolic content [Weinbrenner 2004].

Each region in Crete seems to have its own habits on the oil production (as seen for example by comparing Krya with Dories) which are usually remnants of traditional practices (e.g. simultaneous cultivation of olive trees and animal production). It would be very useful to study all the different habits and practices of many regions that cultivate olive and to attempt a correlation of all these differences.

The deliberate cultivation of legume plants in organic systems as a source of nitrogen seems to be an interesting area of research not only because it can find application in olive trees but because it can be widely used in organic farming. In dry climates such as Crete's, these typical legume plants may not survive if supplementary irrigation is not given. Several legume plants are naturally growing in Crete (*Vicia sativa*) and may be introduced into the olive growing systems as well to see how will react in irrigation deficiency strategies. Long term consequences of deliberate reproduction of these species in Cretan (and other) agro-ecosystems are unknown and can be further studied. A systemic reproduction of legume plants within olive oil orchards might prove to be a

sustainable practice competing with weeds and replacing external sources of nutrients (organic fertilizers), and lowering the overall costs of production in organic systems.

The general crop protection against *B.Oleae* remains a key issue for organic olive oil agriculture and trapping techniques seem to need improvement [Ferreira, 2002]. Alternative traps may be designed with more successful results [Noce, 2009]. The introduction of predators or parasoids inorganic systems to control *B.Oleae* is another area which is interesting because olive fly is in general causing serious damages in olive cultivation and has to be controlled somehow. Biological control of natural predators (or parasites) in organic olive oil production might be effectively in Crete but more investigation is needed on this subject. Introduction of alien parasoids such as *Psyttalia concolor* showed promising results in California [Yokohama 2008] and east Europe – Turkey [Hepdurgun et al., 2009]. If there are no legislation limits these parasoids can be introduced in Crete too.

Alternative processing methods for olive oil which produce olive oil in high yields and do not affect quality can also be studied. Olive oil processing is an interesting area because it appears to be currently seriously affecting both quantity and quality of olive oil [Caponio and Gomes, 2001. For example, recently in Spain a non-thermal technology called pulsed electric fields (PEF) was used to extract olive oil giving increased yields without the use of heat. If this technology is successfully introduced in the industry then experimental testing in local conditions would be necessary for further investment in this technology.

During processing olive leaves are normally excluded from the process. Some producers are deliberately allowed olive leaves to enter the malaxation chambers in order to producer more “bitter” olive oil. Olive leaves are known to contain a group of related natural products, notably natural phenols, including oleocanthal and oleuropein [Tripoli et al., 2005]. Extra virgin olive oil produced in highlands (altitudes around 200 to 600 meters) has been reported to have noticeable higher content of total phenols [Dabbou et al. 2010]. The connection between sensory intensity and phenolic substances in mountainous olive oils containing different amounts of olive leaves during malaxation is unknown and should be studied further. All these treatments may be used

to produce olive oils of optimum quality, with special characteristics.

The varying preferences of different consumer populations in relation to different olive oils is also an interesting area of investigation which can be researched since multiple oils can now be produced with current horticultural knowledge (e.g. extremely bitter oils, fruity oils with different intense etc.). Similar studies have been performed in Tirana [Zhllima, 2010] but not yet in Greece. In a study comparing Greek olives only typical grocery and market oils were used [Krystallis and Ness 2005] but preferences for extremely flavored olive oils or comparisons between olive oils and other type of oils are not well established. For example, a widespread view exists that older generations in Crete prefer bitter olive oils, which may not be the preference for younger generations. What kinds of oil do younger people actually prefer? If it can be shown that different populations and age groups actually have different preferences for olive oil types, this may open up entirely new markets for olive oil production, including those being produced in specialized regional areas such as Krya.

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