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National Olive Variety Assessment – (NOVA) – *Stage 2*

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By Susan Sweeney

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National Olive Variety Assessment (NOVA) – Stage 2

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Foreword

The current interest in Australia in the Mediterranean diet has led to an increased demand for olive products, which has seen imports rise close to $AUS200 million per year since the mid 1990's and has provided the stimulus for the recent investment and expansion of the local olive industry (Sweeney and Davies, 2004).

However, olives and olive oil are international commodities. For the Australian industry to be sustainable, it must be competitive on the international market. This can only be achieved by adopting high quality techniques in management and production technology and ensuring that the local industry uses the best varieties suitable for Australian conditions to achieve optimal yields and quality.

Unfortunately, the selection of suitable varieties is a far from straightforward matter for the Australian olive industry. There is uncertainty over the true identity of olive varieties in Australia and there is limited reliable performance data for any olive variety under the wide range of Australian conditions and the industry relies on overseas information.

The National Olive Variety Assessment Project (NOVA) was established to resolve the confusion in variety identity and to assist olive producers in making informed varietal choices from the comparative physiological information on the performance of olive varieties in Australia.

This project was funded from RIRDC Core Funds which are provided by the Australian Government.

This report, a new addition to RIRDC's diverse range of over 1500 research publications, forms part of our New Plant Products R&D program, which aims to facilitate the development of new industries based on plants or plant products that have commercial potential for Australia.

Most of our publications are available for viewing, downloading or purchasing online through our website:

- downloads at www.rirdc.gov.au/reports/Index.htm
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- The full report 'Olive Variety Regional Performance Study: a qualitative survey of the views of olive growers, processors and harvesters on the performance of olive varieties in various regions of Australia' by Dr Patricia Murray, carried out in conjunction with this Study is available on the RIRDC WebSite.

Peter O'Brien
Managing Director
Rural Industries Research and Development Corporation

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Contents

Executive Summary

There is enormous potential for olive oil and table olive production in Australia as an import replacement and value-added export industry. Australia currently imports close to $AUS 200 million worth of olive products per year. Much of Australia is climatically suitable for growing olives and this has stimulated investment and establishment of olive groves across the country. It is imperative that best management practices for intensive cultivation and latest technology are employed for the Australian industry to compete with imports and achieve success in overseas markets.

One of the major challenges in the establishment of the olive industry has been the selection of varieties that are best suited for Australian conditions, to achieve optimal yields and quality. There has been limited reliable information and performance data for any olive variety under the wide range of Australian conditions and the industry has relied mainly on Northern hemisphere research and information. Another major issue that has confronted the Australian olive industry is that of ensuring the correct varietal identity of a particular tree, as there is a great deal of confusion in olive variety identification. Performance characteristics of a specific genotype are the basis on which a selection is made for a particular usage or physical situation. Correct identification at the time of tree purchase is therefore critical since mistakes may not become apparent for some years.

The National Olive Variety Assessment (NOVA) project, was established to help resolve the confusion in olive variety identity and to evaluate the performance, in different climatic regions of Australia , of the majority of known commercial olive varieties .
There are two major components to the NOVA project:

A. The National Olive Collection was established at the Roseworthy Campus of the University of Adelaide. This replicated experimental trial was planted with most of the known olive varieties that are currently available in Australia. One hundred accessions were sourced from nurseries and government collections across Australia. Eighty-seven of these accessions were provisionally regarded as different olive varieties. Planting was done in two stages, in late 1998 and 1999.

B. The evaluation of olive varieties in commercial situations on grower properties across Australia. From 2000-2004, olive growers from different regions in Australia submitted fruit samples from their olive varieties for analysis of fatty acid profiles and fruit characteristics. For the purpose of this study, agro-climatic classifications were used to designate different olive growing regions in Australia.

Varietal identification of the National Collection

An important part of evaluating the collection at Roseworthy has been the ability to DNA fingerprint all 600 trees, using randomly amplified polymorphic DNA (RAPD), to ensure their true varietal naming. The DNA fingerprints of the 100 accessions were compared to those of a number of named varieties obtained from international and Australian collections. The RAPD typing was later verified using simple sequence repeat (SSR) markers (microsatellites)

It was found that a number of varieties planted at Roseworthy matched with the correct international standards including: Arbequina, Barnea, Coratina, Frantoio, Hojiblanca, Kalamata, Koroneiki, Leccino, Manzanilla de Sevilla, Nevadillo Blanco, Pendolino, Picual, Sevillano, Souri and one of the Verdale types. This consistency is a reassuring result for the Australian industry as these are all popular variety choices.

However there is confusion with other varieties. Of the 100 NOVA accessions tested (which were supposedly 87 different varieties), only 55 different genotypes were detected. While it was not surprising to find some synonyms, it was remarkable that 12 differently named varieties were of the same genotype as the Italian variety, Frantoio. This is particularly significant as many growers may believe that they have different varieties to enhance cross-pollination but may in fact only have a single variety with subsequent deleterious impacts on pollination efficacy and fruit set.

The inaccuracies of variety names is also confusing for variety selection and labelling of varietal oils and table fruit. As well, the product end-use will depend on the type of olive produced. The variety names Belle de Espagne and Big Spanish are likely to be associated with table fruit, whereas the accessions grown in the NOVA trial were genetically similar to Frantoio and Arbequina respectively, which are both varieties with small fruit more suited to oil production.

Not only were there many misnamed varieties in the NOVA collection, in 11% of the samples, the 6 replicate trees were not identical and the anomalous trees have been removed from the collection. This result highlights the difficulties in initially recognising specific varieties and subsequently ensuring that lines are reliably maintained.

Identification of characteristics of the National Collection

The physiological data evaluated included: time to reach full bloom and harvest ripeness and fruit physical and chemical characteristics from 2002 - 2004. Many of the same fruit attributes were measured for the commercial-scale evaluation.

Flowering

Time to reach full bloom was measured for all of the varieties at Roseworthy and the least variable of the varieties were placed into the following groups based on the mean flowering time:

Early flowering:	UC13A6, Arbequina, Gordal Sevillana, Barouni
Mid flowering:	Oblitza, Azapa, Atro Rubens, Barnea, Large Pickling, Manzanilla de Sevilla, Californian Mission, Picual, Hojiblanca, Verdale Aglandau, I77, Jumbo Kalamata, Pendolino, Black Italian (Blackwood), Group VII, Frantoio, Ascolano, WA Mission, Koroneiki, Benito, Souri, Group III, Leccino, Group V, Atroviolacea Brun Ribier, Gros Reddeneau, Nevadillo Blanco, Early Blanquette and Group II.
Late flowering:	Kalamata, Regalise de Languedoc, Amelon, Volos, Manaiki, Buchine, Pigale, FS17, Areccuzo, Institute and Rouget.

Variance was not considered and there will be a large amount of overlap at the category boundaries.

Actual full bloom times will be different in different regions of Australia however they should still broadly remain in the categories of early, mid and late. This could be important in regions that commonly suffer from late frosts as early flowering varieties should be avoided. As well, this could help varietal choice for cross pollination purposes by matching varieties with similar flowering times.

Harvest Timing

Time to ripening (maturity index = 3) for many varieties was highly variable at Roseworthy but the following less variable varieties could be placed into these broad groupings based on the mean harvest time.

Early	UC13A6, Pendolino and Group I.
Mid	Leccino, Group VI, Mission (Californian), Manzanilla de Sevilla, Benito, Gordal Sevillana, Barouni, Verdale (SA), Barnea, Group VII, Frantoio, Hojiblanca, Oblitza and Kalamata

Late	Rouget, Picual, Group III, I77, Arbequina, Atro Rubens, Verdale Aglandau, Manaiki, Koroneiki, Coratina, Areccuzo, Azapa, Katsourela, Jumbo Kalamata, Mission (WA), Columella and Large Pickling.

As for flowering, variance was not considered and there will be a large amount of overlap at the category boundaries. Actual ripening times will be different in different parts of Australia however the broader ripening categories should be similar.

Fruit yields

Fruit yields were only available for the Roseworthy trees up to 5 years of age and not for the Australia wide study. The best performing varieties in terms of total fruit yield at Roseworthy were (in descending order): Picual, UC13A6, Barnea, Hojiblanca, Arbequina, Koroneiki, Group VII and Manzanilla de Sevilla.

Kalamata, Frantoio and its close relative WA Mission, extensively planted and highly regarded varieties in Australia, had poor yields in their early years at Roseworthy. Yields may improve as the trees age but the results so far indicate that they may not be suitable for producers seeking high, early yields from their trees.

The varieties Rouget, Oblitza, Group III, Jumbo Kalamata, Benito, Leccino and FS17 may have been disadvantaged due to poor quality or immature planting material, however they appear to be rapidly catching up based on their 2004 yields.

Varieties such as UC13A6, Large Pickling, Group VI, Coratina, Barouni, Blanquette – Early, Institute, Ascolano, Buchine, Verdale (Blackwood) and Kalamata, yielded much better in 2003 than in 2004. This may mean these particular varieties have already started an alternate bearing pattern in only their fourth year.

Fruit Analyses

At Roseworthy and from samples around Australia.

Oil Content in Dry Flesh

The varieties with highest percentage oil content in dry flesh at Roseworthy were (in descending order): Buchine, Group V, Gros Reddeneau, Manaiki, Group IV, Arbequina, FS17, Atro Rubens, Barnea, Regalise de Languedoc, Volos, Souri, Mission (WA), Frantoio, Coratina, Columella, Nevadillo Blanco, I77, Ascolano, Kalamata, Gordal Sevillana, Pigale, Verdale Aglandau, Verdale (Blackwood), Oblitza, Group I and Picual. However, not all of these varieties yielded well at Roseworthy so would not produce a large total amount of oil.

There was no significant effect of either fruit maturity (within the range of maturity indices of 1-7) or tree age on the oil percentage in the dry flesh. This shows that young trees can yield as much oil as older trees and leaving the fruit on the trees for longer than the optimal harvest time of maximum oil accumulation will not increase oil content in the fruit.

Water in whole fruit

High water content of fruit can make commercial oil extraction difficult due to oil/water emulsions being formed during malaxation. Many of the varieties in this study with high fruit moisture content are used for table olives where high water content is a lesser issue. However, some of the varieties commonly used for oil in Australia do have relatively high fruit moisture content such as: Verdale (SA), Manzanilla de Sevilla, Picual, Hojiblanca, FS17, Pendolino, Barnea, Arbequina and Leccino. They may require careful irrigation management before harvest to avoid high fruit moisture content and may not be suitable for areas that commonly experience rainfall around harvest time.

Conversely, those varieties with naturally low fruit moisture content may be more suited for oil production in areas that commonly experience rainfall around harvest time. Varieties with low inherent fruit moisture content are: I77, Manaiki, Group II, Amelon, Large Pickling, Nevadillo Blanco, Group IV, Kalamata, Volos, Dr Fiasci, Atroviolacea Brun Ribier, Pigale, Mission (Californian), Blanquette – Early, Gros Reddeneau, Verdale (Blackwood), Coratina, Black Italian, Mission (WA), Frantoio (including Bouteillon, Pueblana, Corregiola, Leccure and Paragon), Group V, Buchine and Koroneiki.

It is interesting to observe that Californian Mission and Koroneiki were noted for having relatively low oil contents in the dry flesh but are regarded as good oiling varieties. This may be due to the fact that they do not naturally absorb large amounts of water in the fruit.

Fruit weight and flesh:pit ratio

Varieties with high fruit weight and flesh:pit ratio are reported on in this study. Those varieties with a high weight and flesh:pit ratio, characteristics which contribute to superior table olives are: Jumbo Kalamata, UC13A6, Gordal Sevillana, Ascolano, Buchine, Barouni, Volos, Azapa, Benito and Manzanilla de Sevilla

Fatty acid composition

A number of varieties consistently recorded levels of linolenic acid higher than the IOOC allowable limit of 1%, both at Roseworthy and around Australia. They were: Verdale (SA), Group II (includes Wagga Verdale), Gordal Sevillana (includes Sevillano), Group VI, Rouget, Areccuzo, Group I, Benito, I77, FS17, Hardy's Mammoth, Oblitza and Katsourela. Growers producing olive oil from these varieties should be aware of their susceptibility in producing levels of linolenic acid above the IOOC accepted limit, however there may be an opportunity to blend oils to reduce overall linolenic acid level.

A high level of saturated fatty acids is undesirable in olive oil. Blanquette Early, Large Pickling and Katsourela had high levels of saturated fat at Roseworthy. Varieties to consistently contain high levels of palmitic acid (the dominant saturated fatty acid in olive oil) around Australia were: Katsourela, Priole, Large Pickling, Blanquette – Early, Group II, Azapa, Pigale, Verdale Aglandau, Praecox, Verdale (SA), Benito, Rouget, Group III and Arbequina.

A high level of oleic acid is desirable in olive oil. Those varieties with high oleic acid levels in this study were: Group IV, Black Italian (Blackwood), Katsouroniki, Group VI, Group V, Koroneiki, Buchine, Kalamata, Mission (Californian), Leccino, Regalise de Languedoc, I77, Picual, Coratina and Hojiblanca.

Similarly, a high ratio of monounsaturated:polyunsaturated fatty acids (MUFA:PUFA ratio) in the oil should confer stability to the oil. Those varieties at Roseworthy, with a ratio greater or not significantly less than Picual, noted for having highly stable oil, in descending order are: Black Italian (Blackwood), Group V, Group IV and Koroneiki. Consequently their oil should also be highly stable.

Effect of fruit maturity on fruit characteristics

At Roseworthy, within the range of fruit maturities received (MI = 1-7), stearic acid increased with increasing maturity and oleic acid decreased. There was also an increase in linoleic and palmitoleic acid with maturity but no effect on palmitic and linolenic fatty acids.

The effect of increasing maturity on the morphological variables included an increase in average fruit weight and flesh:pit ratio, but not of oil content in the dry flesh. Fruit water content also decreased with increasing maturity. There may be advantages in leaving table fruit on the trees to increase in size. However, there seems little point in harvesting over ripe fruit to increase oil content as the % oil in the dry flesh is not increasing with maturity. Oil extraction may be facilitated with increased maturity due to decreased fruit moisture content, but this should be managed through careful irrigation practices.

This would indicate that less mature fruit produce higher oil quality due to the higher levels of oleic acid that dominate the desired monounsaturated fatty acids and reduced levels of linoleic and stearic acid.

Effect of tree age on fruit characteristics

Tree age, up to the age of five years, had very little effect on the fruit characteristics evaluated in this study.

Environmental Effects

One of the main aims of this project was to determine the suitability of different olive varieties for different regions of Australia. The agro-climatic classification used was considered a suitable system to stratify Australia into different regions as it is largely temperature based and temperature during the oil accumulation phase (January – May) is likely to have the greatest effect on oil quality.

Between the different agro-climatic zones there were significant differences in all fatty acid levels except for linolenic acid. There were also some significant differences between agro-climatic zones in % oil in the dry flesh and fruit weight and flesh:pit ratio, but no differences in fruit water content.

A more detailed examination of the data revealed that temperature, not altitude, was the main contributing factor to these differences. Eight varieties were studied in detail: Manzanillo, Frantoio, Paragon, Barnea, Corregiola, Nevadillo Blanco, Leccino and Koroneiki.

In all varieties, palmitic acid levels increased and oleic acid levels decreased with increasing average temperature. Except for Nevadillo Blanco, palmitoleic acid increased with increasing average temperature. Linoleic acid also increased with temperature, except in Koroneiki. Temperature had no effect on linolenic acid and had an inconsistent effect on stearic acid. For Manzanillo, Paragon, Corregiola and Leccino, there was a significant increase (and for Frantoio approaching significant increase) in stearic acid with increasing temperature. For Barnea, Nevadillo Blanco and Koroneiki, there was a slight (although non-significant) reduction in stearic acid with increasing temperature.

Therefore, agro-climatic zones with cooler temperatures during oil accumulation, in particular Zone D5 and to a lesser extent E1, E2 and E6, should generally produce superior quality oils in terms of increased oleic acid levels and decreased palmitic acid levels, regardless of variety.

For agro-climatic zones with higher temperatures during oil accumulation, such as Zones I3, E3, E7, F3 and E4, varieties that are less affected by temperature than others in terms of oleic acid may be most suited, assuming that variety will grow there to begin with. Of the 8 varieties evalutated in detail, oleic acid levels in Koroneiki decreased less than the other 7 varieties with increasing temperature. As mentioned, it was the only variety not to increase linoleic levels with temperature. However, palmitic levels in Koroneiki increased more than in the other varieties with increasing temperature, although Koroneiki has relatively low levels of palmitic acid to start off with.

Temperature had a significant effect on % oil in dry flesh on some varieties, with Barnea increasing in oil content with increasing temperature and Leccino and Koroneiki decreasing in oil content with increasing temperature. This may suggest that Barnea is more suited to warmer climates than Leccino and Koroneiki.

All varieties showed a significant weight increase with increasing temperature and only Koroneiki showed no significant increase in flesh:pit ratio with increasing temperature. This indicates that warmer climates are more conducive to producing superior table olives, in terms of size.

Variety recommendations

Koroneiki appears to be the outstanding performer for olive oil production in Australia, based on the criteria examined in this study. It was a consistently high yielding variety at Roseworthy and it has high oleic acid levels and a high MUFA:PUFA ratio, conferring stability, and is less inclined than the seven other varieties evaluated in detail, to reduced oleic acid levels and increased linoleic levels with increasing temperatures during oil accumulation. It also has inherently low fruit moisture content, facilitating oil extraction, making it more suitable than some other varieties for warmer, more humid environments. Its oil has performed well in Australian extra virgin olive oil competitions (Gawel R, pers comm.). Its fruit was taken by birds for some years at Roseworthy, indicating potential vulnerability to bird predation and risk of spread as a feral plant. Also, being small fruited it may be difficult to harvest.

Picual also performed well in most of these criteria except for the tendency of its fruit to absorb moisture, making it less suitable for areas of high rainfall during harvest. In drier areas with astute irrigation management it should perform well.

Kalamata, Coratina and Californian Mission did well in most of the criteria although their oil stability was not as high as other varieties in terms of the MUFA:PUFA ratio. With Kalamata and Coratina there is concern regarding productivity in terms of fruit yield at Roseworthy. They are still young trees but were certainly not yielding well in comparison to other varieties and may already be tending toward alternate bearing. However, they were only evaluated in a few of the agro-climatic regions and more information is needed.

Buchine, and accessions in Group IV and Group V are not widely planted in Australia but look interesting as they have high oil content (particularly Buchine), oleic levels and MUFA:PUFA ratio (except Buchine), as well as low water percent. However their yield performance at Roseworthy was poor and they need to be evaluated in other environments.

Hojiblanca and Leccino were starting to yield well at Roseworthy and had high oleic levels. However their fruit water content was reasonably high and oil content only moderate.

Barnea and Arbequina are two widely planted varieties in Australia and both yielded well at Roseworthy with high oil content. However fruit moisture content is high, particularly with Barnea, and similarly to Picual will need careful irrigation management close to harvest. Their MUFA:PUFA ratios (and consequent stability) are lower than other varieties and Arbequina has a high palmitic acid value.

Frantoio yielded poorly at Roseworthy, but has high oil content and low fruit water content, no doubt contributing to its reputation as an easily processed variety.

In terms of yield, fruit weight and flesh pit ratio, Jumbo Kalamata, UC13A6, Barouni, Volos, Azapa, Benito and Manzanilla de Sevilla were the best performing table fruit varieties studied. However there are other characteristics important for table olives not evaluated in this study.

Future of the National Olive Collection

The National Collection of olive varieties at Roseworthy is unique and the DNA typing of this collection has made an enormous contribution to the accurate identification of olive varieties in Australia. This database should be utilised by the industry. However, the trees have yet to reach maturity and data collection and evaluation needs to continue for a number of years to gain a full picture of the variety production potential.

The physiological data the NOVA collection is providing for each accession will be important to compare with the DNA fingerprinting results in the future. Varieties with similar RAPD fingerprints but differing in agronomic qualities could be studied to find genetic markers for those traits.

1. Introduction

The Australian olive industry has estimated plantings of more than 8 million trees over the last six years. The driving force behind the expansion has been to replace imported olive products valued at close to $200 million per annum. By 2010, Australia may be producing more olive products than it consumes (P. Miller pers comm). For the industry to be sustainable, it must be able to market these products profitably within Australia and abroad. In order to achieve this the industry must reach a level of management and marketing skills far in advance of its current status.

It is dangerous to assert that variety evaluation is not required because of the number of trees already planted. There will be many more tree plantings in Australia and producers will wish to topwork unwanted varieties with more desirable varieties. Also, there is no scientific information on how to manage different olive varieties under Australian conditions to optimise yield and quality for both oil and table fruit. Finally, no scientific information exists on organoleptic properties of different olive varieties grown in Australia. This information is essential for a modern, market driven food industry seeking to meet the varied requirements of an increasingly sophisticated range of consumers or exploiting niche markets such as varietal oils. All major perennial horticultural industries have eventually moved to programs of varietal selection to give them an edge in production or marketing such as new flavours and blends. This gives individual enterprises the opportunity to maximise their own differentiation in marketing.

Regardless of the planting decisions now being made, the information derived from this project will be valuable to improve management of current plantings, for the development and management of future plantings and for the correction of planting errors by topworking.

This project will enable olive producers to make informed varietal choices from the comparative physiological information on the performance of most of the known olive varieties in Australia, grown under intensive, irrigated conditions.

2. Objectives

The National Olive Variety Assessment (NOVA) project, has been established to help resolve the confusion in olive variety identity as well as to evaluate the performance of all known commercial olive varieties in Australia and how some of them perform in different climatic regions of Australia. There are two major components to the NOVA project:

A. The National Olive Collection established at the University of Adelaide's Roseworthy Campus.

B. The evaluation of olive varieties in commercial situations on grower properties across Australia.

3. Methodology

National Collection

Experimental materials and culture

The National Collection was established to scientifically evaluate most of the known olive varieties in Australia, at the University of Adelaide Roseworthy campus (-34^{0}52'S, 138^{0}69'E), a dryland cropping research farm, 50 km north of Adelaide, South Australia. Roseworthy has a Mediterranean-type climate with an average annual rainfall of 440mm with 330mm (75%) occurring between the months of April to October and an average annual Class A Pan evaporation of 1957 mm (Adams et al, 2000). The site was formerly used for dryland wheat production. This study was conducted between July 1999 and November 2004.

The average combined depth of topsoil and upper subsoil is 40cm. Topsoils are subangular blocky pedality but upper subsoils are primarily prismatic pedality. Textures range from sandy loam to sandy clay loam and light medium clay. The upper subsoils with clay texture and prismatic structure had reduced permeability in their present state. These layers were ameliorated with gypsum incorporated by deep ripping to a depth of 0.8 metres at a rate of 5 tonnes per hectare. This treatment was applied to all tree rows.

A carbonate layer that contains high concentrations of fine soil carbonate in light sandy clay loams and clay loams, occurs at an average depth of 40cm. This carbonate layer has only moderate permeability and excessive irrigation may result in water logging problems in the clay subsoils, particularly in spring when the soil profile is already wet from winter and crop water use rates are relatively low. An irrigation schedule based on an objective soil water monitoring program was installed to minimise the risk of water logging. The average values of the EC of the saturated soil paste extract (ECe) and pH (1:5 soil/0.01M $CaCl_2$ extract) were 0.5dS/m and 7.6 respectively in the upper subsoil and 0.8dS/m and 8.6 respectively in the carbonate layer.

Soil nutrient analysis showed the primary concern to be low levels of nitrogen, sulphur and copper. Single super phosphate (9% P) with 1% Cu was broadcast across the site at a rate of 300 kg/ha and then incorporated along the rows pre plant.

The National Collection is a resolvable incomplete block design, in order to limit the observable cultural effects due to soil variability, consisting of 3 replicates of 2 tree plots of 100 accessions (600 trees) sourced from nurseries and old government collections across Australia (Table 1). Eighty-seven of these accessions were provisionally regarded as different olive varieties. Thirteen of the accessions had the same name as others in the trial but were of different provenances or planted at a different time. Not all accessions were ready to plant at once so the trial was planted in two stages:

Stage 1: December 1998 and January 1999
Stage 2: September 1999 and December 1999.

A further challenge was that planting material was variable creating a large nursery effect. Some of this variability was unavoidable due to the poor condition of some source trees in the old government collections.

Some additional changes were required during the period March 2002 to November 2003, partly as a result of DNA testing of every tree in the trial.

- Some trees died or were found by DNA analysis to be incorrectly identified. These trees were replanted with the correct variety where stock was available. These replanted trees were excluded from the yield and fruit analyses.

- Seven incorrectly identified trees were unable to be replaced as no stock was available.
- All 6 trees of the NOVA accession "Oblonga" were removed as this accession was found to be diseased.

Therefore a total of 587 trees remained from the original 600 planted trees (Table 3).

Six varieties (Frantoio, Barnea, Picual, Hojiblanca, Arbequina and Manzanilla de Sevilla) were repeat planted to enable comparison of all accessions between the two stages of planting. Tree spacing is 6 metres within rows by 7 metres between rows. A barrier row of olive trees was planted around the 3 replicates.

The trees were mostly struck from cuttings although some that were difficult to strike were grafted onto Frantoio or feral olive rootstock. They were approximately 12 months from striking or grafting when planted although there were large differences in initial height and diameter that is addressed in the discussion of the results. Ammonium nitrate (34% N) was sprinkled around each tree at $15g/m^2$ after planting. For the first irrigation season from mid February until mid April 1999, 2.5g of urea (46%N) was applied to each tree every 2 weeks. For the 2000 irrigation season (November-April), 2.5g of ammonium nitrate per tree was applied every week through the fertigation system. From the 2001 irrigation season onwards, the equivalent of 2.5g N/tree was applied each week using Polyfeed ® a proprietary fertigation mix. The analysis of Polyfeed ® is: N 19%, P 8.4%, K 15.8%, Fe 0.1%, Mn 0.05%, B 0.02%, Zn 0.015%, Cu 0.011% and Mo 0.007%. For the 2002-2003 irrigation season only, Calcium Nitrate was applied (15.5% N and 26.3% Ca) at the equivalent of 2.5g N/tree each week. Annual leaf tissue tests in January monitored tree nutrient levels

Weeds were suppressed along the tree rows using contact and residual herbicides. A covercrop of ryecorn between tree rows was sown each winter and slashed in November to control weeds mid-row and increase soil organic matter. Leaf chewing curculio beetles (*Otiorhynchus cribricollis*) were controlled with spot sprays of alphacypermethrin. Individual trees affected with black scale (*Saissetia oleae*) were sprayed with petroleum based summer oil when the crawlers hatched.

Pruning

In order to develop a canopy reflecting as much as possible the natural growth habit of the variety but still enable the trees to be mechanically harvested in the future, the single trunk, free canopy system was employed (Gucci and Cantini, 2000)

Irrigation

Irrigation was applied by in-line drippers with a 3.6 L/h flow rate. Lines were placed 0.5 m either side of the tree row to give two drip lines per tree row. Drippers were spaced at 0.75 m intervals along the drip line. When new driplines were buried in September 2001 due to line damage from hares, the dripper flow rate was changed to 2.9 L/h and spacings to 0.6m. Lines were still placed 0.5 m either side of the tree row however they were buried to a depth of 0.1 m. Root intrusion of the buried inline drippers was prevented by dissolving minute quantities of trifluralin herbicide (3 ppb at the drippers) into the water at each irrigation. Flow to each replicate was monitored with an in-line meter. Irrigation water was mains water of potable quality.

The irrigation schedule was based on soil moisture monitoring using tensiometers in the first year and EnviroSCAN® probes in subsequent years. Irrigation was applied before crop water stress occurred as the aim was to keep the trees in a well watered condition. However, due to the moderately impermeable subsoil, care was taken not to over water the trees. The irrigation season was usually from November through to April. The trees received approximately 53 mm in 1998/99, 65 mm in 1999/2000 (a very wet summer), 148 mm in 2000/2001, 200 mm in 2001/2002, 265 mm in 2002/03 and 217 mm in 2003/4. Exact irrigation quantities are not possible to report in the first three years due to ongoing chewing damage of irrigation lines by hares.

DNA Fingerprinting

All 600 trees in the trial had their leaf DNA analysed using the randomly amplified polymorphic DNA (RAPD) technique (Guerin et al, 2002). The DNA fingerprints of the NOVA accessions were compared with DNA from standards that were considered most likely to match. Where possible, the DNA fingerprints of the NOVA trees were compared with DNA fingerprints from international standards sourced from the following collections, with the codes used in this paper shown in parentheses: The Olive World Collection, Centro de Investigacion y Desarollo Agrario, Cordoba, Spain (Spain); The Volcani Centre, Bet-Dagan, Israel (Israel); CORIPROL, Pescia, Italy (Italy1); Consiglio Nationale delle Ricerche, Instituto di Ricerca Sulla Olivicultura, Perugia Italy (Italy2); Foundation Plant Material Service, University of California, Davis, California USA (USA and Mexico); Subtropical Plants and Olive Trees Institute of Chania Agrokipio, Chania, Greece (Greece); Jouve-Racamond Nursery, Avignon, France (France).

Where international standards were not available, Australian standards were sourced from named trees in olive variety collections planted at government research stations in the early 1900's. These collections are at Wagga Wagga, NSW (Wagga Wagga), Blackwood, SA (Blackwood), and Roseworthy, SA (Roseworthy). Many of the NOVA trees were also sourced from these collections so in some instances, where no other standards were available, the Australian standard was from the same source as the NOVA tree. In some cases, standards for comparison were only available from commercial nurseries (Nursery), a private SA property (Keith) or in a few instances, no comparators were available at all.

More recently, the National Collection was typed using simple sequence repeat (SSR) markers (microsatellites) and the results were compared with those obtained using RAPD markers (Guerin et al, in preparation).

Flowering

In 2001, 2002 and 2003, the date of full bloom (when 80% of flowers were open) was recorded on all flowering trees.

Fruit Yield

In 2002, 2003 and 2004, when fruit on individually bearing trees was as close to the Maturation Index (MI) of 3 (Hermoso *et al.*, 1997) as possible, the fruit was hand harvested, weighed and sent to the laboratory for analysis.

Fruit Analyses

Ten olives (or with small samples as close to 10 as possible) with a MI of approximately 3, where the skin is reddish and the flesh buff-coloured, were selected from each sample, weighed and cut with a scalpel to remove the flesh. The stone was then scrubbed clean and weighed. The flesh to pit ratio was determined by expressing the weight of the flesh (whole olive weight minus the stone weight) divided by the weight of the stone.

Approximately 5 g of the flesh was weighed, dried to constant weight at 80^{o}C (usually 24 hrs), and extracted with n-hexane (BDH, Australia) in a Soxhlet extractor for 10 hr. Hexane was removed on a rotary evaporator to constant weight and the flask re-weighed to estimate the oil yield.

Fatty acid profiles of the oils were determined by gas chromatographic analysis of the fatty acid methyl esters (FAME) (International Union of Pure and Applied Chemistry, 1991). 100 μL of oil were derivatised by heating with 1 mL of freshly made sodium methoxide (0.5 M) in anhydrous methanol in a capped tube for 60 min at 60^{o}C. After cooling to room temperature, 2 mL of hexane and 5 mL of deionised water were added, mixed by vortexing and centrifuged at 3800 rpm for 10 min.

The hexane supernatant (1 mL) was transferred to a GC autosampler vial, and the fatty acid methyl esters measured on a Shimadzu GC-14A gas chromatograph fitted with a SGE BP20 capillary column, (50m x 0.32 mm ID) operating isothermally at 220^{o}C with a run time of 15 min. Nitrogen was the carrier gas and injector and flame ionisation detector temperatures of 300^{o}C were used. Peaks were identified by comparison with authentic standards (Mix C, Altech USA) and composition quantified on an Area % basis.

Statistical Analyses

The definition of variety was that obtained from DNA analyses as described in Guerin et al, 2002 and Guerin et al, in preparation (Tables 1 and 2).

Although most of the fruit was close to MI of 3, there was a range of maturities of the fruit when processed. This affected in particular the fresh weight of the fruit. MI was included as a covariate and data was adjusted accordingly.

Unfortunately there had to be a range of planting dates due to availability of stock, incorrect identification or tree losses. This was included as a simple covariate based on tree age for the yield analysis. However, there was little (if any) effect of tree age on the fruit and fatty acid profiles so this correction was not made for the other fruit analyses.

The trial was designed as a resolvable incomplete block design with two tree plots. The analyses of the yield data were no more precise using an incomplete block design as compared to the randomised block analysis. This was due to the necessity to use covariates to correct for the planting dates so the simpler randomised block analysis of variance was used.

In some cases data were pooled across years. For some variables a simple average was taken, as weighting by the precision would in some cases not reflect the between seasonal effects in a meaningful manner – for example when a variety was well represented in one year but poorly in another, placing most of the weight in accord with available samples was not appropriate. Where a simple average was used, the resultant LSD was calculated from the maximum observed LSD in each year. No correction for missing samples was made, as that would have required generating LSD’s for each comparison pair. The LSDs offered are therefore only a guide, and will be under estimated when there was incomplete data available for analysis (see Table 12 for details of where these gaps occurred).

In other cases, coefficients were averaged across years (for example the effect of maturity on oleic acid content). In those cases the average was weighted inversely proportional to the variance of the estimate, and the appropriate SE of the pooled estimate was calculated as

$$C_{pooled} = \sum \frac{Cy}{SE_y^2} / \sum \frac{1}{SE_y^2}$$

and

$$SE(C_{pooled}) = sqrt(\frac{1}{\sum_{years} 1/SE_{year}^2})$$

Commercial Scale Evaluation

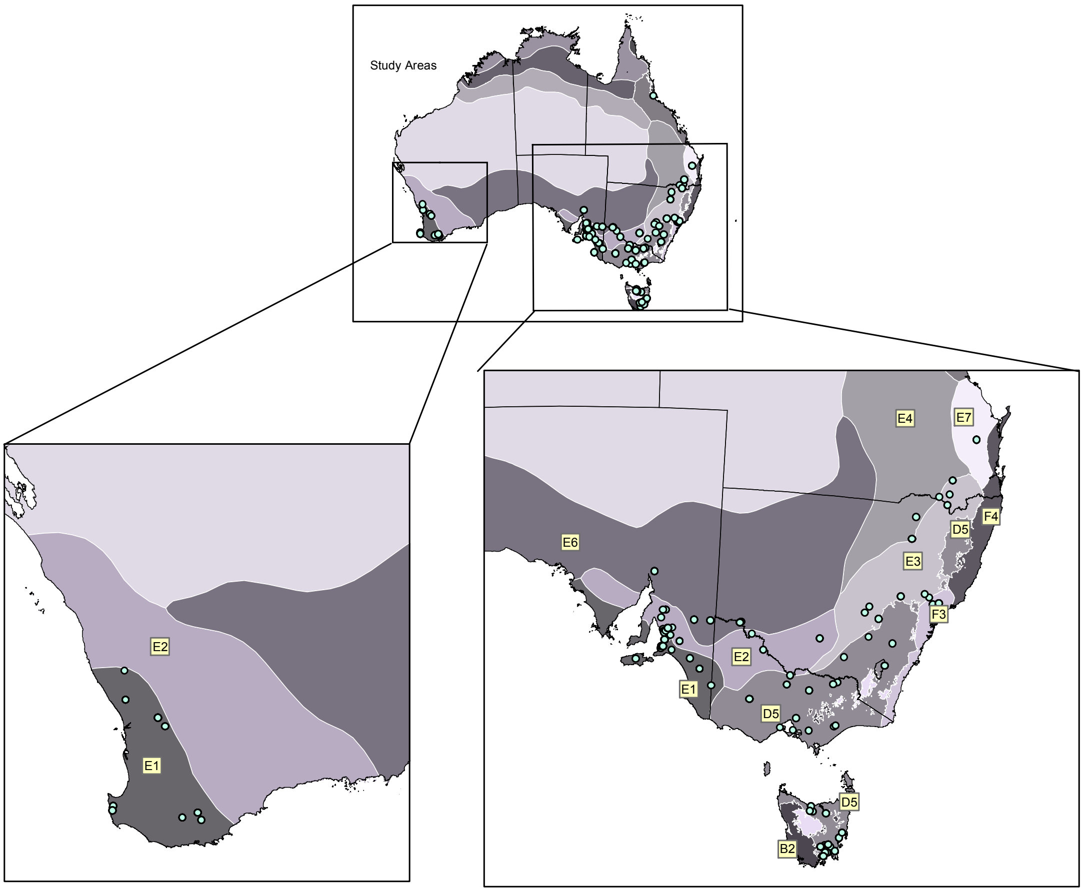
Plant Material and Sampling

From 2000-2004, olive growers from different regions in Australia submitted fruit samples from their olive varieties for analysis of fatty acid profiles and fruit characteristics. Samples from the National Collection site at Roseworthy were also included in this study. Figure 1 shows where the samples came from in Australia and also shows Australia divided into different regions based on an agro-climatic classification (Hutchinson et al, 2005, Hutchinson et al, 1992). For the purpose of this study, these divisions are used to designate different olive growing regions in Australia.

The following agro-climatic classifications are used:

Code	Agro-climate	Location and Land Use
D5	Cool – wet. Moisture availability high in winter-spring, moderate in summer, most plant growth in spring	Tasmanian lowlands, southern Victoria, southern and northern Tablelands of NSW. Forestry, cropping, horticulture, improved and native pastures
E1	Classic "Mediterranean" climate with peaks of growth in winter and spring and moderate growth in winter.	South-west WA and southern SA. Forestry, horticulture, winter cropping, improved pastures.
E2	"Mediterranean" climate, but with drier cooler winters and less growth than E1.	Inland of E1 in south-west WA, southern SA, north-west Victoria and southern NSW. Horticulture, winter cropping, improved pastures
E3	Most plant growth in summer, although summers are moisture limiting. Temperature limits growth in winter.	Western slopes of NSW and part of the North Western Plains. Winter cereals and summer crops, grazing
E4	Growth is limited by moisture rather than temperature and the winters are mild. Growth is relatively even through the year.	Unique in the World to sub-tropical continental eastern Australia and associated with the Brigalow belt of Queensland and NSW. Winter cereals (after summer fallowing), summer crops (including cotton) and sown pastures
E6	Semi-arid climate that is too dry to support field crops. Soil moisture tends to be greatest in winter	Southern edge of the arid interior in WA, SA, NSW and Queensland. Rangeland
E7	Moisture is the main limit on crop growth. Growth index lowest in spring.	Maritime sub-tropical areas in southern Queensland. Sugar, crops and cattle grazing
F3	Cooler end of the warm, wet sub-tropical climates	The Sydney Basin and the NSW south coast. Cooler temperatures slightly favour temperate crops and sown pastures
I3	Strongly developed wet and dry seasons with plant growth determined by moisture availability. I3 has cooler winters than I1 and I2 with a growing season lasting at least six months.	Occurs in the coastal and hinterland areas of north-east Qld, south of Cape York Peninsula. Sugar, cropping and rangelands

Fig. 1 – Map of Australia showing sample sites (small circles) and agro-climatic regions



Each participating grower collected a random sample of 100 olives from five trees of a single variety (20 olives per tree), evenly spaced along the diagonal in the area of the orchard containing that variety. More than 90% of the samples came from trees aged between 3 and 8 years old. Samples were collected when the olives were as close to a MI of 3 as possible.

To minimise spoilage of fruit, clean, dry samples were delivered as quickly as possible (maximum 3 days in the post, usually less) to the laboratory and stored at 4^0C until processed.

Fruit Analyses

The fruit was analysed as for the National Collection.

Statistical analyses

Analysis of covariance in GENSTAT (Version 5, Release 4.1, Lawes Agricultural Trust) was used to adjust the varieties for site means and maturity (linear adjustment) where the site effects were considered random and the variety effects were considered as fixed.

Although the majority of olives selected for analysis were at a MI of approximately 3, some samples had only very green or very ripe olives and ranged between a MI of 1-7. This effect was removed by using MI as a covariate so that all the results were adjusted to the mean MI of 3.4.

4. Detailed Results

National Collection

Varietal identification of the National Collection

Table 1 shows all the accessions in the NOVA collection and from where they were sourced, and the standards used for comparison and from where the standards were sourced (Guerin et al, 2002, Guerin et al, in preparation). Where there was no match with the standard or there was still uncertainty about the correct identity of the NOVA accession, the DNA fingerprint from the NOVA accession was then compared with other fingerprints in the database. The final column in Table 1 shows that in many cases the NOVA accessions DNA fingerprint matched another standard not previously compared or a group of differently named accessions in the NOVA collection had identical DNA fingerprints.

The main difference between the RAPD and the microsatellite results was that the microsatellites showed Gros Reddeneau to have a slightly different fingerprint than Verdale Aglandau and Mission (WA) to have a slightly different fingerprint than Frantoio, therefore they are now classed as separate varieties. This makes a total of 55 different varieties from the original 100 accessions.

Table 2 shows groups of differently named NOVA accessions with identical fingerprints (Guerin et al, 2002, Guerin et al, in preparation). In some instances the DNA fingerprints matched a known international standard and the group is named after this standard. In other instances the DNA fingerprints matched no known international standard and these groups were numbered I-VII.

Table 1. Details of varieties in the NOVA collection, the NOVA variety source, planting date, rootstock where used, the standards that were used for the RAPD analyses, the source of the standard, whether a positive match was identified and whether another match of the NOVA variety was found. (n/a – not available)

NOVA Accession	NOVA Source	Planting Date	Rootstock	DNA Standard	DNA Standard Source	Match	Other Match
Amelon	Wagga Wagga	14/9/1999		Amelon	Wagga Wagga	no	
Arbequina 1	Nursery	3/12/1998		Arbequina	Spain	yes	
Arbequina 2	Nursery	14/9/1999		Arbequina	Spain	yes	
Areccuzo	Roseworthy	14/9/1999		n/a			
Ascolano	Blackwood	14/9/1999		Ascolano	USA	yes	
Atro Rubens	Wagga Wagga	14/9/1999		Atro Rubens	Wagga Wagga	yes	
Atroviolacea Brun Ribier	Blackwood	21/12/1999		Atroviolacea Brun Ribier	Blackwood	yes	
Attica	Wagga Wagga	14/9/1999		Attica	Wagga Wagga	yes	Californian Mission
Azapa	Nursery	3/12/1998		n/a			
Barnea 1	Nursery	3/12/1998		Barnea	Israel	yes	
Barnea 2	Nursery	14/9/1999		Barnea	Israel	yes	
Barouni	Nursery	3/12/1998		Barouni	Nursery	yes	
Belle de Espagne	Wagga Wagga	14/9/1999		Sevillano	Israel	no	Frantoio
Benito	Nursery	3/12/1998		n/a			
Big Spanish	Wagga Wagga	14/9/1999		Sevillano	Israel/Spain	no	Arbequina
Black Italian 1	Nursery	3/12/1998		Black Italian	Blackwood	no	Verdale (USA)
Black Italian 2	Blackwood	21/12/1999		Black Italian	Blackwood	yes	
Blanquette	Wagga Wagga	14/9/1999		Blanquetta	Spain	no	Group IV
Blanquette - Early	Blackwood	21/12/1999	Frantoio	Blanquetta	Spain	no	
Blanquette - Late	Blackwood	14/9/1999		Blanquetta	Spain	no	Group II
Boothby's Lucca	Roseworthy	14/9/1999		Lucca	Blackwood	yes	Frantoio
Borregiola	Blackwood	21/12/1999	Frantoio	Frantoio	Italy2/Spain/Greece	no	Group V
Bouquettier	Blackwood	14/9/1999		Bouquettier	Roseworthy	yes	Group II
Bouteillon	Blackwood	21/12/1999		Bouteillon	Wagga Wagga	yes	Frantoio
Buchine	Blackwood	21/12/1999		Buchine	Blackwood	yes	
Californian Mission 1	Blackwood	21/12/1999		Mission	USA/Mexico	yes	
Californian Mission 2	Nursery	3/12/1998		Mission	USA/Mexico	no	Verdale (USA)
Columella	Wagga Wagga	14/9/1999		n/a			
Coratina	Nursery	3/12/1998		Coratina	Spain	yes	
Corregiola 1	Yanco	14/9/1999		Frantoio	Italy2/Spain/Greece	yes	
Corregiola 2	Nursery	21/12/1999		Frantoio	Italy2/Spain/Greece	yes	

NOVA Accession	NOVA Source	Planting Date	Rootstock	DNA Standard	DNA Standard Source	Match	Other Match
Cucco	Wagga Wagga	14/9/1999		Cucco	Wagga Wagga	yes	Gordal Sevillana
Del Morocco	Roseworthy	14/9/1999		Del Morocco	Roseworthy	yes	Group VII
Dr Fiasci	Wagga Wagga	14/9/1999		Dr Fiasci	Wagga Wagga	yes	
Emu Flat	Keith	22/12/1998		Emu Flat	Keith	yes	Frantoio
Frantago	Nursery	14/9/1999		Frantoio	Italy2/Spain/Greece	no	Group VI
Frantoio 1	Nursery	3/12/1998		Frantoio	Italy2/Spain/Greece	yes	
Frantoio 2	Nursery	14/9/1999		Frantoio	Italy2/Spain/Greece	yes	
Frantoja	Blackwood	14/9/1999		Frantoio	Italy2/Spain/Greece	yes	
FS17	Nursery	14/9/1999		n/a			
Gaeta	Blackwood	14/9/1999	Frantoio	Gaeta	Blackwood	yes	Group V
Gros Reddeneau	Blackwood	14/9/1999		Gros Reddeneau	Blackwood	yes	
Hardy's Mammoth	Blackwood	14/9/1999		Hardy's Mammoth	Blackwood	no	Verdale Aglandau
Hojiblanca 1	Nursery	3/12/1998		Hoji Blanca	Spain	yes	
Hojiblanca 2	Nursery	14/9/1999		Hoji Blanca	Spain	yes	
I77	Nursery	3/12/1998		n/a			
Institute	Blackwood	14/9/1999		Institute	Blackwood	yes	
Jumbo Kalamata	Nursery	3/12/1998	Frantoio	n/a			
Kalamata	Nursery	28/1/1999	Feral	Kalamata	Italy2/Israel	yes	
Katsourela	Nursery	28/1/1999	Feral	Katsourela	Nursery	no	
Koroneiki/Maniataki/Badska	Nursery	22/12/1998	Feral	Koroneiki	Greece/Spain	yes	
Large Fruited	Wagga Wagga	14/9/1999		Large Fruited	Wagga Wagga	no	Group III
Large Fruiting	Blackwood	14/9/1999		Large Fruiting	Blackwood	yes	Group III
Large Pickling	Roseworthy	14/9/1999		Large Pickling	Roseworthy	yes	
Leccino	Nursery	3/12/1998		Leccino	Italy2/Israel	yes	
Leccure	Roseworthy	14/9/1999		Lucque	France	no	Frantoio
Longue d'Ascoli	Blackwood	14/9/1999	Frantoio	Longue d'Ascoli	Blackwood	yes	Group V
Lucca	Blackwood	14/9/1999		Lucque	France	no	Frantoio
Manaiki	Nursery	3/12/1998	Feral	Manaiki	Nursery	yes	
Manzanillo 1	Nursery	3/12/1998		Manzanilla de Sevilla	Spain	yes	
Manzanillo 2	Nursery	3/12/1998		Manzanilla de Sevilla	Spain	yes	
Manzanillo 3	Nursery	21/12/1999		Manzanilla de Sevilla	Spain	yes	
Marchiosa	Roseworthy	14/9/1999		Marchiosa	Roseworthy	yes	Verdale Aglandau
Marcocarpa	Wagga Wagga	14/9/1999		Marcocarpa	Wagga Wagga	yes	Group I
Mediterranean	Nursery	28/1/1999	Feral	Frantoio	Italy2/Spain/Greece	yes	
Morihioso	Blackwood	14/9/1999	Frantoio	Morihioso	Blackwood	yes	Group V

NOVA Accession	NOVA Source	Planting Date	Rootstock	DNA Standard	DNA Standard Source	Match	Other Match
Nab Tamri	Nursery	3/12/1998		n/a			Gordal Sevillana
Nevadillo Blanco	Wagga Wagga	21/12/1999		Nevadillo Blanco	USA	yes	
O de Grasse	Wagga Wagga	14/9/1999		O de Grasse	Wagga Wagga	yes	Group VII
Oblitza	Wagga Wagga	14/9/1999		Oblitza	Wagga Wagga	yes	
Oblonga	Wagga Wagga	14/9/1999		Oblonga	Wagga Wagga	yes	Group VI
Oje Blanco Doncel	Wagga Wagga	14/9/1999		Hoji Blanca	Spain	yes	
Palermo	Blackwood	21/12/1999		Palermo	Roseworthy	no	Group III
Palsano	Roseworthy	14/9/1999		Palsano	Roseworthy	yes	Frantoio
Paragon	Nursery	3/12/1998		Frantoio	Italy2/Spain/Greece	yes	
Pendolino	Nursery	3/12/1998		Pendolino	Italy2/Spain/Israel	yes	
Pendulina	Wagga Wagga	14/9/1999	Frantoio	Pendolino	Italy2/Spain/Israel	no	Group I
Picholine	Blackwood	21/12/1999	Frantoio	Pecholene	Italy1	no	Group V
Picual 1	Nursery	3/12/1998		Picual	Spain	yes	
Picual 2	Nursery	3/12/1998		Picual	Spain	yes	
Picual 3	Nursery	14/9/1999		Picual	Spain	yes	
Pigale	Roseworthy	14/9/1999		Pigale	Wagga Wagga	no	
Polymorpha	Wagga Wagga	14/9/1999		Polymorpha	Wagga Wagga	yes	Group I
Praecox	Wagga Wagga	14/9/1999		Praecox	Wagga Wagga	yes	
Pueblana	Blackwood	14/9/1999		Pueblana	Blackwood	yes	Frantoio
Queen of Spain	Nursery	3/12/1998	Frantoio	Sevillano	Israel	no	
Regalise de Languedoc	Blackwood	14/9/1999		Regalise de Languedoc	Blackwood	yes	
Rouget	Blackwood	14/9/1999		Rouget	Blackwood	yes	
Rubra Baillon d'Aise	Blackwood	21/12/1999		Rubra Baillon d'Aise	Blackwood	yes	Group IV
Salome	Blackwood	14/9/1999		Salome	Blackwood	yes	Verdale Aglandau
Sevillano	Nursery	3/12/1998		Sevillano	Israel	yes	Gordal Sevillana
Souri	Nursery	22/12/1998		Souri	Israel	yes	
Tarascoa	Roseworthy	14/9/1999		Tarascoa	Wagga Wagga	no	Verdale Aglandau
UC13A6	Nursery	3/12/1998		UC13A6	Nursery	yes	
Verdale 1	Wagga Wagga	14/9/1999		Verdale	USA	no	Group II
Verdale 2	Nursery	3/12/1998		Verdale	USA	yes	
Verdale 3	Blackwood	14/9/1999		Verdale	USA	no	
Volos	Nursery	21/12/1999		n/a			
Wallace	Nursery	3/12/1998		n/a			Koroneiki
WA Mission	Nursery	3/12/1998		Mission	USA/Mexico	no	

Table 2. Lists of variety names from the Roseworthy trial with identical DNA fingerprints. Groups I-VII contain accessions that each had identical fingerprints but did not match any international standard.

Frantoio (Italy2)	**Verdale Aglandau (France)**	**Gordal Sevillana (Spain)**	**Verdale (USA)**	**Hojiblanca (Spain)**
Belle de Espagne Boothby's Lucca Bouteillon Correggiola Emu Flat Frantoio Frantoja Leccure Lucca Mediterranean Palsano Paragon Pueblana	Hardy's Mammoth Marchiosa Salome Tarascoa	Cucco Nab Tamri Sevillano	Black Italian 1 Californian Mission 2 Verdale 2	Hoji Blanca Oje Blanco Doncel
Koroneiki (Greece)	**Arbequina (Spain)**	**Mission (USA)**		
Koroneiki Wallace	Arbequina Big Spanish	Attica Californian Mission 1		

Group I	**Group II**	**Group III**	**Group IV**	**Group V**
Marcocarpa Pendulina Polymorpha	Blanquette Late Bouquettier Verdale 1	Large Fruited Large Fruiting Palermo	Blanquette Rubra Baillon D'Aise	Borregiola Gaeta Longue de Ascoli Morihioso Picholine
Group VI	**Group VII**			
Frantago Oblonga	Del Morocco O'de Grasse			

Table 3 Planting times and replants for each correctly identified variety. Number in parenthesis represents number of trees of that variety unable to be replaced.

Variety	Stage I	Stage	Replan	Total
Amelon		6		6
Arbequina	6	12		18
Areccuzo		6		6
Ascolano		6		6
Atro Rubens		6		6
Atroviolacea Brun Ribier		6		6
Azapa	6			6
Barnea	6	6		12
Barouni	6			6
Benito	6			6
Black Italian (Blackwood)		6		6
Blanquette – Early		5		5 (1)
Buchine		6		6
Columella		6		6
Coratina	6			6
Dr Fiasci		6		6
Frantoio	23	67		90
FS17		6		6
Gordal Sevillana	12	6		18
Gros Reddeneau		6		6
Group I		18		18
Group II		18		18
Group III		18		18
Group IV		12		12
Group V		29		29 (1)
Group VI		6		6
Group VII		12		12
Hojiblanca	5	12	1	18
I77	6			6
Institute		6		6
Jumbo Kalamata	6			6
Kalamata	6			6
Katsourela	6			6
Koroneiki	12			12
Large Pickling		6		6
Leccino	4		2	6
Manaiki	6			6
Manzanilla de Sevilla	11	6	1	18
Mission (Californian)		12		12
Mission (WA)	6			6
Nevadillo Blanco		6		6
Oblitza		6		6
Pendolino	6			6
Picual	12	3	3	18
Pigale		6		6
Praecox		6		6
Queen of Spain	4			4 (2)
Regalise de Languedoc	1	5		6
Rouget		6		6
Souri	3		3	6
UC13A6	6			6
Verdale (Blackwood)		6		6
Verdale (SA)	18			18
Verdale Aglandau		24		24
Volos		3		3 (3)
Grand Total	189	388	10	587

Flowering

Table 4 shows the correlation between full bloom dates for the three years, 2001, 2002 and 2003.

Table 4 Correlation (r) between full bloom dates for 2002, 2003 and 2004

	2001	2002	2003
2001	1	0	0
2002	0.559	1	0
2003	0.567	0.737	1

Table 5 shows the comparison of mean full bloom times in 2001, 2002 and 2003 as well as the combined mean times for all three years. Variability represents the average number of days the trees were in full bloom either side of the mean time. For example, Coratina was in full bloom for an average of 2.9 days either side of November 4th. No Least Significant Difference (LSD) is given for 2001 as many varieties did not flower in that year. More detailed charts and an explanation of the analyses are given in Appendix A.

Table 5 Comparison of means and variability of full bloom times of varieties for 2001, 2002 and 2003. Units are days in November (negative numbers are October, e.g. -3 represents 29th October). C, M and V indicate number of flowering trees, mean and variability. * equals no flowers. Varieties ordered by mean full bloom time.

	2001			2002			2003			All Years	
Variety	C	M	V	C	M	V	C	M	V	M	V
Coratina	5	1.6	3.1	4	3.3	1.1	3	8.3	4.4	4.4	2.9
UC13A6	1	-1.0	0.0	6	0.5	0.8	6	15.7	1.2	5.1	0.7
Verdale (SA)	18	-0.9	7.5	16	0.8	2.2	18	17.9	1.4	5.9	3.7
Group I	3	-3.0	4.0	18	5.8	2.1	18	16.3	1.0	6.4	2.4
Arbequina	16	0.3	3.0	16	3.8	1.7	18	17.1	1.3	7.1	2.0
Gordal Sevillana	15	3.1	3.6	16	1.1	1.5	18	17.5	1.2	7.3	2.1
Columella	4	-0.5	4.5	3	5.0	1.3	6	17.5	0.7	7.3	2.2
Barouni	6	0.7	1.1	6	5.8	4.1	6	16.7	0.7	7.7	2.0
Oblitza	6	3.2	2.2	6	3.2	2.2	6	17.2	0.8	7.8	1.7
Azapa	6	4.2	0.6	6	1.0	2.0	6	19.2	1.6	8.1	1.4
Atro Rubens	2	3.5	0.5	5	4.0	3.6	5	18.0	0.8	8.5	1.6
Barnea	6	2.5	1.0	6	4.3	0.6	12	19.1	0.3	8.6	0.6
Large Pickling	6	4.3	0.6	4	3.3	1.1	6	18.7	0.4	8.8	0.7
Manzanilla de Sevilla	11	5.5	3.8	13	2.5	1.4	17	18.4	1.1	8.8	2.1
Queen of Spain	3	8.0	4.0	4	3.3	2.6	3	15.3	6.9	8.9	4.5
Group VI	6	7.7	12.2	6	3.7	5.6	6	15.3	2.2	8.9	6.7
Mission (Californian)	2	5.0	0.0	10	4.1	1.0	11	17.6	1.5	8.9	0.8
Picual	15	4.0	1.5	13	4.5	1.6	15	18.7	0.6	9.0	1.2
Hojiblanca	7	5.7	1.9	16	3.6	1.3	17	18.5	0.6	9.3	1.3
Verdale Aglandau	11	4.9	2.8	24	5.1	2.4	23	18.9	0.5	9.6	1.9
I77	6	4.3	0.9	5	5.6	2.5	6	19.0	0.7	9.6	1.3
Jumbo Kalamata	6	9.3	0.7	6	2.5	2.5	6	17.3	1.3	9.7	1.5
Pendolino	6	4.7	0.4	6	5.3	3.3	6	19.3	0.4	9.8	1.4
Black Italian (Blackwood)	4	9.3	2.4	6	3.2	1.5	6	17.0	1.0	9.8	1.6
Group VII	12	7.2	1.8	9	3.9	0.2	12	18.4	1.1	9.8	1.0
Frantoio	12	6.5	1.8	76	4.4	2.0	82	19.1	1.2	10.0	1.7
Ascolano	4	4.0	2.0	5	7.4	1.7	6	19.0	0.0	10.1	1.2
Mission (WA)	2	7.0	1.0	5	3.4	1.9	6	20.0	0.7	10.1	1.2
Koroneiki	12	4.9	3.1	8	6.5	1.9	12	19.1	0.2	10.2	1.7
Benito	6	6.2	0.9	6	5.3	3.9	6	19.3	1.2	10.3	2.0
Group IV	6	6.7	3.9	9	6.0	2.9	12	18.3	0.8	10.3	2.5
Souri	3	4.3	1.8	3	7.7	0.9	5	19.8	1.0	10.6	1.2
Group III	5	11.0	2.4	15	3.3	1.4	18	17.6	0.9	10.6	1.6
Leccino	1	10.0	0.0	5	3.8	2.2	4	18.3	0.4	10.7	0.9
Group V	3	9.3	1.0	26	4.0	1.8	28	19.3	1.3	10.9	1.4
Atroviolacea Brun Ribier	0	*	2.2	6	3.5	1.7	5	18.4	0.5	11.0	1.5
Gros Reddeneau	1	10.0	0.0	4	4.8	2.3	6	18.5	0.7	11.1	1.0
Nevadillo Blanco	0	*	2.2	6	4.8	1.4	6	17.5	1.2	11.2	1.6
Blanquette - Early	0	*	2.2	3	3.7	1.8	1	19.0	0.1	11.3	1.4
Group II	2	10.0	0.1	16	5.2	2.3	18	19.2	0.3	11.5	0.9
Kalamata	6	9.2	1.5	5	5.6	1.3	6	20.7	0.7	11.8	1.1
Regalise de Languedoc	0	*	2.2	5	4.6	1.9	6	19.2	0.3	11.9	1.5
Amelon	0	*	2.2	4	6.3	1.1	5	17.8	1.0	12.0	1.4
Praecox	0	*	2.2	6	5.2	4.6	6	19.3	0.4	12.2	2.4
Verdale (Blackwood)	0	*	2.2	6	6.2	4.2	6	18.5	1.3	12.3	2.6
Volos	0	*	2.2	1	8.0	0.1	3	16.7	0.4	12.3	0.9
Dr Fiasci	0	*	2.2	6	6.8	3.4	4	18.0	3.5	12.4	3.1
Manaiki	4	9.5	0.5	6	6.3	0.9	6	21.7	2.3	12.5	1.2
Buchine	0	*	2.2	4	5.0	2.0	4	20.3	1.3	12.6	1.8
Pigale	3	15.0	2.0	6	4.5	1.7	6	19.7	0.7	13.1	1.4
FS17	0	*	2.2	4	7.5	0.8	6	18.7	0.6	13.1	1.2
Areccuzo	6	14.8	1.9	4	5.5	2.3	6	19.7	0.4	13.3	1.5
Institute	0	*	2.2	4	4.3	0.4	6	22.5	2.3	13.4	1.6
Rouget	6	13.7	1.7	6	5.5	2.0	6	21.0	1.3	13.4	1.7
Katsourela	4	16.5	1.5	5	6.8	3.0	6	18.7	4.6	14.0	3.0
Mean		6.1			4.6			18.3		10.1	
Maximum LSD		NA			7.8			5.2		4.3	

Harvest Timing

Table 6 shows the correlation between harvest dates for the three years, 2002, 2003 and 2004.

Table 6 Correlation (r) between harvest dates for 2002, 2003 and 2004

	2002	2003	2004
2002	1	0	0
2003	0.512	1	0
2004	0.602	0.583	1

Table 7 shows the mean harvest time of trees in 2002, 2003 and 2004 in order of average harvest time. Trees were picked when olives were as close as possible to a maturity index of 3. Variability represents the average number of days the fruit reached a maturity index of 3 either side of the mean time. For example, UC13A6 reached a maturity index of 3 an average of about 2 days either side of April 21st.   Maturation times within varieties were highly variable and Table 8 shows varieties ordered by average variability of harvest time. Appendix B shows more detailed charts of harvest time.

Table 7 Count (C), mean harvest time (day in year) (M) and mean variability (V) ordered by average harvest time

	2002			2003			2004			All Years		
Variety	C	M	V	C	M	V	C	M	V	M	Dat	V
Dr Fiasci	0			2	99	0	0			99	8/4	0
Volos	0						3	10	0	106	15/	0
UC13A6	3	11	6	6	12	2	6	96	0	112	21/	2
Pendolino	6	98	0	6	13	2	6	10	0	113	22/	7
Atroviolacea Brun	0			6	12	1	6	11	0	120	29/	9
Group I	2	12	0	1	13	2	1	10	4	121	30/	1
Leccino	1	13	0	5	16	3	4	11	0	137	16/	1
Group VI	4	12	0	6	11	3	6	17	0	138	17/	1
Praecox	0			6	11	1	6	16	0	139	18/	7
Amelon	0			4	13	8	5	15	0	142	21/	4
Mission (Californian)	2	13	0	9	13	1	1	16	9	144	23/	8
Manzanilla de Sevilla	9	12	12	1	15	2	1	15	2	146	25/	1
Benito	2	15	13	6	15	4	6	12	0	147	26/	1
Gordal Sevillana	1	13	5	1	13	2	1	17	7	147	26/	1
Pigale	0			5	12	5	6	16	0	147	26/	2
Nevadillo Blanco	0			6	16	3	6	12	0	149	28/	1
Regalise de Languedoc	0			4	12	7	6	17	0	149	28/	4
Buchine	0			4	12	6	6	17	0	149	28/	3
Barouni	4	14	13	5	14	2	6	17	0	153	1/6	5
Verdale (SA)	1	13	4	1	14	2	1	18	1	154	2/6	1
Verdale (Blackwood)	0			6	14	3	6	16	0	156	4/6	1
Barnea	6	16	1	6	14	1	1	15	1	156	4/6	9
Group VII	8	16	5	8	14	2	1	16	8	157	5/6	1
Institute	0			4	14	2	6	17	0	157	5/6	1
Ascolano	2	14	4	5	17	1	0			158	6/6	1
Frantoio	5	14	9	5	16	3	8	16	1	158	6/6	1
Group V	0			2	14	2	2	17	1	158	6/6	1
Hojiblanca	6	16	4	1	14	2	1	17	5	158	6/6	1
Oblitza	6	14	0	5	15	2	6	17	0	158	6/6	8
Kalamata	4	11	7	4	18	1	6	17	0	158	6/6	5
Rouget	5	17	1	5	12	4	6	18	0	159	7/6	1
Picual	1	16	3	1	15	3	1	15	1	160	8/6	1
Group III	3	16	5	1	14	2	1	17	4	161	9/6	1
FS17	0			4	17	2	6	14	0	161	9/6	1
Gros Reddeneau	0			3	13	1	6	18	0	162	10/	5
I77	5	16	6	3	16	3	6	16	0	163	11/	1
Group II	0			1	15	3	1	17	1	164	12/	2
Arbequina	1	16	3	1	15	3	1	16	1	165	13/	1
Atro Rubens	1	16	0	5	13	3	6	19	0	166	14/	1
Verdale Aglandau	4	15	11	2	15	3	2	18	6	167	15/	1
Black Italian	0			6	16	2	6	17	0	168	16/	1
Manaiki	2	14	11	4	17	4	6	18	0	169	17/	1
Koroneiki	0			5	19	1	1	15	0	171	19/	5
Blanquette - Early	0			2	17	4	0			171	19/	4
Group IV	0			8	17	2	1	16	4	171	19/	1
Coratina	5	16	6	4	15	3	1	19	0	171	19/	1
Areccuzo	6	16	9	3	17	2	6	18	0	172	20/	1
Azapa	6	17	5	6	15	4	6	18	0	172	20/	1
Katsourela	3	15	2	3	19	4	6	17	0	174	22/	2
Jumbo Kalamata	5	16	4	6	18	8	6	17	0	177	25/	4
Mission (WA)	1	17	0	5	18	2	6	18	0	178	26/	1
Columella	4	16	5	2	18	0	6	18	0	179	27/	2
Large Pickling	6	16	10	2	18	0	6	18	0	181	29/	3
Souri	0			3	18	9	0			184	2/7	9
Queen of Spain	0			4	20	9	4	17	0	187	5/7	4
Mean		14			15			16				
Maximum LSD					50			30		40		

Table 8 Count (C), mean harvest time (day in year) (M) and mean variability (V) ordered by average variability of harvest time

	2002			2003			2004			All Years		
Variety	C	M	V	C	M	V	C	M	V	M	Dat	V
Dr Fiasci	0			2	99	0	0			99	8/4	0
Volos	0						3	10	0	106	15/	0
Group VI	4	12	0	6	11	3	6	17	0	138	17/	1
Rouget	5	17	1	5	12	4	6	18	0	159	7/6	1
Atro Rubens	1	16	0	5	13	3	6	19	0	166	14/	1
UC13A6	3	11	6	6	12	2	6	96	0	112	21/	2
Pigale	0			5	12	5	6	16	0	147	26/	2
Katsourela	3	15	2	3	19	4	6	17	0	174	22/	2
Columella	4	16	5	2	18	0	6	18	0	179	27/	2
Buchine	0			4	12	6	6	17	0	149	28/	3
Large Pickling	6	16	10	2	18	0	6	18	0	181	29/	3
Amelon	0			4	13	8	5	15	0	142	21/	4
Regalise de Languedoc	0			4	12	7	6	17	0	149	28/	4
Jumbo Kalamata	5	16	4	6	18	8	6	17	0	177	25/	4
Queen of Spain	0			4	20	9	4	17	0	187	5/7	4
Barouni	4	14	13	5	14	2	6	17	0	153	1/6	5
Kalamata	4	11	7	4	18	1	6	17	0	158	6/6	5
Gros Reddeneau	0			3	13	1	6	18	0	162	10/	5
Koroneiki	0			5	19	1	1	15	0	171	19/	5
Pendolino	6	98	0	6	13	2	6	10	0	113	22/	7
Praecox	0			6	11	1	6	16	0	139	18/	7
Mission (Californian)	2	13	0	9	13	1	1	16	9	144	23/	8
Oblitza	6	14	0	5	15	2	6	17	0	158	6/6	8
Atroviolacea Brun	0			6	12	1	6	11	0	120	29/	9
Barnea	6	16	1	6	14	1	1	15	1	156	4/6	9
Souri	0			3	18	9	0			184	2/7	9
Group I	2	12	0	1	13	2	1	10	4	121	30/	1
Areccuzo	6	16	9	3	17	2	6	18	0	172	20/	1
Mission (WA)	1	17	0	5	18	2	6	18	0	178	26/	1
Gordal Sevillana	1	13	5	1	13	2	1	17	7	147	26/	1
Institute	0			4	14	2	6	17	0	157	5/6	1
Ascolano	2	14	4	5	17	1	0			158	6/6	1
Hojiblanca	6	16	4	1	14	2	1	17	5	158	6/6	1
Group III	3	16	5	1	14	2	1	17	4	161	9/6	1
Leccino	1	13	0	5	16	3	4	11	0	137	16/	1
Group VII	8	16	5	8	14	2	1	16	8	157	5/6	1
FS17	0			4	17	2	6	14	0	161	9/6	1
Coratina	5	16	6	4	15	3	1	19	0	171	19/	1
Manzanilla de Sevilla	9	12	12	1	15	2	1	15	2	146	25/	1
Verdale (SA)	1	13	4	1	14	2	1	18	1	154	2/6	1
Picual	1	16	3	1	15	3	1	15	1	160	8/6	1
Group IV	0			8	17	2	1	16	4	171	19/	1
I77	5	16	6	3	16	3	6	16	0	163	11/	1
Black Italian	0			6	16	2	6	17	0	168	16/	1
Azapa	6	17	5	6	15	4	6	18	0	172	20/	1
Verdale (Blackwood)	0			6	14	3	6	16	0	156	4/6	1
Group V	0			2	14	2	2	17	1	158	6/6	1
Verdale Aglandau	4	15	11	2	15	3	2	18	6	167	15/	1
Benito	2	15	13	6	15	4	6	12	0	147	26/	1
Nevadillo Blanco	0			6	16	3	6	12	0	149	28/	1
Frantoio	5	14	9	5	16	3	8	16	1	158	6/6	1
Arbequina	1	16	3	1	15	3	1	16	1	165	13/	1
Manaiki	2	14	11	4	17	4	6	18	0	169	17/	1
Group II	0			1	15	3	1	17	1	164	12/	2
Blanquette - Early	0			2	17	4	0			171	19/	4
Mean		14			15			16				
Maximum LSD					50			30		40		

Fruit Yields

Table 9 shows the "adjusted" average fruit yields (kg) for varieties for 2002, 2003 and 2004 and then for all years combined shown in descending order of "adjusted" average yield. Due to the two planting stages, yields have been adjusted down for first stage plantings and up for the second stage plantings. Therefore, yields are a relative figure and not the actual yields. Small (statistically insignificant) negative yields have resulted from this adjustment.

Unfortunately, Koroneiki had its fruit removed by starlings before it was due to be harvested in 2002 and 2003 however observations indicated it would have produced similar yields as Arbequina. In 2004, 12 netted Koroneiki trees produced a "relative" adjusted yield of 10.91 kg.

The accession called "Queen of Spain", which did not have the same genetic fingerprint as Gordal Sevillana, performed very poorly and never produced sufficient fruit for analysis. Therefore is not included in any further analyses.

Table 10 shows the average yield of just the Stage I plantings in 2004. These yields have not been adjusted down, so show the actual average yield for some 5 year old varieties.

Table 11 shows the correlation between the mean yield of varieties from one year to the next. Replicate and planting time effects have been removed.

Table 9 “Adjusted” mean yields (kg) for each year and average “adjusted” yield (kg) in descending order of average “adjusted” yield. LSDs are for 3 or 6 replicates

DNA Match	Replicates	Yield 2002	Yield 2003	Yield 2004	Average Yield
Picual	15	6.15	6.71	9.87	7.58
UC13A6	6	-0.74	15.68	7.25	7.40
Barnea	12	1.83	10.53	8.03	6.80
Hojiblanca	17	0.9	5.75	12.53	6.39
Arbequina	18	1.74	5.80	10.3	5.95
Group VII	12	1.4	4.40	10.53	5.44
Manzanilla de Sevilla	17	0.91	8.00	7.36	5.42
Rouget	5	1.84	4.79	9.45	5.36
Oblitza	6	1.7	4.76	8.95	5.14
Group III	18	0.62	4.35	10.08	5.02
Large Pickling	6	1.16	8.70	5.17	5.01
Verdale (SA)	18	1.93	7.54	5.45	4.97
Jumbo Kalamata	6	-0.56	6.28	9.11	4.94
Areccuzo	6	2.47	6.75	5.29	4.84
Azapa	6	4.49	5.90	4.01	4.80
Mission (Californian)	12	0.75	5.30	7.17	4.41
Pendolino	6	-0.17	7.26	6.08	4.39
Columella	6	0.63	6.77	5.62	4.34
Benito	6	-0.98	1.32	11.99	4.11
Group VI	6	0.64	10.41	1.2	4.08
Group I	18	0.41	6.78	4.6	3.93
Leccino	4	-1	-0.60	13.23	3.88
Black Italian	6	0.91	6.30	4.29	3.83
FS17	6	0.4	2.45	7.09	3.31
Coratina	6	1.52	9.08	-0.72	3.29
Verdale Aglandau	22	0.45	3.88	5.42	3.25
Barouni	6	-0.05	6.39	3.21	3.18
Volos	3	0.76	4.25	4.16	3.06
Nevadillo Blanco	6	0.91	4.41	3.5	2.94
Gros Reddeneau	6	0.4	2.58	5.73	2.90
Group IV	12	0.65	4.06	3.98	2.90
Group V	29	0.59	4.05	3.66	2.77
Blanquette - Early	5	0.85	5.21	1.97	2.68
Institute	6	0.4	6.71	0.92	2.68
Katsourela	6	0.95	4.25	2.67	2.62
Ascolano	6	0.43	6.52	0.79	2.58
Frantoio	88	0.15	2.52	4.9	2.52
Buchine	6	0.91	4.25	1.82	2.33
Gordal Sevillana	18	-0.28	3.44	3.68	2.28
Verdale (Blackwood)	6	0.4	4.25	1.9	2.18
Praecox	6	0.4	2.29	3.57	2.09
Pigale	6	0.4	1.23	4.41	2.01
Atroviolacea Brun Ribier	6	0.91	1.96	3	1.96
Kalamata	6	-0.62	6.11	-0.05	1.81
Amelon	6	0.4	1.60	2.98	1.66
Atro Rubens	6	0.42	1.17	2.12	1.24
Dr Fiasci	6	0.4	1.68	0.79	0.96
Group II	18	0.4	-0.25	2.42	0.86
I77	6	0.83	-0.72	2.43	0.85
Manaiki	6	-0.95	-2.04	5.14	0.72
Regalise de Languedoc	5	0.35	-0.16	1.08	0.42
Mission (WA)	6	-0.79	-2.75	1.31	0
Souri	3	-0.95	-1.69	-1.68	0
LSD 6		1.39	4.07	4.34	3.53
LSD 3		1.96	5.76	6.14	4.99

Table 10 Average yields (unadjusted) in 2004 for Stage I plantings

Variety	*Replicates*	*Yield 2004*
Arbequina	6	11.6
Azapa	6	5.8
Barnea	6	10.9
Barouni	6	5.0
Benito	6	13.7
Coratina	6	1.4
Frantoio	22	6.4
Gordal Sevillana	12	5.8
Hojiblanca	5	17.2
I77	6	4.4
Jumbo Kalamata	6	10.9
Kalamata	6	1.5
Katsourela	6	6.4
Koroneiki	12	13.0
Leccino	4	15.2
Manaiki	6	7.0
Manzanilla de Sevilla	11	8.7
Mission (WA)	6	3.3
Pendolino	6	7.8
Picual	12	11.8
Souri	3	0
UC13A6	6	9.1
Verdale (SA)	18	7.2
Maximum LSD		10.5

Table 11 Correlation (r) between yields of varietal means

	Yield 2002	Yield 2003	Yield 2004
Yield 2002	1		
Yield 2003	0.318	1	
Yield 2004	0.173	0.152	1

Fruit Analyses

It was not financially feasible to chemically analyse every fruit sample from every tree each year so in 2003 and 2004, fruit from individual trees of each accession was combined and representative samples were obtained for analysis. Table 12 shows the number of replicates per variety per year for the fruit analyses. Each year, (unless there was no fruit), every accession in the trial was sampled. Some varieties have a greater number of replicates than others due to the genetic grouping of each accession.

Table 13 shows percentage oil in dried flesh, individual fruit weight, percentage moisture in the whole fruit, and flesh to pit ratio. These figures are averaged from 2002-2004. Individual year data are shown in Appendix C. There were significant ($P<0.001$) differences between varieties, so a protected least significant difference can be used.

Table 14 shows the means of the fatty acid concentrations of the same varieties. There was no significant effect of the replicate blocks, maturity of the crop or tree age. No corrections were therefore applied to the mean.

Table 15 shows derived ratios of the different fatty acids averaged from 2002-2004

Table 12 shows the number of replicates per variety per year for the fruit analyses.

	2002	2003	2004	Total
Amelon	0	1	1	2
Arbequina	11	9	3	23
Areccuzo	6	3	1	10
Ascolano	2	4	0	6
Atro Rubens	1	2	1	4
Atroviolacea Brun Ribier	0	2	1	3
Azapa	6	3	1	10
Barnea	6	6	2	14
Barouni	4	3	1	8
Benito	2	3	1	6
Black Italian (Blackwood)	0	3	1	4
Blanquette – Early	0	1	0	1
Buchine	0	0	1	1
Columella	4	3	1	8
Coratina	5	3	1	9
Dr Fiasci	0	3	0	3
Frantoio	5	28	20	53
FS17	0	3	1	4
Gordal Sevillana	10	10	3	23
Gros Reddeneau	0	3	1	4
Group I	2	10	3	15
Group II	0	2	3	5
Group III	3	8	3	14
Group IV	0	7	2	9
Group V	0	14	5	19
Group VI	4	3	1	8
Group VII	8	5	2	15
Hojiblanca	6	9	3	18
I77	5	3	1	9
Institute	0	1	1	2
Jumbo Kalamata	5	3	1	9
Kalamata	4	3	1	8
Katsourela	3	0	1	4
Koroneiki	0	3	2	5
Large Pickling	6	3	1	10
Leccino	1	3	1	5
Manaiki	3	2	1	6
Manzanilla de Sevilla	9	10	3	22
Mission (Californian)	2	7	2	11
Mission (WA)	1	2	2	5
Nevadillo Blanco	0	3	1	4
Oblitza	6	3	1	10
Pendolino	6	3	1	10
Picual	15	9	3	27
Pigale	0	4	1	5
Praecox	0	1	1	2
Regalise de Languedoc	0	1	1	2
Rouget	5	2	1	8
Souri	0	2	0	2
UC13A6	3	3	1	7
Verdale (Blackwood)	0	0	1	1
Verdale (SA)	18	9	3	30
Verdale Aglandau	4	12	4	20
Volos	0	0	1	1
Total	181	243	100	524

Table 13 Percentage oil in dried flesh, whole fruit weight (g), percentage moisture in the whole fruit, and flesh to pit ratio for all varieties at Roseworthy, averaged from 2002-2004.

Variety	% oil in dry flesh	fruit weight (g)	%water in whole fruit	flesh:pit ratio
Amelon	52.0	6.2	58.6	7.3
Arbequina	61.9	2.3	60.1	6.9
Areccuzo	51.5	1.9	64.4	6.2
Ascolano	54.1	8.0	65.8	14.4
Atro Rubens	61.1	3.7	61.1	8.5
Atroviolacea Brun Ribier	50.0	4.0	56.0	6.0
Azapa	39.5	5.9	62.0	10.6
Barnea	61.0	3.8	61.4	8.8
Barouni	48.1	7.9	63.5	9.1
Benito	47.7	5.5	68.9	8.4
Black Italian (Blackwood)	51.4	2.8	60.9	5.4
Blanquette - Early	51.9	4.4	55.0	8.4
Buchine	73.9	7.9	49.2	8.5
Columella	56.8	4.6	63.0	8.8
Coratina	57.1	4.4	54.7	8.2
Dr Fiasci	43.7	2.6	56.7	7.2
Frantoio	57.4	3.0	53.3	6.0
FS17	61.7	3.4	63.6	11.7
Gordal Sevillana	54.0	9.1	67.0	10.7
Gros Reddeneau	62.8	3.9	55.0	7.0
Group I	52.6	6.9	61.6	7.2
Group II	45.0	2.6	59.0	5.3
Group III	46.3	3.4	66.8	8.4
Group IV	62.0	2.6	57.3	6.5
Group V	66.0	4.8	51.2	7.4
Group VI	48.7	3.4	67.3	6.3
Group VII	50.8	3.5	62.5	6.8
Hojiblanca	40.4	4.4	64.7	9.2
I77	54.5	4.7	59.8	6.7
Institute	50.5	4.2	72.2	11.8
Jumbo Kalamata	47.4	10.7	64.1	11.2
Kalamata	54.1	4.0	57.2	8.1
Katsourela	51.3	3.9	61.9	8.1
Koroneiki	47.8	1.6	47.3	5.4
Large Pickling	48.2	3.5	58.0	7.9
Leccino	47.6	3.6	60.1	7.1
Manaiki	62.2	4.3	59.2	10.6
Manzanilla de Sevilla	41.5	5.4	66.3	11.3
Mission (Californian)	48.2	4.7	55.5	7.7
Mission (WA)	59.6	3.4	54.4	7.0
Nevadillo Blanco	54.7	3.0	57.5	7.0
Oblitza	53.2	4.9	65.4	9.3
Pendolino	41.4	3.0	61.9	6.8
Picual	52.1	4.4	64.9	8.4
Pigale	53.9	3.6	56.0	5.4
Praecox	31.0	1.6	61.4	5.6
Regalise de Languedoc	60.7	5.3	65.5	12.0
Rouget	50.8	2.8	68.2	10.1
Souri	60.2	3.6	60.1	9.1
UC13A6	25.0	9.9	71.4	11.6
Verdale (Blackwood)	53.5	4.1	54.8	4.6
Verdale (SA)	42.9	6.5	67.4	7.0
Verdale Aglandau	53.7	4.1	60.0	8.9
Volos	60.5	7.6	56.8	9.4
Maximum LSD	11.63	0.87	5.64	1.40

Table 14 - Mean percentage composition of six fatty acids from olive trees at the Roseworthy site, averaged from 2002-2004. The accepted limits for fatty acid composition of Virgin Olive Oil (International Olive Oil Council 2001) are shown in the first row.

	% Composition					
Variety	Palmitic	Palmitoleic	Stearic	Oleic	Linoleic	Linolenic
Accepted Limits	7.5-20	0.3-3.5	0.5-5.0	55.0-	3.5-21.0	≤ 1.0
Amelon	13.62	0.98	1.91	63.61	18.43	0.85
Arbequina	13.00	1.49	1.69	70.69	11.43	0.60
Areccuzo	10.23	0.58	1.78	72.20	12.68	1.17
Ascolano	11.02	0.97	1.69	75.80	8.37	0.99
Atro Rubens	8.96	0.77	2.95	76.45	9.03	0.74
Atroviolacea Brun Ribier	13.55	1.91	1.85	70.37	10.15	0.64
Azapa	13.78	1.38	2.50	68.31	12.74	0.85
Barnea	9.98	0.74	2.12	75.12	10.42	0.63
Barouni	11.92	1.30	1.65	74.99	7.67	0.73
Benito	13.82	1.02	2.56	72.34	8.29	1.15
Black Italian (Blackwood)	9.65	0.97	1.92	81.69	4.11	0.60
Blanquette - Early	15.59	1.14	2.51	57.85	21.55	0.66
Buchine	9.00	0.82	2.66	78.67	7.43	0.58
Columella	13.21	1.43	1.39	63.43	18.40	0.87
Coratina	11.49	1.28	1.96	74.60	7.48	0.72
Dr Fiasci	15.06	1.37	1.75	71.02	8.40	0.99
Frantoio	11.78	1.03	1.99	72.88	10.46	0.69
FS17	11.40	0.95	1.71	72.20	11.46	1.06
Gordal Sevillana	11.24	0.65	1.87	70.16	13.41	1.18
Gros Reddeneau	9.99	0.76	2.23	76.07	9.44	0.82
Group I	11.08	0.98	2.00	70.16	13.94	0.99
Group II	15.04	1.34	2.30	61.48	17.05	1.22
Group III	14.15	1.26	2.41	70.58	9.41	0.88
Group IV	8.45	0.99	2.24	81.89	4.70	0.67
Group V	8.89	0.54	3.17	80.26	4.47	0.65
Group VI	10.30	0.76	1.29	80.35	5.37	0.98
Group VII	12.56	1.03	2.64	69.50	10.69	0.99
Hojiblanca	9.47	0.59	2.81	76.93	7.97	0.84
I77	9.59	0.49	1.49	77.08	8.14	1.06
Institute	14.02	1.35	2.53	72.81	7.43	0.82
Jumbo Kalamata	14.73	1.02	3.15	68.83	11.36	0.78
Kalamata	8.20	0.45	1.21	78.38	8.97	0.65
Katsourela	15.34	1.40	1.83	59.33	20.90	1.02
Koroneiki	10.09	0.80	2.53	79.16	4.98	0.66
Large Pickling	15.61	1.79	2.18	68.13	10.24	0.70
Leccino	12.50	1.23	1.62	77.57	5.80	0.73
Manaiki	9.12	0.49	2.59	72.78	14.20	0.56
Manzanillo	12.54	1.21	3.24	74.68	6.36	0.67
Mission (Californian)	8.56	0.62	2.08	77.64	9.47	0.78
Mission (WA)	11.23	1.05	1.90	74.53	9.23	0.61
Nevadillo Blanco	12.01	0.99	1.75	72.94	8.76	0.82
Oblitza	9.48	0.47	2.77	76.14	9.14	0.78
Pendolino	15.68	0.97	1.41	72.69	7.47	0.76
Picual	11.76	0.90	2.53	76.99	4.82	0.75
Pigale	15.56	2.32	1.95	66.12	11.77	0.91
Praecox	14.46	1.98	1.85	66.18	11.98	0.87
Regalise de Languedoc	8.78	0.74	2.37	77.39	7.55	0.76
Rouget	13.85	1.05	2.12	61.39	19.79	1.18
Souri	11.52	0.72	3.30	74.06	7.72	0.54
UC13A6	15.17	2.11	1.42	69.61	10.12	0.61
Verdale (Blackwood)	12.98	1.09	2.01	74.94	7.50	0.75
Verdale (SA)	13.01	0.99	2.20	69.35	12.33	1.32
Verdale Aglandau	14.09	1.71	2.17	68.47	11.98	0.77
Volos	12.17	0.86	2.29	71.51	11.38	0.56
Maximum LSD	1.25	0.28	0.48	3.16	2.28	0.27

Table 15 Derived ratios of the different fatty acids averaged from 2002-2004.

DNA match	Sum Monounsaturated Oleic and Palmitoleic	Sum Linoleic and Linolenic	Sum Saturated Palmitic and Stearic	Monounsaturated / polyunsaturated
Amelon	63.76	19.18	15.86	3.12
Arbequina	71.35	12.33	15.17	5.87
Areccuzo	72.19	14.26	12.56	5.11
Ascolano	77.10	9.42	12.39	7.91
Atro Rubens	76.10	9.77	12.42	7.77
Atroviolacea Brun Ribier	73.20	10.83	14.83	7.11
Azapa	68.13	13.97	17.16	4.96
Barnea	75.86	11.28	12.14	6.96
Barouni	75.81	8.77	13.79	8.84
Benito	72.32	9.99	16.85	7.48
Black Italian (Blackwood)	82.59	4.66	11.74	18.30
Blanquette - Early	58.86	22.08	18.38	2.90
Buchine	79.49	8.01	11.66	10.45
Columella	64.50	19.48	14.96	3.25
Coratina	77.67	8.49	12.64	10.01
Dr Fiasci	72.34	9.34	16.92	7.81
Frantoio	73.46	11.54	13.97	6.68
FS17	73.37	12.51	13.13	5.88
Gordal Sevillana	69.55	14.95	13.77	4.85
Gros Reddeneau	74.65	10.13	13.85	7.98
Group I	70.87	15.11	12.74	4.82
Group II	62.31	18.27	17.77	3.22
Group III	71.61	10.42	16.77	6.87
Group IV	82.82	5.34	11.06	16.49
Group V	80.70	5.11	12.27	17.31
Group VI	80.66	6.33	11.94	12.16
Group VII	70.61	11.53	15.79	6.04
Hojiblanca	76.45	9.02	13.11	8.94
I77	77.86	9.37	11.48	8.50
Institute	72.79	8.15	16.56	8.94
Jumbo Kalamata	69.39	12.66	17.14	5.82
Kalamata	79.18	9.93	9.54	8.26
Katsourela	59.17	22.23	17.99	2.80
Koroneiki	80.42	5.74	12.62	14.24
Large Pickling	70.22	10.88	18.28	6.41
Leccino	78.22	7.55	13.41	12.49
Manaiki	70.72	15.80	12.62	4.81
Manzanilla de Sevilla	75.37	7.18	16.29	10.49
Mission (Californian)	76.55	10.67	11.67	7.57
Mission (WA)	75.50	10.16	13.31	7.57
Nevadillo Blanco	73.94	9.58	14.35	8.07
Oblitza	75.38	10.23	13.05	7.54
Pendolino	74.46	8.35	16.27	9.17
Picual	79.02	5.54	14.70	16.47
Pigale	68.66	12.70	17.57	5.44
Praecox	69.20	12.99	17.07	5.84
Regalise de Languedoc	75.83	9.07	11.50	9.49
Rouget	67.66	16.35	14.79	2.89
Souri	69.24	14.29	15.19	11.13
UC13A6	71.32	11.72	15.96	6.60
Verdale (Blackwood)	71.80	10.27	17.32	8.94
Verdale (SA)	69.73	13.16	16.07	5.06
Verdale Aglandau	69.68	12.79	16.19	5.40
Volos	71.53	11.41	16.00	6.28
Maximum LSD	3.63	2.58	1.57	2.71

Effect of fruit maturity on fruit characteristics

The fruit samples were collected at approximate time of maturity (MI = 3), but there was a range of maturities between the individual trees of the same variety (MI 1-7). After the removal of the effect of the variety, there was in some cases a relationship between maturity and the various fruit attributes as shown in Table 16. The shaded squares have an effect that is significant at the $p < 0.05$ level.
In several cases these effects were consistent across years (e.g. oleic acid). In that case the effect of -0.614 is to be interpreted as a reduction of 0.614% for each unit increase of maturity.

Table 16 Effect of maturity on attributes of fruit characteristics

	2002		2003		2004		Pooled		
	Effect	SE	Effect	SE	Effect	SE	Effect	SE	P
Palmitic	0.15	0.22	-0.32	0.20	-0.12	0.11	-0.115	0.088	0.196
Palmitoleic	0.09	0.07	0.045	0.057	0.08	0.02	0.077	0.018	<0.001
Stearic	0.04	0.05	0.246	0.060	0.29	0.07	0.163	0.034	<0.001
Oleic	-0.83	0.58	-0.54	0.51	-0.59	0.26	-0.614	0.215	0.006
Linoleic	0.50	0.33	0.65	0.28	0.41	0.24	0.509	0.160	0.002
Linolenic	0.05	0.05	0.002	0.034	-0.03	0.03	-0.005	0.021	0.813
% oil in dry flesh	-0.30	1.25	-1.4	1.6	0.10	1.30	-0.419	0.785	0.596
Fruit weight	0.47	0.17	0.48	0.17	0.32	0.06	0.351	0.054	<0.001
%Water in whole fruit	-0.08	0.66	-0.96	0.64	-2.08	0.82	-0.90	0.40	0.027
flesh_pit	0.67	0.18	1.01	0.27	0.35	0.12	0.52	0.09	<0.001

Effect of tree age on fruit characteristics

The range in planting dates enabled a study of the effect of tree age on various fruit characteristics as shown in Table 17. Variety effect has also been removed. Note that the regression is against the planting date (in years). Thus for 2002 data, the 0.64 effect for palmitic indicates that the younger trees have larger palmitic acid content (0.64 per year). The shaded squares have an effect that is significant at the $p < 0.05$ level.

Table 17 Effect of planting date (years) on fruit characteristics

	2002		2003		2004		Pooledd		
	Effec	SE	Effec	SE	Effec	SE	Effect	SE	P
Palmitic	0.64	0.58	0.67	0.26	-0.44	0.14	-0.155	0.121	0.205
Palmitoleic	0.083	0.074	0.106	0.074	-0.03	0.03	0.001	0.026	0.976
Stearic	-0.15	0.13	0.25	0.06	0.18	0.10	0.180	0.048	0.000
Oleic	-1.90	1.49	-0.35	0.66	0.84	0.36	0.461	0.309	0.141
Linoleic	1.04	0.85	-0.30	0.77	-0.67	0.34	-0.415	0.292	0.161
Linolenic	0.16	0.13	0.03	0.04	0.03	0.04	0.036	0.028	0.199
%_oil_in_dry_flesh	-5.19	3.23	-3.3	2.1	-0.15	1.93	-2.176	1.301	0.100
fruit_weight	0.80	0.43	0.05	0.23	0.08	0.09	0.103	0.082	0.218
%Water in whole	-0.08	0.66	1.84	0.84	2.1	1.17	0.891	0.474	0.065
flesh_pit	1.31	0.47	0.67	0.37	0.60	0.17	0.680	0.147	0.000

Commercial Scale Evaluation

The temperature during the oil accumulation phase (January through to harvest) is likely to have the greatest affect on oil quality (Aparicio and Luna 2002, Beltran et al 2004, Canvin 1964). An average of minimum and maximum temperatures of January, February, March, April and May was used in this study. This study did not address the question as to which of the individual temperature measures is the most relevant.

There was a range of data across years. The year effects cannot be simply removed, as there would be little similarity between a year effect in Queensland as contrast to Tasmania. The year effect is further confounded with tree age. The year effect has not been removed in these analyses, so what is presented is an average across years.

The lack of removal of the year effect could potentially introduce some correlation structure amongst the residuals. Similarly, spatial clustering of locations could also induce non-random residual structures. The assumption of independence of residuals is therefore questionable. The effect of this failure is considered unlikely to have any effect on the estimation of the parameters and only a small effect on the estimation of variances.

Except for the trees from the National Collection at Roseworthy, none of the trees had been positively identified with DNA testing. Therefore, variety was determined as the 'most likely variety' based largely on the opinion of the grower. Even where 'most likely variety' was probably another variety based on DNA evidence from other studies (Guerin et al, 2002), eg Paragon is probably Frantoio, we used the variety name given by the grower as the trees from growers in this study were not DNA tested.

The numbers of samples received in this study are given in Table 18, classified by year and variety and in Table 19 where they are classified by year and the agro-climatic classification as discussed in Section 3.

Table 18 Numbers of samples for each variety available from each year for use in the commercial analyses.

	2000	2001	2002	2003	2004	Total
Amelon	0	0	0	1	1	2
Arbequina	3	10	11	9	3	36
Areccuzo	4	3	6	3	1	17
Ascolano	1	1	3	5	0	10
Atro Rubens	0	1	1	2	1	5
Atroviolacea Brun Ribier	0	1	1	3	1	6
Azapa	0	2	6	3	1	12
Barnea	1	4	12	18	18	53
Barouni	1	0	4	3	1	9
Benito	0	1	2	3	1	7
Black Italian	1	1	0	1	0	3
Black Italian (Blackwood)	1	1	1	4	1	8
Blanquette – Early	0	1	1	1	0	3
Blanquette – Late	0	0	1	0	0	1
Bouteillon	1	0	0	1	1	3
Buchine	0	1	1	0	1	3
Columella	0	0	4	3	1	8
Coratina	3	7	5	3	1	19
Corregiola	3	12	9	16	2	42
Dr Fiasci	0	0	1	3	0	4
Frantoio	8	15	14	33	31	101
FS 17	0	0	0	3	1	4
Gordal Sevillana	0	1	10	10	3	24
Gros Reddeneau	0	1	1	4	1	7
Group I	0	0	2	10	3	15
Group II	0	2	2	4	3	11
Group III	0	4	5	9	3	21
Group IV	0	1	1	7	2	11
Group V	0	4	6	14	5	29
Group VI	0	0	5	3	0	8
Group VII	0	1	8	5	3	17
Hardy's Mammoth	0	0	0	2	0	2
Hojiblanca	0	1	6	9	3	19
I-77	1	1	5	3	1	11
Institute	0	1	1	2	1	5
Jumbo Kalamata	0	2	5	3	1	11
Kalamata	3	6	6	4	1	20
Katsourela	2	2	3	0	1	8
Katsouroniki	1	1	1	1	0	4
Koroneiki	12	5	0	4	2	23
Large Pickling	0	0	6	3	1	10
Leccino	3	6	6	12	1	28
Leccure	0	1	0	1	0	2
Manaiki	2	1	3	3	1	10
Manzanillo	21	44	35	44	51	195
Mediterranean	1	1	0	0	2	4
Mission (Californian)	0	3	5	8	3	19
Mission (WA)	6	4	6	7	2	25
Nevadillo Blanco	3	5	6	7	3	24
Oblitza	0	0	6	3	1	10
Paragon	8	12	11	27	20	78
Pendolino	2	4	7	8	1	22
Picual	3	12	19	10	3	47
Pigale	0	0	0	4	1	5
Praecox	0	0	0	1	1	2
Priole	0	1	1	0	0	2
Pueblana	0	1	1	4	0	6
Regalise de Languedoc	0	1	1	1	1	4
Rouget	0	1	6	4	1	12
Sevillano	0	1	1	0	0	2
Souri	0	0	0	2	0	2
UC13A6	0	4	3	4	1	12
Verdale (Blackwood)	1	1	1	1	1	5
Verdale (SA)	9	15	22	13	4	63
Verdale (Wagga)	0	2	1	1	0	4
Verdale Aglandau	0	3	5	15	4	27
Volos	0	0	0	0	1	1
Total	105	217	302	395	204	1223

Table 19 Numbers of varieties in each agro-climatic zone

	D5	E1	E2	E3	E4	E6	E7	F3	I3
Amelon	0	0	2	0	0	0	0	0	0
Arbequina	0	0	36	0	0	0	0	0	0
Areccuzo	0	0	17	0	0	0	0	0	0
Ascolano	0	4	6	0	0	0	0	0	0
Atro Rubens	0	0	5	0	0	0	0	0	0
Atroviolacea Brun Ribier	0	3	3	0	0	0	0	0	0
Azapa	0	0	12	0	0	0	0	0	0
Barnea	15	9	23	3	3	0	0	0	0
Barouni	0	0	9	0	0	0	0	0	0
Benito	0	0	7	0	0	0	0	0	0
Black Italian	3	0	0	0	0	0	0	0	0
Black Italian (Blackwood)	0	4	4	0	0	0	0	0	0
Blanquette - Early	0	2	1	0	0	0	0	0	0
Blanquette - Late	1	0	0	0	0	0	0	0	0
Bouteillon	2	0	1	0	0	0	0	0	0
Buchine	0	2	1	0	0	0	0	0	0
Columella	0	0	8	0	0	0	0	0	0
Coratina	0	0	19	0	0	0	0	0	0
Corregiola	18	10	10	1	0	3	0	0	0
Dr Fiasci	1	0	3	0	0	0	0	0	0
Frantoio	4	28	63	2	3	0	0	1	0
FS 17	0	0	4	0	0	0	0	0	0
Gordal Sevillana	0	0	24	0	0	0	0	0	0
Gros Reddeneau	0	3	4	0	0	0	0	0	0
Group I	0	0	15	0	0	0	0	0	0
Group II	0	6	5	0	0	0	0	0	0
Group III	0	5	16	0	0	0	0	0	0
Group IV	0	2	9	0	0	0	0	0	0
Group V	0	10	19	0	0	0	0	0	0
Group VI	0	0	8	0	0	0	0	0	0
Group VII	0	0	17	0	0	0	0	0	0
Hardy's Mammoth	2	0	0	0	0	0	0	0	0
Hojiblanca	0	0	19	0	0	0	0	0	0
I-77	0	0	11	0	0	0	0	0	0
Institute	0	3	2	0	0	0	0	0	0
Jumbo Kalamata	0	0	11	0	0	0	0	0	0
Kalamata	0	6	14	0	0	0	0	0	0
Katsourela	0	0	8	0	0	0	0	0	0
Katsouroniki	0	0	4	0	0	0	0	0	0
Koroneiki	1	3	17	1	0	1	0	0	0
Large Pickling	0	0	10	0	0	0	0	0	0
Leccino	2	14	8	1	3	0	0	0	0
Leccure	2	0	0	0	0	0	0	0	0
Manaiki	0	1	9	0	0	0	0	0	0
Manzanillo	51	54	53	13	2	6	3	11	2
Mediterranean	0	3	0	0	0	1	0	0	0
Mission (Californian)	0	4	13	0	0	2	0	0	0
Mission (WA)	0	15	7	0	0	3	0	0	0
Nevadillo Blanco	4	5	11	0	2	2	0	0	0
Oblitza	0	0	10	0	0	0	0	0	0
Paragon	39	19	3	11	0	3	3	0	0
Pendolino	1	5	16	0	0	0	0	0	0
Picual	0	3	41	0	0	3	0	0	0
Pigale	0	0	5	0	0	0	0	0	0
Praecox	0	0	2	0	0	0	0	0	0
Priole	2	0	0	0	0	0	0	0	0
Pueblana	0	3	3	0	0	0	0	0	0
Regalise de Languedoc	0	2	2	0	0	0	0	0	0
Rouget	0	3	9	0	0	0	0	0	0
Sevillano	1	0	0	1	0	0	0	0	0
Souri	0	0	2	0	0	0	0	0	0
UC13A6	1	1	10	0	0	0	0	0	0
Verdale (Blackwood)	0	4	1	0	0	0	0	0	0
Verdale (SA)	9	4	44	0	0	6	0	0	0
Verdale (Wagga)	3	0	0	1	0	0	0	0	0
Verdale Aglandau	0	4	23	0	0	0	0	0	0
Volos	0	0	1	0	0	0	0	0	0
Total	162	244	720	34	13	30	6	12	2

Fruit Analyses

Comparison of varieties across agro-climatic zones

The comparison of varieties across agro-climatic zones was obtained by analysis of covariance removing an agro-climatic zone effect using dummy covariates to represent the agro-climatic zones. As discussed previously, the assumptions concerning the independence of errors is open to question, but experience of the statistician indicates that the tests are fairly robust against minor deviations from the assumptions.

The results are presented separately for fruit characteristic means (Table 20) and fatty acid concentration means of the oil (Table 21) where the varieties are shown in alphabetical order.

Each table also has a protected typical least significant difference (LSD) that compares minimal replication (typically one) against maximum replication. In all cases the actual number of samples for each variety is shown.

Table 20 Percentage oil in dried flesh, whole fruit weight (g), percentage moisture in the whole fruit, and flesh to pit ratio for all varieties averaged from 2000-2004 and corrected for agro-climatic zone.

Variety	% oil in dry flesh	fruit weight (g)	% water whole fruit	flesh:pit ratio	Number of samples
Amelon	49.76	6.30	55.81	7.16	2
Arbequina	55.23	1.89	57.77	6.07	36
Areccuzo	44.29	2.08	62.85	6.33	17
Ascolano	53.38	7.06	61.75	12.39	10
Atro Rubens	56.36	2.89	59.02	8.78	5
Atroviolacea Brun Ribier	45.37	2.87	51.38	5.69	6
Azapa	38.57	5.77	59.79	9.74	12
Barnea	54.24	3.64	59.49	8.16	53
Barouni	46.12	9.00	59.20	9.16	9
Benito	43.42	4.55	65.41	7.57	7
Black Italian	53.70	3.05	47.00	5.64	3
Black Italian (Blackwood)	48.40	2.51	55.76	4.87	8
Blanquette - Early	51.04	2.69	54.89	5.60	3
Blanquette - Late	33.52	4.84	59.84	8.50	1
Bouteillon	43.22	2.33	51.08	4.99	3
Buchine	62.51	5.45	54.57	7.65	3
Columella	53.06	4.86	63.41	8.79	8
Coratina	52.95	3.94	53.70	6.32	19
Corregiola	54.16	3.02	48.90	5.75	42
Dr Fiasci	44.36	2.45	52.25	6.38	4
Frantoio	52.93	2.80	47.63	5.15	101
FS 17	60.70	3.35	63.11	13.59	4
Gordal Sevillana	51.94	9.66	63.87	11.52	24
Gros Reddeneau	52.70	3.03	50.29	6.70	7
Group I	52.31	6.94	63.05	7.91	15
Group II	43.23	2.16	53.23	5.65	11
Group III	43.73	3.37	61.90	8.11	21
Group IV	57.35	2.32	55.41	6.82	11
Group V	59.25	4.95	49.38	7.67	29
Group VI	45.30	3.15	67.58	7.51	8
Group VII	46.87	3.57	62.34	7.50	17
Hardy's Mammoth	49.91	5.83	65.96	9.63	2
Hojiblanca	39.06	4.47	62.82	8.98	19
I-77	53.41	5.13	57.31	6.57	11

Variety	% oil in dry flesh	fruit weight (g)	% water whole fruit	flesh:pit ratio	Number of samples
Institute	62.21	3.62	64.68	10.00	5
Jumbo Kalamata	44.80	10.44	59.51	12.08	11
Kalamata	49.52	4.53	54.11	8.45	20
Katsourela	42.64	3.70	56.77	7.37	8
Katsouroniki	58.24	1.26	52.75	4.74	4
Koroneiki	46.81	0.96	48.59	4.51	23
Large Pickling	44.01	3.20	60.16	7.95	10
Leccino	49.36	3.55	54.41	6.18	28
Leccure	65.35	3.61	48.64	6.20	2
Manaiki	55.48	3.22	56.90	8.55	10
Manzanillo	41.31	5.46	64.12	10.89	195
Mediterranean	54.23	3.23	59.87	6.10	4
Mission (Californian)	45.06	4.03	53.48	7.26	19
Mission (WA)	54.12	2.85	46.50	5.46	25
Nevadillo Blanco	46.69	3.38	55.05	7.40	24
Oblitza	45.62	5.94	68.26	11.28	10
Paragon	54.85	3.09	50.74	5.81	78
Pendolino	41.21	2.46	59.19	6.19	22
Picual	48.24	4.26	61.48	8.34	47
Pigale	47.98	3.64	55.08	5.06	5
Praecox	29.04	1.71	56.58	5.64	2
Priole	38.46	3.31	63.35	9.76	2
Pueblana	57.11	2.58	49.82	5.21	6
Regalise de Languedoc	55.86	5.32	57.51	13.93	4
Rouget	45.74	2.77	67.45	10.98	12
Sevillano	31.63	6.71	67.00	9.75	2
Souri	60.49	3.34	58.09	8.11	2
UC13A6	28.20	9.47	69.02	11.59	12
Verdale (Blackwood)	44.83	3.07	54.50	5.22	5
Verdale (SA)	35.66	5.91	66.18	6.94	63
Verdale (Wagga)	46.01	5.11	60.26	6.44	4
Verdale Aglandau	51.29	3.74	56.92	8.50	27
Volos	58.65	7.20	57.35	8.81	1
Maximum LSD	19.87	1.93	12.64	3.28	
P	<0.001	<0.001	<0.001	<0.001	

Table 21 - Mean percentage composition of six fatty acids for all varieties, averaged from 2000-2004. The accepted limits for fatty acid composition of Virgin Olive Oil (IOOC 2001b) are shown in the first row.

Variety	Palmitic	Palmitoleic	Stearic	Oleic	Linoleic	Linolenic	Count
Accepted Limits	7.5-20	0.3-3.5	0.5-5.0	55.0-83.0	3.5-21.0	≤ 1.0	
Amelon	13.68	0.84	1.89	63.93	17.62	0.83	2
Arbequina	14.50	2.06	1.70	68.96	11.13	0.57	36
Areccuzo	11.75	0.70	1.67	71.63	12.38	1.10	17
Ascolano	11.03	0.88	1.82	75.81	8.53	0.85	10
Atro Rubens	9.96	0.67	2.80	75.12	9.05	0.76	5
Atroviolacea Brun Ribier	12.62	1.39	2.05	71.92	9.89	0.73	6
Azapa	15.47	1.86	2.49	65.37	13.29	0.81	12
Barnea	11.13	0.89	2.07	72.83	11.52	0.70	53
Barouni	12.08	1.52	1.76	74.37	8.16	0.66	9
Benito	14.71	1.11	2.61	71.11	8.47	1.24	7
Black Italian	12.54	1.02	1.98	72.85	10.38	0.55	3
Black Italian (Blackwood)	9.45	0.81	1.97	82.38	3.82	0.58	8
Blanquette - Early	16.19	1.00	3.15	58.57	19.42	0.80	3
Blanquette - Late	12.67	1.45	2.88	75.22	6.25	0.65	1
Bouteillon	11.51	0.93	1.66	74.00	9.92	0.96	3
Buchine	9.16	0.50	2.45	77.97	8.32	0.66	3
Columella	13.79	1.94	1.32	62.39	18.69	0.88	8
Coratina	10.57	0.39	1.95	77.96	7.70	0.63	19
Corregiola	13.16	1.17	1.93	70.84	11.30	0.72	42
Dr Fiasci	14.23	1.28	1.88	72.01	8.71	0.87	4
Frantoio	12.44	1.01	2.09	72.82	9.96	0.68	101
FS 17	11.23	0.77	1.62	73.53	10.79	1.06	4
Gordal Sevillana	12.22	0.90	2.03	68.30	13.64	1.17	24
Gros Reddeneau	13.61	1.66	2.29	70.66	9.93	0.67	7
Group I	11.23	1.05	1.85	69.60	13.64	1.10	15
Group II	15.53	1.27	2.44	61.60	17.11	1.05	11
Group III	14.55	1.37	2.61	70.24	9.26	0.77	21
Group IV	8.85	1.04	2.25	82.50	3.93	0.65	11
Group V	10.12	0.50	3.30	78.42	4.97	0.70	29
Group VI	11.21	0.97	1.34	78.65	5.59	1.17	8
Group VII	13.33	1.08	2.49	70.44	9.93	0.98	17
Hardy's Mammoth	14.02	1.05	2.03	62.92	16.60	1.05	2
Hojiblanca	10.51	0.41	2.80	76.17	7.84	0.85	19
I-77	10.16	0.32	1.51	78.40	7.67	0.88	11
Institute	13.76	1.31	2.87	73.43	6.42	0.73	5
Jumbo Kalamata	13.45	1.08	3.24	67.92	12.62	0.76	11
Kalamata	9.06	0.71	1.84	76.17	10.31	0.62	20
Katsourela	17.49	2.02	2.09	56.39	20.43	0.98	8
Katsouroniki	10.18	0.42	2.14	80.38	5.29	0.73	4
Koroneiki	11.60	0.96	2.27	79.05	4.63	0.70	23
Large Pickling	16.51	2.34	2.07	68.11	9.62	0.86	10
Leccino	12.71	1.11	1.79	77.28	5.68	0.67	28
Leccure	13.52	1.05	1.93	71.57	9.65	0.65	2
Manaiki	11.07	0.68	2.49	71.74	12.43	0.62	10
Manzanillo	12.91	1.45	2.98	74.32	6.49	0.65	195
Mediterranean	13.19	1.02	1.59	74.28	8.35	0.70	4
Mission (Californian)	9.00	0.63	2.28	76.98	9.34	0.79	19
Mission (WA)	12.85	1.27	1.85	71.51	10.99	0.66	25
Nevadillo Blanco	12.47	0.94	1.77	73.12	9.43	0.83	24
Oblitza	10.98	0.39	2.68	73.63	9.99	1.02	10
Paragon	12.42	0.96	1.86	73.52	9.57	0.69	78
Pendolino	13.66	1.10	1.36	73.55	8.70	0.89	22
Picual	12.27	1.25	2.50	78.72	3.88	0.72	47
Pigale	15.46	1.93	1.96	67.64	10.99	0.96	5
Praecox	14.78	2.64	2.44	66.08	12.57	0.83	2
Priole	17.22	2.35	1.73	62.17	15.40	0.80	2
Pueblana	12.33	0.86	2.11	73.81	9.01	0.67	6
Regalise de Languedoc	9.02	0.68	2.45	77.20	7.78	0.67	4
Rouget	14.67	1.38	2.14	60.92	18.89	1.17	12
Sevillano	13.69	1.17	1.90	71.09	9.65	1.18	2
Souri	11.18	0.59	3.39	74.38	7.82	0.53	2
UC13A6	14.39	2.17	1.50	70.56	9.91	0.58	12
Verdale (Blackwood)	12.46	1.01	2.33	75.85	6.75	0.86	5
Verdale (SA)	14.76	1.24	2.14	66.44	12.80	1.35	63
Verdale (Wagga)	13.53	1.11	2.19	71.76	9.25	1.09	4
Verdale Aglandau	14.80	1.89	2.21	67.42	11.68	0.80	27
Volos	11.88	0.69	2.24	72.88	10.47	0.58	1
Maximum LSD	3.08	0.76	0.88	6.53	4.67	0.40	
P	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	

Estimation of environmental effects

A previous study had shown that levels of oleic acid from the same variety varied in different parts of Australia (Sweeney et al, 2002). This study attempts see if this variation occurs between agro-climatic zones and then to determine whether temperature or altitude are environmental reasons for this variation.

The effect of environment was assessed by considering varieties that were represented by at least 20 samples across 4 agro-climatic zones. For varieties Manzanillo, Frantoio and Paragon, there are six tables designated a-f. ns = not significant and NA = not applicable

Table 22a Effect of agro-climatic zones on fatty acid composition of Manzanillo

			% Composition			
ZONE	Palmitic	Palmitoleic	Stearic	Oleic	Linoleic	Linolenic
D5	10.5	1.01	2.62	80.0	4.0	0.62
E1	13.2	1.24	3.10	75.1	5.6	0.61
E2	13.3	1.59	3.03	73.2	7.0	0.65
E3	16.0	2.03	2.99	66.4	11.1	0.68
E4	14.3	2.05	3.80	67.8	10.2	0.60
E6	12.9	1.47	3.93	71.2	8.4	0.70
E7	15.5	2.03	3.20	67.1	10.4	0.57
F3	14.8	1.85	3.56	69.3	9.1	0.66
I3	20.0	3.05	4.00	67.1	4.4	0.15
LSD	2.3	0.58	0.96	4.37	2.7	0.21
P	<0.001	<0.001	<0.001	<0.001	<0.001	ns

Table 22b Relative contribution to effect of agro-climatic zone of elevation and temperature together, only elevation and only temperature on fatty acid composition of Manzanillo

			% Composition			
	Palmitic	Palmitoleic	Stearic	Oleic	Linoleic	Linolenic
Elevation and temperature	93%	81%	68%	88%	63%	ns
Elevation	7%	9%	0%	9%	12%	ns
Temperature	92%	79%	64%	87%	59%	ns

Table 22c Summary of regression of fatty acid composition against temperature for Manzanillo

			% Composition			
	Palmitic	Palmitoleic	Stearic	Oleic	Linoleic	Linolenic
Effect	0.779	0.157	0.134	-1.770	0.725	-0.007
Standard error	0.041	0.011	0.019	0.074	0.061	0.005
t	19.05	14.25	6.94	-23.82	11.94	-1.44
P	<0.001	<0.001	<0.001	<0.001	<0.001	ns

Table 22c indicates that for each degree increase in temperature there was a loss of 1.77% of oleic acid content. Similar interpretations can be made for other olive varieties and for other acids.

Table 22d Effect of agro-climatic zone on fruit characteristics of Manzanillo

ZONE	% oil in dry flesh	Fruit weight	Water in whole fruit	Flesh:pit
D5	42.7	3.9	62.0	8.5
E1	38.6	5.4	61.4	10.0
E2	40.6	5.8	64.4	11.9
E3	40.1	6.3	65.7	11.8
E4	36.5	5.5	55.0	10.4
E6	39.2	6.1	64.3	11.9
E7	35.8	7.9	62.5	11.5
F3	48.6	5.8	66.0	12.4
I3	30.8	6.4	67.7	10.8
LSD	13.7	1.5	8.1	3.1
P	0.056	<0.001	0.012	<0.001

Table 22e Relative contribution to effect of agro-climatic zone of elevation and temperature together, only elevation and only temperature on fruit characteristics of Manzanillo

	% oil in dry flesh	fruit weight	water in whole fruit	Flesh:pit
Elevation and temperature	9%	88%	NA	65%
Elevation	0%	6%	NA	0%
Temperature	18%	88%	NA	69%

Table 22f Summary of regression of fruit characteristics against temperature for Manzanillo

	% oil in dry flesh	fruit weight	water in whole fruit	Flesh:pit
Effect	-0.49	0.409	0.14	0.5872
Standard error	0.287	0.028	0.173	0.0621
t	-1.71	14.61	0.81	9.46
P	ns	<0.001	ns	P<0.001

Table 23a Effect of agro-climatic zone on fatty acid composition of Frantoio

			% Composition			
	Palmitic	Palmitoleic	Stearic	Oleic	Linoleic	Linolenic
ZONE						
D5	9.3	0.5	1.5	81.6	5.7	0.7
E1	13.8	0.9	2.2	72.2	9.3	0.6
E2	12.2	1.1	2.1	72.4	10.5	0.7
E3	15.3	1.5	1.9	68.1	11.7	0.8
E4	14.7	1.6	2.2	64.7	15.6	0.6
E6	*	*	*	*	*	*
E7	*	*	*	*	*	*
F3	15.2	1.2	2.1	64.7	14.8	0.9
I3	*	*	*	*	*	*
LSD	4.02	0.91	1.18	9.83	7.72	0.41
P	<0.001	<0.001	0.058	<0.001	<0.001	ns

Table 23b Relative contribution to effect of agro-climatic zone of elevation and temperature together, only elevation and only temperature on fatty acid composition of Frantoio

	% Composition					
	Palmitic	Palmitoleic	Stearic	Oleic	Linoleic	Linolenic
Elevation and temperature	20%	82%	28%	78%	86%	0%
Elevation	2%	0%	0%	3%	0%	0%
Temperature	18%	83%	28%	73%	83%	0%

Table 23c Summary of regression of fatty acid composition against temperature for Frantoio

	% Composition					
	Palmitic	Palmitoleic	Stearic	Oleic	Linoleic	Linolenic
Effect	0.463	0.148	0.059	-1.970	1.302	0.008
SE	0.135	0.025	0.034	0.270	0.192	0.012
t	3.430	6.004	1.744	-7.296	6.781	0.650
P	<0.001	<0.001	ns	<0.001	<0.001	ns

Table 23d Effect of agro-climatic zone on fruit characteristics of Frantoio

ZONE	% oil in dry flesh	fruit weight	water in whole fruit	Flesh:pit
D5	53.6	2.4	50.9	4.6
E1	45.0	2.6	43.5	4.6
E2	56.5	3.0	49.1	5.6
E3	51.9	2.7	49.3	4.9
E4	46.6	3.7	48.7	5.8
E6	*	*	*	*
E7	*	*	*	*
F3	62.7	3.3	49.0	5.3
I3	*	*	*	*
LSD	21.0	1.4	16.0	2.5
P	<0.001	0.027	ns	0.02

Table 23e Relative contribution to effect of agro-climatic zone of elevation and temperature together, only elevation and only temperature on fruit characteristics of Frantoio

	% oil in dry flesh	Fruit weight	water in whole fruit	Flesh:pit
Elevation and temperature	2%	56%	NA	35%
Elevation	2%	NA	NA	7%
Temperature	1%	63%	NA	28%

Table 23f Summary of regression of fruit characteristics against temperature for Frantoio

	% oil in dry flesh	fruit weight	water in whole fruit	Flesh:pit
Effect	0.540	0.169	-0.480	0.196
SE	0.916	0.054	0.649	0.102
t	0.590	3.124	-0.740	1.920
P	ns	0.002	ns	ns

Table 24a Effect of agro-climatic zone on fatty acid composition of Paragon

	% Composition					
	Palmitic	Palmitoleic	Stearic	Oleic	Linoleic	Linolenic
ZONE						
D5	9.71	0.50	1.73	79.56	6.89	0.66
E1	12.35	0.83	1.84	74.83	8.55	0.64
E2	12.83	1.00	2.03	71.63	11.23	0.63
E3	16.41	1.35	1.93	64.78	13.82	0.76
E4	*	*	*	*	*	*
E6	13.93	1.00	1.93	68.90	12.97	0.77
E7	16.67	2.17	2.23	64.30	12.40	0.53
F3	*	*	*	*	*	*
I3	*	*	*	*	*	*
LSD	1.89	0.48	0.63	3.81	3.12	0.32
P	<0.001	<0.001	ns	<0.001	<0.001	ns

Table 24b Relative contribution to effect of agro-climatic zone of elevation and temperature together, only elevation and only temperature on fatty acid composition of Paragon

	% Composition					
	Palmitic	Palmitoleic	Stearic	Oleic	Linoleic	Linoleni
Elevation and temperature	93%	78%	44%	89%	81%	0%
Elevation	45%	31%	0%	40%	0%	0%
Temperature	92%	78%	44%	89%	81%	0%

Table 24c Summary of regression of fatty acid composition against temperature for Paragon

	% Composition					
Fatty acid	Palmitic	Palmitoleic	Stearic	Oleic	Linoleic	Linolenic
Effect	0.892	0.1284	0.0452	-1.9	0.84	0.0009
SE	0.0481	0.0138	0.0153	0.116	0.0882	0.00799
t	18.5	9.304	2.954	-16.3	9.524	0.113
P	<0.001	<0.001	<0.005	<0.001	<0.001	ns

Table 24d Effect of agro-climatic zone on fruit characteristics of Paragon

	% oil in dry flesh	Fruit weight	water in whole fruit	Flesh:pit
ZONE				
D5	53.9	2.0	47.0	4.2
E1	53.8	3.0	49.0	5.1
E2	55.7	2.7	46.4	5.1
E3	53.5	3.2	52.6	5.5
E4	*	*	*	*
E6	54.5	3.3	50.1	5.9
E7	43.1	4.0	53.2	5.7
F3	*	*	*	*
I3	*	*	*	*
LSD	13.3	1.4	8.9	1.2
P	ns	<0.001	ns	ns

Table 24e Relative contribution to effect of agro-climatic zone of elevation and temperature together, only elevation and only temperature on fruit characteristics of Paragon

	% oil in dry flesh	fruit weight	water in whole fruit	Flesh:pit
Elevation and temperature	0%	91%	43%	96%
Elevation	12%	20%	0%	14%
Temperature	0%	92%	76%	95%

Table 24f Summary of regression of fruit characteristics against temperature for Paragon

	% oil in dry flesh	fruit weight	water in whole fruit	Flesh:pit
Effect	0.07	0.2168	0.72	0.2286
SE	0.445	0.0235	0.295	0.0369
t	0.157	9.226	2.441	6.195
P	ns	<0.001	0.017	<0.001

Table 25and 26 summarises the effect of temperature on the fatty acid composition and fruit characteristics on the above 4 varieties of olives and 4 more varieties. These 4 extra varieties also had at least 20 samples across 4 agro-climatic zones. The t value needs to be greater than ± 2 to be significant ($P < 0.05$).

Table 25 Effect of temperature on fatty acid composition for 8 varieties of olives

		% Composition					
		Palmitic	Palmitoleic	Stearic	Oleic	Linoleic	Linolenic
Manzanillo	Effect	0.779	0.157	0.134	-1.770	0.725	-0.007
	Standard error	0.041	0.011	0.019	0.074	0.061	0.005
	t	19.050	14.250	6.940	-23.820	11.940	-1.440
Frantoio	Effect	0.463	0.148	0.059	-1.970	1.302	0.008
	Standard error	0.135	0.025	0.034	0.270	0.192	0.012
	t	3.430	6.004	1.744	-7.296	6.781	0.650
Paragon	Effect	0.892	0.128	0.045	-1.900	0.840	0.001
	Standard error	0.048	0.014	0.015	0.116	0.088	0.008
	t	18.545	9.304	2.954	-16.379	9.524	0.113
Barnea	Effect	0.596	0.075	-0.011	-1.810	1.195	-0.005
	Standard error	0.090	0.017	0.016	0.221	0.170	0.009
	t	6.620	4.564	-0.701	-8.190	7.029	-0.520
Corregiola	Effect	0.777	0.151	0.061	-1.610	0.674	0.000
	Standard error	0.071	0.016	0.020	0.177	0.145	0.011
	t	10.923	9.226	3.102	-9.096	4.646	-0.019
Nevadillo Blanco	Effect	0.499	0.088	-0.034	-1.650	1.077	0.022
	Standard error	0.139	0.051	0.024	0.329	0.243	0.024
	t	3.590	1.722	-1.441	-5.015	4.432	0.915
Leccino	Effect	0.420	0.124	0.095	-1.230	0.754	0.002
	Standard error	0.149	0.037	0.046	0.299	0.256	0.017
	t	2.819	3.353	2.044	-4.114	2.945	0.130
Koroneiki	Effect	0.931	0.147	-0.009	-1.100	0.033	0.016
	Standard error	0.275	0.048	0.038	0.359	0.189	0.019
	t	3.385	3.064	-0.235	-3.064	0.175	0.807

Table 26 Effect of temperature on fruit properties for 8 varieties of olives

		% oil in dry flesh	fruit weight	water in whole fruit	Flesh:pit
Manzanillo	Effect	-0.490	0.409	0.140	0.587
	Standard error	0.287	0.028	0.173	0.062
	t	-1.710	14.610	0.810	9.460
Frantoio	Effect	0.540	0.169	-0.480	0.196
	Standard error	0.916	0.054	0.649	0.102
	t	0.590	3.124	-0.740	1.920
Paragon	Effect	0.070	0.217	0.720	0.229
	Standard error	0.445	0.024	0.295	0.037
	t	0.157	9.226	2.441	6.195
Barnea	Effect	1.310	0.265	0.100	0.558
	Standard error	0.609	0.036	0.350	0.097
	t	2.151	7.326	0.286	5.759
Corregiola	Effect	0.080	0.124	-0.150	0.178
	Standard error	0.515	0.065	0.410	0.073
	t	0.155	1.902	-0.366	2.448
Nevadillo Blanco	Effect	0.160	0.236	-0.140	0.351
	Standard error	0.751	0.061	0.606	0.084
	t	0.213	3.863	-0.231	4.159
Leccino	Effect	-1.510	0.361	-0.390	0.339
	Standard error	0.763	0.079	0.716	0.133
	t	-1.979	4.547	-0.545	2.547
Koroneiki	Effect	-3.730	0.083	1.540	-0.078
	Standard error	1.480	0.030	0.789	0.132
	t	-2.520	2.797	1.952	-0.591

5. Discussion of Results

National Collection

Varietal identification of the National Collection

Standard Matches:
Many of the varieties planted at Roseworthy were sourced from well known nurseries that are selling certified trees or in the process of DNA testing their mother stock. Most of these varieties matched with the correct international standard including: Arbequina, Barnea, Coratina, Frantoio, Hojiblanca, Kalamata, Koroneiki, Leccino, Manzanilla de Sevilla, Nevadillo Blanco, Pendolino, Picual, Sevillano, Souri and one of the Verdales. This is a reassuring result for the Australian industry as these are all popular variety choices. It should be noted that the Nevadillo Blanco at Roseworthy matches with a USA standard and is not genetically similar to Picual as stated in some text (International Olive Oil Council, 2000).

However there is clearly confusion with other varieties. Californian Mission has been widely mislabelled in Australia, with the accession sourced from a nursery in this study matching with Verdale (USA). However the Californian Mission accession from Blackwood did match with the international standard, as well as an accession named Attica from Wagga Wagga. Similarly, it was believed that the commercially valuable Spanish varieties Hojiblanca and Arbequina had not been introduced to Australia. Consequently they were recently imported and propagated at considerable effort and expense. This study has revealed that they were already in Australia under the synonyms of Oje Blanco Doncel and Big Spanish respectively.

Where no other standards were available, in some cases both the standard and the NOVA samples were originally derived from the same mother tree. In three of these instances (Amelon, Hardy's Mammoth and Large Fruited) the NOVA fingerprint did not even match the standard from the same mother tree. This may have occurred by leaves being taken from different parts of the tree which could have been part rootstock and part scion, or simply a mix up with labelling during collection or in the laboratory.

Synonyms:
The investigation by Guerin et al (2002) and Guerin et al, in preparation, into the genetic identity of accessions within the NOVA collection has shown that many of the commercially used varieties known under different names have identical DNA fingerprints ie they are synonyms. Of the 100 NOVA accessions tested (which were supposedly 87 different varieties), only 55 different genotypes were detected. Table 2 lists the 44 NOVA accessions which have found to be synonyms with one of 15 other varieties in the collection.

While it was not surprising to find some synonyms, it was remarkable that 12 differently named varieties were of the same genotype as the Italian Frantoio. The synonyms, Paragon, Frantoja and Correggiola, have previously been reported (Archer, 1999; Mekuria et al., 1999) and the current work confirms these earlier results. The synonyms Emu Flat, Paragon and Mediterranean originated within Australia. This proliferation of new names has arisen through the collection and propagation of trees with good oiling potential but of unknown origin.

Others synonyms of Frantoio found in this study were Belle de Espagne, Bouteillon, Pueblana, Palsano, Lucca, Boothby's Lucca and Leccure. This indicates that Australia may not be the only country with naming confusion as there is documented evidence from the Blackwood collection to show that Pueblana, Bouteillon and Lucca were sourced directly from Italy and Frantoja from France. There is a small chance that all of these varieties were grafted on Frantoio rootstock that eventually overtook the scion material but this is unlikely. The Frantoja accession may simply have been a transcription error.

Oblonga has also been found to be a synonym of Frantoio (Barranco and Trujillo, 2000). However, while the accession named Oblonga from the NOVA trial was genetically identical to another NOVA sample named Frantago, it did not match the Italian Frantoio. Unfortunately the Oblonga accession developed a disease and was destroyed before any fruit could be analysed.

Three accessions of Verdale had different fingerprints with none of them matching the French Verdale Aglandau standard, although four other NOVA accessions did have the same fingerprint as the Verdale Aglandau standard. Verdale 2 matched the standard from USA that has also been shown to match other Australian accessions called 'SA Verdale' (Mekuria et al., 1999). Black Italian 1 and Californian Mission 2 also had matching fingerprints to the USA Verdale. Verdale 1 from Wagga Wagga (often called Wagga Verdale in Australia) showed high genetic similarity with Bouquettier and Blanquette late, and Verdale 3 was genetically similar but not identical to Large Pickling.

The microsatellites distinguished an extra 2 varieties (WA Mission and Gros Reddeneau) however it is likely that RAPD's would have achieved the same level of discrimination if more primers were applied (Guerin et al, in preparation).

Flowering

Table 4 shows that there was a moderate correlation between full bloom times and years of the different varieties. Table 5 shows in more detail (with even greater detail in Appendix tables A3-A5) the actual full bloom time of the trees. Some varieties full bloom dates were highly variable each year, for example the average variability of full bloom for trees in Group VI was 7 days either side of the mean. A variability of 2 days or less means we are 95% sure that the variety will reach full bloom within 4 days of the mean full bloom date at the Roseworthy site.

If we divide the time period between November 4 and November 14 (mean full bloom time all years) into 3 equal time categories of early, mid and late flowering, varieties are listed from earliest to latest flowering within each category, based on the means only.

Early flowering:	UC13A6, Arbequina, Gordal Sevillana, Barouni
Mid flowering:	Oblitza, Azapa, Atro Rubens, Barnea, Large Pickling, Manzanilla de Sevilla, Californian Mission, Picual, Hojiblanca, Verdale Aglandau, I77, Jumbo Kalamata, Pendolino, Black Italian (Blackwood), Group VII, Frantoio, Ascolano, WA Mission, Koroneiki, Benito, Souri, Group III, Leccino, Group V, Atroviolacea Brun Ribier, Gros Reddeneau, Nevadillo Blanco, Early Blanquette and Group II.
Late flowering:	Kalamata, Regalise de Languedoc, Amelon, Volos, Manaiki, Buchine, Pigale, FS17, Areccuzo, Institute and Rouget.

As the variance was not considered in determining these categories, there is likely to be a large amount of overlap at the borders of these categories and actual full bloom times will be different in different regions of Australia. Nevertheless, this information could be useful in regions that commonly suffer from late frosts as early flowering varieties should be avoided. As well, this could help varietal choice for cross pollination purposes by matching varieties with similar flowering times.

A survey of olive growers across Australia indicated that these categories are reasonable although some growers considered Manzanillo and Barnea to be early flowering varieties and Leccino to be a late flowering variety (Murray and Sweeney, 2005). In this study, both Manzanilla de Sevilla and Barnea were on the earlier side of the mid flowering group and Leccino was on the later side of the mid flowering group.

Nevadillo Blanco is generally regarded as an early flowering variety in Australia (Murray and Sweeney 2005, Ravetti, 2004a). Therefore this particular Nevadillo Blanco accession, which was on the later side of mid flowering time, may not be genetically the same as other Nevadillo Blancos reported in the literature.

Coratina and SA Verdale are two important varieties in Australia not mentioned in this list due to their more variable full bloom times. With less confidence, it could be said they are both early flowering varieties.

Harvest Timing

Table 6 shows that there was only a moderate correlation between harvest dates and years of the different varieties. This may reflect the young age of the trees and with maturity they may ripen more consistently at the same time each year.

Tables 7 and 8 reflect this variability in harvest timing and should be used with caution. Some varieties such as Dr Fiasci, Volos, Souri and Blanquette – Early, only have very limited available data to analyse. Many varieties only have two years of data to analyse. As previously stated, the trees immaturity may cause variability in ripening time.

By evenly dividing the time period from April 21 to June 29 (range of harvest dates for all years for trees with 3 years of data) into 3 groups, the following list places the varieties into one of the groups, depending on when they reach a maturity index of 3. Early – by the end of April, mid – by June 6 and late – after June 6. Only varieties with 3 years of data are included (except Koroneiki, which had fruit taken by birds in 2002).

Early	UC13A6, Pendolino and Group I.
Mid	Leccino, Group VI, Mission (Californian), Manzanilla de Sevilla, Benito, Gordal Sevillana, Barouni, Verdale (SA), Barnea, Group VII, Frantoio, Hojiblanca, Oblitza and Kalamata
Late	Rouget, Picual, Group III, I77, Arbequina, Atro Rubens, Verdale Aglandau, Manaiki, Koroneiki, Coratina, Areccuzo, Azapa, Katsourela, Jumbo Kalamata, Mission (WA), Columella and Large Pickling.

As for flowering, variance was not considered and there will be a large amount of overlap at the category boundaries and actual ripening times will be different in different parts of Australia. Nevertheless, knowing approximately when varieties will ripen assists with planning harvesting and processing.

Fruit Yields

The better and poorer performing varieties in terms of average "adjusted" fresh fruit yield from 2002-2004 (2.5-4.5 year old trees) are clearly indicated in Table 9. The trees are still young and as mentioned in the methodology, planting material was variable creating a large nursery effect.

Varieties at the top of the average "adjusted" yield list in Table 9 such as Picual, UC13A6, Barnea, Hojiblanca, Arbequina, Koroneiki (not listed, see explanation in results), Group VII and Manzanilla de Sevilla appear to be high yielders at an early age (without considering statistical significance). However, some varieties such as Rouget, Oblitza, Group III, Jumbo Kalamata, Benito, Leccino and FS17 possibly did not yield well early on due to poor quality or immature planting material but appear to be rapidly catching up based on their 2004 yields.

Also of interest is that some varieties such as UC13A6, Large Pickling, Group VI, Coratina, Barouni, Blanquette – Early, Institute, Ascolano, Buchine, Verdale (Blackwood) and Kalamata, yielded much better in 2003 than in 2004. This is also reflected in the poor correlations between varieties and years in table 11. This may indicate that even though alternate bearing is supposedly less apparent in young trees (Lavee, 1996), these particular varieties have already started an alternate bearing pattern in only their fourth year.

The unadjusted 2004 yield for the Stage I plantings (5 year old trees) shows that average yields for even the better performing 5 year old varieties, ranging up to 17.2 kg per tree per variety are not as high as reported elsewhere in the world for irrigated trees of this age (Civantos 1996). As discussed previously, there were problems with the irrigation system due to line damage by hares when the trees were very young. As well, the varieties were all pruned to a single trunk free canopy, which may not be the ideal form for some varieties. Although soil moisture sensors were used to apply water when required, irrigation quantities applied to the young trees at Roseworthy were quite low, therefore the trees may have been underirrigated, causing reduced yields. However, generally the trees were healthy and well maintained. Although some individual trees did yield up to 30 kg (unpublished data), these average yield results may reflect realistic yields across a whole grove in Australia.

Of particular interest, Kalamata, Frantoio and its close relative WA Mission, widely planted and highly regarded varieties in Australia (Murray and Sweeney, 2005), performed very poorly yield wise in their early years. Presumably their yields will improve as the trees age but this early data indicates they may not be suitable for those seeking high, early yields from their trees.

Fruit Analyses

Oil Content in Dry Flesh

Oil content was represented as a percentage of dry matter rather than fresh weight, as the former variable reaches a maximum value and then stays constant whereas the latter tends to increase with ripening. This occurs because oil synthesis in olives stops after a certain ripening stage whereas the water content decreases (Di Giovacchino, 1996). In addition, the dry flesh oil percentage is more stable than the whole dry fruit oil percentage (Del Rio and Romero, 1999) and is more useful in characterising olive varieties. However, it cannot be directly equated to the amount of oil that can be extracted from the fruit in a commercial processing plant because of factors such as; ease of oil extraction, polydispersity of flesh to pit ratios and variation in moisture contents across orchards.

There was no significant effect of either fruit maturity (within the range of maturity indices of 1-7) or tree age on the oil percentage in the dry flesh at the $p < 0.05$ level (Tables 16 and 17). This shows that young trees can yield as much oil as older trees and leaving the fruit on the trees for longer than the optimal harvest time of maximum oil accumulation will not increase oil yield in the fruit.

There were however differences in oil content observed across the different varieties examined. If Picual is used as an indicator of a recognised high oil yielding variety then a number of varieties with higher yields than Picual, show promise as high oil yielders to the extent that oil percent in dry flesh is a predictor of oil yield (Table 13). These varieties are, in order from highest oil content in dry flesh: Buchine, Group V, Gros Reddeneau, Manaiki, Group IV, Arbequina, FS17, Atro Rubens, Barnea, Regalise de Languedoc, Volos, Souri, Mission (WA), Frantoio, Coratina, Columella, Nevadillo Blanco, I77, Ascolano, Kalamata, Gordal Sevillana, Pigale, Verdale Aglandau, Verdale (Blackwood), Oblitza and Group I

It should be noted though, that many of these varieties listed above have yielded poorly at Roseworthy so would not produce a large quantity of oil. There are also many other factors to consider when assessing suitability for oil production such as ease of oil extraction and oil composition, so oil content in dry flesh alone should not be the only variable used for selecting good oiling varieties. This is highlighted by the fact that a number of varieties regarded as high oil yielders such as Koroneiki and Californian Mission (International Olive Oil Council, 2000) did not have particularly high (but not significantly less than Picual) oil contents. This may mean that their oil is particularly easy to extract using commercial processing techniques.

Only Azapa, Praecox and UC13A6 had a significantly lower oil percentage in dry flesh than Picual. Only Buchine and Group V had significantly higher oil percentage in dry flesh than Picual.

Fruit Weight

Large fruit are usually highly desired for table olives. Given that Manzanilla de Sevilla is a recognised table olive variety it would seem that those varieties in Table 13 larger than Manzanilla de Sevilla should be suitable for table olives. These are (in descending order of size): Jumbo Kalamata, UC13A6, Gordal Sevillana, Ascolano, Buchine, Barouni, Volos, Group I, Verdale (SA), Amelon, Azapa and Benito. Buchine is interesting as it also has a very high oil content in the dry flesh but it has not yielded well at Roseworthy so far.

Fruit weight is one of the main variables, along with fruit removal force, considered when assessing the suitability of an olive variety for mechanical shaking at harvest (Civantos, 1996). If all other variables are equal, Table 13 shows that varieties with fruit weighing less than 3g such as Black Italian (Blackwood), Rouget, Group IV, Group II, Dr Fiasci, Arbequina, Areccuzo, Koroneiki and Praecox, may not be dislodged by mechanical shaking as easily as some of the varieties with heavier fruit discussed previously. However, a further complication is that many of these larger fruit are picked as green table olives that may not be suitable for mechanical harvest anyway due to susceptibility to bruising.

Tables 16 and 17 shows that fruit increases in weight with increasing fruit maturity but tree age has no effect on fruit weight.

Water in whole fruit

High water content of fruit can make commercial oil extraction difficult due to oil/water emulsions being formed during malaxation (Di Giovacchino, 1996). Fruit with greater than 60% moisture has been shown to greatly reduce extraction efficiency in Australia (Ravetti, 2004b). This study shows the relative differences between varieties in water content of the fruit. Although these varieties were not all harvested at the same time so there were opportunities for differences in rainfall events before harvest, the figure is averaged over 3 years so it should be a good indicator of varieties which have a natural predilection for absorbing moisture in their fruit or not. Varieties with greater than 60% moisture in descending order of water content were: Institute, UC13A6, Benito, Rouget, Verdale (SA), Group VI, Gordal Sevillana, Group III, Manzanilla de Sevilla, Ascolano, Regalise de Languedoc, Oblitza, Picual, Hojiblanca, Areccuzo, Jumbo Kalamata, FS17, Barouni, Columella, Group VII, Azapa, Katsourela, Pendolino, Group I, Barnea, Praecox,
Atro Rubens, Black Italian (Blackwood), Arbequina, Leccino, Souri and Verdale Aglandeau.

Some of these varieties are only used for table fruit where high water content is not an issue. However, many of these varieties are commonly used for oil in Australia such as Verdale (SA), Manzanilla de Sevilla, Picual, Hojiblanca, FS17, Pendolino, Barnea, Arbequina and Leccino and will need particularly careful irrigation management before harvest to avoid high fruit moisture content. They may not be suitable for areas which commonly experience rainfall around harvest time.

Conversely, those varieties with naturally low fruit moisture content may be more suited for oil production for areas which commonly experience rainfall around harvest time. Those varieties with less than 60% fruit moisture (in descending order of water content) are: I77, Manaiki, Group II, Amelon, Large Pickling, Nevadillo Blanco, Group IV, Kalamata, Volos, Dr Fiasci, Atroviolacea Brun Ribier, Pigale, Mission (Californian), Blanquette – Early, Gros Reddeneau, Verdale (Blackwood), Coratina, Mission (WA), Frantoio, Group V, Buchine and Koroneiki.

It is interesting to observe that Californian Mission and Koroneiki were noted for having relatively low oil contents in the dry flesh but are regarded as good oiling varieties. This may be due to the fact that they do not naturally absorb large amounts of water in the fruit.

Table 16 shows that increasing maturity does have a significant effect on reducing fruit water content which is why more mature fruit may tend to release more oil when processed. Rather than forsaking oil quality, it would be better to manage fruit water content to facilitate processing at a more desirable level of ripeness. Table 17 also shows that younger trees tend to contain more water in the fruit. Therefore, varieties with high fruit waster content may tend to absorb less moisture as they get older.

Flesh to pit ratio

Flesh to pit ratio is an indicator of suitability of olives for table fruit with a ratio greater than 5:1 being regarded as desirable (Burr, 1998). Table 13 shows that virtually all of the varieties have ratios greater than 5:1, indicating their suitability for table olive production. However, there are many other factors such as shape, ease of pitting, colour and texture that are also of great importance (Garrido Fernandez *et al.*, 1997) that are not considered in this study.

Kalamata is considered a superior table olive in Australia (Murray and Sweeney, 2005). Those varieties that have flesh to pit ratios greater than or equal to Kalamata (8.1), in descending order are: Ascolano, Regalise de Languedoc, Institute, FS17, UC13A6, Manzanilla de Sevilla, Jumbo Kalamata, Gordal Sevillana, Azapa, Manaiki, Rouget, Volos, Oblitza, Hojiblanca, Barouni, Souri, Verdale Aglandau, Barnea, Columella, Atro Rubens, Buchine, Benito, Blanquette – Early, Group III, Picual, Coratina and Katsourela.

Some of these varieties such as FS17 and Rouget have small fruit but would possibly still make good eating olives due to their high flesh to pit ratio.

As for fruit weight, Table 16 shows that flesh:pit ratio increase with maturity. Interestingly, table 17 shows that younger trees have a higher flesh to pit ratio even though fruit weight was not affected by age.

Fatty acid composition

The following fatty acids were evaluated:

Monounsaturated:	Oleic and Palmitoleic acids
Polyunsaturated:	Linoleic and Linolenic acids
Saturated:	Palmitic and Stearic acids

The ranges of fatty acid composition for most of the varieties listed in Table 14 fall within the accepted limits for fatty acid composition of Virgin Olive Oil (International Olive Oil Council, 2001). However the exception is for linolenic acid where a number of varieties recorded levels higher than the 1% limit. In descending order these were: Verdale (SA), Group II, Gordal Sevillana, Rouget, Areccuzo, Benito, I77, FS17 and Katsourela.

Growers producing olive oil from these varieties should be aware of their susceptibility in producing levels of linolenic acid above the accepted limit. They may need to blend their oils to reduce linolenic acid levels.

A high level of oleic acid is considered favourable in olive oil due to enhanced oxidative stability (Smouse, 1996) and superior nutritional quality (Kritchevsky, 1996). Those varieties in Table 14 with oleic acid levels greater than Picual, which is noted for having high oleic acid levels (Beltran et al, 2004) in descending order are: Group IV, Black Italian (Blackwood), Group VI, Group V, Koroneiki, Buchine, Kalamata, Mission (Californian), Leccino, Regalise de Languedoc and I77.

Similarly, a high ratio of monounsaturated:polyunsaturated fatty acids in the oil should confer stability to the oil (Aguilera et al 2005, Aparicio and Luna 2002, Aparicio et al 1999, Beltran et al 2005, Beltran et al 2004). Table 15 shows derived ratios averaged from 2002-2004. Those varieties with a ratio higher or not significantly less than Picual, once again noted for having highly stable oil (Beltran et al, 2004) in descending order are: Black Italian (Blackwood), Group V, Group IV and Koroneiki. Consequently their oil should also be highly stable.

A high level of saturated fatty acids is not desirable for the human diet (Grande Covian, 1996). Varieties with high levels of saturated fatty acids such as Blanquette Early, Large Pickling and Katsourela would produce less healthy oil than those with lower levels such as I77, Group IV and Kalamata.

Effect of fruit maturity on fruit characteristics

Table 16 shows that stearic acid (a saturated fatty acid) content increased with increasing maturity in each year, and overall there was a significant ($P < 0.001$) effect of 0.163. This means that for each increase in maturity there is a 0.163% increase in stearic acid. For oleic acid (monounsaturated), there was a significant effect ($p = 0.006$) indicating that for an increase in a maturity unit there was a decrease of 0.61% in oleic acid content. There were also significant increases in linoleic (polyunsaturated) and palmitoleic (monounsaturated) acids with maturity but no effect on palmitic (saturated) and linolenic (polyunsaturated) fatty acids.

This would indicate on balance that less mature fruit are more desirable for oil quality due to the higher levels of oleic acid which dominate the desired monounsaturated fatty acids and lower levels of linoleic and stearic acid.

These results only partially confer with others in the literature. Guttierrez et al (1999) found that in Picual and Hojiblanca, levels of palmitic and linolenic acid fell during ripening and oleic, palmitoleic and stearic acid did not change. They also found that levels of linoleic acid and oil content in dry flesh increased with ripening. Aparicio and Luna (2002) reports that one study found that oleic acid increase with ripeness in Leccino and Frantoio, while the content of linoleic acid rose with ripeness in Coratina but decreased in Leccino and Frantoio. Beltran et al (2004) found that in Picual, palmitic, stearic and linolenic acids decreased during ripening while oleic and linoleic increased. Their differences (except for linoleic acid increases) compared with our results may be because they studied individual varieties, whereas our results are of all varieties at Roseworthy combined.

Effect of tree age on fruit characteristics

In Table 17, although there appears to be some effects of tree age, they are not consistent across years and as a result the pooled effect was not significant for most fruit characteristics. Stearic acid and flesh:pit ratios were the exception. In view of the number of hypotheses being tested, some ‘significant’ effects would be expected to appear by chance. In view of this no biological significance was attributed to the effect of planting date (or tree age).

There is general feeling that younger trees will give different fruit characteristics than older trees (Murray and Sweeney, 2005) but our study, at least in the fruit characteristics that were studied, show there is little difference in younger and older trees (up to the age of 5 years old).

Commercial Scale Evaluation

As discussed previously, only the Roseworthy trees in this part of the project were DNA tested, so correct variety identification cannot be guaranteed. However, as also discussed previously, the majority of the well known commercial varieties grown in Australia appear to be correctly identified so it probably only the less well known names in this survey that we are less sure of their true identity.

It is difficult to draw many major conclusions in tables 20 and 21 due to the small number of replication for some varieties and consequent high LSD’s. In table 20, the only variety with significantly less oil in the flesh than Picual, which was used as a standard known oil variety previously, was UC13A6. The variety with the highest oil % in dry flesh (65.35%) was called Leccure. The accession called Leccure in the Roseworthy collection had the same genetic fingerprint as Frantoio, so this particular Leccure from the D5 climatic region may also be Frantoio.

Of particular interest for ease of processing are those varieties that do not tend to naturally contain a high water content in their fruit. Those varieties with a significantly lower water % in the whole fruit than Manzanilla de Sevilla (known to have inherently high fruit water content (Murray and Sweeney, 2005)), in descending order were: Atroviolacea Brun Ribier, Bouteillon, Paragon, Gros Reddeneau, Pueblana, Group V, Corregiola, Leccure, Koroneiki, Frantoio, Black Italian and Mission (WA).

In table 20, varieties with significantly similar levels of oleic acid as the highest variety (Group IV) include: Black Italian (Blackwood), Katsouroniki, Koroneiki, Picual, Group VI, Group V, I-77, Buchine, Coratina, Leccino, Regalise de Languedoc, Mission (Californian), Hojiblanca and Kalamata.

Varieties with greater than 1% linolenic acid, in descending order were: Verdale (SA), Benito, Sevillano, Group VI, Gordal Sevillana, Rouget, Areccuzo, Group I, Verdale (Wagga), FS 17, Hardy's Mammoth, Group II and Oblitza.

Varieties with significantly similar levels of palmitic acid as the highest variety (Katsourela) were: Priole, Large Pickling, Blanquette – Early, Group II, Azapa, Pigale, Verdale Aglandau, Praecox, Verdale (SA), Benito, Rouget, Group III and Arbequina.

Estimation of Environmental Effects

One of the main aims of this project was to determine the suitability of different olive varieties for different regions of Australia. The agro-climatic classification described previously was considered a suitable system to stratify Australia into different regions as it is largely temperature based. As stated previously, temperature during the oil accumulation phase (January – May) is likely to have the greatest effect on oil quality.

Tables 22-24 (and associated sub-tables) look in detail at the environmental effects on the fatty acid profile and fruit characteristics of Manzanillo, Frantoio and Paragon.

Fatty Acid Profile

Tables 22a, 23a and 24a show that the different agro-climatic zones have a significant effect on fatty acid levels except for linolenic acid in all varieties and stearic acid in Paragon.

Although not significant, it is interesting to note just how low linolenic levels are in the I3 region for Manzanillo (22a) compared with the other regions.

Levels of oleic acid were significantly highest in Zone D5 for all three varieties, with zones E1 and E2 showing slightly higher levels than the other zones.

Levels of palmitic acid were generally significantly less in Zone D5 for all three varieties with a general trend for zones E1, E2 and E6 showing lower levels than the other zones. It was also interesting to note how high palmitic levels were in the I3 zone for Manzanillo.

Linoleic levels generally tended to be lower in D5 than the other zones.

Differences in temperature and elevation are considered to have considerable influence on fatty acid composition. In a review on monovarietal olive oils, Aparicio and Luna (2002) report that palmitoleic acid is higher at lower altitudes and linoleic acid is lower at lower altitudes. They also state that it is well known that the percentage of unsaturated fatty acids increases with decreasing temperature or increasing altitude. Beltran et al (2004) reported that lower ripening temperatures reduced palmitic acid and increased oleic acid in Picual. Aguilera et al (2005), showed that at higher altitude, the oils of Leccino and Frantoio showed a higher content of oleic acid. Rial and Falque (2003), also showed that Picual grown at higher altitudes show higher contents of oleic acid and lower levels of palmitic, linoleic and linolenic acid.

Tables 22b, 23b and 24b take a closer look at how much these environmental effects are likely to be contributing to differences between the agro-climatic zones in our study. For example, table 22b shows that for palmitic acid, for all the variation between the agro-climatic zones, 92% can be accounted for by temperature and 7% by elevation. In all three varieties, temperature has a much greater effect than altitude on fatty acid levels, except for linolenic acid, which is not affected by either altitude or temperature.

Tables 22c, 23c and 24c then look at how temperature affects fatty acid levels across agro-climatic zones. Table 25 also looks at the effect of temperature on 5 more varieties. Temperature has a significant effect in all varieties on palmitic and oleic acid, in all cases increasing palmitic levels with increasing temperature and decreasing oleic levels with increasing temperature. For example, for each degree increase in temperature, Manzanillo increases in palmitic by 0.779% and decreases in oleic by 1.77%.

Given that palmitic and oleic acid levels are so significantly affected by temperature, table 22a (Manzanillo is the only variety represented in all zones) indicates that Zones I3, E3, E7, F3, E4 have higher temperatures during the oil accumulation phase, followed by, E6, E2, E1 with D5 substantially cooler than the other 8 zones.

For agro-climatic zones with higher temperatures during oil accumulation, varieties that are less affected by temperature than others in terms of oleic acid may be most suited (Dr Marino Uceda, Pers comm.), assuming that variety will grow there to begin with. Table 25 shows that of these 8 varieties, oleic acid levels in Koroneiki decrease less than the other 7 varieties per degree increase in temperature. Koroneiki is also the only variety that does not have a significant increase in linoleic acid per degree increase in temperature. However, palmitic levels in Koroneiki increase more than in the other varieties per degree increase in temperature, although Koroneiki has relatively low levels of palmitic acid to start off with (Table 21).

In terms of the other fatty acids, table 25 shows that there is a significant increase in palmitoleic acid per degree increase in temperature, except for Nevadillo Blanco. Temperature has no effect on linolenic acid and an inconsistent effect on stearic acid. For Manzanillo, Paragon, Corregiola and Leccino, there is a significant increase (and for Frantoio approaching significant increase) in stearic acid for each degree increase in temperature. For Barnea, Nevadillo Blanco and Koroneiki, there is a slight (although non-significant) reduction in stearic acid per degree increase in temperature.

Fruit Characteristics

Tables 22d, 23d and 24d show there is a significant difference in % oil in the dry flesh for Frantoio between the agro-climatic zones, approaching significance for Manzanillo and no significant difference for Paragon. For both Frantoio and Manzanillo Zone F3 has the highest level of oil in the dry flesh and for Paragon, Zone F3 was not represented.

Interestingly, despite differences in rainfall between climate zones (Hutchinson et al, 2005) there was not a significant difference in water content of the whole fruit between climatic zones, although it was approaching significance for Manzanillo. Presumably this is partly confounded by irrigation.

There were differences in fruit weight, particularly for Manzanillo and Paragon (Frantoio approaching significance) with Zone E7 having the highest fruit weight in Manzanillo and Paragon (Frantoio not represented in E7). Zone D5 had the lowest fruit weights for all 3 varieties.

There was also a significant difference in flesh:pit ratio in Manzanillo with Zone D5 having a significantly lower flesh:pit ratio than some of the other zones. Differences in flesh:pit ratio were approaching significance for Frantoio but there were no significant differences for Paragon.

Similarly to the fatty acid profile, Tables 22e, 23e and 24e look at the relative contribution to effect of agro-climatic zone of elevation and temperature on fruit characteristics. Elevation and temperature contribute very little to % oil in dry flesh for all 3 varieties and water in the whole fruit for Manzanillo and Frantoio but to some extent in Paragon. However, temperature does appear to contribute considerably toward fruit weight and flesh:pit ratio in all 3 varieties.

Tables 22f, 23f, 24f and 26 looks at the effect of temperature on fruit characteristics for Manzanillo, Frantoio and Paragon, plus 5 extra varieties. Table 26 in particular shows that temperature does have a significant effect on % oil in dry flesh on some varieties, with Barnea increasing 1.3% with every degree increase in temperature and Leccino decreasing by 1.5% and Koroneiki decreasing by 3.7% with every degree increase in temperature. This may suggest that Barnea is more suited to warmer climates than Leccino and Koroneiki.

Paragon was the only variety showing any significant difference in water content due to temperature, increasing slightly with increasing temperature. As stated previously though, irrigation may have had an effect.

All varieties showed a significant weight increase with increasing temperature and only Koroneiki showed no significant increase in flesh:pit ratio with increasing temperature. This indicates that warmer climates are more conducive to producing superior table olives, in terms of size and flesh:pit ratio.

6. Implications

Varietal identification of the National Collection

The identification of genetically identical synonyms is of enormous significance to the Australian olive industry. Many of these supposedly different varieties have been popular choices due to their good oiling reputation. It is now possible to ensure that groves, which are planned to contain different varieties, do not inadvertently contain genetically identical material with consequent deleterious impacts on pollination efficacy and fruit set (Wu et al., 2000), and ultimately financial return.

The plethora of variety names is also confusing for variety selection and labelling of varietal oils and table fruit. As well, the product end-use will depend on the type of olive produced. The variety names Belle de Espagne and Big Spanish are likely to be associated with table fruit, whereas the accessions grown in the NOVA trial were genetically similar to Frantoio and Arbequina respectively, which are both oiling varieties with small fruit.

Not only were there many misnamed varieties in the NOVA collection, in 11% of the samples, the 6 replicate trees were not identical and the anomalous trees are being removed from the collection. This result highlights the difficulties in initially recognising specific varieties and subsequently ensuring that lines are reliably maintained.

Care must be taken in interpretation of the results to confine them to the individual trees tested and not to extrapolate to all accessions of the same name, as they may have different genotypes. For example the Palermo fingerprint from Blackwood did not match the Palermo fingerprint from Roseworthy and the Tarascoa from Roseworthy did not match Tarascoa from Wagga Wagga.

Mekuria et al. (1999) and Gemas et al. (2000), have shown that intra-variety variation in olives has been detected using the RAPD technique. However, not all clonal selections can be distinguished by DNA fingerprinting where differences have arisen through somatic mutation and may occur at only one or more sites in the genome (Bowers et al., 1993). Small changes in the genetic structure would be difficult to detect using RAPD, or any other genotyping method, but may affect the agronomic performance of the tree (Guerin et al, 2002).

The NOVA collection is also providing physiological data for each accession that will be important to compare with the DNA fingerprinting results in the future. Varieties with similar RAPD fingerprints but differing in agronomic qualities could be studied to find genetic markers for those traits (Guerin et al, 2002).

Flowering and Harvest Timing

The broad groupings for some varieties developed in this study of early, mid and late flowering and harvest timing will assist growers in regions that commonly suffer from late frosts as early flowering varieties should be avoided. As well, they could help varietal choice for cross pollination purposes by matching varieties with similar flowering times and assisting with planning for harvesting and processing

Fruit Yields

The relative fruit yield results for the trees at Roseworthy clearly show the better and poorer performing varieties in relative terms of fruit yield. However, average yields for even the better performing 5 year old varieties at Roseworthy, ranging up to 17.2 kg per tree per variety are not as high as reported elsewhere in the world for irrigated trees of this age. Although some individual trees did yield up to 30 kg (unpublished data), these average yield results may reflect realistic yields across a whole grove in Australia.

Of particular interest, Kalamata, Frantoio and its close relative WA Mission, widely planted and highly regarded varieties in Australia, performed very poorly yield wise in their early years. Presumably their yields will improve as the trees age but this early data indicates they may not be suitable for those seeking high, early yields from their trees. As well, some varieties were already showing tendency toward alternate bearing, even at this young age.

Oil Content in Dry Flesh and Water Content in Whole fruit

A number of varieties known as high oil yielders did not have particularly high oil contents in the dry flesh. This is probably due to their inherent low fruit water content facilitating processing.

Some of the varieties commonly used for oil in Australia such as Verdale (SA), Manzanilla de Sevilla, Picual, Hojiblanca, FS17, Pendolino, Barnea, Arbequina and Leccino will need particularly careful irrigation management before harvest to avoid high fruit moisture content and may not be suitable for areas which commonly experience rainfall around harvest time. Conversely, those varieties with naturally low fruit moisture content may be more suited for oil production for areas which commonly experience rainfall around harvest time.

Fatty acid composition

The linolenic acid levels for many of the varieties was higher than the IOOC limit of 1.0% set for virgin olive oil. Those producers using these varieties for virgin oil production should be aware of this factor. If these oils are tested in export markets and found to exceed the allowable linolenic acid limits, the virgin classification of the olive oil may be in question.

The results indicate on balance that less mature fruit (within the range of fruit maturities received) are more desirable for oil quality due to the higher levels of oleic acid which dominate the desired monounsaturated fatty acids and reduced levels of linoleic and stearic acid.

Estimation of Environmental Effects

Average temperature during the fruit accumulation was found to significantly affect most fatty acid levels except for linolenic acid. Oleic acid was found to decrease in warmer environments.

For agro-climatic zones with higher temperatures during oil accumulation, varieties that are less affected by temperature than others in terms of oleic acid may be most suited (Dr Marino Uceda, Pers comm.), assuming that variety will grow there to begin with. Oleic acid levels in Koroneiki decreased less with increasing temperature than the other varieties evaluated in this study.

7. Recommendations

The DNA typing of the National Collection at Roseworthy has made significant advances into the positive identification of olive varieties in Australia. This database is now available to be utilised by the industry, particularly by propagation facilities, to ensure positive identification of olive varieties in the future. However it is necessary for there to be recognition of the importance of correct varietal identification and sufficient demand for this service to enable the testing to be done on a commercially viable basis.

The collection at Roseworthy is unique in that every tree has been DNA typed as well as being evaluated physiologically. The collection can provide the Australian industry with reliable genetic material and could be the basis of a plant improvement collection for the industry.

However the trees have yet to reach maturity and data collection and evaluation needs to continue for a number of years to gain a full picture of the variety production potentials. Sensory evaluation, such as in Appendix E, should also be performed to give more quality information on the olive oil.

The industry should consider providing funding to maintain the collection at Roseworthy until such a time when more funding becomes available to continue evaluation.

Some varieties such as Buchine and accessions in Group IV and Group V show particular promise in terms of high oil content, high oleic content and low fruit moisture content. However they have yielded poorly at Roseworthy. This may just be due to bad planting material due to poor condition of parent trees and these varieties should be further evaluated across other agro-climatic zones.

Linolenic acid is inherently high in some olive varieties and producers should ensure they test the oil produced from these varieties for linolenic acid levels and take action if necessary such as blending with oil with low linolenic acid levels.

Irrigation management for controlling fruit water content is an important issue for the Australian industry and warrants further research, as the varieties that naturally have high water content have already been widely planted for oil production, either under irrigation or in climate zones that have high rainfall around harvest time.

The laboratory method described for extracting oil from the olive samples, while useful, does not duplicate conditions in commercial processing plants. An experimental processing facility is needed to monitor quality of oil produced under realistic commercial processing conditions with the type and quality of fruit being processed. Such a machine should be of the order of 50kg/hr. With this small processing mill it would be possible to forge the links between fruit maturity and quality at harvest and oil quality and yield in an environment which relates to that in commercial mills. In particular several parameters need to be investigated (in addition to fatty acids and oil content). These include: total phenolics and the compounds responsible for bitterness and pungency in olive oil: oleauropin and deacetoxy.

Appendices

Appendix A Comparison of full bloom times

Tables A.1 and A.2 are results of analyses of variance. The means are given in Table 4. A Levine's test was used to compare the variability of the varieties.
There were significant differences between the flowering times of varieties. As a guide, differences of 5 days are significant at the P < 0.05 level. There were also differences between the variability between varieties.

Table A.1 Comparison of means

		2002		
Source of variation	d.f.	s.s.	m.s.	v.r.
Variety	42	4394.89	104.64	4.96
Residual	226	4765.88	21.09	
Total	268	9160.77		
		2003		
Source of variation	d.f.	s.s.	m.s.	v.r.
Variety	55	1121.483	20.391	2.6
Residual	442	3465.16	7.84	
Total	497	4586.643		
		2004		
Source of variation	d.f.	s.s.	m.s.	v.r.
DNA	55	1054.006	19.164	5.55
Residual	500	1726.776	3.454	
Total	555	2780.78		

Table A.2 Comparison of variability of varieties

		2002		
Source of variation	d.f.	s.s.	m.s.	v.r.
Variety	56	2024.067	36.144	10.39
Residual	543	1888.597	3.478	
Total	599	3912.664		
		2003		
Source of variation	d.f.(m.v.)	s.s.	m.s.	v.r.
DNA	55	448.252	8.15	3.29
Residual	442(92)	1093.44	2.474	
Total	497(92)	1482.46		
		2004		
Source of variation	d.f.	s.s.	m.s.	v.r.
Variety	55	284.758	5.177	3.26
Residual	534	847.436	1.587	
Total	589	1132.194		

Table A.3 Full bloom dates for trees in 2001. Units are number of trees.

Variety	22/10/2001	25/10/2001	28/10/2001	31/10/2001	03/11/2001	06/11/2001	09/11/2001	12/11/2001	15/11/2001	18/11/2001	21/11/2001	24/11/2001	27/11/2001	Total
Arbequina		2	8		6									16
Areccuzo								2	4					6
Ascolano				2	1	1								4
Atro Rubens					2									2
Azapa					6									6
Barnea				4	2									6
Barouni			2	4										6
Benito					2	4								6
Black Italian (Blackwood)						3		1						4
Columella		2			2									4
Coratina			3	1			1							5
Frantoio					5	5	1	1						12
Gordal Sevillana			3	6	2	2	2							15
Gros Reddeneau							1							1
Group I		2			1									3
Group II							2							2
Group III						1	2	2						5
Group IV				1	2	1	1		1					6
Group V						1	2							3
Group VI			4								1	1		6
Group VII					3	6	2	1						12
Hojiblanca					5	1		1						7
I77					6									6
Jumbo Kalamata						1	5							6
Kalamata						3	2	1						6
Katsourela									2	2				4
Koroneiki				5	1	4	2							12
Large Pickling					5	1								6
Leccino							1							1
Manaiki							4							4
Manzanillo				5	1		5							11
Mission (Californian)					2									2
Mission (WA)						2								2
Oblitza				4		2								6
Pendolino					6									6
Picual				4	9	2								15
Pigale								1	1	1				3
Queen of Spain				1			1	1						3
Rouget								4	2					6
Souri				1	1	1								3
UC13A6			1											1
Verdale (SA)	8	2		5	1						1	1		18
Verdale Aglandau				1	5	3	1	1						11

Table A.4 Full bloom dates for trees in 2002. Units are number of trees.

DNA Match	1/11/2002	4/11/2002	7/11/2002	10/11/2002	13/11/2002	16/11/2002	19/11/2002	22/11/2002	25/11/2002	28/11/2002	1/12/2002	Total
Amelon			1									1
Arbequina	14	4										18
Areccuzo		1	4	1								6
Ascolano		3	3									6
Atro Rubens	4									1		5
Atroviolacea Brun Ribier		3										3
Azapa		4	2									6
Barnea	3	9										12
Barouni	4											4
Benito		1	4	1							2	8
Black Italian (Blackwood)	4	1	1									6
Blanquette - Early										1		1
Buchine												0
Columella		6										6
Coratina	5											5
Dr Fiasci			1	4								5
Frantoio		42	26									68
FS17		2	4									6
Gordal Sevillana	16	1										17
Gros Reddeneau	5	1										6
Group I	9	8										17
Group II		2	8	2								12
Group III	7	9										16
Group IV	9	2	1									12
Group V	1	9	17									27
Group VI										6		6
Group VII		10										10
Hojiblanca		15	2									17
I77		2	3									5
Institute												0
Jumbo Kalamata	3	3										6
Kalamata			4	2								6
Katsourela												0
Koroneiki		3	9									12
Large Pickling		6										6
Leccino		1	2	1								4
Manaiki			2	2								4
Manzanillo	12	4	1									17
Mission (Californian)		7	5									12
Mission (WA)		1	5									6
Nevadillo Blanco	1	4	1									6
Oblitza	5	1										6
Pendolino		5	1									6
Picholine												0
Picual		15										15
Pigale			2	4								6
Praecox												0
Queen of Spain		1										1
Regalise de Languedoc		1	3	1								5
Rouget			2	4								6
Souri		1	2									3
UC13A6	5									1		6
Verdale (Blackwood)												0
Verdale (SA)	3									15		18
Verdale Aglandau	3	17	3									23
Volos		2										2

Table A.5 Full bloom dates for trees in 2003. Units are number of trees.

Variety	12/11/2003	13/11/2003	15/11/2003	16/11/2003	17/11/2003	18/11/2003	19/11/2003	20/11/2003	21/11/2003	22/11/2003	23/11/2003	24/11/2003	25/11/2003	Total
Amelon					3		2							5
Arbequina		1	3	1	2	9	2							18
Areccuzo							2	4						6
Ascolano							6							6
Atro Rubens					2	1	2							5
Atroviolacea Brun Ribier						3	2							5
Azapa					2		3					1		6
Barnea						1	9	2						12
Barouni				3	2	1								6
Benito						2	3				1			6
Black Italian (Blackwood)				3	1	1	1							6
Blanquette - Early							1							1
Buchine							2		1	1				4
Columella				1	1	4								6
Coratina			1											1
Dr Fiasci							1		2					3
Frantoio				2	8	8	31	17	6	4	2			78
FS17					1		5							6
Gordal Sevillana	1		1		5	5	5							17
Gros Reddeneau						4	1	1						6
Group I			6	4	5	2	1							18
Group II							17			1				18
Group III				1	11		6							18
Group IV					2	6	3		1					12
Group V				1	4	1	14	1	3	2	2			28
Group VI	2			2		2								6
Group VII				1	1	6	3				1			12
Hojiblanca					2	4	11							17
I77						2	3		1					6
Institute					1				1			3	1	6
Jumbo Kalamata			1	1	1	1	2							6
Kalamata								2	2	1				5
Katsourela							2	1				1	1	5
Koroneiki							11	1						12
Large Pickling						2	4							6
Leccino						3	1							4
Manaiki							2	1		1			2	6
Manzanillo					6	3	7					1		17
Mission (Californian)			2		5		2	1	1					11
Mission (WA)							2	3		1				6
Nevadillo Blanco				2	1	1	2							6
Oblitza				2	1	3								6
Pendolino							4	2						6
Picual					2	2	10	1						15
Pigale							3	2	1					6
Praecox							4	2						6
Queen of Spain								1	1					2
Regalise de Languedoc							4	1						5
Rouget								2	1		2			5
Souri							3							3
UC13A6	1			4		1								6
Verdale (Blackwood)				1	1		3		1					6
Verdale (SA)	2				1	3	12							18
Verdale Aglandau					1	4	15	1		1				22
Volos				1	2									3

Appendix B Comparison of harvest times

Table B.1 Harvest dates for trees in 2002. Units are number of trees.

Variety	08/04/2002	15/04/2002	22/04/2002	29/04/2002	06/05/2002	13/05/2002	20/05/2002	27/05/2002	03/06/2002	10/06/2002	17/06/2002	24/06/2002	01/07/2002	Total
Arbequina									2	4	5			11
Areccuzo						1			1	2	2			6
Ascolano						1		1						2
Atro Rubens											1			1
Azapa											2	2	2	6
Barnea										4	2			6
Barouni				1				2			1			4
Benito								1			1			2
Black Italian (Blackwood)														0
Columella									2	2				4
Coratina									1	3		1		5
Frantoio								4			1			5
Gordal Sevillana				2	4	4								10
Gros Reddeneau														0
Group I				2										2
Group II														0
Group III									1	1	1			3
Group IV														0
Group V														0
Group VI				4										4
Group VII									4	2	2			8
Hojiblanca									3	2	1			6
I77									2		3			5
Jumbo Kalamata									1		4			5
Kalamata		2		2										4
Katsourela									2	1				3
Koroneiki														0
Large Pickling									2	2			2	6
Leccino						1								1
Manaiki						1			1					2
Manzanillo			7			1				1				9
Mission (Californian)						2								2
Mission (WA)											1			1
Oblitza								6						6
Pendolino	6													6
Picual										6	9			15
Pigale														0
Queen of Spain														0
Rouget											5			5
Souri														0
UC13A6		2		1										3
Verdale (SA)					2	6		10						18
Verdale Aglandau								2	1		1			4

Table B.2 Harvest dates for trees in 2003. Units are number of trees.

Variety	Early Apr	Mid Apr	Late Apr	Early May	Mid May	Late May	Early Jun	Mid Jun	Late Jun	Early Jul	Mid Jul	Mid Jul	Early Aug	Total
Amelon			1											1
Arbequina								2	2	6	6		2	16
Areccuzo						2				4				6
Ascolano						4		1		1				6
Atro Rubens					2	2								4
Atroviolacea Brun Ribier	2		1											3
Azapa											2		4	2
Barnea								2	2	2	6			12
Barouni			2			4								6
Benito				2				2			2			6
Black Italian (Blackwood)					4	2								6
Blanquette - Early										1				1
Columella										2	2		2	4
Coratina													5	0
Dr Fiasci	2			3										5
Frantoio			2	5	6	4		3	6	3	16		2	45
FS17										2	4			6
Gordal Sevillana			4	12						1				17
Gros Reddeneau				4							1			5
Group I	3		4	8										15
Group II	2		2											4
Group III			4	4	5	2								15
Group IV				3	1	2				3	1			10
Group V				6	2	7		7		1	2			25
Group VI			4	2										6
Group VII				8	2									10
Hojiblanca				2	6	9								17
I77				5										5
Institute				2										2
Jumbo Kalamata										2	4			6
Kalamata									2	2	2			6
Koroneiki						2			4					6
Large Pickling										4	2			6
Leccino	1			3										4
Manaiki						2							2	2
Manzanillo	2			7	6					2				17
Mission (Californian)				8	1					1	2			12
Mission (WA)									2		1			3
Nevadillo Blanco			3	2										5
Oblitza			2						2		2			6
Pendolino			4	2										6
Picual					11	2		2						15
Pigale	4													4
Praecox			2											2
Queen of Spain													1	0
Regalise de Languedoc				2										2
Rouget								2		2	2			6
Souri					3									3
UC13A6				6										6
Verdale (SA)				10	2	2				2	2			18
Verdale Aglandau	2		2	4				5	2	3	4		1	22

Table B.3 Harvest dates for trees in 2004. Units are number of trees.

Variety	Early Apr	Mid Apr	Late Apr	Early May	Mid May	Late May	Early Jun	Mid Jun	Late Jun	Early Jul	Total
Amelon							5				5
Arbequina						6			6	6	18
Areccuzo										6	6
Ascolano											0
Atro Rubens										5	5
Atroviolacea Brun Ribier			5								5
Azapa										6	6
Barnea						6		6			12
Barouni									6		6
Benito				6							6
Black Italian (Blackwood)								6			6
Blanquette - Early											0
Buchine								4			4
Columella										6	6
Coratina										1	1
Dr Fiasci											0
Frantoio				6	12	2	13	17	28		78
FS17						6					6
Gordal Sevillana								12		5	17
Gros Reddeneau										6	6
Group I		12	6								18
Group II							6		12		18
Group III								6	12		18
Group IV								12			12
Group V							6	6		10	22
Group VI									6		6
Group VII							6	6			12
Hojiblanca							5		12		17
I77							6				6
Institute									6		6
Jumbo Kalamata									6		6
Kalamata									5		5
Katsourela								5			5
Koroneiki						12					12
Large Pickling										6	6
Leccino			4								4
Manaiki										6	6
Manzanillo							17				17
Mission (Californian)							6	5			11
Mission (WA)									6		6
Nevadillo Blanco				6							6
Oblitza									6		6
Pendolino		6									6
Picual						6	6		3		15
Pigale								6			6
Praecox								6			6
Queen of Spain								2			2
Regalise de Languedoc								5			5
Rouget										5	5
Souri											0
UC13A6	6										6
Verdale (Blackwood)								6			6
Verdale (SA)							6			12	18
Verdale Aglandau									5	17	22
Volos		3									3

Appendix C Fruit analyses from individual years

Table C1 Percentage oil in dried flesh, whole fruit weight (g), percentage moisture in the whole fruit, and flesh to pit ratio for all varieties at Roseworthy, 2002. * = no fruit for analysis.

Variety	% oil in dry flesh	fruit weight (g)	% water in whole fruit	flesh:pit ratio
Amelon	*	*	*	*
Arbequina	62.5	2.3	64.3	8.6
Areccuzo	55.1	2.4	69.2	8.8
Ascolano	50.8	8.3	63.1	14.7
Atro Rubens	65.4	3.8	60.5	9.8
Atroviolacea Brun Ribier	*	*	*	*
Azapa	29.5	7.0	66.5	11.8
Barnea	63.1	4.2	68.4	10.8
Barouni	40.8	10.2	64.1	10.8
Benito	39.3	5.4	74.1	10.3
Black Italian (Blackwood)	*	*	*	*
Blanquette - Early	*	*	*	*
Buchine	*	*	*	*
Columella	52.7	5.1	65.7	9.5
Coratina	51.1	4.8	58.9	8.1
Dr Fiasci	*	*	*	*
Frantoio	54.1	3.7	59.0	7.9
FS17	*	*	*	*
Gordal Sevillana	43.6	10.6	68.2	13.8
Gros Reddeneau	*	*	*	*
Group I	47.9	4.9	54.9	6.2
Group II	*	*	*	*
Group III	39.6	3.9	70.0	11.1
Group IV	*	*	*	*
Group V	*	*	*	*
Group VI	40.4	2.6	66.9	6.5
Group VII	52.5	3.6	64.7	9.3
Hojiblanca	35.7	4.5	68.1	10.4
I77	54.3	5.9	62.2	8.7
Institute	*	*	*	*
Jumbo Kalamata	41.6	11.8	64.3	14.4
Kalamata	51.5	4.9	58.0	9.3
Katsourela	44.5	4.4	63.3	10.0
Koroneiki	*	*	*	*
Large Pickling	48.7	3.1	62.9	8.3
Leccino	51.4	5.4	66.9	10.0
Manaiki	54.9	4.6	61.6	12.3
Manzanillo	37.3	6.1	68.6	14.1
Mission (Californian)	42.2	5.2	59.8	9.6
Mission (WA)	61.6	4.0	61.7	9.2
Nevadillo Blanco	*	*	*	*
Oblitza	42.8	6.6	72.1	12.2
Pendolino	36.6	2.5	62.9	6.5
Picual	50.0	4.5	69.2	9.4
Pigale	*	*	*	*
Praecox	*	*	*	*
Regalise de Languedoc	*	*	*	*
Rouget	47.2	2.9	74.4	12.4
Souri	*	*	*	*
UC13A6	18.8	10.4	72.3	12.6
Verdale (Blackwood)	*	*	*	*
Verdale (SA)	35.4	7.1	73.1	9.2
Verdale Aglandau	46.5	4.6	64.7	10.5
Volos	*	*	*	*
Maximum LSD	18.9	2.5	10.0	2.7

Table C2 Percentage oil in dried flesh, whole fruit weight (g), percentage moisture in the whole fruit, and flesh to pit ratio for all varieties at Roseworthy, 2003. * = no fruit for analysis.

Variety	% oil in dry flesh	fruit weight (g)	% water in whole	flesh:pit ratio
Amelon	55.58	7.54	60.45	8.97
Arbequina	60.92	2.46	61.76	7.46
Areccuzo	49.95	2.19	62.95	6.60
Ascolano	57.98	7.82	67.54	14.04
Atro Rubens	49.31	3.07	65.34	10.05
Atroviolacea Brun Ribier	47.19	2.90	58.60	5.19
Azapa	47.86	6.11	62.10	10.40
Barnea	62.53	3.68	60.40	9.05
Barouni	52.47	9.96	63.73	11.15
Benito	41.97	4.92	65.67	8.50
Black Italian (Blackwood)	52.71	2.87	60.20	5.60
Blanquette - Early	51.90	4.44	54.97	8.40
Buchine	*	*	*	*
Columella	58.79	5.15	63.17	9.23
Coratina	65.23	3.64	54.67	7.61
Dr Fiasci	43.74	2.62	56.70	7.22
Frantoio	60.51	3.35	53.72	6.61
FS17	63.52	3.92	66.93	15.65
Gordal Sevillana	59.74	9.64	68.39	11.98
Gros Reddeneau	56.34	4.33	58.65	8.85
Group I	55.66	7.66	67.39	9.27
Group II	47.31	2.46	62.37	5.26
Group III	51.03	3.94	67.25	9.04
Group IV	60.60	2.69	59.93	7.89
Group V	64.73	6.36	53.75	8.24
Group VI	60.93	3.58	69.19	9.10
Group VII	47.77	4.26	66.39	7.40
Hojiblanca	41.91	5.30	66.67	9.89
I77	52.06	5.57	63.41	7.48
Institute	50.51	3.97	68.88	11.86
Jumbo Kalamata	50.47	10.94	65.49	11.63
Kalamata	57.15	3.26	57.66	7.71
Katsourela	*	*	*	*
Koroneiki	48.92	1.47	49.70	6.53
Large Pickling	42.09	3.90	58.27	8.56
Leccino	49.94	3.96	60.66	7.40
Manaiki	61.94	4.60	60.43	10.37
Manzanillo	39.28	6.25	68.18	13.59
Mission (Californian)	54.62	4.57	55.51	8.32
Mission (WA)	59.66	3.00	52.11	7.21
Nevadillo Blanco	56.60	3.06	61.50	7.90
Oblitza	57.02	5.45	66.01	11.61
Pendolino	48.72	2.84	63.41	7.43
Picual	53.22	4.70	66.75	9.23
Pigale	46.71	4.15	59.03	5.85
Praecox	32.64	1.56	63.18	5.51
Regalise de Languedoc	59.83	5.24	68.15	13.36
Rouget	47.05	3.31	69.31	11.25
Souri	60.19	3.63	60.06	9.06
UC13A6	34.33	9.26	72.57	13.68
Verdale (Blackwood)	*	*	*	*
Verdale (SA)	42.55	6.39	68.84	7.54
Verdale Aglandau	55.63	4.42	61.97	10.12
Volos	*	*	*	*
Maximum LSD	20.39	2.17	8.06	3.34

Table C3 Percentage oil in dried flesh, whole fruit weight (g), percentage moisture in the whole fruit, and flesh to pit ratio for all varieties at Roseworthy, 2004. * = no fruit for analysis.

Variety	% oil in dry flesh	fruit weight (g)	% water in whole fruit	flesh:pit ratio
Amelon	48.17	5.965	53.68	6.799
Arbequina	62.11	2.2	48.47	5.905
Areccuzo	48.48	1.757	59.82	4.834
Ascolano	*	*	*	*
Atro Rubens	68.62	3.824	51.4	7.435
Atroviolacea Brun Ribier	52.98	4.236	49.38	6.288
Azapa	43.22	5.646	54.26	10.039
Barnea	56.53	3.709	52.33	7.771
Barouni	52.52	7.106	61.66	7.687
Benito	64.72	5.663	68.49	7.395
Black Italian (Blackwood)	49.86	2.747	62.58	5.345
Blanquette - Early	*	*	*	*
Buchine	73.85	7.896	49.18	8.512
Columella	59.92	4.414	57.8	8.249
Coratina	56	4.44	47.79	8.468
Dr Fiasci	*	*	*	*
Frantoio	58.11	2.806	42.39	4.851
FS17	59.77	3.333	54.87	10.398
Gordal Sevillana	60.91	8.69	61.28	8.763
Gros Reddeneau	69.87	3.829	45.42	6.416
Group I	55.3	7.116	57.96	6.95
Group II	42.55	2.621	50.26	5.311
Group III	49.65	3.235	60.23	6.896
Group IV	63.5	2.569	50.54	6.004
Group V	67.38	4.444	44.59	7.155
Group VI	45.86	3.524	63.14	5.266
Group VII	51.89	3.321	48.98	5.538
Hojiblanca	44.86	4.175	54.13	8.445
I77	57.33	4.329	46.17	5.555
Institute	*	4.223	80.83	11.748
Jumbo Kalamata	51.45	10.484	60.45	9.668
Kalamata	54.08	4.067	54.64	7.721
Katsourela	59.96	3.797	59.48	7.257
Koroneiki	46.67	1.583	40.93	5.103
Large Pickling	54.22	3.445	48.99	7.526
Leccino	40.11	3.288	47.18	5.651
Manaiki	71.72	4.142	51.8	9.891
Manzanillo	49.4	5.034	57.37	9.316
Mission (Californian)	49.02	4.612	48.39	6.553
Mission (WA)	57.1	3.39	47.97	5.962
Nevadillo Blanco	52.68	2.984	47.3	6.768
Oblitza	62.11	4.55	52.61	7.274
Pendolino	39.35	3.061	56.55	6.688
Picual	53.58	4.309	52.66	7.597
Pigale	61.75	3.492	48.23	5.218
Praecox	29.11	1.61	56.92	5.571
Regalise de Languedoc	61.73	5.35	58.69	11.554
Rouget	59.43	2.67	54.63	8.576
Souri	*	*	*	*
UC13A6	22.77	9.937	66.76	10.434
Verdale (Blackwood)	53.52	4.105	54.84	4.55
Verdale (SA)	52.88	6.429	54.19	5.708
Verdale Aglandau	60.88	3.975	46.68	7.742
Volos	60.54	7.648	56.81	9.382
Maximum LSD	21.47	1.02	13.04	1.89

Table C4 - Mean percentage composition of six fatty acids from olive trees at the Roseworthy site for 2002. The accepted limits for fatty acid composition of Virgin Olive Oil (International Olive Oil Council 2001b) are shown in the first row. * = no fruit for analysis.

	% Composition					
Variety	Palmitic	Palmitoleic	Stearic	Oleic	Linoleic	Linolenic
Accepted Limits	7.5-20	0.3-3.5	0.5-5.0	55.0-83.0	3.5-21.0	≤ 0.1
Amelon	*	*	*	*	*	*
Arbequina	14.63	2.482	1.58	66.33	13.22	0.68
Areccuzo	12.03	0.493	1.60	68.7	14.95	1.33
Ascolano	9.27	0.596	1.66	77.77	9.01	0.80
Atro Rubens	9.55	0.313	3.06	75.3	9.31	0.79
Atroviolacea Brun Ribier	*	*	*	*	*	*
Azapa	16.38	2.668	2.19	61.94	15.07	0.97
Barnea	10.42	1.06	1.89	73.77	11.77	0.59
Barouni	12.35	2.054	1.56	72.73	9.65	0.76
Benito	15.36	1.607	2.22	67.61	11.02	1.49
Black Italian (Blackwood)	*	*	*	*	*	*
Blanquette – Early	*	*	*	*	*	*
Buchine	*	*	*	*	*	*
Columella	14.49	2.634	1.24	60.02	19.81	0.84
Coratina	10.76	0.401	1.76	77.1	8.29	0.84
Dr Fiasci	*	*	*	*	*	*
Frantoio	12.56	1.525	1.83	69.84	12.78	0.83
FS17	*	*	*	*	*	*
Gordal Sevillana	13.19	1.227	1.82	65.53	15.3	1.37
Gros Reddeneau	*	*	*	*	*	*
Group I	9.22	1.007	2.23	70.24	14.88	1.27
Group II	*	*	*	*	*	*
Group III	14.37	1.804	2.29	69.48	10.29	0.98
Group IV	*	*	*	*	*	*
Group V	*	*	*	*	*	*
Group VI	10.67	0.8	1.34	79.82	5.1	1.17
Group VII	13.17	1.095	2.42	70.92	9.95	0.96
Hojiblanca	11.3	0.362	2.84	74.33	9.17	0.98
I77	10.31	0.34	1.395	77.3	8.78	0.94
Institute	*	*	*	*	*	*
Jumbo Kalamata	13.63	1.637	2.91	65.86	14.51	0.84
Kalamata	8.92	0.866	1.49	76.99	10.21	0.51
Katsourela	17.61	2.31	1.96	54.31	22.18	1.11
Koroneiki	*	*	*	*	*	*
Large Pickling	16.66	2.61	2.06	67.75	9.45	0.94
Leccino	8.96	0.454	1.42	75.91	11.63	0.99
Manaiki	11.71	0.601	2.34	63.42	20.61	0.57
Manzanillo	13.27	1.899	2.85	73.15	7.26	0.73
Mission (Californian)	11.74	0.91	1.85	70.91	12.3	0.81
Mission (WA)	12.14	1.351	1.63	72.58	10.47	0.88
Nevadillo Blanco	*	*	*	*	*	*
Oblitza	11.73	0.293	2.68	72	10.8	1.11
Pendolino	14.13	1.835	1.31	73.55	7.79	0.95
Picual	12.07	1.513	2.30	78.94	3.82	0.90
Pigale	*	*	*	*	*	*
Praecox	*	*	*	*	*	*
Regalise de Languedoc	*	*	*	*	*	*
Rouget	14.95	1.59	2.19	62.1	17.22	1.22
Souri	*	*	*	*	*	*
UC13A6	15.39	2.823	1.23	66.7	13.02	0.56
Verdale (Blackwood)	*	*	*	*	*	*
Verdale (SA)	13.95	1.595	2.04	64.47	15.15	1.56
Verdale Aglandau	14.66	2.27	2.06	65.92	12.66	1.02
Volos	*	*	*	*	*	*
Maximum LSD	3.40	1.12	0.77	8.73	4.99	0.74

Table C5 - Mean percentage composition of six fatty acids from olive trees at the Roseworthy site for 2003. The accepted limits for fatty acid composition of Virgin Olive Oil (International Olive Oil Council 2001b) are shown in the first row. * = no fruit for analysis.

			% Composition			
Variety	Palmitic	Palmitoleic	Stearic	Oleic	Linoleic	Linolenic
Accepted Limits	7.5-20	0.3-3.5	0.5-5.0	55.0-83.0	3.5-21.0	≤ 0.1
Amelon	14.33	1.04	1.82	60.86	19.52	0.94
Arbequina	13.04	1.58	1.67	70.62	11.13	0.65
Areccuzo	10.32	0.68	1.91	73.99	11.09	1.02
Ascolano	12.00	1.12	1.71	74.76	8.04	1.05
Atro Rubens	10.48	0.95	2.82	72.91	9.88	0.81
Atroviolacea Brun Ribier	11.24	1.07	1.76	74.65	9.24	0.84
Azapa	14.58	1.49	2.40	66.55	13.49	0.88
Barnea	9.51	0.54	2.15	76.59	9.68	0.64
Barouni	12.68	1.56	1.57	73.85	7.09	0.68
Benito	14.30	1.15	2.67	72.06	7.81	1.32
Black Italian (Blackwood)	9.93	0.95	2.02	81.69	3.82	0.48
Blanquette - Early	15.59	1.14	2.51	57.85	21.55	0.66
Buchine	*	*	*	*	*	*
Columella	12.95	1.28	1.44	64.56	17.69	0.89
Coratina	8.31	0.29	1.83	82.69	5.12	0.72
Dr Fiasci	15.06	1.37	1.75	71.02	8.40	0.99
Frantoio	11.43	0.85	1.99	74.19	9.54	0.65
FS17	11.06	0.85	1.62	73.19	11.16	1.06
Gordal Sevillana	12.33	1.03	1.98	68.47	12.92	1.15
Gros Reddeneau	15.03	2.09	2.21	67.20	11.13	0.79
Group I	11.52	1.21	1.79	68.49	13.95	1.16
Group II	16.13	1.34	2.22	59.86	16.62	1.34
Group III	14.60	1.32	2.50	70.05	9.05	0.81
Group IV	9.13	1.12	2.12	81.64	4.41	0.71
Group V	9.24	0.51	3.15	80.10	4.04	0.69
Group VI	11.49	1.01	1.34	78.49	5.49	0.96
Group VII	14.01	1.20	2.59	67.80	10.91	1.05
Hojiblanca	10.92	0.65	2.59	75.25	7.97	0.89
I77	10.80	0.66	1.40	78.03	6.72	0.92
Institute	14.07	1.27	2.67	68.45	8.57	0.77
Jumbo Kalamata	12.30	0.75	2.92	69.56	11.77	0.95
Kalamata	8.55	0.40	0.93	81.01	6.93	0.60
Katsourela	*	*	*	*	*	*
Koroneiki	10.18	0.79	2.34	80.51	4.44	0.58
Large Pickling	16.22	2.05	2.14	68.66	9.69	0.66
Leccino	13.69	1.46	1.64	77.49	4.13	0.68
Manaiki	10.28	0.64	2.59	71.78	12.96	0.63
Manzanillo	13.82	1.64	3.37	72.40	6.49	0.64
Mission (Californian)	8.88	0.73	2.10	77.52	8.80	0.76
Mission (WA)	11.02	0.71	1.92	76.49	8.36	0.57
Nevadillo Blanco	13.35	1.72	1.61	72.15	7.94	0.88
Oblitza	9.86	0.56	2.56	75.67	8.97	0.89
Pendolino	13.70	1.25	1.27	73.60	7.91	0.98
Picual	12.80	1.41	2.31	78.33	3.33	0.77
Pigale	15.45	1.96	1.92	67.43	11.12	1.03
Praecox	16.13	3.64	1.47	67.48	9.56	0.97
Regalise de Languedoc	10.02	0.92	2.28	72.18	8.03	0.84
Rouget	14.29	1.23	1.92	57.96	21.69	1.30
Souri	11.52	0.72	3.30	74.06	7.72	0.54
UC13A6	14.19	2.15	1.41	70.81	8.97	0.75
Verdale (Blackwood)	*	*	*	*	*	*
Verdale (SA)	15.46	1.34	2.08	65.62	12.89	1.48
Verdale Aglandau	14.92	2.06	2.18	66.11	12.70	0.85
Volos	*	*	*	*	*	*
Maximum LSD	2.59	0.73	0.77	6.48	3.6	0.43

Table C6 - Mean percentage composition of six fatty acids from olive trees at the Roseworthy site for 2004. The accepted limits for fatty acid composition of Virgin Olive Oil (International Olive Oil Council 2001b) are shown in the first row. * = no fruit for analysis.

	% Composition					
Variety	Palmitic	Palmitoleic	Stearic	Oleic	Linoleic	Linolenic
Accepted Limits	7.5-20	0.3-3.5	0.5-5.0	55.0-83.0	3.5-21.0	≤ 0.1
Amelon	13.34	0.97	2.09	64.70	17.20	0.77
Arbequina	12.63	1.39	1.96	71.64	10.76	0.51
Areccuzo	9.80	0.56	1.91	72.22	13.20	1.26
Ascolano	*	*	*	*	*	*
Atro Rubens	8.24	0.77	2.99	78.10	7.90	0.67
Atroviolacea Brun Ribier	14.46	2.08	2.04	68.67	11.18	0.46
Azapa	12.90	1.25	3.32	70.35	10.58	0.79
Barnea	10.07	0.76	2.51	74.82	10.49	0.63
Barouni	11.53	1.18	1.97	75.92	7.23	0.77
Benito	13.30	0.95	3.02	73.45	7.28	0.89
Black Italian (Blackwood)	9.54	0.97	1.70	81.69	4.43	0.71
Blanquette - Early	*	*	*	*	*	*
Buchine	9.00	0.82	2.66	78.67	7.43	0.58
Columella	13.04	1.37	1.59	63.70	18.40	0.87
Coratina	12.90	1.55	2.62	70.85	9.68	0.69
Dr Fiasci	*	*	*	*	*	*
Frantoio	11.74	1.03	2.31	73.00	10.18	0.69
FS17	11.54	0.97	1.89	71.80	11.80	1.07
Gordal Sevillana	10.39	0.52	1.74	71.81	12.91	1.14
Gros Reddeneau	8.02	0.49	2.27	79.59	7.56	0.86
Group I	11.31	0.94	2.02	70.80	13.40	0.73
Group II	14.61	1.34	2.45	62.13	17.54	1.10
Group III	13.92	1.21	2.45	71.02	9.31	0.91
Group IV	8.19	0.97	2.49	81.99	5.02	0.64
Group V	8.75	0.55	3.23	80.32	4.97	0.61
Group VI	9.76	0.71	1.06	81.20	5.40	0.94
Group VII	11.86	0.99	3.18	69.88	10.85	0.93
Hojiblanca	8.51	0.60	3.21	78.15	7.30	0.75
I77	8.96	0.47	1.86	76.65	9.38	1.23
Institute	14.00	1.37	2.23	74.55	6.15	0.86
Jumbo Kalamata	15.92	1.02	4.15	69.16	9.13	0.60
Kalamata	7.91	0.43	1.25	77.63	10.57	0.74
Katsourela	14.84	1.33	1.56	60.39	20.18	0.99
Koroneiki	10.06	0.80	2.92	78.63	5.60	0.74
Large Pickling	15.14	1.67	2.49	68.00	11.30	0.67
Leccino	12.80	1.25	2.02	77.95	4.38	0.69
Manaiki	8.10	0.45	3.12	75.15	11.98	0.49
Manzanillo	11.88	1.06	3.78	75.91	5.71	0.67
Mission (Californian)	7.74	0.57	2.51	79.11	8.64	0.78
Mission (WA)	11.11	1.09	2.40	74.16	9.51	0.56
Nevadillo Blanco	11.48	0.84	2.03	73.26	9.68	0.77
Oblitza	8.84	0.47	3.39	77.20	8.40	0.57
Pendolino	16.80	0.85	1.92	72.15	6.78	0.49
Picual	11.28	0.75	3.47	76.04	7.05	0.68
Pigale	15.60	2.39	2.02	65.60	12.50	0.80
Praecox	13.81	1.65	2.65	65.66	14.70	0.77
Regalise de Languedoc	8.29	0.71	2.58	79.46	7.00	0.70
Rouget	13.44	0.97	2.39	62.60	19.10	1.07
Souri	*	*	*	*	*	*
UC13A6	15.50	2.05	1.82	69.75	9.78	0.49
Verdale (Blackwood)	12.98	1.09	2.01	74.94	7.50	0.75
Verdale (SA)	11.84	0.88	2.77	71.86	10.11	1.09
Verdale Aglandau	13.64	1.59	2.35	69.94	10.79	0.62
Volos	12.17	0.86	2.29	71.51	11.38	0.56
Maximum LSD	1.59	0.32	1.09	4.01	3.74	0.41

Appendix D Olive Variety Regional Performance Study:

A qualitative survey of the views of olive growers, processors and harvesters on the performance of olive varieties in various regions of Australia.

Patricia Murray and Susan Sweeney

Summary of survey and conclusions

This survey was prompted by uncertainty as to the performance of different varieties of olive in different regions of Australia. In late 2004 and early 2005 a survey of thirty-five growers, together with processors and harvesters in nine climatic regions was conducted. Phone interviews by an experienced olive consultant lasting up to one hour, supplemented by email questionnaires, were the principal means of data collection. The data was subjected to qualitative analysis. The objective of the survey was to investigate growers' perceptions of performance of olive varieties in a range of climate regions.

- In total growers had planted or had experience with forty-eight varieties of olive.
- Of varieties grown Frantoio would be planted again by 13 of 29 growers in this survey, 4 of 7 of these growers growing Frantoio on good soils and 5 of 8 on well drained soils. Though the number was smaller in total, half of those growing Coratina or Kalamata would plant those varieties again. Less than 20% of those growing Manzanillo recommended the variety and it was mainly recommended by those growing it for table fruit, not for oil. Indeed Manzanillo together with Hardy's Mammoth were varieties growers would not recommend be planted again or are considered among the worst varieties by growers.
- Fewer than one quarter of growers of any olive variety reported pest or diseases for that variety and no pests or diseases were reported for the majority of varieties.
- Trees are generally three to four years at the time of their first harvest, with a range of from 2 to 10 years. Small harvests were reported at first, building to good production levels when trees are around five to six year old trees.
- Varieties have differing habit and differing pruning requirements. Diversity in grower approach to pruning and training was reported.
- Frost was an issue in all regions except E7 and I3, Manzanillo, Barnea and Frantoio were most frequently noted as frost susceptible. Leccino was reported to be frost tolerant.
- Flowering time seems to vary from one variety to another and from one region to another. Issues of pollination are further complicated by uncertainty regarding varietals.
- The moisture content of the fruit requires careful management to ensure that fruit suitable for processing and yielding high oil percentages is produced. Processing problems as a result of moisture content were reported particularly by Manzanillo, Barnea and Picual growers as well as by processors. Irrigation management prior to harvest was recommended to prevent levels of moisture in the fruit becoming a problem.
- Large fruited varieties were reported to be easier to harvest, while most problems were reported with small fruited varieties such as Corregiola and Frantoio. Fruit left after harvest was commonly reported.
- Manzanillo, while pickling well, was noted for its processing problems; Frantoio was most frequently cited as processing well.
- Kalamata, Coratina and Frantoio are varieties that growers have said they would plant again if they were starting their groves from scratch, seven growers who would plant Picual again. Nearly as many Manzanillo growers said they would not plant Manzanillo again as said they would and half of all Hardy's Mammoth growers ranked the variety as among the worst.

Regions

- Growers in region D5 reported high fruit yields for Manzanillo, but low oil percentage yields. Half of the four Frantoio growers reported oil percentages of 20% or above, on all soil types, however only one has said they would plant this variety again. Manzanillo and Hardy's Mammoth were held to be among the worst varieties by growers in this region.
- Two of the four Nevadillo Blanco growers in region E1 reported the variety suffered with black scale and pollination problems were also reported for this variety. Oil yields of 20% and above for Nevadillo Blanco and Frantoio together with some high fruit yields were reported. All Coratina and Arbequina growers in this region would plant these varieties again, though only two of the five Frantoio growers would plant Frantoio again.
- Manzanillo were noted by two of the four growers in region E2 to be affected by black scale. Oil percentages of 20% or above were reported by Nevadillo Blanco growers on sandy soil in this region. Both Kalamata and Coratina growers in this region would plant these varieties again, as would the only California Queen grower in the survey.
- In region E3 black scale and thrip were noted to affect Frantoio, Kalamata and Manzanillo. Low oil percentages for Manzanillo were reported by five of eight growers but three of eight Frantoio growers reported 20% or above oil percent. Three of eight and three of nine Corregiola and Frantoio growers respectively would plant these varieties again.
- Manzanillo growers in region E6 have reported high fruit yields but low to mid oil percentage yields. All Frantoio growers in this region would plant the variety again.
- Growers in region E4, reported few pests or diseases. Both Coratina growers in this region would plant the variety again, however the only grower with Frantoio would not plant the variety again.
- The Arbequina and Azapa growers in region E7 would plant these varieties again, one Manzanillo grower reporting anthracnose.
- In region F3 two Nevadillo Blanco growers reported black scale and anthracnose as problems, two Manzanillo growers also reported black scale. Two of the three Manzanillo growers reported low fruit yields. Two of three Frantoio growers and both Kalamata growers would plant these varieties again.
- Only one grower was interviewed in I3 region, indicating that it is possible to grow olives there.

Differences in soil type may be influencing varietal performance and this together with regional differences are indicated as being important in explaining differences in performance of olive varieties across Australian olive growing regions. Small numbers have meant that meaningful comparisons were not always possible with this data.

Other issues which have emerged include the importance of preparation and nutrition management for establishing a successful olive enterprise. Small numbers interviewed in some regions, E4, E7, F3 and I3 have meant that no more than an indication of performance of varieties was possible.

Appendix E The Aroma and Taste Characteristics of Different Cultivars of *Olea Europaea* Grown at Roseworthy, South Australia.

Gawel, R.[1], Cox, P.[2] and Sweeney, S.[3]

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Abstract

The aroma and taste profiles of olive oils made from three different cultivars (Arbequina, Coratina, and Picual) grown at Roseworthy, South Australia and harvested at similar maturities were compared over two seasons. The aroma and taste profiles of three further varieties (Barnea, Paragon and Pendolino) harvested in a single season were also assessed. In the first season, the Picual oil was significantly lower, and the Pendolino and Coratina oils were significantly higher in bitterness and pungency compared to the other varieties. The Coratina oil was also significantly more flavoursome than the Arbequina oil. However, the tasters were unable to discriminate any specific aroma differences between the oils. In the second season, the oils were perceived to have different aroma profiles. The Arbequina oil showed the most intense caramel and raw potato characters, the Picual was highest in guava character, and the Paragon and Coratina oils higher in grassy character. The Barnea and Paragon cultivars produced oils with the least overall aroma. Consistent with the previous season, the Coratina oil was the most bitter and pungent.

Introduction

The plantings of most olive growing regions in Europe are dominated by a single or at most, a small number of cultivars. As an example, the variety Picual accounts for over 90% of plantings in the Jaen region of Andalucia. Similarly, the Koroneiki cultivar dominates plantings in the Peleponese Peninsula of Greece, as does Frantoio in Tuscany.

In contrast to this varietal concentration, most Australian regions are typically planted to a large number of varieties of various national origins. For example, it is not unusual for a single Australian region to have substantial plantings of the cultivars Picual, Paragon, Manzanillo, Leccino, Frantoio, Koroneiki and others. Furthermore, as other varieties such as Coratina and Arbequina have become available, they too have been trialed and planted for commercial production.

To date, the selection of varieties by Australian olive growers appears to have been conducted primarily on the basis of expected oil yield, horticultural factors such as frost tolerance, expected time to bearing, perceived market acceptability of the variety, and the availability of planting material. However, it appears that sensory aspects of the olive oil such as desirable aroma/flavour profiles or appropriate levels of bitterness and pungency to meet a particular market requirement, have rarely been considered when the varieties have been selected. For example, some anecdotal evidence exists that some Australian regions are currently dominated by varieties that produce oils with bitterness in excess of what the market currently demands, and that due to the dominance of stylistically similar varieties, blending options are not readily available (Gawel, 2005).

It is likely that a lack of information concerning the sensory characteristics of different varieties grown under Australian conditions has been one of the reasons why aroma and taste criteria have not been widely applied in variety selection decisions. This research begins to address the lack of knowledge regarding the aroma and taste profiles by comparing olive oils made from different varieties of trees grown at a single Australian site and made in an identical fashion. Such information is necessary to ensure that growers plant varieties which have both the aromas and flavours, and perhaps more importantly, are of a style desired by their customers. With more reliable information arising from formal sensory assessment, it is hoped that better informed planting decisions may be made in the future.

Methods

The Site and Varieties Selected for Comparison

The olive varieties selected for sensory analysis for the 2002 season were (with their maturity index as described by Hermosa et al. (1997) given in brackets): Picual (3.2), Coratina (3.1), Arbequina (3.0) and Pendolino (2.7). For the 2003 season the varieties compared were Picual (3.4), Coratina (2.5), Arbequina (3.8) and Paragon (3.0). Samples were collected as close to maturity index 3 as possible but it was difficult to achieve this exact maturity index due to variability within the varieties. Some varieties chosen in this study - Barnea, Picual, Pendolino and Paragon have been planted in many Australian regions while Arbequina and Coratina are becoming increasingly popular and as such were included for comparison.

The site was chosen for this study was at the Roseworthy Campus of the University of Adelaide, 45 km NNE of Adelaide, South Australia (34^{o} 31’ 35’’ S, 138^{o} 41’ 26’’W), elevation 72 metres. Its climate can be categorised as ‘Mediterranean’ with hot dry summers and mild to cool wet winters. As such, it can be considered to be typical of a number of olive growing regions of South Eastern and South Western Australia. The collection was planted in 1998 and was sourced from nurseries and collections across Australia. The identity of the cultivars used in this study were confirmed by comparing their DNA fingerprints with standards obtained from trees in a number of international and Australian collections (Sweeney, 2003).

Production of Oil Samples for Tasting

Oil samples were extracted from 1.8 kg of freshly picked and washed fruit using a mini-extraction unit. The fruit was crushed with a hammer mill, malaxed for 30 minutes at 28^{o}C for 30 minutes. The oil was separated from the aqueous material following 2 minutes of centrifugation and decantation. The oils were then filtered through cotton wool before being stored in the dark at 4^{o}C in dark amber bottles. The 2002 Picual sample was treated with 2% talc due to difficulties in extracting the oil.

Sensory Methods

Twelve tasters assessed the oils approximately 8 weeks after they were extracted. All tasters were initially selected by demonstrating their ability to accurately rate the intensity of olive fruit and of olive oil defects. Nine of the twelve tasters had participated in an ongoing oil assessment training program for a period of six years and had regularly assessed the intensity of fruit, bitterness and pungency of Australian and European olive oils. The remaining three tasters had six months experience conducting this form of tasting.

The five oils were presented to the tasters in blue olive oil tasting glasses which masked the appearance of the oils. No information regarding the identity of the oils was provided to the tasters. The tasters were asked to smell the oils and independently list the aroma attributes perceived. The chosen aroma descriptors were compiled and discussed amongst the tasters until a consensus was achieved regarding the relevant aroma attributes of the oils.

The olive oils were presented in a randomised order and the intensities of the selected aroma attributes, overall flavour, bitterness and pungency were assessed using a ten point structured category scale, with 0 being not detected, 1=just perceptible, 3=slight, 5=moderate, 7=strong and 10=extremely strong. The presentation order was then re-randomised and the oils re-evaluated.

As there was no prior training in the identification or rating of aroma attributes, the ability of tasters to reproduce their ratings was used as a criterion for inclusion of the taster’s data to create the sensory profiles. Reproducibility was calculated by simply correlating the ratings given to the same oil over the repeat tastings.

The sensory profile of the five oils was produced by calculating the mean of the intensity ratings provided by the judges who were able to adequately reproduce their ratings. Significance between means was determined by two way ANOVA with interaction (assessor x variety) whereby assessors were considered a random effect and variety a fixed effect.

Results and Discussion

Judge Rater Performance

When rating the oils from the 2003 harvest, 11 of the 12 assessors were able to both reproduce their ratings of the individual aroma attributes, and to the other general attributes of overall aroma, flavour, bitterness and pungency (Appendix 1a). Two other assessors were unable to demonstrate significant reproducibility for either the individual aroma attributes (assessor 6) or the overall aroma and palate attributes (assessor 9). The ratings given by these judges were not subjected to further analysis. Significant assessor by variety interaction was observed for the attributes 'caramel' and 'apple'. This suggests that there was disagreement between the judges regarding the intensities of these aroma attributes. Further inspection of individual assessor means (data not shown) demonstrated that for both these attributes, there was significant variation between most of the judges when rating these attributes. As this suggests that the assessors may not have had a consistent understanding of these attributes, the mean ratings of these descriptors should be cautiously interpreted.

The performance of judges was lower when assessing oils from the 2002 harvest (Appendix 1b). Again, only data from the reproducible judges was further analysed and their results reported. No significant judge x variety interaction was observed (Table 3) suggesting that the judges were in general agreement with respect to the intensities of both the selected aroma attributes and the general palate attributes of flavour, bitterness and pungency.

Variety Effect on the Aroma and Taste Profile

For the 2003 season, significant intensity differences were observed for the overall aroma, and for the specific aroma attributes ‘caramel’, ‘green grass’, ‘guava’, and ‘raw potato’ (Table 1). Specifically, Arbequina was significantly higher in ‘caramel’ aroma than all other varieties and was also significantly higher in ‘raw potato’ character than all varieties other than Coratina (Table 2 and Figure 1). Morales et al. (1995) found that compared with Coratina and Picual, Arbequina produced oils with more intense ‘artichoke’ aromas, a trait which was independent of ripeness of the olive fruit at harvest (Morales et al. 1996). These authors attribute this character to the existence of the compound (E)-3-hexenal. This compound has also been described as being green vegetable like (Anon, 2003) which may equate to the ‘green potato’ characters perceived by the tasters in this study. Many of the oils displayed a similar degree of ‘green grassy’ and ‘green tomato’ aroma, although Paragon and Coratina were most distinct in these respects (Table 2). These two varieties were picked at a less mature stage which may explain the ‘greener’ nose displayed by these oils. However, green aroma notes and/or high levels of the herbaceous compound (E)-2-hexenal have previously been reported in Coratina oils from Puglia (Morales et al. 1995) and Sicily (Benincasa et al. 2003).

The 2003 Picual oil was strongly characterised by an intense ‘guava’ like aroma, an attribute perceived in very low levels in the other varieties (Table 2 and Figure 1). This aroma characterised this variety for this harvest season, and to the best of our knowledge this descriptor for Picual oils has not been reported elsewhere in the literature. However, together with ‘tomato’, the term ‘guava’ has often been used to describe Australian Picual oils by judges in Australian olive oil shows (Gawel, 2005). Further studies are required to determine whether this is a characteristic of Picual oils grown at this site, or whether it was simply a different interpretation of another aroma. The latter explanation is a possibility as tasters did not have access to aroma references, and were therefore reliant on their past experience and memories of the selected aroma attributes. However, as it can also be reasonably expected that climatic conditions affect the formation of volatile compounds contributing to aroma and flavour (Vichi et al. 2003), the occurrence of a guava like aroma in this Australian Picual is equally feasible.

The 2003 Picual, Coratina and Arbequina oils had equally intense overall aromas, and were in turn more intense than the Barnea or Paragon oils (Table 2). Little difference in the overall aroma intensity of Coratina, Picual and Arbequina oils grown in three different regions have also previously been reported (Morales et al. 1996). The differences in overall flavour were less pronounced, with no variety showing significantly higher levels than another. However, the Coratina oil was more pungent and bitter than the other varieties. The Arbequina, and Paragon were the least bitter of all the varieties. The Coratina variety has been consistently reported as being a high polyphenol producer compared with Picual and Koroneiki oils (Stefanoukaki et al. 2000). In direct taste comparisons, the bitterness and pungency of Coratina oils have been shown to be higher that that of Picual and Arbequina oils (Aparicio and Luna, 2002) and of Picual and Koroneiki oils (Stefanoukaki et al. 2000). It is noteworthy that in this study the 2003 Coratina olives were harvested at a less mature stage than the other varieties which may explain the higher level of bitterness and pungency displayed in these oils (Morello et al. 2004). However, the Coratina oil produced in the previous year also displayed a high level of bitterness and pungency but was picked at an intermediate ripeness compared with the other varieties (Table 4). This suggests that the robustness displayed by the Coratina oil was a variety rather than a maturity effect.

For the 2002 harvest oils the judges did not discriminate any significant differences between the intensities of any of the individual aroma attributes (Table 4). This may have been either the result of climatic factors which reduced varietial differences between the oils or a lack of aroma discriminative power of the assessors. Significant differences in palate attributes were observed with the Coratina oil being the most flavoursome, and the Pendolino oil, the most bitter and pungent. The latter result may be a maturity effect as the Pendolino oil was harvested at a less mature stage than the other varieties. At the other end of the style spectrum, the Picual oil was the least bitter and pungent, and the Arbequina and Pendolino oils the least flavoursome. The reasons for these differences are unclear.

Conclusion

Olive oils made from different cultivars grown at the same location at Roseworthy, South Australia displayed different aroma and flavour profiles in one of the two years under study. The different cultivars also produced oils which differed stylistically in that they showed different levels of flavour, bitterness and pungency. This study shows that sensory criteria can be used in addition to horticultural criteria when deciding upon appropriate cultivars to plant for a given site. However, the cultivar effects reported here are only relevant to the site under study as their generality to different sites and climatic conditions has yet to be tested.

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Table 1: Analysis of variance statistics of aroma and palate attribute ratings of 2003 varietal olive oils.

	Variety	p	Judge x Variety Interaction	p
Aroma Attributes				
Rocket	0.46	0.765	1.42	0.123
Caramel	2.68	0.050	3.70	0.001
Green grass	5.27	0.002	1.09	0.383
Apple	0.64	0.640	2.04	0.010
Guava	19.71	0.001	0.79	0.770
Green banana	0.96	0.439	1.16	0.310
Green tomato	1.04	0.402	1.53	0.082
Raw potato	4.17	0.007	1.54	0.077
Floral	0.88	0.483	1.31	0.184
Overall aroma	2.81	0.040	1.57	0.070
Palate Attributes				
Flavour	1.43	0.245	1.61	0.061
Bitterness	14.86	0.001	1.27	0.213
Pungency	14.06	0.001	1.62	0.057

Table 2: Mean Attribute Ratings of 2003 Varietal Olive Oils

Variety	Arbequina	Barnea	Coratina	Paragon	Picual	LSD 5%
Aroma Attributes						
Rocket	1.7^{a}	1.5^{a}	1.8^{a}	2.0^{a}	1.3^{a}	ns
Caramel	2.8^{b}	1.2^{a}	1.1^{a}	0.5^{a}	0.4^{a}	1.0
Green grass	4.1^{bc}	3.7^{ab}	4.8^{cd}	5.1^{d}	2.9^{a}	1.0
Apple	1.8^{a}	2.1^{a}	2.1^{a}	2.9^{a}	1.9^{a}	ns
Guava	1.3^{a}	0.8^{a}	0.4^{a}	0.5^{a}	4.4^{b}	1.1
Green Banana	2.2^{a}	2.2^{a}	1.9^{a}	1.3^{a}	1.8^{a}	ns
Green Tomato	2.6^{ab}	1.8^{a}	2.8^{b}	3.1^{b}	2.5^{ab}	ns
Raw Potato	3.5^{c}	1.1^{a}	2.4^{bc}	0.9^{a}	1.9^{b}	1.3
Floral	0.6^{a}	1.1^{a}	0.9^{a}	1.1^{a}	1.2^{a}	ns
Overall aroma	6.3^{b}	5.5^{a}	6.1^{b}	5.4^{a}	6.3^{b}	0.6
Palate Attributes						
Flavour	5.0^{a}	4.8^{a}	5.4^{a}	4.6^{a}	5.1^{a}	ns
Bitterness	4.2^{ab}	4.7^{b}	6.7^{c}	3.8^{a}	4.7^{b}	0.7
Pungency	4.7^{a}	4.7^{a}	7.0^{b}	4.9^{a}	4.6^{a}	0.7

Means superscripted with different letters are significantly different at 5% significance level.

Figure 1: Mean attribute ratings for aroma attributes of 2003 varietal oils.

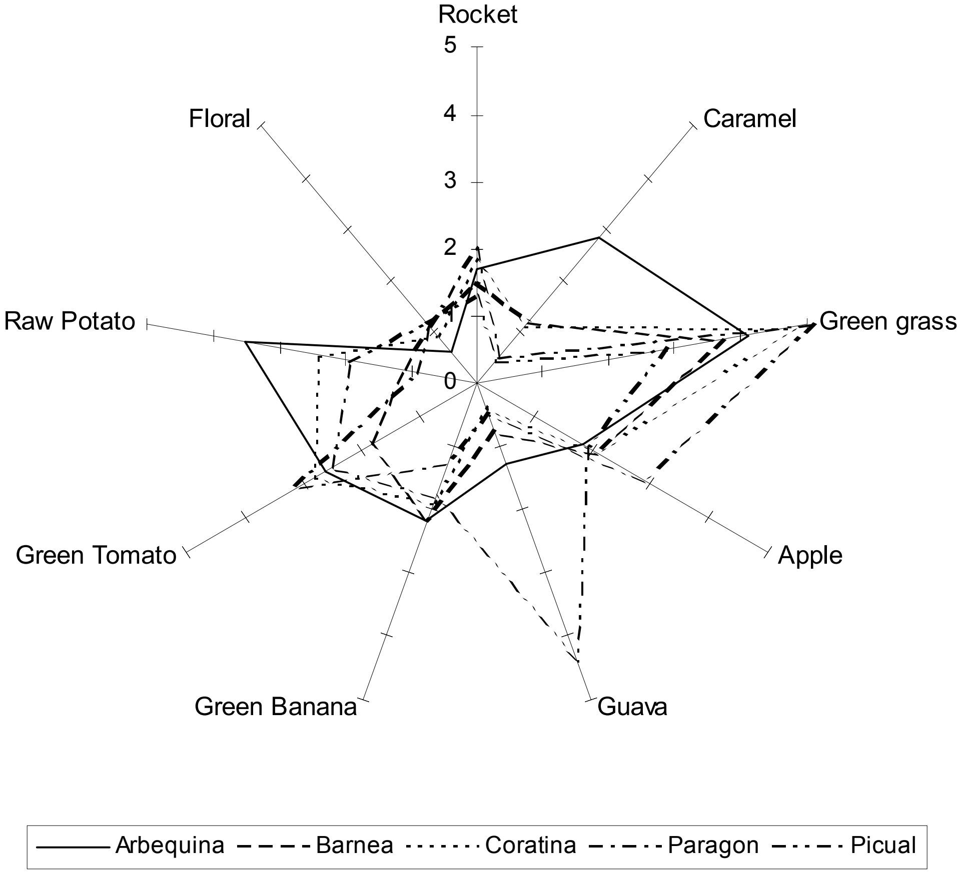


Figure 2: Mean attribute ratings for overall aroma and palate attributes 2003 season

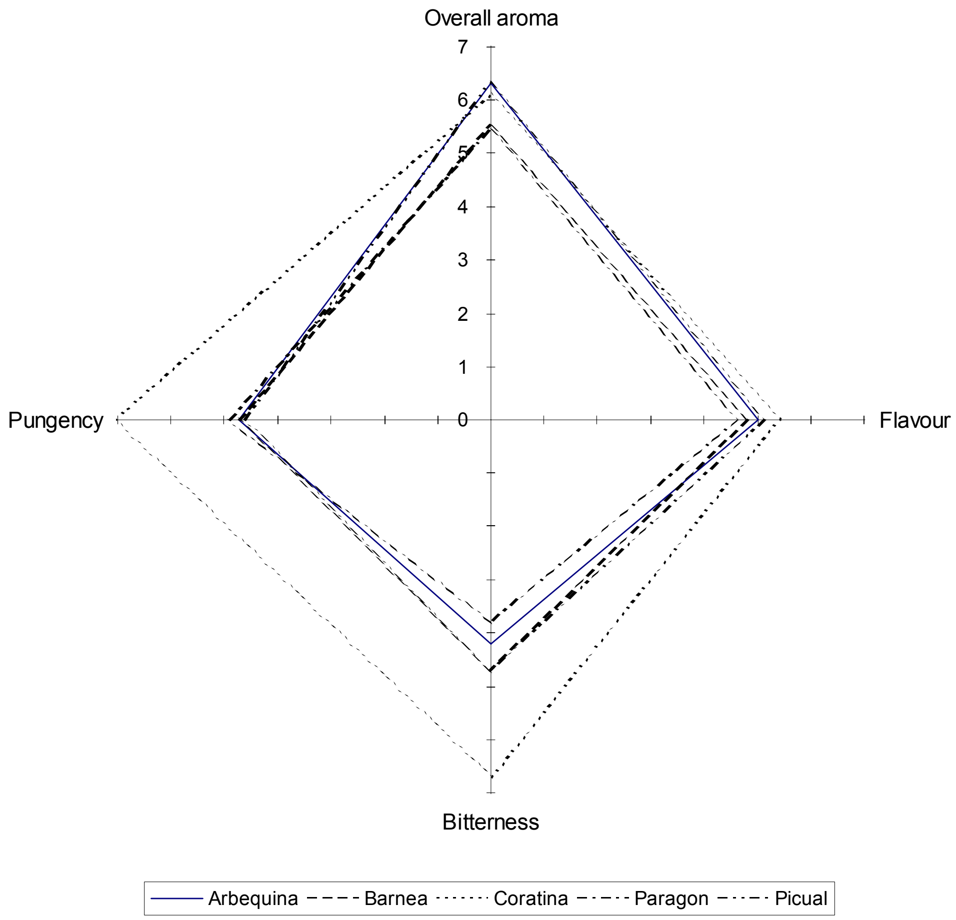


Table 3: Analysis of variance statistics of aroma and palate attribute ratings of 2002 varietal olive oils

	Variety	p	Judge x Variety Interaction	p
Aroma Attributes				
Apple	0.67	0.583	1.01	0.478
Green grass	1.87	0.170	1.57	0.139
Hay	0.72	0.554	0.99	0.499
Caramel	0.51	0.683	0.89	0.591
Pepper	0.46	0.712	0.81	0.678
Green tomato	0.19	0.903	0.88	0.600
Floral	0.60	0.623	1.13	0.377
General Attributes				
Overall flavour	2.46	0.095	0.59	0.879
Bitterness	5.26	0.009	0.51	0.928
Pungency	3.68	0.032	0.52	0.924

Table 4: Mean Attribute Ratings of 2002 Varietal Olive Oils

Variety	Arbequina	Coratina	Pendolino	Picual	LSD 5%
Aroma Attributes					
Apple	0.0 [a]	0.4 [a]	0.2 [a]	0.1 [a]	ns
Green grass	2.8 [a]	3.3 [a]	3.7 [a]	4.1 [a]	ns
Hay	0.7 [a]	0.8 [a]	0.5 [a]	0.3 [a]	ns
Caramel	1.1 [a]	1.0 [a]	0.5 [a]	0.8 [a]	ns
Pepper	2.3 [a]	2.1 [a]	1.7 [a]	2.2 [a]	ns
Green tomato	0.9 [a]	0.7 [a]	0.8 [a]	1.0 [a]	ns
Floral	0.0 [a]	0.1 [a]	0.2 [a]	0.1 [a]	ns
General Attributes					
Overall flavour	2.8 [a]	3.7 [b]	3.1 [ab]	3.5 [ab]	0.9
Bitterness	3.6 [a]	4.5 [ab]	5.3 [b]	2.8 [a]	1.7
Pungency	5.2 [ab]	5.4 [ab]	5.7 [b]	3.8 [a]	1.7

Figure 3: Mean attribute ratings for aroma attributes of 2002 varietal oils

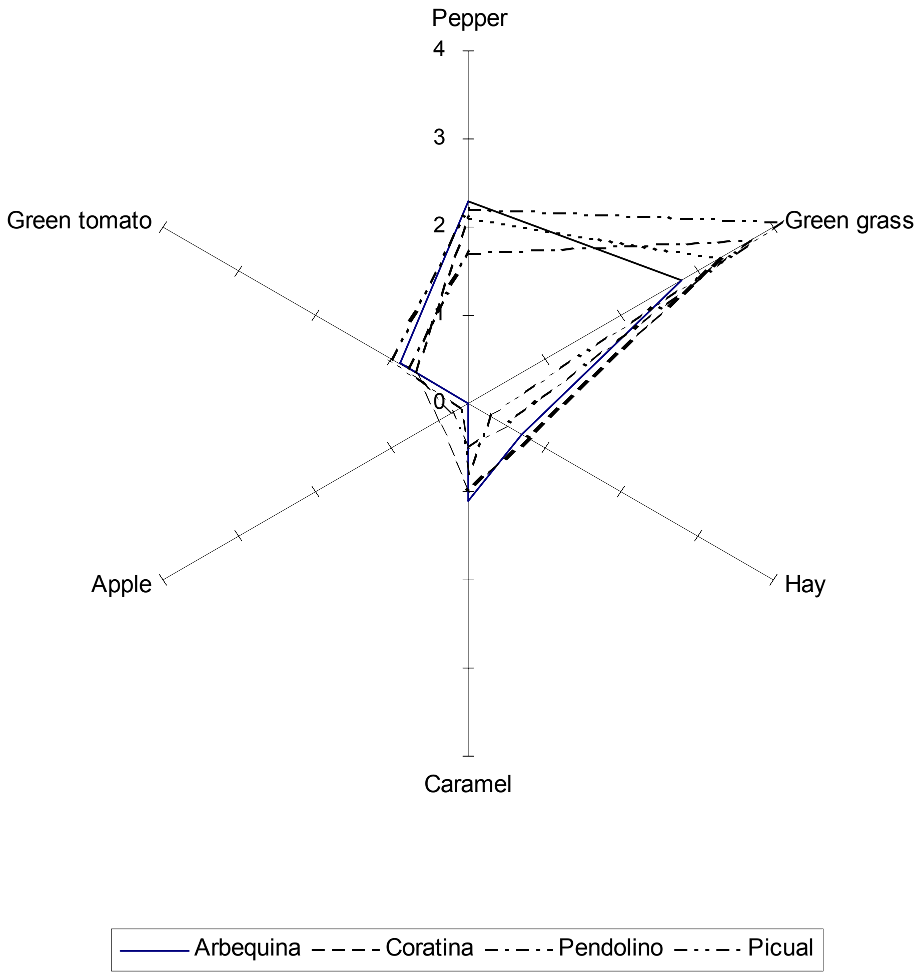
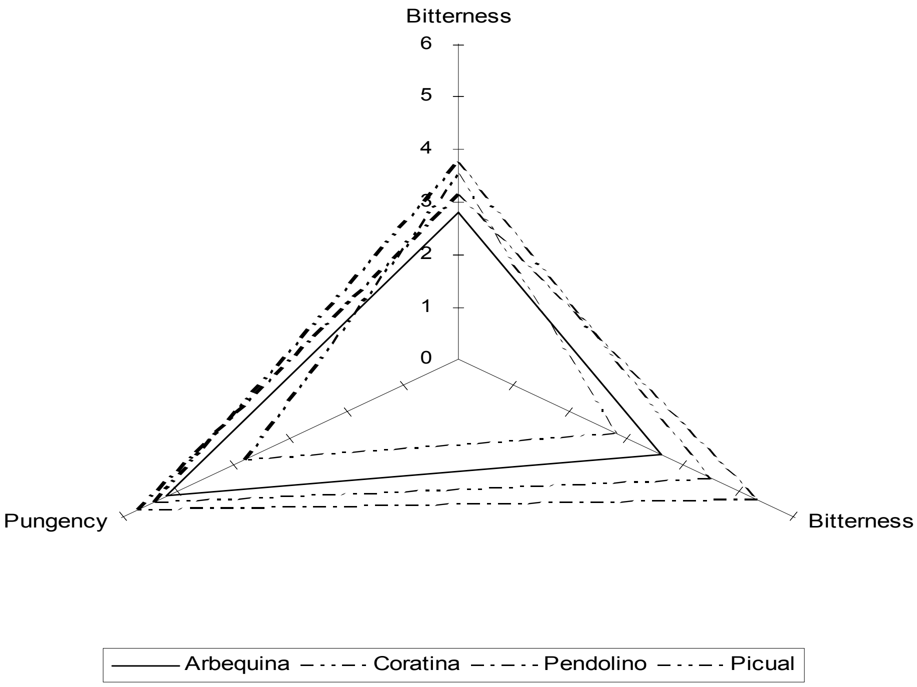


Figure 4: Mean attribute ratings for palate attributes 2002 season



Appendix 1a: 2003 taster performance in rating the intensity of 1) nine aroma attributes and 2) three palate attributes (flavour, bitterness and pungency) of olive oils produced from 5 different varieties.

	Aroma Attributes		Overall Aroma and Palate Attributes	
Assessor No.	Reliability	Significance level	Reliability	Significance level
1	0.54	***	0.65	**
2	0.51	***	0.72	***
3	0.32	*	0.55	**
4	0.08	ns	0.11	ns
5	0.74	***	0.78	***
6	0.60	***	0.05	ns
7	0.40	**	0.41	*
8	0.53	***	0.42	*
9	0.08	ns	0.81	***
10	0.50	**	0.82	***
11	0.38	**	0.43	*
12	0.34	*	0.50	*

ns, *, **, *** indicate not significant, and significant at 5%, 1% and 0.1% respectively.

Appendix 1b: 2002 taster performance in rating the intensity of 1) nine aroma attributes and 2) three palate attributes (flavour, bitterness and pungency) of olive oils produced from 4 different varieties

	Aroma Attributes		Palate Attributes	
Assessor No.	Reliability	Significance level	Reliability	Significance level
1	0.85	***	0.22	ns
2	0.39	*	0.72	***
3	0.56	**	0.51	**
4	0.51	**	0.04	ns
5	0.87	***	0.11	ns
6	0.10	ns	0.04	ns
7	0.44	*	0.22	ns
8	0.06	ns	0.29	ns
9	0.76	***	0.26	ns
10	0.09	ns	0.08	ns
11	0.06	ns	0.18	ns
12	0.40	*	0.50	**

ns, *, **, *** indicate not significant, and significant at 5%, 1% and 0.1% respectively.

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