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& DEVELOPMENT CORPORATION

Olive Variety Assessment

for Subtropical Summer Rainfall Regions

A report for the Rural Industries Research and Development Corporation

by Greg O'Sullivan

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Foreword

Olive trees have been cultivated in Australia on a small scale since the early 1800s but olives have never been a major contributor to the value of the primary industry of this country. Interest in the planting of olive groves in Australia has increased significantly over the past decade, mainly through the entrepreneurial activities of olive propagators and growers, the encouragement of local olive associations and general promotion of the crop for its nutritional and health benefits.

Most of the Australian plantings of olives have been made in areas with a Mediterranean type of climate, similar to that of the traditional olive growing areas in Europe. Many recent olive plantings have, however, been made in areas in Australia which do not have such a climate. Although much olive genetic variability has been imported into Australia over the last century. There has been little systematic evaluation of this variability, particularly in the new environments into which the latest plantings are now spreading.

South-east Queensland has a subtropical environment of predominantly summer rainfall and relatively warm winters. Olive plantings have been expanding in this region, with limited knowledge of the adaptability of the available germplasm to the area or the prevailing climatic conditions.

This publication presents preliminary observations of growth, fruit set and yield among sixty olive varieties in a summer rainfall, warm winter environment, typical of the agricultural regions of south-east Queensland and north-eastern New South Wales. The sixty genotypes investigated in this study represent most of the important commercial varieties currently under cultivation in Australia as well as a range of lesser known varieties sourced from government research trials and private plantings.

This project was jointly funded by Olives Australia Pty Ltd and from RIRDC Core Funds which are provided by the Federal Government.

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Simon Hearn
Managing Director
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Executive Summary

Interest in the planting of olive groves in Australia has increased significantly over the past decade. It is estimated that approximately 7.5 million olive trees have been planted in Australia since 1990 (RIRDC, 2002). Most of the Australian plantings of olives have been made in areas with a Mediterranean type of climate, similar to that of the traditional olive growing areas in Europe. Many recent olive plantings have, however, been made in areas which receive predominantly summer rather than winter rainfall - a factor on which very little international olive industry research is available.

South-east Queensland, the region under investigation, has a subtropical environment of predominantly summer rainfall and relatively warm winters. Olive plantings have been expanding in this region, with limited knowledge of the adaptability of the available germplasm to the area or the prevailing climatic conditions.

This three year project evaluated the performance of sixty olive varieties in a warm winter summer rainfall environment in south-east Queensland with the aim of identifying varieties suitable for future plantings into similar climatic regions. The olive genotypes investigated represented most of the important commercial varieties currently under cultivation in Australia as well as a range of lesser known varieties sourced from government research trials and private plantings.

After three years, an early start to bearing and relatively high productivity was observed in ten varieties viz. 'Tiny Kalamata', 'Arbequina', 'Big Spanish', 'Belle of Spain', 'Del Morocco', 'Special Koroneiki', 'I-77', 'Arecuzzo', 'Rosciola' and 'Oblonga'. The majority of the remaining varieties have expressed satisfactory tree growth but little fruit set. Six of the bearing varieties, 'Tiny Kalamata', 'Arbequina', 'Big Spanish', 'Belle of Spain' 'Del Morocco' and '1-77' produced fruit with a high oil content (>20%). The average yields of these varieties were also relatively high ranging from 11.3 to 18.8 kg between varieties in their third year after planting.

The winter chilling hours recorded at the site averaged 488.4 hours which suggests that insufficient winter chilling may be a limiting factor in floral induction and subsequent fruit set in some of the varieties in this study. As most varieties do not start bearing commercially until their fourth or fifth year, it is too early at this stage to speculate on the influence that the climate may have on flowering.

Tree growth is closely related to productivity and at this stage of the trial it is the primary characteristic that can be used to evaluate varietal performance. The ten varieties showing the highest rate of vegetative growth were; 'Tiny Kalamata', 'Lecqure', 'Koroneiki', 'No.14', 'Frantoio'/'Paragon', 'Mediterranean', 'Correggiola', 'Pecholine', 'Helena' and 'Fantago'.

Preliminary oil extraction results indicate that high fruit moisture at the time of processing is problematic and can affect commercial oil extractability. McCulloch (2001) suggested that the larger-fruited pickling or dual purpose varieties have a higher tendency to accumulate fruit moisture and present subsequent oil extraction difficulties, than oil varieties. The limited data obtained in the present study suggests that, under the prevailing climatic conditions, oil varieties such as 'Arbequina' can be similarly affected. However, the propensity to accumulate fruit moisture was found to vary between varieties.

These findings highlight the importance of reducing fruit moisture as a means of improving olive oil extraction. Pre and post-harvest technologies will need to be developed to improve olive oil extraction from fruit produced in this environment. Some Australian olive growers are currently implementing regulated deficit irrigation (RDI) type strategies in the months leading up to harvest in an attempt to reduce fruit moisture content. Further research is required to evaluate the effect of RDI on fruit moisture in summer rainfall regions.

Five of the early bearing varieties identified are small-fruited varieties with a fruit weight less than 2 grams. Although small-fruited varieties are extensively grown as commercial oil varieties throughout the world, fruit that ranges in size from 1-2 grams are not suited to traditional mechanical harvesting methods because of the low fruit weight to attachment ratio. Improved harvesting technologies such as the use of chemical fruit loosening agents will be required to overcome the harvesting disadvantages associated with the cultivation of these varieties.

Field observations and DNA analyses (Archer, 2001) have suggested that at least two of the obscurely named varieties in the trial are important commercial varieties that have been at some point in the past erroneously named. These are, 'Big Spanish' and 'Tiny Kalamata' which are identical to 'Arbequina' and 'Koroneiki' respectively.

This initial research has identified several early bearing, high yielding varieties with adaptability to the prevailing climate. It also provides important base line information for future comparisons. At this stage, an indication of the fruiting capabilities of most of the varieties has not been derived. As it is not uncommon for young olive trees to remain in a vegetative state until their fourth or fifth year after planting an evaluation of the commercial performance of the varieties will not be obtained until the sixth year. Ongoing research is now required to determine the mature fruiting capabilities and long term performance of the trees.

1. Introduction

Olive trees have been cultivated in Australia on a small scale since the early 1800s (Robards and Mailer, 2001) but olives have never been a major contributor to the value of the primary industry of this country. Interest in the planting of olive groves in Australia has increased significantly over the past decade, mainly through the entrepreneurial activities of olive propagators and growers, the encouragement of local olive associations and general promotion of the crop for its nutritional and health benefits. It is estimated that approximately 7.5 million olive trees have been planted in Australia since 1990 (RIRDC, 2002). The majority of new olive groves being established in Australia are intensive, fully irrigated groves designed for mechanized harvesting. Most have been planted for oil production.

Most of the Australian plantings of olives have been made in areas with a Mediterranean type of climate, similar to that of the traditional olive growing areas in Europe. Many recent olive plantings have, however, been made in areas in Australia which do not have such a climate. Much olive genetic variability has been imported into Australia over the last century. There has been little systematic evaluation of this variability (Marti, 1995), particularly in the new environments into which the latest plantings are now spreading. Investigators have also suggested there is much duplication under various varietal synonyms (Marti, 1995).

Several climatic factors are apparently critical for olive performance, in terms of flowering, fruit growth and oil production and quality. Some winter chilling is required for floral initiation (Hartmann, 1962) but this requirement varies quantitatively between variety. Generally, varieties originating from California, Italy and Spain require more winter chilling than those commonly grown in Crete, Egypt, southern Greece and Israel (Martin *et al.*, 1994). In the olive growing regions of Chania, Crete and California's Central Valley the number of chilling hours below 7 ^{o}C range from 86 to 1400 hours respectively (Hartmann and Whisler, 1975). In research undertaken by Hartmann and Whisler (1975) sufficient flowering occurred in 'Manzanillo,' 'Sevillano,' 'Mission' and 'Ascolana' when the daily temperature fluctuated between 2 ^{o}C and 15 ^{o}C for 70 to 80 days. Fewer flowers were produced on trees subject to temperatures between 7 ^{o}C and 18 ^{o}C. In Dukou a southerly region of China olives did not bear fruit unless winter minimum temperatures fell below 0 ^{o}C (Weiying *et al.*, 1998). In tropical regions that do not provide sufficient winter chilling, olives trees grow well vegetatively but fruit production is low or nonexistent (Hartmann and Whisler, 1975).

A long growing season with relatively high summer temperatures is required for fruit development (Hartmann, 1962). Annual sunlight in excess of 1912 hours has been described as sufficient for olive cultivation (Weiying *et al.*, 1998). Olives are sensitive to water deficits in summer, suffering reduced shoot growth, less carbohydrate production and shrivelled fruit (Beede and Goldhamer, 1994). Excessive water during ripening can reduce oil yield and quality (Motilva *et al*., 1999) and high fruit moisture content at the time of processing is often associated with poor oil extraction (Mailer, 2002). Excessive summer/autumn rainfall can also favour disease development such as peacock spot (*Spilocaea oleaginea*), anthracnose (*Gloeosporium* sp) (Lopez-Villalta, 1999) and root rot (Weiying *et al.*, 1998).

South-east Queensland, the region under investigation, has a subtropical environment of predominantly summer rainfall and relatively warm winters. Olive plantings have been expanding in this region, with limited knowledge of the adaptability of the available germplasm to the area or the prevailing climatic conditions (O'Sullivan and Fletcher, 2002).

This report presents preliminary observations of growth, fruit set and yield among sixty varieties in a summer rainfall, warm winter environment, typical of the agricultural regions of south-east Queensland and north-eastern New South Wales. The sixty genotypes investigated in this study represent most of the important commercial varieties currently under cultivation in Australia as well as a range of lesser known varieties sourced from government research trials and private plantings. Each genotype is referred to by its varietal name currently in use in Australia. The identity, however, of many of the genotypes is yet to be confirmed.

2. Materials and Methods

Trees were propagated from semi-hardwood stem cuttings at Olives Australia Pty Ltd, Grantham, 20km south of Gatton, and grown on for 11-15 months in 2 litre pots in the open at that site.

The research grove was established in May 1999 at Buaraba (Long 27^o 33' Lat 152^o 20') 35 km NNE of Gatton in south-east Queensland. Trees were planted into 5 x 8 metre spacings on 45 cm raised beds. The sixty varieties were planted with 3 replications and 4 trees per experimental unit, in a generalised lattice design. Each tree was serviced with a micro irrigation sprinkler, capable of supplying 36 l/hour. An on-site Davis weather station (Davis Instruments CA, USA) recorded air temperature, rainfall, wind speed, solar radiation, relative humidity and evapotranspiration.

All trees were maintained in their natural growth form for the first three years after planting and were subject to only minimal pruning. The grove was subjected to standard horticultural practices. Annual leaf tissue analyses were undertaken to monitor nutritional status and determine fertiliser requirements.

A severe summer storm caused serious damage to the research grove during February 2002, the third year after planting. The storm affected 70% of the trees with many being uprooted and totally destroyed. Others were blown over but were able to recover after re-staking and severe pruning. As a result of the storm damage severe limitations were placed on the evaluation and statistical analysis of the surviving intact trees. Where post-storm data is presented the number of trees used to obtain the varietal means are indicated in the text. A table of the surviving trees is presented in Appendix 2.

2.1 Growth measurements

Trunk diameter 30cm above ground, tree height from the average position of the lowest branches to the top of the tree and mean canopy width measured east-west and north-south were measured at the beginning and the end of each growing season for a period of three years from July 1999 to May 2002.

Seasonal shoot growth was measured by tagging four young lateral shoots on the periphery of the canopy on each tree. The length of each shoot was measured at the beginning and end of the growing season in September and May respectively for the period from July 1999 to May 2002. Four new shoots were tagged at the beginning of each growing season.

2.2 Fruit set, yield and oil content

Each tree was scored for fruit set during February in the third year after planting, using ratings of 0 (nil fruit set), 1 (sparse fruit set), 2 (medium fruit set) or 3 (high fruit set).

Fruit yield, individual fruit weight, oil content and moisture content were derived from trees bearing more than 1.5 kg of fruit in the 2002 season. Trees were harvested over a 10-week period from March to May. Each variety was harvested when either; 75% of the fruit were coloured purple/black, or greater than 5% fruit drop had occurred. Trees of the same variety were harvested on the same day. Fruit weight, oil content, moisture content and maturity index were derived from a collective sample of each variety. Fruit yield values were the means of all intact varietal experimental units.

Oil content of the fruit was derived using the standard Soxhlet oil extraction method. Where fruit yield was greater than 25kg per variety, samples were also processed in a commercial Oliomio 50 two-phase centrifugal extraction unit (Toscana Enologica Mori, Italy- supplied by Olive Agencies, Grantham, Queensland). Results obtained from both extraction methods were expressed as a percentage of fresh weight standardised at 50% moisture. Maturity index was determined using a subjective evaluation of the colour of the olive skin and pulp (IOOC, 1990).

2.3 Statistical analysis

Growth data was statistically analysed using an analysis of variance through the SAS system.

3. Results

3.1 Growth measurements

A summary of the vegetative growth and fruit set of the sixty varieties 26 months after planting is presented in Table 1. Significant differences were found amongst the trees in all parameters measured. 'Manzanillo' which makes up a large percentage of the recent plantings in Australia is used as a standard for comparative purposes in the table. Trees were ranked using measurements of trunk diameter and tree height increase.

Mean tree height at planting ranged from 48.8 to 130.2 cm between varieties, averaging 95.0 cm. After 26 months, height ranged from 194.2 to 444.4 cm, averaging 306.9 cm. The percentage increases in height between varieties ranged from 118.7 to 471.3%, averaging 231.6%. The increase in trunk diameter between varieties over the same period ranged from 3.60 to 8.78 cm, averaging 6.42 cm. There was a significant relationship between trunk and tree height increases for the 60 varieties (Figure 1). Mean canopy diameter after 26 months ranged from 88.7 to 238.9 cm, averaging 176.8 cm.

Mean annual shoot growth for the 2000-2001 season ranged from 35.4 to 62.6 cm between varieties, averaging 18.9 cm (Table 2). Winter shoot growth as a percentage of the total annual growth ranged from 2.8 to 43.8%, averaging 15.9 %.

After the storm damage in February 2002, 24 varieties remained with between four and twelve trees intact. Trunk diameter increase, tree height increase and tree height for these varieties, three years after planting is presented in Table 3.

A comparison of the growth habit amongst the sixty varieties using height and width dimensions 26 months after planting is presented in Figure 2. Illustrations in each quadrant of the graph are indicative of varietal growth habit.

Table 1. Trunk diameter increase, original transplant height, tree height, canopy width 26 months after planting and fruit set score in the third season for 60 varieties of olive grown at Buaraba in south-east Queensland.

Rank	Variety	Trunk diameter Increase (cm) July 99-Sept 01	Original height (cm) July 1999	Tree height (cm) Sept 01	Height increase (cm) July 99-Sept 01	Height increase (%) July 99-Sept 01	Canopy width (cm) Sept 01	Fruit set score Feb 02
1	**'Tiny Kalamata'**	**8.16 ± 0.12a**	**108.4 ± 2.62**	**361.6 ± 4.80**	**253.8 ± 4.48**	**234.1**	**229.3 ± 8.7a**	**2.33 ± 0.14a**
2	'Lecqure'	7.96 ± 0.14**a**	112.0 ± 2.40	365.0 ± 6.29	251.9 ± 7.32	224.9	212.0 ± 8.7	0.33 ± 0.19
3	'Koroneiki'	8.78 ± 0.26**a**	119.7 ± 2.64	364.5 ± 6.62	243.8 ± 6.18	203.7	238.9 ± 9.0**a**	1.44 ± 0.20
4	'No.14'	8.07 ± 0.20**a**	119.3 ± 1.72	360.6 ± 9.34	240.4 ± 9.00	201.4	213.0 ± 9.9	1.33 ± 0.35
5	'Frantoio'/'Paragon'	7.53 ± 0.18**a**	100.8 ± 4.81	353.5 ± 6.17	252.9 ± 8.71	251.0	201.0 ± 9.0	0.00 ± 0.00**a**
6	'Mediterranean'	7.56 ± 0.38**a**	86.4 ± 5.12	335.9 ± 15.07	245.7 ± 16.45	284.4	200.8 ± 9.0	0.50 ± 0.16
7	'Correggiola'	7.68 ± 0.19**a**	121.4 ± 1.48	360.9 ± 8.65	239.4 ± 8.22	197.2	216.4 ± 8.7	0.33 ± 0.14
8	'Pecholine'	6.96 ± 0.18	80.2 ± 3.49	337.3 ± 6.44	256.6 ± 4.95	320.1	176.7 ± 8.7	0.33 ± 0.14
9	'Helena'	7.70 ± 0.11**a**	118.6 ± 1.00	355.0 ± 8.04	236.5 ± 7.77	199.5	212.8 ± 9.0	1.17 ± 0.21
10	'Fantago'	6.94 ± 0.28	69.2 ± 5.93	322.8 ± 10.27	260.6 ± 8.40	376.4	191.2 ± 11.0	0.22 ± 0.18
11	'UC13A6'	7.75 ± 0.24**a**	74.9 ± 6.18	302.6 ± 7.16	228.4 ± 9.36	304.8	164.1 ± 9.0	0.00 ± 0.0**a**
12	'Boutillon'	7.56 ± 0.24**a**	86.9 ± 3.03	326.8 ± 7.02	236.9 ± 8.80	272.6	206.6 ± 8.7	0.83 ± 0.11
13	'Manzanillo' No 2	6.96 ± 0.14	105.8 ± 2.93	350.3 ± 7.67	245.1 ± 9.06	231.6	180.4 ± 9.4	0.33 ± 0.16
14	'UC6A7'	7.60 ±0.89**a**	114.1 ± 5.23	444.4 ± 13.91	226.1 ± 59.40	198.0	216.1 ± 16.6	0.54 ± 0.40
15	'Boultillan'	7.20 ± 0.32	112.1 ± 1.90	339.3 ± 14.21	230.6 ± 14.81	205.8	196.8 ± 9.4	0.25 ± 0.15
16	'Picual'	6.61 ± 0.18	87.5 ± 2.59	333.2 ± 8.18	246.1 ± 8.64	281.3	162.3 ± 9.4	1.25 ± 0.21
17	'Belle of Spain'	7.59 ± 0.23**a**	94.4 ± 4.55	332.5 ± 8.49	216.7 ± 9.04	229.5	215.5 ± 9.4	0.67 ± 0.36
18	'Rosciola'	7.24 ± 0.24	94.4 ± 4.55	310.8 ± 8.06	217.2 ± 5.77	230.0	211.5 ± 8.7	1.42 ± 0.23
19	'Nab Tamri'	7.02 ± 0.21	79.4 ± 2.71	299.0 ± 5.43	220.5 ± 6.49	277.7	185.5 ± 8.7	0.33 ± 0.14
20	**'Big Spanish'**	**7.05 ± 0.19**	**111.0 ± 3.33**	**323.5 ± 3.37**	**213.0 ± 4.03**	**191.9**	**204.6 ± 9.4**	**3.00 ± 0.00a**
21	'Volos'	6.44 ± 0.34	85.7 ± 6.06	322.9 ± 12.98	237.4 ± 15.33	277.1	171.2 ± 9.0	0.00 ± 0.00**a**
22	'Hojiblanca'	6.23 ± 0.38	106.8 ± 5.11	349.2 ± 9.03	242.7 ± 10.50	227.1	162.1 ± 9.0**a**	0.17 ± 0.12**a**
23	**'Oblonga'**	**6.99 ± 0.11**	**101.0 ± 3.01**	**315.3 ± 5.25**	**211.6 ± 7.28**	**209.5**	**208.7 ± 9.0**	**2.78 ± 0.12a**
24	'A Prugo'	6.42 ±0.45	69.8 ± 2.44	299.4 ± 14.33	228.5 ± 14.51	327.6	162.4 ± 10.4	0.00 ± 0.00**a**
25	'Correggiola' No 2	7.00 ± 0.18	114.6 ± 9.17	323.0 ± 3.75	207.7 ± 10.34	181.2	178.5 ± 8.7	0.00 ± 0.00**a**
26	'Atro Rubens'	6.21 ± 0.25	85.1 ± 5.22	320.9 ± 5.02	235.7 ± 6.45	277.0	160.6 ± 8.7	0.33 ± 0.14
27	**'Special Koroneiki'**	**6.82 ± 0.20**	**96.6 ± 3.89**	**307.5 ± 5.88**	**207.5 ± 5.98**	**214.8**	**179.3 ± 8.7**	**2.67 ± 0.14 a**
28	'Manzanillo'	6.23 ±0.20	117.6 ± 2.58	341.4 ± 10.45	227.5 ± 11.06	193.5	175.3 ± 8.7	1.00 ± 0.21
29	'Bot'	6.60 ± 0.37	74.9 ± 3.17	285.0 ± 9.72	209.8 ± 10.48	280.2	173.2 ± 9.0	0.00 ± 0.00**a**
30	'Benito'	6.36 ± 0.40	67.5 ± 3.39	280.3 ± 15.87	214.3 ± 14.85	317.6	183.8 ± 9.4	0.00 ± 0.00**a**
31	**'Arbequina'**	**6.54 ± 0.25**	**102.5 ± 2.83**	**311.5 ± 7.26**	**209.5 ± 7.96**	**204.5**	**184.3 ± 8.7**	**2.78 ± 0.12 a**
32	'Museum'	6.25 ± 0.20	81.8 ± 4.02	297.6 ± 5.09	216.3 ± 5.99	264.5	151.3 ± 8.7**a**	0.42 ± 0.15
33	'Palermo'	5.99 ± 0.48	54.3 ± 1.98	281.8 ± 16.09	225.1 ± 15.47	414.2	161.2 ± 9.4**a**	0.53 ± 0.17
34	'Mazzone'	6.50 ± 0.16	98.1 ± 3.45	301.7 ± 7.16	202.4 ± 6.54	206.4	175.4 ± 9.0	0.00 ± 0.00 **a**
35	'Tarascoa'	6.72 ± 0.18	106.8 ± 1.82	291.6 ± 6.83	184.8 ± 7.63**a**	173.1	170.3 ± 9.0	1.25 ± 0.19
36	'Del Morocco'	6.19 ± 0.27	81.3 ± 5.23	294.4 ±7.64	211.6 ± 8.81	260.2	177.6 ± 8.7	1.42 ± 0.34
37	'Nevadillo Blanco'	6.79 ± 0.41	109.9 ± 2.33	293.2 ± 10.25	184.5 ± 9.66**a**	167.9	183.9 ± 9.4	0.33 ± 0.16
38	'Gethsemane'	6.80 ± 0.30	98.7 ± 2.16	275.9 ± 7.13	178.1 ± 5.76**a**	180.5	184.5 ± 8.7	0.92 ± 0.19
39	'Wallace'	4.95 ± 0.28**a**	48.8 ± 3.61	280.2 ± 8.27	230.2 ± 8.05	471.3	129.5 ± 9.0	0.42 ± 0.15
40	'Pendulina'	6.33 ± 0.27	89.6 ± 3.69	273.6 ± 6.61	185.2 ± 7.21**a**	206.6	172.3 ± 8.7	0.42 ± 0.15
41	'UC22A11'	6.47 ± 0.23	111.9 ± 2.72	289.8 ± 9.01	178.1 ± 9.25**a**	159.1	183.3 ± 9.0	0.53 ± 0.21
42	'Wagga Verdale'	6.01 ± 0.20	94.0 ± 5.96	287.4 ± 4.40	192.0 ± 4.90	204.3	168.0 ± 9.0	0.61 ± 0.20
43	'Black Italian'	5.05 ± 0.14**a**	68.1 ± 1.95	282.1 ± 4.80	212.7 ± 5.99	312.4	139.7 ± 9.4	0.00 ± 0.00**a**
44	'Queen of Spain'	5.57 ± 0.41	77.2 ± 2.39	275.5 ± 11.63	200.6 ± 10.85	260.0	137.4 ± 8.7	0.00 ± 0.00**a**
45	'Sevillano'	5.48 ± 0.32	59.8 ± 4.83	264.5 ± 11.50	201.2 ± 11.40	336.7	158.2 ± 9.9**a**	0.25 ± 0.16
46	'Mission'	5.62 ± 0.37	119.4 ± 4.45	311.9 ± 13.96	191.3 ± 14.65	160.2	161.6 ± 8.7**a**	0.92 ± 0.19
47	'Manzanillo' No 14	5.27 ± 0.30	101.3 ± 5.64	302.6 ± 11.09	201.1 ± 13.58	198.7	168.8 ± 9.0	1.33 ± 0.30
48	'Arecuzzo'	6.33 ± 0.35	99.6 ± 2.79	260.8 ± 9.08	159.8 ± 9.08	160.5	180.9 ± 8.7	1.78 ± 0.23
49	'Nab Tamri'- OA	5.79 ± 0.34	87.5 ± 1.69	269.9 ± 9.69	183.5 ± 9.56**a**	209.8	169.8 ± 9.0	0.00 ± 0.00**a**
50	'Borreggiola'	5.06 ± 0.31**a**	70.4 ± 3.02	271.6 ± 10.37	200.2 ± 10.30	284.2	152.3 ± 9.0**a**	0.25 ± 0.14
51	'Azapa'	5.14 ± 0.20	99.7 ± 4.02	288.6 ± 8.91	189.2 ± 10.08	189.8	180.7 ± 9.9	0.00 ± 0.00**a**
52	'Verdale'	5.50 ± 0.14	106.7 ± 2.35	289.1 ± 6.30	182.4 ± 7.73**a**	171.0	170.2 ± 9.0	0.25 ± 0.14
53	'Hardy's Mammoth'	6.08 ± 0.44	119.5 ± 1.51	260.1 ± 7.55	141.8 ± 7.75**a**	118.7	190.0 ± 9.0	0.08 ± 0.08**a**
54	'I-77'	5.51 ± 0.35	130.2 ± 4.75	307.5 ± 10.10	176.8 ± 9.47**a**	135.9	162.4 ± 8.7**a**	1.50 ± 0.29
55	'No.1'	5.29 ± 0.12	110.2 ± 1.78	286.1 ± 6.06	177.7 ± 5.21**a**	161.3	166.5 ± 9.0**a**	0.00 ± 0.00**a**
56	'South Australian Verdale'	5.35 ±0.22	109.4 ± 2.96	282.4 ± 6.19	171.2 ± 5.34**a**	156.5	154.6 ± 9.0**a**	0.00 ± 0.00**a**
57	'White'	4.76 ± 0.33**a**	80.6 ± 8.22	243.6 ± 11.20	161.3 ± 13.08**a**	200.2	130.3 ± 0.4**a**	0.42 ± 0.18
58	'Kalamata'	4.07 ± 0.63**a**	87.1 ± 1.72	254.7 ± 16.86	170.2 ± 16.33**a**	195.5	88.7 ± 10.4**a**	0.00 ± 0.00**a**
59	'Barouni'	4.91 ± 0.61**a**	107.6 ± 4.31	263.1 ± 12.51	159.0 ± 14.91**a**	147.8	138.2 ± 9.9**a**	0.25 ± 0.17
60	'UC23A9'	3.60 ± 0.42**a**	75.3 ± 2.82	194.2 ± 16.96	120.8 ± 14.03**a**	160.5	127.5 ± 9.9**a**	0.33 ± 0.18
	LSD *(P=0.05)*	**1.14**			**39.7**		**26.3**	**0.82**
	Mean	6.42	95.0	306.9	209.7	231.6	176.8	0.68
	Min	3.60	48.8	194.2	120.8	118.7	88.7	0.00
	Max	8.78	130.2	444.4	260.6	471.3	238.9	3.00

Values are means ± SE. Means followed by the letter **a** are significantly different from 'Manzanillo'. Varieties listed in **bold** had good fruit set. Fruit scores : **0**-nil fruit set: **1**-sparse fruit set; **2**- medium fruit set; **3**-high fruit set. Rankings are based on trunk diameter increase and tree height increase.

Table 2. Seasonal shoot growth, annual shoot growth and percentage winter shoot growth of 16 month old olive trees grown at Buaraba in south-east Queensland.

Rank	Variety	Shoot growth Sept 2000 to May 2001 (cm)	Shoot growth June 2001 to Aug 2001 (cm)	Annual shoot growth 2000/2001 (cm)	Percentage winter shoot growth
1	'UC6A7'	50.1 ± 10.1	12.5 ± 2.8	62.6	20.0
2	'Rosciola'	44.4 ± 4.6	13.1 ± 1.1	57.5	22.8
3	'No.14'	44.8 ± 5.3	10.3 ± 1.3	55.1	18.7
4	'Hardy's Mammoth'	46.9 ± 4.6	4.8 ± 1.2	51.7	9.3
5	'Azapa'	46.7 ± 4.9	4.3 ± 1.3	51.0	8.5
6	'Benito'	43.6 ± 5.0	6.1 ± 1.3	49.7	12.3
7	'Mission'	41.0 ± 5.0	8.1 ± 1.2	49.1	16.6
8	'A Prugo'	38.5 ± 4.9	8.5 ± 1.4	47.0	18.1
9	'Frantoio'/'Paragon'	35.1 ± 4.7	11.7 ± 1.2	46.8	24.9
10	'Nab Tamri'	34.7 ± 4.4	8.9 ± 1.1	43.6	20.3
11	'Manzanillo' No 14	36.8 ± 4.7	5.4 ± 1.2	42.1	12.7
12	'Manzanillo'	37.1 ± 4.4	4.1 ± 1.2	41.2	10.0
13	'Pendulina'	36.3 ± 4.6	4.5 ± 1.2	40.8	11.0
14	'Arecuzzo'	35.2 ± 4.7	5.1 ± 1.2	40.3	12.6
15	'Volos'	32.3 ± 5.0	7.5 ± 1.2	39.8	18.8
16	'Oblonga'	34.1 ± 4.6	5.5 ± 1.2	39.6	13.9
17	'Sevillano'	32.1 ± 5.0	7.4 ± 1.3	39.5	18.9
17	'South Australian Verdale'	36.8 ± 4.5	2.7 ± 1.1	39.5	6.7
19	'Manzanillo' No 2	29.0 ± 4.8	10.3 ± 1.2	39.4	26.2
19	'Nab Tamri'- OA	32.5 ± 4.7	6.9 ± 1.2	39.4	17.6
21	'Lecqure'	26.7 ± 4.5	12.0 ± 1.1	38.8	31.1
22	'Correggiola' No 2	37.0 ± 4.4	1.6 ± 1.1	38.6	4.1
23	'Bot'	29.5 ± 5.0	8.9 ± 1.2	38.4	23.1
24	'No.1'	36.6 ± 5.0	1.6 ± 1.2	38.2	4.2
25	'Wagga Verdale'	34.2 ± 4.5	3.8 ± 1.2	38.0	10.1
26	'Arbequina'	33.1 ± 4.5	4.8 ± 1.1	37.9	12.7
27	'Belle of Spain'	30.5 ± 5.0	6.9 ± 1.3	37.4	18.4
28	'Fantago'	32.1 ± 5.5	5.1 ± 1.5	37.2	13.6
29	'Atro Rubens'	29.3 ± 4.8	7.2 ± 1.3	36.5	19.7
30	'UC22A11'	30.5 ± 4.5	4.7 ± 1.2	35.2	13.4
31	'Gethsemane'	28.9 ± 4.4	5.5 ± 1.2	34.4	15.9
31	'Tiny Kalamata'	28.7 ± 4.4	5.8 ± 1.1	34.4	16.7
33	'Verdale'	32.9 ± 4.7	1.4 ± 1.2	34.3	4.0
34	'Borreggiola'	31.4 ± 5.0	2.3 ± 1.3	33.8	6.9
35	'Del Morocco'	31.7 ± 4.4	1.9 ± 1.2	33.6	5.8
36	'Barouni'	27.8 ± 5.0	5.2 ± 1.4	33.1	15.8
37	'Helena'	26.7 ± 4.7	5.7 ± 1.2	32.4	17.7
38	'Mazzone'	23.2 ± 4.6	8.3 ± 1.2	31.5	26.2
39	'Correggiola'	24.4 ± 4.4	7.0 ± 1.1	31.3	22.2
40	'UC13A6'	24.7 ± 4.5	6.2 ± 1.2	30.9	20.0
41	'Boultillan'	25.0 ± 4.9	5.6 ± 1.3	30.6	18.3
42	'Big Spanish'	28.7 ± 4.7	1.7 ± 1.2	30.4	5.6
43	'Black Italian'	27.7 ± 5.3	2.0 ± 1.2	29.7	6.7
43	'Museum'	26.3 ± 4.4	3.4 ± 1.1	29.7	11.4
45	'Koroneiki'	24.6 ± 4.5	4.6 ± 1.2	29.2	15.9
46	'Boutillon'	21.8 ± 4.4	7.0 ± 1.2	28.8	24.4
47	'Hojiblanca'	24.5 ± 4.5	4.2 ± 1.2	28.7	14.6
48	'Picual'	26.0 ± 4.8	0.8 ± 1.2	26.8	2.8
49	'White'	22.1 ± 6.4	4.5 ± 1.7	26.6	17.0
50	'Mediterranean'	19.2 ± 5.3	6.0 ± 1.3	25.2	23.9
51	'Pecholine'	21.8 ± 4.4	2.7 ± 1.1	24.6	11.2
52	'Palermo'	20.4 ± 5.0	3.3 ± 1.2	23.7	14.1
53	'Special Koroneiki'	19.8 ± 4.4	3.5 ± 1.2	23.3	15.1
54	'Nevadillo Blanco'	17.7 ± 4.9	5.0 ± 1.2	22.6	21.9
55	'Kalamata'	12.4 ± 7.5	9.7 ± 1.8	22.1	43.8
56	'Wallace'	17.2 ± 5.3	4.4 ± 1.2	21.6	20.3
57	'I-77'	18.9 ± 4.4	2.5 ± 1.1	21.4	11.5
58	'Queen of Spain'	17.0 ± 4.6	3.7 ± 1.2	20.7	18.0
59	'UC23A9'	14.3 ± 8.2	5.6 ± 2.3	19.9	28.0
60	'Tarascoa'	17.2 ± 4.6	1.6 ± 1.2	18.9	8.6
	LSD *(P=0.05)*	**14.2**	**3.7**		
	Mean	29.8	5.6	35.4	15.9
	Min	12.4	0.8	18.9	2.8
	Max	50.1	13.1	62.6	43.8

Values are means ± SE. Rankings are based on annual shoot growth.

Table 3. Trunk diameter increase, tree height increase and tree height 3 years after planting for 29 varieties of olive grown at Buaraba in south-east Queensland.

Variety	No. of trees measured	Trunk diameter increase (cm) July 99-May 02	Height increase (cm) July 99-May 02	Tree height (cm) May 02
'Arbequina'	5	8.9 ± 0.58	286.2 ± 23.5	388.7
'Arecuzzo'	4	8.3 ± 0.65	160.6 ± 26.3	260.2
'Atro Rubens'	9	8.7 ± 0.65	274.6 ± 26.3	359.7
'Belle of Spain'	6	10.2 ± 0.53	298.8 ± 21.3	393.2
'Big Spanish'	8	8.7 ± 0.46	280.7 ± 18.4	391.7
'Correggiola' No 2	4	9.8 ± 0.65	284.8 ± 26.1	399.4
'Del Morocco'	6	8.9 ± 0.53	274.5 ± 21.3	355.8
'Fantago'	6	10.0 ± 0.53	371.2 ± 21.3	440.4
'Hardy's Mammoth'	7	10.2 ± 0.49	238.8 ± 19.8	449.2
'Hojiblanca'	4	10.3 ± 0.65	306.6 ± 26.3	358.3
'Frantoio/ Paragon'	4	9.9 ± 0.65	348.4 ± 26.2	413.4
'Manzanillo'	8	9.0 ± 0.46	303.4 ± 18.4	421.0
'Mazzone'	4	8.3 ± 0.65	272.2 ± 26.1	370.3
'Mission'	4	8.6 ± 0.65	256.0 ± 26.3	375.4
'Museum'	7	8.8 ± 0.49	285.7 ± 20.0	367.5
'Palermo'	4	5.9 ± 0.65	202.7 ± 26.1	257.0
'Pecholine'	9	9.6 ± 0.43	346.7 ± 17.4	426.9
'Pendulina'	7	9.2 ± 0.49	241.9 ± 19.8	331.5
'Rosciola'	9	9.8 ± 0.43	257.4 ± 17.4	351.8
'Tarascoa'	8	9.2 ± 0.46	264.8 ± 18.5	371.6
'Tiny Kalamata'	4	10.2 ± 0.65	295.6 ± 26.1	404.0
'UC22A11'	7	8.5 ± 0.49	218.6 ± 20.0	330.5
'UC23A9'	4	4.4 ± 0.66	138.4 ± 26.8	213.7
'Wagga Verdale'	12	8.4 ± 0.37	242.6 ± 15.0	336.6
Mean		8.9	268.8	365.3
Min		4.4	138.4	213.7
Max		10.3	371.2	449.2

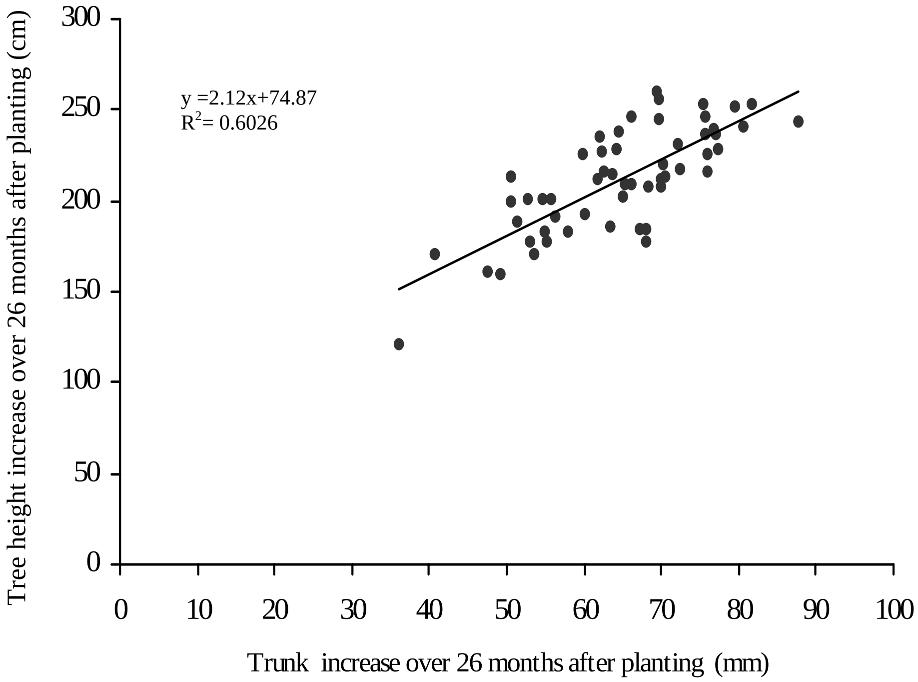
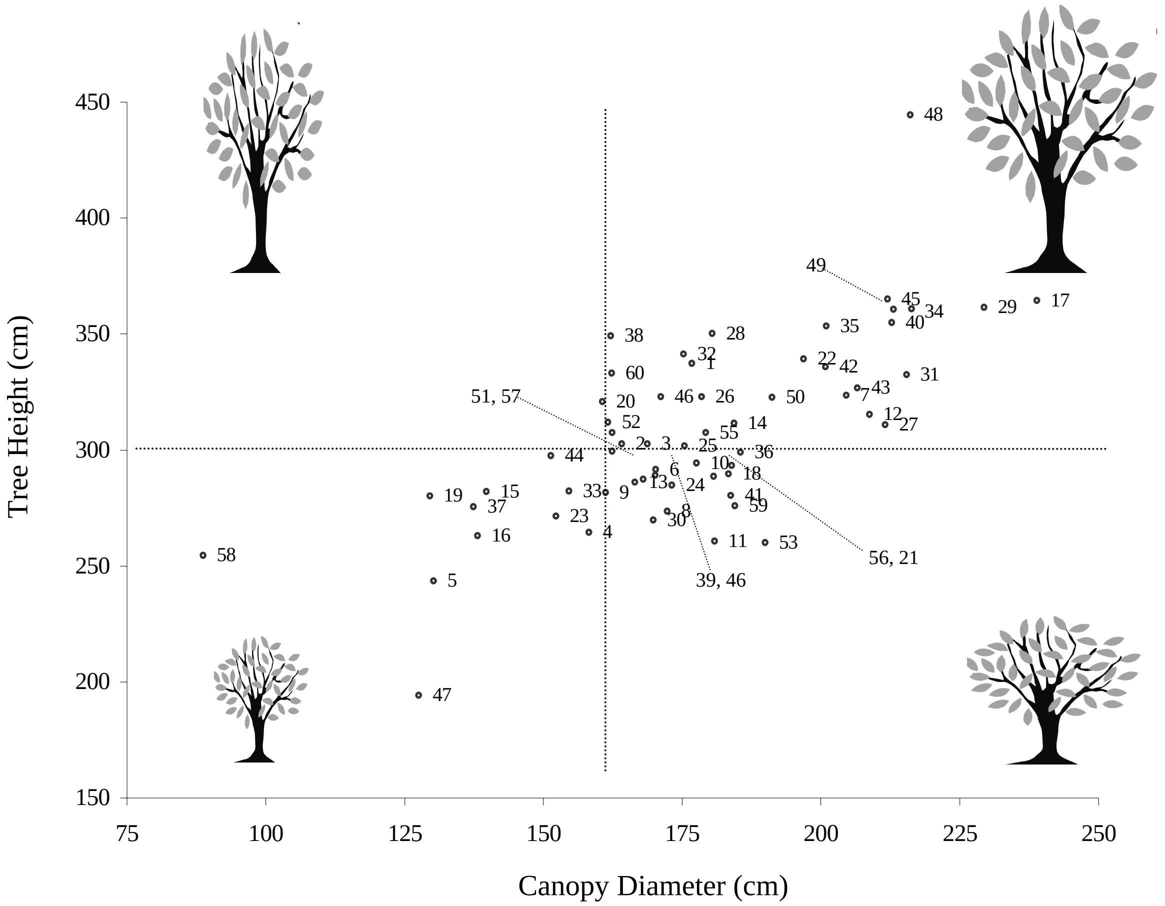


Figure 1. Relationship between trunk increase and tree height increase for 26 months after planting for 60 varieties of olive grown at Buaraba in south-east Queensland.



Legend

'A Prugo'	51	'Correggiola' No 2	26	'Mazzone'	25	'Rosciola'	27
'Arbequina'	14	'Del Morocco'	10	'Mediterranean'	42	'Sevillano'	4
'Arecuzzo'	11	'Fantago'	50	'Mission'	52	'South Australian Verdale'	33
'Atro Rubens'	20	'Frantoio'/'Paragon'	35	'Museum'	44	'Special Koroneiki'	55
'Azapa'	21	'Gethsemane'	59	'Nab Tamri'	36	'Tarascoa'	6
'Barouni'	16	'Hardy's Mammoth'	53	'Nab Tamri'- OA	30	'Tiny Kalamata'	29
'Belle of Spain'	31	'Helena'	40	'Nevadillo Blanco'	56	'UC13A6'	2
'Benito'	41	'Hojiblanca'	38	'No.1'	13	'UC22A11'	18
'Big Spanish'	7	'I-77'	57	'No.14'	49	'UC23A9'	47
'Black Italian'	15	'Kalamata'	58	'Oblonga'	12	'UC6A7'	48
'Borreggiola'	23	'Koroneiki'	17	'Palermo'	9	'Verdale'	46
'Bot'	24	'Lecqure'	45	'Pecholine'	1	'Volos'	54
'Boultillan'	22	'Manzanillo'	32	'Pendulina'	8	'Wagga Verdale'	39
'Boutillon'	43	'Manzanillo' No 14	3	'Picual'	60	'Wallace'	19
'Correggiola'	34	'Manzanillo' No 2	28	'Queen of Spain'	37	'White'	5

Figure 2. Tree height vs canopy diameter of 60 olive varieties 26 months after planting at Buaraba in south-east Queensland. Illustrations in each quadrant are indicative of varietal growth habit.

3.2 Fruit set, yield and oil content

Fruit set score measured in February 2002, the third year after planting, averaged 0.68, indicating nil to sparse fruit set over the 60 varieties, with 15 (25%) having no fruit set in that season. Five varieties had a high mean fruit set score and these also had a satisfactory level of tree growth. These varieties were 'Tiny Kalamata', 'Big Spanish', 'Arbequina', 'Special Koroneiki' and 'Oblonga' (Table 1).

Fruit and oil yield of olive varieties harvested in the third year after planting is presented in Table 4. The three highest yielding varieties were 'Tiny Kalamata', 'Arbequina' and 'Big Spanish' which produced mean yields of 18.8, 18.8 and 17.9 kg respectively. The varieties expressing the highest oil content were 'Belle of Spain', 'Tiny Kalamata' and 'Arbequina' with oil percentages (Soxhlet) of 24.3, 23.5 and 22.8 % respectively.

Fruit weight ranged from 1.2g to 5.2g between varieties. Five of the ten varieties bearing fruit in the third year had a mean fruit weight less than 2g.

Fruit moisture content across all harvest dates ranged from 54.3 to 70.0 % between varieties. The variation in fruit moisture content of the 7 varieties harvested on the same day (26/04/02) ranged from 54.3 to 69.1%.

There was a significant inverse relationship between moisture content and oil content in all varieties processed (Figure 3). The differing linear responses between the Soxhlet and the Oliomio extraction techniques suggest that high fruit moisture at the time of processing had a negative influence on commercial oil extractability.

Table 4. Harvest date, fruit yield, oil content, moisture content, maturity index and individual fruit weight of 13 olive varieties harvested in the 2002 season; 3 years after planting at Buaraba in south-east Queensland.

Variety	Harvest date	Harvest week No.	No. of trees sampled	Fruit Yield (kg/ tree)	Moisture %	Oil Soxhlet % (w/w)	Oil Oliomio % (w/w)	Fruit weight (g)	Maturity index
'Tiny Kalamata'	21/05/02	21	4	18.8	54.3	23.5	17.5	1.2	2.7
'Arbequina'	26/04/02	17	6	18.8	62.4	22.8	13.2	1.7	3.2
'Big Spanish'	26/04/02	17	4	17.9	61.1	22.1	12.1	1.6	2.6
'Belle of Spain'	26/04/02	17	2	13.4	54.8	24.3	16.8	2.9	2.5
'Del Morocco'	21/05/02	21	2	13.8	63.0	20.8	10.8	3.5	2.7
'Special Koroneiki'	26/04/02	17	2	14.5	65.6	16.5	8.3	1.6	2.3
'I-77'	26/04/02	17	1	11.3	58.5	20.3	NA	5.2	2.3
'Arecuzzo'	26/04/02	17	1	10.5	69.1	17.8	NA	2.5	2.8
'Rosciola'	8/04/02	15	2	7.2	69.3	15.9	NA	3.5	3.3
'Oblonga'	15/03/02	11	2	9.9	70.0	10.1	NA	2.6	3.8
'Manzanillo No14'	8/04/02	15	1	NA	71.3	21.5	NA	6.0	5.3
'Tarascoa'	26/04/02	17	1	NA	66.9	22.0	NA	4.4	2.7
'Koroneiki'	21/05/02	21	1	NA	54.8	24.6	NA	1.5	3.2
Mean				13.6	63.9	20.0	11.6	3.2	3.0
Minimum				7.2	54.3	10.1	5.8	1.2	2.3
Maximum				18.8	70.0	24.3	17.5	5.2	3.8

All oil content percentages calculated on a fresh weight basis standardised at 50% moisture.
NA: data not collected due to storm damage and/or insufficient fruit for Oliomio extraction.

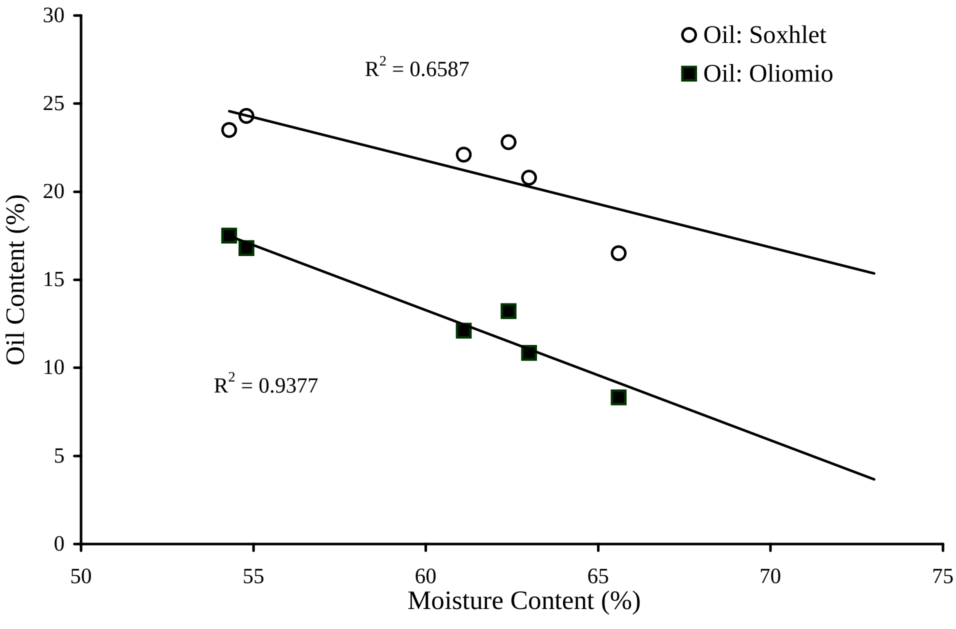


Figure 3. Relationship between fruit moisture and oil content of six olive varieties ('Tiny Kalamata', 'Arbequina', 'Big Spanish', 'Belle of Spain', 'Del Morocco' and 'Special Koroneiki') processed using Soxhlet extraction and an Oliomio 50 processing plant. All oil content percentages calculated on a fresh weight basis standardised at 50% moisture.

3.3 Climatic data

The monthly mean values of air temperature, rainfall, evapotranspiration, sunlight hours and chilling hours at Buaraba over the period June 1999 to November 2002 are presented in Table 5. Mean monthly rainfall and temperature values are presented graphically in Figure 4. The climatic data for individual years 1999 to 2002 is presented in Appendix 1.

Over the period from 1999-2002 the annual chilling hours (<7^0C) ranged from 446 to 644 hours averaging 488.4 hours (Table 5). Annual hours of sunlight over the same period ranged from 3007 to 3280 hours, averaging 3301.5 hours. Annual rainfall was 693.6 mm with 56 % of the annual rainfall occurring in summer and 14.2 % in winter.

A comparison of the monthly rainfall distribution and air temperatures between Cordoba in Spain, a prominent olive growing region with a typical Mediterranean climate, and Gatton, 35 km SW of the trial site in south-east Queensland are presented in Figure 5. The Cordoba records are the mean values of 38 years data. The Gatton records are the mean values of 21 years of temperature and 89 years of rainfall data.

Table 5. Air temperature, rainfall, chilling hours, evapotranspiration and sunlight hours Buaraba; 1999-2002 monthly means.

Month	Mean	Mean Min	Mean Max	Absolute High	Absolute Low	Rainfall (mm)	ETo [1]	Sunlight [2] (Hrs)	Chilling Hours (<7^0C)
Jan	24.3	20.9	29.6	40.2	13.1	64.2	173.2	334.5	0.0
Feb	23.3	20.3	26.2	36.4	11.9	101.0	124.0	268.2	0.0
Mar	22.8	19.7	25.7	36.6	11.1	66.2	128.2	292.7	0.0
Apr	19.6	16.8	22.3	32.1	7.4	27.1	92.4	255.5	0.0
May	15.5	10.3	19.7	30.0	1.4	28.9	69.8	233.3	42.7
Jun	12.9	8.9	17.2	26.4	-0.6	31.9	41.8	217.2	88.0
Jul	12.1	8.6	16.5	25.3	-4.2	31.0	67.4	243.6	184.0
Aug	13.4	9.9	17.0	28.6	-1.3	35.5	92.5	277.5	136.1
Sep	17.4	13.4	22.9	35.9	3.3	24.5	130.4	301.5	28.6
Oct	20.3	16.8	25.1	39.9	4.8	57.4	143.7	279.4	9.0
Nov	21.1	17.6	25.1	36.8	7.8	106.5	143.0	291.9	0.0
Dec	23.2	19.3	28.1	40.4	11.7	119.4	165.1	306.3	0.0
Year	17.2	13.5	21.7	40.4	-4.2	693.6	1371.3	3301.5	488.4

1. Evapotranspiration (ETo) estimated using standard turf model.
2. Sunlight hours calculated using solar radiation threshold of 150 W/m^2.

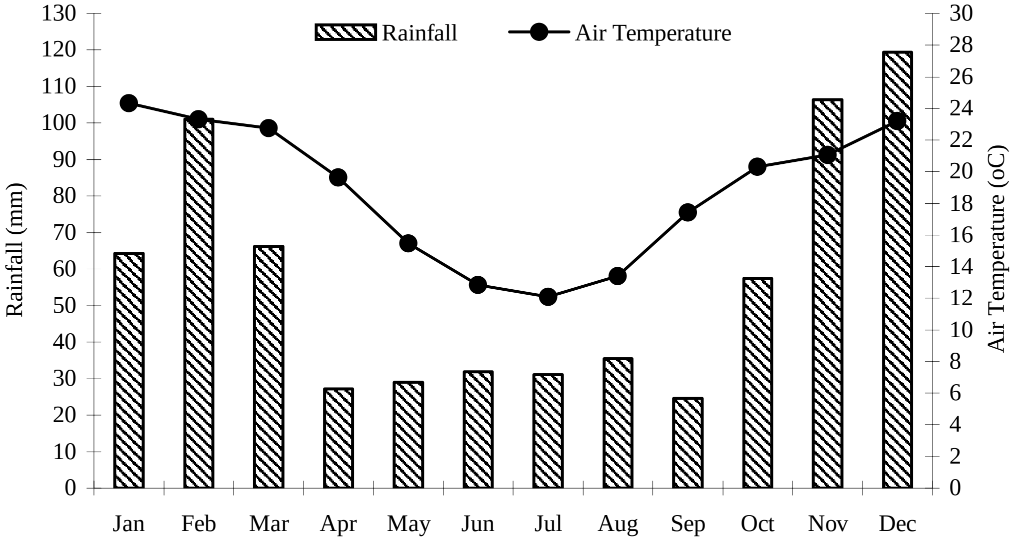


Figure 4. Air temperature and rainfall, Buaraba; 1999-2002 monthly means.

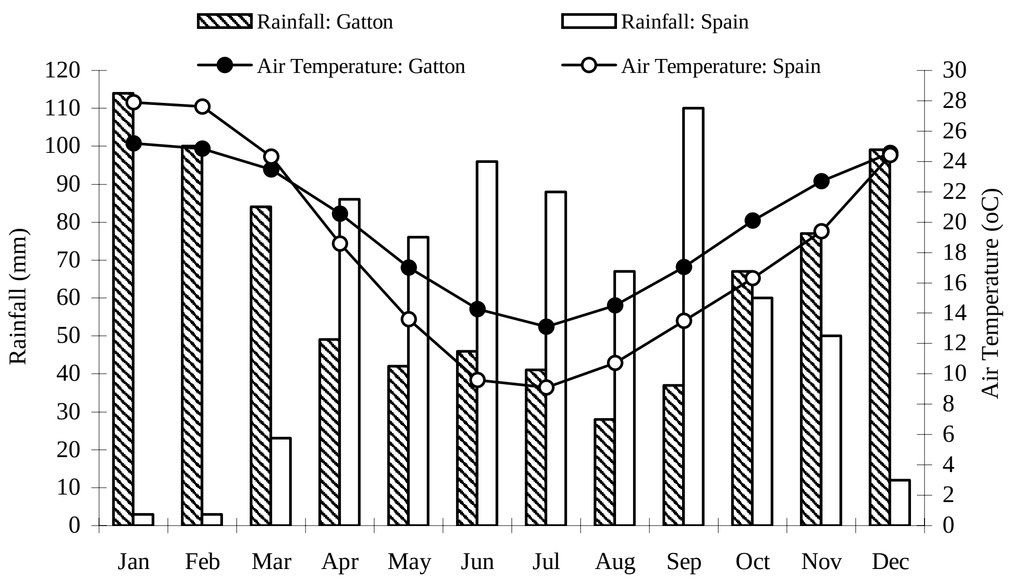


Figure 5. Air temperature and rainfall at Gatton, south-east Queensland and Cordoba, Spain. The Cordoba data has been transposed by six months to equate with southern hemisphere seasons. The Cordoba records are the mean values of 38 years data. The Gatton records are the mean values of 21 years of temperature and 89 years of rainfall data. (Hobman, 1995, Australian Bureau of Meterology, 1995).

4. Discussion and Conclusions

An early start to bearing and relatively high productivity has been observed in the ten varieties viz. 'Tiny Kalamata', 'Arbequina', 'Big Spanish', 'Belle of Spain', 'Del Morocco', 'Special Koroneiki', 'I-77', 'Arecuzzo', 'Rosciola' and 'Oblonga'. The majority of the remaining varieties have expressed satisfactory tree growth but little fruit set at this stage of the trial.

Six of the bearing varieties, 'Tiny Kalamata', 'Arbequina', 'Big Spanish', 'Belle of Spain' 'Del Morocco' and '1-77' produced fruit with a high oil content (>20%). The average yields of these varieties were also relatively high ranging from 11.3 to 18.8 kg between varieties in their third year after planting.

Little information is available on the potential effects of non-Mediterranean climates on olive performance. In various subtropical summer rainfall regions of China research has indicated that in general, compared to Mediterranean countries, tree growth is greater, shoots are longer, fruit set is increased and fruit bearing begins earlier. However, annual rainfall in excess of 1000 mm, poor soil drainage, insufficient sunlight and high humidity were shown to be problematic factors in some regions (Weiying *et al.,* 1998). Early growth observations made on 12 olive varieties in a monsoon climate in India found that vegetative growth of the trees was virtually uninterrupted throughout the whole year. Four distinct growth patterns were evident amongst the varieties with only six varieties showing good overall growth and potential adaptability to the climate (Bartolini and Fabbri, 1994).

Rapid tree growth is a desirable attribute in olive production (Palliotti *et al.*, 1999). Generally, tree growth is related to productivity and at this stage of the trial it is the primary characteristic that can be used to evaluate the performance of the sixty varieties. The ten varieties with the highest rate of vegetative growth 26 months after planting were; 'Tiny Kalamata', 'Lecqure', 'Koroneiki', 'No.14', 'Frantoio'/'Paragon', 'Mediterranean', 'Correggiola', 'Pecholine', 'Helena' and 'Fantago'.

The relationship between trunk diameter and tree height suggests that trunk diameter could be used for initial screening for tree growth. Trunk diameter has the advantage of being an easier parameter to measure than tree height.

Slow growing olive varieties expressing low vigour have the potential to be used in high density mechanically harvested olive groves either as a size-controlling rootstocks or as dwarf varieties (Piedra *et. al.*, 1997). The use of size controlling rootstocks is common in other fruit tree crops but is yet to be exploited by the olive industry. There are a number varieties identified at this stage of the trial that are relatively slow growing (Figure 2) and may have dwarfing potential. Further research is required to determine whether the low vigour expressed by these varieties is maintained in the long term.

The winter chilling hours recorded at the site averaged 488.4 hours which suggests that insufficient winter chilling may be a limiting factor in floral induction and subsequent fruit set in some of the varieties in this study. Most varieties, typically, do not start bearing commercially until their fourth or fifth year (del Rio and Caballero, 1994). It is therefore too early at this stage to speculate on the influence that the climate may have on flowering.

The preliminary oil extraction results indicate that high fruit moisture at the time of processing is problematic and can affect commercial oil extractability. This is a view that has been reported previously (Archer, 2000, McCulloch, 2001, Mailer, 2002). McCulloch (2001) suggested that the larger-fruited pickling or dual purpose varieties had a higher tendency to accumulate fruit moisture and present subsequent oil extraction difficulties, than oil varieties. The limited data obtained in the present study suggests that, under the prevailing climatic conditions, oil varieties such as 'Arbequina' can be similarly affected. However, the propensity to accumulate fruit moisture was found to vary between varieties. High fruit moisture is of little concern in table fruit destined for pickling, as it does not adversely affect processing. Increased moisture in table fruit can have a beneficial effect on quality by increasing fruit size (Hobman, 1994).

These findings highlight the importance of reducing fruit moisture as a means of improving olive oil extraction. Pre and post-harvest technologies will need to be developed to improve olive oil extraction from fruit produced in this environment. Research undertaken by Motilva *et al*., (1997) in Spain found that regulated deficit irrigation (RDI) improved oil yield of 'Arbequina' but had no effect on fruit moisture content. The RDI concept imposes tree water deficits during specific stages of crop development and is used primarily to reduce excessive vegetative growth and to optimise water use (Goldhamer, 1999). Some Australian olive growers are currently implementing RDI type strategies in the months leading up to harvest in an attempt to reduce fruit moisture content. Further research is required to evaluate the effect of RDI on fruit moisture in summer rainfall regions.

Five of the ten early bearing varieties identified in this study are small-fruited varieties with a mean fruit weight less than 2 grams. Although small-fruited varieties are extensively grown as commercial oil varieties throughout the world including 'Arbequina' in Spain (Barranco, 1995) and 'Koroneiki' in Greece (Archer, 1996), fruit that ranges in size from 1-2 grams is not suited to traditional mechanical harvesting methods because of the low fruit weight to attachment ratio. Improved harvesting technologies such as the use of chemical fruit loosening agents (Metzidakis, 1999) will be required to overcome the harvesting disadvantages associated with the cultivation of these small-fruited high yielding varieties.

Field observations and DNA analyses (Archer, 2001) have suggested that at least two of the obscurely named varieties in the trial are important commercial varieties that have been at some point in the past erroneously named. These are, 'Big Spanish' and 'Tiny Kalamata' which are identical to 'Arbequina' and 'Koroneiki' respectively. Some of the varieties in the trial, however, are unique Australian selections, these include; 'Hardy’s Mammoth', 'South Australian Verdale' and 'Wagga Verdale'. 'Hardy’s Mammoth' is a large fruiting variety of obscure origin but is believed to have originated in Queensland (Marti, 1995). 'South Australian Verdale' and 'Wagga Verdale' are both selections of the French 'Verdale' variety (Archer, 1996). These selections along with the original 'Verdale' make up much of the early commercial plantings Australia.

This initial research has identified several early bearing, high yielding varieties with adaptability to the prevailing climate. It also provides important base line information for future comparisons. At this stage, an indication of the fruiting capabilities of most of the varieties has not been derived. As it is not uncommon for young olive trees to remain in a vegetative state until their fourth or fifth year after planting an evaluation of the commercial performance of the varieties will not be obtained until the sixth year. Ongoing research is now required to determine the mature fruiting capabilities and long term performance of the trees.

5. References

Archer, J. (1996). The commercial viability of existing olive varieties for various Australian climates. HRDC Report, Project No. FR546.

Archer, J. (2000). Maximising olive oil yields. The Olive Press. Summer edition: 13-14

Archer, R. (2001). Pers. Comm. Director, Olives Australia Pty Ltd.

Australian Bureau of Meteorology. (1995). Climatic averages. Australian Government Publishing Service.

Bartolini G. Fabbri, A. (1994). The olive tree in a monsoon climate first results in India on the performance of 12 cultivars. Acta Hort. **356**: 119-121.

Beede, R.H., Goldhamer, D.A. (1994). Olive irrigation management, pp. 61-68. In: L. Ferguson, G.S. Sibbett and G.C. Martin (eds.) Olive Production Manual. University of California, Oakland, CA.

del Rio, C. and Caballero, J. M. (1994). Preliminary agronomical characterisation of 131 cultivars introduced in the olive germplasm bank of Cordoba in March 1987. Acta Hort. **356**: 110-115

Goldhamer, D.A. (1999). Regulated deficit irrigation for California canning olives. Acta Hort **474**: 369-372.

Hartmann, H.T. (1962). Olive growing in Australia. Economic Botany, **16** (1): 31-44.

Hartmann, H.T. and Whisler J.E. (1975). Flower production in olive as influenced by various chilling temperature regimes. J.Amer.Soc. Hort. Sci. **100** (6): 670-674.

Hobman, F. (1994). The olive industry in Central Italy and Southern Spain.
RIRDC Report No. 94/7

IOOC. (1990). Olive oil quality improvement. International Olive Oil Council, Madrid.

Lopez-Villalta, M.C. (1999). Olive pest and disease management. International Olive Oil Council, Madrid.

Mailer, R. J. (2002). What is the oil content? The Olive Press. Autumn edition: 28-29

Marti, J.T. (1995). The olive in Australia. Olivae **55**: 10-14.

Martin, G.C., Ferguson, L., Polito, V.S. (1994). Flowering, pollination, fruiting, alternate bearing and abscission, pp 51-60. In: L. Ferguson, G.S. Sibbett and G.C. Martin (eds.) Olive Production Manual. University of California, Oakland, CA.

McCulloch, M. (2001). A processor's perspective. The Olive Press. Spring edition: 14

Motilva, M.J., Romero, M.P., Alegre, S., Girona, J. (1999). Effect of regulated deficit irrigation in olive oil production and quality. - Acta Hort. **474**: 377-380.

O'Sullivan, G.J. and Fletcher R. J. (2002). Preliminary olive variety assessment at a subtropical summer rainfall location in south-east Queensland. Adv. Hort . Sci. In Press.

Palliotti, A., Famiani, F., Proietti, P., Boco, M., Antognozzi, E., Preziosi, P., Ferrandini, N. and Guelfi, P. (1999). Effects of training system on tree growth, yield and oil characteristics in different olive cultivars. Acta Hort. **474**: 189-191

Piedra, A.P., Guillen, J. H., Munoz-Cobo, M. P., Martin, M. L., Colina, J. C., Goldaracena, I.M., Reyes, C. P., Rubia, E.R., Corral, J. M. and Barreda, L. G. (1997). High density orchards in olive farming: some necessary concepts. Olivae **69**: 44-47

RIRDC. (2002). Research and development plan for the Australian olive industry 2003 – 2008. RIRDC Publication No. 02/119.

Robards, K and Mailer, R. (2001). Olive oil yield, quality and cultivar identification. RIRDC Publication No. 01/23.

Weiying, X., Mingquan, D., Ning, Y. (1998). Study on the regions of China adaptable to olive growing. Olivae **70**: 19-31.

Appendix 1. Climatic Data 1999-2002

Climate data 1999

Month	Mean	Mean Min	Mean Max	Absolute High	Absolute Low	Rainfall (mm)	ETo [1]	Sunlight [2] (Hrs)	Chilling Hours (<7^{0}C)
Jun	13.3	7.2	20.0	23.9	-0.2	63.7			54.0
Jul	13.9	10.9	17.1	24.3	2.9	60.0	67.2	220.0	101.0
Aug	13.7	10.4	18.5	25.9	2.4	62.4	86.9	319.0	7.0
Sep	16.6	13.6	20.7	28.0	5.3	63.2	129.0	342.0	0.0
Oct	20.2	18.1	23.0	31.6	8.6	77.0	134.3	300.5	0.0
Nov	19.6	16.4	23.6	31.7	8.5	126.8	146.9	315.0	0.0
Dec	21.0	17.1	25.7	35.3	12.2	145.2	155.0	300.0	0.0

1. Evapotranspiration estimated using standard turf model.
2. Sunlight hours calculated using solar radiation threshold of 150 W/m^2.

Climatic data 2000

Month	Mean	Mean Min	Mean Max	Absolute High	Absolute Low	Rainfall (mm)	ETo [1]	Sunlight [2] (Hrs)	Chilling Hours (<7^{0}C)
Jan	23.2	20.0	30.2	39.3	13.1	78.2	163.5	322.0	0.0
Feb	22.1	19.2	24.8	32.7	12.6	25.0	114.3	254.0	0.0
Mar	22.4	20.0	24.2	32.5	13.1	60.6	121.4	292.5	0.0
Apr	19.9	16.8	23.4	32.1	9.3	28.2	89.6	236.0	0.0
May	16.2	10.8	21.7	27.6	3.1	28.8	71.4	230.0	6.5
Jun	13.0	10.4	16.3	26.4	2.1	40.0	43.1	212.5	50.0
Jul	12.0	8.6	17.7	25.2	-0.4	25.8	67.0	245.0	191.0
Aug	13.2	10.1	16.2	28.1	0.1	8.6	101.0	270.5	153.0
Sep	18.7	14.9	26.9	35.9	3.6	1.6	145.1	291.5	45.5
Oct	20.0	16.9	25.5	33.6	7.6	68.0	145.1	279.5	0.0
Nov	20.8	18.1	25.3	35.3	10.5	89.6	130.5	273.5	0.0
Dec	23.6	19.8	28.3	38.1	11.7	95.8	170.8	308.0	0.0
Year	17.3	14.1	22.3	39.3	-0.4	550.2	1362.8	3215.0	446.0

1. Evapotranspiration estimated using standard turf model.
2. Sunlight hours calculated using solar radiation threshold of 150 W/m^2.

Climatic data 2001

Month	Mean	Mean Min	Mean Max	Absolute High	Absolute Low	Rainfall (mm)	ETo [1]	Sunlight [2] (Hrs)	Chilling Hours (<7^{0}C)
Jan	24.5	21.2	28.7	39.2	13.8	74.8	178.1	338.0	0.0
Feb	23.1	20.1	25.6	35.0	14.8	186.0	124.8	277.0	0.0
Mar	23.5	18.7	27.5	33.6	11.1	32.4	134.3	292.0	0.0
Apr	19.5	16.6	21.8	29.3	7.4	40.2	95.3	262.0	0.0
May	15.1	9.2	19.0	26.8	3.1	36.8	65.5	228.0	44.0
Jun	13.6	8.8	17.4	25.6	-0.3	11.2	55.8	232.5	101.0
Jul	12.3	7.6	15.9	25.1	-1.9	35.8	66.8	247.5	170.5
Aug	13.1	9.0	16.4	26.1	-1.3	11.4	99.2	270.5	160.0
Sep	16.2	13.1	19.6	27.8	4.2	20.8	111.4	282.5	34.5
Oct	20.1	17.1	24.8	35.7	7.4	48.8	128.1	240.0	0.0
Nov	21.1	18.7	25.3	33.1	7.8	135.8	145.3	299.0	0.0
Dec	25.0	20.9	30.4	40.4	12.9	117.2	169.4	311.0	0.0
Year	17.3	13.6	21.4	40.4	-1.9	751.2	1374.0	3280.0	510.0

1. Evapotranspiration estimated using standard turf model.
2. Sunlight hours calculated using solar radiation threshold of 150 W/m^2.

Climatic data 2002

Month	Mean	Mean Min	Mean Max	Absolute High	Absolute Low	Rainfall (mm)	ETo [1]	Sunlight [2] (Hrs)	Chilling Hours (<7^{0}C)
Jan	25.3	21.4	29.8	40.2	14.2	39.6	178.0	343.5	0.0
Feb	24.7	21.6	28.3	36.4	11.9	92.0	132.8	273.5	0.0
Mar	22.4	20.4	25.4	36.6	12.1	105.6	128.9	293.5	0.0
Apr	19.5	16.9	21.8	30.9	7.7	13.0	92.2	268.5	0.0
May	15.1	11.0	18.5	30.0	1.4	21.2	72.4	242.0	77.5
Jun	11.5	9.0	15.2	22.6	-0.6	12.6	26.5	206.5	99.0
Jul	10.2	7.1	15.2	25.3	-4.2	2.4	68.6	262.0	320.5
Aug	13.6	10.0	16.9	28.6	0.1	59.6	82.7	250.0	130.5
Sep	18.2	12.0	24.4	33.7	3.3	12.4	135.9	290.0	27.5
Oct	20.9	14.9	27.1	39.9	4.8	35.8	167.4	297.5	9.0
Nov	22.7	17.2	26.3	36.8	11.6	73.6	149.3	280.0	0.0
Dec									
Year	16.2	11.7	20.9	40.2	-4.2	467.8	1234.7	3007.0	664.0

1. Evapotranspiration estimated using standard turf model.
2. Sunlight hours calculated using solar radiation threshold of 150 W/m^2.

Appendix 2. Tree Survival Table

Variety	Intact	Cut-back	Total	Variety	Intact	Cut-back	Total
'A Prugo'	0	3	3	'Mazzone'	4	1	5
'Arbequina'	7	5	12	'Mediterranean'	1	4	5
'Arecuzzo'	4	0	4	'Mission'	6	3	9
'Atro Rubens'	4	4	8	'Museum'	7	1	8
'Azapa'	4	3	7	'Nab Tamri'	0	0	0
'Barouni'	3	1	4	'Nab Tamri'- OA	0	2	2
'Belle of Spain'	6	1	7	'Nevadillo Blanco'	1	5	6
'Benito'	0	3	3	'No.1'	0	5	5
'Big Spanish'	8	1	9	'No.14'	0	0	0
'Black Italian'	1	4	5	'Oblonga'	2	1	3
'Borreggiola'	1	3	4	'Palermo'	4	0	4
'Bot'	3	3	6	'Pecholine'	9	1	10
'Boultillan'	1	3	4	'Pendulina'	7	0	7
'Boutillon'	2	2	4	'Picual'	0	4	4
'Correggiola'	2	2	4	'Queen of Spain'	1	3	4
'Correggiola' No 2	4	1	5	'Rosciola'	9	0	9
'Del Morocco'	5	4	9	'Sevillano'	0	3	3
'Fantago'	6	2	8	'South Aust.Verdale'	0	6	6
'Frantoio'/'Paragon'	4	2	6	'Special Koroneiki'	3	4	7
'Gethsemane'	4	2	6	'Tarascoa'	5	2	7
'Hardy's Mammoth'	7	3	10	'Tiny Kalamata'	4	0	4
'Helena'	2	3	5	'UC13A6'	0	1	1
'Hojiblanca'	4	2	6	'UC22A11'	8	1	9
'I-77'	1	3	4	'UC23A9'	4	3	7
'Kalamata'	3	5	8	'UC6A7'	3	1	4
'Koroneiki'	3	1	4	'Verdale'	1	5	6
'Lecqure'	3	0	3	'Volos'	1	1	2
'Manzanillo'	8	2	10	'Wagga Verdale'	12	0	12
'Manzanillo' No 14	3	6	9	'Wallace'	3	6	9
'Manzanillo' No 2	0	4	4	'White'	1	7	8

Trees identified as cut-back were pruned severely to assist recovery after being blown over during a violent storm in February 2002. Originally 12 trees of each variety were planted.