NSW DEPARTMENT OF
PRIMARY INDUSTRIES

Growing lemons in Australia- a production manual - Readers' Note

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http://www.dpi.nsw.gov.au/agriculture/horticulture/citrus/lemon-manual

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20. Literature Search

Abu-Awwad, A.M. 2001. Influence of Different Water Quantities and Qualities on Lemon trees and Soil Salt Distribution at the Jordan Valley. Agricultural Water Management 52: 53-71.

Young lemon trees (Eureka) were studied for five years (1996-2000). Five water levels and three water qualities were imposed via trickle irrigation system on clay loam soil. In saline substrates Na+ and C1- are usually the dominant ions. The lemon tree is a salt-sensitive crop to salinity, and even low salt concentrations may affect its growth and productivity. A field experiment was conducted to investigate the influence of different water and salinity levels on the development of young lemon (Eureka) trees.

Materials and Methods
A field experiment was conducted for 5 years. One dripper per tree for the first year, two drippers 1.0 m apart per tree for the second year, and thereafter four drippers 1.0 m apart. 8L/hr of five water levels and three water qualities.

Conclusion
Increasing irrigation water salinity increased salt concentration and osmotic potential in the root zone, and consequently reduced lemon annual water use, stem diameter and fruit yield. Regardless of irrigation water salinity, the significantly highest fruit yield was at irrigation water depth equal to evaporation depth from class A pan when corrected for tree canopy percentage shaded area.

Adriaensens, S.Z., Past and Present Situation of the Spanish Citrus Industry, 1993.

Lemon group
The **Verna** is a typically Spanish variety of unknown origin. The tree is vigorous, and with a few thorns. Onto sour orange rootstock it forms a conspicuous overgrowth of the scion on the stock. It flowers several times a year, thus providing a staggered production. The major crop is harvested between February and July, and there are other harvests of varying amounts, especially that of September-October. The fruits are elongated, with only a few seeds.

The **Fino** lemon is more vigorous than the Verna, more thorny and with a tendency to produce suckers. It flowers abundantly once a year, and the harvesting takes place from October to February. The fruit is spherical to oval, small, smooth rind, containing about 10 seeds.

Other lemon varieties such as Eureka and Lisbon have not had an important spread.

Barbera, G., Fatta Del Bosco, G., Occorso, G. and Lo Cascio, B. 1981. Some Aspects on Water Stress Physiology on Forced Lemon Trees. Proc. Int.Soc. Citriculture Vol.2 : 522-523.

Forcing or “forzatura” treatment has the purpose of accentuating the summer bloom and consequently obtain production in the following summer when prices are high. It is accomplished by withholding the irrigation during the summer (June-July) until trees are wilted. They withhold water at the beginning of summer and after a dry period (the length of which varies according to

climate and soil field capacity the irrigation stars again so as to accentuate the summer bloom and achieves production called “Verdelli”.

Methods
20year old Femminello trees on sour orange. The resumption of water was established when leaf water potential reached -13bars.

Results
There is different stomatal behaviour in the trees depending on the water stress history. Leaf water potential was closely dependent on soil water potential. In regular irrigation schedules leaf water potential is dependent on the atmospheric water potential and no relationship exists when trees are subjected to heavy water stress.

Barkley, P. A Citrus Grower, Packer and Marketer Visit to South Africa. May 2003, HA Report CT02060.

Citrus Research Institute, Nelspruit (Tim Grout and Hennie Le Roux)

Eureka Lemon Orchard 1
Trees were lemon on Rough lemon, 13 months old, planted 5 x 1.5m apart under OHS for oil and juice under a 10 year contract with Coke. Blocks are selectively harvested for market fruit, and the rest is sent for oil and juice. Trees are fertilised constantly with the fertiliser rates changing monthly. White paint is put into the RoundUp to prevent application to tree trunks. This ensures that workers don’t make any mistakes by accidentally spraying the trees. The white paint shows up the application area. One main branch is taken from the centre each year, and trees are not topped. Other branches are trimmed. The changing fertiliser program is designed to encourage early and heavy yields, which take the vigour out of the vegetative growth. The trees had produced their first harvest now (May) and Henni estimates 15-17t/ha.

Eureka Lemon Orchard 2
4 year old orchard of Lowveld lemon on Rough lemon at 1,000 trees per hectare under OHS. Yields were: 17t, 50t, 80t, 90t/ha, estimated for this current crop. The OHS was managed by a computer program card changed monthly. Irrigation was 7 times per day for 8 mins. Henni did emphasize the need to water during the day, never at night.

Eureka Lemon Orchard 3
Eureka lemon on X 639 rootstock planted in December 2000, at 1.5 x 5m spacing on mounds in virgin soil. X639 is a good rootstock for lemons, and tolerates salinity. There is very little scab in this area, and trees were from Du Roi Nursery. The life span of lemons is considered to be 15 years.

There is a little niche for lemons between California and Chilean and Argentinean lemons.

Barkley, P. A. Citrus Grower Visit to Italy to Study Blood Orange Production and New Mandarin Varieties. Horticulture Australia Project CT99019 Report. 2004.

Lemon Production at Campisi Italia farm
For Italy as a whole, 500,000 tonnes of lemons are produced, of which 50% goes to the fresh market and 50% to juice.

This farm in Syracusa 120 ha specialises in the organic production of the Syracuse lemon as an IGP product under a HACCP system. The variety grown is Femminello Siracusano 2kr. This lemon has good size, and high acid but is susceptible to mal secco (caused by the fungus *Deuterophoma tracheiphila* and difficult to control in an organic orchard). 5000 tonnes are harvested annually.

Lemons are harvested from January to May and from October to December and exported to Northern Europe within 3-4 days of picking. 75% of fruit go to fresh fruit and 25% to juice. Femminello is also important for processing, as it is rich in essential oils. While this farm exports lemons to France, Austria, and England, it is Germany that is the favoured market for organic citrus.

Pruning is carried out by 12 specialised pruners, (one for every 10 ha), as a management tool and to control mal secco. Trees are on sour orange rootstock, providing excellent fruit quality. The Primo Fiore fruits are picked over twice – the first pick is for size and fruit are clipped. Summer cropping is not possible in the volcanic soils of this area. Pickers receive E43 per day.

Ben-Yehoshua, S., Shapiro. B. and Even-Chen, Z. 1981. Mode of Action of Individual Seal-Packaging in High Density Polyethylene (HDPE) Film in Delaying Deterioration of Lemons and Bell Pepper Fruits. Proc. Int.Soc. Citriculture Vol.2 : 718-721.

The softening of lemons is very highly correlated with water content and weight loss of non sealed lemons.

Results
Sealing individual lemons in high density polyethylene film markedly delayed the softening and shrinkage of fruit as determined by residual deformation (mm) and percentage weight loss. Seal-packaging in plastic film delayed softening of fruits. Lemons are non-climacteric fruit and fruit did not soften. Sealed lemons remained almost as firm as freshly picked fruit for longer than 10 months.

Brown, R.D. and Jones,V.P. 1983. The Broad Mite on Lemons in Southern California. California Agriculture, July-August.: 21-22.

The broad mite usually attacks fruit 3 cm or less in diameter.

Identification and life cycle
Four life stages: egg, larva, nymph, and adult. Eggs laid on the undersides of new leaves and in the depressions of small fruit, hatch within two days to become six-legged slow-moving white larvae 0.1 mm long. After one day, the larva becomes a quiescent nymph that is clear and pointed at both ends. The nymphal stage lasts about a day: nymphs are usually found in depressions on the fruit, although female nymphs are often carried about by males.

Detection
Low levels of the broad mite can be detected by examining the shaded side of small fruit on the interior of trees with the thickest canopies.

Control
On new growth, the broad mite prefers to feed. Sulfur and oxythioquinox (Morestan) have given consistently good control of the broad mite. Omite (Mitac) did not control broad mite.

Calabrese, F. and Di Marco, L. 1981. Researches on the "Forzatura" of Lemon Trees. Proc. Int.Soc. Citriculture Vol.2 : 520-521.

In Sicily the "forzatura" of lemon trees consists in stopping irrigation in summer long enough to cause water stress in the trees. After this the trees are irrigated again and shortly after blossom, and a new crop called the "Verdelli" matures in 12 months. Without this forcing trees bloom spontaneously in summer but the production of "Verdelli" in this case is poor.

Methods
35 year Femminello lemon trees on sour orange. Rainfall 550 mm (September to May) and summer temperatures regularly average 24-26. Each plot divided into 2 parts, one plot irrigated normally using the basin method, the other subjected to "forzatura". The last rain recorded on June 8th and June 4th. Water was then again applied on July 28th and August 3rd. Water changes were determined by 12 tensiometers at depths of 30 and 60 cm. The effects of "forzatura" were observed by measuring the diameters of fruit.

Results
During "forzatura" tensiometers were not able to measure the water content since they reached values above 0.5 bar when soil moisture decreased below 19-20%. Water contents decreased from about 22% at the beginning of June to 16% at 30cm and 17-18% at 60cm at the end of July before water was applied and in some cases reached levels of 12-13%. The fruits of the spring blossom grew more slowly in the trees of the unirrigated plots. The "Verdelli" in the unirrigated plots stopped growing and in some cases their volume decreased. No differences were found in the acids or TSS.

Conclusions
The fruits of the spring blossom and "Verdelli" of the previous year are affected by the water stress and reduce their growth. The former regain their volume after irrigation.

Calero, F.A., Guillen, Ma.C. and Escriche, A. 1981 Physiological Disorders in the Storage of Lemon Fruits. Proc. Int.Soc. Citriculture Vol.2 : 768-772.

The physiological disorders in the varieties of lemon 'Verna' and 'Fino' were studied. The parameters considered were: the period of storage between 1 and 2 months, temperature between 10°C and 14°C, relative humidity between 85% and 99%, controlled atmosphere, the level of O_2 between 3-5% and 13-16% and CO_2 between 0% and 7 - 8%. Relative humidity was more influential than controlled atmospheres in the development of these physiological disorders.

Peteca. Sometimes this disorder appears in fruits which have been sprayed with heavy oils before picking. Low temperatures in the storage chamber, excessive waxing, and bad ventilation can exacerbate it.

Oleocellosis. Is associated with high humidity and low temperature during the picking season, and high humidity in the storage chamber.

Results
A high intensity of peteca was associated with fruits having high values of weight, formol index and maturity index, and low values of juice and vitamin C contents. Low values for weight, juice content and vitamin C and moderate or

high values for formol index and maturity index were associated with a high intensity of this disorder.

Peteca appears least at the highest temperature, favoured by high relative humidities, and low temperatures in the storage. Fruits stored in controlled atmospheres, were more susceptible in the presence of CO_2, this disorder is most serious.

Fruits from the second flowering showed a lower sensibility to peteca than those from the first flowering. The most favourable conditions to prevent the development of this disorder for two months of storage in normal atmosphere are relative humidity of 85 - 90% and temperature of 13°C. In controlled atmosphere, best results with atmospheres without CO_2 and very low in oxygen, about 5%, with temperature of 13°C.

Oleocellosis is greatest when temperature is higher. The longer is the storage period, the greater is the risk that this disorder can appear. This influence is more important when the storage temperature is higher. Fruits from second flowering shown less sensibility to this disorder. Best conditions to avoid this disease: ambient conditions with 90 – 95% R.H. and temperature of 13°C for about 2 months storage. Under controlled atmosphere, best mixtures are those with very low levels of O_2, about 5%, and without CO_2.

'Verna' lemons

Peteca. Low temperatures encourage the hazard of this disorder. This disorder was more severe when relative humidity increased. The longer the storage period, the greater was the risk. The best conditions to avoid this disease are: temperature of 13°C and R.H. of 85 – 90%; under controlled atmosphere the same temperature and about 10% O_2 and up to 2% CO_2.

Oleocellosis

'Verna' lemons are not very sensitive to this disorder. This disease was most severe when temperature was lower. Oleocellosis tended to be more severe with high humidity in storage. Fruits stored under modified atmosphere are more sensitive to oleocellosis. This disorder is more frequent with long storage periods. The best conditions to avoid this disease: 85 – 90% relative humidity, temperature of 13°C. Best atmospheres involved low levels of O2 (about 12%), with CO2 about 1% to 2%.

Castro-Lopez,T., Izquierdo, I. And Perez. L. 1981. Response of Lemons to Various Harvesting and Postharvest Treatments. Proc. Int.Soc. Citriculture Vol.2 : 737-739.

Several picking methods, 2 postharvest treatments. Only picking time significantly influenced the amount of oleocellosis. Lemons require careful handling during harvesting and transport to avoid injury. Harvest to take place when humidity is not very high and the fruit turgidity is low. Clippers and cotton gloves be used in order to prevent the appearance of oleocellosis. Younger fruit is more sensitive. Lemons should be cured, kept at a temperature of 15.6°C, and a relative humidity of 95% for 48 hours. Storage temperatures for Australian lemons vary between 9°C to 12°C , depending on the duration of storage. In California, temperatures from 12.5°C to 15°C are used.

Materials and methods
Twelve treatments were used in harvesting, following a random block model. A. Harvesting time; B. Harvesting method; C. Stay in the field after the harvest. After harvest, the fruit was given a preliminary treatment of 1,000 ppm of thiabendazole (TBZ). It was then stored at room temperature for 48 hours. The boxes were then stored at 12°C for 44 days.

Results
Increase of percentage juice content during storage.

After storage at 12°C for 44 days, indications were that the percentage juice content increased by 22.4% during this period. Highly significant differences in the levels of oleocellosis were found according to the time of day of harvest. It was recommended that lemons be harvested in conditions of low humidity. Harvesting time (A), harvesting method (B) and period in the field after the harvest (C) did not significantly influence the amount of decay. Prolonged refrigerated storage is therefore a useful means for achieving marketable colour in lemons.

Decay was caused by *Geotrichum candidum, Penicillium sp., Doplodia natalensis and Phomopsis citri* fungi. Prestorage "curing" for 5 days at room temperature significantly increased decay. It is very important to transport the fruit immediately after it is processed, and to keep it at from 15°C to 16°C during curing in order to reduce the development of decay.

Conclusions
When the fruit is stored from 40-45 days, it develops added yellow colour that is favourable for marketing. The internal quality of the fruit is also improved during refrigerated storage; percentage juice content increases considerably.

Currie, A., Sutton, P., Machin, T. and Anderson, P. 2002. Yen Ben Lemon Rootstock Trial. The Orchardist, June : 50-51.

High quality Lisbon sport selected in Queensland by Walter Benham in the late 1930s. The performance of 'Yen Ben' on ten rootstocks including P. trifoliata was tested. Five rootstocks 'Cleopatra', 'Troyer', Rangpur X Troyer', 'C-35' and 'Swingle' showed symptoms of incompatibility ranging from slight scion overgrowth to death of the tree.

In conclusion, 'Benton' was the best rootstock in terms of yield, fruit size and acceptable quality. 'Brazilian' also produced better crops than 'Rich 16-6'. However, 'Rich 16-6' was the rootstocks with the best internal fruit quality.

Summaries
For C-35 all trees died five years from planting. Overall 'Carrizo' did not perform well for 'Yen Ben' lemons. Cleopatra is not recommended for 'Yen Ben' due to low yields, low yield efficiency, and small fruit. 'Rangpur X Troyer' and 'Swingle' citrumelo were both incompatible with 'Yen Ben'. Trifoliata 'Rich 16-6' produced the smallest of the healthy trees, but also an efficient tree, similar to 'Brazilian' and 'Sweet orange' and second only to 'Benton' in terms of yield efficiency. 'Troyer' showed signs of incompatibility. 'Sweet orange' produced only moderate yield efficiency.

Domingo, R., Ruiz-Sanchez, M.C., Sanchez-Blanco, M.J. and Torrecillas, A. 1996. Water relations, growth and Yield of Fino Lemon trees under Regulated Deficit irrigation. Irrig.Sci. 16:115-123.

Fino on sour orange were submitted to three different irrigation treatments over four years: 100% ETc all year (T-O), 25% ETc all year except during the rapid fruit growth period when 100% ETc was applied (T-1) and 100% ETc all year, except during the rapid fruit growth period when 70% ETc was applied (T-2). Leaf water potential decreased during deficit irrigation periods in T-1 and T-2 treatments. Larger differences were found in values taken at predawn than at midday, indicating that Ypd is a more useful indicator of plant water status. A clear separation between the main periods of shoot and fruit growth was found. Onset of the critical period of rapid fruit growth could be determined precisely by considering the decrease in relative fruit growth rate values. T-2 treatment caused a delay in reaching marketable lemon fruit size. Chemical characteristics of lemon fruit were not significantly modified by irrigation treatment.

Regulated deficit irrigation (RDI) is an irrigation strategy based on limiting nonbeneficial water losses, and applying water so that plant water deficits are controlled and occur during times of the season when adverse effects on productivity are minimised. Some problems have been found in applying RDI in heavy and deep soils, in which soil water depletion and refill are delayed. Adequate water supply is of major importance during citrus flowering and fruit set. A second critical period coincides with the period when fruit growth is rapid (stage II). The abscission of flowers and young fruits will be affected in the first case, as will fruit size in the second case.

Materials and methods
Experiments were performed on 25-year old lemon trees. The mean maximum summer temperature was 32ºC, with a mean relative humidity of 51%.

Irrigation treatments
Three drip irrigation treatments were applied:

- T-0, receiving water equivalent to 100% of seasonal crop evapotranspiration. Rainfall exceeding 5 mm day, and not exceeding 30 mm week was considered effective.
- T-1, water application of 25% of control treatment all year, except during the period of rapid fruit growth, stage II, when 100% ETc was applied.
- T-2, treatment, irrigation was scheduled as T-0, except during stage II of fruit growth when 70% ETc was applied.

Four replicates. One drip irrigation line was used for each row. There were 3 emitters on both sides of each tree at distances of 0.5, 1.5 and 2.5 m from the tree trunk. Irrigation frequency was the same, and varied from one to three times per day, 7 days a week in spring and summer, and one time per day, 2-6 days a week, in winter and autumn (around 45 – 55 l per tree).

Results
In T-1 treatment, this reduction was greater at 30 and 60 cm depth than at 90 cm depth. Citrus trees are unable to develop osmotic adjustment under water deficit conditions.

Vegetative and fruit growth

Terminal shoots growth was unaffected by irrigation treatment. Two main growth periods were noted, one during the second half of March, and the other during the first half of June. The plateau in shoot growth between these two growth periods coincided with the flowering-fruit set period. The end of seasonal shoot growth was coincident with the rapid fruit growth period. Trunk and canopy volume growth were not affected by irrigation treatment during the experimental period. Some leaf chlorosis and slight defoliations were found in T-1 treatment at the end of the deficit irrigation periods. These leaf symptoms disappeared when irrigation amounts of 100% ETc were provided. Irrigation treatments did not affect intensity of flowering or fruit-set. However, before the end of the June drop fruit period, a higher percentage of fruits of less than 10 mm diameter were recorded in T-1 treatment, which may indicate a more prolonged flowering process. The "Verdelli" effect was not observed in this experiment. This can be explained by the fact that water deficits during summer (T-2 treatment), and previously to summer (T-1 treatment) were mild in relation to that induced by Barbera et al. (1988). The Fino is not a reflorescent cultivar. Lemon fruit growth was similar in the three irrigation treatments.

The period of rapid lemon fruit growth started when 90% of total shoot growth was completed. This clear separation between main periods of vegetative and fruit growth is essential for the successful application of regulated deficit irrigation strategies in fruit trees.

Yield and fruit quality

There were no differences on total yield among the three irrigation treatments in any of the years studied. A water deficit situation during the critical period, corresponding to the stage II of rapid fruit growth, caused a delay in attaining marketable fruit size. Deficit irrigation on T-1 treatment did not substantially affect yield. Thus a moderate water deficit applied during flowering-fruit set-fruit cell division period was not critical in terms of yield. Significant difference were found in some lemon quality characteristics between both harvests, with the fruits from the second harvest having higher juice content, fruit shape index and lower peel thickness index than lemons from the first harvest.

Conclusion

A water saving of 20%, with moderate water irrigation deficit during the rapid fruit growth period, which is coincident with the period of less availability of water for irrigation practices in the southeast of Spain, did not induce significant reduction in total yield. However, from an economical point of view, the delay in reaching marketable fruit size limits the use of this treatment. (T-1 treatment), which reduced irrigation amount during the season except in the rapid fruit growth period, saved around 30% of water without affecting total yield, and only caused a reduction of lemon yield on the first harvest in one year. In consequence, the T-1 treatment appears to be a promising irrigation strategy in areas with scarce water resources.

Duddy, N., McNamara D. and Falivene, S. Queensland Citrus Study Tour, 28 April to 5 May 1997. HRDC Report.

Golden Mile Orchards: They hard prune one half of the Meyer lemon trees, then prune the other side when it has recovered. To encourage an out-of-season crop, they cut off the spring flowers in November, then hedge the trees severely in spring so that hardly any leaves are left. Lisbon lemons are hard pruned for two years to reduce their willowy growth habitat.

2PH orchards: They water stress trees in November to encourage a crop in February to March. Trees are hedged annually.

Duddy, N. and Chown, M. USA Citrus Study Tour, 16 August to 3 September 1997. HRDC Report.

Green Leaf Farms, California: All lemons hand pruned. The insides of trees are pruned by removing two thirds of the internal wood. Trees are topped to 10 feet. The cost is easily compensated by good export prices.

Forsyth, J.B., Report on a Citrus Study Tour to California, 1986, Miscellaneous Bulletin 21, NSW Agriculture.

The Californian Citrus Industry

Ventura County

Most of the lemons are produced in the coastal and intermediate zones of Ventura County. They are picked almost all year round. The heaviest picking is between February and June. Green lemons can be held in storage for up to five months. Cultural costs for growing lemons are now approximately $1,326 per acre.

Lemon Production

California is also a major producer of lemons, and 81.2% of the United States production. The main lemon growing counties are Ventura (48% of the California area), Riverside (13.7%), Tulare (9.5%), San Diego (8.0%), and Kern (7.2%).

Ventura is the main county, and lemons are picked all year round, with main crop between February and June. Green fruit can be stored for five months. Eureka plantings total 16,901 acres, and Lisbon 5,265 acres. The climate of the near coastal areas is similar to the Central Coast, but drier. In the slightly more inland/intermediate (Fillmore) areas, conditions are more suitable for the Lisbon variety.

Harvesting and Curing/Storage

Lemons can be picked all year round in the Southern California producing districts, due to the coastal climatic influence. Main cropping period is from January - August (winter-spring), with lighter crops also produced from September - December (summer-autumn). In the other main inland lemon growing districts, cropping is more seasonal with no normal spring-summer production.

Fruit is normally picked according to size, rather than maturity and rind colour development. Colour sorting by electronic equipment permits yellow tree-ripe fruit to be quickly marketed (may still be stored for one week), and other basic

fruit to be selectively stored, i.e. silver (6 weeks), light green (2 months), and dark green (4-5 months).

Freshly picked lemons are therefore mainly immature, and normally cured before packing in controlled environment storage area – temperature 55-50^{0}F, and relative humidity 85-90%.

Rootstocks

C. macrophylla has been a prolific performer in lemons in Ventura. Although susceptible to *Phytophthora sp*., the sweet orange can be an excellent rootstock. Some new varieties, such as Citrumelo 4475, are doing quite well being *Phytophthora* and nematode resistant.

Verdelli Summer Lemons

Water stress in lemons can induce summer flowering, and set a crop which is harvested the following summer (Verdelli crop) during peak demand and prices. This fruit is marketed fresh with light green rind, and juice may be reduced while the rind may be thicker but fine textured. Fruit can be stored for up to two months, or degreened with ethylene to improve rind colour prior to marketing.

After three years of local Verdelli experience, it is now confident to recommend to all lemon growers of this County to take maximum advantage to try the Verdelli process, for the production of a second crop of lemons, harvested during the summer. The Verdelli cultural practice guidelines are as follows:

a) ***Starting the Stress*** – Turn water off during the first two weeks of June. Allow trees to use up the available soil moisture and reach the "permanent wilt" level of water stress (25 to 35 bars, negative predawn xylem pressure potential). Visual symptoms include: slight defoliation, yellowing and curling of leaves, complete cessation of growth, and leaves wiled at dawn. If this level of stress is reached in less than 50 to 60 days, start a deficit irrigation before a significant number of trees reach 50% defoliation, approximately -45 bars. Excessive defoliation will weaken the tree, and reduce Verdelli fruit set, and the quality of the winter crop. If the desired stress (25 to 35 bars) is reached after 50-60 days, delete Part B. (Deficit Irrigation). Sandy and shallow soils will usually dry before 50 days and require Part B.

b) ***Deficit Irrigation*** – Upon reaching this 25 to 35 bar level, a deficit irrigation regime should be initiated. Apply one-fourth of the normal crop water, use in weekly to three times weekly irrigations. Typical rates will be 70 to 100 gallons per tree per week during the deficit irrigation regime. The amount of applied water on any one day should not be sufficient to initiate new growth, but only to keep the plant from defoliating. Plant water stress levels of 20 to 30 bars during this period appear to be optimal.

c) ***Resumption of Irrigation*** – The trees should be rewatered after 50 to 60 days from the start of the dry period. The first irrigation must be sufficient to refill the primary root zone – top 18 inches of soil. Sprinklers have been the most effective for rapidly bringing the trees out of stress. After the root zone has been replenished, normal irrigation should be resumed. Overhead sprinkler irrigation should be avoided during Verdelli bloom to minimise pollination and disease problems.

d) ***Fertilisation*** – Nitrogen fertiliser appears to have minimal effect on the production of bloom, but is thought to be beneficial for fruit set and growth. Soil applied nitrogen of 100 to 200 pounds of N per acre has been the traditional approach, but foliar urea, one week and three weeks after resumption of irrigation also appears effective.

e) ***Pruning*** – Heavy pruning should be avoided during April or May before the Verdelli stress, but trees pruned after two to three weeks of stress have produced a successful Verdelli crop.

The currently suspected negative effects of moisture stress on defoliation, endoxerosis (internal breakdown like stylar end rot), long-term yield and tree vigour currently limits more widespread adoption. The stress will also cause the collapse of any trees suffering from root rot.

Pruning
The amount of routine pruning carried out regularly, which may be from 12-18-24 month intervals, varies depending on the rootstock vigour, density and main market outlet, but is a common cultural practice.

A number of alternative lemon pruning programs can be carried out:

Hand pruning
Machine topping
Machine topping alternating with hand pruning
Skirt pruning
Hedging box rows

Although mechanical topping, and to a lesser extent side hedging is often carried out, complementary hand pruning of water shoots and stubby growth may also proceed throughout the year, particularly where fresh marketing is more important. Inside fruit is then protected from rind wind scarring.

Gallasch, P.T. Citrus Study Tour to Italy, Spain and the United States of America, Department of Agriculture South Australia. Technical Report No. 201, October 1992.

Maturity periods in Spain (Southern Hemisphere equivalent).

Eureka - late March to end November
Fino - April to June
Verna - August to March

Maturity periods in Italy (Southern Hemisphere equivalent).

Femminello	*Apireno*	April to September
Femminello	*Siracusano*	April to May
Femminello	*Zagara Blanca*	Early April to early June
Femminello	*S Teresa*	Early May to early July

Femminello - Italy

Selections of this variety make up 90% of production in Italy. F Zagara Bianca is the most popular. Lemon plantings are declining due to the fungal pathogen Malsecco which reduces yields by 50%.

Spain - lemons are pruned every second year

California - lemon industry based on selections of Eureka and Lisbon.

Gallasch, P. T. Citrus Study Tour of California., February 1996. Sardi Research Report Series No. 8.

In lemons, the improved Meyer was most in demand followed by Variegated Pink flesh Eureka and the Limoneira 8A Lisbon.

Garcia-Sanchez, F. and Martinez, V. Salinity and Water Effects on Yield, Fruit Quality, and Mineral Composition of 'Fino 49' Lemon. Proceedings of the International Society of Citriculture IX Congress, 2000. Pp 527-531.

Abstract. Effects of salinity on fruit yield and quality during 1999, and leaf mineral composition, were studied in a field experiment with 6-year-old 'Fino 49' lemon trees on macrophylla rootstock.

Although CI^- and Na^+ transport to the scion is regulated primarily by the rootstock, a number of reports demonstrate that scions, as well as rootstocks, may influence CI^- and Na^+ accumulation in leaves. Nieves et al. (1991) compared the lemon scions 'Verna' and 'Fino' grafted on sour orange and *C. macrophylla*, and found that leaves on 'Fino' scion had higher concentrations of Na^+ and CI^- than those of 'Verna' regardless of rootstock.

Materials and Methods

Grafted plants of 'Fino 49' lemon rootstock *Citrus macrophylla* were studied under saline conditions. The trees were 6 years old. Three salinity treatments were combined with two irrigation levels in a factorial design. The saline treatments S1 and S2 were imposed by adding NaCI to the irrigation solution to produce concentrations of 15 and 30 mm NaCI. The control treatment SO, consisted of water having a conductivity value of about $1dS.m^{-1}$. For each concentration of NaCI, trees were irrigated with two different rates: control (100%) and 125% of the control.

Results

Increasing salinity significantly decreased yield. Salinity significantly decreased fruit number, but not fruit size. Increasing the irrigation level reduced fruit size, and significantly increased the number of fruits.

Juice, pulp, and peel percentage. Salinity significantly decreased the percent juice, the values being 38.7% in the control and 32.16% in the S2 treatment.

Total soluble solids (TSS), titratable acidity (TA), and TSS:TA ratio. Salinity and increasing irrigation rate significantly reduced TSS and TA.

Chloride and sodium. Under saline conditions, leaves of lemon accumulated Na and CI with time.

Potassium, magnesium, phosphorus, and calcium. Potassium, calcium and phosphorus concentrations in leaves increased with time. Salinity treatments produced significantly greater Ca and lower P concentrations in leaves with respect to the control. Neither levels of irrigation nor salinity treatments affected the K concentration in leaves. Irrigation level did not affect leaf K, Ca, P, or Mg concentration.

Discussion

All salinity treatments produced a decline in yield with respect to the control treatment. Yield differences were due more to differences in the number of fruit per tree, than to differences in individual fruit weight.

Different irrigation rates in the saline and control treatments did not affect yield, suggesting that application of water in excess of the irrigation requirement had no effect on total production.

Salinity reduced juice percentage, thus decreasing marketable fruit quality, and also reduced juice quality by decreasing TSS and TA.

Gill, D.S., Jwa, M.S.B., GH, R.SI. and Brar, W.S. 1982. Effect of Ethrel Spraying on Lemon Fruit Development. Citrus. Science and Culture, November.

Fruit splitting

Studies were undertaken on the five-year old lemon plants (Baramasi). The six treatment of ethrel at 50, 100, 250, 500, 1000 ppm concentrations and water spray were replicated three times. The first spray was given towards the end of June, and the second 20 days after the first spray. Fruits treated with 500 ppm showed better colour development than other concentrations within 7 days. All the concentrations except 1000 ppm gave significantly better juice percentage including control.

The lowest fruit splitting (2.29%) in 500 ppm concentration which gave 92% less splitting over control. The next best concentration (250 ppm) gave less than 10% fruit splitting, but in control 40% fruits were found effected with this disorder. The application of ethrel proved quite effective in degreening the rind of baramasi lemon which avoided splitting too, because the crop was harvested before the sudden changes in environmental conditions occurred i.e. factors leading to cracking and splitting of fruits.

Growing Citrus in New Zealand, A Practical Guide, Produced by New Zealand Citrus Growers Incorporated, July 1997

Lemons and Limes

Introduction

The main lemon crop in New Zealand is picked in winter (June-August), with smaller crops in spring and late summer. For export purposes, lemons are picked when still partially green, but starting to colour (silver-green). Lemons have been New Zealand's main citrus export crop for many years; primarily to Japan.

Lemon Cultivars

The main commercial lemon cultivars fall into two broad groups; the Eureka group, which consists of Villafranca, Genoa, and Eureka selections; and the Lisbon group, which includes many different clones and nucellar selections.

Villafranca

Until the advent of Yen Ben, it was New Zealand's predominant lemon cultivar, but had a reputation for producing thick-rinded fruit. Trees of Villafranca are typically grown on sweet orange. Villafranca trees are typically very vigorous, and this excessive growth is difficult to manage.

Genoa

Genoa has never been widely planted here, but has recently attracted attention because certain local budlines are free of exocortis viroid, and appear to be compatible with trifoliata rootstock. Fruit from Genoa trees on *trifoliata*

produce thinner rinds than those from trees on sweet orange rootstock. Tree growth is similar to that of Villafranca.

Yen Ben
The high-quality fruit attracted the interest of New Zealand researchers in the mid-1970s, and large numbers of trees were subsequently propagated by nurseries. Yen Ben produced fruit with the smoothest and thinnest rinds, and with the lowest seed numbers.

Yen Ben has since become the cultivar of choice for export plantings. The attractive appearance and high juice content of the fruit have been well received on the Japanese market. Yen Ben appears to be reasonably compatible with trifoliata, and produces precocious trees with smaller canopies on this rootstock. The main cultural problem encountered is excessive fruit set, resulting in small fruit.

Minor Lemon Cultivars

Verna and Fino
Verna and Fino have yet to be fully evaluated under New Zealand conditions, but initial observations are that neither have fruit as attractive as Yen Ben. Verna fruit mature much later than other lemon cultivars, but thick rind and protruding necks have been unattractive features. Fino fruit have a similar appearance to Eureka, but have proved quite seedy.

Lisbon
Lisbon is not grown commercially in New Zealand to any extent.

Variegated Pink Eureka
Variegated Pink Eureka has been recently introduced. Although the fruit is yet to be seen in New Zealand, in California it is reported to be smaller than Eureka, often ribbed, and the young fruitlets are variegated. The interior flesh is light pink.

Lemon Hybrids

Meyer
Most parts of a Meyer tree can withstand temperatures down to minus 6^0C. Meyer has been grown commercially in New Zealand for many years, particularly in Gisborne and the Bay of Plenty. The fruit is unfortunately not well accepted on international markets. It is also too tender and juicy to withstand handling, shipping, and storage without excessive waste.

Lemonade
Tree Spacing
Lemons – Yen Ben 5.0 x 3.0 metres.

Citrus Nutrition

Lemons with several growth flushes per season should have several dressings of nitrogen to coincide with the start of the major flushes which are usually in spring, summer, and late summer/autumn.

Potassium
The need for lemons to have more potassium than dessert citrus should always be borne in mind.

Crop Removal Rates

Fruit Type	Crop Removal (kg)											
	1t			15t			30t			45t		
	N	Ca	K	N	Ca	K	N	Ca	K	N	Ca	K
Villafranca Lemons	1.3	1.4	2.6	20	21	39	39	42	78	59	63	117

Training, Pruning and Tree Size Control

Those cultivars that particularly need to be pruned and trained to maintain fruit size and peel and juice quality, are lemons and both Clementine and Satsuma mandarins.

Vase Training for Lemons and Clementine Mandarins

Varieties such as lemons will need an intensive training and pruning regime throughout their lives to maintain good fruit size and quality. Tree shaping for these varieties should begin from planting. The aim is to develop four to six permanent scaffold branches with good strong branch angles. During the next two to three years, the main emphasis is on developing the scaffold branches. Regularly rub off sprouts (young vertical shoots) not required for tree development.

With Mandarins and Lemons
Prune lemons at or after harvest in the winter-spring period.

Growth Regulators

Post-harvest Uses
The addition of 2,4-D to post-harvest wax applications aids the retention of the stem button on lemons. Using ethylene for curing lemons can cause an increase in the percentage of stem button drop. Bagging the fruit in polyethylene liners during curing increased the stem button drop, and this may have been due to an increase in the ethylene levels in the bags. In local trials, no stem button drop occurred where 2,4-D at 500 ppm was added to the wax.

Picking and Post-Harvest Practices

Export Lemons - 100-180g, prefer 120-150 g
Domestic Local Lemons - 55-75 mm diameter
Export Pack - 17 kg
Lemon colour - silver-green (export), yellow-green (local)

Picking Practice
Procedures

- Lemons (but not mandarins) may be held in the orchard for 24 hours if cool and dry (but not in direct sun or hot weather). This will make the peel more tolerant of handling.
- Some fruit may be single-clipped at the button. This is easier on lemons.

Packing

- Lemons picked silver-green may be cured by holding at 15-20^{0}C, 90-95% humidity for three to six weeks. This results in thinner peel, increased juice content, and a peel that better withstands handling.

Storage

- Typical storage conditions are:

  Lemons – 12-14^{0}C, 85-90% humidity
  Fruit normally store satisfactorily 5-8 weeks.

Citrus Diseases

Citrus Scab (Verrucosis)
Different cultivars vary in their susceptibility to scab. Highly susceptible cultivars commonly grown in New Zealand are: Yen Ben, Villa Franca, Meyer lemon, Lemonade, and Clementine and Kara mandarins.

Brown Rot
The disease attacks fruit of all cultivars, and can be particularly serious on lemons and New Zealand grapefruit.

Citrus Blast
Citrus blast is a disease caused by the bacterial pathogen *Pseudomonas syringae*. The bacterium is often present on citrus leaves, but the disease manifests itself only under wet, cool conditions. It is most active at about 12^{0}C and rarely progresses at temperatures above 18^{0}C or below 8^{0}C. Infection is greatly facilitated by damage to the foliage from strong winds, heavy rain and hail, or other abrasions such as wind rub. In New Zealand, infections occur mainly in late winter or early spring, and are often facilitated by strong north-east winds accompanied by heavy rain. The same organism can lead to the formation of black sunken pits on the fruit of both standard lemons and Meyers. Experience suggests that lemons are the most susceptible. Citrus blast is rarely a problem in well-sheltered blocks.

Citrus Economics

Over a number of years, Agriculture New Zealand Ltd and, formerly, MAF Technology, have collected gross margins from a number of citrus growers, but the collections have not been enough to make the following data watertight in terms of statistical reliability.

Gross margins – main citrus cultivars 6 year average gross margin $/ha

	88/89	89/90	90/91	91/92	93/94	94/95	6 year average
Lemons	11,039	15,331	18,730	16,505	10,131	8,277	13,335

Hare, J. D. A Reconsideration of the Economic Impact of the Citrus Bud Mite on Value of Southern California Lemon Crops. Proceedings of the International Society of Citriculture IX Congress, 2000. 737-739.

The citrus bud mite, *Aceria sheldoni* (Ewing), has a reputation as being a serious pest of lemons, although recent studies failed to reveal a consistent economic impact. In order to resolve some previous inconsistencies, we evaluated the economic value of treatments to suppress citrus bud mite populations on a commercial scale over 3 years. Experiments were conducted in six groves, and included two treatments of 100 trees each. In one treatment ("treated"), trees were managed according to conventional commercial

practices, and included one to two annual applications of narrow-range petroleum oil to suppress citrus bud mite populations. In the other treatment ("untreated"), experimental trees were managed identically as treated trees, except that oil spray applications for citrus bud mites were withheld.

There are always greater observed foliage symptoms than fruit damage from this mite. Results clearly documented the lemon tree's ability to differentially abort bloom and fruit damaged by citrus bud mites.

Materials and Methods
Four commercial groves were made available to us. Both 'Eureka' and 'Lisbon' lemons were compared for bud mite population, damage, pack out, and economic return. The data on the economic impact of the citrus bud mite that were collected in this study was derived from commercial packout reports.

Results
With the exception of the Saticoy site, mite-months were significantly greater in the untreated plots, and show that citrus bud mite populations were indeed suppressed by the bud mite pesticide applications.

Discussion
Oil sprays effectively reduced both the density and the incidence of citrus bud mite infestations. These reductions however, had minimal impact on the fruit volume, grade distribution, and value of lemon fruit. There was no significant difference in crop value between treated and untreated trees at any site, even before subtracting the cost of pesticide application. Because no improvements in crop value were achieved for up to three seasons after citrus bud mite populations were suppressed, these studies do not support the assumption that oil sprays for citrus bud mite suppression are needed to maintain the economic productivity of coastal lemon groves in southern California.

It is interesting that the numerical reductions in crop values after oil sprays, were greater for 'Lisbon' than for 'Eureka' lemons. Possibly 'Lisbon' trees are more sensitive to oil sprays than 'Eureka', or less susceptible to citrus bud mites, or both.

In conclusion, we were unable to identify a level of citrus bud mite infestation where the cost of suppression consistently provided an economic benefit.

Harty, A. 2002. Yen Ben Lemon- An Attractive Option for Citrus Growers. The Orchardist July, 58-59

Yen Ben is the only variety grown in NZ accepted on international export markets. 125 canopy hectares in Kerikeri. It will produce 3000 export tonnes. Most is currently exported to South East Asia. Can be reliably sea freighted without using postharvest fungicides. There is potential to plant another 120 canopy hectares.

Lemons are multi cropping, and a minimum of 5ha is required to justify investment. You need good drainage, pH 5.8-6.2 and adequate phosphorous, magnesium and calcium. Mature shoots and fruits are not damaged unless canopy frosts below 2 degrees are experienced for several hours.

Setting up costs about $14000, growing costs $7500/ha. Gross return $44,000 and net return $24,000.

Trees flower 4-5 times per year with 4-5 different sets of fruit on the tree at once. 75% fruit matures in winter-spring (late May-November) and the remaining 25% December to March. Need to clip fruit for export. Block have 500 trees/ha and produce 2T after 2 years increasing to 40-45T by year 10. Productive tree life 25-30 years.

Rootstock used *P. trifoliata* but other rootstocks Benton citrange and Brazilian sour orange being trialled.

Harty, A., Anderson, P., Sutton, P. & Machin, T., Lemon Rootstock Trial: First Results, 2000, HortResearch, Kerikeri Research Centre.

Yen Ben has been propagated to date almost entirely on P. *trifoliata* rootstock, which produces a compact, productive tree. Although it gives excellent fruit quality, it also induces small fruit size. In 1993 we planted a trial of Yen Ben propagated on 10 different rootstocks.

Rootstocks/scion compatibility
There are some which have clearly not formed strong unions. The most apparent is Rangpur x Troyer, which has produced very small trees with marked overgrowth of the scion. Cleopatra mandarin also shows some scion overgrowth. Swingle citrumelo has since developed some unusual creasing around the bud unions. It appears that Swingle is exhibiting delayed incompatibility.

Fruit quality
Benton citrange, C-35 citrange, Brazil sour orange and *trifoliata* all produced fruit with rinds of comparable thickness and juice content. Sweet orange had the thickest rinds and third lowest juice content of all the rootstocks, and these characteristics preclude it from further consideration.

Summary
Which candidate is best of the three showing most promise at this stage: Brazil sour orange, C-35 citrange and Benton citrange. The relative merits of these three rootstocks are:

- ***Brazil sour orange*** – export yield and yield efficiency have been to date the best of these three. The trees are compact (similar to *P. trifoliata*) and the bud unions are good. A complicating factor is its susceptibility to citrus triateza virus.
- ***C-35 citrange*** – export yield is higher than *P. trifoliata*, and the size profile tends to large fruit. The bud unions are good, and trees are vigorous (the largest of these three).
- ***Benton citrange*** – export yield was higher than *P. trifoliata*, and the size profile showed the greatest trend to large fruit.

Results
Graft Compatibility
Over the five years since planting, five rootstocks in the trial have developed symptoms of incompatibility with Yen Ben.

All trees on C-35 citrange developed severe leaf yellowing. The trees have subsequently died.

Josan, J.S., Sandhu, A.S. and Singh, R. Changes in Physico-Chemical Characters of Lemon Fruit as Affected by Various Levels of Irrigation. Punjab Hort. J. 33 (1-2):5-8.

Lemon cv. Baramassi. There were six treatments at 20 per cent, 40 per cent and 60 per cent available soil moisture depletion (ASMD), irrigation at 40 per cent ASMD.

Lanza, G., di Martino Aleppo, E.; Strano, M. C. and Reforgiato Recupero, G. Education of Hot Water Treatments to Control Postharvest Green Mold in Organic Lemon Fruit. Proceedings of the International Society of Citriculture IX Congress, 2000. 1167-1168.

Green mould is one of the most economically important postharvest diseases in citrus fruit.

Materials and Methods

Mature fruit (primofiore, bianchetto, and verdello crop) from 'Femminello Siracusano' lemons were selected by hand from field bins after harvest before any commercial postharvest treatments were applied. Samples of blemish-free fruit of uniform size and appearance were washed with water at room temperature, air-dried, and placed randomly in plastic cases.

Hot water treatment. Fruit of each replication were placed in a perforated plastic crate, covered with a perforated lid, and submerged for 180 seconds in a stainless steel tank. The water was uniformly circulated with a circulating pump, and heated with one 2000-W heater. An electronic temperature controller was used to maintain the water temperature at 52 ± 1^0C. During the short hot water brushing (SHWB) treatments, fruit were washed on a brush roller sprayed with heated water at 52 or 62^0C for 20 seconds. Temperature was constantly monitored with a digital thermometer. These treatments were compared with an untreated control and an effective, standard fungicide treatment (Imazalil). Imazalil treated fruit were dipped for 60 seconds in water containing 1 $g.L^{-1}$ a.i.

After treatments, fruit were kept at 23^0C at high relative humidity (RH) for 2 weeks.

Results

Hot water dipping and short hot water brushing at 62^0C were effective in reducing green mould decay in innoculated fruits. Hot water dipping was as effective as Imazalil on green, summer-harvested lemons. Short hot water brushing at 52^0C, although reducing the incidence of green mould compared to the untreated control, did not give satisfactory results since decay incidence exceeded commercially acceptable levels. Heating at 62^0C was also more effective at inhibiting *P. digitatum* spore germination than heating at 52^0C for longer exposure times. Treatments had no effect on fruit colour. No rind injury was observed on winter and summer-harvested lemons after hot water treatments, even in those treated at 62^0C. Some risk of injury can occur when fruit is cold and turgid at the time of treatment.

Martin, P. and Harty, A. Producing Summer Lemons. Kerikeri Horticultural Research Station, Citrus Research Seminar 20 June 1991.

Lemons flower heaviest in spring, with other smaller flowerings throughout the year.

In a trial on Villa franca lemons they applied:

1. GA3 in winter to inhibit spring flowering
2. Ethephon (Etherel) in late spring to reduce fruitlet numbers
3. Paclobutrazol (Cultar)® in summer to enhance late flowering.

Harvest data in the following season indicated that the cropping pattern was significantly altered by some treatments. The Ethephon application resulted in a large autumn crop, 15 months after spraying. GA shifted the cropping pattern slightly later, but the Cultar® spray had very little effect.

Morrish, P. Mildura Fruit Company Spanish Study Tour Final Report, 2002, Prepared for the Murray Valley Citrus Marketing Board.

Open Hydroponics System (OHS) – Murcia
Fino lemon trees were planted at 6m x 8m, producing 60 to 75kg per tree in the fourth year. Irrigation water used is 2,500 to 3,000 EC units, of which they fertigate at 5.8pH. Chelates are also incorporated into the fertigation system, but they are put in separately, as the water goes out to the orchard. They use nitric acid to adjust pH, and by balancing chemical tanks. It is possible to use phosphoric acid, but they only mix it as it is used.

Morton, J. F. Fruits of Warm Climates: Lemon. pp. 160-168. 1987.

'Berna' ('Bernia', 'Vema', 'Vernia'). This is the leading cultivar of Spain, and important in Algeria and Morocco.

'Eureka' 'Lambert Eureka' is a chance seedling found in 1940 on the property of Horace Lambert in New South Wales.

'Femminello Ovale'. This is the leading cultivar in Italy.

'Rough Lemon'. The scant pulp and juice limit the Rough lemon to home use.

Climate
Because of its more or less continuous state of growth, the lemon is more sensitive to cold than the orange, and less able to recover from cold injury. The tree is defoliated at 22^0 to 24^0F (-5.56^0 – 4.44^0C). A temperature of -6.67^0C will severely damage the wood unless there has been a fortnight of near-freezing weather to slow down growth. Flowers and young fruits are killed by 29^0F (-1.67^0C) and nearly mature fruits are badly damaged below 28^0F (-2.22^0C). The lemon attains best quality in coastal areas with summers too cool for proper ripening of oranges and grapefruit. The fruits are scarred, and the tree readily defoliated by winds. Lemons are grown in both dry and humid atmospheres.

Soil
The lemon tree has the reputation of tolerating very infertile, very poor soil.

Culture
They are cut back severely after 12 years or replaced. Lemon trees are very sensitive to herbicides.

In Sicily, growers made a practice of withholding water in summer for 35 to 60 days until the trees begin to wilt. Then the trees are heavily irrigated, and given high nitrogen fertilizer which induces a second bloom in August or early September, producing a crop the following summer when lemons are scarce, and prices are high. Adequate bloom did not occur on sandy or shallow soils.

Harvesting and Handling
California and Arizona adopted the practices of picking at any time after the fruits reach a 25% juice content.

Lemons under 5.4 cm are too immature to attain proper quality for marketing, and fruits over 6.25 cm are too large.

Food Uses
Slices of lemon are served as a garnish on food/beverage. Lemon juice, fresh canned, concentrated and frozen, or dehydrated and powdered is primarily used for lemonade drinks.

Nieves, M., Garcia, A. and Cerda, A. 1991. Effects of Salinity and Rootstock on Lemon Fruit Quality. Journal of Horticultural Science 66(1): 127-130.

Summary
Physical characteristics and constituents of juice were studied in 'Verna' lemon fruit in relation to the salinity of the irrigation water and to three rootstocks, sour orange, Cleopatra mandarin and macrophylla. Juice quality was affected by both salinity and rootstock.

Results
The thickness of the peel of lemons grown on macrophylla rootstock increased with salinity, except at the highest concentration, where it was reduced. Juice content was not affected by salinity. Fruits grown on macrophylla had lower TSS, density and titratable acidity than those on Cleopatra mandarin and sour orange.

Conclusions
The yield of lemon trees irrigated with saline waters was reduced mainly by a decrease in the number of fruits per tree. However, juice quality was influenced by both salinity and rootstock. Sour orange and Cleopatra mandarin rootstocks were superior to macrophylla because their fruits were highly satisfactory in both TSS and acidity.

Revelant, L. J., Beattie, B. B. and Nardi, D. South Africa Citrus Study Tour Report., July 1996.

For lemons, pruning is an important management tool. Trees are topped annually, and hedged on alternate sides every second year. The main variety is Eureka on Rough lemon, with production at 70t/ha.

Ruiz-Sanchez, M. C. Domingo, R., Morales, D. and Torrecillas, A. 1996. Water Relations of Fino Lemon Plants on Two Rootstocks Under Flooded Conditions. Plant Science 120 (1996) 119 - 125.

Grafted on two different rootstocks: Sour orange and C. macrophylla.

Fino lemon trees grafted on sour orange or Citrus macrophylla are widely cultivated along the Mediterranean coast of Spain with an annual rainfall of ca. 250 mm. The overriding effects of soil flooding are to limit the availability of oxygen to the roots [2], and to reduce root permeability to water uptake. Citrus flood resistance is considered intermediate in relation to other fruit trees. Citrus plants grafted on sour orange are more resistant to flooding than those grafted on C. macrophylla. The experiment was carried out on two year old lemon plants. Flooding stress did not induce a Yp decrease in either scion/ rootstock combinations, during the first four days of the stress period. The overriding effect of flooding is to limit the diffusion rate of oxygen in the soil. Sour orange rootstock tolerate soil flooding better than C. macrophylla. Fino lemon plants grafted on sour orange is a more appropriate combination to resist an occasional very heavy rainfall situation.

Sale, P., Curing Lemons in Transit to Japan Looks Feasible, The Orchardist, *March 1993.*

Treatments

New Zealand lemon exports to Japan include both standard lemons and Meyers. This fruit was graded, washed and waxed, but given no special fungicide treatment to control moulds.

The following treatments were compared in the trial:

1. Genoa in export cartons
2. Genoa in polyliners in export cartons
3. Meyer in export cartons
4. Meyer in polyliners in export cartons.

The container was set at a temperature of 20^0C, and ran consistently at that setting for the 28 days of the trial.

Assessments

Assessments were carried out to measure the following parameters at 0, 7, 14, 21 and 28 days:

1. Fruit weight
2. Fruit diameter
3. Skin texture
4. Skin thickness
5. Juice content
6. Fungal rots.

Discussion

Fruit Colour

The Genoa fruit was mainly at the green to silver-green stage with a few fully coloured. The Meyers were mainly approaching full colour. After 28 days curing, not all the Genoa were fully coloured, but all the Meyers were a full

orange/yellow colour. The polyliner appeared to have no influence on the colouring.

Fruit Weight
There was a 4-5% reduction in fruit weight which occurred steadily over the 28 days. This loss was reduced when the fruit were in polyliners.

Fruit Diameter
There was a small reduction in diameter of about 2% over the 28 days in all treatments, except the Genoas in polyliners, where the reduction was only about 0.5%.

Skin Texture
A steady improvement in skin texture occurred during the 28 days of curing.

Skin Thickness
A significant and steady reduction in skin thickness occurred over the 28 days of curing of well over 10%. The reduction in the thickness of the skin of the Meyers was somewhat less, but still well over 7%.

Juice Content
The juice content expressed as a percentage by weight of the total fruit weight, increased with both varieties with and without polyliners.

Rots
No rots were seen until day 14, when it was apparent that the line of Meyers used in the trial had a high level of rots. The use of polyliners greatly increased the incidence of rots in both Genoas, and Meyers. All the rots recorded in the trial samples were typical of green mould.

Conclusions

It appears distinctly possible to cure standard lemons in a container at 20^0C over a period of 28 days, the time within which a seafreight container should reach Japan from New Zealand. Standard lemons for curing should be at, or beyond the silver green stage. Rot control measures are vital. Polyliners should not be used in curing lemons, as they increase the amount of rots in fruit.

Sarooshi, R. A. Report on a Citrus Study Tour to Spain, and Attendance at Mandarin Symposium, Corsica, 1995. NSW Agriculture, Plant Industries Report No. 16

70% of Spanish lemons are grown in the provinces of Murcia and Alicante. Over 95% of lemons produced are from two varieties Fino and Verna. Other varieties grown include Eureka, Lisbon and Villa Franca. Eureka is more sensitive to salinity.

Verna (selections 51 and 62) - trees are vigorous with few thorns. New plantings are on C. *macrophylla*, which produces larger fruit with later maturity, and yield is twice that on sour orange. Previous plantings were on sour orange on which the scion forms an overgrowth at the bud union. Selection 51 has smaller fruit. Verna flowers several times a year, with the main crop produced between February and July, and a pronounced minor crop in September to October. To obtain good quality, Verna need arid conditions and poorer soils. It is a late harvested variety, an alternate bearer, and has higher costs of production than Fino.

Fino (Selection 49) is more vigorous and thorny than Verna, and has a tendency to produce suckers. It flowers once a year, and is harvested between September and April. Preferred size for export is 58 - 62 mm. Well-managed orchards of this variety yield up to 100t/ha. A new selection Fino 95 is slightly earlier maturing, seedless, with good fruit size and has smaller, fewer spines than Fino 49.

Preferred rootstock's for lemons are C. *macrophylla* (preferred) and sour orange. Rough lemon is not used due to problems with *Phytophthora*.

Pruning Citrus
Tree training is carried out in the first year after planting, leaving 3-5 well-spaced main branches around the trunk, and rubbing out young shoots from the canopy centre 2-3 times a season when trees are young. In older trees, pruning is carried out in the 2-3 month period after harvest. Mechanical pruning using disc saws is undertaken on some large lemon orchards.

Torrecillas, A., Leon, A., delAmor, F., Monllor, Ma.R. and Llorente. S. 1981. Influence of the Cultivar and the Irrigation Systems on the Boron Leaf levels in Lemon Trees. 1981. Proc. Int.Soc. Citriculture Vol.2 : 589-591.

Leaf boron levels studied in Fino and Verna 17-21 years on sour orange. Verna had lower boron leaf levels than Fino in all cases. Drip irrigation systems promoted lower boron levels.

Methods
Plots with drip irrigation had four emitters per tree with 4 litres/hour dispensed.

Results
The use of drip irrigation with water volumes aided by sufficient nitrogen can be a suitable method for avoiding boron excess in citrus and especially in Verna lemons.

Torrecillas, A., Ruiz-Sanchez, M.C., Domingo, R. and Hernandez-Borroto, J. 1993. Regulated deficit Irrigation on Fino lemon Trees. Acta Horticulture 335 : 205-212

Fino were grown at Santomera under field conditions at two different drip irrigation treatments: 100% of ETc all year, and 25% of ETc all year, except during rapid fruit growth period (stage II) when 100% of ETc was applied. 630 mm and a 30% less water to RDI treatment.

Materials and methods
Fino grafted on sour orange. Tree spacing was 6 x 6 m.

Results
Two main periods of vegetative growth were reported for Fino lemon trees. The extension of primary shoot occurred during the second half of March and the first half of June. The period of rapid fruit growth started when 90% of total shoot growth was completed (at the beginning of second half of June).

Discussion
The clear separation between main periods of vegetative and lemon fruit growth observed, allows the possibility of regulate vegetative growth, without

detrimental effects on fruit growth, by means of irrigation management under deficit irrigation conditions. This growth pattern is essential for the successful application of RDI in fruit trees. It can be deduced that stage II has fundamental importance in determining final fruit size. It is noted that a steeper slope during stage II is characteristic of earlier cultivars as Fino one is.

In the first pick, an important reduction of yield per tree (about 50%) in RDI treatment was obtained by means of a parallel reduction in number of fruits per tree. This can be due to the fact that RDI treatment supported a water deficit situation from flowering to fruit set period. A water deficit during this critical period may lead to enhance flowers and young fruits abscission with the corresponding loss in yield. These first and provisional results show that RDI strategy applied to Fino lemon trees had not impact on total yield, saved irrigation water (30%) with the consequent higher water use efficiency. However, RDI induced a harvest delay, as it can be concluded from the first pick data.

Torres, G. J., Leal, B. N., Carrizo, Gastaminza, G. A., and Willink, E. Effect of Cold Quarantine Treatments on Quality of Four Commercial Lemon Cultivars. Proceedings of the International Society of Citriculture IX Congress, 2000. 1141-1143.

The objectives of this research were to study the behaviour of four lemon cultivars to cold quarantine treatments. Cultivars included: 'Eureka Frost', 'Lisbon Frost', 'Genoa EEAT' nucellar, and 'Limoneira 8A'. Two treatments were tested: 1) direct thermal treatment: 18 days at 2^0C (quarantine) + 17 days at 8^0C (transit) + 14 days at 20^0C (marketing); 2) preconditioned treatment: 7 days at 16^0C (preconditioned) + 18 days at 2^0C (quarantine) + 17 days at 8^0C (transit) + 14 days at 20^0C (marketing). Relative humidity was held at 85% to 90%.

For lemon, temperatures below 6 to 8^0C produce physiological and biological changes that are manifested as chilling injury (CI). The susceptibility to CI also depends on factors such as cultivar, actual temperature, duration of exposure, fruit maturity, harvest season, fruit location in the tree, nutritional condition, growing region, climatic conditions prior to harvest etc.

Results

The greatest weight loss occurred during preconditioning in the preconditioned treatment, and during the marketing period in the direct thermal treatment. Weight loss was least during the quarantine period for both treatments.

CI developed in 4.5% of the fruit receiving the direct thermal treatment, and in 0.5% of the fruit receiving the preconditioned treatment. In the direct thermal treatment, 'Limoneira 8A' developed more CI than 'Genoa'. There was no difference in CI development among cultivars in the preconditioned treatment. Both cultivars developed more CI in response to the direct thermal treatment than in response to the preconditioned treatments.

Internal fruit quality always remained within international marketing standards in both treatments. At the end of the marketing period, fruit retained 99% of their buttons in both treatments.

Discussion
Brix, acidity, maturity index, and vitamin C content of the lemons were not significantly affected by low temperatures in both treatments. CI was the principal physiological disorder that developed. Other principal physiological disorders included pitting and peteca. The preconditioned treatment at 16^0C over 7 days, significantly reduced CI in 'Eureka' and 'Lisbon' cultivars. The preconditioned treatment resulted in less decay and button fall than the direct thermal treatment.

Tugwell, B. L., Gallasch, P. T. and Moulds, G. Citrus Production and Handling in South Africa, October 1996. Sardi Research Report Series No. 13.

Lemons: Varieties include Eureka, Fino (Fino 49 and 95 [seedless] and Genoa (from Argentina). Trees are planted 6m x 3m apart producing 70-80 t/ha. Eureka on Rough lemon produces 122 t/ha over two years. Annual pruning is the normal practice, and can occurs more often to increase light penetration into the canopy. Eureka provides 99% of exports.

Vakis, N.J. 1975. Effects of Ethephon and Waxing on the Degreening of Cyprus-grown Lemons and Grapefruit. J.Hort. Sci. 50:311-319.

Results
Response of cultivars to ethephon concentration

Lemons. Fruit of the cvs Local, Strong Lisbon, and Rosenberg Lisbon degreened satisfactorily with 2000 ppm ethephon. Time required for full colouration ranged from 10 to 14 days.

Effect of Stage of maturity
Lemons. Fruit maturity (date of picking) was a major factor for both natural degreening and for the degreening of ethephon-treated fruit. Fruit picked later, however, had comparable rates of degreening with all ethephon concentrations. As fruit maturity advanced, increased ethephon concentrations (4000 ppm) tended to inhibit colour changes.

Effects of Waxing
Lemons. Waxing of lemons after ethephon treatment had little effect on degreening.

Wild, B.L. and Hele, T. 1988. Report on Lemon Export Attempt May-August 1987. Rural Newsletter, Summer/Autumn: 8-10.

Procedure involved picking lemons, bulk dipping the fruit in the fungicides Fungaflor® and Panoctine®, and stored for 8 weeks. Weight loss on an average sample of 4 kg varied from 4.0% to 8.1% with an average of 6.0%. A 20-30% pack-out was obtained instead of the expected 50 to 60%. Rejection was due to causes such as rind blemish, citrus scab, melanose, scale infestations and torn and plugged bottoms.

Conclusions
Fruit should be clipped, and with prompt application of fungicide.

Wild, B.L., McGlasson, W.B. and Lee, T.H. 1977. Long Term Storage of Lemon Fruit. Food Technology in Australia, September :351-357.

The 'curing' of the fruit results in thinner rinds which are more flaccid and less susceptible to decay. It has been found that juice yield and ascorbic acid content in these fruits are higher than in those freshly harvested.

Reasons for Storage
The winter crop is also considered to have finer rinds and texture, superior keeping quality and higher juice yields than those of crops from other seasons.

Problems of Storage
The principal cause of wastage is green mould. The disorder sour or soft rot, *Geotrichum candidum* L.k.ex.Pers, is a pathogen that can cause serious losses. The rot can develop rapidly from an injury site, reducing the fruit to a soft mass of disintegrated tissue.

Stem end rot. The same fungus is responsible for melanose spotting of fruit and dieback of twigs. This organism infects fruit buttons in the orchard when rain washes pycnospores from the infected dead twigs onto fruit, the organism remains dormant until after harvest, where upon senescence and death of the button, the fungus develops.

Control of Moulds and Rots
The factors influencing the control of pathogenic disorders during lemon storage are (a) type and condition of fruit selected for storage, (b) method of and degree of care exercised during harvest, (c) types of fungicides applied, (d) time of fungicide application in relation to harvest, and (e) use of plant hormones.

Postharvest factors
Lemons should be medium to large in size and silver to light green in colour. Such fruit are physiologically younger and are less likely to carry infections of *Diaporthe*. They would also be of reasonable size after the weight loss experienced during curing and storage. It is recommended that fruit be harvested from dry trees when fruit turgidity is low, and that fruit be clipped from the tree and that cotton gloves be worn by pickers to reduce the possibility of finger nail punctures.

Postharvest factors – mould and rot treatments
Benomyl was established with almost complete control of green mould. Stem-end rot decay by Alternaria is most effectively reduced by 2,4-dichlorophenoxyacetic acid (2,4-D).

Senescence and Methods Available to Reduce its Development
Temperature: The reduction of storage temperature reduces fruit respiration with a resulting proportionate increase in fruit storage life and quality. By reducing the growth rate of pathogens causing fruit decay, greater mould control is obtained. Lemon respiration responds rapidly to increasing temperature, particularly between 5 and 10^{O}C. Extended storage at lower temperatures induces physiological breakdown and decay in the fruit. Temperatures employed in California range from 12.5 to 15^{O}C. Successful storage at 10^{O}C for 6 months and longer has been achieved without any physiological breakdown. This response may be a result of treatment with the plant hormone 2,4-D and gibberellic acid (GA) in wax.

Controlled atmosphere – carbon dioxide: Because of the high incidence of decay with increased carbon dioxide levels, no worthwhile benefit in keeping quality of lemons could be achieved by allowing its accumulation in storage atmospheres.

Ethylene: Citrus infected with green mould can produce large quantities of ethylene.

Recent Research Developments
Experiments were conducted to investigate beneficial effects of removing accumulated ethylene from CA storage environments. The low oxygen content of the CA environments markedly reduced the rate of greencolour loss from the rind of the lemon fruit.

Wild, B.L. and Rippon, L.E. 1973 Quality Control in Lemon Storage. Agricultural Gazette of N.S.W. Vol 84, Part 3, June :142-144.

Pre-harvest considerations
Selection of fruit: Fruit for medium and long-term storage should be taken from young vigorous trees free from dead wood.

Colour: Light green, through silver green, to a fresh yellow.

Pre-harvest spray: Application of GA 4 to 6 weeks ahead of maturity, will delay the colour change of lemons and keep them in the more juvenile state. A spray of 10 ppm GA is recommended.

Problems of storage: The main problems of storage are wastage from moulds and stem-end rots, and the aging of sound fruit. The common green mould *Penicillium digitatum* is the first to appear. The fungus *Diaporthe citri*, can cause losses from stem-end rot during storage. Lemons lose excessive amounts of water during medium and long-term storage, causing shrivel. The rind colour becomes deeper yellow, while buttons can die, shrivel and drop off.

Harvest and postharvest treatments: Careful picking and handling are necessary. A fungicide application to prevent mould, a wax application to reduce moisture loss and shrivel, to keep buttons alive and reduce stem-end rot are necessary treatments.

Waxing and use of 2,4-D: The incorporation of the plant hormone 2,4-D in the wax at 500 ppm is an effective aid in reducing the incidence of stem-end rot in stores lemons.

Cool storage: Accepted 12^{O}C to 13^{O}C in a normal atmosphere.

Recent developments in lemon storage research
Benomyl, compared with TBZ, showed the two fungicides to be almost equally effective for mould control for the first 2 months. For storage up to 6 months, benomyl was superior.

Wright, G. C. and Pena, M. A. Evaluation of Lemon Scions for the Southwest Arizona Lemon Industry. Proceedings of the International Society of Citriculture IX Congress, 2000. Pp 508-510.

Abstract. Four ‘Lisbon’ lemon scion cultivars, ‘Frost Nucellar’, ‘Corona Foothills’, ‘Limoneira 8A’, and ‘Prior’ were selected for evaluation on *Citrus volkameriana*. Results from 1994 to 2000 indicate that the yield and fruit size

of the 'Limoneira 8A Lisbon' selection has been superior up until 1998-99. Today, Arizona lemons comprise 45% of all harvested citrus acreage in the state.

Varieties in each trial site

***1993 Lemon scion trial*:**

- Corona Foothills Lisbon
- Frost Nucellar Lisbon
- Limoneira 8A Lisbon
- Prior Lisbon

1995 Lemon scion trial:

- Allen Eureka
- Cascade Eureka
- Cook Eureka
- Cavers Lisbon
- Frost Nucellar Lisbon
- Limoneira 8A Lisbon
- Prior Lisbon
- Rosenberger Lisbon
- Limonero Fino 49
- Villafranca

Results and Discussion

1993 Trial: 'Limoneira 8A' still appears to be an outstanding cultivar at this point, because of its consistency for the last 6 years.

1995 Trial. For 1997-98, all the 'Eureka' lemons had significantly less yield than the 'Lisbon' and other lemons, except the 'Frost Nucellar'. 'Villafranca', Rosenberger Lisbon', and 'Cavers Lisbon' had the highest yields for the first harvest, while 'Rosenberger' had the best yield for the second harvest. 'Limonero Fino 49', 'Villafranca', and 'Cavers' had the greatest percentage of fruit harvested early.

For this experiment, 'Cavers Lisbon' and 'Limonero Fino 49' appear to be the best cultivars tested.