Hydroponics, greenhouse vegetable and olive tour of Peru, Spain and Portugal, August 08

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South Australia Research & Development Institute (SARDI)

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by Barbara H. Hall & Kaye L. Ferguson
South Australian Research and Development Institute
November 2008

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This report presents information on the latest knowledge gained from attendance at the International Symposium on Soilless culture and Hydroponics in Peru and the 6th International Symposium on Olive Growing in Portugal and visits to greenhouse and olive production areas in Spain. This report incorporates information provided in reports from Industry participants, Domenic Cavallaro & David Schofield (Stoller Australia), Branton Frahm (Landmark) and Andrew Meurant (Elders).

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MEDIA SUMMARY

Key SARDI researchers and Industry partners undertook a study tour Peru, Spain and Portugal to gather new information and keep abreast of the latest developments in production systems and disease control in horticultural crops, and to develop contacts and exchange ideas and information with key international researchers in these areas.

Dr Kaye Ferguson (SARDI), Mr David Schofield (Stoller Australia), and Mr Brenton Frahm (Landmark), attended the International Symposium on Soilless Culture and Hydroponics in Lima, Peru. The symposium brought together researchers, growers and industry personnel from around the world to report on evaluation of growing media, plant nutrition and salinity, oxygen supply to the root system and root diseases and disinfection. The conference also included a tour of several commercial hydroponic properties around Lima and provided direct contact with growers who are successfully producing vegetables in greenhouses using simple hydroponic systems. Attendance at the conference provided the opportunity to meet with international experts in the hydroponics field and develop a network of expertise that could be used to improve the productivity of the Australian hydroponic greenhouse industry.

Dr Ferguson then joined Mrs Barbara Hall (SARDI), Mr Domenic Cavallaro (Stoller Australia) and Mr Andrew Meurant (Elders Ltd) in a visit inspecting the greenhouse production area of Almeria in south eastern Spain. The Almeria region is comparable to many of the Australian greenhouse growing regions, particularly South Australia, in terms of the climate, the crops grown, property size, the pest and disease issues and the grower demographic. However growing systems and technology around Almeria, even though simple, are more advanced than the majority of those in Australia. This provided an invaluable opportunity to learn from the successes and failures of an industry that mirrors our own. The trip to Almeria also included a visit to the research institute and provided the opportunity to meet with researchers in plant pathology and hydroponic technology.

The olive production around Ubeda and Cordoba, Spain has over 650,000 Ha of olives. Mrs Barbara Hall (SARDI), Mr Domenic Cavallaro (Stoller Australia) and Mr Andrew Meurant (Elders Ltd) joined Spanish researchers and growers in a tour of properties in the Ubeda area, and a visit to researchers at the Junta of Andalucía and the University of Cordoba. The comparison of their large, but often traditional industry with the small but vibrant and progressive Australian Industry was enlightening. However, both countries are facing similar water and sustainability issues, and valuable information was gained from these visits. The olive tour concluded with the 6th International Symposium on Olive Growing in Evora, Portugal, with presentations from international speakers and technical tours to local olive production areas. Mrs Hall presented a poster at the Olive Symposium on olive diseases and disorders in Australia.

The knowledge gained during the conference and study tour will contribute significantly to current and future HAL projects, for example VG07144, which aims to help growers who wish to improve productivity by converting from soil growing to hydroponics. Links have been established with greenhouse researchers and growers from New Zealand, Spain and South Africa and it is anticipated that this network of expertise will prove to be extremely valuable for projects in protected cropping. A network of contacts has been developed to facilitate development of a greenhouse grower tour planned for the South Eastern region of Spain in spring 2009. The Industry participants have also been able to extend new knowledge back to their growers, from demonstrations of basic but effective hydroponic systems, to using the knowledge and opportunities to help benchmark the Australian industry against the international scene.

INTERNATIONAL SYMPOSIUM ON SOILLESS CULTURE AND HYDROPONICS, LIMA PERU

The International Symposium on Soilless Culture and Hydroponics was held at the Universidad Nacional Agraria La Molina in Lima, Peru from 25-28 August 2008. Researchers, industry personnel and growers from all over the world including South and Central America, the United States, Canada, Europe, South Africa, China, Iran, Pakistan, South Africa and Australia attended the symposium. The three main topics of the symposium were Crop Physiology, Growing Techniques and Growing Media. The symposium also included a one day tour during which delegates visited several commercial hydroponic operations in the region surrounding Lima.

The symposium was attended by Dr Kaye Ferguson (SARDI), a key researcher involved in three HAL projects providing research into improving productivity within protected cropping systems (VG07144, VG08064 and VG05094). She was accompanied by Mr David Schofield, Stoller Australia Territory Manager for Victoria, NSW and Tasmania and Mr Brenton Frahm, sales Agronomist with Landmark.

Delegates of the International Symposium on Soilless Culture and Hydroponics held at the Universidad Nacional Agraria La Molina Lima, Peru on 25-28 August 2008.

RESULTS OF DISCUSSIONS

Presented at the Symposium was research on improving hydroponic systems to minimise inputs such as fertiliser and electricity and on developing more sustainable systems. Many papers compared effectiveness of various growing substrates on crop production and disease suppression.

- Dr Jiang Weijie (Chinese Academy of Agricultural Sciences, Beijing, China) presented information on the new systems "eco-organics" now being practiced by more than 60% of the soilless vegetable producers in China. There has been a huge increase in soilless vegetable production in China in the last 20 years, from 0.1ha in 1985 to 1650ha today. Initially based on the substrate and water culture systems learnt from Western countries, a research project initiated in 1996 began investigating soilless systems that were more suited to local conditions. They developed a system "eco-organics", based on floating capillary systems using organic fertilisers combined with irrigations with fresh water in place of nutrient solutions. Organic fertilisers account for 80-100% of the total fertilisers in the system, and growers decrease their initial investment by 60-80% because of reduced fertiliser costs. Research is also investigating using agricultural wastes such as sunflower stem, corn stem, sawdust, coir, rice husk and mushroom waste as alternative substrates to peat and rockwool.
- Three non-circulating methods for growing hydroponic lettuce were outlined by Dr Bernard Kratky (University of Hawaii, Hawaii, USA). The methods do not require pumps or electricity as plants roots are in constant contact with a stationary nutrient solution and are watered by capillary action. The nutrient solution is not topped up during the growth of the plant and so a moist air space develops as the solution level drops thereby ensuring the roots receive adequate nutrients, water and air. The crop is harvested before the nutrient solution is exhausted. Dr Kratky detailed several commercial systems operating in Hawaii that are based on this simple concept, with various methods of supporting the plants in the nutrient solution. The electrical conductivity (EC) is maintained at around 1.5mS and pH at 5.5-7. Mosquitoes breeding in the nutrient solution are a potential problem and research is currently underway into techniques that discourage development of mosquitoes in the system. Control measures for mosquitoes include salt-tolerant fish, *Bacillus thuringeinsis israelsis* toxins or pyrethrum based insecticides.
- E. van Os (WUR Greenhouse Horticulture, Wageningen, The Netherlands) presented the results of a study comparing non-chemical and chemical treatments for disinfecting nutrient solutions for small holdings of 1000-5000m^2 in closed hydroponic systems. While closed hydroponic systems have better water use efficiency and lower fertiliser costs than open systems, the risk of spreading soil-borne pathogens is greater. Thus the nutrient solution must be disinfected before being re-used, but this can be prohibitively expensive. Treatments investigated included non-chemical methods (heat, ultra-violet light, membrane filtration and slow-sand filtration) and chemical methods (ozone, hydrogen peroxide, sodium hypochlorite, chlorine dioxide, copper-silver ionisation and active carbon adsorption). If the 'kill' is the most important factor, then heat and UV treatment are the best options, however if cost is the most important factor, the best option is slow sand filtration.
- There are concerns in the US hydroponic vegetable industry about the sustainability of non-renewable resources currently used as growing media such as peat and perlite. Although renewable resources are a better option Mr Jonathon Franz (Agricultural Research Service USDA, Toledo Ohio) questioned whether those currently being used as growing media such as coir, switchgrass, rice husks and wood chips should be

relied upon, as they are essentially waste products from other industries. Mr Frantz outlined studies using two alternative products in floriculture growing media. FiberFill is a synthetic fibre made from recyclable polyethylene terephthalate (PET) and is itself recyclable. Tencel is a cellulose polymer (CP) produced from Eucalypt pulp. Several floriculture crops were grown in 100% FibreFill or 100% Tencel but with the exception of Begonia, these crops had lower yields than traditional media. Blending both the products with peat or coir improved yields but results were consistently better with FibreFill blends than with the equivalent Tencel blend. There were advantages and disadvantages with both products. PET has high aeration but low water holding capacity and still has some sustainability concerns. CP compresses when wet and can be colonised by fungi. Neither of the products can be poured into bags, as rockwool is, however CP is now available in a pelletised form. Mr Frantz speculated that Tencel would still be favoured by the floriculture industry over FibreFill as the industry is moving towards increased sustainability. As there is not yet a market for either product the economics are unclear but it is likely both would be more expensive than perlite.

- Dr Mike Nichols (Massey University, Palmerston North New Zealand) spoke about the increasing acceptance of coconut coir as growing media in New Zealand. Peat is now considered a limited resource and rockwool production has high-energy demands and high disposal costs both financially and environmentally. Coir is a mixture of different size fibres of the husk of the coconut and has excellent aeration and water holding characteristics. However many studies comparing coir to traditional growing media have failed to define the water and air holding capacities of the media. Dr Nichols suggests that grading coir for particle size, by sieving, and then appropriately mixing the different size grades could provide an opportunity to match particular grades of coir to particular crops. Thus the physical characteristics of the media would be optimised and crop productivity greatly improved. He also discussed the results of trials investigating zeolite amendments in perlite, coir, rockwool and sawdust media. Zeolites are naturally occurring minerals that have a high cation exchange capacity and good water holding capacity. At rates of 10 and 20% zeolite improved yield when added to sawdust and in some cases with perlite but the effects in coir were inconsistent. The type of media to which it was added strongly influenced the effect of the zeolite, and the mineral composition of the zeolite also strongly influenced crop production. The mechanism of the zeolite effect on crop yields requires further research.

- Dr Martin Moboko (Agricultural Research Council – Vegetable and Ornamental Plants, Pretoria, South Africa) presented his research on four tomato cultivars grown either in soil or in an open bag hydroponic system using sawdust as a media. Plants grown in the soilless system developed faster and had a higher percentage of marketable yield than plants grown in soil. The total soluble solids, measured in % Brix, were not influenced by growing system. Some cultivars performed better in the soilless growing system whereas there was no significant difference between cultivars grown in the soil. The results indicated that soilless culture could improve yield and quality of tomatoes but cultivar selection was also an important consideration.

- Mr Jeff Huber (University of Guelph, Guelph Canada) reported on the development of a system that incorporates a synthetic growth substrate with an internal irrigation system, called the Enviro-Grow System (EGS). The system is delivered in custom lengths for each greenhouse and because it is shipped in rolls that can be unrolled directly into the greenhouse, both shipping and installation is easier than with rockwool slabs. Large-scale trials were conducted in 2008 with cucumbers comparing the EGS with conventional rockwool production. The crop grown in the EGS showed a significantly higher relative growth rate compared to the rockwool crop resulting in higher yields and an earlier harvest date (1 day).

- Dr Beth Fausey (Ohio State University Extension Agricultural, Bowling Green Ohio) outlined the services offered to growers by the Ohio Hydroponics Crop Research and Extension Program (OHCP). The OHCP provides technical, cultural and marketing support to help small and medium sized producers remain competitive in the market place. Research and extension aims to maximize crop growth and yield of high-value locally grown hydroponic crops. Recent tools made available to growers include a water quality assessment package, diagnostic tools for nutrient imbalances in hydroponic lettuce and environmental sensors to examine the effect of greenhouse climate conditions on crop growth and yield. Monthly newsletters, fact sheets and educational bulletins are produced regularly by the OHCP. A demonstration greenhouse has been designed to illustrate hydroponic production techniques, conduct yield comparisons and examine alternative crops for hydroponic production.
- Research in Italy and Brazil has investigated the use of saline water for hydroponics, showing high potential for using saline water on lettuce and endive, with the crop cycle being shorter with an earlier crop maturity. Desalination waste water was effectively used for NFT hydroponic cultivation of tomato, known to have a higher salt tolerance than many other crops. While crop yield was reduced at the 6 and 9 dS/m rates, the anti oxidant properties of the tomatoes were improved.
- Spanish researchers have shown that by substituting N-nitrate with N-ammonium the yield and nutritional value of greens was improved, reducing the leaf content of nitrates and oxalates which can be harmful to human health. Work in Mexico has also shown that using a 20/80 Ammonia to Nitrate Nitrogen mixed increased basil production, but not dill or chives. Work from the Netherlands showed the effect of Ammonium was variable, and most likely a result of the Ammonia reducing the pH in the roots, increasing nutrient uptake.
- Franz Schroeder and his researchers from University of Applied Sciences, Dresden Germany gave a great presentation on the use of hydroponics in Urban areas. Basket units were hung on the outside of high rise building to cool the buildings (they found cities are 3 to 4 degrees warmer than the rural areas). However the plants were also cleaning toxic pollutants from the city air as well as used for food.

The technical tour began with a walk through of the hydroponics research centre at the Universidad Nacional Agraria La Molina where research is being conducted into hydroponic production of lettuces in NFT and raft systems, strawberries in NFT and column systems, tomatoes in bags and radishes and spinach in boxes with sand as a media. The tour then visited Commercial hydroponic operations.

- Invernaderos Hidroponics del Peru S.A., located 35km south of Lima in the district of Pachacamac, currently has 8 greenhouses and plans to expand to a further 13 greenhouses in the near future. The company produces lettuce, spinach, chards, tomatoes, capsicums, eggplants, cucumbers and French beans in an open hydroponic system with a sand substrate. Sticky traps were used throughout the inside and the perimeter of all greenhouses and hygiene was a major priority on the property. Contamination with run-off is becoming an issue, so they are considering changing to a closed system. Produce is sold directly to the biggest supermarket chain in Lima (Wong) and they also export lettuce to the USA.

(L) *Floating rafts of hydroponic lettuces grown next to hydroponic tomato crop, ensuring good use of the whole area.* ***(R)*** *Sticky traps on outside of greenhouse.*

- Landa produce a small family company situated 87km south of Lima in the district of Mala, producing hydroponic lettuces using a floating raft system in $0.5m^2$ plastic-lined wooden boxes. Water is purchased from a bore that has an EC of 1mS, and this is shandied with better quality water from the mountains. Fertiliser is their biggest expense, as the nutrient solution supplied to the lettuces is only used once. Depending on the temperature there is usually about 25% of the nutrient solution left in the box at the end of the crop. Wastewater is used on the garden or given to their neighbours. The only labour required was to lower the planting tray as the water level falls. They aim to produce 12 crops each year, sold to a local supermarket labelled 'hydroponic', which gives a market advantage as consumers are uncertain about what has been applied to field grown lettuces. The family raises their own seedlings in peat.

Hydroponic lettuce growing in a raft system on plastic lines wooded boxes ***(L)*** *at the research centre, and* ***(R)*** *at Landa Produce.*

- Machu Picchu Cuy is located 67km south of Lima in the district of Chilca. The company produces guinea pigs that are a traditional food in the highlands of Peru. There are currently 7000 animals on the property that are fed daily with cereal sprouts produced via a hydroponic green forage (HGF) method. HGF has a digestibility of 85-90% and allows the production of contaminant free food with greatly increased production per unit of land compared to conventional broad-acre cropping. HGF is also more water and labour efficient, and is completely soilless. Grown entirely on-site and takes approximately 12 days from sowing to when it is ready to be fed to the guinea pigs, supplemented with a pelleted food source.

(L) *Hydroponic green forage (HGF) in production towers.* ***(R)*** *Guinea pigs in pens with HGF and pelleted food sources.*

IMPLICATIONS FOR AUSTRALIAN HORTICULTURE

- The New Zealand research into using coconut coir is of particular relevance to Australian growers, as the suppliers of cocopeat (coir) slabs to Australia and New Zealand are the same and they vary greatly in cost and in quality. Larger growers who have used coir for several years are able to order their own grades for different crops, however smaller producers who are just starting out in hydroponics do not have the knowledge or experience to request specific grades. Many growers are driven by price alone and purchase cheaper sub-standard slabs that often don't expand properly or perform inconsistently across the greenhouse. This results in a negative experience with what could otherwise be an economical and effective growing media.
- The use of closed systems and options for disinfection of the nutrient solution is particularly relevant to Australian systems because we have limited water availability and many low technology producers in small holdings. Future changes in legislation may also mean that growers will be legally required to capture and re-use run-off water from their properties.
- As well as food for humans, the use of hydroponics for growing stock food has potential for development in Australia for drought feeding of animals, and to clean up and beautify urban landscapes. Both these areas of use should be investigated within Australian conditions and situations.
- The contact with researchers in hydroponic systems will benefit current and future HAL projects in protected cropping. For example Dr Martin Maboko (Agricultural Research Council – Vegetable and Ornamental Plants, Pretoria, South Africa) is involved in a project that is very similar to the HAL project VG07144, helping growers to transition from soil to hydroponic growing. There are many similarities between Australia and South Africa in terms of climate and greenhouse technology levels.
- Exposure of tour members to the research and production techniques used in other countries has provided benefit for local growers. As Mr Brenton Frahm explained: "The trip was rewarding and interesting - to see the culture of other countries and the way horticulture was progressing. The International Symposium On Soilless Culture and Hydroponics in Lima, Peru was the highlight of the whole trip as it triggered me to look at the food chain and lack of water available to produce the food for the future population. We visited some properties to see lettuce growing in boxes without running water and it was very successful. I have adopted some of this and set up some trial plots with Lettuce, Tomatoes, Capsicum, Strawberries and Cucumbers. One of these I have displayed in our Landmark store in Mildura." David Scholfield had determined that six lettuces could be grown in a polystyrene box with 25gms *Nitrophoska*™ type fertiliser. "Hydroponics has great application in Australia with our water shortages and nutrient runoff and disposal problems. The world will have to move to soilless and hydroponic food culture to save precious water and nutrient reserves, but also to manage the reduction in land suitable for intensive agriculture. Before going to Peru I thought the world would be able to grow enough food for the world's population. However in countries like Peru, with poor soils, limited water and no foreign reserves to import food, hydroponics has to be the answer. We need to communicate what we have learnt and encourage growers, researchers and venture capitalists to attend further Symposiums of this type".

(Top L) Plants grown in simple hydroponic demonstration system. **(Top R)** Plants in pots are placed in holes in the lid of a foam box. **(Bottom R)** The pots are suspended through the lid and sit in the nutrient solution **(Bottom L)** in the base of the foam box

GREENHOUSE PRODUCTION AREA – ALMERIA, SPAIN.

Almeria, Spain, has approximately 30000 hectares of greenhouse vegetable production. The production is mainly concentrated southwest of Almeria with another smaller region located east of Almeria (Figure 6). The main crops grown are capsicums, cucumbers, melons, tomatoes and zucchinis. In comparison there is only around 1600 hectares of greenhouse vegetable production in Australia. The greenhouse owners in the Almeria region are mainly Spanish with some foreign partners. Some growers rent the land, but the majority own the land on which they grow.

Google map of greenhouses in the Almeria area, south eastern Spain.

A group consisting of two SARDI staff (Mrs Hall and Dr Kaye Ferguson) and two Industry representatives (Domenic Cavallaro, Technical Manager with Stoller Australia, and Andrew Meurant, National Horticulture and Forestry Business Development Manager with Elders Pty Ltd) took part in the tour. A representative from Stoller Iberica (Mr Thierry Ruiz), and Seminis seed company (Mr Leonardo Velasco) acted as hosts.

RESULTS OF DISCUSSIONS

Almeria has a Mediterranean climate similar to Adelaide, and most of the greenhouses are low technology, which made it an ideal area to visit to gain information pertinent to local production. As well as commercial greenhouses, visits were made to vegetable industry resellers, a nursery, the seed production facility of Seminis and to researchers with the Junta (local Department of Agriculture). Much of the industry in Almeria is related to the greenhouses, as they are the main industry in the regions. There are about 20 – 25 nurseries servicing the growers in Almeria, 3 of them high technology and automated, and at least 5 plastic producing and recycling factories.

Eight greenhouses were visited, both in soil and hydroponics, growing either capsicum (peppers) or tomatoes. Tomatoes are generally grown to the east of Almeria, where the water is poor and usually high in salt. In the main area west of Almeria, water is good quality and plentiful, so less salt tolerant crops are grown, including capsicums, eggplants and melons. Water is sourced from underground aquifers that are fed by streams in the mountains to the north. Legislation dictates that all growers must capture, store and use rainfall on their properties but not all growers comply with the legislation.

Unlike a lot of the greenhouse vegetable growing regions in Australia, the greenhouses in the Almeria region are very close together and there is little surrounding vegetation. Old crops cannot be left lying around in piles, and must be composted. The local government regulates greenhouse hygiene and growers can be fined for not complying, with local inspectors who regulate the cleanliness of properties. This means there is little reservoir for insect pests or diseases to harbour or build up in numbers.

There is no organised grower training for new or existing growers, only training in specifics such as chemical application or IPM. A lot of information is shared between growers but mostly in an informal way.

Greenhouse production – capsicum, melon

Greenhouse structures

The vast majority of greenhouses in the Almeria region are of very simple construction with wooden or steel posts and wire mesh and plastic coverings. The greenhouses are meant to be completely enclosed and insect meshed, with holes in the plastic being immediately fixed, however not all growers comply. Heating is not common but the majority of greenhouses had venting in the roof. Several of the greenhouses visited had maximum/minimum thermometers measuring temperature. The average grower has around 10000m^2 of greenhouses, in a single block or in several blocks. Growers construct a house with a roof as high as they can afford because a higher roof makes it easier to regulate the climate inside the house**.** Set-up costs for a greenhouse structure are around 8EUR/m^2. All-inclusive cost with irrigation, plants etc would be around 27EUR/m^2.

The local government regulations also state there must be no holes in the greenhouse plastic and all greenhouses must have double-door entry ways.

(L) *Greenhouse structure with capsicum.* ***(R)*** *Roof venting with insect mesh.*

Soil & crop management

Typically coarse sand from nearby quarries is brought into greenhouses and laid over the top of the natural soil. In some properties a layer of compost is placed over the natural soil before the sand is laid. One of the local manufacturers supplies compost from plant waste with micronutrients and *Trichoderma* added during the composting process. Because of the hygiene requirements, old crops are trucked to the local company for composting. Growers pay for all transport costs but receive a 50% discount on any compost they buy from the company. The gravel on top of the natural soil acts as mulch, decreasing evaporation during summer and retaining heat during winter and also reducing weeds and soil diseases.

The sand is then used as a growing media for crop production and is either irrigated constantly with a nutrient solution or intermittently with fresh water and then fertigation. In some greenhouses close to the coast the sandy soil is very shallow (10-15mm) on top of clay (15mm) on top of sea sand or rock. If the profile is soil/clay/sand then the irrigation will drain away but if it is soil/clay/rock then the grower has to rip the rock to improve drainage.

(L) *Capsicum crop growing in sand (gravel) over soil.* ***(R)*** *Close up of sand over soil;*

The typical growing schedule is a capsicum crop planted at the end of July and will be grown through until February. A short crop of melon will follow and then solarisation of the soil from May to July. Where soilborne issues are less of a concern, the old stems of the previous crop are left in the ground and the new crop planted alongside.

Less typically, plants were grown in perlite slab bags on top of the sand layer. However these had been split at the base to allow roots to move through into the base layer of either soil or compost. The whole mound was covered with black plastic. Perlite is siliceous volcanic rock that is heated to around 980°C until it expands to small sponge-like particles. It is used as a hydroponic substrate in closed systems, but does not have a high water holding capacity so takes experience to manage plants in this system. Cutting the base of the slabs and letting the roots go through gives the plants access to a greater reserve of water to guard against water stress or waterlogging. Where compost is layered under the bags, extra nutrients can be accessed, reducing the need for fertigation.

Perlite slabs on top of compost mound covered with black plastic, growing capsicum

(L) *Hydroponic cucumber crop in perlite slabs on sand (gravel) base;* ***(R)*** *Perlite slabs showing slits in base with roots.*

The lack of root diseases and minimal salt accumulation allows growers to reuse slabs repeatedly. *Trichoderma* is applied through the drippers every 30-45 days.

Around 20% of growers produce vegetables using a hydroponic system in artificial media. Many growers in the region set up hydroponic growing with the help of local consultants. Some growers stopped using consultants once their system was established and then ran into problems because they no longer had outside expertise and advice. Salt problems can occur when the greenhouses are converted back to "in soil" growing, with some areas having accumulated salt from the previous hydroponic crops causing plant stunting. Irrigation with water only is slowly cleaning the soil.

Irrigation

About 50% of growers use some kind of soil moisture monitoring equipment to schedule irrigations, others irrigate on time. Early in the life of the crop irrigations are scheduled every 3-4 days, as the crop grows irrigation is increased to every second day. Water can be sourced from underground, fed by streams from the Sierra Nevada Mountains. Some properties share bores, which can be up to 1500m deep. The cost of water is 0.12-0.18 EUR/m^3.

IPM in greenhouses

At least 50% of the growers are part of co-operatives that export produce and have no tolerance for residues. The other 50% sell produce to local markets where regulations are more lax but residues are still not tolerated. Residue testing is done by the co-operatives and also at the destination market. Due to previous issues with insecticide residues detected in Germany, the local government (Junta de Andalucía) encourages the use of biological controls for insects and gives subsidies to growers who practice integrated pest management (IPM) and maintain their residues below the required levels. There are approximately six different companies that produce biocontrol agents for Spanish greenhouses. The majority of growers in the Almeria region now practice IPM and growers only use insecticides in the first 20 days of the crop before IPM commences, and only use insecticides that are compatible with IPM. The legislation that requires growers to keep their premises free of weeds and crop debris, contributes to the success of the IPM, as there are limited alternative habitats for the pests.

The primary pests in the region are western flower thrips (WFT) *Frankliniella occidentalis* and silver leaf whitefly (SLWF) *Bemisia tabaci*. The two most common biological control agents that are released are 'Swirski', *Amblyseius swirskii,* a predatory mite that predates on both WFT and SLWF, and 'Orius', *Orius laevigatus*, a sucking insect that predates on WFT.

Biological control agents used for integrated pest management of western flower thrips and silver leaf whitefly in greenhouses in Almeria region, Spain. ***(L)*** *Orius (*<u>Orius laevigatus</u>*);* ***(R)*** *Swirski (*<u>Amblyseius swirskii</u>*).*

Biocontrol agents are released 21 days after seedlings are transplanted. Orius is delivered in a bottle and released in boxes with approximately 50/box at a spacing of six metres between boxes. Swirski is released in pre-packaged bags each containing 125 insects that are hung on the strings or on plants every six plants to give a density of approximately 75 insects/m^2. The insects move along rows via the strings but do not move between rows. The cost for IPM is 3300EUR/ha/year and without the subsidies offered by the local government, growers would not be able to afford to practice IPM. With the subsidy, the cost is comparable to conventional chemical control. Yellow and blue sticky traps are used outside and inside the greenhouse. In some greenhouses, overhead sprinklers are used to increase the relative humidity to favour the establishment of the biocontrol agents. The sprinklers are only positioned over the walkways, not over the crop to reduce the risk of foliar diseases.

Virus affected plants are generally rogued as soon as symptoms are seen to minimise spread. The main viruses are Tomato Spotted Wilt Virus (TSWV) or 'el spotted' to the locals, and Tomato Yellow Leaf Curl (TYLC) virus (spoon virus to the locals) and pepino mosaic virus.

Soilborne diseases are managed by fumigation when required, and solarisation for 1-2 months over summer, which has the added benefit of reducing weeds. *Fusarium*, *Phytophthora* and nematodes are the main reasons for fumigation. There is concern that both fumigants will be withdrawn from use within the next 2 years. *Trichoderma* is applied regularly (every 2-3 weeks) through the drippers. Aliette® (fosetyl-al) is applied through the drippers for *Phytophthora*.

Like Australia, the main foliar fungal diseases are powdery mildew and *Botrytis cinerea* (grey mould). Spraying is done either by the grower or by outside contractors and all is done by hand. To spray 8000m^2 takes approximately 3 hours. Where downy mildew is an issue, growers use Aliette® (fosetyl-al) and mancozeb.

(L) *Spray wand used for crop spraying, inset: 2 spray nozzles;*
(R) *Local consultant Javier with Thierry Ruiz (Stoller), Barbara Hall (SARDI), Domenic Cavallaro (Stoller) and Andrew Meurant (Elders).*

A range of control measures are used for powdery mildew, from tolerant varieties to fungicides. Fungicides such as Bayfidan® (triadimenol) are used widely and there is some evidence of resistance developing in the triazole fungicide group (Group C). Sulphur is also used, and phosphite is applied through the drippers. Most growers are aware of the necessity to rotate fungicides to avoid problems with resistance.

Where *B. cinerea* is a problem, pruning wounds are treated with copper fungicides. With flower infection occurs, Switch® (cyprodinil + fludioxinil) or Bravo® (chlorothalonil) is applied. A microbiological product called Bioclean® is also used for *Botrytis*.

Greenhouse production - tomatoes

The area east of Almeria is traditionally a tomato growing area, as the water quality in this region is not as good and tomato are more tolerant of salinity than cucurbit or capsicum crops.

Greenhouse structures

The greenhouse structures are similar to the other areas, and comply with the double doors, hygiene and no holes requirements.

Soil & crop management

The greenhouse visited had deep sand bought in to level the ground and the majority of the tomato crop was being grown using the sand as a media, in the system typical of the Almeria region. The grower stressed the importance of ensuring that the sand has the desired physical characteristics, like correct particle size and water holding capacity. Some of his was of poor quality and didn't retain moisture well, so was using perlite slabs with the base cut for root extrusion.

The grower had experimented with planting densities and found that at lower density he could achieve the same yields with less disease problems, higher quality and lower costs.

Irrigation
The area uses recycled mains water from Almeria and some underground water. The crop is irrigated with a hydroponic nutrient solution mixed from five 1000L fertigation tanks. There is one tank for each of the calcium, potassium and phosphorous salts, one for everything else including the micronutrients, and one for the nitric acid that is used to control the pH of the solution.

IPM in greenhouses
Biological products are used widely throughout the tomato greenhouses to manage insects. WFT can sometimes become a problem in spring towards the end of the tomato crop, when conditions are more favourable, but there are less issues at the beginning of the season.

Virus infected plants (mostly TSWV and TYLC) occur, and plants are rogued when symptoms are observed. The white fly is worst in Sept – October, but managed with biological controls. The tomato leaf miner (*Tuta absoluta*) is a microlepidoptera that causes yield losses by feeding on leaves, fruits, flowers, buds and stems of solanaceous crops. It has only recently been detected, and is becoming an increasing problem in the Almeria region. Pheromone traps are used to trap the moths.

The main foliar disease is again powdery mildew. However in the last few years leaf mould (*Cladosporium fulvum*) has become an increasing problem, particularly when the ventilation was inadequate and there was high relative humidity. It is difficult to manage in these situations. *Botrytis* was only a problem at higher planting densities.

Of the soilborne pathogens, *Fusarium* can be a major problem in tomatoes. Seedlings are grafted onto a tomato rootstock that has resistance to *Fusarium radicii*, *F. oxysporum* sp. *lycopersici* and nematodes. The majority of growers use these grafted transplants, even though they are more expensive (Grafted transplants cost around 0.76EUR each, transplants on their own roots cost 0.28EUR each). Even when *Fusarium* is not a problem, growers will use grafted seedlings as it can improve production. *Trichoderma* is also applied through the drippers. *Pythium* problems can occur in transplants, and Previcur® (propamocarb) is used.

There is a permanent line in the greenhouse used for spraying the crop. The spray wand can be attached at various points throughout the greenhouse.

(L) *Tomato crop in sand*
(R) *Hydroponic tomato crop in perlite bag*

Research Institute, Junta de Andalucía

Each province in Spain has a research institute funded by the local government and dedicated to research in the particular crops of that province. The main agricultural industries in Andalucía are greenhouse vegetables and olives. Research is also funded by the national government and private companies. The European Union (EU) has identified Andalucía as a suppressed region and so has access to several different sources of funding.

The visit to the research institute provided an overall picture of the Almeria region and good information to add to that acquired from the growers' visits. While the Junta legislates for hygiene, weed free, entire greenhouses without holes, only the better growers comply on a regular basis. Currently some growers are struggling with input costs, and labour is difficult to obtain. The Moroccan industry is enlarging, and can provide a good product at a lower price, so the market is reducing. However as the greenhouse industry is sustaining the whole district, the growers have significant political power, so government assistance is usually forthcoming when issues arise. Hence the assistance with IPM compliance.

Diagnostic services are also provided free by the Junta, but extension activities are generally managed by the co-operative technicians. Many of these are young and inexperienced, as the co-operatives do not always pay good wages. The technicians get their information from the internet or the Junta experts. The growers talk to either these technicians, or direct to the seed company rather than coming to the Junta themselves. One downside of this is that when growers have a disease issue, their first contact is often with the seed company representative. The seed company may then identify the problem, but without advising the Junta. So new diseases or issues sometimes occur in the district without the local Junta pathologists being aware.

Plant Diseases

The plant pathologist (Dr Dirk Janssen) explained that the main disease problems in the greenhouse are viruses: TSWV vectored by WFT; cucurbit yellow stunting disorder (CYSDV) and cucumber vein yellowing (CVY) in cucumbers, both vectored by whitefly; TYLC and turnip crinkle virus (TCV) in tomatoes vectored by whitefly and pepino mosaic virus which is spread by contact transmission. The EU initiated the adoption of IPM two years ago and it is now mainstream in the Almeria region, assisted by the Junta. The EU also directs the use of fungicides, which are followed by the main exporters.

Soil diseases are not a big problem in Almeria because water is mainly sourced from underground not from rivers or dams. Pathogens like *Fusarium* and *Verticillium* aren't resident in the soil but may be brought in with sand that is laid in greenhouses.

Other regions in Spain such as Granada have a more classical geology and river or canal irrigation and therefore more problems with soil diseases. The greenhouse production areas further up the coast near Murcia also have more disease issues than Almeria, with soil borne diseases like *Fusarium* and more severe virus infection, as they grow tomato crops continuously with no rotation.

Solarisation

Solarisation works well in the greenhouses, as 'soil' is essentially artificial, over a bed of rock. Only about 5% of growers use solarisation effectively. Most use it in combination with metham sodium, and only when they have an issue with soilborne diseases. Telone C35 has been tried, but results are not reliable. However many growers don't always correctly diagnose the cause of the problem and also only solarise for up to 45 days, when 60 days is needed. Julio, the soil pathologist at the research institute has worked on soil solarisation for 20 years. He is now investigating biofumigation, which is increasing the organic matter in the sand. He has investigated the use of *Trichoderma* also, and it can delay the onset of *Fusarium* infection by at least 10 days. Composting has been used to manage disease also.

Hydroponic systems

Approximately 20% of the growers in the Almeria grow hydroponically with the main growing media being perlite and rockwool, which cost about the same. Around 2% of growers use cocopeat for capsicum crops. Growers are converting to hydroponics mainly because of the economic advantages, it is cheaper to use slabs of growing media than to pay for labour to come and replace the sand. The hydroponics expert (Dr Pilar Lorenzo) said that cutting the bags to let the roots grow through is not common; normally the roots would stay confined in the bags. With the good clean water that is available in the area, hydroponic growers generally have no soil disease problems. The hydroponic growers tend to be more technologically advanced than those growing in-soil, some systems are fully automated, others still have manual control. Some systems are closed (recirculating) but it is more common to have an open system because there is ample good quality water.

Hydroponic research

Research funded by the national government is investigating irrigation scheduling by measuring weight loss from the plants. As there is no evaporation in the completely closed system being tested, weight loss directly reflects transpiration. Measurements of relative humidity, temperature, vapour pressure deficit, radiation and foliar leaf area are related to transpiration with the aim of developing an equation to automatically schedule irrigations. This would be a significant advancement on the current scheduling systems which use measurements of accumulated radiation or run-off. It would take into account so many more parameters that affect the irrigation requirements of a crop. The system had already been trialled in cucumber and tomato crops at the research institute.

Seminis seed company

Leonardo Velasco, the pathologist from Seminis seed company, showed the group the greenhouse facility where new varieties are screened for resistance, particularly to virus. Different methods of inoculation are used, usually mechanical or insect vectored.

(L) *Greenhouse with movable sun shade at Junta Research Station.*
(R) *Cucumber virus resistance screening at Seminis*

IMPLICATIONS FOR AUSTRALIAN HORTICULTURE

- Many of the positive aspects of the Almerian system, such as the greenhouse design, including ventilation and double-door entry, greenhouse hygiene and area-wide IPM and the variety of biocontrol agents currently used, could be readily adopted into Australian low technology systems with benefits for crop health and crop safety.
- Results of research being undertaken in Almeria into improving the efficiency of irrigation scheduling in greenhouse vegetable crops, and management of soilborne diseases could prove extremely beneficial to Australian growers, and contact will be maintained to obtain the latest results.
- Greenhouse growers from South Australia would benefit from visiting the Almeria regions, and Mr Thierry Ruiz (Stoller Iberica) and Leonardo Velasco (Seminis seeds) have both agreed to assist a grower group tour that is planned for Spain and the Netherlands in 2009-10.
- A study tour to be organised by SARDI researchers in conjunction with commercial partners such as seed and chemical companies for 8-10 greenhouse vegetable growers to go to Spain and the Netherlands to visit hydroponic greenhouse properties and undertake specialist training courses available at PTC+ in the Netherlands. Proposals to source funding to subsidise the cost of the tour to be submitted to HAL and other potential funding sources to be investigated e.g. FarmBiz.
- Attendance of Industry representatives was beneficial in having the information distilled directly to the growers, as well as into research projects. Mr Andrew Meurant has indicated the benefits to him and his clients:
    - The visit to Almeria gave me an appreciation of another industry with similar practices to our covered vegetable production. The size of the industry was significant, with 35,000 Ha of greenhouse in the Almeria region and hearing that the Morocco industry is kicking off as well.
        - individual growers who are too small to do their own marketing, sell through co-ops or private companies who also sell them the chemicals
        - old greenhouse plastic goes to recycling factory to make black plastic
        - plant / crop residue recycled into a reusable green mulch
        - The size of the industry allows for a critical mass to support suppliers and products such as the beneficial insect ranges from Koppert and Syngenta Bioline.
    - Competitive advantages and disadvantages over Australia:
        - Utilising their 3,000 hours of sunlight with practises such as solarisation
        - Cheap and plentiful labour from Africa
        - Relative closeness to the EU markets
        - Strong demographic and source of farmers and industry professionals
        - A looming EU requirement for zero residue tolerance on produce
    - Potential new products for Australia:
        - Syngenta Bioline range - Suppliers of bumblebees for crop pollination, beneficial insects, mites and monitoring systems for Integrated Crop Management 'ICM' programmes
        - Koppert range - pollination systems and integrated pest management for protected and high-value crops

- Potential new or improved practises:
    - Exceptional hygiene with their greenhouse production
    - Recycling plastic and green waste systems
    - monitoring and enforcement of hygiene practices by government
    - Insect exclusion mesh and double door entry with extensive use of sticky traps
    - Specialist commercial consultants in IPM

Mr Domenic Cavallaro (Stoller Australia) found the aspects of most relevance to Australia that should be adopted and encouraged were the use of IPM, hygiene the simple production techniques that were so effective.

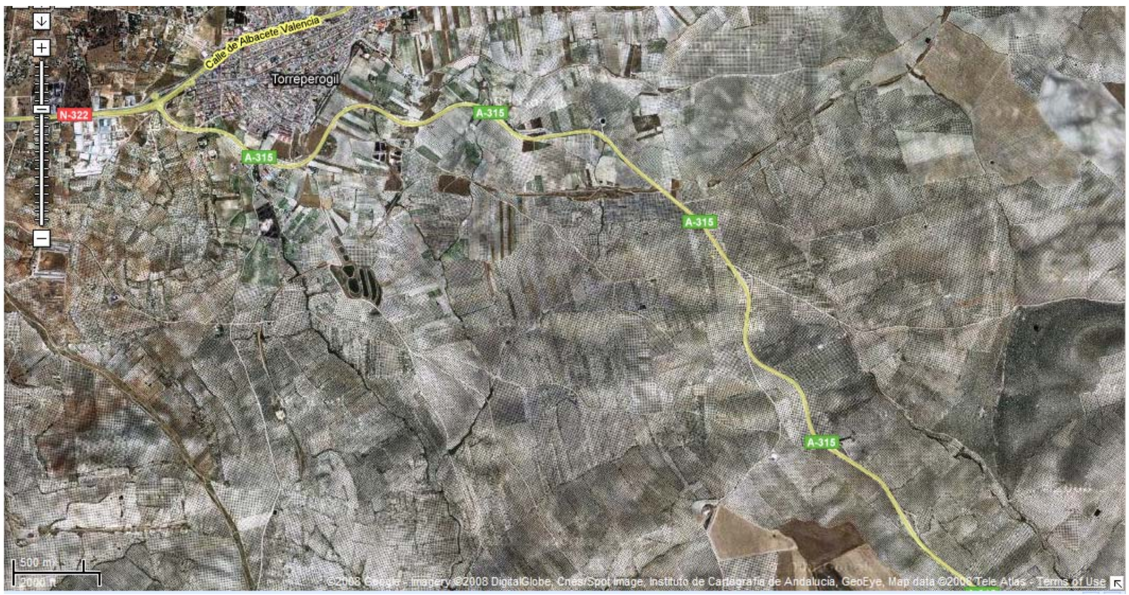
- It was interesting to note that with capsicum production there was a high emphasis on IPM. The change agent for this was the detection of chemical residue in produce found the previous season in the EU market which almost crippled the industry. In 12 to 18 months the industry has not only adopted IPM but has had a strong support from aliened industries and the local Junta.
- It was noted that other crops such as tomatoes and cucumbers did not necessarily use IPM but it was expected that adoption would follow.
- IPM cost was in the order of $3,000E per hectare of greenhouse which was subsidised by the local Junta. It appears that once the scale of economies was established that this cost would reduce and the need for the local Junta to subsidise would be reduced.
- Most greenhouse sites were approximately 1 hectare in size. Families made a good living with the vertical integration that was apparent from the seed company to the cooperative pack house and selling agent.
- Hygiene was very impressive around the greenhouse with crop residues composted by contractors and reused into the greenhouse production system and weed control around the greenhouse kept to a minimum. This cleanliness is enforced and supported by the local Junta. The support by local and national government was impressive and a key to the long term survival of this horticultural industry.
- Production of greenhouse crops was based on a simple hydroponic system of various forms. It gave the group an appreciation of how simple systems can work and why this industry is a threat to the intensive hydroponic systems found elsewhere around Europe.

OLIVE PRODUCTION AREA – UBEDA, SPAIN.

Following the greenhouse production visits, the group met with olive researchers in Ubeda and Cordoba, hosted by Dr Juan M. Caballero and Dr. Javier Hidalgo, researchers with the Junta of Andalucía.

RESULTS OF DISCUSSIONS

There are approximately 650,000 Ha of olives in the Ubeda area, with 1.5mHa in Andalucía, 2.5mHa in Spain. Australia has approximately 40,000 Ha. The majority of trees are cv. Picual. Over 50% of the trees in Spain are over 100 years old, commonly old plantations are 70-80 trees/Ha with 3-4 trunks per tree. The oldest tree in the Ubeda area is 1000yo. Nearly all trees are irrigated. Irrigation of olives started about 30 years ago and areas previously cropped or grazed are gradually being planted. The average rainfall is 500mm p.a., mainly in winter (Sept/Oct to March/April). Fruit for oil are harvested in late autumn (Oct/Nov), when the fruit are a good size but still green. Table olives are harvested up to 2 months earlier.



Google map of Torreperogil area, east of Ubeda, Spain. The area in the centre and right of the map is all olive trees. The smaller oblong patches close to the town are vegetables, cotton and other crops.

Irrigation scheme

In the Torreperogil district east of Ubeda, a community irrigation scheme provides water for ~150,000 ha of olives. There are many schemes like this, as it is difficult and expensive for growers to manage their own irrigation with the relatively small acreage. Water is drawn either from the river (Rio Guadalimar or a tributary) or underground.

Bores are 600-700m deep, with water from 380m. The water from underground is hot and sulphuric, and every couple of weeks causes issues with pumps. If not rapidly fixed, this will often mean no water for irrigations and trees become deficient. The hot water is pumped into pools to cool and treated with an oxygenation device to eliminate the sulphuric. The aquifer is not well managed and over exploited, in the last 5 years the water level has dropped 70m.

Water can only be pumped from the river in winter, to a maximum of 1500m3/Ha. It is stored in dams for later use. The river is fed by mountains, both snow and rainfall. If there are good flows, they are allowed to pump extra in summer (an extra 600m3/Ha has been allowed this year). The river is approx 300m below the village, but intake for pumps is 5Km away. River water is alkaline, so have to add acid to increase pH. The dams hold ~0,5cubic hectometres, and are used for settling sediment.

The irrigation community is managed by a council of 4-5 elected growers and they decide when and how much to water, and how much fertiliser to add to the water before distribution. A technician is employed to ensure the watering orders are carried out and advises and monitors irrigation. Each grower is allocated water based on their tree number.

Watering over summer on drippers is constant, assuming there is enough water. When water is scarce, they only water at the critical times for irrigation – blooming and maturation. Currently there are trials comparing 700m^3/Ha/year applied only at blooming and maturation vs 1500 m^3/Ha/year constant irrigation. After 2 years, they have found there is similar production. Most schemes are trying to become more water efficient, as more trees are being planted with no increase in water availability.

Reduced irrigation is also encouraging deeper root growth. The root system of olives is generally very shallow under irrigation (less than 1m), depending on the soil type, rainfall and irrigation.


*Olives near Torreperogil **(L)** and Ubeda **(R)**, planted following the contours of the hills.*


(L) *Holding dam for water pumped from river.* ***(R)*** *Irrigation pumping shed.*


Summer pruning of suckers.

Olive plantation

The plantation visited was typical of many in the area, with several ages of trees. The main area was a traditional orchard, with 60 yo. trees cv. Picual, considered to be self pollinating. Planting followed the contour of the land, planted on mounds to reduce effect of winter waterlogging, and there were significant problems with erosion. The density was 140trees/ha, twice the normal because of the land contours. The expected yield for these trees was 70Kg/tree, and the average for property from the Picual was 10,000 Kg/Ha with 2000 Kg oil/Ha.

Winter pruning is usual, with summer pruning to remove suckers. Prunings are either used as landfill to protect against erosion from run-off, or as mulch in centre of rows. Prunings were traditionally burnt, but is now banned by the authorities. However they will still burn prunings from *Verticillium* affected trees to prevent spread.

They trees are harvested with mechanical trunk shaker, which usually removes 70-80% of fruit. By applying ammonium phosphate as chemical absciser agent 1-10 days before harvest they can increase the removal efficiency to 85-95%. The chemical is applied as a foliar spray, but good coverage is essential.

A newer planting of 400 trees, 20yo. Arbequina, yields 13-14,000 Kg/Ha. This variety is not common in this areas, but they get more money per Kg. The management is same for the Picual, but the harvest shaking is less stressful on the trees. Some orchards use high density plantings, but this loses production from the lower part of the tree, as the trees are smaller and the management more difficult. It is considered by some to be less sustainable, particularly as water becomes scarcer.

Another area of 30year old trees had mixed cultivars of Hojiblanca and Picual. They yield 9,000Kg/Ha with same level of water as the Arbequina. However the trees have become water stressed as they had used all their water allocation too early and fruit has shrivelled. They were expecting rains in next 2-3 weeks, after which the fruit will recover but oil quality will be poor. Trees killed by *Verticillium* are replanted with tolerant varieties, usually Frantoio.

The interrow is cropped or mulched with prunings, and the area under the trees is treated with herbicide to maintain bare earth. The usual herbicides used are terbutilazine & Diuron, applied in winter. Residual herbicides were used in the past, but are now banned.

Pest & Disease management

There are three systems of pest and disease management in Spain– traditional, organic and integrated. Each has its own set of regulations about chemical application. Many of the properties are "integrated". Certain rules are enforced by authorities, and growers have to keep management diaries of pesticides and fertilisers with good records to ensure traceability of product. This sometimes gives a market advantage, not often more money but more quality: seen as "politically correct" oil and labelled to suit.

The main foliar disease is peacock spot. The usual treatment is copper in spring and summer, but they are looking for other options as copper is becoming expensive and there is still a suggestion it may be banned. The biggest disease problem is *Verticillium*, which has significantly increased over the last 30 years as new land is planted. Olives traditionally were grown in the hills with cotton and other crops in the valleys. However olives are now grown in valleys on old cotton ground. There is also a suspicion that nurseries have used infected soil for seedlings.

Olive fly is not normally a problem in this area and they do get bud mite on some leaves, but it only becomes a problem if it gets onto fruit.

(L) *Tree dying with Verticillium.* ***(R)*** *Young trees on hillside killed by frost.*

Research station, Cordoba

Olive breeders (Raul de la Rosa, Lorenzo Leon and Angjelina Belaj) at the Centro "Alameda del Obispo" owned by the Junta of Andalucía, maintain a germplasm collection at the research station and are currently working on breeding olives with resistance to drought and *Verticillium*.

The breeding program is also aimed at providing more productive cultivars, and developing dwarf cultivars for high density production. They propagate by rooting and grafting, using Arbequina rootstock. A new cultivar has recently been released, a dwarfed variety for hedgerow close planting. Called Chiquitita, it is a cross between Picual and Arbequina. They commenced the breeding program for this cultivar in 1994 and it has taken 16 years to release.

They have also developed a drought resistant variety – Lechin de Granada, which is grown near Almeria. Wild olives were found near Cadiz that showed no drought stress in middle of summer when other cvs nearby were badly stressed, and are being used as crosses.

Verticillium is blamed for most tree death, but suspect *Phytophthora* often the cause. The defoliating strain of *Verticillium* usually has similar symptoms to the non-defoliating, the leaf drop depending on the season; leaves will drop in spring but not in autumn. *Verticillium* resistance has not been found in the germplasm bank, therefore selections of wild olives are being screened.

This team is not trying to determine mechanisms of resistance, simply searching for and breeding with potential candidates found with required characteristics. Other collaborators are looking at the mechanisms of any resistance found.

Dr. Belaj has also been investigating the self incompatibility of olive varieties. Many cultivars though to be self pollinating, are actually not. It is though that the pollen can travel significant distances and there are enough varieties to provide pollination. However they may not be achieving the maximum set possible. Picual is actually self incompatible, even though most think it is self pollinating.

***(L)** Chiquitita, new dwarf variety* ***(R)** Wild olive collection.*

University of Cordoba

The group visited with pathologists at the University of Cordoba (Miguel A. Blanco-Lopez, Antonio Trapero, Javier Lopez-Escudero) to discuss disease management in Spain.

Verticillium (Javier Lopez-Escudero)
Verticillium is the main disease issue facing growers in Spain. There is the defoliating and non-defoliating types "and everything in between". Dieback occurs on both old and young trees, and is usually seen at the end of winter/beginning of spring. The decline of trees, with defoliation & necrosis, is seen throughout spring into the beginning of summer. If conditions in autumn are similar to spring, the symptoms may appear again. Trees can be free of symptoms for 2-3 years and then repeat again. This can depend on the climate and levels of stress. Some farmers believe trees have recovered from chemical application, but they can actually recover naturally.

There has been a significant increase in *Verticillium* in the last 20-30 years. Surveys have been undertaken in Spain from the 1980's to 1994 to determine the distribution. In 1996, 26% of orchards visited were infected. In a survey in 2000, infection had risen to 43% of the orchards in Cadiz, with less in Cordoba (24%), Jaen (26%) and Seville (12%). The factors attributed to this increase in *Verticillium* include planting olives in infected ground, using infected planting material, using inappropriate cultural practices, and introduction of irrigation to previously dry land orchards. Nurseries are usually close to the rivers in old vegetable ground and have seedlings in contact with infected soil. Intercropping of vegetable and cotton crops for extra income was also practised, bringing infection into otherwise clean ground. It is recommended that farmers quantify *Verticillium* levels pre planting. >1propagule/g soil is considered dangerous.

Management used is a combination of physical (solarisation), biological (organic amendments), chemical (not effective - symptoms return) and using resistant cultivars.

Resistance is the first priority. Picual, the main cultivar planted in Spain, is a very susceptible cultivar, as is Hojiblanca. The pathologists test material from the breeders, and so far have evaluated 110 cvs of 444 cvs in the collection. They are also involved in long term experiments planting various cultivars on roots stocks and grafted trees in highly infected ground. In addition they are taking stem cuttings or seed and GPS marking from the ~ 80,000 wild olives in Andalucía, to determine if there is any natural resistance.

Destroying infected plant material is recommended. Microsclerotia are produced in the last part of the disease cycle, and are present in leaves. Tilling spreads the pathogen and some organic growers buy prunings from other growers without knowing the disease history. The fungus is also dispersed by water run off and river flow, and has been detected in both the filters in the main pumping channels and in the water. *Verticillium* also survives passage through a sheep gut, therefore animal compost is a potential source.

Solarisation mid summer can be useful but expensive. Microsclerotia loose germination power after heat, and the disease can be reduced in established plantations by spot solarisation. None of the chemicals trialled have long term efficacy. Trunk injections are only effective to pathogen in stem xylem, but doe not kill the pathogen in roots so will get re-infection. Therefore the treatment needs to be repeated every 3-4 months.

Phytophthora

- *Phytophthora* has symptoms similar to *Verticillium*, and is often confused with it. It occurs mainly in waterlogged areas, and trees are mounded to avoid waterlogging. The species *P. megasperma* is the most important, with detections also of *P. inundata* and *P. palmivora*.
- Some cultivars show resistance – Arbequina is not as susceptible, manzanillo is susceptible.
- Phytophthora fruit rot also occurs in certain conditions.

Foliar diseases (Antonio Trapero Casa)

- Three foliar diseases are common in Spain, *Spilocaea oleagina* – 'Repilo' (Peacock spot), *Pseudocercospora* – 'Emplomado' (leaf blight) and *Colletotrichum* – 'Antracnosis' (anthracnose). *Colletotrichum* also caused the fruit rot.
- Peacock spot can remain latent in the leaves for at least a year, possibly more. Therefore a latent infection test on leaves is used to assist growers making management decisions about chemical applications.
- Leaf blight is similar, except the latent infection may be present for up to 2 years. The pathologists are currently studying the epidemiology of this fungus.
- *Colletotrichum* can cause branch death, from toxins produced by the fungus. It can also exists non symptomatically in olive branches. Flowers, young fruit, shoots and branches are all potential inoculum sources. Wounded fruit gets more infection and there can be an interaction with olive fly.

Miscellaneous

- "Escudete" – *Camarosporium dalmaticum*. This fruit rot is strongly correlated with olive fly damage and is more an issue with table olives. Neither the disease or the fly occur in Australia.
- *Armillaria* and *Sclerotinia* are becoming problems in high density orchards in some areas.
- *Pseudomonas syringae* is not an economic problem, but again can be an issue in high density plantings.
- *Macrophomina* occurs when the temperatures are high. It has not been well studied as it is not a major problem.

6TH INTERNATIONAL SYMPOSIUM ON OLIVE GROWING, EVORA PORTUGAL

The 6th International Symposium on Olive Growing was held in Evora, Portugal, 9th – 13th September 2008. Comprising 2½ days f presentations, and two technical tours, the symposium was attended by over 100 olive researchers and industry representatives from around the world. Over 250 papers were presented; both oral and posters, and full articles will be published by the International Society of Horticultural Science in *Acta Horticulturae.* The technical tours visited research farms to look at research discussed during the symposium, and to visit local production areas and olive mills.

The symposium was attended by Mrs Barbara Hall (SARDI), Mr Domenic Cavallaro, (Technical Manager with Stoller Australia) and Mr Andrew Meurant (National Horticulture and Forestry Business Development Manager, Elders Pty Ltd).

Mrs Hall presented a poster on "Diseases and Disorders of Olives in Australia".

RESULTS OF DISCUSSIONS

The presentations were grouped under 6 topics: Germplasm, genetic improvement and genomics of olive; Olive biology, physiology: Plant protection; Crop management; Olive and oil technology; Economy and marketing of olive products.

- Many papers presented work on classification of germplasm collections and determination of characteristics useful for breeders, including genetic diversity, variability and stability. There are many breeding programs looking at resistance – to disease, drought, salt and other necessary characteristics.
- A significant amount of research is being undertaken world wide on use of water, including effective irrigation, irrigating with saline water, methods of measuring water uptake, water stress and water status of trees.
  - Water stress – trees may benefit in yield and quality with some water stress. Remote thermal imagery can be used to calculate water stress of trees.
  - Irrigation is often based on plant water status measurements, and trunk diameter is used to calculate water status. Investigations have shown this many not be a reliable parameter on older trees.
  - 1998 – 2006 trials in Spain using drip irrigation with saline water and Ca^{++}, comparing 0, 5 & 10 dS/m on salt tolerant cultivars. Production acceptable, but need enough winter rainfall to leach salt accumulation. Trials in Israel have yielded positive results with brackish water from the start. Leaching management is necessary, including mulching and irrigation during rain. Problems occur if the salt accumulation on the soil surface during summer gets washed in with rain. Salinity affects the osmotic process, so there is no accumulation of salt in leaves. Tolerant varieties control salinity at the root level. 1-4 dS appear acceptable and sandy soils can cope with higher levels. Osmotic stress also increases oil quality like water stress does. While research is this area is new but promising, questions were raised on the long term sustainability of using brackish water.
- Sustainable management of olives was well discussed. World wise there are issues with minimising water use, as there is less water and often of a lower quality. Soil degradation is also occurring with erosion and salinity.

- Italian researchers have been investigating the used of waste water recycling and deficit drip irrigation to save water and nitrogen. The crop residues used as mulch. However in Italy, there are difficulties with using waste water for irrigation because of unjustified stringent microbiological limits, which means the water is at a much higher cost. They have also shown that olive trees are important for C-sequestration. In sustainable orchards, 3.96 t/ha/yr $CO2$ was sequestered vs 5.36 lost under conventional. However fruit trees are not included in the Kyoto targets, and no benefit can be obtained with carbon saving schemes.
- It was recognised that there is a need to develop sustainability in old orchards – increase their efficiency and not concentrate all work on moving to high density. Production should be optimised, not maximised.

- The cost of labour, and the difficulty in obtaining it was also a significant issue. Mechanical harvesters, high density production, and other measures to mechanise production were discussed, particularly in table olives where more labour is required.
  - Mechanical harvesters for table olives have been developed and evaluated in the USA. So far results are variable. There is significant bruising and fruit damage, and the picking efficiency is low. Much of that is to do with the canopy management of the tree. So work is also underway to compare pruning methods to provide good production for mechanical harvesters.
  - Work in Portugal is looking at the adaptability of local varieties to super high density production & comparing results to Arbequina. Cobrancosa was the best, however there was a lower oil content, possibly due to being harvested too early. Galega vulgar has a poor structure for high density, as the branches are too widely spread. The technical tour visited the research farm (Operational and Technological Irrigation centre - COTR) situated on the eastern bank of Guadiana River in the Moura district where this work is being undertaken, as well as evaluation of varying plantation densities, irrigation regimes, fertiliser levels and different soil conservation techniques.
- Pest and disease issues were not as well covered as water and crop management. Work was undertaken on biological controls and soil amendments, with some investigations on chemicals.
  - Viruses widespread in Portugal olives, however there is now an EU directive that all propagation material traded within EU must be virus free. Therefore PCR tests are being developed to detect virus in rootstocks. Virus symptoms are often induced on grafted rootstocks, with symptom expression not seen on own rooted trees. Therefore it is often difficult to determine the relationship between the virus and the symptoms seen.
  - There is a significant interest in reducing pesticide use. Investigations are looking for biological controls of olive pests, and studying the effects of natural vegetation. Natural vegetation increased predator levels and activity and parasitism levels of olive moth (*Prays oleae*), but did not increase attack by the moth of olives. Work is also underway to determine wether the presence of high insect taxa could be used to indicate farming systems (ie low pesticide use). Preliminary results have shown a possibility that high coleoptera numbers are indicative of organic farming.
  - Compost and soil amendments are being investigated as potential disease suppressive agents. The addition of commercial animal based bio-product to growing media encouraged growth of seedlings and reduced *Verticillium* levels

in grafted trees. Compost added to potting media at 20% showed good suppression of phytobacteria on inoculated olive plants, with potential to act as a control of olive knot.

- Work on the fungus *Colletotrichum* shows it has a latent phase on fruit – leaves and branches are short term reservoirs, with the fungus surviving on plant material all year. Fungicides (Dithianon, trifloxystrobin) were shown to be more effective that copper.
- New fungicides formulations were introduced by the chemical companies. Syngenta have a new product "Cuprocol" (58.34% copper oxychloride, 2.5% difenaconazole) which is curative and preventative against peacock spot with good efficacy against *Colletotrichum*. Bayer introduced Flint for Colletotrichum and Flint Max for peacock spot (trifloxystrobin 25%, tebuconazole 50%).


(L) *Olive fly damage on fruit* ***(R)*** *Olive fly larva in fruit*


(L) *Researchers discussing variety trials*
(R) *Olive knot*

Portuguese olive production in the Alentejo

350,000 Ha of olives are grown in Portugal, 150,000 Ha in the Alentejo. Many are old orchards with 10x10m or 12x12m tree spacing. Since irrigation, density has been increase by inter planting with new olive trees, or other trees such as fig.

Most areas provide their fruit to cooperatives, as farms are too small to act alone. The Moura and Barrancos Agricultural Cooperative is one of the largest, with ~1200 local producers and over 17,000 Ha olives producing over 3million tonnes virgin olive oil each season.

There are also companies such as Olivais do Sul, who not only own property but manage others in the district and have an olive grove management team to advise growers on all aspects of olive growing. Most of the company's trees are new plantings in a super high density system with drip irrigation and weed control without soil mobilisation (Inter row cover crop mowed, herbicide under trees).

In one area, the government has bought up land from growers (appropriated some) and set up a complete grower cooperative scheme. Many of the growers had small <1 Ha properties which were unsustainable. The cooperative consists of 300Ha with 62 farmers. All have their own trees, but they are managed as one enterprise. The cultivar is mostly Cobrancosa and irrigated. All field work is done by the association and the growers pay for their share when crop is picked. The trees were planted by the government as an EU project, and the government also support the costs of irrigation and infrastructure.

A very large dam has been constructed to supply water into the future for both towns and growers. At this stage the water is free, but they will be charged but are unaware of the projected costs. Some areas south or the dam are still waiting for water, as construction of pipework etc is well behind schedule. Old olives removed from the flooded area are being sold for over 500 Euro each.

(L) *View of olives in Alentejo,Portugal* ***(R)*** *Dam*

IMPLICATIONS FOR AUSTRALIAN HORTICULTURE

- Water quality and quantity for olives is a major issue world wide, and a significant amount of research is being undertaken throughout the Mediterranean in all aspects of water use. This needs to be investigated as to it's applicability to Australian conditions.
- Breeding for the characteristics required by olives to survive and be profitable is undertaken in many areas, and these new varieties should be tested in Australia to determine their applicability for our use. Drought resistant olive cultivars would be most useful in the current climate.
- The damage caused by olive fly is significant, and many applications of chemicals are used to manage the pest. Quarantine efforts to keep this pest out of Australia should be encouraged.
- New fungicides formulations were introduced by the chemical companies Syngenta and Bayer for peacock spot and anthracnose. These need to be considered as to their "fit" in any chemical program developed for the olive industry.
- The cost of labour and the difficulty in obtaining it was also a significant issue worldwide. Many areas are investigating the use of mechanical harvesters and developing high density production, particularly in table olives where more labour is required. Australia is already quite highly mechanised in the larger oils production areas, but not in the more traditional table olive production.
- Optimisation of production was recommended rather than maximisation. Rather than increasing tree numbers to improve yield, with the potential of lack of water issues, productivity of the current orchards needs to be improved. Sustainability of olive orchards needs to be promoted, with strategies developed to promote the use of IPM, reduce water use, increase soil health and prevent soil degradation.
- Many of the olive areas develop as cooperatives, as the orchards are quite small. While our orchards are usually much larger, the potential in irrigated areas exists to develop similar water cooperatives, sharing the water more equitably among the smaller growers.
- *Verticillium* is a worldwide issue, particularly as olive plantings encroach further into old horticultural ground. Nurseries need to ensure they are not spreading the disease with planting stock, and growers be more proactive about developing ground for planting.
- Significant research is being undertaken in Cordoba University on epidemiology and management of diseases. As minimal research is undertaken in Australia in this area, it is necessary to maintain close ties with the overseas researchers and diagnosticians to obtain the benefit of this research.
- Attendance at the Symposium increases the international profile of the Australian Industry and its personnel. Mrs Hall was invited to co-chair a session on olive diseases at the 2010 International Horticulture Symposium in Portugal, and has been invited to contribute a chapter on olive diseases in Australia by an Italian consortium who are intending to publish a book on olive pests and diseases.
- Attendance by industry members ensures rapid extension of information into the grower community, with benefits for both. A. Meurant, Elders, concluded:
    - This tour and the symposium gave me an appreciation of the oil and fresh eating olive industries in both countries and an insight into the scientific advances and

projects internationally. Highlights included networking with the Spanish university team and reviewing their field and laboratory trials.

  - Also farm visits reviewing farming practises in Spain and gaining an appreciation of the significant size of their industry and at the same time, seeing how their traditional practises dominate and are not necessarily world best practise. The farm visit in Portugal to Olivais do Sul demonstrated that new developments in this industry were best practice and also are integrating the value chain with a paddock to plate approach that includes processing and marketing.
  - Seeing both old and new farming practises operating in a EU supported industry demonstrated that the Australian industry was in a great position to compete in our counter season market window.
  - The Symposium presentation on “The modern Australian olive industry” delivered by Leandro Ravetti from Boundary Bend Olives gave a sense of home pride as it painted Australia as an emerging and highly professional player on the international circuit.

Domenic Cavallaro, Stoller Australia, found that the production systems in Portugal were more compatible with Australia than Spain, however both countries were concerned with limited water.

- Olives both in Spain and Portugal had a very traditional production system especially where the production was based on either natural rainfall or limited irrigation.
- Modern production systems spacing and more intensive systems were seen in Portugal and resemble production systems in Australia.
- It is interesting to note that water supplies and availability was a limiting factor that is limiting the expansion of the olive industry in these countries.
- It was also interesting to note the extensive research being conducted in Cordoba, Spain on pollination and developing new varieties. A new compatibility chart of varieties for pollination was to be released shortly and should be monitored by the industry.
- Labour costs related to harvesting is a major issue for the olive industry. It was interesting to note that the Olive industry in Australia has captured this as an opportunity by establishing and designing orchards which can be mechanically harvested while other countries struggle to develop machinery which can harvest traditionally designed orchards.

INFORMATION DISSEMINATION

The information gained from this tour will be disseminated in many ways. Articles will be written for grower magazines such as The Grower and The Olive Press. Information will also be presented at grower meetings and field days held in conjunction with the respective projects. Information will be disseminated by attendees through personal contact with clients and other industry personnel. The proceedings from both Symposia will be provided to the participants when published (usually in the year following the symposia), and will be available to read on request.

Information gained by the case studies of commercial greenhouse facilities will be incorporated into the best practice manual for hydroponic systems being developed in HAL VG07144. Knowledge of current research and practices will also be used in formulating new projects in vegetable and olive research.

ITINERARY

25-28 August 2008	International Symposium on Soilless Culture and Hydroponics – Lima, Peru
29-31 August	Travel from Peru to Spain
1-3 September	Study tour of greenhouses in Almeria, Spain
4-7 September	Olive plantation and university visits, Ubeda & Cordoba
8-14 September	6th International Symposium on Olive Growing

RECOMMENDATIONS

- It is recommended that HAL continue to support and encourage attendance at conferences and study tours to establish and maintain personal contact with international researchers and primary producers. Such links are vital to ensuring Australia remains current and relevant in the international research environment. The collaborative research projects that can result strengthen the industries and provide world class research.
- A study tour to be organised by researchers in conjunction with commercial partners such as seed and chemical companies for 8-10 greenhouse vegetable growers to go to Spain and the Netherlands to visit hydroponic greenhouse properties and undertake specialist training courses available at PTC+ in the Netherlands. Proposals to source funding to subsidise the cost of the tour to be submitted to HAL and other potential funding sources to be investigated e.g. FarmBis.
- It is recommended that HAL encourage and continue to support study tours which involve a combination of researchers and Industry technical personnel. The combination of knowledge is synergistic, and with the discussions held between the attendees and the international hosts and growers, more information is assimilated.
- Discussions with other Australian researchers and industry personnel in protected cropping should include the potential for adoption of the positive aspects of the Almerian system such as greenhouse design, including ventilation and double-door entry, greenhouse hygiene and area-wide IPM, including the biocontrol agents currently used in Spain.
- That vigilance in Quarantine needs to be maintained to prevent incursions of diseases such as the tomato viruses and pests such as olive fly. Training of Industry to recognise these pest and diseases should be undertaken to promote early detection. Funding in this area needs to be a joint effort between industry bodies, Research providers and Biosecurity.
- Development of sustainable production of both protected cropping and olive orchards in Australia needs to be investigated and encouraged.

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APPENDIX. ABSTRACT

6th International Symposium on Olive Growing
Poster presentation

DISEASES AND DISORDERS OF OLIVES IN AUSTRALIA.

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A survey of diseases in olive plantations throughout Australia was undertaken during 2001 – 2005 as part of a national project on sustainable pest and disease management in the Australian olive industry. Olive trees with disease symptoms were tested to determine the causal agent(s). Where new pathogens were detected, greenhouse studies were undertaken to confirm pathogenicity. The common leaf diseases detected were olive leaf spot (*Spilocaea oleagina)* and Cercospora leaf mould (*Pseudocercospora (= Cercospora, = Mycocentrospora) cladosporioides*. Anthracnose (*Colletotrichum acutatum, C. gloeospiroiodes)* was the main disease or fruit, however the disorder apical end rot was prevalent and caused significant damage. *Verticillium dahliae* and several *Phytophthora* sp. were recovered from mature trees, causing wilting and death. Several bacteria, including *Pseudomonas syringae*, *Ralstonia solenacearum*, *Xanthomonas campestris* and *Pseudomonas* sp. were found to infect at wound sites, causing stem cankers and local lesions. Two new diseases detected included olive knot (*Pseudomonas savastanoi* pv. *savastanoi)* and charcoal rot (*Macrophomina phaseolina = Rhizoctonia bataticola)* which caused a dry rot of roots and crown.