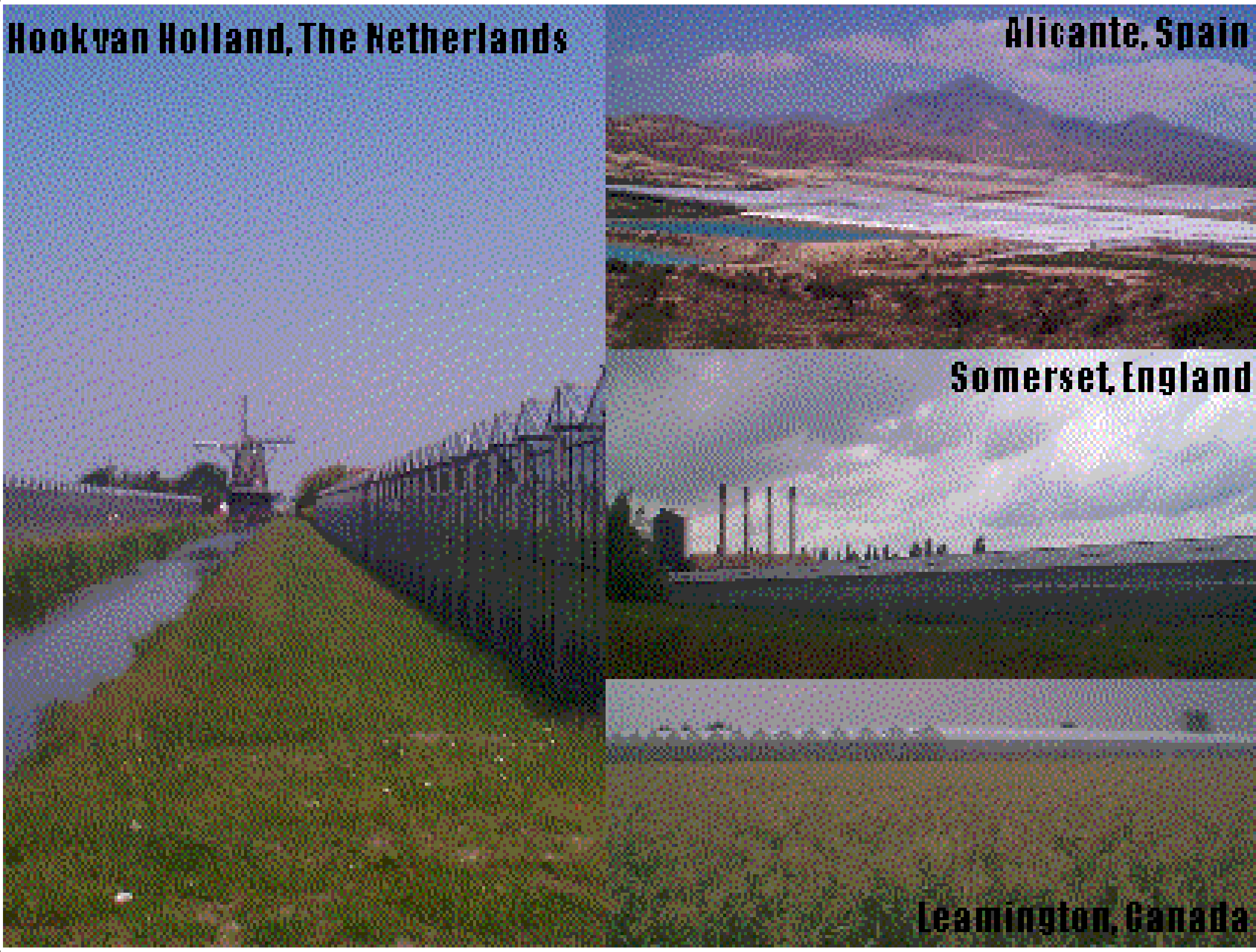
# Greenhouse Horticulture

## - beyond Australia




Churchill Fellowship 2001

**Jeremy Badgery-Parker**

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NSW Agriculture

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*A report on a study tour of the greenhouse and soilless horticulture industries of England, The Netherlands, Spain and Canada.*


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Churchill Fellow 2001



Winston Churchill Memorial Trust of Australia

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## Executive Summary

The Australian protected cropping industry, specifically the greenhouse and hydroponic industry is at a point of change, and an opportunity to match it with the best in the world. For this potential to be realised, however, it is paramount that the industry actively seeks out information about greenhouse horticulture. In this regard, Australian growers need to learn from other industries and adopt appropriate practices. This study tour was focussed on seeing the operational and technology aspects of commercial greenhouses overseas so that this learning could be used as a background to the development of our industry.

Internationally, the level of technology used in greenhouse and hydroponic systems is significantly better than the majority of Australian operations. The minimum benchmark in the vegetable industries visited is for structures to have a gutter height of at least 4 metres, hydronic heating and carbon dioxide supplementation. Trolley and rail systems and automation substantially improve labour efficiencies. These factors alone have the potential to improve Australia's productivity by up to twenty percent.

Scale of investment is another characteristic because the greenhouse industry gains significantly from economies of scale. Viability requires a minimum operational size. In Australia, research has indicated that a return on investment of up to 27% is possible in some crops, provided the operation is 2 hectares in size. New commercial greenhouses overseas are at least 3 hectares, with many exceeding twenty hectares.

In greenhouse crop production, integrated management of pests and diseases is standard practice and involves the precise management of the growing environment and the comprehensive use of biological control organisms. Hygiene is taken seriously to reduce disease pressure and the greenhouse industry internationally, is coming increasingly closer to being free of the need for harmful chemical pesticides. Growers specialise in a single crop leading to greater individual expertise.

Co-operative marketing with an export focus is the backbone of much of the success and prosperity of the international greenhouse industry, while the active search for innovation and better practices and, especially the sharing of information between growers, are features of the progressive industries.

Many of the challenges and constraints to the development of the Australian industry, including marketing, land use conflicts and waste management issues, are not unique to Australia. It is the co-operation of growers and long term planning by government and industry that has enabled greenhouse horticulture to become the industry of the future for so many countries.

Australia has fundamental comparative advantages in terms of our mild climate, labour, training opportunities, clean green resources, greenhouse research facilities and professional expertise. But the industry needs to adopt appropriate practices and technology for these advantages to be of use. Above all, Australian growers need to work together.

The National Centre for Greenhouse Horticulture has an important role as the focal point in encouraging and assisting the Australia industry to gain access to information. It is critical that the facility be used to provide an on-going visual text for the extension of research information and especially for training programs in this industry.

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## Objectives

- Undertake a Churchill Fellowship to study some international protected cropping industries
- View the commercial operations of the vegetable and floriculture greenhouse industries in The Netherlands, Spain, England and Canada
- Broaden my appreciation of international greenhouse practices by reviewing a diversity of commercial operations
- Identify cultural, technical and market trends in leading greenhouse industries
- Identify opportunities in greenhouse production for Australian growers
- Inspect international approaches to key issues arising from intensive horticultural production
- Develop international contacts in the protected cropping industry

## Author

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## An Australian Industry Overview

The protected cropping industry encompasses the production of vegetable and ornamental crops. Greenhouses and hydroponics are the most prominent components of this industry. Greenhouse horticulture in New South Wales is conservatively valued at $350 million per annum, while the total area of greenhouses is increasing by approximately 10% per year. The largest production areas are located in the Sydney basin and on the North Adelaide Plains. These two regions account for as much as 1000 hectares of greenhouses. Smaller areas of production are to be found in Victoria, Tasmania and Western Australia. The area of greenhouses in Queensland is rapidly expanding as large field production operations are put under cover. Tomatoes and cucumbers are the primary crops. Capsicum, eggplant, herbs and hydroponic lettuce are also produced by the industry.

The majority of greenhouse operations in Australia are family businesses with only a few corporate investment operations established to date. This is despite the fact that protected cropping offers a more defined risk profile than many agricultural and particularly horticultural industries and export opportunities are largely unsatisfied. Generally, the Australian industry can be subdivided into a traditional, low technology industry and a more contemporary industry that is adopting newer technology and superior greenhouse designs.

Greenhouses offer a higher return per area than field based production of the same – and many other crops. This makes intensive cropping a viable business opportunity on small land areas and on the rural/urban interface. A sophisticated greenhouse can produce 15-20 times more produce than a field of the same area. In addition, soilless production systems can use up to 80% less water. Every hectare of greenhouse production loosely represents up to 10 full time jobs. Indirect employment such as in transport and marketing of greenhouse crops compounds this figure.

Protected cropping also offers substantial environmental benefits in areas such as water management and pesticide use. The full advantages of this technology, however, are not yet being realised in Australia. The average greenhouse operation here currently performs behind international benchmarks in yield and quality and lags behind some industries in addressing environmental and technical issues. A few leading Australian operations compare well with international benchmarks.

The recent establishment, by NSW Agriculture, of the National Centre for Greenhouse Horticulture (NCGH) has been a significant step forward for the Australian protected cropping industry. The Centre offers world-standard research and extension for the greenhouse and hydroponics industries. The aim of the Centre is to increase the profitability, productivity and environmental sustainability of the industry through better access to knowledge and by physical demonstration of production principles and technology. The Centre offers a research and extension service previously unavailable in this country.

## Industry Snap shots

THE GREENHOUSE INDUSTRY OF THE NETHERLANDS

| | |
|---|---|
| Approx. area of production: | 12,000 hectares |
| Main production region/s: | Westlands<br>Aalsmeer district |
| Crops (vegetable): | Tomato, capsicum, eggplant, cucumber |
| Crops (cutflower): | Rose, tulip, chrysanthemum, gerbera, carnation |
| Key Features: | Glass cladding<br>Gutter height 4 - 5.5 metres<br>Passive ventilation<br>Automatic environmental control<br>Automatic irrigation control<br>Predominantly media based hydroponics<br>Hydronic heating<br>Integrated Pest Management<br>Recycled water |

THE GREENHOUSE INDUSTRY OF SWEDEN

| | |
|---|---|
| Approx. area of production: | 100 hectares |
| Main production region/s: | Skåne region<br>Dalarna region |
| Crops (vegetable): | Tomato, capsicum, eggplant, cucumber |
| Crops (cutflower): | Rose, tulip, chrysanthemum, gerbera, carnation |
| Key Features: | Glass cladding<br>Gutter height 3 - 4 metres<br>Passive ventilation<br>Automatic environmental control<br>Automatic irrigation control<br>Predominantly media based hydroponics<br>Hydronic heating<br>Integrated Pest Management<br>Recycled water |

THE GREENHOUSE INDUSTRY OF BRITAIN

| | |
|---|---|
| Approx. area of production: | 400 hectares |
| Main production region/s: | Sussex, Essex<br>Somerset, Yorkshire<br>Cornwall |
| Crops (vegetable): | Tomato, capsicum, eggplant, cucumber |
| Crops (cutflower): | Rose, tulip, chrysanthemum, gerbera, carnation |
| Key Features: | Glass cladding<br>Gutter height 4 - 5.5 metres<br>Passive ventilation<br>Automatic environmental control<br>Automatic irrigation control<br>Predominantly media based hydroponics<br>Hydronic heating<br>Integrated Pest Management<br>Some recycled water |

THE GREENHOUSE INDUSTRY OF SPAIN (NEW INDUSTRY)

Approx. area of production: 500 hectares

Main production region/s:` Alicante
Mucia
Almeria

Crops (vegetable): Tomato,
capsicum,
cucumber

Key Features:
Glass cladding
Gutter height
4 - 5.5 metres
Passive ventilation
Automatic environmental control
Automatic irrigation control
Predominantly media based hydroponics
Hydronic heating
Integrated Pest Management
Recycled water

THE GREENHOUSE INDUSTRY OF SPAIN (TRADITIONAL INDUSTRY)

Approx. area of production: 40,000+ hectares

Main production region/s: Alicante
Mucia
Almeria

Crops (vegetable): Tomato, capsicum,
cucumber

Key Features:
Plastic cladding
Roof height 2 - 3 metres
Minimal ventilation
Automatic irrigation control
Predominantly soil production
Little Heating, gas air heating
Some Integrated Pest Management
Some Recycled water

THE GREENHOUSE INDUSTRY OF CANADA (ONTARIO)

Approx. area of production: 1000 hectares

Main production region/s: Leamington
Niagara

Crops (vegetable): Tomato, capsicum, eggplant, cucumber

Crops (cutflower): Rose, tulip, chrysanthemum, gerbera, carnation

Key Features:
Glass or plastic cladding
Gutter height 3.5 - 5 metres
Passive ventilation
Automatic environmental control
Automatic irrigation control
Predominantly media based hydroponics
Hydronic heating
Integrated Pest Management
Recycled water

THE GREENHOUSE INDUSTRY OF CANADA (BRITISH COLUMBIA)

Approx. area of production: 400 hectares

Main production region/s: Vancouver – Delta, Surrey, Langley, Abbotsford
Vancouver Island

Crops (vegetable): Tomato, capsicum, eggplant, cucumber

Crops (cutflower): Rose, gerbera, freesia, lily, alstroemeria, daffodil, tulip

Key Features:
Plastic or glass cladding
Gutter height 3 - 5 metres
Passive ventilation
Automatic environmental control
Automatic irrigation control
Predominantly media based hydroponics
Hydronic heating
Integrated Pest Management
Recycled water

## Introduction

Widely recognised as the matriarch of the greenhouse industry, the Dutch industry spreads over some 12000 hectares. Approximately 7000 hectares are to be found in the region known as the Westlands (mostly vegetables), with a further 4000 hectares in the Aalsmeer district (mostly floriculture) and the remainder scattered around the country, with a concentration in the areas around Venlo and Emmen. The greenhouse industry has been part of the Dutch scenery for decades. For example, in the area of Naaldwijk, in the Westlands, glasshouses currently cover 25% (or 3000 hectares) of the land area. Subsequently glasshouses are hand-in-hand with windmills and canals in representing the lifestyle of The Netherlands. The estimated minimum viable operation is 4000m$^2$, though most new developments range between three and 30 hectares in scale.

The Netherlands: Canals, Glasshouses and Windmills

England is very much a small-scale version of the Dutch industry. Greenhouse production covers approximately 400 hectares and is found throughout the mid to southern regions. A similar situation is found in Sweden, though, the industry in Sweden is of much lesser significance than the British industry. In Sweden, the technology and practices are a near carbon copy of the Dutch industry, or more accurately, the Dutch industry of 10-20 years ago. The most striking feature of these industries (Dutch and pseudo-Dutch) is the similarity between one operation and the next. These industries demonstrate a base level of technicality, which every operation has attained. In fact, the difference in technology at the top compared with the bottom of the industry is extremely narrow.

In contrast, there are two divergent industries in Spain, similar to the situation found in Australia. The larger, traditional Spanish industry has evolved its own unique greenhouse structure, which has minimal environmental control and is dominantly used for winter production. The smaller, newer industry on the other hand, reflects the world's best standards in technology and greenhouse design. A heavy Dutch and British influence is detectable, with many modern operations, in fact, involving direct international - often Dutch - investment. In total, the greenhouse industry in Spain covers as much as 40000 hectares, though this may be a conservative estimate. The newer industry possibly accounts for no more than two percent of the total industry at present.

The expansive Spanish greenhouse industry covers vast areas creating a 'sea of plastic'

The industry in Canada (in the two provinces I was able to visit) more closely spotlights the potential of the Australian industry than anywhere else I visited. A strong Dutch influence is noticeable though there remains a distinct range of technological levels throughout the industry unlike the Dutch industry that varies little between growers. Two key areas of the Ontario industry

Better known for the waterfalls, the Niagara Peninsula is home to the largest greenhouse floricultural production area in Canada

are the Leamington and the Niagara districts, to the south and southeast respectively of Toronto. The Leamington area is primarily involved in the growing of vegetables while the Niagara peninsula is the largest floricultural production area in Canada. There are approximately 800-1000 hectares of greenhouses in Ontario, with around half the area used for vegetable production, half for floriculture. Tomato is the single biggest greenhouse vegetable crop in Ontario, with over fifty percent of the harvest exported to the USA.

On the West Coast of Canada, the British Columbian greenhouse vegetable industry is around 300 hectares and floriculture accounts for a further 100 hectares of structures. Vegetable and floricultural operations are mixed throughout the region of Vancouver from the Delta region east to Abbotsford. A small proportion of the industry is located on Vancouver Island.

A range of greenhouses are used, including glass and plastic clad structures and the level of technology varies significantly from one end of the industry to the other, though this difference does not necessarily correlate with the profitability of an operation. The average size of floricultural greenhouse operations is approximately 1 hectare while vegetable operations are twice this area.

## Greenhouse technology and design

### The Dutch (and pseudo Dutch) industry

The Dutch and pseudo Dutch (particularly Britain and Sweden) industries are founded on glass. Two key greenhouse designs are used – the narrow glasshouse, often called the Dutch Venlo is the dominant design used for vegetable production, while the wide span is favoured in the production of cutflowers.


Dutch narrow span (Venlo)


Dutch widespan

The height of greenhouses has a significant impact of the capacity to control the growing environment. In these industries, the older structures that have not been replaced have gutter heights in the range of 3 – 4 metres. There are few of these structures remaining. More recently constructed greenhouses have higher structural designs. Common heights are 4.5 metres, with some being built to 5.5 metres. Some greenhouse manufacturers expect future designs will have higher gutters.

Thermal screens are used in a lot of this industry as a method of saving energy (as much as 19%) in heating the greenhouse, however, though they can have a dual purpose by preventing excess energy from entering the greenhouse in summer, they are seldom used for this second purpose. Growers have found that when drawn, the adverse impact on ventilation, coupled with lower light levels is not acceptable. Subsequently, greenhouses are whitewashed for the summer period instead. Many operators apply the whitewash through sprinklers installed on the roof of the greenhouse using products that either readily wash off or becomes clear in rain. This ensures maximum light reaches the crop in overcast conditions.


Above: A fully automated Dutch nursery where the plants, located on containers (large mobile benches), are potted, fed, irrigated, grown, sorted and dispatched by the computer.

Below: Water storage reservoirs are constructed in the greenhouse, beneath the mobile benches.

The Dutch industry produces approximately 60% of the cutflowers sold in the world market and 50% of potted plants. The production of potted plants is increasing at a faster rate than cutflowers. In vegetables, tomatoes have the reputation as the largest crop area, but new developments have tended towards capsicums. Overseas, growers build greenhouses for particular crops; they specialise and become expert in a single crop. Very few growers produce more than one type of crop.

Automation of the greenhouse is standard practice in these industries. As in Australia, labour is expensive and often difficult to recruit. Computers monitor and control the growing environment as well as the nutrient dosing and irrigation of the hydroponics system. The pinnacle of this drive for automation is found in some of the nursery operations in which a computer is able to control not only the growing environment of the plant, but also move and sort plants within the greenhouse. In one 20 hectare nursery, a total of just six employees, are involved in little more than supplying inputs such as potting mix to the potting machine and nutrients to the dosing system, and plastic sleeving the plants that are ready for shipping – everything else is undertaken by the computer.

**The Canadian industry**

The greenhouses used in Canada are similar to the Dutch industry and the Dutch influence is quite strong. Growers travel to The Netherlands on a frequent basis. The primary difference is seen in the use of plastic cladding, which is rarely used in Holland. Plastic offers the Canadians a less expensive option and because of the higher light levels experienced in Canada, particularly Ontario, compared with Holland, there are not the same disadvantages. As a result, plastic greenhouses outnumber glass by roughly 2:1. A notable innovation, however, is the development of curved glass sheets enabling the construction of glasshouses with curved roof designs. A curved roof permits a higher average level of light transmission over the course of the day and season.

Curved glass is a new development by a Canadian manufacturer, which offers the improved light transmission of both glass and a curved roof design.

Structures in this industry have high gutter heights, which enable improved management of the growing environment. Greenhouses tend to have gutters 4 – 5 metres above the ground level. Older sheds with smaller air volumes (lower rooves) are generally used for cucumber production because they are less suitable for solanaceous (tomato, capsicum and eggplant) crops.

The floricultural industry makes greater use of glasshouses. The largest flower producing area in the country is the Niagara Peninsula. In British Columbia floriculture has been growing at a rate of around five percent per annum. This is similar to most other countries, including Australia, which are experiencing a strong demand for cutflower crops. Fully automated floriculture greenhouse operations may cost as much as $350/m$^2$ to build.

**The Spanish industry**
There are over 40000 hectares of greenhouse structures in Spain, concentrated along the coast from Alicante on the east to Almeria in the south. The majority of the structures are of the traditional Spanish greenhouse, but new developments are mostly of modern European designs. Almost half this area is used to produce tomatoes, though flower exports from Spain are growing annually.

The structures in the traditional Spanish industry are basic. Typically a tent structure, the greenhouses are used for production of vegetable crops sold into the European supermarkets. The supermarket chains tend to source Spanish product during winter.

Top: Traditional Spanish 'tent' greenhouse
Middle: Setting the posts is critical as the strong sea breezes have been known to lift the greenhouse out of the ground
Bottom: The expansive Spanish industry seemingly occupies almost every available space

This traditional greenhouse evolved in Spain as poor land holders began to realise the benefits of covering crops with plastic. These structures are generally unheated and poorly ventilated. The greenhouses are used to produce crops from autumn to spring. Very few are used during the hot summer months. The structures are essentially two layers of wire netting suspended by posts. The older greenhouses have wooden posts, while the more recently built structures make use of stainless steel. Plastic film and occasionally woven plastic sheeting is inserted between the netting. Production may be in either hydroponics or soil. Though the move towards soilless systems is occurring, the vast scale of the industry and the relaxed attitude of the growers will probably mean that soil production will continue for many years to come.

The newer greenhouse industry takes after the more typical European, that is Dutch, designs. Structures have a minimum gutter height of 4 metres, several extending to 5.5 metres to attain better environmental management during the intensely hot summers. Plastic and glass cladding are used, though where the investment directly involves a Dutch connection, glass is used without question – a habit more than a requirement, as the Spanish industry is quite south compared with other greenhouse production areas in Europe and consequently receives a lot more sunlight. Polycarbonate is increasingly popular and is used on some or all the walls as this material provides extra structural integrity in the face of moderate sea breezes. Gable and curved roof designs are most common. Hydronic heating is standard and often involves co-generation of carbon dioxide for use in the crop. Insect screens are used in many of the modern structures.

## Production practices and technology

### Crop production

<u>Cucumber</u>

Usual practice for growing cucumbers is 2 crops per year. In some operations, growers run 3 crops every twelve months. Typically cucumbers are transplanted at 10 – 14 days from sowing and harvest begins at 4 – 5 weeks after transplanting. Plants may be seeded on-site, usually into rockwool blocks, however many growers buy in transplants.


Cucumber seedlings, propagated in rockwool blocks, arrive in crates ready to plant into the greenhouse.

Crop wires are generally suspended at least 1.8 above the ground, and up to 3 metres. The height used relates to the gutter height of the greenhouse. Cucumbers are usually produced in lower structures than other vegetable crops. Heating and passive ventilation are used. Temperatures tend to be based on 24 hour averages. In winter, an average of approximately 21°C is targeted in many operations.

Carbon dioxide is supplemented to maintain a minimum concentration of 400ppm. The target electrical conductivity is typically in the range 2 – 3mS/cm. Planting densities tend to range around 1.5 – 2.5 plants per square metre, depending on available light. In high light conditions, growers may make use of twin heading – allowing the lateral at around the fifth node to grow as an additional plant.

<u>Tomato</u>

Tomatoes are generally grown as long crops, that is, around eleven months in duration. Crop wires are typically 3 – 4 metres high. Greenhouse designs used for tomato production are almost all at least 4 metres to the gutter. Plants are moved into the greenhouse at around 5 weeks. Heating and passive ventilation are used. Temperatures tend to be based on 24 hour averages. In winter, an average of approximately 21°C is targeted in most operations, while summer crops are kept a little cooler at 19°C.


De-leafing of tomatoes maintains vigour and ensures adequate air circulation around the crop. The heating-rail system is standard in practice.

Carbon dioxide is supplemented to a concentration up to 1200ppm. Electrical conductivity for tomato is typically in the range 4.5 – 5mS/cm during winter (low light) and around 2.5 – 3mS/cm in summer. Planting densities are often increased in mid spring when light levels are greater. This is achieved by twin heading the crop, which means allowing a second lateral from every couple of plants to grow as a new plant. Winter densities are around 2 – 2.5 plants. Summer densities are up to 3.5 plants per square metre. Hives of bumble bees are maintained in the greenhouse to pollinate the flowers.

Capsicum
Capsicums are grown as long crops, from ten to eleven months in duration. Crop wires are typically 3 – 4 metres high. Greenhouse designs used for capsicum production are almost all at least 4 metres to the gutter. Hydronic heating and passive ventilation are used. Temperatures are based on 24 hour averages which are kept between 20 – 22°C. Cooler night temperatures (around 18 – 19 degrees) are needed to set fruit.


The use of rail and trolley systems in capsicum crops improve labour efficiency.

Carbon dioxide is supplemented to a concentration of between 500 and 1000ppm. Electrical conductivity for tomato is typically in the range 2.5 – 3mS/cm. Planting densities tend to be around 3 –3.5 plants per square metre. Twin heading the crop is used to increase density during the season.

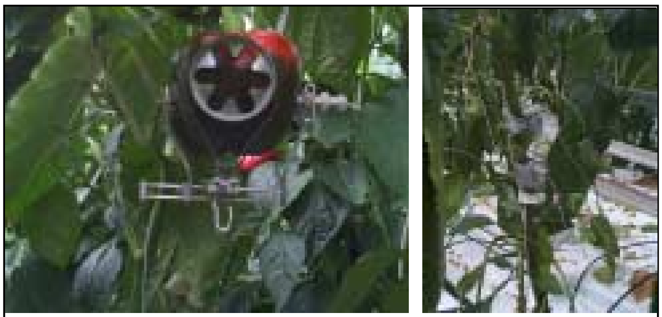
**Information and data collection**

The collection and analysis of data from the greenhouse is an important part of successful management. At the most fundamental level, conditions of the growing environment are monitored and recorded and controlled as necessary to maintain the desired growing conditions. In nutrient management, analysis of the drainage water on a regular and routine basis is standard practice.


Electronic collection of data on greenhouse activities and harvests can be used to assist management.

Significant advantages are being achieved through the daily collection of row data. Staff record times taken to prune, twist, pick or otherwise work on a crop and the yields are also collated and matched with individual rows. A number of benefits are attained. Firstly, a greater efficiency in job allocation can reduce costs in large operations, while the staff are able to monitor their own efficiency which assists in maintaining motivation and pride in the job being undertaken. The data also enables management and staff to review activities and employees when problems arise. A few growers claim that the daily records of yields per row can be used to give a faster feedback on problems in the crop. One grower has found that daily staff records show up crop problems before they are visible in the plants.

Beyond this is the application of specialised sensors that monitor specific parts of a plant, measuring stress and other conditions in individual plants. This is still basically experimental equipment, which is only just now beginning to be used as a research tool. However, these tools have already been adopted by some commercial operators as a way of increasing the amount of information available to the


Specialised equipment records detailed information about plant growth and stress from the fruit (left) and the stem (right). Some growers are using this information to fine tune their management.

grower, which in turn, assists in optimising crop production.

## Integrated pest management

The integration of pest management tools is fundamental to sustainable production. There is increasing concern over pesticide use in most countries, by growers and the public alike. In addition, not only are the costs of pesticides and their application increasing, but the efficacy of these products comes under question as pest species develop tolerance, if not resistance, to the chemical products being used. Consequently, growers have become receptive to the concept of integrated pest management (IPM). The underlying principle being the complementary application of all the available practices and tools to manage pests in a responsible and sustainable fashion.

Several growers have produced successful crops for more two years now without the need to apply chemical sprays. Pest and disease control is achieved primarily through prevention – hygiene and careful monitoring, coupled with appropriate action when necessary. In situations when chemicals are required, spot spraying is used in preference to blanket sprays and ‘soft’ products are selected where available. ‘Soft’ chemicals refer to products that do not adversely impact on beneficial organisms in the greenhouse. Understanding the pests and the beneficials involved is a significant part of this process. In this regard, many growers actively share information about experiences and pest problems for the benefit of all.


The release of biological control organisms is a routine part of pest management.

One example of how grower experiences can assist others comes from a greenhouse in British Columbia where whitefly became a serious problem despite scheduled releases of biological control organisms. Vigorous de-leafing of lower leaves in a tomato crop to improve air circulation around the plants resulted in the accidental removal of the beneficial insect (in this case Dicyphus) which had parasitised the whitefly eggs on the lower leaves. Subsequently, despite what was believed to be an appropriate release of the predator, the pest species – greenhouse whitefly – were virtually uncontrolled. The massive increase in whitefly were detected in the normal course of monitoring as well as by the staff working in the crop. From this experience, because the grower wished to continue de-leafing in this manner, the solution has been to increase the number of beneficials released. This compensates for the leaf removal. Furthermore, pruned leaves are left on the floor of the greenhouse for several days to allow more predators to emerge and enter the crop. Interestingly, other operators who used raised troughs, found an additional problem. In this situation, the Dicyphus nymphs, emerging from eggs on the pruned leaves, are unable to get to the crop. Some growers are experimenting with strings to assist the insects to climb up to the plant.


Yellow sticky traps are placed in the crop to monitor pest populations. The information collected is used to plan control measures.

The timely release of biological control organisms (preventive and curative) and using the available greenhouse technologies to maintain optimal growing environments for the crops are important components of integrated pest management.

Every greenhouse operation I visited has some application of biological control in use. Furthermore, every grower makes use of (yellow) sticky traps for the monitoring of pest species in the crop. These are typically used at a density of 1 trap per two hundred square metres, though in some more demanding operations, a density of up to 1 per fifty square metres is used. The more concentrated use of monitoring traps provides a greater degree of information for the grower.

Banker plants are used to maintain a ready population of beneficial insects in the crop. In this operation, cereal grasses (hanging baskets) and castor oil plants (foreground) are both used.

Biological controls are used as the primary pest control method in most operations. In Canada, greenhouse growers may budget as much as $\$3.00/m^2$/year for biological controls, though the usual cost for many growers is in the order of $\$1.00/m^2$/year. This investment means that in many operations, crops are being successfully produced without any chemical spray applications, opening up numerous marketing opportunities for their products. Dusting of sulphur under heating pipes is, in many greenhouses, the only non-biological pest or disease control used. The sulphur volatilises with the heat and is used for control of foliar fungal diseases.

Banker plants, used to build up and sustain populations of benefical organisms in the greenhouse, are a standard part of IPM in the greenhouses visited. For example, cereal grasses are grown in pots within the greenhouses as a habitat for grain aphids, which act as hosts for the aphid parasitoid used for control of aphids in the crop.

Rolls of sticky tape are used quite successfully in several greenhouses as a physical method of controlling pests. The use ranges between an emergency trapping system to deal with whitefly outbreaks through to use as the primary control method. It has been found that the tape is more effective when hung vertically in the crop, but this is often difficult to achieve and so a compromise is to hang the tape horizontally down the row.

Sticky tape is used as a physical method of pest control as part of an IPM program.

An interesting non-chemical method of bacterial disease control being used in one nursery is cupric ions. A copper electrode is installed in the irrigation pipe. Gradual corrosion of the copper produces cupric ions, which are deadly to bacteria. The system is able to maintain a concentration of cupric ions at around of 1ppm, which is lower enough not to harm the crop.

Insect screening is an important component of an integrated pest management program. Screens reduce the risk of pest species getting into the crop. Unfortunately, screens reduce air flow and thus ventilation capacity. One solution is to increase the area of screen to compensate for the reduced ventilation, for example, a ‘harmonica screening system’ has many folds of material so the total surface area through which air can pass is increased, compensating for the reduction in air flow.

### Hydronic heating systems

Piped hot water is preferred method of greenhouse heating and is standard practice. The pipes can also be used a rails to improve labour efficiency.

Heating is used in all structures throughout the industries visited with the exception of the traditional Spanish industry. The latter relies more on the Mediterranean climate to produce crops through the cooler months of the year without supplementary heating. However, even though a crop is able to grow and yield without supplementary heating, the result is not the same as when an optimal growing environment is provided, which results in higher overall productivity. The newer Spanish industry does use heating to attain higher yields and better growth rates year-round.

The heating systems used are hydronic (piped hot water) except for a handful of greenhouses in Spain, which are making do with gas fired air heaters. These operators, however, have plans to install hydronic heating systems within the next 12 months – subject to budget. One large operation of 18 hectares has an installation schedule covering the next 2-3 years. The reason for these installation plans is the basic superiority of heated water pipes compared with heated air in providing a stable and plant friendly growing environment. Hot water pipe heating produces a dry, uniform radiant heat that enables a greater degree of uniformity in heat distribution and avoids the drawbacks of other systems including uneven heat distribution and the potential release of moisture and pollutants into the greenhouse atmosphere.

In colder climates, steam heating may be used. This system is similar steam rather than hot water is used. The higher temperature attained enables a faster heating response compared with hot water. However, such a system is only of advantage in cold climates as it may otherwise dissipate too much heat, too quickly.

In the majority of operations, the heating system is combined with a trolley and rail system to extract greater logistical efficiency within the greenhouse. Heating pipes may also be suspended within or above the crop – often height-adjustable. These pipes may be in addition to pipe systems on the ground.

### Co-generation of electricity and carbon dioxide with greenhouse heating

A significant trend, particularly in Britain and The Netherlands, is the co-generation of electricity as part of the greenhouse heating process. The production of electricity by combustion of fuel, such as natural gas, produces heat and carbon dioxide ($CO_2$) as waste products. However, both of these ‘waste products’ are important and costly inputs in greenhouse horticulture.

Top: Electricity generators are installed as part of a greenhouse complex for co-generation of power and heat. Middle: Carbon dioxide gas is extracted from the hot water boiler for use in the greenhouse. Bottom: Waste carbon dioxide gas is pumped from a nearby factory.

Power utilities have established mini electricity generation plants as part of large greenhouse complexes. The company sells the power through the national electricity grid and the greenhouse grower is able to use the heat generated for heating of the greenhouse. The grower also uses the carbon dioxide produced. One draw back of this system is that the gas price paid by growers is often dependent upon the size of the gas delivery pipe, that is, they pay per peak delivery pipe size. Subsequently, if demand for power declines once a system is installed, the grower still has a higher overall fuel price for their gas. In most situations, negotiations between the utilities and the growers seem to achieve reasonable outcomes for both parties. In The Netherlands, the government is encouraging the use of what they term CHP or combined heat and power units. Surplus energy is sold to the power utility while heat and $CO_2$ is used in the greenhouses.

Even when co-generation of power is not undertaken, a significant number of greenhouse operations in Europe, Britain and Canada also harness the heat generation process to make carbon dioxide for use in the greenhouse. Typically a gas-fired boiler is used to generate the hot water for the heating system. Other fuels are used to a small extent. Carbon dioxide is a by-product of this combustion reaction. The $CO_2$ is collected from the waste fumes with a carbon dioxide scrubber and cooled using return (cool) water from the heating system. It is then pumped into the greenhouse. During warmer periods when carbon dioxide is demanded but heat is not, the heat is stored as hot water in large insulated tanks near the greenhouses and the carbon dioxide is used in the crop. During the night, or at other times when heat is demanded, this stored hot water is recirculated through the hydronic heating system.

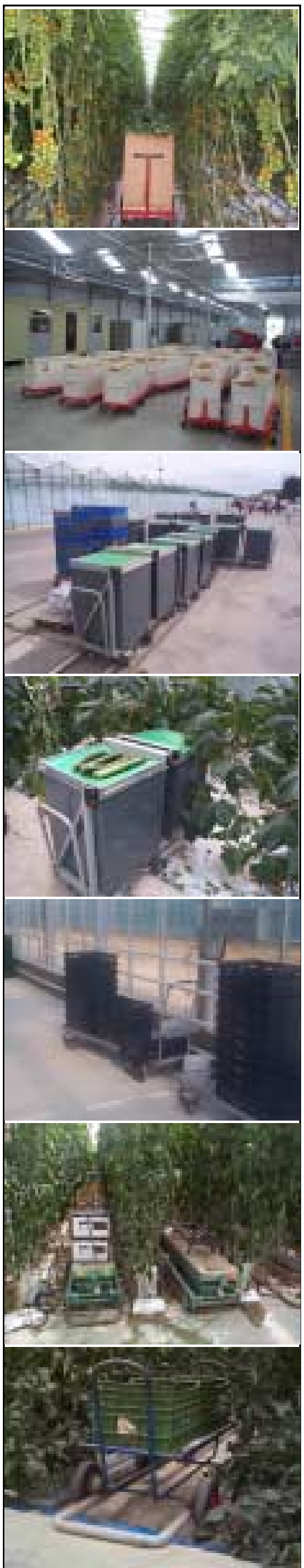
**Carbon dioxide fertilisation**

Carbon dioxide is a key input to the growth cycle of a plant and has a significant bearing on the yield of crops. The ambient level of carbon dioxide is 340 parts per million. Within a greenhouse, carbon dioxide levels can be drawn down significantly during periods of low venting as the plants use the available gas. This is especially the case in cooler climates. As a result, supplementary fertilisation of carbon dioxide has substantial advantages. Target concentrations are typically between 400 and 1200ppm. In some operations, target levels were up to 1700ppm, however, sustained $CO_2$ concentrations above 1500ppm have been shown to adversely impact on plants.

Carbon dioxide gas is injected into the crop through plastic tubing between the plant rows.

In warmer growing areas where ventilation is regularly used, the need to maintain ambient levels of carbon dioxide is less critical because air exchange when venting replaces the gas used. However, supplementation still provides productivity increases, especially during periods of low venting. The cost effectiveness of supplementing carbon dioxide needs to be determined for specific locations and greenhouse operations.

A 30% increase in weight of produce has been achieved by raising the level of carbon dioxide in the growing environment by around 350 ppm. Similar productivity increases are attained with tomatoes when levels of carbon dioxide are increased by as much as 700 ppm.


A range of trolleys is in use.

In the countries visited, buying in carbon dioxide is uneconomical so growers generate their own carbon dioxide as a part of the heating system, which they are run anyway. Since the $CO_2$ exits the burner at fairly high temperatures, water from the heating system is used to cool the gas before injecting it into the greenhouse. The carbon dioxide gas is supplied through plastic tubes between the crop rows.

An interesting observation is that in a greenhouse in Canada, it was found that parasitism of whitefly by biological control organisms is significantly less near the $CO_2$ outlets in the greenhouse. This has posed the question as to whether carbon dioxide microclimates (such as air temperature or concentration) may adversely impact on some biological control organisms.


Middle: Some trolleys carry fruit right to the packing line. Bottom: Trolleys make staff more efficient !

**Rail and trolley systems**

The use of rail and trolley systems is widespread in greenhouse vegetable production overseas. These systems combine the advantages of hydronic (piped hot water) heating with labour efficiencies gained through improvements in logistical operations. The movements of produce out of a greenhouse and the labour demands involved in the harvest of fresh vegetable crops are expensive operations in the overall horticultural business.

A range of designs is in use. All systems center around the dual application of hot water heating pipes in the greenhouse as rails for the trolleys that are used for crop pruning and maintenance and the movement of harvested product out of the greenhouse and in some circumstances, to the packing house.

The use of powered picking trolleys provides enormous advantages in the greenhouse. The most obvious being the ability for trolleys to move along the row at a pace suitable for the workers to undertake the harvest or other cultural task. The use of these systems improves labour efficiency by as much as three hundred percent.

**Soilless production systems**

From top: panda film used to form NFT channels, rockwool blocks on cocopeat, coconut husk in pots, rockwool blocks on perlite, rockwool blocks on rockwool, foam.

Hydroponic production forms the basis of the modern greenhouse industry around the world. With the exception of the Spanish industry, soilless production of greenhouse vegetable crops is the norm. In floriculture, chrysanthemums are typically soil grown in all industries but other flower crops are being cultivated in hydroponic systems. The advantages of soilless production include more efficient water and nutrient application, faster crop growth, environmentally sustainable closed system production and generally higher yields. Disadvantages include disposal difficulties of some growing media and a higher level of technical and horticultural management skills.

Flow-through soilless media based systems are the most common. There is a range of media used, the most usual ones being foam, perlite, cocopeat, rockwool, pinebark and sawdust. Most propagators use rockwool plugs and blocks to produce seedlings. These are then placed onto the other media. Water based systems – specifically nutrient film technique (NFT) – are also in use in a proportion of greenhouses. Often purported to increase crop growth rates and yields, NFT has been losing favour in The Netherlands (grower preference being the only reason I could discern) and has only limited use in other countries. Advantages of NFT include a faster turn-around between crops (compare 3 – 4 days with 10 – 14 days for media systems) and smaller water requirements. Despite this, growers continue to find the simplicity of media based systems more rewarding.

The British industry makes a lot of use of foam as a growing medium. With an expected useful period of ten years, this medium offers a fairly economical choice for growers. However, the foam is sterilised each year and not every grower has the capacity to do this. Grower experience, to date, reveals that reuse for eight years has not reduced the material’s structure that is so important in providing suitable air filled porosity and water holding capacity.

In The Netherlands rockwool is readily used and cocopeat is increasing as a medium of choice. Despite the large stockpiles of used rockwool, it remains the number one medium. Meanwhile, cocopeat has been found to result in good root penetration, superior capillary action and is a relatively cheaper medium that is more easily disposed. Furthermore, cocopeat tends to be cooler in summer. This is a interesting characteristic as the Canadian industry, in Ontario particularly, has moved away from NFT because of problems with the nutrient solution becoming too warm in summer, which can result in a loss of oxygen from the water leading to levels as low as 2ppm. This adversely impacts on root health.

The high technology sector of the Spanish industry makes most use of cocopeat and perlite. For cucumbers, perlite is favoured for winter cropping as it is felt that a drier root zone in the cooler season results in a healthy crop while cocopeat, allowing a moister root zone, is preferred for summer cropping.


A media based system is raised off the ground to assist airflow and management.

In Canada and The Netherlands, raised gutters are increasingly popular for soilless production systems. The system improves air circulation around the crop, provides more room for lowering plants and also places the crop at a manageable height in the early stages. In NFT systems, the channels are simply raised, while in media systems, containers are rested on a raised gutter.

**Relative humidity management**

Maintaining an optimal relative humidity is pertinent to sustaining crop growth. Usual practice is to maintain a relative humidity with a desired range. Humidity in the greenhouse is controlled through temperature management and is influenced by heating, venting and air exchange as well as factors such as the stage of the crop – a mature plant transpires more water and therefore makes a greater contribution to the humidity. Misting and fogging systems in the greenhouse can be used to increase relative humidity. The advantage of fogging over misting is the smaller droplet size ensures 100% evaporation of the moisture before it reaches the crop and thus the foliage is not wet by the system. Larger droplet sizes as in misting systems can result in wet plants and consequently damage and disease.


High pressure fogging systems assist cooling and relative humidity management without wetting the crop..

Increasingly, crops are being managed with reference to vapour pressure deficit (VPD). Vapour pressure deficit is a measure of the water loss from the plant and is a more accurate assessment of the plants' capacity to transpire (and grow) because VPD is a function of both plant tissue temperature and relative humidity. The optimal range of VPD is between three and seven grams per cubic metre.

**Consultants**

The use of consultants is an underlying feature of many operations. The application of external expertise is often centred around pest monitoring and recommendations on the application of biological control organisms. In some operations, more than one consultant is occasionally engaged so that advice received can be cross-checked. Growers will also make use of international consultants for specific areas of their operations.

## Industry Issues

1. Rising fuel and energy prices are one of the major challenges for the protected cropping industries around the world. The price of fuel impacts directly on operating costs, while oil prices also affect the cost of construction (particularly in the cost of plastics), transport, packaging and marketing. European growers are working harder than ever to reduce energy inputs. This involves trialing lower growing temperatures, installing thermal screens on the top and sides of structures, clustering operations to make use of shared heat, electricity and transport resources and striving for increased yields per unit of energy used. British Columbia has a program known as EcoDesign Innovation or EDI in which industries are encouraged to reduce costs through improving energy efficiencies. Companies that qualify in the program, receive matching funds from the government.
The use of artificial lighting during winter to increase yields of vegetable crops is one avenue being investigated. With assimilated lighting (artificial), the Dutch have expectations for tomato yields of up to 100kg/$m^2$/yr, while the lighting also provides an element of heating.

2. There is a significant trend towards organic and eco-farming throughout Europe and the United Kingdom. The fundamentals of this are reduced chemical use and often relies on soil based production. In England, approximately 20% of greenhouse tomatoes are organically grown. Presently, the product receives a premium, though growers indicate that there are twice as many input costs and productivity is lower compared with hydroponics.

3. The greenhouse industry in all parts of the world faces very similar issues, many of these involve the impact that the industry has on the surrounding environment - natural and social.

A number of social issues exist with this industry. An important one results from the insufficient local labour found in many greenhouse industry areas. In Canada, the main labour pool is Mexico. The Spanish bring in workers from South America. Problems, however, may occur because the labour is predominantly single males and the industry has had to address issues such as the social lives of the workers outside working hours.

Pollution

a) Aesthetics

Screening and setbacks are touted as being one of the most effective methods of reducing the impact of industry, including greenhouse horticulture, on surrounding land uses. Australia faces some very real pressures in terms of urban-rural conflict and the industry needs to be proactive in reducing these issues. The English greenhouse industry is practically invisible compared with the acute visibility of the Australian industry. Nurseries in England are well hidden behind historic hedgerows and very few visual conflict issues appear to exist.

Invisibility is a big advantage for the industry. In other countries the profile of the greenhouse is creating a focus for issues. For example, the industry in The Netherlands is a significant contributor to the country’s economy and history yet light pollution and visual amenity are increasing pressures on the industry.

b) Light

Light pollution is of growing concern in The Netherlands. Despite the greenhouse industry being a substantial and famous part of the country, the public is showing signs of dissatisfaction and annoyance with elements of the industry. In particular, light pollution has become a problem of greenhouse/urban interface and is a conflict common in the industry around the world. Many people directly involved in the greenhouse industry do not tend to be aware of this issue and the potential impact on their business.

Green waste is pulled from greenhouse and collected by contractors. It is composted off-site.

c) Nutrient loaded waste water
Run-off water is collected in lined dams and treated before it is reused or discharged into waterways. Most operations in Europe have closed systems. In England, run-off water tends to be discharged directly into the surrounding fields.

d) Green waste
Green waste tends to be composted off-site. In Britain, the removal of crop residue is continuously being made more efficient. Shredders operating inside the greenhouse are one of the latest must-have pieces of equipment, while operators and contractors alike are improving the methods of pulling spent crops out of the structures.

Another innovation is the use of organic crop strings in place of the synthetic strings currently used in the majority of operations. In this way, the strings can be shredded and composted with the plant material. In greenhouses where synthetic string is still used, it is also shredded but must be removed at a later stage in the composting cycle, or is dumped with the crop residues and not recycled.

e) Waste disposal
The frequent replacement of plastic greenhouse coverings as well as strings, bags and plastic sleeves means that there is a substantial volume of waste generated by the greenhouse industry every year around the globe. In Holland, large stockpiles of used rockwool await an economical method of recycling. In Spain, plastics are often dumped into river beds or burnt.

Smoke stacks amongst the expanse of Spanish greenhouses are a sign of burning piles of plastic.

## Growers Working Together

A common theme amongst the protected cropping industries visited is the interdependence of growers. Associations, co-operatives, central pack houses and study groups are an essential part of a progressive and profitable industry. Growers demonstrate an appreciation of the numerous benefits of working together to exchange information, knowledge and ultimately expand the market to the benefit of all.

In Spain, most, if not every, grower is a member of a co-operative. As individuals, growers are unable to effectively market their relatively small volumes of produce, but by combining resources, particularly packing and marketing resources, small businesses are able to gain better leverage with buyers. Several hundred co-operatives exist in the Spanish greenhouse industry. Memberships of each of these production and marketing groups number into the hundreds. Incredibly, even these co-operatives are discovering that they remain limited in their ability to develop their businesses and are in fact undergoing consolidation. Some in the industry forecast that within a couple of years, the Spanish industry will be represented by only a handful of larger co-operatives.

The advantages of growers forming groups are not limited to the economic benefits of increasing leverage with buyers. Information exchange and market development are perhaps two of the key windfalls of grower co-operation. Market development benefits everyone involved in the industry. By working together, growers are able to minimise competition with each other for part of a limited market and instead expand the market for the benefit of everyone. Perhaps one of the best examples of this is the Aalsmeer flower auction. More than 3000 growers are members of the organisation. By forming together, the industry in this region has been highly successful in expanding the market for their produce. The Netherlands presently produces 59% of the world's cutflowers.

Information exchange is perhaps the most important advantage that individual growers can gain by working together. Study groups are a regular part of the greenhouse vegetable industry in British Columbia, Canada. Growers meet routinely to discuss crop problems and share lessons learned. The growers take it in turn to host meetings on their farms. Hosts give a short tour of their operation and highlight successes or difficulties they are experiencing. The outcome of these meetings, is that the whole group move forward and are able to improve their growing practices and ultimately their businesses.

The key to the growth of the industries overseas is that the growers "seek out information and share it".

In British Columbia, while regulations force greenhouse vegetable growers together to market through a 'single desk', the real benefit of this has been the interaction of growers. Today, the industry is modern, progressive and capable of extending its quality product into the massive American market. Growers freely exchange information on production practices and methods to deal with pests and diseases. This unity of growers is enabling the industry to develop together with an outlook for the sale of produce to export.

The Dutch are historically successful traders and marketeers. In fact a strong theme I came to know in The Netherlands was that the Dutch advantage has probably been through good marketing skills rather than through production. These marketing skills led the Dutch to develop large co-operative marketing organisations. Aalsmeer Flower Auctions is a prime example. Most produce in Holland is exported.

The large scale of many greenhouses is impressive. Some structures are 30 hectares.

**Large scale investment**

The scale of greenhouse developments in the countries visited is breathtaking when compared to the development of the Australian industry. International greenhouse operations are substantial business developments with the size of greenhouses counted in hectares rather than square metres. In The Netherlands, new developments are almost exclusively greater than three hectares in production area and they range upwards to as much as 30 hectares in a single development. A similar scale of operation is to be seen in the new industry of Spain as well as Canada and Britain. This advantage is gained through central pack houses and grower co-operatives as well as aggressive export marketing.

These large operations are a testament to the value and long term future of this form of agriculture. The large scale of operations offers substantial labour and set up efficiencies.

## Land Use – Rural/Urban Issues

**Urban encroachment**

Urban sprawl is a fundamental problem for the greenhouse industry around the world. Even in the Netherlands where the greenhouse industry is a highly conspicuous and important part of the economy, the need to expand residential areas has meant that greenhouse growers are being relocated. Rural-urban conflict is a fact of life for greenhouse industries around the world. Growers need to take steps to minimise complaints and areas of potential conflict. Areas of concern common to the industries visited include lights, noise, waste water run-off, pesticides and aesthetics of the greenhouses themselves.

The Dutch government has investigated, with the assistance of consulting firms, new areas for the development the greenhouse industry. Eleven regions have been identified for relocation of greenhouses away from the expanding cities of Amsterdam, Rotterdam and Den Haag. Seven areas have so far been approved for development. In built up areas, many growers are buying out neighbours as the room to expand businesses is constrained by urban development.

Growers are encouraged to work together to develop efficiencies in construction, production costs and transport by planning the sites. In many development areas, greenhouse estates have been developed, much like the housing estates found in Australia – services are provided and blocks are sold to interested parties. Only residential houses directly linked with the greenhouse developments, that is the houses of the owners, may be built in the regions. A common theme is to cluster development so that growers can share common inputs such as heat, water and $CO_2$, potentially also labour, packing and transport, as well as waste management. The expectation is that, with complete preplanning of new regions, substantial sharing of resources is possible by complementary cropping, that is, peaks in one crop can be accommodated by down time in neighbouring crops.

The Spanish industry has similar threats. The key production areas coincide with the main tourist resort locations. As the pressure to develop the more lucrative tourist industry bites, protected cropping will face increasing constraints. Already, urban development is questioning the development of new greenhouse facilities given the limited water resources available. Meanwhile the industry in Sweden has very few of the problems associated with urban development due to the small scale of the industry, the rural locations of the industry and the low population of the country.

The Canadian industry also faces the difficulties of urban/rural conflict including issues such as the aesthetic aspects of greenhouses, chemical use, perceived pollution, noise and water use. The identification of agricultural zones in British Columbia as distinct from residential areas has been well received. The basis of the zoning is that the protected cropping industry is given degree of land use security and protected from the pressures of urban development both directly in terms of buffer zones and indirectly from reduced potential for conflict.

In Britain, interestingly, very little urban/rural conflict appears to exist. In determining why, the response tended to reflect the notion of ‘out of sight, out of mind’. The ubiquitous hedgerows and shrubbery of this country hide even the largest of greenhouses from public roads and residences, while the link between the urban population and agriculture remains stronger than in many other countries, including Australia. This indicates that implementing suitable measures to mitigate conflict before it occurs could take a lot of the pressure off the greenhouse industries around the globe.

## Locations of Special Interest

**Eden Project**
Located in the south west of England in the county of Cornwall, the Eden project is a fascinating application of greenhouse technology. At a cost of over £74 million, the world's tallest environmentally controlled greenhouse, is built in an old Cornish clay pit outside St Austell near the south coast of Cornwall, England.

A series of 'biomes', or dome shaped conservatories have been constructed to house a showcase of the all the major plant species from around the globe. A project aim was to build the biomes as world class architecture, yet have them perform like commercial greenhouses.

The massive biomes are made up of hundreds of triple layer foil panels. The triangular panels are air vents.

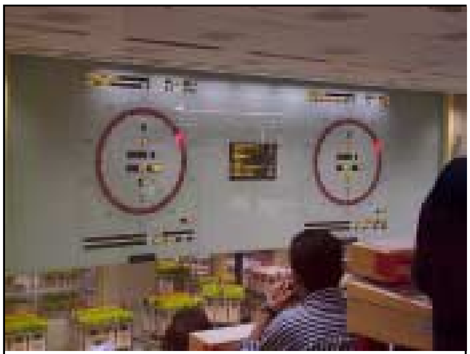
The material used is a triple glazed foil made of ethyl tetra fluoro ethylene (ETFE). The material is strong, lightweight, anti static and highly transparent to UV light. It is not broken down by sunlight, has better insulation properties than glass and is recyclable. The conservatories are made of 831 panels (mostly hexagons and some pentagons). The largest hexagon is almost 11 metres across. Lightweight galvanised steel tubular frames hold the panels of foil. The structures are designed as 'lean-to greenhouses' and use a back wall as a solar sink, which captures solar energy during the day and radiates it as heat during the night.

The structures have a series of triangular panels that open to passively vent the greenhouses and supplementary heating is via gas fired combined heat and power unit. The environmental management is fully computerised. Each panel is constructed of three layers of foil separated by an air pocket, providing excellent insulation and therefore heat and energy conservation.

The largest biome is 240m long, 55m high and 110m wide and has an area of 15590 square metres (a volume of over 330000 cubic metres). The smaller structure has an area of 6540 square metres (a volume of over 85600 cubic metres). There are no internal supports.

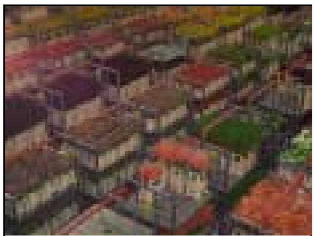
Water collected from the rooves of the biomes is used both to water the plants via a fully automated irrigation system, as well as maintain appropriate levels of humidity through misting and sprinkler systems.

**Aalsmeer Flower Auction**
Aalsmeer Flower Auction (VBA) is one a couple of auctions in The Netherlands selling flowers into the world market. With a turnover in excess of $1.3 billion last year (two thirds of which comes from cutflowers, the remainder from potted plants), VBA had been the largest


Dutch auction clocks count down the price until a bid is made.

auction house in The Netherlands until this year, when the merger of two other sales organisations created an even larger organisation – FloraHolland.

Aalsmeer Flower Auction is a 76 hectare complex dedicated to the efficient sale of floricultural products. Approximately 7000 growers sell through the markets including 3500 grower co-operative members who are obligated to sell through this auction. A Dutch auction clock is used. The markets employ some 1800 people. Three hundred different types of blooms are sold in the markets. The top blooms are rose, tulip, chrysanthemum, gerbera and carnation. Up to recently, around 53% of Dutch exports go through Aalsmeer markets. The major export destinations for Dutch floricultural produce include Germany, France, United Kingdom, Italy, Belgium and Switzerland.


Behind the scenes, thousands of blooms on carts awaiting auction.

Railed carts transport blooms and potted plants through the auction room. Lots are viewed and bids are made. Buyers use computerised keypads to make bids for the lots on offer. The lot number, the minimum purchase size and the price are displayed on large 'clocks' at the front of the room. The Dutch auction, unlike a traditional auction, starts at a top price and the price falls until a bid is made. At this point the clock stops. The successful bidder then selects the quantity that he/she will purchase at that price. If a buyer does not want the entire lot, the auction starts again with the remaining product in the lot. The price drops until another purchase is made. Several thousand transactions can be undertaken every hour.

**Innovation and Practical Training Centre (IPC)**
The IPC offers internationally recognised practical training in the greenhouse industry, including greenhouse management and crop production. Courses can be run on demand. A range of technology and equipment is on show and in use in the facility for the benefits of students, who come from all over the world.

**Greenhouse and Processing Crops Research Centre, Harrow**
The Centre boasts a fully computerised 24 greenhouse complex. Research conducted at the facility aims at improving crop efficiency and product quality. Research priorities include nutrition management, integrated pest management and postharvest quality. A substantial amount of research funds for the Centre is donated annually by the Ontario Greenhouse Vegetable Growers – an industry grower association. The association levies members on their production area to raise funds for research and marketing. A grower committee identifies research priorities for the Centre.


Sir Winston Churchill's family home - Chartwell

**Chartwell House**
To the south of London, located near Westerham in Kent, Chartwell House is the family home of Sir Winston Churchill. The National Trust manages the house and grounds now.

**Blenheim Palace**

Blenheim Palace is one of the largest palaces in Europe. It is located to the south of Woodstock. Built by Vanbrugh and Hawksmoor between 1704 and 1722, the palace has been described as an enormous baroque fantasy. Queen Anne gave the property to John Churchill as a reward for his assistance in defeating Louis XIV. The palace was the birthplace of Sir Winston Churchill.

## Benchmarks

While productivity benchmarks are only part of the story (profitability being critical to business sustainability), basic yield benchmarks remain an interesting and useful point for comparison. Crop production estimates for some hydroponic greenhouse vegetable industries are summarised in the following table.

| | **Tomato** kg / $m^2$ / yr | **Capsicum** kg / $m^2$ / yr | **Cucumber** fruit / $m^2$ / yr |
|---|---|---|---|
| The Netherlands | 40-60 (100*) | 25 | 140-160 |
| Spain | 28-30 | 20-22 | - |
| Britain | 48-50 | 25-35 | 130-160 |
| Canada | 55-74 | 20-25 | 120-150 |
| Sweden | 30-40 | 20-25 | - |
| Australia | 20-50 | 20-25 | 100-120 |

* yield expectation using assimilated lighting

## Conclusions

Internationally, the basic practices undertaken by growers in the industries visited can be reasonably summarised into fundamentals for the modern greenhouse industry. In this regard, these practices should be standard in the Australian industry.

Integrated pest management (IPM) is undertaken in the majority of operations overseas. The release of biological controls forms a basis in all pest management programs and comprehensive monitoring of pest populations is essential practice. This strategy is coupled with computerised and automated greenhouses, which enable growers to maintain optimal growing environments. The net result is that pests are well controlled and a minimum of pesticides is needed. Many growers have practically eliminated harmful chemicals from their greenhouses. The reduction in pesticide use is a common goal as is the aim to develop and maintain fully closed and sustainable production systems.

**Australian greenhouse growers should be encouraged to;**

- Actively seek out new information on greenhouse technology and production practices
- Work together and share information with other growers
- Develop links with research organisations
- Undertake domestic and international study tours
- Use external expertise such as consultants to streamline operations
- Form marketing co-operatives
- Strive for economies of scale
- Seek corporate investment for central packing facilities

The industries overseas are characterised by the co-operation of growers rather than competition. Growers are forward in sharing experiences – problems and solutions – with others in the industry. Study groups are well received. In contrast, Australian growers are reluctant to spare time during the working day to meet with others and, generally, remain shy of sharing production information with fellow growers. Internationally, growers travel frequently to see what is happening in other areas. This is one of the most effective methods of developing change and should be encouraged in Australia through the organisation of domestic and international study tours.

The co-operation of growers is further represented by the development of business co-operation. This takes the form of marketing and packing co-operatives and industry associations. The organisation of co-operatives in the Australian industry will enhance the development of greenhouse horticulture by boosting the investment capacity of the industry and its marketing advantages.

In general terms, the Australian industry currently lags behind the standard industry practices found in international greenhouse industries. This is partly due to a lack of capital investment but more importantly a result of weak information exchange. Australian growers appear reluctant to seek out information and those that have it are hesitant about sharing their experiences with others in the industry. This combination of attitudes is in contrast to the progressive and motivated industries overseas. Internationally, growers make good use of consultants, actively lobby (and fund) research, participate in grower study groups and regularly explore new ideas. It is essential that growers be given the opportunity to see, learn and interact if the real potential of greenhouse horticulture is to be realised in this country.

From what I have been fortunate enough to see and to study on this Fellowship, I see it as vitally important that the industry be encouraged to seek out information. Furthermore, access to complete information must be a pivotal part of any extension program, rather than just the provision of information that relates to immediate research projects. The extension strategy being undertaken by NSW Agriculture through the National Centre for Greenhouse Horticulture and the protected cropping team, has only just begun, but with its key focus on demonstration combined with a general information centre as well as the provision of workshops, training programs and study groups, the strategy promises to be the correct approach.

**Constraints on the Australian Industry**

- Limited sharing of information between growers
- Reluctance of growers to seek out new information and information resources
- Poor land use security
- Limited business skills pertaining to long term investments
- High level of urban conflict resulting from misconceptions about industry

## Recommendations

As a result of this study tour, I believe it is important that the National Centre for Greenhouse Horticulture can be most effective as a central point in encouraging and assisting the industry to seek out information. It is critical that the facility be used to provide a visual text for the extension of research information and especially for training programs in this industry. The appropriate display of industry contacts, technology and cultural practices is paramount to assisting the Australian industry to ‘catch up’ to international best practice.

Growers should also be encouraged to form study groups, so as to interact with each other and with experts to develop a more complete understanding of the systems, technology and business in which they are investing. The organisation and offering of field days, workshops, demonstrations, training courses and study tours needs to be a significant component of extension. Published materials would be more effective as a secondary tool. A focus on electronic extension tools is needed to meet the increasing application of computer and communication technology. Without such a focus now, it is foreseeable that extension services will fall behind.

A greater focus on developing economic analyses of the industry is also critical to ensure investment is forthcoming and uneconomic practices are identified and changed.

Finally, for the industry to successfully meet economic, environmental and social challenges, industry associations are essential. Growers need to be encouraged to join relevant organisations and shown the benefits of membership.

## Extension of Learning

The successful dissemination of information is an important part of the future prosperity of the protected cropping industry in Australia. As an extension officer with NSW Agriculture my role is to facilitate this process. The Churchill Memorial Trust enabled me to undertake this study tour so that I could develop my own skills and knowledge in the area of protected cropping and extension in order to provide a better service to the Australian industry.

The extension of the information and learning that I have attained by this work, is an on-going process and will be integrated into every activity and role I conduct as a horticulturist in this industry. The Fellowship has added to my background knowledge of the industry and practices undertaken. In addition to this, I was invited to present a seminar on the study tour at the Australian Hydroponic and Greenhouse Conference, held on the Central Coast of NSW from 29 July to 1 August, 2001. This presentation was well received and I shall present another seminar for flower growers in Sydney in late October.

In the past month, I have been able to show over thirty growers (a total of around fifty visitors) through the demonstration greenhouses at the National Centre for Greenhouse Horticulture and my experiences and knowledge from the study tour have formed a significant part of this activity.

Based on my conclusions from the tour, I will be further developing the extension strategy of the protected cropping team to include the formation of crop study groups and build upon preliminary discussions that have been had concerning grower study tours.

## Itinerary

**May**

| | |
|---|---|
| Friday 11th | Depart Sydney |
| Saturday 12th | Arrive Stockholm |
| | |
| Monday 14th | Tour of city |
| Tuesday 15th | Travel to Skane region |
| Wednesday 16th | Tour Skane agricultural region |
| Thursday 17th | Travel to Malmo |
| Friday 18th | Travel to Gothenburg |
| | |
| Monday 21st | |
| Tuesday 22nd | Travel to Mora, in Dalarna |
| Wednesday 23rd | Tour Dalarna region |
| Thursday 24th | Tour Dalarna region |
| Friday 25th | Return to Stockholm |
| Saturday 26th | Depart Stockholm |
| | Arrive Amsterdam |
| Monday 28th | Travel to Ede, visit IPC training centre |
| Tuesday 29th | Aalsmeer flower auction |
| Wednesday 30th | Tour of greenhouses in Aalsmeer district |
| Thursday 31st | Travel to Den Haag |

**June**

| | |
|---|---|
| Friday 1st | Tour of Westlands region |
| | |
| Monday 4th | Tour greenhouses in Rotterdam |
| Tuesday 5th | Tour greenhouses in Hook Van Holland |
| Wednesday 6th | Tour greenhouses in Delft |
| Thursday 7th | Travel to Amsterdam |
| Friday 8th | Depart Amsterdam |
| | Arrive Frankfurt |
| | |
| Monday 11th | Depart Frankfurt |
| | Arrive Paris |
| Wednesday 13th | Depart Paris |
| Thursday 14th | Arrive Barcelona |
| Friday 15th | Tour of city |
| | |
| Monday 18th | Travel to Alicante |
| Tuesday 19th | Tour of greenhouses in region |
| Wednesday 20th | Tour of Alicante region |
| Thursday 21st | Travel to Murcia |
| Friday 22nd | Tour of greenhouses in Murcia |
| | |
| Monday 25th | Travel to Almeria |
| Tuesday 26th | Tour Almeria greenhouse region |
| Wednesday 27th | Tour greenhouses in Almeria |
| Thursday 28th | Tour greenhouses in Mazzaron |
| Friday 29th | Travel to Madrid |

**July**

| | |
|---|---|
| Sunday 1st | Depart Madrid |
| | Arrive London |
| Monday 2nd | Tour of city |
| Tuesday 3rd | Visit to Kew Gardens and Chartwell House, Westerham |
| Wednesday 4th | Tour of greenhouses in Littlehampton area |
| Thursday 5th | Visit Salisbury and Stonehenge |
| Friday 6th | Travel to Cornwall |
| Saturday 7th | Visit the Eden Project |
| | |
| Monday 9th | Tour of greenhouse in Somerset |
| | Travel to York |
| Tuesday 10th | Tour of greenhouses in Beverley |
| Wednesday 11th | Tour of Yorkshire Dales |
| Thursday 12th | Travel to Medmenham |
| Friday 13th | Potting plant nursery |
| | |
| Sunday 15th | Depart London |
| | Arrive Toronto |
| Monday 16th | Travel to Leamington |
| Tuesday 17th | Tour of greenhouses |
| Wednesday 18th | Tour of greenhouses and Harrow Research Station |
| | Travel to Niagara |
| Thursday 19th | Tour of greenhouses |
| Friday 20th | Tour of greenhouses |
| | Travel to Toronto |
| Saturday 21st | Depart Toronto |
| | Arrive Vancouver |
| Monday 23rd | Tour of BC Hothouse packing house |
| | Travel to Abbotsford |
| Tuesday 24th | Visit to flower auction, Burnaby |
| | Travel to Vancouver Island, tour greenhouses |
| Wednesday 25th | Tour greenhouses in Delta and Surrey |
| Thursday 26th | Preparation of AHGA conference presentation |
| Friday 27th | Visit to Whistler |
| Saturday 28th | Depart Vancouver |
| Sunday 29th | Arrive Sydney |
| | |
| Monday 30th | AHGA Conference, Gosford |
| Tuesday 31st | Presentation on Churchill Tour at AHGA conference |

**August**

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|---|---|
| Wednesday 1st | Official opening of the greenhouse complex at the National Centre for Greenhouse Horticulture |

## Publicity for Churchill Fellowship

"Crop Fellowship", *Central Coast Express Advocate*, July 19, 2000
"Study Tour of Duty", *The Land*, July 20, 2000
"Fellowship Opens the World to Horticulturalist", *Good Fruit and Vegetables*, Sept. 2000
"Churchill Fellowship for Institute Member", *Agricultural Science*, AIAST Journal, Vol 13:3, 2000
"Gaining Insights and Learning from Industry Developments Overseas", Conference presentation and proceedings, AHGA Conference, July 31, 2001