Know-how for Horticulture™

Development and extension of improved horticultural practices to increase profitability in the greenhouse cucumber industry

Leigh James
NSW Department of Primary Industries

Project Number: VG00081

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FINAL REPORT

HAL Project VG00081

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Development & Extension of Improved Horticultural Practices to Increase Profitability in the Greenhouse Cucumber Industry

Photo courtesy David Ellement

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Purpose of this Report

The purpose of this Final Report is to document the activities and achievements of the HAL funded Greenhouse Cucumber Extension Project which was designed to improve the communication of relevant, practical scientific outcomes and general industry information to Australian growers in order to improve their horticultural business profitability. Besides providing information on the greenhouse cucumber issues, and their outcomes, addressed by the project, this report also contains recommendations to enhance the future development of the national greenhouse cucumber industry.

Acknowledgements

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Disclaimer

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Media Summary

Industry significance

Although the national greenhouse cucumber industry is estimated by NSW DPI to be worth at least $100m per annum in on-farm production, the industry has largely not been aware of, nor readily able to access, best management information. However, this *Greenhouse Cucumber Extension Project* has assisted industry development by creating better industry networks; providing education and training opportunities; helping grower's access information on improved horticultural practices; and facilitating the dissemination of project outcomes.

Key components

Due to the complexity of establishing good linkages and networks in a demographically diverse industry, a three point strategy was adopted. This strategy achieved:

- The formation of effective relationships between research and development (R&D) providers and the State Vegetable Industry Development Officer's (VIDOs).
- The conduct of a range of extension activities such as grower days and workshops at the National Centre for Greenhouse Horticulture (NCGH) at Gosford and also on-farm, plus a series of interstate grower workshops.
- The development and improved availability of several, distinct sources of information on greenhouse cucumbers.

Underpinning and complementing this project was a research component conducted at NCGH. A series of seven consecutive demonstrations that featured crop and system management for Good Agricultural Practice (GAP) of greenhouse cucumbers was undertaken.

Key outcomes

- The National greenhouse cucumber and vegetable industries are now better linked and enjoy improved communication.
- Growers have access to a range of greenhouse cucumber and vegetable resources and training.
- Improved horticultural practices such as IPM, better greenhouse designs, hanging gutters or channels, and hydronic heating are being adopted by Australian greenhouse cucumber growers.

Clear conclusions

- Australian greenhouse vegetable growers were; a) unaware of the existence of much of the production information and resources already available to their industry, and b) thirsty for access to such information.
- Formal and informal surveys conducted at the start and during the project indicate that its objectives, in terms of developing and extending information about improved horticultural practices (GAPs) for growing greenhouse cucumbers and thus improving the industries profitability, have been met.

- The needs and skills of greenhouse cucumber growers across Australia are cyclic and not static.
- There is an on-going need to provide existing information on greenhouse cucumber crop production, as well as current and future R&D findings, through formalised extension channels because; a) many new, unskilled growers are regularly entering the industry across Australia and, b) many existing growers are making incremental improvements in their horticultural and business management which requires on-going professional guidance to competently reach the next level.
- Although other States, especially South Australia, are beginning to invest in greenhouse development and technology, NSW Department of Primary Industries is the peak government service provider to the National greenhouse vegetables industry because of its holistic greenhouse vegetables team of experienced R&D and particularly its extension specialists, whose services have been utilised for many years by growers across Australia and such demand continues to grow.

Future R&D recommendations

- R&D priorities should be given to investigating and promoting the compatibilities of various biological control agents with various chemical control options so that greenhouse cucumber (vegetables) IPM can be more flexible and adoptable.
- Integrated greenhouse cucumber crop production, hydroponic and greenhouse technology R&D under Australian conditions is comparatively new so ongoing R&D support, especially in areas such as nutrient solution, substrate management and (waste) water management, is needed to develop this relatively new but significant national industry.

Recommendations for practical application to industry

- State VIDOs continue to assist R&D providers and extension services with the provision of regular and on-going communication and technology transfer to the greenhouse cucumber (and vegetable) industry of R&D findings and crop production information in order to maximise production, minimise losses and maintain profitability.
- There is a need to determine the gaps in pesticide registrations and permits for the greenhouse vegetable industry in every State and ensure that, where practical, preference be given to seeking IPM compatible pesticide permits as soon as possible.
- Provide translated editions of existing and future extension materials and resources for Non English Speaking Background growers, particularly in Arabic and Vietnamese as these growers constitute a large proportion of the Sydney and Adelaide industries respectively.
- Unencumbered extension services, particularly with bilingual support, will be vital for Australian growers to be aware of, and adopt practical GAPs at different levels of greenhouse vegetable production.

Introduction

Greenhouse vegetable production is an important means of commercial horticulture and fresh food supply in most Australian States. It is seen as a good and future way to produce consistent quality, high yielding crops year-round whilst satisfying government regulation and community expectation about personal, environmental and food safety issues.

The modern Australian greenhouse industry is only 20 years old. Hence it is a relatively young and emerging industry and has its share of teething problems and impediments associated with new primary industries. Despite this, the industry in most States is a significant contributor to regional and State development and their economies through employment, service industries and crop sales. For example, in the Sydney region, the greenhouse cucumber industry increased six fold from 20 hectares in 1989 to 120 hectares in 1999 when it was estimated to be worth $30m per annum in on-farm production. It's estimated that there about 450 and 500 greenhouse vegetable properties currently farming in the Sydney region and Adelaide Plains respectively. The vast majority of them around Sydney are from Arabic backgrounds while around Adelaide they are Vietnamese, this requisites the need for translated extension materials and bilingual support at extension activities and training for effective adult learning.

NSW Agriculture has been proactive in conducting regular extension programs for greenhouse cucumber growers in the Sydney region since 1989, when development, of the mostly soil-based industry, was impeded by poor: nutrient disorder management; management of pests and diseases and, greenhouse design and environmental control. However the diversity of issues and needs that needed to be addressed required a holistic team approach to effectively service the burgeoning industry and overcome the impediments to its development. Thus in 1999, NSW Agriculture formed the first Australian Greenhouse Vegetables Team consisting of professional R&D entomology (pests and IPM), plant pathology (diseases) and extension expertise.

While it is generally regarded that the industry is expanding in most States, little hard evidence exists about what problems growers encounter and need resolution on. Further, where and how growers would like to source information on greenhouse vegetables is not clearly understood.

It is estimated that there are about 1800 greenhouse enterprises nationally. The largest numbers of farmers being on the north Adelaide plains in South Australia, and in the Sydney basin region of NSW. Currently the three fastest growing areas appear to be in northern Western Australia, around Brisbane and on the NSW mid north coast.

Background

Greenhouse horticulture is a technology based industry and the difference between structures can be substantial. A key indicator, therefore, of industry development is the level of greenhouse technology being used. Technology and greenhouse design has a big impact on productivity and environmental sustainability. It is important to recognise that expansion of an industry (in terms of size) does not necessarily equate to real development – though it is a key driver of development.

The higher the level of technology, the greater potential for achieving tightly controlled growing conditions. This capacity to tightly control the conditions in which the crop is grown is strongly related to the health and productivity of the crop and sustainability of production. Three classifications of greenhouse are described below.

The technology used plays a big part in the industry's value. As a guide, a hectare of a medium technology greenhouse vegetable operation (reasonable structures and some automation) can turn over between $0.5 – 0.75 million per annum. The lower technology end of the industry has a farm gate value of up to $0.4 million per hectare. The high end of the industry, using a high level of technology, can turnover $1 – 2 million per annum per hectare depending on crop and marketing arrangements.

1 Low technology greenhouses

Low technology greenhouses are less than 3 metres in total height. They generally do not have vertical walls. They have poor level of ventilation. This type of structure is relatively inexpensive and easy to erect. Little or no automation is used. These structures are usually clad with a single skin plastic film, however, the low profile glasshouses of yesteryear would also be in this category.

This sort of structure provides basic advantages over field production. Crop potential remains limited by the growing environment and crop management is relatively difficult. Low technology greenhouses generally result in a suboptimal growing environment which restricts yields and does little to reduce the incidence of pests and diseases. Pest and disease control, as a result, is normally structured around a chemical spray program.

Low technology greenhouses have significant production and environmental limitations, but they offer a cost effective entry to the industry.

2 Medium technology greenhouses

Medium technology greenhouses have an eave/gutter height of less than 4 metres and a total height usually less than 5.5 metres. They typically (though not exclusively) have vertical walls. This type of structure may have roof or side wall ventilation or both. Active air exchange may be used, particularly in the floriculture industry, but passive venting is most common for the vegetable industry. Medium technology greenhouses are usually clad with either single or double skin plastic film or glass and use varying degrees of automation.

Medium level greenhouses offer a compromise between cost and productivity and represent a reasonable economic and environmental benchmark for the industry. Hydroponic systems increase the efficiency of water use. There is greater opportunity to use non-chemical pest and disease management strategies but overall the full potential of greenhouse horticulture is difficult to attain.

3 High technology greenhouses

High technology greenhouses have a wall height of at least 4 metres, with the roof peak being up to 8 metres above ground level. These structures offer superior crop and environmental performance. High technology structures will have roof ventilation and may also have side wall vents. As with medium technology structures, active air exchange may be used, particularly in the floriculture industry, but passive venting is most common for the vegetable industry. Cladding may be plastic film (single or double), polycarbonate sheeting or glass. Environmental controls are almost always automated.

These structures offer enormous opportunities for economic and environmental sustainability. Use of pesticides can be significantly reduced and productivity substantially greater per unit area. High technology structures provide a generally impressive sight and, internationally, are increasingly being involved in agribusiness opportunities. This industry sector represents the future of intensive horticulture in Australia.

Proactive strategy

In the March/April 2000 edition of ***Practical Hydroponics & Greenhouses*** magazine (peak industry publication circulated nationally and international) a 6 paged article submitted by NSW Agriculture titled *Future Directions for the Australian Greenhouse Industry* featured. The introduction of the article states;

> "The greenhouse vegetable industry in Australia is less well advanced than in some other countries, particularly in the Northern Hemisphere. In some parts of Australia, existing greenhouse structures erected in earlier times would not be classified as meeting world standards. Some fall way short of this standard. However, Australia like some other countries previously, is now starting to look at improved design in greenhouse structures and effective climate control."
>
> "The State of NSW has the largest population in Australia, mainly concentrated in Sydney, and its greenhouse industry is going through a period of expansion and upgrading to meet the demand for quality, safe produce, from consumers and supermarket customers."
>
> "In NSW, two activities will be critical to the future prosperity of the greenhouse industry. These are a major investment in R&D by NSW Agriculture, as well as attempts to work closely with industry through a new Association for greenhouse vegetable producers. According to industry observers, if this effort should stumble, then the future for many NSW greenhouse producers will be bleak."

The article outlined NSW Agriculture's strategy to focus greenhouse vegetable R&D in Australia and the dissemination of information from R&D outcomes, or technology transfer, to growers throughout the country. It also introduced NSW Agriculture's Greenhouse Vegetable Team R&D and extension specialists, a team unique in Australian horticulture.

Putting the strategy into action

The first part of the R&D strategy involved commitment and investment by NSW Agriculture in new greenhouse capital infrastructure to develop a National Centre for Greenhouse Horticulture at the Horticultural Research & Advisory Station, Gosford, and to dedicate an R&D team to greenhouse vegetable industry issues. The NCGH was officially opened on August 1st 2001, becoming the largest greenhouse research facility in Australia at that time.

The development of the Australian greenhouse cucumber industry relies heavily on good communication of relevant, practical scientific outcomes and general industry information to growers. A need was identified by NSW Agriculture to provide a communication and technology transfer program supported by crop research trials aimed at assisting greenhouse cucumber growers to improve their competitiveness, production and profitability.
Hence the second part of the strategy was a 3 year holistic, multi-faceted HAL (HRDC) funded proposal to improve the competitiveness and profitability of the greenhouse vegetable industry. While the R&D represented a cooperative effort by the NSW Agriculture Greenhouse Vegetable's Team, and the R&D was conducted mainly in NSW to minimise costs, the keystone of the strategy was the dissemination of the R&D findings, and pertinent information generated, to the national industry via a wide-reaching and thorough extension program which included the State VIDOs.

Thus, this *Greenhouse Cucumber Extension Project* was established to assist industry development by creating better industry networks; providing education and training opportunities; helping grower's access information on improved agricultural practices; and facilitating the dissemination of project outcomes.

An article that summarised this project's strategy, linkages, outputs and outcomes was prepared and printed for the VEGE*notes* series in summer 2005.

Technology Transfer Strategy & Methodology/Activities

Strategy & Methodology

After consultation with industry leaders, growers and R&D agencies, NSW Agriculture developed a national R&D strategy for the greenhouse vegetable industries to address the broad range of needs of these industries and, in conjunction with the State VIDOs, communicate the outcomes to growers.

Due to the complexity of establishing good linkages and networks in a demographically diverse industry, a three point strategy was adopted. This strategy aimed to:

- Support effective relationships between research and development (R&D) providers and the State Vegetable Industry Development Officers (VIDOs). These relationships assisted growers by improving their awareness of and access to information about improved greenhouse cucumber horticultural practices.
- Undertake a range of extension activities to increase industry awareness of: R&D, sources of information and training opportunities and also extend existing information regarding good agricultural practices (GAP). These activities were also used to gather industry feedback on industry issues, needs and changes during the life of the project.
- Develop, and make available, distinct sources of information that offer growers opportunities for long-term further education.

Promoting Good Agricultural Practice (GAP) in Greenhouses

The 'Promoting GAP in Greenhouses' workshop program was an extension program targeting greenhouse cucumber growers conducted by Jeremy Badgery-Parker, Extension Horticulturist (Protected Cropping), NCGH. It was initiated, planned and managed as part of this externally funded national extension and communication project (VG00081). Good agricultural practice (GAP) is the basis of an economically and environmentally sustainable industry. To achieve this and facilitate effective dissemination of information and ultimately adoption, good linkages and networks are critical. These are a complex task in an industry as demographically and culturally diverse as the Australian cucumber industry. A three point extension strategy was adopted to initiate the building of better practices in this industry:

1. Support effective relationships between R&D providers and the State Vegetable Industry Development Officer's (VIDOs) to assist them in improving awareness and access to information about improved greenhouse cucumber horticultural practices.
2. Undertake a range of extension activities to increase industry awareness of research and development, sources of information and training opportunities as well as extend relevant information about aspects of good agricultural practices.
3. Develop distinct sources of information that offer long term opportunities to learn.

Within the framework of this strategy, the program involved planning workshop locations and topics based on direct communications with known growers from around Australia.

Then a schedule was developed to accommodate the work demands of professional staff involved. Thirdly a means of assessing the value of the workshops to the participants was devised. Finally the program was rolled out.

The extension program integrated the technical expertise and experience of 5 departmental staff – drawing from two other externally funded projects – and the national vegetable industry development officer network. Professional staff from Queensland, the Northern Territory, Western Australia and South Australia were also involved. The workshop program culminated in a collaborative award winning ('Best trade display') trade display at the national Australian Hydroponic and Greenhouse Association in Melbourne in July 2003.

The objectives of this program was i) to highlight and promote good agricultural practices in greenhouse cucumber production and ii) to capture feedback from the national industry regarding key issues and barriers to adoption.

The advisory program involved a number of workshops in New South Wales (5), Queensland (3), Northern Territory (1), Western Australia (2), South Australia (2) and Victoria (1) over a 12 month period.

Workshops ranged from 3 – 5 hours. Sessions covered integrated pest management, integrated disease management, general cucumber production, greenhouse and hydroponic production systems and getting into the greenhouse industry. In addition, several site visits were made to farms around the workshop locations.

Integrated and complementary strategies & methodology

Underpinning and complementing this extension project was a research component conducted at the National Centre for Greenhouse Horticulture (NCGH), Gosford. A series of prioritised demonstrations featured GAP for crop and system management in greenhouse and hydroponic cucumber production. The nature of these crop and system trials was determined after industry consultation and a literature review to identify gaps in knowledge and practice. They were conducted by Dr Sophie Parks, NCGH. Full reports of all these crop and system demonstrations and trials are presented in Appendix 2.

A unique aspect of this Greenhouse Cucumber Extension Project was its integration with two other concurrent HAL funded greenhouse cucumber research being conducted by NSW DPI at the NCGH at Gosford. These two projects were:

- ***Improvements to biological control systems and development of biorational chemicals for IPM in the greenhouse vegetable industry***, HAL project VG00066 (conducted by Dr Stephen Goodwin and Marilyn Steiner – NCGH)
- ***Integrated management of greenhouse cucumber and capsicum diseases***, HAL project VG00069 (conducted by Len Tesoriero – Elizabeth Macarthur Agriculture Institute).

Pest and disease management practices and outcomes from these two research projects formed an important part of a series of workshops held for growers across Australia.

Proposed and developed technology transfer outputs

The outputs that were stated in the project submission or put-in-place early on into the project to assist and enhance technology transfer were:

- To form a project steering committee, made-up of recognised industry identities from across Australia, to guide R&D priorities and technology transfer extension methodology.
- Conduct a National Greenhouse Vegetable Industry Benchmark Survey.
- Communicate results from R&D investigations into crop agronomy, physiology and IPDM in cucumber crops for all three projects, and conduct greenhouse cucumber demonstration trials at NCGH to assist industry adoption.
- Hold workshops for cucumber growers on greenhouse environmental management, IPDM, nutrient and hydroponic management, quality management and the 3 project findings.
- Prepare or utilise existing publications on nutrient disorders, diseases and IPM strategies for cucumber crops to assist growers identify production problems on-farm.
- Develop an industry list server and project webpage to help extend project materials nationally.
- Produce a best practice manual for greenhouse cucumber production which encompasses greenhouse management technology.
- Develop guidelines addressing environmental management issues for greenhouse crops.
- Initiate the production of greenhouse cucumber production planning guides.
- Develop costings of protected cropping systems for cucumber growers.

A seven point ***Extension Plan & Activities*** for the three HAL Greenhouse Vegetables Projects being conducted at NCGH was devised and accepted by the Projects' Steering Committee in February 2002 and subsequently sanctioned by NSW Agriculture's Horticultural Products Program. This Extension or Technology Transfer Plan became the blueprint to ensure the proposed outputs and outcomes came to fruition. At the time this plan was considered the first of its type for a project, certainly so for NSW Agriculture's Horticulture Products Program. The seven points covered;

- Printed articles and PR (in National and State industry magazines, newsletters etc – see the Bibliography),
- Workshops (IPM and, Disease ID & Management),
- Electronic Extension Tools (Web Pages and, List server – email chat room),
- National Industry Review (Industry benchmark survey at the start of the project) plus on-going or concurrent surveys and assessments,
- Grower Days/Farm Walks (At NCGH and on-farm),
- Cucumber Crop Demonstrations in the new *Harford Greenhouses Maxi-Span* square greenhouse (~500m^2) at NCGH and,
- Production of a Commercial Greenhouse Cucumber Production Manual at the completion of the project.

The flyers produced to advertise extension activities and training in the Sydney basin were produced in separate or combined English and Arabic versions – see Appendix 1. Another important facet of the extension strategy for greenhouse cucumber growers in the Sydney basin was to provide Arabic bilingual support at all extension activities and training sessions.

Ongoing evaluation of industry changes

The regular extension activities also provided an ongoing means to formally and informally assess the level and nature of industry change during the project and also, the impact and adoption attributable to this project, from the participants.

A) *Summary of Extension Activities*

A range of extension activities were undertaken throughout the project to increase industry awareness of GAPs for greenhouse cucumbers. Extension activities and training sessions conducted in the Sydney basin were held with Arabic bilingual support. Extension activities included:

- An initial benchmark survey of greenhouse vegetable growers established industry needs and goals. It also provided a forum for growers to voice their opinions on the industry.
- Feature articles outlining R&D activities appeared in national industry magazines such as *Practical Hydroponics & Greenhouses* and *Good Fruit & Vegetables* – see the Bibliography for details.
- Growers in Queensland, New South Wales, Victoria, South Australia, Western Australia and the Northern Territory participated in workshops which outlined the latest R&D outcomes for: improved pest and disease management; implementing Integrated Pest Management (IPM) programs; crop nutrient disorders; and greenhouse hydroponic cucumber production.
- An award winning display booth set-up by the NCGH team (encompassing all three projects) featured at the biennial Australian Hydroponics and Greenhouse Conference in Melbourne in 2003.
- In the Greater Sydney Region, a number of "Grower Days" were held at the NCGH, as well as on-farm, to provide growers with GAP information on IPM, diseases and nutrient disorders, automated greenhouse spraying, irrigation and substrate media, hydroponics and crop management. Flyers advertising these activities were produced in separate or combined English and Arabic versions.
- During 2002-03, the Project Team initiated a ***Greenhouse Water Use Efficiency Benchmarking Project*** in the Sydney basin. The main aims of this project were to improve greenhouse vegetable crops water use efficiency and benchmark existing industry practices. This work fed into and provided a delivery platform for the ***WaterWise*** and ***The Business of Greenhouse Hydroponic Vegetables*** courses provided by NSW Agriculture. This benchmarking work also assisted NSW Agriculture to help greenhouse vegetable growers in the Sydney basin provide Local Government with **Water Recycling Plans** for their properties.
- The meetings and workshops held across Australia provided a greater number of greenhouse cucumber growers with access to training and accredited courses. In NSW these courses included ***SMARTtrain*** (accredited AQF3 farm chemical training ~200 growers trained), ***WaterWise*** (~20), ***Freshcare*** (~25), ***An Introduction to Computers*** (~20), and ***IPM Basics*** which is also a module of a new package for greenhouse growers called ***The Business of Greenhouse Hydroponic Vegetables***

which is currently under development. These gatherings and activities also presented growers with the latest information on IPM and disease management practices as provided by the two dovetailed IPM and Disease Management Greenhouse Cucumber Projects. These activities also provided the platform to formally and informally gauge the level and nature of industry change during the project from the participants.

Extension Resources and Training Resources

Existing Resources

The project also involved promoting the availability and use of a range of existing resource materials to help growers get the best information possible. These resources included:

- ***Pests, Diseases, Disorders and Beneficials in Greenhouse Vegetables: Field Identification Guide***, NSW Agriculture, First Edition 2002, 140 pages.
- ***Integrated Pest Management in Greenhouse Vegetables: Information Guide***, NSW Agriculture
- ***Disease Management for Greenhouse Cucumbers***, NSW Agriculture, Agfact H8.3.4, First Edition 1999, 16 pages and,
- ***Nutrient Disorders of Greenhouse Lebanese Cucumbers***, NSW Agriculture, Agfact H8.3.3, First Edition 1998, 10 pages.

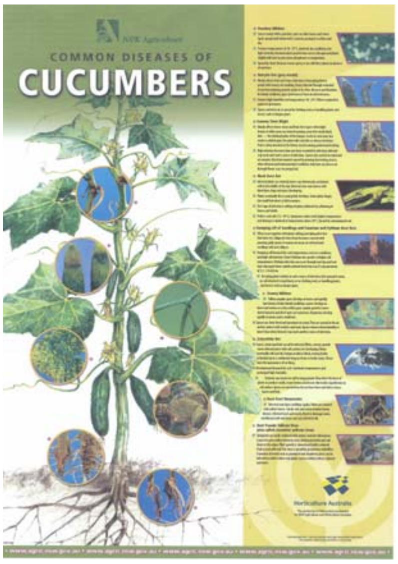
In September 1999, NSW Agriculture produced seven, First Edition, two page Agnotes about protected cropping. The titles were: ***Protected cropping***, ***The technology of protected cropping***, ***The greenhouse, Building a greenhouse***, ***Light in the greenhouse***, ***Covering materials*** and, ***Local government and environmental issues of greenhouses***.

New Resources

In addition to the greenhouse cucumber resources already available, several new resources relevant and useful for growers were developed. These included a comprehensive but easy to read ***Commercial Greenhouse Cucumber Production Manual***. At the time of writing this final report, the 180 paged draft version of the first edition of manual, prepared by NSW DPI's greenhouse vegetables extension specialists Jeremy Badgery-Parker and Leigh James, was being peer reviewed and refereed by selected peak growers, consultants and Rijk Zwaan a world leading Dutch greenhouse vegetables seed company. This review will ensure accuracy as well as relevance, practicality and comprehension in order for it to be recognised as the prime resource for Australian greenhouse cucumber growers.

This much anticipated resource will be available mid-2005 and will be free-of-charge to all levy paying greenhouse cucumber growers across Australia. The State VIDOs will help in the distribution of the bound manual. It is intended to revise the manual as required and to also include translated chapter summaries for Arabic and Vietnamese NESB growers, both concepts pending adequate future funding.

In addition to the manual, two up-to-date informative wall posters, entitled ***Common Diseases of Cucumbers*** and ***Common Pests of Cucumbers***, were produced in 2004 and forwarded to the relevant State VIDOs for distribution to greenhouse cucumber growers. The posters, set out below, are A1 in size and printed on synthetic rip resistant paper with fade resistant dyes. The posters are designed to provide growers with an on-farm pest and disease reference and they include information on Western Flower Thrips, as well as a new disease called Pseudo-Yellows Virus.



During the term of the three HAL greenhouse cucumber projects conducted at NCGH, three separate webpages were set-up on the NSW Agriculture Internet site and all three could be accessed at *Horticulture Australia Greenhouse Vegetable Projects* at www.agric.nsw.gov.au/reader/8187.

A national greenhouse vegetables email chat line, ***ListServe®***, was established with about 100 addressees and administered by NSW Agriculture. This service is still operational and has been regularly used by advisers, consultants, Associations and growers across Australia to post news and technical information.

While the use of the Internet and email is still relatively new to many growers, the technology has been utilised to provide an on-going opportunity for growers to network, communicate and source information. This resource, like the manual and posters, will continue to provide opportunities for growers to learn well beyond the conclusion of this project.

Besides being instrumental in the formation of **Greenhouse Vegetables NSW** in 2000, NSW Agriculture also provided secretariat support for the Association which included the production and distribution of a six monthly ***Members' Newsletter*** which contained Association and industry news, extension activities and training, technical information and, contacts.

The State VIDOs nominated this project as a **VEGE*notes*** priority article. A four page leaflet was finalised for publication in summer 2005.

Other complementary resources for greenhouse cucumbers and vegetables that were developed by NSW Agriculture in parallel during the term of this project include: ***Managing Waste Water with a Wetland***, ***Being Safe in the Greenhouse***, ***Guidelines for the Development of Controlled Environmental Horticulture – Striving for consistency, consensus and community***, and ***Industry Investment Opportunities - Greenhouse Horticulture - Protecting Your Investment***.

B) *Summary of all greenhouse cucumber crop R&D trials conducted at the NCGH*

The following summarises the seven greenhouse cucumber R&D crop trials conducted at NCGH that were a component of this project from July 2001 until December 2003. The selection and priority of the nature of the crop trial investigations were based on industry needs, issues and gaps determined during regular consultation with industry and growers, a literature review and natural R&D progression. The findings or outcomes of these crop trials have been extended and promoted at relevant industry conferences, workshops, grower days and via National industry publications. Full final reports of these crop trials are presented in Appendix 2.

Title: Effect of greenhouse environment and system on plant growth and yield July – September 2001
Aims: To gain experience growing greenhouse cucumbers, compare Run-To-Waste (RTW) and Nutrient Film Technique (NFT) systems of production, and measure the environmental uniformity of the new square greenhouse at NCGH.
Outcomes: First crop grown successfully. The new greenhouse did not produce uniform growth of cucumber plants presumably due to greater light levels in the northern end of the greenhouse. The total fruit count and fruit weight was not significantly different between growing methods, although the NFT yields were far less variable than the RTW yields.

Title: Effect of pruning method on crop productivity
September – December 2001
Aim: To compare the effect four different pruning systems (conventional umbrella, minimal pruning, unconventional excessive pruning and, conventional twin heading) has on fruit numbers and weight.
Outcomes: Twin-heading and minimal pruning yielded the greatest fruit count and weight. However, this result would need to be tested with more experimentation as this crop was confined to one row of the greenhouse. Twin-heading and standard pruning systems require greater labour for harvest. Excessive fruit load left plants prone to disease while non-yielding plants were more tolerant of disease. NFT plants became infected with *Pythium* and eventually died.

Title: Effect of growing media on cucumber production and quality
March – July 2002
Aim: The aim was to compare five substrate types (coir, sawdust, perlite, rockwool and soil conditioner) in the production of a winter cucumber crop.
Outcomes: This project demonstrated that a range of substrates can be successfully used in cucumber production. No differences occurred in growth (marketable fruit number and weight) or in fruit quality among treatments. The more organic substrates, soil conditioner, sawdust and coir were more attractive to fungus gnats in this experiment.

Title: Effect of nutrient solution concentration on cucumber yield and growth
September 2002 – January 2003
Aim: This autumn/summer crop was used to investigate the effect of different concentrations of nutrient solution 1, 2, and 3 dS/m on cucumber crop growth and production.
Outcomes: This cucumber crop was not affected by different concentrations of nutrient solutions. This demonstrates that lower concentrations of nutrients, than that typically used for greenhouse cucumbers, can adequately support crop production without excess nutrient runoff from greenhouses or the extra expense in fertilisers.

Title: Aging coir and sawdust media effects on cucumber crop growth
May – September 2003
Aim: This project aimed to investigate the effects of aging on sawdust and coir media and cucumber crop production. Media aged up to 11 months in previous crops was used in this experiment.
Outcomes: Crop growth in terms of marketable fruit number and weight was not different among treatments. However, aging significantly affected physical qualities of growing media. Water holding capacity increased, and air filled porosity decreased, with time, particularly sawdust. Coir tended to have greater stability over time. This project demonstrates the variability of media over time. Growers need to assess media to derive irrigation strategies for every crop planted. Protocols for assessing media are being developed.

Title: Additives and nutrient solution strength effects on greenhouse cucumbers
June – December 2003
Aim: During this winter/spring cucumber crop additives, claiming to enhance crop nutrition, available on the market were investigated. Mycorrhizal fungi (applied to coir growing media), and, fulvic acid (applied through irrigation), were used as treatments on underfed cucumber plants.
Outcomes: These particular crop additives did not enhance crop nutrition even under nutrient stress for this cucumber crop. A presentation on the recommended approach to testing new nutritional products for greenhouse crops was given to growers by Dr Sophie Parks at the Hydroponic Farmers Federation Conference, Bendigo, July, 2004.

Title: The effect of over supplying a cucumber crop with nutrients
June – December 2003
Aim: The aim of this winter/spring cucumber crop was to demonstrate that inaccurate supply of nutrients, in this case oversupply, can limit crop productivity. Cucumber plants were grown in independent units (Autopots), supplied with either a normal or high concentration of nutrient solution within the greenhouse.
Outcomes: Overfed plants, although they appeared healthy for the first few weeks, had a lower average of total fruit weight than those fed a normal nutrient concentration. Overfed plants were greener in terms of chlorophyll content but suffered marginal burn on lower leaves. This problem often occurs when the same media is used for several crops, gradually building up excess nutrients. This experiment demonstrated the adverse affect of this type of practice on production.

Evaluation & Measurement of Outcomes - Impact & Adoption

Expected outcomes

The outcomes anticipated from undertaking this project as stated in the project submission were:

- A greater degree of information transfer and industry education.
- Improved productivity and profitability through the adoption of better technology and crop production practices.
- A reduction in pesticide use and crop residues.
- Improved pest and disease management in cucumber crops grown in protected structures.
- Fewer environmental concerns regarding protected cropping enterprises.
- Growers better informed on improved crop production and crop protection opportunities and technologies, and
- The development of the biocontrol industry in Australia.

Evaluations and measures

Three forms of evaluation were constantly conducted during this project to objectively measure the level of change or impact and adoption of both its messages and technology transfer strategy in order to gauge the magnitude and significance of the outcomes. These included; a) findings of a National benchmark survey conducted at the start of the project to record the existing greenhouse cucumber status quo, b) a written evaluation of the field days and workshops conducted as part of this project were sought from growers and, c) formal and informal feedback and observations made by industry representatives and growers as individuals and in group activities. A fourth subjective method drew on observations made by the professional field staff of NSW DPI's Greenhouse Vegetables R&D Team. The highly experienced professional field staff members of this team were also constantly observing changes in individual grower and industry knowledge and practice during the course of this project.

Evaluation of National greenhouse vegetables surveys & industry change

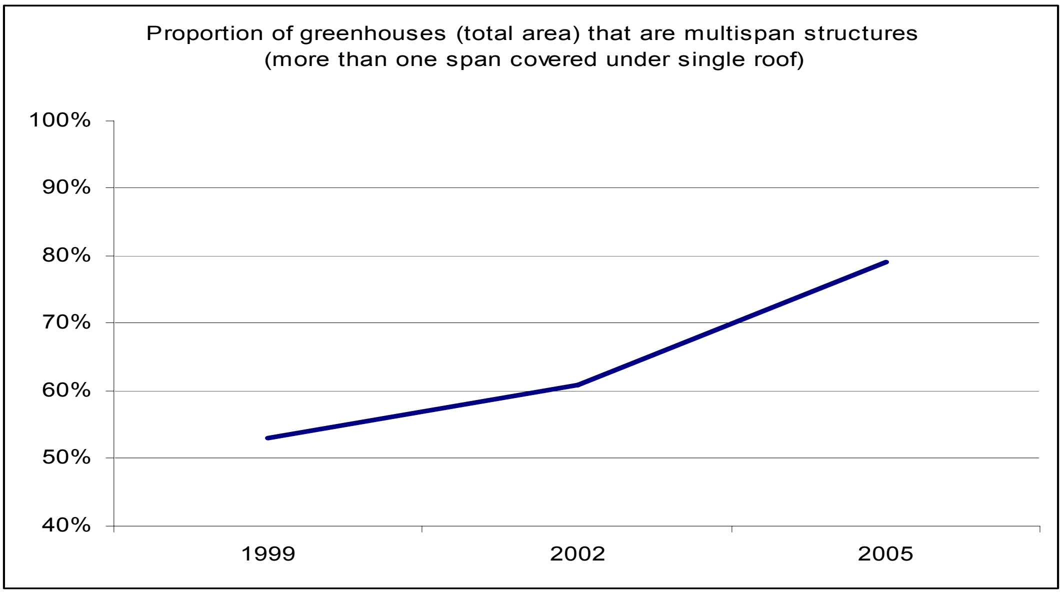
A grower survey was conducted in 2002. This survey provided an important opportunity to establish better information about the greenhouse industry. It essentially generated a small snapshot of where the industry was in late 2001, early 2002. The survey response rate was only 7% so it can only be relied on to provide a general picture of the industry. Data compiled by NSW DPI in 1999 and 2005 is a collation of information derived from various sources and extension activities. The information from these three periods is relatively consistent and we hold a degree of confidence in it being a fair representation of the industry. A scoping study, which was largely a desk-top survey, commissioned by HAL and undertaken by Cardinal Horticultural Services (T. Biggs) in mid 2004 provided another perspective. The results of this study are in line with our summation of the Australian greenhouse vegetable industry.

At the end of 2004, the greenhouse industry is irrefutably undergoing change. There are several recognisable drivers of this change and potentially a few hidden change agents.

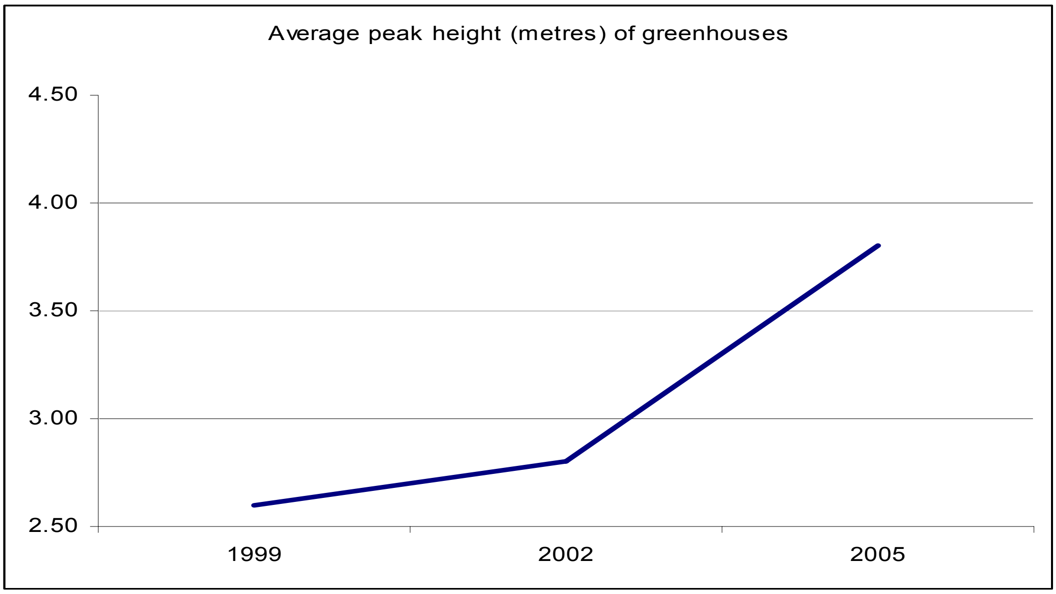
Industry expansion and technology

In 2002, there were an estimated 1200 hectares of greenhouses in Australia, producing some $300m worth of vegetables each year. Almost three quarters of these greenhouses were low technology structures with most of the remainder being medium technology. There are now approximately 1350 hectares of greenhouses used for vegetable production. The proportion of low technology structures has fallen to around 60% of the total area. Medium technology greenhouses make up close to 30% and the remaining 10% are high technology greenhouses.

The construction of multispan greenhouses is an important indicator of improved greenhouse technology. Though a multispan structure is not necessarily higher technology, they are closely linked to improved production systems including venting capacity and heating, automation and specialised screens. The shift towards multispan greenhouses has increased rapidly in the past three years. The most prominent exception to this is in South Australia where new multispan greenhouses are low profile and fundamentally remain low technology structures.



The height of a greenhouse is a significant indicator of its potential performance and is a key criterion of technology level. Over the last couple of years there has been a noticeable move towards taller greenhouses. This is closely linked with the trend to multispan greenhouses which tend to be taller (except in South Australia). Greenhouse height has also been consistently promoted through extension programs which are arguably one of the drivers of this trend.



The average Australian greenhouse enterprise currently manages approximately 6000 m^2, up from around 5000 m^2 in 2002. This may reflect the economic benefit of economies of scale in greenhouse horticulture as well as the recent rapid growth in relatively large high technology greenhouses. The shift towards multispans is also likely to be a contributing factor to larger greenhouse production areas due to reduced construction costs and greater land use efficiency.

In low technology operations, the average farm is closer to 7000 m^2. While many medium technology operations cropped an average of 2000 m^2 in 2002 (mostly new industry entrants with turn-key operations), redevelopment and upgrading of existing low technology farms in NSW has moved the average medium technology enterprise towards the 5000 m^2. The consistent and on-going promotion of using better technology greenhouses undertaken in the Sydney basin region through extension programs is undoubtedly one of the key drivers of this change.

Cropping

The biggest group of growers (45%) produce one tomato and one cucumber crop per year. Specialised cucumber growers (28% produce only cucumbers – 2 or 3 crops per year) marginally exceed specialised tomato growers (19% producing 2 tomato crops per year) and almost 7% of greenhouse growers produce a single tomato crop (long crop) per year. The remaining 1% of growers produce other crops including capsicum, eggplant or herbs.

Industry value

From a farm gate value of some $200m per annum in 1999, the industry was estimated to be worth close to $300m in 2002. Today, the Australian Hydroponic and Greenhouse Association (AHGA) estimates their industry to be worth some $600 million per annum. Our own estimates (based on the area of production and average wholesale prices) value the industry in 2004 at up to $728m per year – made up of cucumbers ($214m), tomatoes ($507m) and other crops ($6.5m), though valuation of the cucumber industry when estimated on total market throughput, rather than production area is closer to $130m per annum. This large discrepancy illustrates the paucity of hard data available. It also indicates that average crop yields may be significantly lower than current expectations and that there is a much more critical need for expenditure on extension and training in greenhouse horticulture for the industry to develop to its potential. One certainty, however, is that the industry is getting bigger in value terms.

Industry demographics

The industry is relatively young in experience. The average grower has just 7 years experience in greenhouse horticulture. Eighty-five percent of growers plan to still be in the industry in 2015. This highlights the need for practical skills development in this industry. Over 70% of growers in the industry were born overseas.

Information and communications

Just under half of respondents are members of an industry association. While this means that almost 1 in 2 growers can be reached through their association, getting new information to a significant portion of the industry is more difficult.

Information about the management of greenhouses is predominantly obtained from greenhouse suppliers, followed by grower meetings. Other growers, consultants and publications are the next most common source of information. Overall, growers find it difficult to access relevant information on greenhouse management.

Pest and disease management information is easier to access and is mostly obtained from chemical resellers. Approximately two thirds of growers are happy with the quality and quantity of information provided. This is an interesting benchmark as more recent information (2004) from NSW indicates that growers are increasingly unhappy with pest management and pesticide use information from chemical resellers. Dissatisfaction is related to greater awareness of registrations (or lack of) in particular to greenhouse use as well as a greater interest in IPM and subsequently fewer appropriate products.

IPM, itself, is widely accepted as being a “good thing” but adoption is very limited.

Publications and consultants and other growers are commonly used sources of information on pest and disease management.

Nutrient management is a critical area for both productivity and pest and disease management. A wide range of information sources are used. The majority of growers are happy with the quantity and quality of the information received though 35% of respondents indicated that they have regular problems with plant nutrition. Private consultants are the primary source of information on nutrient management.

Almost all greenhouse growers (except in South Australia) use hydroponics. Of these, 70% use substrate culture systems. Sawdust, cocopeat and rockwool are the most common substrates used. Information about the management of hydroponic/irrigation systems is mostly obtained from resellers though a lot of growers get their irrigation advice from other growers.

On general production issues, the industry is fairly evenly split between whether information is easy or difficult to find. However, growers overwhelmingly request better access to information on good practices in all areas. This suggests that there is significant room for improvement in accessing information and may be a reflection of the level of association membership. The most accessible method of communicating to industry is through the industry magazines (*Practical Hydroponics and Greenhouses* and *Good Fruit and Vegetables*), association newsletters and extension workshops.

Impact and Adoption – what has changed

Recorded observations of industry change made by industry representatives and advisers, and frontline NSW Agriculture staff during the period of the project include;

- Australian greenhouse cucumber growers are now far better aware of where to seek information on; crop production, greenhouse and hydroponic system management, disease diagnosis, biocontrol agents and their management, assessing the need for & obtaining pesticide permits and, crop nutrient disorder symptoms.
- There has been a steady increase in the number of greenhouse cucumber growers across Australia submitting disease specimens for laboratory diagnosis by NSW Agriculture.
- There has been a steady increase in the number of growers across Australia requesting information on, and ordering of biocontrols for the control of insect pests in greenhouse cucumber crops.
- Before the commencement of this project it was quite common, particularly in the Sydney basin and Adelaide Plains, for greenhouse growers to misread nutrient disorders as diseases and treat them with fungicides. However, growers are now aware of a) on-farm visual aid resources, and b) diagnostic services, that are available to expedite an appropriate corrective measure that will minimise crop losses.
- Compared to its infancy when it was dominated by soil based production, the industry is now virtually completely soilless or hydroponically based.
- Over recent years there has been a definite trend away from low technology poly tunnel house structures to mid technology multi-span greenhouse structures. Its estimated by NSW DPI that low technology greenhouses now represent 61% of greenhouse structures in NSW.
- Over recent years there has been a definite swing from fan forced heating to boiler (hydronic) heating of greenhouses, particularly in the Sydney basin.
- There has been an increase in the number of Biological Control options utilised by Australian greenhouse vegetable growers. Low to mid technology growers, particularly in the Sydney basin, have released the fungus gnat predatory mite *Hypoaspis*, and *Steinernema feltiae* which is an entomopathogenic nematode for fungus gnat control.
- There has been an increase in the number of greenhouse vegetable growers using sticky traps to monitor pest and beneficial insect numbers.

Written grower evaluations of project field days & workshops

Formal grower evaluation of the first ***Greenhouse Cucumber Growers Inspection Day*** held at NCGH on December 19th 2001. About 20 growers from low to medium technology enterprises attended and were presented with information on; The Control of Western Flower

Thrips and Other Greenhouse Insect Pests, Greenhouse Cucumber Disease Management Strategies, R&D Crop Trials & Cucumber Crop Management Practices, and the Wetlands Project. A random sample of the growers present were asked to complete a formal evaluation sheet which contained 11 questions. Their responses to key questions were:

- *The amount of information presented was*; 80% assessed it as good while 20% assessed it as excellent.
- *The quality of the information presented was*; 80% assessed it as good while 20% thought it was excellent.
- *The interest value of the information presented was*; 80% thought it was good while 20% thought it was excellent.
- *The relevance or usefulness of the information presented was*; 60% assessed it as being good while 40% thought it was excellent.
- Although 100% of respondents said they would recommend the format of the Grower Day to other growers as a good means of getting information on greenhouse cucumbers, 40% suggested Fact Sheets as an alternative means of effectively communicating such information while 60% stated that practical workshops were also an effective and desirable way of disseminating information to growers.

Formal grower evaluation of the ***Greenhouse Vegetables IPM Scoping Workshop*** held in Bundaberg, 9th March 2004. About 20 growers from mid to high technology enterprises participated in this workshop and 15 completed the formal evaluation sheet which contained 17 questions. Their responses to the key questions were:

- *The information presented was relevant and useful*; 47% strongly agreed while another 47% agreed.
- *Not enough information was provided*; 47% strongly disagreed while the other 53% disagreed.
- *Do you think you will use what you have learned?* 40% strongly agreed, 33% agreed while 20% were impartial.
- *Did the workshop cover the topic fully?* 20% strongly agreed, 33% agreed while 47% were impartial.
- *This workshop will help my farm business/work*; 33% strongly agreed while 60% agreed.
- Of the volunteered written comments, 66% said they liked the sections on Biological Control and pesticide compatibilities with IPM the best.

Formal grower evaluation of the ***Greenhouse Cucumber & Capsicum Disease & Nutrient Management Workshop*** held in Perth (Baldivis), 4th May 2004. About 20 growers from mid to high technology enterprises participated in this workshop and 18 completed the formal evaluation sheet which contained 17 questions. Their responses to the key questions were:

- *The information presented was relevant and useful*; 33% strongly agreed, 22% agreed while 44% were indifferent.
- *Not enough information was* provided; 11% strongly disagreed, 78% disagreed while 11% were impartial.
- *Do you think you will use what you have learned?* 17% strongly agreed, 61% agreed while 11% were indifferent and 11% disagreed.

- *Did the workshop cover the topic fully?* 17% strongly agreed, 28% agreed while 44% were impartial and 11% disagreed.
- *This workshop will help my farm business/work*; 33% strongly agreed, 44% agreed while 17% were indifferent and 6% disagreed.
- Of the volunteered written comments, 50% said they liked the sections on Disease Management the best, while the other 50% said they preferred the section on nutrient disorders.

Other formal evaluations of project workshops by Australian greenhouse cucumber growers – Promoting Good Agricultural Practice (GAP) in Greenhouses program

Evaluation of the workshop program was conducted. The primary assessment tool used to gauge impact of the workshop program was the development of feedback forms and their use at each workshop.

Participants were asked for feedback on the content of the workshops, the presenter and some general aspects of the workshops. Growers are asked to grade the workshops on a scale of 1 – 5 against a range of questions. An overall group assessment of each workshop is obtained in terms of mode and mean scores (as a score out of 5). Where questions are reversed, the scores are as well. For workshops conducted in Sydney with growers from an Arabic speaking background, the feedback sheet was double sided with Arabic and English. The overall results of some workshops are presented as examples.

TITLE	LOCATION	PRESENTER	MODE	MEAN
Greenhouse and hydroponic production	Bundaberg	J Badgery-Parker	4	3.93
Comments:	Best part was general discussion sessions where growers could ask about a range of issues and get answers rather than specific information areas			
Greenhouse and hydroponic production	Darwin	J Badgery-Parker	5	4.37
Comments:	Want more general Q&A sessions on all aspects of greenhouse production			
Introduction to hydroponics	Sydney	J Badgery-Parker	5	4.44
Comments:	Need more repetition of key information and more courses please			

Assessment of the overall impact of the program on industry has not yet been determined, however, some industry changes which can be linked to this program include the development of a greenhouse growers' group in Bundaberg (Queensland) who now meet a few times per year. This group did not exist prior to the extension program and its inaugural meeting was as a result of the workshop program. Facilitation of this group is now undertaken by the Queensland vegetable industry development officer. Building the IDO network with the greenhouse industry was a key objective of the extension strategy. A similar situation has been achieved in Western Australia.

In NSW, the primary outcome of this program has been the opportunity to refine and implement a more targeted workshop program for Sydney based growers which meets their specific needs.

Specific workshop impact evaluation in the Sydney region

Following is an evaluation, made in March 2004, of two workshops on monitoring and using sticky traps for Arabic greenhouse vegetable growers in the Sydney region conducted by Jeremy Badgery-Parker with bilingual support from Basem Al-Khawaldeh

The majority of greenhouse growers in the Sydney Basin feel they are not able to use or adopt IPM. Typical responses to IPM in the past have been “we can’t do it” and “our greenhouses are not good enough”. This belief is mostly due to a lack of knowledge about what IPM encompasses. It is also a result of information about IPM that they have received in the past which has confused or given the perception that “IPM” is too complex for them and requires large changes in practice, for example, new structures.

In order to address these perceptions and develop a more receptive attitude to IPM, a workshop was held on the basic elements of monitoring and sticky traps as part of the current greenhouse and hydroponics extension program. The intention of the workshop was to develop awareness of some of the basic components of IPM, begin to break down some of the resistance/hesitation growers hold regarding IPM, demystify the concept and impart some useful farm management skills.

Two grower groups attended the workshops (total of 24 growers). Before the workshop, growers were asked to define IPM and to relate their view on how hard it is to adopt and whether they thought they needed to adopt IPM.

In the first group, 8% could provide a reasonable definition of IPM. No growers in the second group could define IPM. After the workshop, 92% in the first group (someone wasn’t paying attention!) and all of the second group could give a reasonable explanation of IPM.

When asked how difficult they felt IPM would be to learn, two thirds of the growers in group 1 and 90% of group 2 felt it would be very difficult. Following the workshop which showed them a couple of basic elements – monitoring and the use of sticky traps – two thirds of growers felt that they would be able to learn and adopt IPM as a management practice. Eighty six percent felt more comfortable with what IPM involved. This is a very good result indicating that basic exposure in an appropriate format has been useful in reversing some of the negative perceptions the growers have developed.

The value growers place on IPM as a necessary part of their business management was also improved by this approach of demystifying the concept. Prior to the workshop, half of group 1 and just 10% of group 2 felt IPM was necessary. Following the workshop, 92% and 70% of group 1 and 2 respectively thought that IPM was something they should adopt. This is a very promising outcome. It indicates that the workshop that was delivered has gone someway to changing the growers’ perceptions. This is the first step in developing an active interest in training and adoption of IPM practices.

On the workshop itself, growers were asked whether the workshop helped them to better understand the concept and whether they were more interested now in pursuing training in

IPM. Sixty to 80% of the growers feel that the workshop focussing on a couple of the basic parts of IPM, made the whole concept a little easier to grasp. This level of change corresponds to the change in perception about how hard IPM would be to learn.

The workshop had a positive impact in developing interest in IPM training which is expected to be manifested in demand in the near future. Approximately 90% of the growers are now interested in practicing IPM. Almost all growers (100% and 90% for groups 1 and 2 respectively) were encouraged by the workshop and feel that IPM is something which they will be able to learn and start to use. Though not quite as many, a high proportion of growers (81%) claimed to be motivated by the workshop to learn more about IPM.

In terms of delivery, in group 1, two thirds of the growers said they would like IPM training in the same format being used in the current extension workshop program, while the remainder would like it delivered a day a week. Group 2 is evenly divided between these two delivery options.

The basic strategy of the workshop hydroponic/greenhouse extension program (which is currently focussing on water management in line with the Waterwise courses being delivered) is to deliver short, practical workshops on farms to small grower groups. Each workshop directly addresses just 1 or 2 key points/skills and provides practical action that a grower can take following the workshop. Additional transferable skills, like record keeping are also being targeted in the workshops as is awareness and general information exchange.

Discussion

The January 1992 edition of ***Good Fruit & Vegetables*** carried the front page feature, *Greenhouse Vegetables – What future for Sydney industry?* Inside Tony Biggs wrote a 5 page Enterprise Of The Month article on the industry. Besides writing about the past history, the article also delved into the opportunities and impediments of the industry at that time. In summary the future viability and expansion of the industry was seen to be reliant on;

- The installation of better design technology greenhouses which would offer greater environmental control resulting in higher and more uniform year-round crop production
- Growers gaining a better understanding of the options and how best to manage pest and disease problems
- The need to develop biocontrols in the face of increasing insecticide resistance problems and the scarcity of chemical control options
- The need to breed and introduce commercial disease resistant or tolerant greenhouse cucumber varieties
- A move to soil-less culture to overcome increasing soil-borne disease problems and seasonal crop production variations, and
- Growers improving their knowledge and management skills of greenhouses and hydroponic systems

The final point, but probably the most important that was not made and should have been mentioned regarding the viable future of the industry, was the need for formal on-going R&D to be coupled with existing extension or technology transfer programs to holistically address the industry impediments, gaps and needs identified in the article.

The Australian greenhouse cucumber industry is a relatively young and emerging industry, and as such, has had a myriad of teething problems associated with its development. NSW Agriculture was not only aware of the importance but also the impediments of the emerging greenhouse vegetables industry, so in 1997 they appointed an Extension Horticulturist for Protected Cropping to Gosford.

Although NSW Agriculture has been conducting regular extension programs and activities for greenhouse cucumber growers in the Sydney region since 1989, it was due to the rapid expansion of the industry in the late 1990's still being dogged by impediments recognised by NSW Agriculture and supported Tony Biggs that NSW Agriculture formed its specialists Greenhouse Vegetables R&D and Extension Team in 1999.

It is because of both the R&D and technology transfer needs, that were considered to be common across greenhouse cucumber production areas in Australia, that in 2000 NSW Agriculture successfully submitted the three pronged integrated greenhouse cucumber projects covering biocontrols & IPM, disease management and extension to Horticulture Australia Ltd.

NSW DPI's ongoing commitment to the Australian greenhouse industry is reflected by the fact that once again it is the only State DPI sponsoring (silver) the Australian Hydroponics & Greenhouse Industry National Conference, which is being held in Bundaberg in July 2005.

Conclusions

The recent NSW DPI surveys show that at the end of 2004 the Australian greenhouse industry is still an immature industry with great growth potential. It is still based on low technology structures and basic practices but a dramatic development towards a highly productive, sustainable industry using the best technology and better farm practices has occurred in the past couple of years. Since 2002, the greenhouse vegetable industry has under gone significant growth and change.

The industry is expanding at between 3 – 6% per annum. Access to capital and limitations on industry skills continue to constrain development. New entrants tend to either be low budget low technology producers or they invest significant amounts in high technology facilities. In the existing industry there is substantial investment in better technology but a weakness in greenhouse management skills remains. Information which was mostly obtained from product suppliers is now increasingly being sourced from other areas. There is an overall demand for better information on good greenhouse practices.

This project has changed and benefited the Australian greenhouse cucumber industry because:

- The relationships developed between R&D providers and the VIDOs assisted growers by improving their awareness of and access to information about improved greenhouse cucumber horticultural practices. This has led in part to some of the changes listed on page 22.
- The extension activities increased industry awareness of: R&D, sources of information and training opportunities, and also
- The development and improved availability of information about greenhouse cucumbers offers growers opportunities for long-term further education.

This project has not only established better access to commercial greenhouse cucumber production information and met the expected outcomes, it has also helped industry members gain a better understanding of Industry roles, needs and opportunities. For example, greenhouse cucumber growers now have a better;

- knowledge of the AusVeg Levy,
- understanding of the pesticide permits process, and
- understanding of the need to promote R&D priorities.

The development of good relationships and industry linkages has enabled growers around Australia to meet researchers, learn about what they do and gain an understanding of R&D and how it improves greenhouse cucumber practices and profitability.

Recommendations

Formal and informal grower and industry feedback gathered during the course of this project has provided the basis for the following R&D and extension or Technology Transfer recommendations.

Key areas of research and development identified include:

- Practical application of integrated pest and disease management strategies to farm situations
- Improving and defining greenhouse design and technology, including covering materials to optimise production under Australian conditions
- Crop nutrition and fertiliser management in hydroponic production systems to optimise production under Australian conditions
- Improving and defining hydroponic growing substrates and management practices to optimise production under Australian conditions
- Developing better chemical application methods and registrations for greenhouse and hydroponic production systems
- Water management and improving water efficiency
- New crop development
- Improving energy efficiency
- Development of crop specific growing guidelines for controlled environment crops
- Improving labour efficiencies in key operations such as pollination, pruning and harvest

In extension and industry development, key areas include:

- Extension and training to facilitate adoption of Good Agricultural Practices (GAP) including horticultural and business practices, environmental performance, quality assurance, IPM and OH&S
- Developing and delivering high level, practical based training of greenhouse managers for the Australian industry
- Delivering basic production skills extension and training for greenhouse operators and workers
- Facilitating implementation of benchmarking greenhouse and business practices
- Facilitating grower study tours to enhance assimilation of international best practices
- Facilitating adoption of improved technology and production systems
- Improved industry marketing skills and practices
- Industry communication and access to information
- Providing translated extension materials, particularly in Arabic and Vietnamese for these important sectors of the Australian greenhouse cucumber and vegetables industry
- Regular, periodic revision and up-dating of the *Commercial Greenhouse Cucumber Production* manual with at least Chapter summaries in Arabic and Vietnamese
- The development of a GAP Greenhouse Cucumber/Vegetables DVD which should be at least partly useable in Arabic and Vietnamese

A final remark is that the need for widespread and regular benchmarking of the greenhouse industry is paramount for its sustainable development. Benchmarking is necessary to ensure the right information can be provided in a timely manner and to ensure that investment dollars in technology and R&D are spent wisely.

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- ***NCGH - Helping Greenhouse Horticulture to Grow.*** *WA Grower*, p29, May 2003.
- ***Activity Update - National Centre for Greenhouse Horticulture.*** *Soilless Australia*, p6, July 2003.
- ***Best Exhibit – NCGH, AH&GA Conference.*** *Good Fruit & Vegetables* magazine, p46, September 2003.
- ***National Centre for Greenhouse Horticulture advisory committee.*** *Good Fruit & Vegetables magazine*, p58, November 2003.
- ***Nutrient disorders of greenhouse Lebanese cucumbers.*** *Soilless Australia*, pp 8-15, Issue 2 2004.
- ***Cucumber pest & disease posters available.*** *Good Fruit & Vegetables* magazine, p40, August 2004.
- ***WA: Boost for greenhouse growers.*** *Good Fruit & Vegetables* magazine, p37, August 2004.
- ***Advancing greenhouse horticulture with training and technology***. *Good Fruit & Vegetables* magazine p50, September 2004.
- ***Chinese growers visit Gosford site.*** *Good Fruit & Vegetables* magazine, p62, September 2004.
- ***Greenhouse Hydroponic Horticulture in NSW***. *Practical Hydroponics & Greenhouses* magazine, pp 41-45, January/February 2005.
- ***Sydney Basin greenhouse sets standard***. Enterprise Of The Month, *Good Fruit & Vegetables* magazine, pp8-11, February 2005.
- ***Greenhouse leaders set R&D priorities***. *Good Fruit & Vegetables* magazine, p14, February 2005.

- ***New booklet on greenhouse safety.*** *Good Fruit & Vegetables* magazine, p15, March 2005.
- ***2005 National Conference of the Australian Hydroponic & Greenhouse Industry***. *Practical Hydroponics & Greenhouses* magazine, p14, March/April 2005.
- ***Greenhouse Cucumber Extension Project***. VEGE*notes*, 4 pages, Summer 2005.

Articles in NSW industry publications

- ***Greenhouse sets new standards when growing vegetables***. The District Reporter, p3, December 1st, 2000.
- ***Green Growing – Greenhouse growers get together.*** The Land, p21, January 4th, 2001.
- ***NSW Vegetable Industry Needs Workshops.*** *VegeLink NSW*, p2, September 2001.
- ***Greenhouse Cucumber Inspection & Spit Roast BBQ.*** *VegeLink NSW*, p2, December 2001.
- ***New Committee for Greenhouse Vegetables NSW Inc.*** *VegeLink NSW*, p2, December 2001.
- ***Greenhouse Cucumber Field Day.*** *VegeLink NSW*, p3, March 2002.
- ***Greenhouse Industry Supply Chain Meeting.*** *VegeLink NSW*, p3, March 2002.
- ***Field Trip for Greenhouse Vegetable Growers.*** *VegeLink NSW*, p3, March 2002.
- ***In The Spotlight – Leigh James & Jeremy Badgery-Parker.*** *VegeLink NSW*, p6, June 2002.
- ***Cucumber Grower Day – "Not all hydroponic media are the same".*** *VegeLink NSW*, p6, June 2002.
- ***Modern Greenhouse Technology.*** *Vegie Bites*, NSW Agriculture, p4, July-August 2002.
- ***Greenhouse growers board SMARTtrain.*** *NSW Agriculture Today*, p9, November 2002.
- ***Friendly fungi for greenhouses.*** *NSW Agriculture Today*, p9, December 2003.
- ***NSW Greenhouse Growers Visit SA.*** *VegeLink NSW*, P6, Summer 2002-03.
- ***Protecting Your Greenhouse Vegetables – Pest and disease identification and management.*** *VegeLink NSW*, p6, Summer 2002-03.
- ***Cucumber Pest & Disease Posters Available.*** *VegeLink NSW*, p3, Spring 2004.
- ***Chinese Growers' Association Members Visit NCGH.*** *VegeLink NSW*, p6, Spring 2004.
- ***Horticulture training and technology.*** *NSW Agriculture Today*, p4, September 2004.
- ***Cucumber disease and pest posters.*** *NSW Agriculture Today*, p17, September 2004.

Industry resources

The following is a list of recent local resources developed for, or relevant to, Australian greenhouse cucumber and vegetable growers.

- ***Pests, Diseases, Disorders and Beneficials in Greenhouse Vegetables: Field Identification Guide***, NSW Agriculture, First Edition 2002, 140 pages.
- ***Integrated Pest Management in Greenhouse Vegetables: Information Guide***, NSW Agriculture

- ***Disease Management for Greenhouse Cucumbers***, NSW Agriculture, Agfact H8.3.4, First Edition 1999, 16 pages.
- ***Nutrient Disorders of Greenhouse Lebanese Cucumbers***, NSW Agriculture, Agfact H8.3.3, First Edition 1998, 10 pages.
- ***A Review of The Protected Cropping Industry of the Sydney Region,*** NSW Agriculture, 1999, 20 pages.
- ***Being Safe in the Greenhouse – Occupational Health and Safety guidelines for the NSW Greenhouse Industry***, NSW Department of Primary Industries, First Edition 2004, 28 pages.
- ***Managing Waste Water with a Wetlands – Preparing your greenhouse or market garden for a sustainable future***, NSW Agriculture, First Edition 2003, 36 pages.
- ***Commercial Greenhouse Cucumber Production Manual,*** NSW DPI and HAL, First Edition 2005. Ready for distribution mid 2005.
- ***Guidelines for the Development of Controlled Environmental Horticulture – Striving for consistency, consensus and community. Planning Greenhouse and Hydroponic Horticulture in NSW.*** NSW DPI, Draft 2005, 68 pages.
- ***Greenhouse Horticulture – protecting your investment***, NSW Agriculture *Industry Investment Opportunities* series, six pages, 2001.
- ***Protected cropping,*** NSW Agriculture, Agnote DPI/248, First Edition, September 1999, 2 pages.
- ***Protected cropping technology,*** NSW Agriculture, Agnote DPI/253, First Edition, September 1999, 2 pages.
- ***The greenhouse,*** NSW Agriculture, Agnote DPI/249, First Edition, September 1999, 2 pages.
- ***Building a greenhouse,*** NSW Agriculture, Agnote DPI/250, First Edition, September 1999, 2 pages.
- ***Light in the greenhouse,*** NSW Agriculture, Agnote DPI/254, First Edition, September 1999, 2 pages.
- ***Covering materials,*** NSW Agriculture, Agnote DPI/251, First Edition, September 1999, 2 pages.
- ***Local government and environmental issues of greenhouses,*** NSW Agriculture, Agnote DPI/252, First Edition, September 1999, 2 pages.

APPENDIX 1

The following three pages show examples of flyers produced in separate and combined English and Arabic versions for greenhouse cucumber extension activities held in the Sydney basin.

Horticulture Australia | GREENHOUSE VEGETABLES NEW SOUTH WALES INC. | NSW Agriculture

Cucumber Disease Workshop

Friday 7th June, 2002

1:00 – 4:00 pm

55 Herley Ave, ROSSMORE

(Other locations will be available soon including Tahmoor, Richmond and Coffs Harbour)

Professional greenhouse cucumber growers are invited to a FREE disease management workshop with Len Tesoriero (NSW Agriculture) at Rossmore.

- **identify the main cucumber diseases**
- **understand how to best manage these diseases**
- **take a look at your own crop disease samples (bring one in)**

Places are limited.
Please complete the reservation slip below and return it by fax or mail.

✂--✂------------------------------------

Post to: Jeremy Badgery-Parker
NSW Agriculture
REPLY PAID 75367
GOSFORD, NSW 2250

Fax to: 02 - 4348 1910

Name: ______________________________
Address: ______________________________
Telephone: ________________ Facsimile: ______________
Area of greenhouses: ______________________
Number of plants: ______________________
Average yield: ______________________

Horticulture Australia

GREENHOUSE VEGETABLES NEW SOUTH WALES INC.

NSW Agriculture

Cucumber Disease Workshop

حلقة دراسية عن آفات الخيار

مزارعو الخيار المحترفون مدعوون الى حلقة دراسية حول كيفية معالجة آفات الخيار المزروع في الخيم البلاستيكية فارشإب Len Tesoriero من وزارة الزراعة في نيو ساوث ويلز،

وذلك راهن الجمعة 7 حزيران 2002

من الساعة الواحدة حتى الرابعة بعد رهظلا

على العنوان الآتي: 55 Herley Ave, Rossmore

يتم خلالها معالجة النقاط التالية:

- ♦ تشخيص آفات الخيار الرئيسية
- ♦ معرفة أفضل الطرق لمعالجة هذه الآفات
- ♦ النظر الى الأمراض الموجودة في مزرعتك (أحضر نموذجاً عن هذه الأمراض)

الأماكن محدودة. لمن يرغب في الحضور، الرجاء إكمال القسيمة أدناه وإرسالها على العنوان الآتي:

✂--✂--

Post to: Jeremy Badgery-Parker
NSW Agriculture
Reply Paid 75367
Gosford, NSW 2250
Fax to: 02 – 4348 1910

Name: ____

Address: ____

Telephone: ______________________ Facsimile: ______________________

Area of greenhouses: ____

Number of plants: ____

Average Yield: ____

Horticulture Australia

GREENHOUSE VEGETABLES NEW SOUTH WALES INC.

NSW Agriculture

Hydroponics for Cucumbers

الزراعة المائيه للخيار

Part 1

When: **Friday 11th July, 2003**

Time: 8:30 – 10:15 am Introduction to hydroponics

مبادىء الزراعة المائيه

10:15 – 10:30 am Coffee break

10:30 – 11:30 pm Where is your industry now?

الوضع الحالي للزراعه المائيه

AND

Part 2

When: **Monday 14th July, 2003**

Time: 10:00 – 11:45 pm Using hydroponic media

ادارة واستعمال اوساط الزراعة المائية

11:45 – 12:00 pm Coffee break

12:00 – 1:00 pm Making a plan for your industry

اعداد خطه مستقبلية لصناعة الزراعة المائية

Learn how to make your hydroponic system work better for you

تعلم كيفية جعل زراعتك المائيه تعمل افضل

And help set the direction of your industry

وساعد في تحديد الاتجاهات لصناعتك

For more information and to reserve your place contact:

لمزيد من المعلومات والحجز الاتصال بـ:

Lina Hatem 0418960660 or Joe ElBustani 0417446044

لينا حاتم٠٤١٨٩٦٠٦٦٠أو جوالبستاني٠٤١٧٤٤٦٠٤٤

Please: **RSVP by Monday 7th July**

الرجاء:الحجزقبل يوم الأثنين الموافق٧ تموز٢٠٠٣

ملاحظة...ورشتا العمل في نفس الموقع (55 Herley Ave, ROSSMORE)

APPENDIX 2

Full reports of crop R&D trials conducted at NCGH not supplied in Milestone Reports

1. Effect of nutrient strength of hydroponic solution on cucumber production

Introduction
The light intensity received by plants directly affects the quantity of photoassimilates and influences the transpiration rate and water uptake by the plant, affecting the concentration of nutrients around the root. Water deficit can arise from high EC (electrical conductivity) levels (low water potential of nutrient solution) restricting uptake of water and nutrients to the shoot. Sometimes this is encouraged by growers as a higher EC will cause cucumber plants to grow more slowly, have shorter internode lengths and produce more flowers. However, management of a higher EC nutrient solution is difficult as the risk of salt stress is high particularly in hot and dry conditions.

The aim of this work was to investigate the effect of nutrient solution strength on the production of marketable Lebanese cucumbers in a typical commercial production setting.

Materials and Methods
The first cucumber crop was established in the 500m^2 single poly skin greenhouse at Gosford National Centre for Greenhouse Horticulture (NCGH) in late autumn and fruit was collected November 2002 – January 2003. Planting density was 1.6 plants m^{-2}. The EC levels used were 1.75, 2.5 and 3.5 dS m^{-1}. Runoff EC was also monitored. In the greenhouse three rows were randomly assigned to each EC treatment level. Plants were grown in growool blocks. Three varieties of Lebanese cucumbers (*Cucumis sativus*) were also used (A: Austin, B: Cu 703, C: Corbra) and blocked within rows. Within each row 7 growool blocks made up an experimental block. Blocks were pseudo replicated 3 times. The marketable fruit weight total of 21 plants within the experimental block was recorded. Plant yield (fruit weight) was recorded. Analysis of variance was used to separate treatment means.

A second crop was established in the same greenhouse the following summer and fruit was collected for four weeks (November/December 2003). In this experiment there were two EC levels 1.00 and 2.00 dS m^{-1}. Within each row 5 coir slabs made up an experimental block. Blocks were pseudo replicated 3 times. The marketable fruit weight total of 5 plants within the experimental block was recorded. In addition twelve autopots were placed within this crop. These are bottom-fed pots each attached to a separate nutrient tank (approximately 40L). The use of autopots allowed the water used by cucumber plants growing in the pots to be measured. Six autopot units were fed 2.00 dS m^{-}1 nutrient solution and 6 were fed 2.60 dS m^{-1} nutrient solution. As nutrient solution was replaced in the autopot tanks, the volume replaced was recorded. The chlorophyll content of leaves in autopot plants was sampled and determined using the method of Inskeep and Bloom (1985). Analysis of variance was used to separate treatment means.

Nutrient analyses were carried out on the 5th fully expanded leaf of selected plants grown in various cucumber crops at the NCGH under a range of conditions. A summary of these analyses is relevant to the discussion of nutrient solution strength and so is presented in this report.

Results & Discussion

Different nutrient strengths of the solution fed to hydroponic cucumbers in summer experiments conducted at the National Centre for Greenhouse Horticulture did not affect the production of marketable cucumbers. This work demonstrates that lower nutrient concentrations can be used to produce cucumbers in summer. Adoption of this practice reduces the risk of nutrient toxicity in hot and dry conditions and reduces the environmental impact of the crop in terms of nutrient run off.

The first experiment showed that three solution strengths used to grow three varieties of Lebanese cucumber did not affect fruit production (Table 1). Additionally, varietal differences did not occur in terms of fruit production.

The second experiment showed that two solution strengths did not affect cucumber production (Table 2). The use of autopot technology revealed that approximately 80 L of nutrient solution was used by a cucumber plant for establishment and four weeks of summer fruit production (Table 3). Although production and water use did not differ between solution treatments in the autopot experiment, leaf chlorophyll was affected. The stronger nutrient solution (2.60 dS m^{-1}) resulted in a visibly darker green leaf with a higher chlorophyll concentration. These plants also developed downward leaf curling and marginal burning, symptoms of nutrient toxicity.

Table 4 shows the important effect of deficit irrigation, a common risk in summer, on plant nutrition of cucumbers. In this scenario water is rapidly taken up by plants, the nutrient solution around roots increases in strength and ultimately nutrients are taken up by the plant to excess. For example phosphorus, a highly mobile plant nutrient, doubles in concentration in leaves that develop marginal burn. Subsequent leaf growth results in downward leaf cupping. Leaf margins transpire more rapidly relative to other parts of the leaf and consequently accumulate more phosphorus in times of irrigation deficit causing nutrient toxicity. Leaf damage generally will occur above values of 0.8% phosphorus.

Table 1: Crop 1 mean total fresh weight (kg) of fruit per experimental block (8 weeks)

Variety/Treatment	1.75 dS m^{-1}	2.5 dS m^{-1}	3.5 dS m^{-1}	Significance
Austin	141.4	153.9	146.5	N.S.
Cu 703	135.6	141.3	138.1	N.S.
Corbra	142.0	136.9	135.5	N.S.
Significance	N.S.	N.S.	N.S.	

N.S. Non significant

Table 2: Crop 2 mean total fresh weight (kg) of fruit per experimental block (4 weeks)

EC treatment	Mean fresh weight (kg)
1.00 dS m^{-1}	32.15
2.00 dS m^{-1}	38.14
Significance	N.S.

N.S. Non significant

Table 3: Crop 2 cucumber plant responses to autopot nutrient concentration after 4 weeks of harvesting fruit

EC treatment	Mean total fruit number/plant	Mean total fruit weight/plant (kg)	Mean total water used/plant (L)	Chlorophyll concentration (ug/cm^2)
2.00 dS m^{-1}	36.25	5.85	83.3	36.51
2.60 dS m^{-1}	35.42	5.65	79.8	40.12
Significance	N.S.	N.S.	N.S.	*

N.S.,* Non significant or significant F test at P<0.05.

Table 4: Nutrient analyses (excluding N) of the 5th fully expanded cucumber leaf grown under different conditions

Nutrient	Normal	Pre irrigation deficit	Post irrigation deficit	Non symptom leaves	Symptom leaves
Phosphorus (%)	0.64	0.81	0.85	0.88	1.33
Potassium (%)	2.4	4.54	4.42	3.05	3.52
Calcium (%)	3.5	3.52	3.78	7.28	4.71
Magnesium (%)	0.48	0.9	0.8	0.83	0.65
Sulphur (%)	0.7	0.77	1.25	0.98	0.78
Sodium (%)	0.08	0.07	0.032	0.12	0.07
Copper (mg/kg)	7.9	3.6	9.3	3.0	3.3
Zinc (mg/kg)	80	71	83	72	84
Manganese (mg/kg)	99	96	120	150	96
Iron (mg/kg)	227	131	127	142	172
Boron (mg/kg)	39	129	51	76	44
Aluminium (mg/kg)	30	15	25	30	68

Reference

Inskeep, WP and Bloom PR (1985). Extinction coefficients of chlorophyll a and b in N,N-dimethylformamide and 80% acetone. Plant Physiology 77, 483-485.

2. Effect of commercial additives to cucumber production

Introduction

A number of commercial products are available to greenhouse growers that claim to boost crop growth. Usually these claims have not been verified experimentally. The aim of this work was to investigate the benefit of some 'biological additives' in greenhouse cucumber production. The additives included a product used in growing substrate and an additive for hydroponic nutrient solution. The substrate additive used in this study was vesicular arbuscular mycorrhizal (VAM) root inoculant, demonstrated to be successful in increasing the phosphorus nutrition of some field crops. The nutrient solution additive was a solution containing fulvic acid and 'growth enhancing compounds'.

Materials and Methods

A Lebanese cucumber (*Cucumis sativus*) crop was established in the $500m^2$ single poly skin greenhouse at Gosford National Centre for Greenhouse Horticulture (NCGH). The experiment was conducted in summer and fruit was collected for four weeks (November/December 2003). Plants were grown in coir slabs. Planting density was 1.6 plants m^{-2}.

The treatments were: VAM inoculated coir irrigated with low (1.0 dS m^{-1}) and normal (1.8 dS m^{-1}) strength nutrient solution, and coir irrigated with low strength nutrient solution (1.0 dS m^{-1}) containing fulvic acid (0.125ml L^{-1}). The VAM inoculant *Glomus intraradices* (Myco-gro) was applied once at the beginning of the experiment. A solution of the inoculant (16.6g L^{-1}) was watered into the coir medium. In the greenhouse three rows were randomly assigned to deliver the fulvic acid treatment in nutrient solution. Within each crop row 5 coir slabs made up an experimental block. Blocks were pseudo replicated 3 times. The marketable fruit weight total of 5 plants within the experimental block was recorded. Analysis of variance was used to separate treatment means.

Results and Discussion

The use of a VAM root inoculant or fulvic acid in a greenhouse cucumber crop was not found to increase cucumber production. Table 1 shows that substrate treatment with VAM did not significantly increase production at two levels of nutrient solution. Table 2 shows that fulvic acid did not significantly increase cucumber production.

Although this work did not demonstrate any benefit of using some additives there is much scope for further work. Some additive products claim to be beneficial in increasing resistance to disease. This was not investigated here but is a research theme in greenhouse crop pathology. Also, there may be a future role for VAM inoculants in 'organic-modified' hydroponic systems that are low in phosphorus.

Table 1. mean total fresh weight (kg) of fruit per experimental block (4 weeks) treated with VAM

Treatment	VAM	No VAM
1.0 dS m^{-1}	39.37	32.15
1.8 dS m^{-1}	40.47	38.14
Significance	N.S.	N.S.

N.S. Non significant

Table 2. mean total fresh weight (kg) of fruit per experimental block (4 weeks) treated with fulvic acid

Treatment	Fruit weight (kg)
Fulvic acid	33.36
No fulvic acid	27.94
Significance	N.S.

N.S. Non significant

3. Substrate effects on greenhouse cucumber growth and fruit quality in Australia

Abstract

The yield and fruit quality of mini cucumbers (*Cucumis sativus* L. cv. Tandora), grown using different substrates in a run-to-waste system, was examined during a 17 week greenhouse experiment. The substrates included coir (*Cocos nucifera*), sawdust (*Pinus radiata*), rockwool, perlite and cucumber mix (a commercial soil conditioner). The management of the crop, including the nutrient and irrigation regime, was the same for each medium. At each harvest, cucumber fruit number and fresh weight were recorded for each experimental plant. Additionally, quality and storability was assessed using fruits harvested at 7 weeks (early), 11 weeks (mid) and 16 weeks (late season) after planting. Fruit was stored for two weeks at 10°C. After an additional day at 20°C, the cucumbers were assessed for weight loss, colour change and textural quality (crush strength and firmness). There was no significant effect of substrate on plant dry weight, cucumber number, cucumber weight or average weight per cucumber, or on the fruit quality measurements. However there were differences in colour, deformation, crush strength and dry matter between harvests. There was no significant linear trend of yield over time for any media treatment. These results demonstrate that a range of growth media can be successfully used for hydroponic cucumber production. However, to maximise yields and fruit quality, further work is needed to tailor crop management for each substrate.

Introduction

In the absence of management guidelines, it is difficult for a producer to asses the suitability of a new substrate product, or a substrate that varies in consistency, for use in cucumber production. Substrates such as sawdust, rockwool, perlite, vermiculite, expanded clay, sand and gravel are used in the production of hydroponic cucumbers and crop management recommendations tend to differ for each substrate (Papadopoulos, 1994). Some products have potential as substrates as they are cheap and readily available to local producers, such as date palm fibres in Egypt (Medany *et al*., 1995), but guidelines for these need to be developed. Additionally, the inconsistency of some substrates may affect cucumber production. In Australia, sawdust is a commonly used substrate for cucumber production and can consist of the wood from one species but often contains the wood of several tree species (Handreck and Black 1994). Also, coconut fibre from different sources can differ in physical and chemical characteristics (Abad *et al*., 2002). The effects of substrate inconsistency on cucumber production are not known. The importance of substrate choice, relative to other production factors, needs to be evaluated for hydroponic cucumber production in Australia.

In addition to gross cucumber production and yield, fruit quality needs to be examined. Colour and textural quality are the major determinates of consumer acceptance of cucumbers. Production factors, such as pruning and training of cucumber plants, have a marked effect on fruit colour and shelf life qualities (Klieber *et al*., 1993; Lin and Ehret, 1991). However, other greenhouse studies limit observation of the effects of substrate on cucumber to production. This paper reports on the effects of a range of substrates in hydroponic production on both cucumber yield and, cucumber quality after storage.

Materials and Methods

Plant Production
Seeds of cucumber ('Tandora') were sown on March 1 2002. At the four-leaf stage seedlings were selected for uniformity and were planted into growing media, in a single skinned Harford polyhouse at the National Centre for Greenhouse Horticulture. Seedlings were irrigated with a complete nutrient solution from 0.5 to 3.5 L per day, depending on accumulated solar radiation and the stage of plant growth. For all substrates the electrical conductivity of the nutrient feed was maintained at 2.0 ds m^{-1} and the pH at 5.8. Plants were grown, using strings for support, to wires 2.57 m above the ground. At the wire one lateral and the main stem were allowed to grow down either side of the wire.

Substrate Treatments
The plants were grown hydroponically a run-to-waste system using five substrate treatments. These included coconut coir or cocopeat (*Cocos nucifera*), sawdust (*Pinus radiata*), rock wool plastic wrapped slabs (750 x 150 x 100 mm), 25 L perlite (2 – 5 mm) bags and cucumber mix (a commercial mulch soil conditioner). Fifteen L of sawdust and cucumber mix were placed in double plastic shopping bags, and coir was placed in 9 L grow bags, practices commonly used by Australian cucumber producers. To achieve the same plant density for each treatment (1.6 plants m^{-2}), three seedlings were planted per bag or slab. In the polyhouse the five treatments were arranged in blocks in a five by five Latin Square design. Each block consisted of four bags or slabs (12 plants in total).

Data Collection

1. *Substrates***.** Air filled porosity (AFP) and water holding capacity (WHC) for each substrate was assessed using the Australian standard for potting mixes (Standards Association of Australia, 1996) at the beginning of the experiment.
2. *Plant growth***.** When fruiting, four plants per experimental block were sampled for fruit number and fruit weight. At the end of the experiment final shoot dry weight was determined. Fruit approximately 14 cm long was harvested three times a week for 10 weeks (12 April to 21 June 2002). The weekly totals and the overall total were calculated for fruit number and fruit weight. At the end of the experiment plants were separated into leaves and stems and all plant material was oven dried at 70^{o}C for 72 hours to determine the shoot dry weight for each plant.
3. *Fruit quality***.** Cucumber quality and storability was assessed at three separate harvest dates: 7 weeks (early), 11 weeks (mid) and 16 weeks (late season). Fruit were assessed at harvest and stored for 2 weeks at 10^{o}C. After one day at 20^{o}C, cucumbers

were assessed for weight loss, colour change (Minolta chromameter) and textural quality. Textural quality was assessed using the firmometer and the twist tester (Studman and Yuwana, 1992). The firmometer was used to measure the deformation of a 40cm long section of cucumber, following application of a 500g weight for a period of 30 seconds. The twist tester was used to measure the crush strength of the tissue as described by Studman and Yuwana (1992).

*4. Data analysis***.** Substrate, plant growth and yield data were analysed using analysis of variance, and by ASREML (Gilmour *et al.*, 1999) for the yield response to treatments over time.

Results and Discussion

This study has demonstrated that a range of substrates can be used to successfully produce hydroponic cucumbers. Although the substrates used in this study showed variation in their physical characteristics (Table 1), they did not affect cucumber yield (Table 2) and only had a limited effect on fruit quality (Tables 3 and 4).

All measures of growth and yield were not significantly affected by substrate. Additionally, there was no significant linear trend of yield over time for any media treatment (data not shown). The few studies that compare various substrates on cucumber production have demonstrated that yield can be affected. For example, Medany *et al.* (1995), in Egypt, produced a larger cucumber crop in cheap local date palm fibres and leaflets than in rockwool. *Eun et al.* (2001) demonstrated that, in a closed hydroponic system, perlite and granulated rockwool produced a greater marketable yield of cucumbers than coconut fibre. However, differences in the growing environment, such as location and the type of hydroponic system used, make comparison of these studies difficult.

Air filled porosity ranged from 19% for rockwool to 47% for sawdust and water holding capacity ranged from 34% for perlite to 84% for rockwool. The figures for rockwool, determined using the Australian standard for potting mix, are different to those determined by Islam *et al.* (2002) and may reflect the use of a different method of determination (Byrne and Carty, 1989). Nonetheless, as a group, the substrates differ in their physical characteristics.

Growing media had little effect on cucumber colour, texture and storability (Tables 3 and 4). These results agree with those of Luoto (1984) who found that the colour and texture of cucumbers produced in peat or mineral wool were not significantly different. However, cucumber quality did vary between harvests with colour, deformation, crush strength and dry matter ratio showing significant differences (data not shown) These differences in quality between harvest dates may be due to differences in the greenhouse environment, plant age or crop load effects. In some cases (colour and dry matter ratio) there was an indication of a treatment effect. Further work would clarify these results.

The importance of the growing environment on cucumber production and quality cannot be ignored. In a limited growing environment substrates have been shown to have an affect on tomato yield and quality. For example, Islam *et al.* (2002) showed that tomato yields did not differ using coir, carbonated rice husks or rockwool as substrates at 25°C. However, at a growing temperature of 30 - 35°C, plants in coir and carbonated rice husks produced greater marketable yields than plants in rockwool. In this study the growing environment was the same for all substrates. The fruit fresh weight per plant of 4.6 kg, over a 10 week period, was typical for the Sydney region and suggests that the growing environment was not necessarily limiting. However, this needs to be further demonstrated. The effect of substrates on crop performance in limited environments is an important area for future research.

Acknowledgments

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Tables

1. Physical characteristics of substrates used in the experiment.
Values are means (*n* = 3)

Substrate	**Air Filled Porosity %**	**Water Holding Capacity %**
Coir	21.9 ab	69.8 d
Perlite	24.6 bc	33.8 a
Rockwool	18.7 a	84.0 e
Conditioner	26.2 c	46.4 c
Sawdust	47.0 d	38.8 b
LSD: p=1%	5.20	4.27

2. Measures of cucumber growth. Values are means across all treatments (*n* = 20)
.

Measures of Growth	**Grand Mean**	**LSD: p = 5%**
Total fruit number/plant	32.05	4.45
Total fruit weight/plant	4.63 kg	0.72
Mean fruit weight/plant	144.05 g	4.45
Leaf dry weight	48.10 g	13.09
Stem dry weight	34.55 g	4.60
Total shoot dry weight	82.70 g	17.28

3. Effect of growing media on cucumber quality (harvest 2 data presented)

Treatment	**Hue Angle**	**Deformation (x 0.01mm)**	**Crush Strength (kPa)**	**% Dry Weight**
Coir	130.2	70.76	671.4	4.048
Perlite	129.2	72.84	699.3	3.402
Rockwool	130.3	64.00	673.4	4.006
Conditioner	129.9	67.76	662.1	3.758
Sawdust	129.3	66.58	664.1	4.048
p = 5%	**ns**	**ns**	**ns**	**ns**

4. Effect of growing media on cucumber storage quality (harvest 2 data presented)

Treatment	**Final Hue Angle**	**Initial-Final Hue**	**Deformation (x0.01mm)**	**Crush Strength (kPa)**	**% Weight loss**
Coir	126.2	3.712	63.40	582.0	7.478
Perlite	126.0	3.507	67.01	618.6	8.160
Rockwool	126.2	3.672	55.64	633.9	7.412
Conditioner	125.9	3.896	57.71	641.3	7.604
Sawdust	125.7	4.170	65.64	615.4	8.290
p = 5%	**ns**	**ns**	**ns**	**ns**	**ns**

4. Aging coir and sawdust media effects on cucumber crop growth

This project aimed to investigate the effects of aging on sawdust and coir media and cucumber crop production. Media aged up to 11 months in previous crops was used in this experiment.

Crop growth in terms of marketable fruit number and weight was not different among treatments (Table 1). In table 1 the grand means are presented only as the arrangement of treatments in the greenhouse limited the robustness of growth statistics. However, aging significantly affected physical qualities of growing media (Table 2). Water holding capacity increased, and air filled porosity decreased, with time, particularly sawdust. Coir tended to have greater stability over time. This project demonstrates the variability of media over time. Growers need to assess media to derive irrigation strategies for every crop planted. Protocols for assessing media are being developed.

Table 1. Production figures for the cucumber crop

Measures of Growth	Grand Mean
Total fruit number/plant	21.77
Total fruit weight/plant	2.833 kg

Table 2. Effect of cropping time on physical characteristics of coir and sawdust Values are means (*n* = 4), n.s. = not significant.

Time (months)	Air Filled Porosity % *Coir* (n.s.)	Air Filled Porosity % *Sawdust*	Water Holding Capacity % *Coir*	Water Holding Capacity % *Sawdust*
0	27.9	38.1	66.7	50.8
4	27.7	39.0	71.3	57.6
7	25.8	37.5	74.4	61.1
11	23.0	28.1	71.9	68.7

5. The effect of planting density on greenhouse cucumber production

Introduction

Cucumber plant densities used in the industry tend to range between 1.6 – 2.0 plants m^{-2}. It was the aim of this work to investigate the effect of planting density on hydroponic cucumber production in a greenhouse situation.

Materials and Methods

A winter cucumber crop (*Cucumis sativus* L. Mascot) was established in the 600m^2 double poly skin greenhouse at Gosford National Centre for Greenhouse Horticulture (NCGH). The experimental design is presented in Table 1. There were 4 rows available with each row accommodating 28 coir slabs. In each row, a plot consisted of 2 adjacent coir slabs, making 14 plots per row. Rows 1 and 2 were paired as were rows 3 and 4. The experimental unit consisted of 4 slabs – 2 slabs in row 1, and 2 slabs in row 2 in corresponding positions. Rows 1 and 2 had identical treatment allocation, and rows 3 and 4 had the same treatment allocation as each other. The 7 density treatments were arranged in 4 randomised blocks, with 2 blocks per pair of rows as shown in the plan below. The treatments were 2,3,4,5,6,7,8 plants per 2 slabs. To simplify the experiment one leader only was grown up to and over the wire.

Cucumbers were harvested, counted and weighed 44 times over the growing season (usually 3 times per week). Weekly totals as well as grand totals were calculated for both fruit number and fruit weight. Data were collected for each plot. Light readings for above and below the canopy were recorded for row 4 on 24th September and for rows 1 and 2 on 23rd September.

Table 1. Density planting greenhouse plan. Each cell represents two coir slabs. Treatments (treats) consisted of 2 – 8 plants per two coir slabs.

Buffer row	Row 1	Row 2	Buffer row	Row 3	Row 4	Buffer row
Block	Treats	Treats	Block	Treats	Treats	
1	7	7	3	6	6	
1	2	2	3	2	2	
1	4	4	3	3	3	
1	6	6	3	1	1	
1	3	3	3	5	5	
1	5	5	3	7	7	
1	1	1	3	4	4	
2	4	4	4	3	3	
2	3	3	4	5	5	
2	7	7	4	4	4	
2	1	1	4	6	6	
2	2	2	4	1	1	
2	6	6	4	7	7	
2	5	5	4	2	2	
Buffer row						

Results and Discussion

A significant negative linear relation between total fruit weight per plant and density was found (Figure 1). There is a 1.2 ± .09 kg reduction in total fruit weight per plant with every extra plant added. This shows that as the plant density increases, competition for resources also increases limiting the production potential for each plant. Similarly a significant negative linear relation between total fruit number per plant and density was found. There is a 7.2 ± .54 kg reduction in total fruit number per plant with every extra plant added. The lowest density of 0.6 plants m^{-2} yielded 100 cucumbers and at the highest density of 2.6 plants m^{-2} there was a total of 58 cucumbers for the 16 week crop.

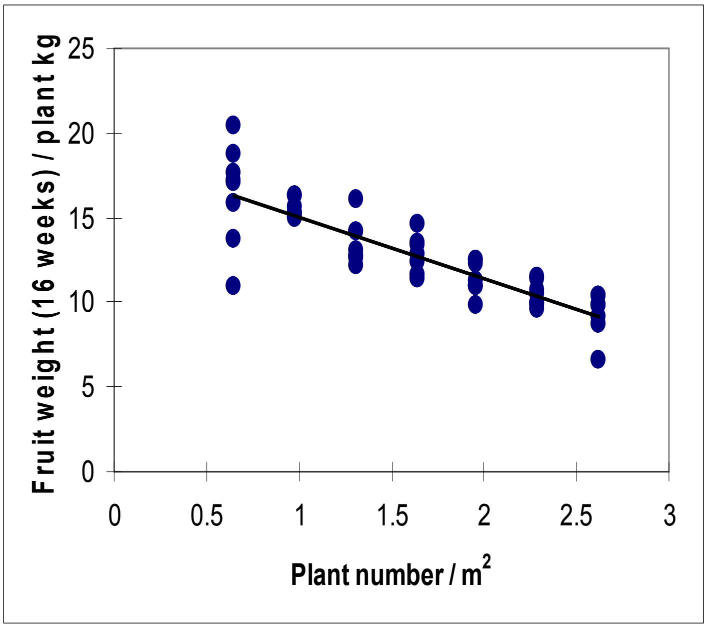

Figure 1. Total fruit weight per plant as affected by plant density.

Increasing the plant density increased the total volume of production achieved but the relationship was not linear. A quadratic relation ($y = 3.895 + 16.7*x - 0.9815*x^2$) was found between total fruit weight and plant density which accounted for 85.8% of the variation (Figure 2). A quadratic relation was also found between total fruit number and plant density ($y = 20 + 104.2*x - 6.064*x^2$) which accounted for 86.9% of the variation.

The planting density yielding the greatest cucumber production was higher than that usually used in the industry. However, training and pruning practices has an important effect on density and needs to be considered before making recommendations on plant density. Pruning and training methods were beyond the scope of this project.

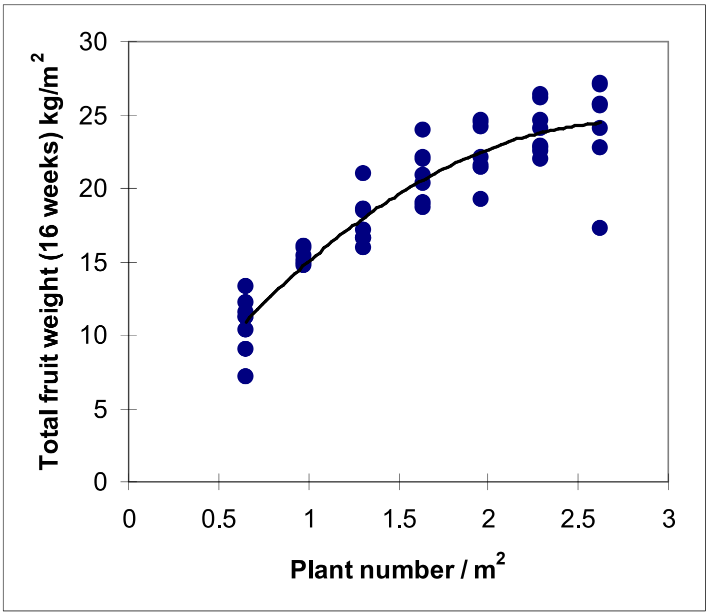

Figure 2. Total fruit weight as affected by planting density

Light within the canopy represented as the percentage of light measured above the canopy is shown in Figure 3. A significant relationship could not be found between plant density and light intercepted.

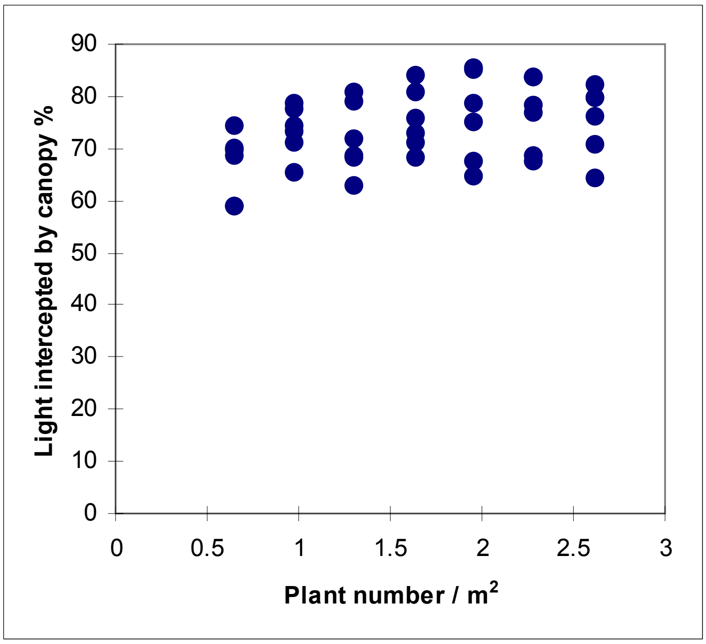

Figure 3. Effect of planting density on light intercepted by the canopy.

There is much scope for further work establishing the relationship between light intensity, light quality and greenhouse canopy interception in an Australian context. Included in this work would be an evaluation of the range of training and pruning practices in the industry on production outputs.