

Converting soil grown production methods to hydroponics in protected cropping.

Is the shift to hydroponic production beneficial?

An overview of the greenhouse industry in the North Adelaide Plains region.



by Hieu Minh Ly

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Scholar Contact Details

Hieu Minh Ly
Ly Hydroponics
P.O. BOX 644
Virginia
South Australia 5120

Phone: (08) 8380 9043
Fax: (08) 8380 9043
Email: ly.hydroponics@gmail.com

In submitting this report, the Scholar has agreed to Nuffield Australia publishing this material in its edited form.

Nuffield Australia Contact Details

Nuffield Australia
Telephone: (03) 54800755
Facsimile: (03) 54800233
Mobile: 0412696076
Email: enquiries@nuffield.com.au
586 Moama NSW 2731

Foreword

The Protected Cropping Industry (Greenhouse grown fruit and vegetables) has played a key role in the horticultural industry in South Australia. The Northern Adelaide Plains region approximately 40kms north of Adelaide has been the main hub for horticulture in the state since the 1960's when farmers displaced by urban sprawl, moved north and enjoyed huge success in producing fresh vegetables.

Protected growing methods in the region have been relatively unchanged in decades but now change seems to be sweeping through like a wild fire. Every time growers gather together they speak of one word. 'Hydroponics'. A farming evolution is happening and it is challenging the perceptions of the protected cropping business.

The key aspects of the report are the arguments for converting from soil based production systems into a soilless or hydroponic system. Special importance will be placed on the main hydroponic crop grown in South Australian greenhouses, tomatoes but this report can also relate to capsicums and cucumbers. Hydroponics is changing the face of farming in South Australia and it is important that growers are aware of the benefits but also the pitfalls that are associated with growing out of the soil.

The Northern Adelaide Plains area has one of the greatest concentrations of greenhouses anywhere in Australia. Greenhouse growers all producing side by side in small plots of land have been successful since the very first Western European settlers started working the land in 1850. Over the generations a steady influx of immigrants have come and created the diverse multicultural community we see and appreciate today. These times have changed. The immigrant dream of land ownership is quickly fading. Immigrant children have grown up and are moving into the suburbs seeking 'real' jobs leaving behind a rapidly aging farming community growing in old greenhouses and in soils that have, in some instances been farmed constantly for half a century.

As one of the fastest growing horticultural industries in Australia, hydroponics brings with it technologies and methods unheard of to a vast majority of growers in Australia. Increased yields can excite growers who convert their farms and fail as they did not understand the fundamentals of growing hydroponically.

Acknowledgements

I am a young farmer who came to Australia as a refugee after the Vietnam war. Farming has always been a way of life for the family. We were among the very first Asian immigrants to farm in Virginia in the early 80's and my parents have always worked hard to send my two sisters, brother and myself to private schools so we could get the education that they missed out on. When I was asked to return home and start a farming business I thought I was going to continue the monotonous farming life my parents had. I was very wrong.

After receiving my Nuffield scholarship and travelling all over the globe I have begun to realise that there is so much more to being a farmer and that I had just never had a chance to witness it. The experience has changed my life and given me opportunities that farmers and non-farmers alike could only dream about.

Thankyou to Horticultural Australia Limited for the sponsorship funds to allow me to witness farming globally. The Nuffield sponsorship through HAL has gained me so many friendships in my field and others. I hope the support for Nuffield continues so that other growers like myself may experience a wine tasting in a French vineyard or the smell of a cattle feed lot in Oklahoma.

A special thanks to all the hosts I have met on the Global Focus Program and on my personal travels. As Nuffield scholars we probably ask too much from them but I'm sure the favour will be returned if they ever wish to come to our beautiful shores. I know if I get the chance to travel through your countries again I will drop by and say hello.

My family have helped me and understood the commitment that was needed to be a Nuffield Scholar and while I was off on my adventures they were making sure the crop was still alive when I came back.

Lastly, a huge thankyou to my Nuffield group of mates. In particular, Don Madden, Christine Ferguson, Steve Newman, Bill O’Keefe and Ian Duthie. The places we went to and the things we saw were amazing and I’m grateful that I had such a great group of friends to witness them all with.

Abbreviations

AUD- Australian Dollar

BER- Blossom End Rot

°C - Celcius

CO₂ - Carbon dioxide

EC- Electrical conductivity

GFP - Global Focus Program

Ha - Hectare

HAF - Horizontal Airflow Fans

M² - Square Metre

Ppm - Parts per million

RO - Reverse Osmosis

UF - Ultra filtration

USD - US Dollar

UV – Ultraviolet

WC - Water Content

Contents

Foreword	3
Acknowledgements	4
Abbreviations.....	5
Contents.....	6
Executive Summary	7
Background	7
Objectives.....	8
Methods Used.....	9
Key Findings:	9
Introduction	10
What Is Hydroponics?	11
Pros	13
Cleanliness.....	13
Control.....	14
Seedlings	15
Weeding.....	16
Labour	16
Cons	17
Holland vs. Australia.....	18
Yields.....	18
Costs Of Sales	18
High Tech Structures.....	19
Imported Labour.....	20
Pest And Diseases	21
Energy Producing Greenhouse	21
Cogeneration Heat And Power.....	22
Energy And Thermal Screens.....	23
High Pressure Fogging	24
Marketing In The Uk.	25
Costs Of Converting To Hydroponics	25
Final Advice	29
Once Canker Has Been Spotted And Verified	31
Recommendations	32
References	35
Plain English Compendium Summary	36

Executive Summary

Background

The Northern Adelaide Plains region has had a long history with agricultural production. Since the 1850s the land has been producing cereal crops and sheep. Many of the original settlers migrated from Ireland after the potato famine.

The 1960's saw a drastic change in production methods as Greek, Italian and Bulgarian immigrants, under pressure from urban sprawl from the East and West of Adelaide moved their horticultural enterprises north. The land offered underground water and a Mediterranean climate to grow vegetables in greenhouses. Protected cropping in the 60's consisted of low (2m to the gutter) greenhouses made from small panes of glass. Summer heat was dealt with by opening the sides of the glasshouses and whitewashing the roofs to limit the intense sunlight and heat that Adelaide is renowned for. Planting in winter was a gamble as although the area has a low incidence of frost, cold night temperatures significantly impact yield and quality. These early glasshouses suffered from extreme weather as strong winds broke glass and hail storms would render entire crops ineligible for consumption for fear of glass shards being embedded in fruit.

The Mid 80's saw a huge cultural shift in the area. The Vietnam War meant an influx of Asian migrants seeking to become business owners and farmers like they had been in their mother country. Newer plastic coverings enabled growers to build greenhouses cheaply and therefore the risks involved with constructing from glass were removed. The idea of a family run business with a manageable one hectare greenhouse and production in 80% of the year appealed to many migrants and wave after wave came making the area one of the most productive in the country.

At present the Northern Adelaide plains faces several problems. Migrants from post-World War 2 and the Vietnam War are now at retirement age. Their children were brought up and told not to become farmers and are moving away from the area.

The mining boom in the mid north and urban sprawl north of Adelaide has put pressure on the farmers' way of life. Increases in the cost of living coupled with skyrocketing land costs means the traditional half hectare farm can no longer sustain a family.

Horticultural farming in the area seems only possible for those whose parents were farmers and already have land. An aging population puts good farms on the market but they are approaching \$500,000AUD and therefore out of reach for most of the new migrants coming into the country. Land is also being bought by wealthy business people and not being used for agriculture.

Hydroponics has the ability to reinvigorate the region and bring back horticulture into an area that faces problems with sustaining the success that it once enjoyed. For decades migrant families have enjoyed a 'lifestyle' of hard work toiling away at the soil but were content that a small profit was enough to pay the mortgage and send their kids to school. The shift to hydroponics forces growers to rethink their farming strategies. Farms must now be run as a business. Yields are calculated to the square metre with tighter margins and profits dependant on crop quality. Hydroponic farms can be much smaller and most importantly, crops are produced away from the diseased soil to limit pest and diseases. Yields for certain vegetables such as tomatoes are far greater in hydroponics.

Objectives

This report is targeted at prospective growers looking at converting their soil farms into hydroponics. People who want to get into the horticulture industry will also benefit as this report will outline the differences between soil and hydroponic production. Due to pest and disease concerns, many of the hydroponic farms in the Northern Adelaide Plains region are closed off to the general public therefore this report will outline the technology available to growers to achieve and sustain yields that make hydroponic farms profitable. This report will focus on the largest proportion of growers who convert to hydroponics in low or medium technology greenhouses.

Methods Used

My Nuffield experience involved visiting farms overseas and in Australia. Visits to research and demonstration centres along with numerous talks with industry experts such as seed representatives gave me an understanding of how important it is to have a network of professionals in every facet of a hydroponic business. I focused on Marketing in the UK, and technology and cultural practices in Holland. I was able to tour factories that supply and install horticultural equipment in Holland, France and Australia and see the equipment that the world's largest hydroponic operations are using. Visits with established farms allowed me to witness how each individual grower has undertaken their own different approach to growing vegetables in Australia.

Key Findings:

- Converting from soil-based production to hydroponics is not just changing a cropping production method but more importantly restructuring an entire business model.
- Understanding of plant physiology, water uptake and fertiliser use is pivotal to the success of any hydroponic grower who wishes to see a profit at the end of the season.
- Growers have historically been blasé about soil production and are finding that hydroponics brings with it a yearlong commitment.
- Growing in high-tech greenhouses is not feasible for a vast majority of growers and therefore companies must market differently compared to overseas growers.
- South Australia's harsh climate usually dictates the more technology a grower has the better their chances at maintaining profitability.
- Growers must be prepared to move away from the main tomato truss varieties and into speciality lines as more growers get into the industry.

- The industry must be prepared in the future for lower prices and therefore offset these with much higher yields and low costs to maintain profitability.

Introduction

There is a misconception in the community that hydroponics is an un-natural way to grow vegetables. It is perceived that we as hydroponic growers feed our vegetables with special mixes of fertilisers and chemicals that produce amazing yields and quality. This is in fact wrong. Commercial hydroponics is a method whereby vegetables are supplied their nutritional needs in a controlled fashion. Fertiliser use is dependent on each cultivar and the actual fertilisers themselves are no different to the ones used in the soil production. When this production method was introduced to Australia in the 1980's growers did not fully understand the special nutritional and environmental requirements needed by plants and therefore many of these early business ventures failed giving hydroponics a bad reputation.

Today's commercial hydroponic farms are capable of producing yields three to four times that compared to soil production whilst using less water. Nutrition plays an important role in this as growers have learnt to adopt new growing methods and moved away from traditional cultivars to achieve high yields. Technology has had a huge part to play in this transition. The old two metre high leaky glasshouses are now making way for 6m-8m high-tech glasshouses from Europe. These new glasshouses come with an array of technology designed to make vegetable production easier for the grower and with less stress on the plants.

In terms of tomato production, traditional growers can expect a six month season whereas a hydroponic grower would expect a twelve month season. The soil grower must choose when to plant careful as the volatility of prices could mean they would not make any

money in the limited three months of harvest. The hydroponic grower on the other hand has nine months of harvest so any low prices can be averaged out over the season by the high prices.

Hydroponics is undoubtedly the future for protected cropping in Australia. In the last decade growers have witnessed the rapidly changing roles of farming with the introduction of technology from overseas. My travels and research shows Australia is lagging behind the rest of the world in terms of greenhouse production.

What Is Hydroponics?

In a commercial farm business the term hydroponics deals with two methods of producing a crop outside of the soil. The first is NFT (nutrient film technique) and second soilless production. This report focuses solely on soilless production.

Early hydroponic growers used a method called nutrient film technique (NFT) that submerged the roots of the vegetables in nutrient rich irrigation water. Irrigation channels commonly made out of PVC pipe circulate the nutrients with a fertiliser mixing unit mixing the stock solutions together. The NFT method is still used today but is favoured by growers of leafy greens and lettuces as they tend to only have a single 'vegetative' state of producing leaves and roots.



Lettuce grown in NFT

Vegetables with both a vegetative state (leaf, root production) and a generative (fruit production) were found to grow much more efficiently in soilless culture and therefore a shift from NFT into soilless production began in Holland in the late 1970's with rockwool (Welleman & Smulder, 1988). Soilless production has crops grown in pot plants or small bags filled with a growing media; they are fed nutrient rich irrigation water through the use of a dripper directly around the root zone. Growing substrates include rockwool, cocopeat, saw dust, peat moss, vermiculate, sand and perlite (Harris, 1994). European growers, in particular the Dutch, were 'steering' their crops between the two stages of growth, prolonging the harvest season and maximising yields. The introduction of rockwool production methods in Holland in the 1970's gave growers another tool in increasing yields together with carbon dioxide enrichment, humidity control, electrical conductivity (EC) and plant maintenance (Jensen, 2008). Rockwool is a growing medium created from molten volcanic rock and spun into fibres. Rockwool allows growers to vary the water content and EC (salinity) of the root zone thus stimulating the crop into either the vegetative or generative state.



Tomatoes grown in soilless production

Pros

Cleanliness

Recent outbreaks in diseases in herbs and vegetables worldwide have caused significant damage to the local horticultural industries. In May 2011 an outbreak of a highly virulent strain of *E coli* in Germany was incorrectly believed to have come from imported cucumbers from Spain. Belgium and Russian immediately banned the import of vegetables from the region as a knee-jerk reaction. In 10 days 1200 cases of food poisoning was reported in 10 countries with studies showing those affected had consumed above-average amounts of tomatoes, lettuce and cucumbers. The affects to the European vegetable industry was phenomenal, The Spanish industry lost \$200 million USD a week. Infected seeds of fenugreek, sent from Egypt to an organic farm in Lower Saxony, Germany were finally identified as the source of the deadly bacteria vindicating Spanish growers.

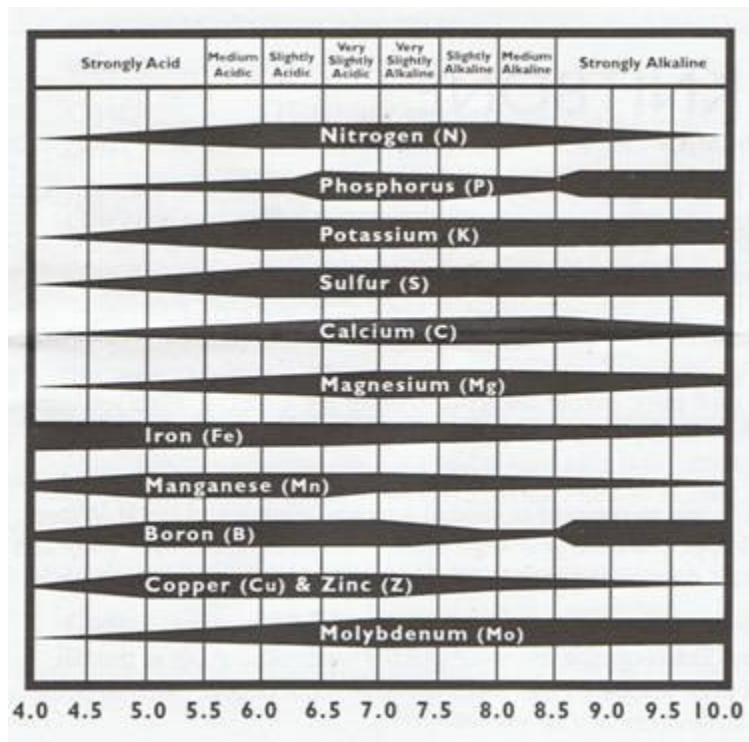
The food poisoning case in Germany highlights the importance of food safety for growers. Soil growers often use animal manures to fertilise crops and therefore pose a real danger of spreading disease. The greenhouse soils of the Adelaide Plains have had

continued use for decades with fumigation and manures added to replenish nutrients during the short fallow periods. Hydroponics takes the crop out of the soil and grows them in a media that is clean. Growing media can be discarded and replaced minimising the risk of soil borne diseases. The US army stationed in Japan during the Korean war was forbidden to eat local soil grown vegetables due to years of unsanitary cultivation. The army established a 22 hectare hydroponic farm based on sterilised gravel which solved the disease problems (Harris, 1994).

Control

Large yields are the aim for all growers but are only possible with healthy plants. Soils can lack the vital macro and micro elements that are vital to healthy plant growth. Soil growers fertilise the soil to combat the deficiencies and irregularities in soil types, irrigation and changing crop demands make it difficult to stay within limits and sustain optimal growth. Greenhouse soil growers in South Australia have traditionally fertilised their mid-season crops with large amounts of fertilisers though the irrigation systems in one large dosage when they perceived the crop needed them, with additional foliar sprays to maintain nutritional balance. 90% of irrigation is with straight bore, rain or Bolivar water (recycled water provided by the local sewage treatment plant). The hydroponic method of growing automatically irrigates a balanced nutrient solution that can be controlled to give higher or lower fertiliser doses depending on crop requirements. pH levels, particularly in flowers, can also be finely controlled allowing planting of specific crops in areas where soil pH is prohibitive to growth. pH also plays an important role in the availability of elements. The chart below describes the preferred pH ranges of common hydroponic elements. For vegetables like tomatoes and capsicums injecting at a

pH of 5.5-6 allows the highest uptake of most important elements (Avocadosource, 2011)



Effect of soil pH on nutrient availability

Seedlings

Soil growers tend to plant their seedlings at a very young age. Hydroponic crops can be sown in a nursery in rockwool cubes and matured in a controlled environment before they are shipped off to the farm. Mature seedlings are much more uniform as they are fed nutrients from beneath through flood and drain irrigation systems (Welleman et al, 1988). Winter plantings benefit greatly from having mature plants delivered, as cold temperatures hamper root development of young plants and this can extend the time before first harvest affecting yield. Tomato seedlings can be delivered with the first flower already setting which is approximately 2-3 weeks ahead of a soil grower. Mature seedlings enable growers to choose which plants they want in their greenhouses by discarding those which show signs of weakness and disease. Uniformity of the young crop can be achieved with extra plants placed in a special nursery or area of the greenhouse and used as spares in case plants in the main greenhouse die. Mature plants offer many benefits over planting young seedlings but the costs have been prohibitive to growers starting out in hydroponics. One grower explained his preference for mature

plants by arguing the extra 2-3 weeks needed to sow them in a nursery was more practical as operating a 2000m² nursery was cheaper than a 10,000m² (one hectare) greenhouse. The savings the grower made by not having to heat his greenhouse for 2-3 weeks offset the higher costs of mature plants.



Seedlings growing on flood and drain benches at Moraitis Tomatoes Victoria.

Weeding

Many greenhouse growers will understand the irritation of weeding. It is hard work and a constant problem for farmers. Weeds are mainly soil borne and can access crop's valuable nutrients, they require labour to remove, grow quickly and can host a variety of pest and diseases spreading them between cropping cycles. As the media used in growing hydroponically is replaced each season for new material and the ground cover is plastic the necessity to weed is removed entirely therefore keeping farms clean.

Labour

Labour costs can be substantial to any business and agriculture is indeed labour intensive. Protected cropping requires long hours and hard work to produce high yielding crops all

year. Unhealthy plants and low quality vegetables add to labour inputs. Hydroponic vegetable production is still labour intensive but automation of many tasks like irrigation has reduced the work load. Growers who have installed pipe and rail heating systems have them serve a dual purpose as rails for crop trolleys to run along the rows and work at heights up to 4m.

Cons

Hydroponics is not the answer for all growers. There will always be a market for soil grown produce; hydroponic vegetables cost more to produce and this is reflected in the price in the supermarkets. Consumers ultimately decide what they are willing to pay for vegetables.

Soil grown produce can still produce excellent quality yields. Some growers believe it is the stress on the crop that gives the plant a stimulus to produce high quality fruit.

Greenhouses for soil production are inexpensive to build and maintain. They have no venting apart from side walls that can be manually open and closed. Low tech greenhouses rarely have a need for electricity. There are in fact farms in the Adelaide plains area with no electricity and no city water connected. A new grower can build 2-3 hectares of soil grown greenhouses at the same price of converting one half a hectare of existing greenhouses into hydroponics. Semi-hydroponic installations are always done with pre-existing greenhouses. Few growers will want to invest in the huge capital and labour needed for a new hydroponic greenhouse and will build a low-tech structure. New low-tech greenhouses are continually constructed but they are intended solely for soil production.

Soil production has far less risks involved compared to hydroponic production. Hydroponic truss tomato varieties have a 12 month cropping cycle. Any problems that occur at any time during that cycle will lead to decreased yields. Hydroponic crops are stimulated to produce high yields and small problems such as a power failure can have

catastrophic effects. In comparison, a soil grown tomato variety has only a six month cropping cycle of three months planting and three months harvesting. It is much easier and cheaper to start the cycle again if a problem occurs.

Holland vs. Australia

Yields

Holland has without a doubt the most technologically advanced protected cropping industry in the world with over 10,000 hectares of greenhouses (Snelder, 2011). As I travelled through areas like The Westlands, it dawned on me that 50 years ago horticulture in Holland probably looked like my hometown at present. The first horticultural greenhouses in Holland were built around 1850 (Snelder, 2011). It was quickly discovered that protected cropping with heat and high light transmission through glass equated to quicker growth and increased yields. Constant greenhouse temperatures allowed growers to grow crops suited to warmer climates. In the late 1970's growers changed over to soilless production starting in rockwool media. In 1986 Dutch hydroponic tomato growers were yielding 50 kg/m² whilst soil growers were yielding 36 kg/m² (Welleman, et al 1988). Currently hydroponic growers are harvesting 65-80 kg/m². New greenhouse technology such as semi closed and closed glasshouses at trial centres in Holland regularly yield 100 kg/m² and this technology is being adapted by commercial growers. A low tech greenhouse in South Australia would expect yields of 35 kg/m² whilst a high-tech greenhouse would expect 65 kg/m². Growers believe our high light levels should allow Australian growers to yield 80 kg/m² if their operations are run efficiently like the Dutch systems.

Costs Of Sales

The scale of investment in Holland was remarkable with over half of Europe's greenhouses located there (www.nationsencyclopedia.com) Australia is so far behind the Dutch that it was often embarrassing to tell the Dutch growers how we grew our tomatoes back home. Our extreme growing conditions in summer did earn us respect as 30°C is considered a hot summer day in Holland. One grower could not believe we even bothered

growing in the 40-45°C temperatures South Australia regularly experiences in summer. Dutch farming operations ranged from two to thirty hectares whereas farms in Australia average 0.5-1 hectares. The setup of horticulture in The Westlands area was very similar to the Adelaide plains as the greenhouses are so closely concentrated together that services were built around the area and growers can benefit from having crop consultants, service technicians and markets close to their farms. Businesses are able to supply the area more efficiently reducing their labour and transport costs resulting in cheaper products. In the eastern states of Australia horticulture is spread out with farms dotted in all parts of the state. Costs of sale for growers in Melbourne and Sydney are higher than growers in the Virginia area of South Australia. As an example one hydroponic tomato grower in the south-western Sydney area pays \$1.30AUD for packaging. Growers in Virginia pay \$1.05. A one hectare truss tomato farm in Sydney packing in 5 kg trays with yields of 60 kg/m² would pay an extra \$30,000AUD per season compared to the grower in Virginia. This is a significant saving which could offset labour, water or fertiliser costs.

High Tech Structures

Australian hydroponic greenhouses can vary depending on grower preferences and level of investment. Some are old structures of wood and glass made in the 1950's and some are plastic covered hoop houses. Greenhouses heights in these structures can vary from 2-4 metres to the gutter. In Holland there is one particular type of greenhouse preferred by Dutch growers; the Dutch Venlo Glasshouse. The Venlo can have heights from 4-8 metres high with large panes of glass and the added benefit double ventilation on both the lee and wind sides of the roof for climate control. The standard height for new structures is 8 metres to the gutter. Trials were done with 10 metre greenhouses but minimal benefits and higher costs resulted in standard heights of new glasshouses set at 8 metres. Unlike the majority of greenhouses in Australia, the Venlo has the ability to be completely sealed once the roof vents are closed to trap in CO₂ and heat from hydronic boiler systems and keep out pests and diseases. Automation is a key element of Dutch businesses and the Venlo glasshouse is highly sophisticated allowing growers to actively

manipulate key aspects of vegetable production such as temperature, humidity and air exchanges/air movement within the crop.



8 metre tall glasshouse at Wageningen UR Glastuinbouw experimental station Holland.

Venlo glasshouses are designed to have a lifespan of 25 years with approximately 500 hectares being replaced or built in Holland each year (UWS, 2010). Dutch glasshouse builders are so adept at building glasshouses and fitting them out that a grower can have a glasshouse operation running in three months. It is estimated that 80% of glasshouses built worldwide are from Dutch companies (Snelder, 2011).

Imported Labour

The greenhouse labour force in the Dutch greenhouses I visited mostly came from Poland. Standards for greenhouse tasks are set by supervisors with data-logging computers monitoring worker's progress. Bonuses are paid to workers who exceed standards whilst those on the bottom scale are replaced. Working in hydroponic greenhouses gives more favourable working conditions compared to other fields of agriculture so workers are keen to stay in the industry. I witnessed levels of crop work and skills that any Australian greenhouse supervisor would envy. The speed of workers

and attention to detail amazed me and it is a reason why the Dutch growers can squeeze every last kilogram out of each plant.

Pest and Diseases

Dutch growers are almost entirely pesticide free. Biological controls through an Integrated Pest Management (IPM) approach are standard practice. In Holland it is safe to assume any vegetable at the supermarket is pesticide free. Australian consumers should expect the same but actually get the opposite with IPM seldom used due to the cost and complexity involved with introducing beneficial insects. The Greenhouse whitefly (*Trialeurodes vaporariorum*) and silverleaf whitefly (*Bemisia argentifolii*) are two of the biggest pests in Australian greenhouse production. They are responsible for damaging fruit and transmitting viruses such as the tomato yellow leaf curl virus (Parker, 2009). One Australian grower had initial success with introducing the *Encarsia formosa* wasp into his greenhouse to combat whitefly. He experienced kill rates of 60 percent until the farmer next door sprayed pesticides and the spray drift came through the vents and decimated the *Encarsia* population allowing the pest to flourish and spread. Unfortunately he had no option but to resume spraying. It is also common for a farmer to target a pest such as whitefly but subsequently have increases in other pests that were not prevalent earlier such as fungus gnats or thrips. Many attempts at IPM have failed due to pesticides being used to combat other pest problems resulting in mortality to the biological insects (AGF, 2006). Sticky traps are also used to trap flying insects. Yellow is used for whitefly and blue supposedly attracts thrips but some growers in South Australia believe blue does not work and the yellow traps are more effective on thrips.

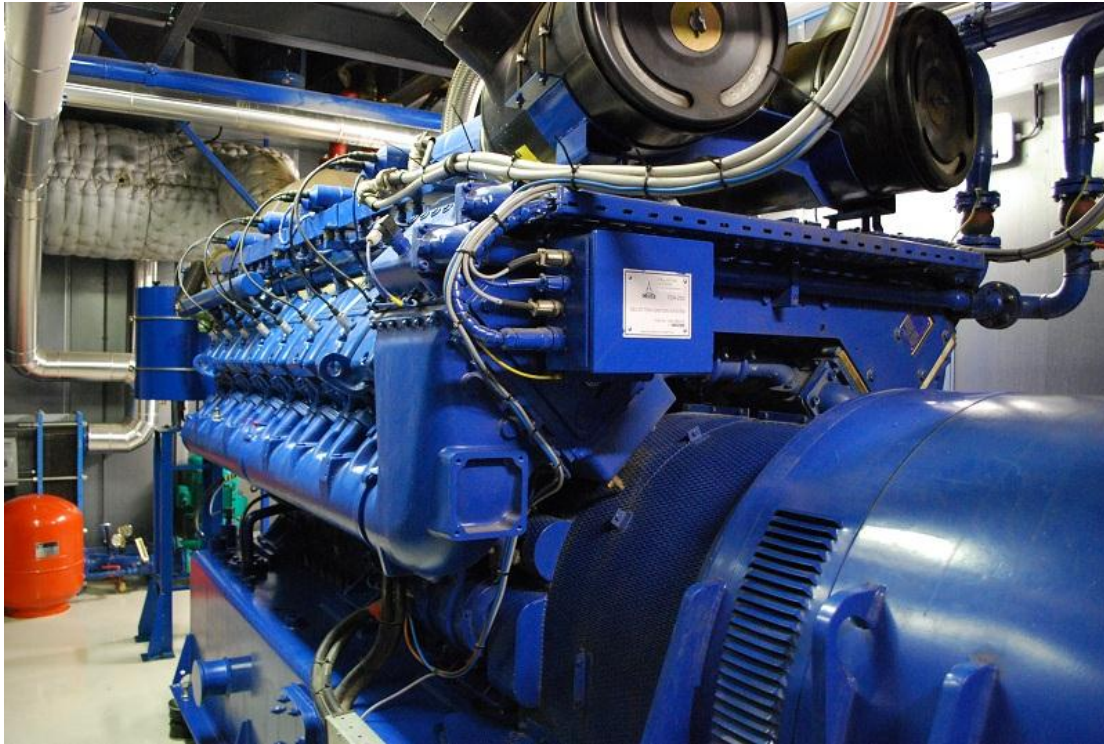
Energy Producing Greenhouse

An emerging trend in Holland is the energy producing greenhouse. The Dutch are aiming to have fossil fuel free greenhouses by 2020 (UWS, 2010). Trials by research centres such as the Wageningen UR Glastuinbouw experimental station are producing energy onsite and storing them for future use. One glasshouse design was heating water in the warmer months and storing it in underground aquifers for use in the winter. Another greenhouse that was built had twin walled polycarbonate roof panels that allowed water to pass through it and heat up through natural solar radiation, this water was pumped to

buffer tanks to be used at night. Research stations like Wageningen work in close collaboration with companies and other universities to come up with greenhouse ideas and trial them before commercial release.

Cogeneration of Heat And Power

One greenhouse technology I saw in operation in many large commercial greenhouse operations in the Netherlands was the use of CHP (cogeneration heat and power). This process burns natural gas and creates electricity, heat (hot water) and CO₂ (Roarty, 1999). The electricity powers the greenhouse or is sold back into the national grid value adding to greenhouse operations. Growers are also able to power artificial lighting for the winter months. The hot water created through CHP is stored in large buffer tanks and pumped through the greenhouses when needed. Another by-product of the CHP process is the production of CO₂. CO₂ is pumped into the greenhouse at levels of up to 1000 ppm leading to significant increases in yield of up to 21% in some studies (Gustafsson, 2008). CO₂ injection increases net assimilation rates as plants can photosynthesise more at higher CO₂ concentrations (Heuvelink & Dorais, 2005), as the outside environment contains roughly 350 ppm and this is often the limiting factor in hydroponic greenhouse production. CHP is twice as energy efficient as natural gas-fired boilers and a third of the emissions compared with burning coal (CEC, 2011). Due to the requirements needed to provide electricity into the national power grid, CHP might have limited use in Australia if surrounding infrastructure is not upgraded to cope with the additional loads. CHP could be a viable option for an Australian grower who wishes produce hot water and CO₂ during the day whilst powering a greenhouse cooling system. A used CHP system from Europe might be option for an Australian high-tech greenhouse operation of larger than 10 hectares.



CHP machine, Rose grower in Holland.

Energy and Thermal Screens

Energy screens are playing an important role in greenhouse management in Holland and are helping to achieve lower energy emissions. Thermal screens are an automated covering which can open and close over the canopy of the crop. Screens come in a multitude of configurations from completely closed to an open weave design. All the growers I visited had a thermal screen covering to trap heat and save on energy inputs at night. The use of screens allows growers to run a slightly lower boiler temperature and savings of 19% can be achieved (Parker, 2001). In Holland I noticed the screens were used primarily for energy savings at night and very rarely used for shading during the daytime. Australian growers use screens for both energy saving and solar shading due to our extreme summer light levels. The preferred option for Dutch growers for solar shading is the use of whitewash paints. This option paints a chalk-like substance over the roof and reduces the amount of radiation on the crop. It is preferred by Dutch growers as screens can hinder ventilation rates and traps heat inside the greenhouse on hot days.



Energy screen. Seen at the Improvement centre, Holland.

High Pressure Fogging

One technology that was not evident in Holland but is essential to South Australian growers is the use of high pressure fogging systems. Fogging releases tiny water droplets into the greenhouse environment. It is considered the most cost effective way to add humidity into a greenhouse when outside humidity can sometimes be as low as 10%. At these extreme humidity levels the natural transpiration rates of vegetable crops cannot cope and plants shut down to survive. Low humidity can soften fruit, burn flowers and cause a physiological disorder called ‘blossom end rot’ (BER) where the tissue at the blossom end of the fruit dies and usually becomes leathery. Keeping humidity levels at 65%-70% has been shown to significantly decrease the occurrence of BER as calcium uptake is continued. Calcium uptake is passive and calcium is therefore drawn into the plant through water uptake. As transpiration increases so does calcium uptake (Rijk Zwaan). As humidity levels drop, leaves start to wilt and the plants shut down. Calcium is needed to sustain cell permeability in the leaf structure and as calcium does not readily translocate through the plant it is pulled from the blossom end of fruit causing lesions. Another benefit to high pressure fogging systems is temperature control in summer. Extreme temperatures limit fruit set. In tomato production temperatures above 30°C are

detrimental to fruit set (Gustafsson, 2008) so growers in summer periods try to keep their greenhouses as cool as possible.

Marketing in the UK.

The UK protected cropping industry is very similar to the Dutch with mostly Venlo glasshouses and hanging gutters. The goal of my visit to the UK was to investigate how marketing of fresh fruits and vegetables is done, particularly truss tomatoes as they are the main produce grown and sold by hydroponic growers in Australia. The large sized tomatoes I found in London supermarkets were truss tomatoes. It was very interesting to see how packaging and labelling is important for UK growers. The truss tomato was in a cluster of five fruits prepacked in a sealed bag. They were produced on a UK farm but more importantly the labelling was extremely detailed. Australian growers are able to get away with just a name tag on each cluster with our business details yet the UK tomatoes had the business details, date of packaging, expiry date and even the name of the tomato variety. I could see no benefits to having varietal names unless the supermarkets stocked different varieties which they did not. I noted around half of the truss tomato buyers looked at the packaging.

Pre-packing tomatoes is an emerging trend in Australia as supermarkets tire of buyers picking off single tomatoes from truss varieties and passing them through the checkout as cheaper field grown fruit. Pre-packaging forces customers to buy the entire cluster although some consumers are reluctant as the packaging can hide defects and mask the tomato aroma which hydroponic fruit are known for.

Costs of converting to Hydroponics

Low-tech greenhouses can be converted over to hydroponics relatively cheaply if there is existing infrastructure present. Semi-hydroponic farms do not have automatic climate control which reduces infrastructure costs significantly. The conversion of a basic farm with an existing shed, forklift and supply of adequate electricity can make the process

much easier with a greenhouse of 5000 m² being adequate for a family run business. A checklist for a soil grower wishing to convert to hydroponic soilless production in a low-tech greenhouse are;

- Greenhouse, suitable size would be 5000m².
- Sheds to house the irrigation equipment and fertiliser tanks
- Sheds to store fertilisers and chemicals
- Irrigation lines from the greenhouse to fertigation unit and irrigation lines within greenhouse
- Hydroponic gutters with stands
- Black/white plastic or weedmatting for ground cover
- Water tanks, 50,000litres is sufficient for 5000m²
- Growing media, first time growers start in cocopeat growbags.



Typical semi-hydroponic greenhouse at the end of season.

As farms in the Virginia area are varied in shape and infrastructure, each farm must be assessed on an individual basis and the checklist adjusted accordingly which is why a good hydroponic consultant is vital in achieving a good outcome. Any grower looking to convert must speak to a consultant first before any work begins. The local fertiliser supplier or seed representative will undoubtedly know the best person to speak to.

The following 5000m² semi-hydroponic greenhouse conversion assumes the grower is in the Adelaide plains area planning on growing tomatoes and undertaking the majority of the work themselves with only some extra workers needed for arduous tasks. Growers in other states should refer to their local suppliers for correct pricing. Adelaide's highly dense horticultural region promotes a range of suppliers specialising in different areas of hydroponic conversions. Growers in other states may pay up to 5-10% more for their goods and services. Prices are in AUD and are only an indication of what a grower might expect to pay.

> Fertigation unit (no climate control, irrigation based on solar radiation)	\$40,000
> Nutrient mixing tanks with automatic stirrers	\$5,000
> Ground covering	\$8,000
> Gutter system to channel waste water away (approximately 2500m)	\$40,000
> Irrigation including drippers, main piping, sub laterals.	\$15,000
> Growing media, cocopeat growbags (2500 bags)	\$7,500
> Supply of fertilisers	\$10,000
> Bobbins to string up tomato crop	\$4,000
> Electrical work	\$5,000
> Miscellaneous	\$10,000
 TOTAL	 \$144,500

A semi-hydroponic grower in their first year of growing would expect a yield starting at 30 kg/m². Based on an average price of \$2 per kilogram for tomatoes a grower would expect a gross return of \$300,000. Many semi-hydroponic growers I have spoken to believe a net financial margin of 30% is standard and therefore a family run semi-

hydroponic tomato grower with 5000 m² could expect an income of at least \$90,000. These figures show why hydroponics is becoming Australia's fastest agricultural industry as incomes generated are 3-4 times more than a soil grown greenhouse of the same size. Farmers will steadily increase their skills and invest in more technology such as;

Automatic climate control

- Ventilation
- Fogging systems
- Horizontal airflow fans (HAF)
- Pad and fan cooling systems
- Energy or thermal screens
- Hydronic heating systems

Irrigation control

- Recycling systems
- R/O water filtration
- UV sterilisation
- Datalogging of EC and PH in run-off water
- Change to rockwool production for precise control over root zone moisture

Greenhouse Structure

- Taller greenhouses
- Change to high-tech cladding such as polycarbonate or glass
- Completely sealed greenhouses



Medium tech greenhouse with fogging, HAF, vents and sticky traps

All these changes, although expensive, benefit the grower immensely as better control over the growing environment stabilises production throughout the year increasing yields. Growers can start at 30 kg/m² and work their way up to 60 kg/m². If a grower goes the route that the Dutch have and builds a high-tech Venlo glasshouse with world class growing practices, yields of 70-80 kg/m² are possible.

Final Advice

In conclusion I would like to describe a disease that threatens the livelihood of farmers in Australia and overseas. Bacterial canker is a disease caused by *Clavibacter michiganensis subsp.* (Parker, 2009) that has spread throughout the world wreaking havoc to horticulture, especially hydroponic solanaceous crops such as tomatoes and capsicums. I have studied this disease for the past few years as it has caused losses of more than 15% in yields to my own farming operation and has caused huge losses overseas and in

Australia. Canker is a described a wilting disease of tomatoes but unlike some other wilting diseases, once canker has taken hold of a plant there is no cure and death is certain.

Canker has many ways of entering a farm. Infected seedlings are one source of the virus. With more and more growers using grafted seedlings, the spread of canker is increasing. Grafting increases the chance of spreading the disease as several seedlings are cut with the same knife. Canker can also enter onto a farm from another grower who has the bacteria on their clothes; it can also enter onto a farm through wind and dust storms.

The proximity to other farms in Virginia increases the chance of crops contracting the disease. Once canker has entered onto a farm, eradication is very difficult as it spreads rapidly and easily. It can survive on greenhouse structures and crop trolleys for weeks and in infected plant material for years. Plants do not show signs of infection for up to eight weeks depending on weather which makes management extremely difficult. Plants showing signs of canker will have contracted it many weeks prior to the evidence of scorch marks. The guaranteed way of spreading the diseases is the spreading of infected plant sap in pruning and harvesting. Canker has been in the Virginia area for many years but has not been a big issue for soil grown tomatoes due to the latency of the disease. The harvesting period is only a few months for soil growers therefore crop losses from the disease will be at the end of the cropping cycle. Hydroponic tomatoes by comparison are harvested for over nine months and therefore huge losses can be expected as the disease infects and spreads throughout the crop.

Infected plants initially show signs of small scorch marks in the centre of leaves. At hot periods of the day plants will wilt but may regain their structure during the night. Eventually the entire plant wilts and dies. Early signs of canker can be mistaken for other diseases and therefore a crop consultant should be advised and material sent off to be tested. If a grower believes that canker has entered a site through wind then it is very difficult to manage as there will be multiple sites with the disease. Greenhouses that have

had canker enter through contact with people or infected seedlings have a better chance of managing the disease.

Once Canker Has Been Spotted and Verified

- Rows with the disease must be cordoned off immediately. The infected row and the 2 adjacent rows either side must be worked on last by the same person who can manage and assess the spread of disease.
- The diseased plant should be removed along with the growing bag and the plants in that bag as canker can spread through water in the root zone. Some growers will remove the entire row that had the infected plant whilst others will remove at least 5 before and 5 after the infected plant.
- Any work in the infected row should have scissors swapped after EVERY plant. Adjacent rows should have scissors swapped after every few plants. Workers on any quarantined row and adjacent row must always work on one side and return on the other side to stop the spread from left to right.
- Infected plants should be placed in a garbage bag to stop the spread when removing them from the greenhouse.
- At the end of the season, all plant material should be removed offsite. Disposal of 5000 m² of tomato waste costs approximately \$2,000AUD.
- Disinfect all trolleys and hand tools that enter and exit an infected greenhouse.
- Train crop workers to spot and immediately report any plant that shows signs of any disease. Supervisors should inspect and take the appropriate action.

Recommendations

Soil growers must meet with a consultant to set out an action plan for conversion to hydroponics. Consultants are expensive but their knowledge of markets and varieties is invaluable. Many soil growers who have spent hundreds of thousands of dollars are realising that hydroponic growing is vastly different to soil production and they do not possess the relevant skills to utilise the new technology.

Any new grower looking to convert to hydroponics must plan for the future. All buildings must be designed for future expansion. Once a hydroponic greenhouse is built it is extremely costly to renovate or rebuild.

Growers should aim at investing in the most high-tech equipment they can afford. Growers who experience large temperature fluctuations through the year like growers in the Adelaide Plains will have more consistent produce if they can stabilise growing conditions and keep plants healthy. A good hydroponic setup in Australia should consist of

- >Vents
- >Growing gutters
- >High pressure fogging system
- >Automated irrigation system
- >Crop consultant
- >A good EC/PH meter



Basic pH/EC meter

Pest and diseases are a huge problem with hydroponic growing as the seasons are extended well beyond a soil crop. Growers stand to make huge losses if they do not approach greenhouse pest and diseases effectively. Growers must look into implementing an IPM program.

Australian greenhouse tomatoes lack the funding and research that field growers have had. There is a distinct lack of pesticides and fungicides available to use and those that are registered have been in use for years with reduced effectiveness. Greenhouse tomatoes should have a levy placed on them to facilitate future research and development programs to combat the increasing number of pest and diseases we face each year. Research can also be done on greenhouse structures to determine which designs benefit our hot dry summers.

The cost of setting up a hydroponic greenhouse is prohibitive to many soil growers and young people trying to enter the industry. Cheaper agricultural loans should be made available to those who can prove their desire to become growers. Subsidies should be available for growers who farm in an efficient manner such as recycling waste water or use IPM.

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Plain English Compendium Summary

Project Title:	
Nuffield Australia Project No.:	
Scholar:	Minh Hieu Ly
Organisation:	Ly hydroponics
Phone:	0411 088 223
Fax:	(08) 83809043
Email:	Ly.hydroponics@gmail.com
Objectives	Research the benefits of converting from soil to hydroponic vegetable production.
Background	Hydroponic production is becoming Australia's fastest growing agricultural industry. The protected cropping industry has seen a boom in the conversion from soil to hydroponic production, especially in the Northern Adelaide Plains area.
Research	Farming practices in countries like Australia, Holland, France, UK and Japan were assessed. Farms from these countries were visited and the technology was seen in action. Interviews with growers planning on converting to hydroponics and those who had already made the change also contributed to this report.
Outcomes	Hydroponics is the future of protected cropping in Australia. Our harsh climate makes passive soil production a challenge when attempting to produce high quality vegetables all year long. The Northern Adelaide Plains area in South Australia needs the investment into all levels of hydroponics from low-tech, semi-hydroponic to high-tech similar to the Dutch. The loss of land, urban sprawl and increasing costs of doing business means farmers must yield more with less. Hydroponics allows growers to do this in a sustainable manner. A good hydroponic grower will yield significantly more, use less pesticides and still be profitable compared to soil growers.
Implications	Costs of entry into the industry are high and out of reach for many young growers. Older generations are reluctant to convert due to high capital costs versus time to recover their costs. New growers, particularly migrants find the new technology difficult to learn and growing techniques are much different after converting to hydroponics. Growers must decide if they are capable of undertaking the hard long hours and investment needed to grow hydroponically successfully.
Publications	Nuffield Australia