Efficient Practices in Low technology Greenhouses

Surviving as a small family farm

A report for

by Bao Duy Nguyen

2017 Nuffield Scholar

July 2019

Nuffield Australia Project No 1724

Supported by:

Scholar Contact Details

Bao Duy Nguyen

Sun City Produce

PO Box 2

Walkaway WA 6528

Phone: 0418 939 982

Email: contact@suncityproduce.com.au

NUFFIELD AUSTRALIA Contact Details

Nuffield Australia

Telephone: (02) 9463 9229

Email: enquiries@nuffield.com.au

PO Box 1021, North Sydney, NSW 2059

Executive Summary

The focus of this study was to seek best efficient practice from around the world that could be implemented in family enterprises at Geraldton, WA. Geraldton is in a warm temperate climatic zone, however the recommendations are suitable for anyone in the low technology greenhouse category regardless of location.

Low technical greenhouse structures that exist around the world vary in shapes and size. They can vary from structures that are single tunnel igloo, single or multi-span gable with pointed roofs, saw tooth multi-span and most common the flat arch multi-span tunnel. In one area of the world specifically Almeria in Spain, the parral greenhouse structures are unique to the area, improvised by the structures used in the original industry of grape farms in the area. They have a flatter roof and are reinforced with mesh wires.

Water quality for all types of greenhouses is a very important factor for growing produce, it impacts directly with production as well as fertilizer management for greenhouse crops. Heights and ventilation within the structure is also a key factor in controlling temperature, humidity, and ventilation. This aims to reduce stress in the plant as well as disease pressure.

The large concentration of low-tech greenhouse production around the world are located in those areas because the climate is already favourable for growing in those regions. This is the largest factor that effects low-tech greenhouses. This considerably effects the growth of the plant and reduces production cost involved in climate control. High tech greenhouse is located in areas where there are greater climate challenges. Therefore, any technical changes to the structure for your low- tech greenhouse should be reflected in profit.

Efficient practices found around the world which are recommended or considered if operating in the low-tech greenhouse space are summarised below.

These investigations highlight the need to know what is happening in the greenhouse so - low-tech systems can maximize returns and remain sustainable. Improving greenhouse management is the key through identifying the systems strengths as well as weaknesses. This can be done by first understanding the environment and performance of the greenhouse. The most accurate way to understand the performance of low-tech greenhouses is through monitoring temperature and humidity, soil water moisture content, EC and nutrients, and solar radiation through a series of instruments and sensors and the utilization of cloud-based

internet for real time analysis. This will allow trialing to be carried out with measurable outcomes.

Recording the cost of production and well as the production for each crop would give an overall indication of the farm's performance year on year. This practice is a key element in good management practices that should form part of every sustainable business. Other elements would include, production controls, hygiene, pest control, and quality management etcetera. It can be tedious but will allow an understanding whether operation is sustainable. This process will help with efficiency and increase production. It is also important to meet food safety, quality produce and legal requirements.

Automation is the key to better working conditions in a highly labour intensive industry. Anything that can make tasks quicker and easier will allow growers to move onto other important tasks as time is usually at a premium. For example, installing automated roll-up sides and roof vents would ensure quick opening and closing of vents when temperature or humidity levels reach peak points. Currently most automation benefits are achieved in the packing shed. However, there are opportunity for automation in the growing environment, for example automated irrigation and fertigation systems.

As margin can decrease, input cost reduction is important. The aim is to strategically cut input cost without sacrificing yield. Integrated pest management (IPM), re-using plastic for practices such as solarisation and sanitation periods are useful ways to reduce input costs as well as offering a healthier option of disease management. Installing a second layer of thin plastic to construct a double plastic roof to insulate and capture condensation on crops is also a cost-efficient solution to keep as much heat in the greenhouse during the winter season, if climate permits growing during the winter period.

For policy makers, the two largest factors in the horticulture industry are water and labour. The availability and price of cheap water is critical for long-term sustainability of this industry. Where there is competitive price or abundant water source there is production. In those areas of limited water, technology has been used to help increase efficiency in water usage. Protective cropping globally already implements efficient drip irrigation practices compared to those of field grown crops. However, the largest input for the greenhouse horticulture industry globally is labour.

A common theme with all the countries visited, is that they all have immigrant labour to assist in vegetable production. The biggest issue is the unwillingness among locals to work in the horticulture environment. The locals lacked desire to work and do not see fruit picking as a favourable career option. This is a contrast to reliable and productive workforces sourced from overseas workers. This problem has caused a huge shortage of labour not only in the horticulture industry but the whole agriculture industry.

The CEO the National Farmers Federation (NFF), Tony Mahar, understands the problem and has been quoted *"The Australian farm workforce is a combination of local and international workers – working pursuant to seasonal worker program and working holiday maker visas. However, alone these programs do not meet the sector's labour needs,"* The NFF is calling on the Government to develop an Agricultural Visa to match international workers with the jobs farmers need filled.

Ideas of low to intermediate skilled visas from countries such as South East Asian countries should be considered, as this would reduce cost of production due to the time wasted re-training workers. Currently, this inability to access reliable workers can also jeopardise competitiveness. Innovation in automation is very exciting in these times and will improve considerably, along with progress in government policies. As for the current situation, horticulture will rely on being resourceful in this industry and attracting local workers who see value in nurturing and having a hands-on approach to the intensive horticulture industry.

Other best practise involved opportunities for collaboration and knowledge enhancement by building relationships with other growers and government organisations such as the Department of Agriculture. 'Always ask questions' was valuable and common advice given by growers encountered from this Nuffield journey.

Implementation of factors identified in this report is suggested in a staged approach in a financial budgeted managed manner to ensure that when a variable is changed it is linked to the result achieved. That is, it is not recommended that everything be changed at once, rather a more measured approach be undertaken to understand the implication of each decision.

Table of Contents

List of Tables

List of Figures

Foreword

My brother and I along with our parents are greenhouse vegetable growers in Geraldton, WA. Dad and mum first arrived in Australia as refugees from Vietnam in the 1980's. They moved to Geraldton and joined a small community of other Vietnamese refugees that were already working as labourers on the tomato farms in the area.

Geraldton has an amazing climate to grow vegetables with only the lack of competitive water price limiting growers. Greenhouse protected cropping is used to reduce the effects of the wind and prevent evaporation that help with water use efficiency.

Over time, my parents gained the skills and knowledge to start their own small farm and with just enough money saved they purchased a small plot of land near the airport in Geraldton. As children we found ourselves helping out, working after school and on weekends picking tomatoes, cucumbers and capsicum. Mum and Dad worked day and night whilst building a happy life for their three children. Our family valued education, with all kids going to university in Perth. I became a geotechnical engineer, Bao La an accountant and Cam a medical scientist.

In 2011, Bao La returned to the family farm to help our parents where he found that he loved the challenge of working with plants so he decided to stay. Two years later I too returned whilst taking a break from engineering and found myself working well with him so we decided to expand. We purchased 60 acres of land near Walkaway (30 minutes from Geraldton) where we now grow mainly cucumbers (and diversifying into other crops) under 4.2 ha of plastic greenhouses. A further two ha of plastic greenhouses is located at our parent's old farm closer to Geraldton.

After the first few years of working day and night we realised that we had reached a plateau on the improvement we could make. Our parents have achieved a lot given the limitations they faced due to their lack of English and learning from experience rather than having the opportunity to travel to see what others were doing around the country or the world. Due to the competitive nature of the horticulture industry they were not able to benefit from knowledge sharing amongst the local growers and therefore were not able to see benefits from knowledge transfer.

We realise if we keep staying on the farm doing what we do, we will be left behind. It is hard when you know you can improve however don't know what improvements to make. As a family operation we also don't have enough time to travel to learn new things. Given the above background, it was very unusual to apply for a Nuffield Scholarship and leave the farm to travel to gain knowledge a first for the region.

Nuffield has opened my world and taken my knowledge of horticulture to a new level. We are always looking for new innovations focusing on new developments in water and nutrient monitoring as well as climate control and integrated pest management. I have gained some valuable knowledge whilst away and we are very excited about putting some of the practices in place on the farm cost permitting, whether they work or not will be a learning experience.

Over the last year I have been involved in industry bodies including committee member with Vegetables WA and as well as Chairman of the newly established Mid-West Horticulture Grower Group Inc. that I helped set-up with a few other growers in the Geraldton area. Our grower group aims to give the local growers a voice and open opportunities in growing as well improving their business for the long term.

My Nuffield experience included participating in the Contemporary Scholars Conference (CSC) and Global Focus Program (GFP). On personal research, I visited Canada, US and with specific visits to Israel, Spain, Italy and the Netherlands.

For Canada, US and the Netherlands I had a chance to explore:

- High technical venlo glass houses
- Hydroponics growing systems including growing in substrate and re-use of drainage water
- Full climate control with cooling misters and heating rails
- Fertigation and irrigation software systems
- Growing lights
- Biosecurity procedures

In Brazil, Israel, Spain and Italy I was able to explore:

- Low technical parral, flat arch and saw tooth greenhouses
- Seasonal growing conditions
- Growing in soil, either in-situ with introduced compost or transported clay loam overlaid with river sand
- Conversion of semi-hydroponics growing systems
- Passive climate control using vents (influenced by wind direction)
- Insulations plastic within greenhouse for temperature and humidity control

- Slug dosing or fertigation systems
- Water collection systems
- Portable climate and moisture sensors
- Integrated Pest Management (IPM)

Acknowledgments

I would like to acknowledge my brother Bao La and my parents for allowing me the time to travel. They have worked longer hours to make it happen however I hope the changes I make to our business and to the local horticulture community will keep the greenhouse horticulture industry going in our region.

I thank my partner Jade for arranging my travels as well as making time to travel with me to many of the countries thus ensuring my experience run more smoothly and enjoyable.

I would also like to thank my GFP companions travelling with me on our travels, you guys made the trip worthwhile. Throughout my travels I would like to thank the following who we met with and arranged my visits with growers and industry: Shahaf Ein-Gedi (Nirit Seeds), Guy Reshaf (Netafim), Moshe Cohen (Biobee), Maayan and Ariel Kitron (Central and Northern Arava Research and Development), Isabel Mª Santorromán (Agrobio), Pepe Bretones & Javier Lopez Rodriquez (Rijk Zwaan, Spain), Luis Manuel Garcia, Rafael Salinas, Antonio Guitierrez and Inma Hernandez (Monsanto), Juan Carlos Rodriquez Lopez (Bayer), José Carlos Jiménez and Maria Luisa Garcia (Meridiem seeds), Juan Alfonso Sánchez López (Onuba Fruit), Johan Otto (Special Fruit), Franco Saccocci & Adriano Neroni, (Growa), Fabio Pappalardo, (Lefroy Valley), Pascal van Oers (VEK Adviesgroep), Sebastiaan Smeur (Meteor Systems), Roger de Jager (Madenkro), Arjen Janmaat (Hortimax), Marion Koning (Konflex), Niels Lauwers (30MHZ), Frank De Koning (Nature and More), André Poldervaart & Biokwekerij Poldervaart, Ton Habraken (Svensson), Jac Verbeek (BioVerbeek) and fellow Nuffield Scholar, Roland Asten.

I would also like to thank Pascal Van Oers from VEK Adviesgroep for preparing most my itinerary in Netherlands. I am grateful for the contacts I made with industry and leading growers in low and high technical greenhouses. I would also like to thank fellow Scholars Karen Daynard, Jim Clark, Mark Wales, Nicole Mackellar and Roland Van Asten for their hospitality in staying with their family as well as their assistance in arranging visits with growers.

The opportunity to explore the various operations in the countries I've visited was made possible with the sponsorship of Hort Innovation. Thank you for the opportunity to broaden my horizon and be able to bring something back for industry.

Abbreviations

CSC	Contemporary Scholars Conference
EC	Electrical Conductivity
GFP	Global Focus Program
GST	Goods and Service Tax
GVP	Gross Value Production
HDPE	High density polyethylene
IPM	Integrated Pest Management
m2	Square metres
NFF	National Farmers Federation
PCA	Protective Cropping Australia
TDS	Total Dissolved Salts
WA	Western Australia

Objectives

- To investigate low technical protective cropping structures currently used for growing intensive vegetable crops
- Define factors that affect low technical greenhouse management
- Find the most efficient world's best practice in vegetable production in Low technical greenhouses
- To make practical recommendations to growers using Low technical greenhouse production in intensive farming crops.

Introduction

The protective cropping horticulture industry has a farm gate value of $1.8 billion in Australia, this includes vegetable and flower production. The industry is expanding at around 4-6%.

Australian Protected Cropping Industry - Estimated GVP Farmgate in 2017

Product	2014-15 est'd GVP Note 1 $ million	2015-2017 % increase Note 2	2017 est'd GVP $ million	Growing system	Protection	Protected % Note 2	2017 Protected est'd GVP $ million
Blueberries	155.5	15%	178.83	soil / fertigate	poly / hail / shade	25%	44.71
Rubus	103.4	20%	124.08	soil / fertigate	poly	85%	105.47
Strawberries	420	5%	441.00	soil / fertigate	poly	30%	132.30
Cherries	122.1	5%	128.21	soil / fertigate	poly	40%	51.28
Summer Fruit	333.9	5%	350.60	soil / fertigate	hail / shade	30%	105.18
Tomatoes	548	15%	630.20	hydro / substrate	poly / glass	80%	504.16
Capsicums	144.7	5%	151.94	hydro / substrate	poly / glass	20%	30.39
Cucumbers	183.5	5%	192.68	hydro / substrate	poly / glass	50%	96.34
Eggplant	16.2	5%	17.01	hydro / substrate	poly / glass	20%	3.40
Herbs	121	5%	127.05	hydro / substrate	poly / glass	25%	31.76
Asian Veges	62.5	5%	65.63	hydro / NFT	poly / hail / shade	40%	26.25
Flowers	266.5	-10%	239.85	soil / fertigate & hydro substrate	poly / glass	60%	143.91
TOTAL	$2, 477.30		$2, 647.05				$ 1, 054.24
Protected Cropping as percentage of total Horticulture GVP below							9.96%
Nursery	$1, 130	0%	$1, 130	seedling & potted	poly / glass	30%	$ 339.00
TOTAL Incl Nursery	$ 3, 607.30		$3, 777.05				$ 1, 470.23
Including Nursery & Protected Cropping as percentage of total Horticulture GVP below							13.88%
GRAND TOTAL Protected Cropping and Nursery GVP Farm Gate estimated							$ 10, 589 million

Note 1 Source; HIA / HIA Freshlogic series; Australian Horticultural Statistics Handbooks
Note 2 PCA estimate

Table 1: Australian Estimated GVP Farmgate in 2017. * Hort Innovation Freshlogic Series; Australian Horticulture Statistics Handbooks, PCA estimates

Statistics on the size of greenhouse production in Australia is out- dated and the leading trend unknown between low technical, mid technical or high technical systems. The table above show estimated greenhouse production that include all three types of technical systems. Protective Cropping Australia (PCA) acknowledge industry do need to initiate a project to better understand the size of the industry and crops grown, so that we can better plan for industry growth and opportunities.

There is a large cost differential between high technical and low technical greenhouses. Simple low technical greenhouse commonly a multi-span tunnel, less than 3m high, covered in plastic (polyethylene) film with no climate control, natural ventilation, and the crops are grown in soil. Whilst high technical greenhouses consisting of wall height greater than 5m, covered in plastic film or glass, automatic climate control technology (cooling and heating systems) and automatic irrigation controllers. High technical greenhouse could be five to ten times more expensive than low technical greenhouse. It is difficult to directly compare as there is such a variance on what growers decide to include and exclude in their structures. Due to sensitivity of the data, the companies interviewed were not able to provide numbers. This is also a reason why there is not much or outdated information in Australia.

Vegetables such as tomatoes, cucumbers, capsicum and eggplant are a matured market in Australia. Given these categories are saturated markets, capital outlay and running cost should be taken in consideration in the budgeting for return on investment for these structures.

Most growers simply do not have the capital required to construct high technical greenhouses and instead choose to remain in low technical systems where risk levels are seen to be lower and mistakes can be endured. The lack of business skills along with English being a second language impacts grower ability to market produce effectively and as 'price takers' are vulnerable to supply and demand of the market system.

High technical growers or multinational companies investing in greenhouse production generally have acumen and scale to negotiate contracts with large supermarkets thus obtaining better prices and eliminating agent costs.

The majority of refugee farmers who arrived in Australia in the 1980's chose to grow in low technical greenhouses due to the low capital cost, lack of English skills, and simplicity of technology. They moved to areas where the climate was suitable for growing profitable outside crops and low technical greenhouse crops are achievable and sustainable. Therefore, if restricted to this type of technology the challenge is to find efficient practices and production that can maximise returns to growers.

The greenhouse structures and climate for growing vegetables in Israel and Spain are similar to Geraldton therefore best practices observed can be replicated or adapted here, resulting in better quality production opening up new market opportunities such as exporting.

"You can make a greenhouse do anything you like. But is the cost warranted?" Javier Lopez Rodriguez, Riik Zwaan

Chapter 1: Climate Control

Cost of Construction – Favourable Weather

The cost of construction of low technical greenhouse structure cost around $10-$20/m2 in Israel and Spain, while Australia is on the upper limit of $20/m2. These are estimates of the low technical greenhouse structures only and do not include irrigation, fertigation and running cost. The higher cost in Australia maybe due to the higher labour cost. The construction cost for the author's low technical greenhouse is around $26/m2 which is above Australia's estimation. This could be due to the cost of materials being higher in a regional location.

Almeria, Spain where approximately 35,000 ha of low technical greenhouses are located, can take advantage of warm winters and therefore less cost required for climate control due to being located next to the Mediterranean coast. With such a large horticulture industry in the region, the scale allows for technical, irrigation services, greenhouse construction companies to concentrate in the area allowing for cheaper construction costs. Low operation cost allows for small growers on an average of 1.5ha to make a living (Gimenez, 2018). Whereas the Netherlands experiences cold winters including snow that requires heating. These higher cost structures result in reduced number of growers with the remaining growers increasing in size.

Table 2 shows breakdown (estimate) costs for construction projects for fully running high technical greenhouse and low technical greenhouse in Australia, relevant to Virginia in South Australia.

Area	42000	m2	
Glasshouse	Qty	Price (ex GST)	$/m2
Venlo Style Greenhouse	110	$4,690,400	$110.00
Climate Control Equipment			
Priva Connext network	1	$219,290	$5.14
Circulation fans including hanging materials		$37,310	$0.88
Automated Shade and Thermal Screens	84	$628,800	$14.75
High Pressure Fog System	1	$302,010	$7.08
Heating System	1	$1,600,000	$37.52
Electricals	1	$183,840	$4.31
Fertigation			
Nutrimix MT660	2	$74,680	$1.75
Stirrers and stirrer timer	16	$14,120	$0.33
Stock tanks & acid tank	8	$19,110	$0.45
UV sterilization			
Priva Vialux - M4 including pre-filtration	2	$117,260	$2.75
Irrigation			
Drippers, Pipe, Tanks, Valves, Connections	2	$630,000	$14.77
Gutters			
Growing gutters	254	$407,940	$9.57
Trolleys			
Berg Meto spray trolley & Meto Trans	1	$54,840	$1.29
Georgia tank trolley	1	$8,870	$0.21
Benomic Star 2 scissor trolley	16	$189,120	$4.44
Benomic Quad scissor trolley	1	$16,930	$0.40
Powerplants galvanized transport trolley	40	$49,230	$1.15
Local Freight	1	$5,625	$1.15
Engineering/Documentation/Project management	1	$40,000	$1.15
Total project pricing excluding GST		$9,289,375	$219.09

Table 2: Breakdown Construction cost for high technical greenhouse, Australia Courtesy Powerplant costing, McLean (2019)

Area	11760	m2	$40.00
Greenhouse	Qty	Price (ex GST)	$/m2
Multispan flat arch	40	$216,642.00	$18.42
Climate Control Equipment			
Side plastic /shade cloth manual winder	1	$19,045.00	$1.62
Electricals	1	$30,000.00	$2.55
Fertigation			
3 venturi doser	1	$9,000.00	$0.77
Stirrers and stirrer timer	3	$1,050.00	$0.09
Stock tanks & acid tank	3	$600.00	$0.05
Irrigation			
Drippers, Pipe, Tanks, Valves, Connections	1	$35,000.00	$2.98
Trolleys	10	$3,000.00	$0.26
Local Freight	1	$1,000.00	$0.09
Engineering/Documentation/Project management	1	$10,000.00	$0.85
Total project pricing excluding GST		$325,337.00	$27.66

Table 3: Breakdown Construction cost for low technical greenhouse, Australia. Costing estimates from Le, T (2019) and Author, Nguyen, B (2019).

Construction cost for high technical greenhouse is almost ten times that of low technical greenhouse. The high capital cost of around $220 /m2 for high technical greenhouses would be out of reach for most new starters who want to come into protective cropping. A construction cost of $28/m2 is a more achievable for family own operating businesses.

The above cost does not include sheds, reverse osmosis systems, earthworks, concrete, staff facilities or amenities. If they were included in the costing, the industry standard would be around $260 - $270/m2 in Australia (Cannon, L, 2019 & McLean, 2019). If we compare this to the Netherlands, the country that are leaders in high technical greenhouse innovation and efficiency, the cost per m2 have been quoted around $180-$220/m2 (Goebertus, T, 2019 & Ores, P, 2019).

Production Levels

It is difficult to compare profitability of high and low technical greenhouses due to the production level and running cost of each system, however production levels for places visited are shown in Table 4.

Country	Technology	Crop	Plant Spacing	Yield
Israel Kitron, A. 2018	Low tech	Tomato	0.75 to 1.5/m2	Double head at 1.5 yielding 18kg/m2
Israel Kitron, M. 2018	Low tech	Capsicum	3 to 3.3/m2	7kg/m2, regions with 4 degrees less in temperature, production can be 10kg/m2
Gozan,E. 2018	Low tech	Tomatoes	1.7 to 1.8/m2	14kg/m2 – small tomatoes
Italy Anillo, 2018		Tomatoes	2 to 2.4 / m2	16kg/m2
Sicily Agnone, A. 2018	Low tech	Capsicum	3/m2	8-12 kg/m2
Spain Sanchez, J. 2018	Low tech	Tomatoes	Information not captured	12-17 kg/m2
Spain Bretones, P. 2018 Sanchez, J. 2018	Low tech	Cucumbers	1 plant/m2 in Winter, 1.3-1.5 plants/m2 Spring & Summer	13-16 cucumber /m2 15-20 cucumber /m2
Spain Gerente, I,B. 2018	Low tech	Capsicum	Information not captured	8kg/m2
Holland Ores, P. 2018	High tech	Tomatoes (truss/clusters)	Information not captured	95-100/m2 with grow light
	High tech	Tomatoes (loose)	Information not captured	65-70/m2
Holland Hendricks, K. 2018	High tech	Cucumber	Full year umbrella system 1.25 plants/m2	200 cucumber/m2
	High tech	Cucumber	Hire wire 2-3/m2 – 2 crops	230-240 cucumber/m2
Koning, J.D. 2018	High Tech	Cucumber	2-3/m2 - 3 crops	200 cucumber/m2
Canada/USA Goebertus, T. 2018	High Tech	Tomatoes	Information not captured	70kg/m2
	High Tech	Cucumber	3 crops	180 cucumber/m2
	High Tech	Capsicum	Information not captured	30kg/m2
Australia Industry Smith G, 2005	High Tech	Tomatoes (Truss)	2-3/m2	60-70kg/m2 75kg/m2

Smith G, 2005	High Tech	Capsicum	Information not captured	30kg/m2
Smith G, 2005	High Tech	Cucumber	Information not captured	100kg/m2 200 cucumber/m2 (assume 500 gram cucumber)
Author Nguyen, BD	Low Tech	Tomatoes (Loose)	1-2/m2	12-13kg/m2
	Low Tech	Cucumbers	2.2/m2	20-25 cucumbers/m2

Table 4: Production Levels for crops observed in the countries visited (Author)

High tech greenhouse production numbers are similar around the world, including Australia, as they all have similar technology as tools to control their climate. Overall, the Netherlands are leaders in production per m2 even with new and emerging technology.

High technical greenhouse has a longer season for the above crops and therefore this adds to more production compared to low technical greenhouse production. The production increases up to four times for tomatoes and capsicum and cucumbers has a significant increase of ten times. That could indicate that it is quite possibly more profitable to grow cucumbers in high technical greenhouses. However, this report investigated more technical efficiencies and unfortunately lacks business running cost analysis, specific to cucumbers.

It was difficult to collect low technical greenhouse production numbers as most growers did not keep records. There are benchmarking projects within Vegetables WA (https://vegetableswa.com.au/), that could explore more of these production numbers. For the author, production in tomatoes are lower than countries visited possibly due to pollination challenges as other countries' use of bumble bees is a more efficient way for pollination. For cucumbers a higher production was recorded than regions visited. This could possibly be due to more sunlight in the mid-west region of Western Australia (WA), and the climate favours the growth of cucumber crops.

Accurate return on investment of the different types of greenhouses was difficult to explore with individual growers, however it is known that Dutch growers aim for ten years return on investment whilst Almeria, Spain is approximately five-to-seven years. (Gimenez, 2018). In Adelaide, growers have anticipated returns of six years for low technical greenhouse (converted hydroponics), (Ferguson, 2012).

An attempt to calculate the running cost for high technical and the author's low technical greenhouse production of tomatoes is summarised in Table 5. These are estimated expenses used to determine current productivity and viability. The largest running expense cost for both low technical and high technical greenhouse is due to labour costs, both are around 30% total expenditure. High technical greenhouse also has high running cost due to heating expenses at 20% of running cost. High technical greenhouses have a longer season of producing, therefore their production is greater and their net profit to total expense ratio is 78%, while the low technical greenhouse production is at 52%. To reach average wage in Australia, twice the size of low technical greenhouse would be required. These numbers do not include expense for cost of investment and assume the grower is the owner. Refer to Appendix on page 72 for full spreadsheet details.

© Graeme Smith Consulting - Greenhouse Cost of Production Worksheet						***Vegetable Season***	***2016***	
High Technical Greenhouse							*Melbourne*	
	Income (gross)							
Greenhouse Size (m2)	**Market System**	**Local Sales**	**Other Sales**	**Total Income**	**Total Production (kg)**	**Production (kg/m2)**	**Total Expenses**	**Potential Net Profit**
3,840	**$485,000**	**$75,000**	**$5,000**	$565,000	**187,000**	48.7	$316,795	$248,205
per kg			**per m2**				**Net Profit/Total Expense**	
Gross Income/kg	**Annual Costs/kg**	**Net Return/kg**	**Gross Income/m2**	**Annual Costs/m2**	**Net Return/m2**			**78%**
$3.02	$1.69	$1.33	147.14	$82.50	$64.64			

© Graeme Smith Consulting - Greenhouse Cost of Production Worksheet						***Vegetable Season***	***2018***	
Low Technical Greenhouse							*Geraldton*	
	Income (gross)							
Greenhouse Size (m2)	**Market System**	**Local Sales**	**Other Sales**	**Total Income**	**Total Production (kg)**	**Production (kg/m2)**	**Total Expenses**	**Potential Net Profit**
3,500	**$93,531**			$93,531	**46,765**	13.4	$61,390	$32,141
per kg			**per m2**				**Net Profit/Total Expense**	
Gross Income/kg	**Annual Costs/kg**	**Net Return/kg**	**Gross Income/m2**	**Annual Costs/m2**	**Net Return/m2**			**52%**
$2.00	$1.31	$0.69	26.72	$17.54	$9.18			

Table 5: Cost of Production for high tech and low tech greenhouse (estimate only)

Low Technical Greenhouses

There were many types of low technical greenhouses observed. Tunnels were either single or multi-span design with the wall height (height to gutter) usually below three metres. They are covered with plastic (polyethylene) film and have net shading cloth for the walls. The typical shape of low technical greenhouses is shown in Figure 1. These types of greenhouses were seen in Israel in the Negev and Arava desert region, in Sicily and part of Almeria in Spain.

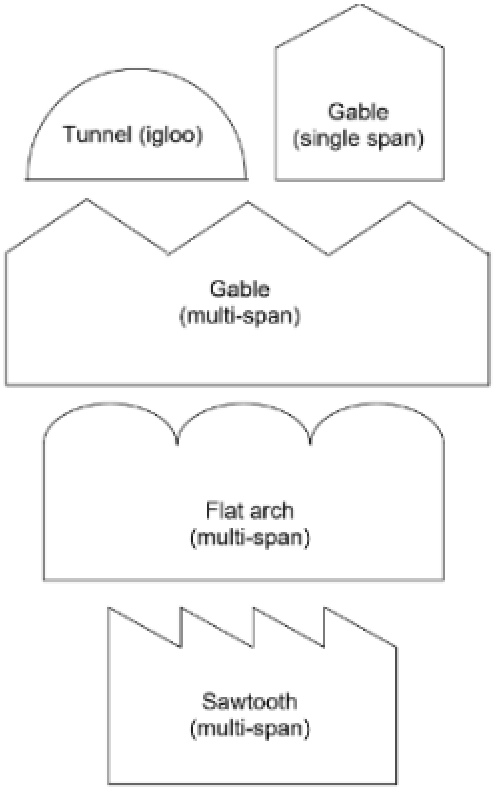

Figure 1: Types of Greenhouse Structures (based on Badgery-Parker, 1999)

The windy climate of Almeria in Spain requires the 'Parral' type that has a flatter roof with reinforcement. Initially the mesh frame was constructed for growing table grapes however as grapes became unviable there was a transition to other crops using the same structure. The plastic film is sandwiched between two wire mesh grids, approximately 300 mm squared.

Figure 2: Parral type greenhouses in Almeria, 2016 Greenhouse Agriculture of Almeria

Plastic is usually 150-200-micron thick for Spain and is used for three years before replacement. In Israel, 100-micron plastic is used only one year. If a crop is not grown in summer, they cover part of the plastic with 30% shade netting to protect the plastic, (Erez Gozan, 2018).

Height and Length

Older low technical greenhouses are shorter as in the beginning the height of the structure was based on the height of the average grower (Javier Lopez Rodrigues Rijk Zwaan). New greenhouse constructions are higher and range between 5 to 6m high. Taller structures have greater air volume resulting in less fluctuation in temperature. The hotter the climate the higher the greenhouses however in cold areas these taller structures are a disadvantage causing heat loss, therefore energy screens are rolled out over the crop to hold the heat in overnight (Habraken, 2018).

Roof Vents

In low technical greenhouses roof vents assist in controlling temperatures although as temperature rises quite rapidly it can be difficult. *"As heat rises the roof vents allow for the hot air to escape. It has been found that in more dense growing crops in mature cucumber plants they were able to keep the temperature cooler." (Parks, 2011).* This was evident in Israel, Adelaide and Geraldton with growers planting cucumbers at 2-3 plants per m2, thus increasing humidity. Humidity increases during the night and early morning as temperatures change at sunrise resulting in condensation on plant leaves and fruit causing fungal diseases to develop. Vents are therefore opened early morning to allow the humidity to decrease therefore reducing condensation.

In places with hot dry climates such as in the Arava Valley (Desert) in Israel, the saw tooth multi-span greenhouses or the flat arch multi-span structures suit. For the multi-span structure, a strip is cut out and replaced with insect netting that is permanently open as the average rainfall is only 20mm. Humidity does not get any higher than 50-70%, because of the dry nature of the place (Kitron, 2018).

Figure 3: Greenhouses with permanent sawtooth vents (Author)

These permanent sawtooth vents can be retrofitted to existing greenhouses. The manufacturers in Brazil have attachments for smaller types of ventilation.

Figure 4: Example of top vent similar to permanent saw tooth vents in Brazil (Author)

On the ocean side of Israel near the Gaza strip the greenhouses are closed with no permanent vents because the area does not get as hot as in the Arava. However, when hotter they replace the roof plastic with netting to extend crop life for another month. Most plastic in Israel is used for one season after which it is sent to a recycling factory. Figure 5 shows plastic cover used while the net shading is left in one corner ready for use when the hotter climate arrives

Figure 5: Plastic cover being used while the net shading is left in one corner ready for use when climate gets hotter (Author)

However, in places like Virginia in South Australia, where the rainfall is greater, they use side windows and medium tech structures use a rack and pinion stem to open and close roof vents.

Figure 6: Roof and window vents, Adelaide 2018 (Author)

Roof ventilation solutions used for the flat roofed parral structure in Spain include an open vent placed longitudinally along every second bay of the greenhouse. The roof vent transverses along the rows with a winch connected to a chain to open and close the window. Depending on the direction of the wind, vents are opened in the opposite direction to avoid infrastructure damage. Spacing of the vents is effective as the greenhouse block can be up to 1 ha fully enclosed.

Figure 7: Spain showing the 'parral' vents (Author)

The old short flat greenhouses have a strip of protective shade screens around 1m wide along the roof of the greenhouse for ventilation. The plastic is underneath with a simple string to pull the vent open or closed.

Figure 8: Small flat vents in Spain (Author)

The flat arch multi-span tunnels have vents that open either way with the roof pivoting off the hinge. These are usually more motorised and heading towards mid-tech greenhouses.

Figure 9: Gothic-type multi-span greenhouse with windows in the ridge (Martinez et al, 2016)

In Israel and Carnarvon, WA, crops are grown under permanent shade cloth rather than plastic to cope with heat and release of humidity. These structures are suited for growing capsicum.

Figure 10: Crop grown under permanent shade cloth in Israel (Author)

Roof Vents Using Fans

Some low technical growers in Australia use fans in the roof to extract heat and humidity. Sun City Produce are currently trialling these fans, being a horizontal air fan (HAF – Powerplant) placed at alternative ends of each tunnel that pushes air towards the middle of the tunnel where it then gets extracted out. In Adelaide, these venting systems have been used for at least three years.

Figure 11: Fans in the roof to extract heat and humidity currently being trialled at Sun City Produce, Geraldton (Author)

Side Vents

The typical multi-span tunnels have sidewalls that consist of insect or shade cloth netting. For additional climate control there is another outside layer of solar weave (plastic). This solar weave is used to hold the heat or humidity in, whichever is lacking. Depending on the temperature and humidity they close, open or semi-open the plastic. Air circulation also needs to be considered when opening the solar weave.

The usual way of opening and closing the solar weave is through a system of rods placed along the length of the solar weave. It is attached through a series of clips with a handle winder at the end of the rod that rolls the solar weave up and down like a curtain. Figure 12 shows mechanical winches. In low technical tunnels simple handles have been welded onto the end that lock into place as shown in Figure 13. High technical greenhouses use automatic motors programmed to open or close according to temperature, humidity or CO_2 levels.

Figure 12: Mechanical winch (Author)

Figure 13: Low technical welded winch (Author)

In Almeria, windy conditions require the plastic to be sandwiched between a series of grid wires and pulleys pull the plastic up to close the greenhouse or release to allow the plastic to fall- down to ventilate.

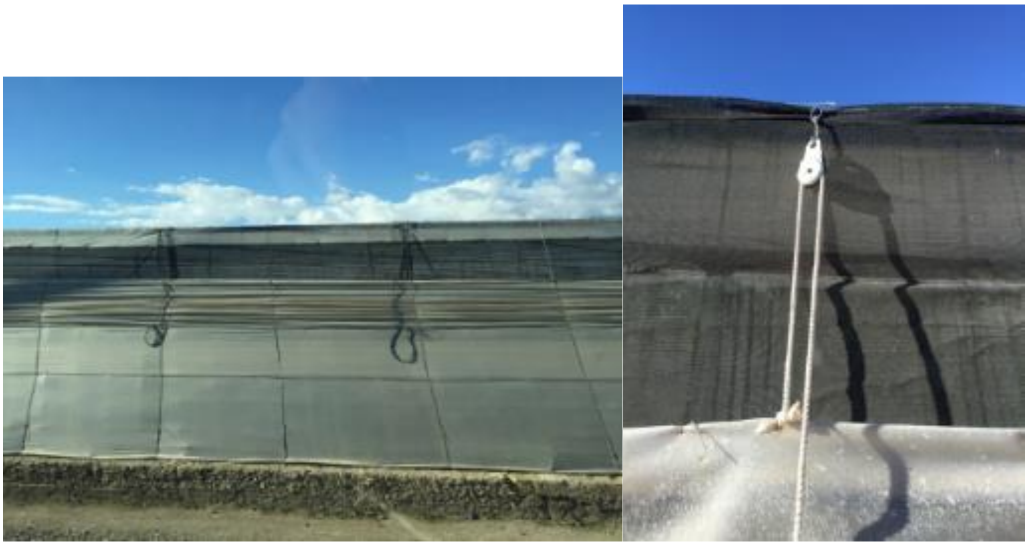

Figure 14: (Left) Pulley system used in Almeria and (right) side vents with pulleys

On the older timber framed structures that are lower, it is not possible to install roof vents. Instead the ends of the greenhouse are used as side vents. Greenhouses in Sicily have three layers (insect screen, solar weave and netting) providing three possible vent options. If the insect screen does not provide sufficient venting, then this screen as well as the solar weave plastic layer are lifted off to fully open the greenhouse and loose netting (third layer) is then installed to keep the moths or larger insect pest out.

Figure 15: Sicily three sides (Author)

When the climate is too hot and humid in Brazil the sidewall netting is not installed at all as shown in Figure 16 below.

Figure 16: Tomato plants in open side greenhouse, Holambra, Brazil (Author)

Double Roof

In cold climates such as experienced in southern Canada (Delta, British Colombia to Leamington, Ontario) and the Netherlands where natural gas is cheap, it is used to heat water then circulated throughout the greenhouses at night, through a system of pipe rails that run along each row. Whilst there are examples where electric and diesel heaters are used in low technical greenhouses, they do not actively use energy to heat greenhouses rather they use less energy intensive ways to keep the heat in the greenhouse.

Figure 17: Gas and diesel heaters (Author)

In the cooler areas of Almeria and Sicily, plastic doubled roof is used to insulate the crop during the colder months. There is the usual top layer, 150-200 micron plastic, then a thinner clear plastic layer around 40 micron thick that is only used for one season. After the season the 40-micron plastic would be taken off used for solarisation or sent to recycling.

Figure 18: Double roof plastic, Almeria, Spain (Author)

The air below the thin clear plastic is warmer than the air above causing condensation to occur on the underside of the roof plastic. New plastic usually has a special anti-drip coating that directs condensation to run to the side of the tunnel. After two years the anti-drip coating is no longer functional resulting in condensation dropping onto plant leaves below and creating an environment for fungi diseases such as downy mildew to develop. The lower clear plastic layer catches the condensation and the water slides down to the lowest point usually on to the footpath.

Figure 19:: Condensation droplets on plastic (Author)

Screening

The double layer skin can be extrapolated to the energy screens in the high technical structures that at night keep the heat in. There are several technology screens developed by companies like Svensson that can operate as heat reflectors as well as keeping the heat in.

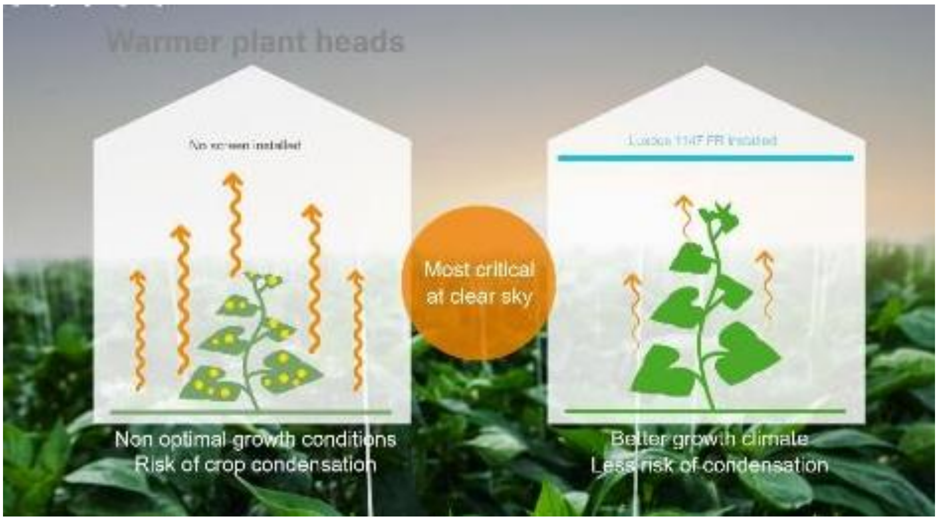

Figure 20: Svensson screen explanation (above) and screening applied in high tech greenhouse (Habraken, 2018)

Roof vents, side vents and side screens can all be made automatic to open and close according to temperature, humidity, light radiation, wind intensity or direction.

Other Climate Control Practices

Low technical climate control practices seen around the world are:

- Evaporative cooling consisting of a mister system at one end of the greenhouse and suction fans at the other end that pull the cool air through the tunnel house.

Figure 21: Evaporative cooling system, Holambra, Brazil (Author)

- In the Arava Desert black netting was placed on the south sidewalls of the greenhouse to block sun rays from the south (for countries in the northern hemisphere).

Figure 22: Black Netting on south sidewalls in Arava Desert, Israel (Author)

- Sprinklers or low-pressure misters sprayed onto concrete walkways to allow for evaporation to create humidity.
- Layers of black plastic placed along crop rows allow water to pool resulting in evaporation increasing humidity.

Figure 23: Black plastic in between plant rows to increase humidity (Author)

Water Quality

The quality of water used to irrigate crops affects nutrient uptake, quality and yield of any crop whether it is in a high or low technical system. Salinity in the water source decreases production with Table 6 showing the percentage of salt that causes decreasing production.

Crop	No yield loss (dS/m)	10 % yield loss (dS/m)	25 % yield loss (dS/m)
Capsicum	1.0	1.5	2.2
Cucumber	1.7	2.2	2.9
Tomato	1.7	2.3	3.4

Table 6: Tolerance of some crops for irrigation with Salinity (https://www.agric.wa.gov.au/fruit/water-salinity-and-plant-irrigation?nopaging=1).

Salt content of water is determined through measuring Total Dissolved Salts (TDS) and Electrical Conductivity (EC). TDS describes all solids that are dissolved in water usually mineral salts (not always the case). The more salts dissolved in the water, the more dissolved ions the higher the EC level (Lenntech, 2018). Not only does the amount of sodium in the water directly affect production it also affects the amount of extra fertiliser required to maintain the same production. The lower the EC level is of the water the less fertiliser is required to achieve the same level of production. However, when the EC of water is at a minimum, you can add more fertiliser to increase production.

In some areas of South East Australia, town water from reservoirs has only an EC of less than 0.6. While areas of the Mid West of WA have town water with an EC of 1.5 with most of it consisting of sodium. As a grower, quality of water is what you have to accept to grow your produce. Though using desalination and mixing with rainwater, are two options if the capital cost or rainfall is available.

Sources of Water

Rainwater

Rainfall can be collected off greenhouses and stored in dams that are usually lined with HDPE plastic and if small enough are covered with black mesh to prevent evaporation. Rainwater contains minimal salts and it is free. All high technical and low technical greenhouse will collect water this way if the rainfall in the areas is considerate. Only areas such as the Arava desert where the rainfall is 20mm/year that dams would not be applicable.

Figure 24: Water Storage, Almeria, Spain (Author)

Along the Granada coast in Spain roof vents are left open and when it rains the water is collected in concrete drains inside the greenhouse then piped to a dam.

Figure 25: Capturing water runoff within greenhouse (Author)

Melted Snow

The mountains on the Granada coast deliver fresh runoff to the growers. The runoff delivers to a lake where growers can utilise the water. In California, concrete aqueducts transport water from the mountains making a dramatic difference to production.

River Water

River water is utilised for production in Canada as well as in the Eastern States of Australia.

Figure 26: River water source for undercover tomato production, Canada (Author)

Desalinated Water

Large scale desalination plants around the world service cities such as Tel Aviv in Israel and Almeria in Spain. Any oversupply of the desalinated water is redistributed to horticulture growers who benefit from the increased quality water. The Netherlands uses rainwater in winter and switch to desalinated water in summer. They pump underground water up and desalinated with the brine (waste) being flushed back down below a clay layer 70m below ground level (Hendriks, 2018).

Bore Water

In some areas of the Arava desert (Israel) bore water has high level of salts however they choose not to remove the salts as they value them as nutrients. Table 7 below shows a typical water sample from the Arava desert.

		Geraldton	Arava, Israel	Sicily, Italy
Element	**Units**	**Scheme**	**Bore**	**Bore**
Ammonium nitrogen	mg/L	< 0.1		
Nitrate nitrogen	mg/L	0.71	11	66.64
Boron	mg/L	0.28	0.54	0.1
Calcium	mg/L	11.28	116	277.8
Chloride	mg/L	302.80	430	521.85
Copper	mg/L	<0.05	<0.003	-
Iron	mg/L	<0.05	0.006	<0.01
Magnesium	mg/L	20.93	53	40.56
Manganese	mg/L	<0.05	<0.003	<0.01
Phosphorus	mg/L	<0.05	<1	-
Potassium	mg/L	10.36	6.8	38.22
Sodium	mg/L	256.20	135	196.88
Sulphur	mg/L	17.11	358	7.61
Zinc	mg/L	<0.05	<0.005	-
Conductivity	dS/m	1.47	2.8	2.42
pH		7.3	7.2	7.0

Table 7: Typical water analysis from the Arava and Sicily compared to Geraldton (Author)

Growers in the Arava, Israel use 2.5 to 3 times the amount of water then the plant requires to flush the salts out (Tripler, 2018). Even though the overall EC is quite high for bore water in Israel and Sicily, the amount of sodium is quite low compared to the Geraldton scheme water. Sodium is the major component of Geraldton tap water and bore water whilst other nutrients beneficial for plant uptake is minimal.

In Sicily the high EC is due to calcium rather than sodium therefore less calcium is required to be added to the fertiliser mix, at times no calcium is required to be added. However, observation of plants is required. "*As the calcium may not be available to the plant, inspections of the plants to determine if there is a deficiency are required* (Agnone, 2018)."

Growers usually compare EC before fertilising as a means to understand the water quality. However, growers need to look at what the EC consists of in their own water rather than follow water regimes of other growers, especially in the case of Sodium that can adversely affect production.

Treated Waste Water

In Israel a large amount of treated wastewater is used and delivered through a grid system however desalinated water is also delivered through the same grid lines at randomly scheduled times. The two sources of water have different EC content that consequently growers have to find a way to manage.

Growing in sand/soil offers low technical growers a greater buffer than those who grow in bags and substrate. Some Adelaide growers use treated wastewater from the Bolivar Waste Water treatment plant that government subsidises. Whilst it is a bit dirty those growing in soil benefit however hydroponic growers experience greater clogging problems and desalinate before using it.

Cost of Water

Protective cropping growers are leaders in water use efficiency by using drip irrigation however the cost of water dramatically affects profitability. Table 8 below show the cost of water in the countries visited.

Place	**Cost of Water**			**Reference**
	Bore	Irrigation water	Town water	
Arava, Israel		$0.37/kL		Kitron, 2018
Netivot, Israel		$0.67/kL (wastewater)	$2.18/kL	Erez, 2018
Sicily, Italy	Bore running cost			
Westland, Netherland	Bore running cost			
Adelaide, Australia	Bore running cost	$0.16/kL (waste water)	$3.60/kL	Hoffman, 2018
Perth, Australia	Bore running cost			
Geraldton, Australia	Bore running cost	$2-3/kL		
Carnarvon, Australia	Bore running cost	$0.35/kL + annual membership fee to water co-operation		Lantzke, 2018

Table 8: Summary of cost of water (Author)

Israel – Arava Desert

There are two places in the world where a large of amount of low technical greenhouses are located however, they are dramatically different in soil types and watering strategies.

The Arava desert has around 3000 ha of greenhouses with five ha per farmer (A. Kitron, 2018). To improve water retention, provide additional nutrients as well as improving microbial diversity is achieved by adding a lot of compost. The compost is placed in the growing line at 10 tonnes/doonan (10kg/m2) at the start then 2 to 5 tonnes per doonan (2-5 kg/m2) (A. Kitron 2018). One doonan is 1000m2.

Growers would water more frequently, however each watering time would have less water. This is the same concept as in hydroponics. The sand is free draining allowing growers to flush with double the required water quantity when the salts build up. Figure 27 shows cherry tomatoes grown in sand. Seedling companies in Israel have knowledgeable growers that show what can be successfully be done with poorer soil conditions.

Figure 27: Growing tomatoes in sand, Nirit seeds, Israel

Spain – Almeria on the Mediterranean Coast

The Almeria coast greenhouses have been built on excavated ground in the side of mountains therefore most of the crops are grown in soils imported from nearby areas. Figure 28 shows a typical sketch of the soil profile from Almeria. The original ground has a 20-50cm layer of clay loam placed on top, overlain with a layer of manure or compost (2-10cm) before capped with 8-15cm layer of river sand.

Figure 28: Sketch of the soil profile common in Almeria, Spain

The clay loam has high water retention properties and cation holding capacity. The manure provides microbial diversity and nutrients whilst the river sand acts as mulch breaking the capillary rise of water therefore holding the water within the soil, not allowing any evaporation thus causing the possibility of unwanted humidity.

Even though Israel and Spain have a very different soil profile, common to both areas is the measurement and monitoring of the amount of watering and fertiliser used within the root zone. This will be discussed in later chapters.

Soil or Growing Media

The majority of low technical growers still grow in soil and only when disease levels increase due to mono cropping is there a transition into hydroponics. This transition has been termed 'fake hydroponics' in Adelaide, Australia. It is done quite effectively as seen across the world.

Hydroponics Substrate

When the soil disease pressure gets too high and impacts production (and profit) growers convert to substrate bags or pots that consist of cocoa peat, perlite, and rock wool. Below are some examples of conversion. It is important that the bags do not touch the ground soil as diseases can easily be transmitted.

Figure 29: Typical setup is on the ground rather than on benches, saves height and allows for more production. (Threading irrigation hose through the bags saves dripper cost)

Figure 30: Using seedling trays below bags (Author)

Figure 31: Using gravel and drain pipe to collect waste from hydroponics and using the run off to grow other crops outside

Moisture Sensors

Moisture sensors monitor the amount of water crops require throughout the growing season. A tensiometer measures soil moisture by measuring the tension or suction that plant roots must exert to extract water from the soil. The higher the tension means the higher the water stress. This tension is a direct measure of the availability of water to a plant. Moisture probes measure the amount of water in the soil, so the more water available the more water the roots can uptake. These two ways of measurements are inversely correlated.

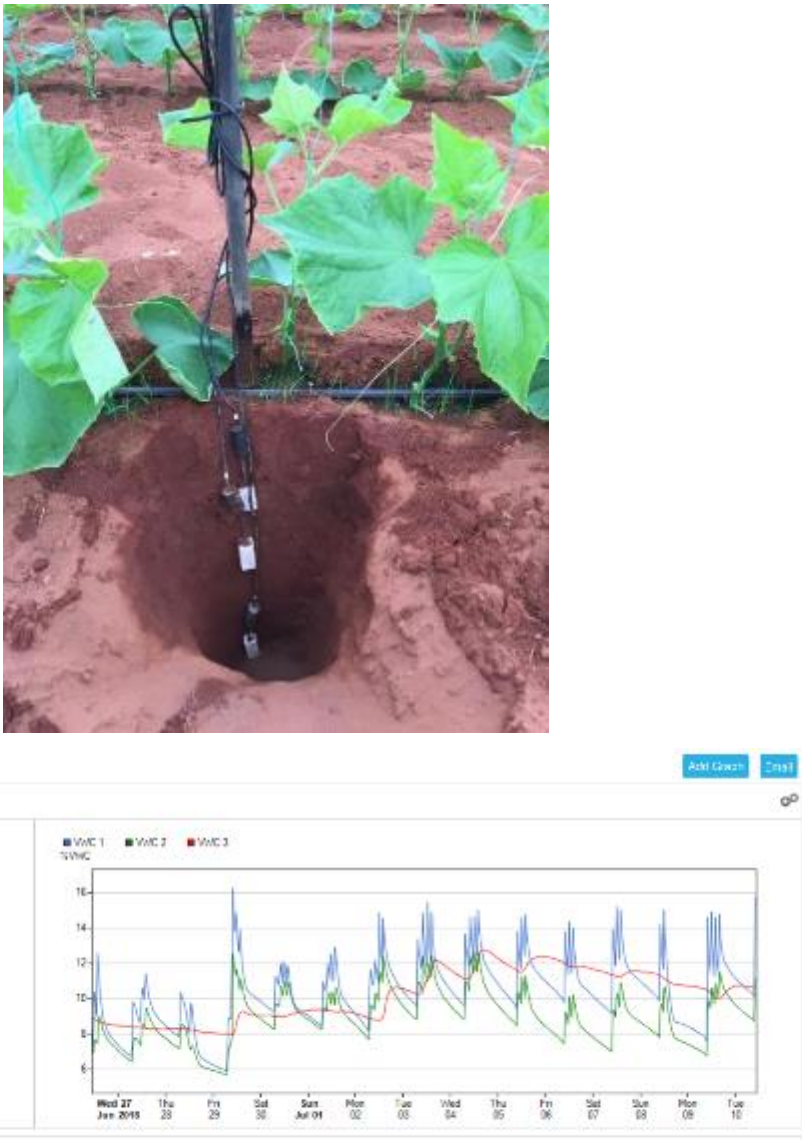

Figure 32: Example of moisture content graph from Wildeye moisture probes

Growers can monitor these daily to ensure enough water is available to the crop as well as enough drainage. A soil sample can be collected to test for permeability or moisture retention capacity curve. This correlates to a tension or soil moisture reading that shows optimum water availability to the plant, so the grower can manage the watering program.

Another way to use water efficiently is by using substrate bags, however if the drain water is not re-used, the water usage maybe higher than the original soil, depending if the soil is sand or clay. Re-using water requires UV, chlorine or hydrogen peroxide treatment to combat disease transfer. Many growers are not comfortable nor have money to invest in UV treatment.

Along with moisture probes, growers in Spain and Israel have small water meters attached to the single irrigation line of random rows in the crop. The water meter logs quantity of water per day and gives the grower an indication whether the irrigation pump is running properly. The pumps and venturi doses can have air locks or suction problems, blockages due to fertiliser precipitates, computer malfunction etcetera. It was found that 30% of the pumps are not running accurately (Kitron, A. 2018).

Figure 33: Water meter attached to irrigation hose for monitoring (Author)

Roots Development for Better Water and Nutrient Uptake

Root development is very important for any plant as a healthy root system translates to a stronger more productive plant. Options to promote root growth include:

- Double line irrigation lines for a single row of plants creating a wider spread of water to stimulate lateral root growth.

Figure 34: Double line T tape (Author)

- Use cocoa peat in the ground thus creating a clean sterile environment for the roots to grow. When transplanting seedlings from trays, the roots get injured creating an access point for disease to enter.

Figure 35: Cocoa peat in the ground (Author)

- In Spain the irrigation line is moved away from the stem after 30 days. Depending on the water holding capacity of the soil the irrigation line can be moved further out. (Rodrigues, 2018).

Figure 37: Movable irrigation line to promote roots growing further away from stem

- Humic acid, seaweed extract, fulvic acid and beneficial microbes are also used to promote root growth.

Irrigation System and Pipes

Low technical greenhouse growers use simple irrigation systems either hydraulic pumps or venturi irrigation systems that do not require a computer to run. With good maintenance these systems can last longer than 20 years.

Figure 36: One dose pump to run both A tank and B tank fertilisers (slug dosing)

Figure 37: 20-year old venturi doses

Spanish growers house irrigation equipment in a well-designed brick shed that keeps everything cool with fertiliser and the computer operating system in specific locations within the shed. Fertiliser tanks usually consist of:

- Tank A – Calcium Nitrate and Iron
- Tank B - Fertiliser containing sulphates and remaining micronutrients
- Ammonium Nitrate tank for Nitrogen application and pH stabilising, and

- Phosphoric or Nitric Acid for pH stabilising.

Figure 38: Typical fertiliser tanks in Spain (Author)

All tanks are mixed with a simple air pump that is quite efficient in blowing air through a spider to all the tanks. The tank outlets always have filters fitted to ensure the venturi system does not become clogged.

Figure 39: Perforated pipes pumped with air for mixing (Author)

Irrigation computers enable watering times to be programmed for the minimum amount of water based on average daily temperatures. On hot, rainy or cool days, growers increase or decrease watering times to suit and as mentioned previously the moisture probe graphs will also assist in decision making. Smart phones can access moisture sensor data and enable control of the irrigation system from anywhere there is Internet connectivity.

“Balance investment and the benefit you get. You have to find it. A greenhouse is susceptible to be improved to the total agreement of the owner. The right thing is to find the balance.” (Javier Lopez Rodriquez, Rijk Zwaan)

“In addition, greenhouse production is notable for its high water and nutrient-use efficiency. The favourable climate, furthermore, allows for much lower energy consumption than is found in other growing areas, such as in Dutch greenhouses. For example, greenhouse production in Almería requires 22 times less energy than in the Netherlands.” Martinez et al, 2016.

Chapter 2: Fertiliser

Israel and Netherlands use liquid fertiliser because it is quicker, flexible (more or less mixed depending on temperature) and accurate however slightly more expensive. Fertiliser tanks are stored on the roof in the Netherlands and gravity fed to the mixer tanks according to amount required on the crops. Sensors on the tanks inform fertiliser supply companies when more is required, who then automatically deliver as tanks are refilled from outside the building using a series of pipes.

Figure 40: Fertiliser tanks in Netherlands (Author)

Figure 41: In Israel, black tanks are outside and depending on set mixes whether vegetative or regenerative, orders get delivered to site.

Spain and Italy use soluble solid fertiliser that is mixed using an air mixer to ensure the fertiliser is mixed thoroughly. To prevent blockages filters and pressure gauges are installed at the valves of each crop section and checked regularly. Irrigation hoses are used for one season or can be reused. Chlorine or Hydrogen peroxide is used to clear fertiliser or bio algae build up.

Lysimeters

Lysimeters collects water samples in the root zone. The water sample is then measured for EC. This enables the monitoring of nutrient minerals or salt build up within the root zone. Lysimeters consist of a tube with a ceramic porous tip that is placed approximately 10-15cm deep in the root zone. A sample of water is collected after irrigation to monitor salt levels in the root zone of crops. A detailed nutrient analysis can be provided by sending a sample to a testing laboratory.

Figure 42: Lysimeter installed in a capsicum crop (Author)

Chapter 3: Mechanising for Automation

High technical greenhouses use heating systems for night and winter heating. These consist of pumping heated water through a rail system along the ground that acts as a heater. The rails also transport trolleys along the crop rows for training, pruning and harvesting the crop. Trolleys can range from seated chairs to powered auto scissor lifts as well as trolley sprayers. The cost of installing this system is quite high especially if heating is not required, and so the rails could not be used for dual purpose.

Figure 43: Scissor lift on rails (Author)

Spain has similar electric scissor trolleys with 4wd tyres installed. However, for the lower tech growers they have manufactured trolleys that are designed to access crops at high levels. The trolleys have handles connected by a chain to the wheels, and cycling the handles makes the trolley move along. Below are other simple inventions to make it easier for labourers.

Figure 44: Moving trolley (Author)

Figure 45: Double way trolleys that can be pushed both ways

Figure 46: Diesel driven 4WD sprayer, it can drive between the rows and spray using fans

Figure 47: Canon sprayers behind tractors blow 25m down a row for preventive spraying

Chapter 4: Disease and Pest Control

Insect Control

Pest management practices in low technical greenhouses include insect netting (50 mesh size) on perimeter walls and a closed greenhouse structure with no openings. The insect netting is very effective against moths, butterflies and fruit fly laying eggs. If insect pressure is minimal, the screen size can be larger.

Two entrance doors are commonly used to keep pests outside. Also, some growers use insect repellents that are sprayed through misters along the inside perimeter of the greenhouse that turn on at certain intervals or when the entrance is opened.

Figure 48: Screening, double entrance doors and insect repellent spraying

Sticky traps are used to monitor insect pressure in the greenhouse and assist scouts in Integrated Pest Management (IPM) as well as being a form of insect control.

Figure 49: Sticky traps used for pest management

Integrated Pest Management (IPM)

Common to both low and high technical systems is the use of beneficial insect control. IPM is widely used in Israel and Spain especially when exporting. Spain turned to IPM back in the

2000’s as a result of Germany banning Spanish vegetables due to high residue levels in the produce. IPM allows for very limited pesticide spraying and growers notice the increase in natural bug populations that effectively assist to control pests such as thrips, aphids and whitefly. This is a cost saving as well as less stress on the plants by not spraying.

Figure 50: IPM in cucumber crop (T.Montdorensis sachet, Author)

Strawberry growers in Israel use IPM as a marketing tool by informing consumers with ‘biological certified’ stickers on their product. Greenhouse growers in Australia could follow this same concept.

Figure 51: Strawberries marketed with IPM, (Biobee, 2018)

Bumble Bees

Bumble bees are well established as the most efficient way to pollinate tomatoes in greenhouses whether they are low or high technical structures. Bumble bees do not exist in mainland Australia other than Tasmania which have European bumblebees. They are a high biosecurity risk to mainland Australia's native bee population and therefore are quarantined in Tasmania. Pollination involves vibration which causes pollen to drop from the anthers onto the stigma causing pollination. Currently in Australia, growers use manual pollination. This involves tapping a plastic pipe on the hanging wires, placing vibrating wand on the stem between flower truss, or a leaf blower.

Figure 52: Bumble station used for pollination, (Agrobio, 2018)

Solarisation and Sanitation

An alternative to Metham Sodium, Teolone or Metham Bromide (now banned in many countries) is solarisation that utilises heat from the sun to sanitise soil, commonly used by low technical and organic growers. The ground is wet using the sprinkler system or drip irrigation then a layer of plastic (usually old roof plastic) is placed over and solarised for 40 to 60 continuous days during the hottest part of the year. The plastic must be clear. A sanitation period follows where nothing is grown for the summer months.

Figure 53: Solarisation carried out in Arava Valley, Israel (Author)

Steaming is a more expensive practice than solarisation. Heavy plastic mats cover the line or row where the crop is to be planted. Steam is then pumped between the plastic layer and ground using a perforated hose placed along the strip or row. Organic growers in the Netherlands install suction pipes buried 50 cm below ground to suck steam down to kill all the diseases to that depth. An alternative is to use steaming pads with spikes that go beyond root depth for sanitising however it is an expensive process.

Figure 54: Steaming pads used to sterilise soil (Author)

Fungal Disease Control

High technical growers are able to control humidity and temperature thus reducing fungal diseases such as downy mildew, powdery mildew or botrytis. Low technical growers can only limit condensation as a means of avoiding fungal diseases by opening roof and side vents early in the morning before the differential between outside and inside temperatures gets to the point where condensation occurs.

High technical greenhouses growers regularly use sulphur canisters on the roof frames and sulphur is burnt over night. Low technical growers place sulphur on the ground to combat fungal diseases.

Figure 55: Sulphur spread on ground for fungal disease control (Author)

Chapter 5: Labour

Labour is by far the most expensive expenditure in a horticulture business. There is a labour shortage in agriculture/horticulture industry in Australia. The many reason consists of isolated regions, physically demanding work and it is not seen as a long-term career option.

"The inability to source adequate labour, is an indisputable constraint on our vision for agriculture to achieve a farmgate output value of $100 billion by 2030", was quoted by National Farmers Federation (NFF) President Fiona Simson, (NFF,2018). To specifically address this labour shortage facing Australia's farm industry, the current Prime Minister, Scott Morrison has confirmed his Government's commitment to an agriculture visa. This is one of the solutions, however, there needs to be a longer-term solution. NFF encourage growers to register on the National Harvest Labour Information Service, so willing able Australians can fill these positions. A common theme of the places visited was that the majority of the labourers were imported on low skilled or training visas.

Country	Workers	Pay & Conditions	AU dollars
Netherlands	East European - Polish, Hungarian, Romanian and Bulgarian people	€9.5 - €10 /hr €16 - €17 / hr seasonal workers (Hendricks, 2018)	$15.17 - $15.97/hr $25.55 - 27.14 /hr
Israel	Thai & Vietnamese Palestinian women	30 Shekels/hour (Kitron and Erez, 2018)	$11.16/hr
USA	Illegal Mexicans	$10 - 15US/hr	
Canada	Caribbean, Mexicans, German Mennonites	$10-15US/hr	
Spain	Moroccan and North African	8-10 Euro/hr (Benavente, 2018)	$12.77 - $15.97 /hr
Japan	Chinese	-	
Australia	Local, Pacific Islands and East Timor		$22-$28/hr $33 which includes all the overheads of employment
Italy	Romania	40 Euro/day for workers (Anillo, 2018, Italy)	$63.87 / day $8/hr approx.

Table 9: Countries, source of their workers and pay

The cost is usually higher for imported workers as housing and transport must be supplied. Robot technology is advancing globally, however there is still limitations of the use of this technology in the immediate future. Mechanisation in the low technical system is difficult, as much of the intricate work requires human labour and mechanisation would add extra costs which would make the operation unsustainable. High technical growers have economies of scale which gives them the ability to utilise more machinery and equipment.

Shade stations in the greenhouse for resting, music playing and lightweight trolleys that can move in both directions are improvements that could be made to make working in greenhouses more appealing. Flexible working hours can also help retain staff. There are periods in the season where labour requirement is less, this can be suitable for parents with young kids, or people who prefer casual work. If the location of the farm is in a rural region, proving possible transport to more social cities for worker's rostered days off, could be beneficial, however I have not seen this practiced as most workers are on a budget.

Managing Labour

High technical growers use electronic software and systems to manage employees usually consisting of a machine within the greenhouse that workers input their code or scan an ID tag. Software apps for smart phones are making data logging and management easier. Two brothers (farmers) from Israel have developed the Pick App that measures and monitors daily farm activities through a series of barcodes on the produce crates or zone allocation within the greenhouse. Data is streamed in real time enabling basic comparison of worker efficiency along with produce quality and yield data.

Chapter 6: Common Practices

Trellising and Spacing

Intensive crops like tomatoes, capsicum, eggplant and cucumbers can be very labour intensive when training the plants up the trellis system, resulting in increased costs. There are two basic ways to train these crops, the hire wire system, which is usually referred to as tomato training and Spanish tying, which obviously originates from Spain and is a less labour alternative.

In the Netherlands they grow tomatoes, cucumbers and capsicum using the hire wire system. This system is usually used for long season crops where the tomato or cucumber stems can be lowered as the crops continue to grow. Whilst more labour intensive, over time production is greater.

Figure 56: Tomato hire wire system (Author)

The Spanish tying consists of two lines of string on either side of the crop that are sandwiched together at certain tying points. This is less labour intensive and suitable for short term crops. Short term crops of capsicum and tomatoes that have a short window for their market.

Figure 57: Spanish tying system (Author)

Commonly cucumber plants are trained through the hire wire system until reaching a fixed wire height before allowing the top or the side shoots to drop down like umbrellas, hence it is called the umbrella training technique.

Figure 58: Umbrella training for cucumbers

Other trellising techniques that low technical growers use to lower labour costs are:

- A pegging system is used to trellis Lebanese cucumbers that are lighter than the normal cucumbers.
- In Israel instead of using string on rollers, they tie just enough string for the season. Once the string has been lowered to the limit the crop is cleaned up. This method eliminates disease contamination from the previous crop carried over on the rollers.
- In Sicily the tomato stem is slanted at 30 degrees and clipped onto the next wire and then the next wire. This practice is used on medium length crops only as the tomato stem cannot be pulled down further.

Figure 59: Cherry tomatoes trellising at 30 degrees to the horizontal

Simple Data Recording

Low technical growers use low cost weather stations that include temperature and humidity gauges that show the maximum and minimum temperatures.

Figure 60: Simple recording gauges (Author)

Figure 61: Simple water meters to monitor usage (Author)

Some growers do collect data from fertiliser mixed, water usage and production but generally do not utilise this data until the end of the cropping season.

Placement of Driveways and Concrete Flooring

Low technical greenhouses predominantly grow in soil that makes it difficult to move especially if using trolleys. In Spain and Israel introducing drive-in bays for tractors bringing in trailer carts for harvested produce and concrete paths for high traffic areas has increased efficiency.

Figure 62: Designed driveways and concrete pathways (Author)

Pruning Preferences

Pruning cucumber leaves whilst picking is a practice that assists in controlling high humidity in a high humidity environment. Whereas leaves left on allow the plants to self-regulate humidity and transpiration in dryer regions.

Figure 63: De-leaf in low greenhouse with humidity and leaves left on plant in areas that require higher humidity.

The concept of removing fruit to alter the picking calendar to take advantage of seasonal market prices is still new to low technical growers. Scheduling planting times can be risky as prices for commodity vegetables are volatile. High technical greenhouse growers remove cucumber flowers (fruit) during winter if the radiation measured is calculated to provide insufficient energy to produce good quality fruit and choose to space out the fruit load on the plant. Spanish growers are not keen on removing fruit as they see it as lost production. However, they are trialling training the growing head of the cucumber crop towards the light to assist fruit development and growing better quality fruit as the plant ages.

Plastic Mulch

Plastic mulch was present in many of the low technical greenhouse farms visited. It is common to leave the plastic used in solarisation of the soil as plastic mulch on the ground and a line cut above the irrigation line to plant the new crop. The plastic cover traps the moisture preventing evaporation and reduces humidity problems in winter. Sometimes reused plastic has been sprayed white that will reflect light whereas black plastic absorbs heat and keeps the roots warm promoting root growth under the plastic. During my travels, there was only one farmer that I saw using biodegradable plastic. He was however, growing corn in open field and needed the clear plastic at the beginning of the season to keep the ground warm. This helps the corn to germinate quicker and reach harvest earlier.

Varieties

Definitely varieties of crops and their genetics will have a role in efficiency and increase production. Grower’s work with seed companies to find disease resistance varieties as well cold and hot season varieties depending on how long the crop in production. Small trials are recommended each year to find varieties that work for your area and give an increase in yield by 5-10%

Chapter 7: Management

Online Data Management

Data management using sensors to a website and cloud- based platform is a relatively new management tool. Stand-alone equipment sensors measure temperature, humidity, dew point, soil moisture, soil temperature, EC wind speed and direction, etc. All this data can be accessed anywhere evaluated in real time for quick decision-making. Some instruments can be set to trigger irrigation if the moisture content drops below a certain percentage. There are many systems (programs) in the market from established and start-up companies.

I am using moisture sensors and climate sensors from companies such as Wildeye and 30Mhz to manage my crop. Both companies have a website platform. There are many growers using this technology in Almeria, Spain. The Netherlands already have these data management tools incorporated into their climate control systems.

Figure 64: Temperature, humidity, soil moisture, EC data logger system, GROWA, 2018

Financial Management

Good financial management and tracking of income and expenses enables growers to identify the viability of their enterprises. The utilisation of management tools that assist to keep track of finances and budgeting can be a challenge to low technical growers especially where English is a second language. This can be overcome with a good accountant, bank manager and financial planner to assist in teaching the growers what key numbers to focus and monitor for a sustainable business.

Cooperative Structures versus Free Market Auction System

A cooperative is a jointly owned enterprise that engages in production or distribution of goods or supplying of services, operated by coop members for mutual benefit. This structure has the ability to negotiate a better price for produce on behalf of the grower members for which a service fee is charged to ensure the organisation is sustainable. The auction system on the other hand is where growers send produce to be sold on the market floor and receive whatever the market is prepared to pay for the product on the day.

Cooperative and Auction systems do exist in Spain and Netherlands. Almeria competitively operates a cooperative structure that through economies of scale negotiates better prices, carries out marketing as well as guaranteeing supply to buyers, enabling it to be competitive against the Netherlands. Competitive purchasing of large quantities of inputs such as fertiliser enables smaller grower members to buy at competitive prices. Crop advisors and quality control personnel work with grower members to support them with paperwork and auditing processes.

Large supermarkets are keen to develop a one-on-one relationship with large producers who can deliver consistent good quality produce. Smaller growers are unable to access supermarkets direct resulting in vulnerability to market forces. However, consumers want to know where their food is coming from which is an opportunity to be explored by growers. Growers are beginning to specialise in packing and/or growing depending on what they are good at. Smaller growers however can access direct to consumers and supermarkets if they have a point of difference or a niche market. They could deliver to local farmers market, promoting local produce. Another option is supplying restaurants with specific niche fruit and vegetables for their menus.

A grower would be able to be an entrepreneur and pack for their growers in the region. They would be able to increase profitability by packing for other growers in their region. This has greater benefit for the community, through employment opportunities, upskilling and longevity in the packing shed operations.

"If you pack for a lot of people, you get better income than you re-invest. (A. Kitron, 2018)"

Research Centres

The Wageningen University in the Netherlands is a leading research institution that collaborates with industry leaders in greenhouse production. Other examples of research and development centres for low technical production include the Central and Northern Arava Research and Development Centre in Arava, Israel and the Fundacion Cajarmar, Almeria, Spain. Both institutions are privately funded through industry and have a wealth of knowledge specific to the growing areas in which they are located. They provide research that assists in growing, pest and disease management as well as investigating new varieties. They also collect large amounts of data specific to the location including temperature and humidity which allows for accurate variances even within the shorter distances of the locations.

Grower Group

The value of working together was noted especially in the Netherlands where a group of about 10 growers came together once per week visiting one or two greenhouses to discuss energy input, fertiliser, water, CO_2 and generally knowledge exchange. Research centres have developed from farmers working together however it is noted that generally low technical growers have not worked together. A remarkable story of working together was a group of growers collectively bargained with Rabobank saving themselves thousands of dollars on business loans about 20 years ago to the value of approx. $AUD 80 million at the time. (Koning, 2018).

The author is current chair of the mid-west Horticulture Growers Group. The group mainly consists of Vietnamese growers, however it is open to all growers in the region. The group has successfully lobbied the government for a more sustainable water price for the industry. Hon Alannah MacTiernan, Minister for Regional Development, Agriculture and Food has helped growers trial a major users agreement contract with the water authority in the region. Growers are able to access a water agreement contract that was previously designed for the mining sector. The author has also been a committee member on the WA horticulture industry body Vegetables WA. This has opened many doors in regards to networking with other growers and leaders in the state.

Market Price Apps

With the emergence of the data revolution growers can monitor market prices around the country at auctions or at market floors, allowing them to decide where to send their produce for maximum benefit. The app is only as good as the accuracy of the data supplied. Farmate is an example of an Australian app that collects data from various market sources including individual supermarkets. Almeria, Spain has a detailed app showing the market details for the whole of northern Europe. Growers log in and depending on the market, decide to send either to the co-operative or the auction market.

Figure 65: Typical screen of market prices on the Farmate app

Conclusion

Growing intensive crops in low technical greenhouses is a viable option when located in an ideal growing region such as Geraldton. The main difference between low and high technical greenhouse is the amount of control the structures have over the growing climate.

However, there are many technologies that can be introduced to improve quality and increase production in the low technology greenhouse. Changing or controlling climate through a venting system or fans will assist in creating a better environment for crops to grow in. New sensor technologies for climate monitoring enables growers to manage the limited climate control aspects available to them.

Sensors are also introduced to monitor nutrient and watering management. The cost of water in horticulture can be very expensive therefore the availability and cost of water will continue to be a key parameter for individual growers and in future planning of the industry.

Environmental sustainability and traceability are common themes in the consumers mind today. Using less pesticide and integrated pest management across all types of greenhouses can be used as a marketing tool and good business practice.

Along with controlling parameters within the production system, ensuring financial sustainability is critical. Therefore, managing expenses such as the cost of implementing automation to combat the lack of and high cost of labour or the conversion to hydroponic substrate due to poor soil health can only be justified if there is a return on investment and is achievable given the cashflow of the business.

There are many start-ups and technology sensor companies that promote better data analysis on production inputs and outputs. *'What you cannot measure, you cannot manage'* however whilst it is important for any business to analyse inputs and outputs, knowing what to record and analyse can be tricky and time consuming.

Better collaboration between growers, government and industry bodies is essential for the health and longevity of the horticultural industry overall. Growers need to realise that working together and sharing knowledge will enhance their business thus ensuring the industry remains competitive and sustainable. However, this psychological aspect can be far more difficult then applying the technical improvement to growing.

Recommendations

Management – Greenhouse/Farm

- Install temperature and data loggers, or at least temperature and humidity gauges inside greenhouse in sections, to build knowledge of capability and limitation of greenhouse thus enabling better decision-making.
- Improve greenhouse management to know exactly what is happening in the greenhouse, identify strong as well as weak points. Look at performance and identify what works best.
- Collect rainfall to apply to young crops thus promoting healthy crop establishment.
- Install opening/closing roof, window or side vents to take advantage of natural ventilation utilising information that data logger collects. Automate if cost permits.
- Monitor water and EC daily, to keep within the boundaries aimed for, and if it's not the same as what is intended, figure out why.
- Install water and nutrient sensors to assist in water and fertiliser decision-making.
- Budget and implement soil, water and leaf analysis.
- Seek advice from a crop advisor.
- Apply IPM. Consultants can advise on disease and pest management. It can also be used as a marketing tool.
- Identify diseases present and send disease samples to plant pathologist. Don't guess.
- Use solarisation as a minimum soil treatment.
- Reuse roof plastic from top of greenhouse to use as floor covering inside the greenhouse.
- Utilise technology to monitor your crops i.e. know computer and iPhone capabilities.
- Apply compost and beneficial microbes as trials and record production.
- Look into grafting root stock if soil has too much disease pressure.
- Look into 'fake hydroponics' by trialling hydroponic grow bags on the ground.

Mechanisation

- Look to mechanise where possible including implementing a trolley system.
- Where possible, improve the working environment by concreting paths, install shade rest stations in the greenhouse.

Collaboration / Knowledge Enhancement

- Participate in a grower group or organisation to extend knowledge and practices.
- Lobby government on policies affecting the horticulture industry. Develop relationships with:
  - Local Department of Agriculture
  - Larger growers to work with and supply produce
- Increase knowledge by following leading research centres and attend conferences in low technical growing areas.
- Always ask questions.

Management - Financial

- Implement document control system to identify product viability.
- Cost benefit analysis of improving low technical greenhouse.
- Negotiate competitive water price.
- Seek and negotiate a better deal for bank financing as a collective (grower group).
- Recording all expenses to gain understanding of the cost of production verse income.

© Graeme Smith Consulting - Greenhouse Cost of Production Worksheet							***Vegetable Season***	***2016***
High Technical Greenhouse							*Melbourne*	
	Income (gross)							
Greenhouse Size (m2)	**Market System**	**Local Sales**	**Other Sales**	**Total Income**	**Total Production (kg)**	**Production (kg/m2)**	**Total Expenses**	**Potential Net Profit**
3,840	**$485,000**	**$75,000**	**$5,000**	$565,000	**187,000**	48.7	$316,795	$248,205
per kg			**per m2**				**Net Profit/Total Expense**	
Gross Income/kg	**Annual Costs/kg**	**Net Return/kg**	**Gross Income/m2**	**Annual Costs/m2**	**Net Return/m2**			**78%**
$3.02	$1.69	$1.33	147.14	$82.50	$64.64			
							=	**#DIV/0!**
Item	**Unit**	**Amount**	**Unit Cost**	**Sub-Total Cost**	**Estimated % Remaining**	**Estimated Actual Cost**	**Cost/m2**	**% of Total Costs**
Heating Fuel	Litre/m3/MJ/Tonne	**189,000**	**$0.37**	**$69,930.00**	**8.1%**	$64,265.67	$16.74	20.3%
Electricity	kWH	**33,000**	**$0.18**	**$5,940.00**	**0.0%**	$5,940.00	$1.55	1.9%
Water	kiloLitre	**3,300**	**$1.00**	**$3,300.00**	**0.0%**	$3,300.00	$0.86	1.0%
Fertilizers	Tonnes	**3.4**	**$1,200.00**	**$4,080.00**	**16.0%**	$3,427.20	$0.89	1.1%
Sprays	Annual Cost	**1**	**$850.00**	**$850.00**	**78.0%**	$187.00	$0.05	0.1%
CO2	kg	**4,600**	**$0.75**	**$3,450.00**	**5.0%**	$3,277.50	$0.85	1.0%
Growing Media	Slabs/Bags	**3,072**	**$3.20**	**$9,830.40**	**2.0%**	$9,633.79	$2.51	3.0%
Seedlings	Seedling	**9,500**	**$1.25**	**$11,875.00**	**0.0%**	$11,875.00	$3.09	3.7%
Beneficial Insects	Annual Cost	**1**	**$3,900.00**	**$3,900.00**	**0.0%**	$3,900.00	$1.02	1.2%
Crop Staff	Annual Cost	**1**	**$101,700.00**	**$101,700.00**	**0.0%**	$101,700.00	$26.48	32.1%
Picking Staff	Annual Cost	**1**	**$14,625.00**	**$14,625.00**	**0.0%**	$14,625.00	$3.81	4.6%
Grower Manager	Annual Cost	**1**	**$0.00**	**$0.00**	**0.0%**	$0.00	$0.00	0.0%
Packaging	3kg Trays	**59,375**	**$1.00**	**$59,375.00**	**15.0%**	$50,468.75	$13.14	15.9%
Packaging	5kg Trays	**0**	**$1.60**	**$0.00**	**0.0%**	$0.00	$0.00	0.0%
Packaging	10kg Cartons	**1,000**	**$1.30**	**$1,300.00**	**15.0%**	$1,105.00	$0.29	0.3%
Packaging	Inserts	**59,375**	**$0.11**	**$6,531.25**	**33.0%**	$4,375.94	$1.14	1.4%
Stickers	Rolls	**1,400**	**$3.00**	**$4,200.00**	**22.0%**	$3,276.00	$0.85	1.0%
Bubblewrap	Rolls	**30**	**$4.75**	**$142.50**	**5.0%**	$135.38	$0.04	0.0%
Freight	Pallet	**307**	**$85.00**	**$26,095.00**	**0.0%**	$26,095.00	$6.80	8.2%
Debt Servicing	Annual Cost	**0**	**$26,000.00**	**$0.00**	**0.0%**	$0.00	$0.00	0.0%
Office Supplies	Annual Cost	**1**	**$256.00**	**$256.00**	**22.0%**	$199.68	$0.05	0.1%
Postage	Annual Cost	**1**	**$27.00**	**$27.00**	**5.0%**	$25.65	$0.01	0.0%
Crop Advisor	Monthly Visit	**10**	**$350.00**	**$3,500.00**	**0.0%**	$3,500.00	$0.91	1.1%
Maintenance	Annual Cost	**1**	**$2,300.00**	**$2,300.00**	**0.0%**	$2,300.00	$0.60	0.7%
Accountancy	Annual Cost	**1**	**$890.00**	**$890.00**	**0.0%**	$890.00	$0.23	0.3%
Rates	Annual Cost	**1**	**$336.00**	**$336.00**	**0.0%**	$336.00	$0.09	0.1%
Bank Fees	Annual Cost	**1**	**$456.00**	**$456.00**	**0.0%**	$456.00	$0.12	0.1%
Insurance	Annual Cost	**1**	**$1,286.00**	**$1,286.00**	**0.0%**	$1,286.00	$0.33	0.4%
Consumables	Annual Cost	**1**	**$275.00**	**$275.00**	**22.0%**	$214.50	$0.06	0.1%
other		**1**	**$0.00**	**$0.00**	**0.0%**	$0.00	$0.00	0.0%
other		**1**	**$0.00**	**$0.00**	**0.0%**	$0.00	$0.00	0.0%
					Totals	**$316,795.05**	**$82.50**	**100.0%**

© Graeme Smith Consulting - Greenhouse Cost of Production Worksheet						Vegetable Season	2018	
Low Technical Greenhouse							Geraldton	
	Income (gross)							
Greenhouse Size (m2)	Market System	Local Sales	Other Sales	Total Income	Total Production (kg)	Production (kg/m2)	Total Expenses	Potential Net Profit
3,500	$93,531			$93,531	46,765	13.4	$61,390	$32,141

per kg			per m2			Net Profit/Total Expense	
Gross Income/kg	Annual Costs/kg	Net Return/kg	Gross Income/m2	Annual Costs/m2	Net Return/m2		52%
$2.00	$1.31	$0.69	26.72	$17.54	$9.18		
						=	#DIV/0!

Item	Unit	Amount	Unit Cost	Sub-Total Cost	Estimated % Remaining	Estimated Actual Cost	Cost/m2	% of Total Costs
Heating Fuel	Litre/m3/MJ/Tonne		$0.37	$0.00	0.0%	$0.00	$0.00	0.0%
Electricity	kWH	5,289	$0.25	$1,322.31	0.0%	$1,322.31	$0.38	2.2%
Water	kiloLitre	1,800	$1.00	$1,800.00	0.0%	$1,800.00	$0.51	2.9%
Fertilizers	Tonnes	3.5	$1,200.00	$4,200.00	0.0%	$4,200.00	$1.20	6.8%
Sprays	Annual Cost	1	$850.00	$850.00	0.0%	$850.00	$0.24	1.4%
CO2	kg		$0.75	$0.00	0.0%	$0.00	$0.00	0.0%
Growing Media	Slabs/Bags		$3.20	$0.00	0.0%	$0.00	$0.00	0.0%
Seedlings	Seedling	3,840	$0.70	$2,688.00	0.0%	$2,688.00	$0.77	4.4%
Beneficial Insects	Annual Cost	1	$2,700.00	$2,700.00	0.0%	$2,700.00	$0.77	4.4%
Crop Staff	Annual Cost	1	$17,952.00	$17,952.00	0.0%	$17,952.00	$5.13	29.2%
Picking Staff	Annual Cost	1	$5,834.40	$5,834.40	0.0%	$5,834.40	$1.67	9.5%
Grower Manager	Annual Cost	1	$0.00	$0.00	0.0%	$0.00	$0.00	0.0%
Packaging	3kg Trays		$1.00	$0.00	0.0%	$0.00	$0.00	0.0%
Packaging	5kg Trays		$1.60	$0.00	0.0%	$0.00	$0.00	0.0%
Packaging	10kg Cartons	4,677	$1.30	$6,079.51	0.0%	$6,079.51	$1.74	9.9%
Packaging	Inserts		$0.11	$0.00	0.0%	$0.00	$0.00	0.0%
Stickers	Rolls		$3.00	$0.00	0.0%	$0.00	$0.00	0.0%
Bubblewrap	Rolls		$4.75	$0.00	0.0%	$0.00	$0.00	0.0%
Freight	Pallet	117	$85.00	$9,937.66	0.0%	$9,937.66	$2.84	16.2%
Debt Servicing	Annual Cost	0	$26,000.00	$0.00	0.0%	$0.00	$0.00	0.0%
Office Supplies	Annual Cost	1	$256.00	$256.00	0.0%	$256.00	$0.07	0.4%
Postage	Annual Cost	1	$27.00	$27.00	0.0%	$27.00	$0.01	0.0%
Crop Advisor	Monthly Visit	10	$350.00	$3,500.00	0.0%	$3,500.00	$1.00	5.7%
Maintenance	Annual Cost	1	$1,000.00	$1,000.00	0.0%	$1,000.00	$0.29	1.6%
Accountancy	Annual Cost	1	$890.00	$890.00	0.0%	$890.00	$0.25	1.4%
Rates	Annual Cost	1	$336.00	$336.00	0.0%	$336.00	$0.10	0.5%
Bank Fees	Annual Cost	1	$456.00	$456.00	0.0%	$456.00	$0.13	0.7%
Insurance	Annual Cost	1	$1,286.00	$1,286.00	0.0%	$1,286.00	$0.37	2.1%
Consumables	Annual Cost	1	$275.00	$275.00	0.0%	$275.00	$0.08	0.4%
other		1	$0.00	$0.00	0.0%	$0.00	$0.00	0.0%
other		1	$0.00	$0.00	0.0%	$0.00	$0.00	0.0%
					Totals	$61,389.89	$17.54	100.0%

References

Agnone, A. (2018, January 28). Antonino Agnone grower, Syracuse, Italy. (B.D. Nguyen, Interviewer).

Bretones, B. (2018, January 17). Pepe Bretones Seed Breeder, Rijk Zwaan, Almeria, Spain. (B.D. Nguyen Interviewer)

Books, A. (2018, January 13). Asaf Books, organic grower, Arava, Israel. (B.D. Nguyen, Interviewer).

Cannon, L. (2019, June 21). Lindsay Cannon, consultant, Achmea Australia (B.D Nguyen, Interviewer).

Gerente, I,B. (2018, January 17). Isaias Benevente Gerente grower owner Bena Sabor S.L, Almeria Spain. (B.D. Nguyen, Interviewer).

Gimenez, T, D. (2018, January 12). Diego Teruel Gimenez Business Director of Tecnova Technology center, Almera, Spain. (B.D. Nguyen, Interviewer)

Habraken, T (2018, January 30). Ton Habraken adviser at Svensson, Netherlands. (B.D. Nguyen, Interviewer).

Hoffman, D (2018, July 16). Daniel Hoffman grower, Virginia, South Australia. (B.D. Nguyen Interviewer).

Kitron, A. (2018, January 12). Ariel Kitron grower, Arava Sapir, Israel. (B.D. Nguyen, Interviewer)

Koning, J,D. (2018, February 1). John De Koning grower, Westland, The Netherlands. (B.D. Nguyen, Interviewer).

Ferguson et al, (2012), Improving greenhouse systems and production practices (greenhouse production practices component) (Parent - VG07096), Horticulture Innovation Australia.

Goebertus, T. (2019, June 20). Tineka Goebertus, Consultant Vortus Greenhouse Consultants Inc, BC, Surrey Canada (B.D. Nguyen, Interviewer).

Lauwers, N. (2018, February 2). Niels Lauwers CEO of 30MHz, Amsterdam, The Netherlands. (B.D. Nguyen, Interviewer).

Lantzke, N. (2018, July). Neil Lantzke Western Horticultural Consulting, Potential use of recycled water for horticulture in Geraldton, report for Northern Agricultural Catchments Council WA, NACC, Perth, Australia.

Le, T. (2019) Thang Le grower, Virginia, South Australia, Australia. (B.D. Nguyen, interviewer).

Martinez et al. (2016), Greenhouse agriculture in Almeria, A comprehensive techno-economic analysis edited by Cajamar Caja Rural, Almeria, Spain.

McLean, A. (2019, June 21), Alastair Control and Water Systems Division Manager, Hallam VIC, Australia Breakdown Construction cost for high technical greenhouse, Powerplant Australia. (B.D. Nguyen interviewer).

Meurs, L.V (2018, February 1). Leo van Meurs Demo Manager Trial Center Tomato Rijk, Zwaan, Kwintsheul, Netherlands. (B.D. Nguyen, Interviewer).

NFF. 2019, March, National Farmers Federation says workers and farmers need an ag visa. https://www.miragenews.com/national-farmers-federation-says-workers-and-farmers-need-an-ag-visa/

NFF. 2018, October, Prime Minister confirms commitment Ag Visa https://www.nff.org.au/read/6181/prime-minister-confirms-commitment-ag-visa.html

Oers, P,V. (2018, January 30). Pascal Van Oers Director of VEK Adviesgroep, Honselersdijk, The Netherlands. (B.D. Nguyen, Interviewer).

Parks, S. (2011), Dr Sophie Parks, Improving greenhouse systems and production practices (greenhouse technology systems component) (Parent-VG07096), Project number VG07145, Sydney, Australia.

Rodriguez, L.J (2018, January 17). Javier Lopez Rodriguez Seed Breeder, Rijk Zwaan, Almeria, Spain.

Saccoci, F. & Neroni, A. (2018, January 25). Franco Saccocci and Adriano Neroni CEO of GROWA Smart Agriculture, Frosinone, Italy. (B.D. Nguyen, Interviewer).

Smith G (2005) Overview of the Australian Protected Cropping Industry. In 'Soilless Australia' p. 28. (PCA: Australia).

Tripler, E. (2018, January 12). Dr. Effi Tripler, Soil and Water Scientist, Arava, Israel. (B.D Nguyen, Interviewer

Worthington, B (2017), Calls for an overhaul of farm visas as unemployed Australians refuse to pick fruit. https://www.abc.net.au/news/rural/2017-10-11/call-for-overhaul-farm-worker-visa-unemployed-trial/9029964

Plain English Compendium Summary

Project Title:	Efficient Practices in Low technical Greenhouses, surviving as a small family farm
Nuffield Australia Project No.:	1724
Scholar:	Bao Duy Nguyen
Organisation:	Sun City Produce PO Box 2 WALKAWAY WA 6528
Phone:	0418 939 982
Email:	contact@suncityproduce.com.au
Objectives	• To investigate Low technical protective cropping structures currently used for growing intensive crops. • Define factors that affect Low technical greenhouse management • Find the most efficient world's best practice in vegetable production in Low technical greenhouses from around the world. • To make practical recommendations to growers using Low technical greenhouse production in intensive farming crops.
Background	Second-generation Vietnamese vegetable grower to travel the world to find the most efficient best practice in Low technical greenhouse structures and management.
Research	Visiting farmers, researchers and attending conferences; reading reports and research papers.
Outcomes	Knowledge informs and enables better decisions to be made therefore improving systems and increasing data collection on moisture, temperature, humidity and radiation is advantageous. Secondly improvements in the greenhouse structure through automating roof and side vents that can control the factors measured will make production much easier and quicker.
Implications	Increased cost however production levels will increase.
Publications	Presented at: • Mid-West Horticulture Grower Group Inc. Grower Update, Geraldton 2018. • Protective Cropping Forum, Mandurah, 2018 • Nuffield National Conference, Melbourne, September 2018 • Mid-West Water Forum, Geraldton 2019