Protected Cropping in Tropical Australia

Securing food production in Northern Australia

A report for:

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Executive Summary

The northern horticultural industry is one with its own set of unique problems and limitations which over time, have limited the implementation of conventional environmental protection technologies. Problems with current technologies include inability to handle increasingly severe weather events, exacerbation of the problem they were originally trying to solve, creation a different, more invasive problem, or lead to a higher cost of production than possibly could be currently accepted by the market.

Research and the subsequent following report identify the technologies relevant and applicable to the three core setup features in a tropical indoor protected cropping system.

Structure - The buildings or coverings suited to shielding the intense heat but flexible enough to manage severe weather events.

Growing media - The material in which crops are grown and the limitations/advantages associated with each.

Irrigation/Fertigation Systems – The two main options when considering the water and nutrient demand supply methods within the protected structure and the considerations to be made.

Each possible option detailed in this report include the following specific points and an explanation to allow local producers to identify what would be best suited to their desired production situation.

Global Example – A personal real-world example of the specific aspect being evaluated, and the feedback/points taken directly from that farm.

Capital Costs – Like all specific financial situations in agriculture, the accurate cost is greatly influenced by the presented situations different attributing factors such as but not limited to local climate, financial capacity, skill capacity, crop etc. That being said a broad indication of the costing structure is indicated relative to the spectrum of available options.

Operation – Like capital costs and operational details of a specific aspect of a protected cropping system implemented into a tropical climate is greatly affected by the specific

situation and them being too vast and variable within themselves made a specific outline hard to obtain. That being said an indicative guideline relative to the spectrum of available options is outlined.

Yield Potential – Instead of listing specific crop types and varieties, an indication is established on the long-term average of most suitable crops (i.e. crops currently grown outdoors at or close to the production climate zone).

Advantages / Disadvantages – A simple itemised list of the advantages and disadvantages that this protected cropping system technology provides.

All these varied technology investigations and conclusions are not meant to be a specific recommendation for what all farm production systems d should look like, but instead are to give the reader a broad understanding of the changes that can quickly be made to production systems to begin the evaluation and commercialisation process. Through global experience and on farm commercialisation trial experience, all advice and products and protected cropping technologies should be evaluated on face value and proven within a unique production system, crop and climate.

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Foreword

I have lived and grown up in the small town of Ayr, 100km south of Townsville all my life. After leaving high school and completing a qualification as an engine builder (specialising in the performance industry) I made my way back to work on and develop our family farm.

After a year, my two younger brothers, who also had trade qualifications, decided to join the family farm with me. With ample encouragement from our father, we began to slowly learn the basics of horticulture production and how to find our place in a competitive market where, we could add value to customers and grow. Over the next five years we slowly grew, helped immensely by the direction and advice from David Vernon from VF+, linking us with customers and getting us to understand what their problems are and how as a business we could find solutions. This then led us down the complicated and somewhat daunting road of getting the crops and production systems from an outside environment, where they are susceptible to everything mother nature can throw, to indoors, but in a manner through the use of production efficient techniques and systems that will still present a good value proposition for the end consumer. At the same time, I was presented with the great opportunity to complete a Nuffield Scholarship on this topic, allowing me the opportunity to travel to the following countries to investigate produce and production system opportunities:

- Japan – High end indoor speciality melons/fruits and vertical indoor farms.
- Israel – A widespread look at a range of crop protection structures and infrastructure systems.
- The Netherlands – An analysis of high-tech horticulture buildings and systems specific to low light and heat environments.
- USA – Lower tech protected horticultural production but at a massive scale.
- Mexico – A comprehensive simultaneous review of production methods, structures and crops in a climate very similar to our own.

After receiving my scholarship, our business set about the construction and crop production trials of our own on farm 2000m2 research facility. We began the process of implementing, evaluating and refining the different techniques, crops and management systems to get a better real-world perspective on what information from industry, current research literature and my Nuffield International research was actually practical in our climate and what elements of other global systems may be of use if coupled with other new or existing technology. To date, this research facility has conducted yield, production cost and quality trials and evaluations on tomato, cucumber, rockmelon, eggplant and capsicum crops, each with multiple seed varieties through the whole spectrum of seasonal conditions.

Figure 1: Burdekin bridge between Ayr and Home Hill spanning the Burdekin river in the dry season

Acknowledgments

Without the help, encouragement and advice from the following organisations and people, this report, the time taken to research it and the implementation to our own production operation in the Burdekin would not be possible.

Nuffield Australia – Jim, Jodie and the whole organisation for doing what they do so well.

Hort Innovation – For seeing the same exciting value that this production model could bring to northern horticulture and the financial support to get us there.

The Viertel Foundation – For the backing and absolute trust to chase the vision our team had.

My family – Parents Ross and Giovanna and Brothers Joshua and Christopher Pirrone for picking up the slack while I was away.

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CRAVO – Richard, Bede and all the team at Cravo for presenting not just their products but also a whole industry snap shot.

Abbreviations

GVP – Gross Value of Production

Ha – Hectare

NT – Northern Territory

QLD – Queensland

RIRDC – Rural Industries Research and Development Corporation

WA – Western Australia

Objectives

There are many factors to take into consideration when evaluating the implementation of a protected cropping system in tropical northern Australia, as there are anywhere else in Australia or the world. What this report outlines are the three main foundational factors that set the potential and limitations of all operations evaluated, and a broader investigation into the parts of these technologies, that when incorporated with compatible crops, have made tropical indoor production a commercial reality globally. These three factors are:

- Structure type.
- Growing medium.
- Irrigation/fertigation.

Of these three main pillars, key evaluation points that were considered to better understand the suitability to certain crop, market, location situations and other factors which include:

- A global example.
- Capital costs.
- Operation.
- Yield potential.
- Advantages and disadvantages.

Chapter 1: Introduction

Northern Australian fruit and vegetable production from the states of Queensland (QLD), Northern Territory (NT) and Western Australia (WA), is almost a billion-dollar industry, providing the nation and exporters with a large variety of seasonal vegetables that account for 58% of total national production. This equates to 790,000 tons of high value product, with this production concentrating on the vast share of the winter staple commodities such as pumpkin, tomato, capsicum, eggplant etc. With the ever-increasing pressures from production and market forces such as climate change, quality standards, environmental regulations, chemical restrictions -both industry and consumer driven, on farm profitability, farm waste, supply guarantees, a different approach to address as many of these issues as possible must to be investigated. The importance of northern Australian production to the country requires both rapid and flexible response capabilities to tackle these issues.

The protected cropping industry in Australia currently has a farm gate value of 1.8 billion dollars (Rural Industries Research and Development Corporation, (RIRDC) 2012) when fruit, vegetables, cut flowers, herbs and speciality crops are combined. Of this, only 20% is attributed to the production of vegetables. However, in recent years the sector has seen a steady 4% to 6% growth in covered area. This amounts to 1341 ha, of which 37% are in NSW and 43% are in South Australia (RIRDC, 2012). Current areas of protected vegetable production in QLD are estimated to be around the 2% (40ha), mainly situated in the south-east corner (Brisbane) and central south (Bundaberg) areas of the state, with recent trends in a growing expansion rate. Blueberries have however seen a rapid expansion in protected growing areas with the use of high tunnels in QLD (Bundaberg and Mareeba). This expansion demonstrates the viability and adoption capability of these production methods when market forces and associated pricing structures demand it.

Production pressures include:

- Resistant insect populations
- Limited outdoor genetics and disease packages
- Cyclones

- Extremely heavy downpours and flash floods
- Extreme heat
- Extreme cold and frosts
- Herbicide drift
- Labour

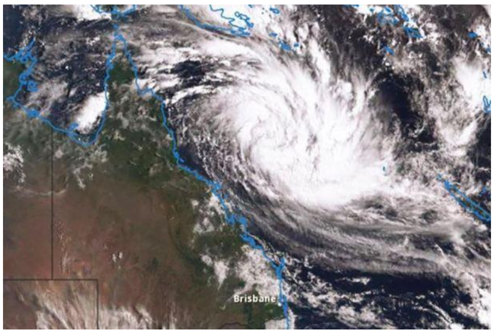

Figure 2: Cyclone Debbie that crossed the north eastern Australian coast in March 2017

Like all other cyclones and storms before, cyclone Debbie inflicted a massive hit onto the whole region's horticultural production and the nation's food security in 2017. The financial losses were reported by various sources to be over 100 million dollars within the northern horticultural industry from this event alone. The end result is that these costs are passed onto consumers through higher prices at the checkout.

The key points that the four main considerations of structure, growing medium and irrigation/fertigation should take into account are:

- Capital cost.
- Operation - Management/running costs.
- Yield potential.
- Advantages and disadvantages (over conventional field growing techniques).

Below is a snapshot of where some of the current protected horticultural crops are situated in terms of percentage of production undercover and the dollar value to the industry these represent. While it is unlikely that most lines will ever transition fully to 100% protected production, it is becoming quite evident that the marketplace, recently domestically in Australia and historically internationally, are beginning to realise the long-term value of secured production systems over traditional low-cost low security production methods.

Estimated Australian Protected Crop Value Comparison	’14-’15 GVP M$ *	’15-’17 % GVP Increase **	’17 GVP M$	Growing Medium	Structure	Protected % of GVP **	Protected GVP M$
Blueberries	155.5	15	178.83	Soil	Poly/Shade	25	44.71
Rubus	103.4	20	124.08	Soil	Poly	85	105.47
Strawberries	420	5	441	Soil	Poly	30	132.3
Cherries	122.1	5	128.21	Soil	Poly	40	51.28
Sum - Fruit	333.9	5	350.6	Soil	Shade	30	105.18
Tomatoes	548	15	630.2	Soil/hydro	Poly/Glass	80	504.16
Capsicum	144.7	5	151.94	Soil/hydro	Poly/Glass	20	30.39
Cucumbers	183.5	5	192.68	Soil/hydro	Poly/Glass	50	96.34
Eggplant	16.2	5	17.01	Soil/hydro	Poly/Glass	20	3.4
Herbs	121	5	127.05	Soil/hydro	Poly/Glass	25	31.76
Asian Veg	62.5	5	65.63	Soil/hydro	Poly/Shade	40	26.25
Flowers	266.5	-10	239.85	Soil/hydro	Poly/Glass	60	143.91

Table 1: Estimated Australian Protected Crop Value Comparison. Source Hort Innovation Fresh Logic Series, Australian Horticultural Handbooks. *PCA Estimates. GVP = Gross Value of Production*

Chapter 2: Types of Structures

Below is a brief summary of the three main structural types that can be used or which have a practical application in tropical environments. Due to the wide range of application situations, freight costs, management capabilities, and crop genetic availability; all estimated costings, yields and structure suitability are estimates or bracket indications and need to be evaluated strategically on an application by application basis.

Retractable Roof

Retractable roof greenhouses can be defined as the ability of the roof, and in some cases the walls, on a structure to be drawn back, folded up or collapsed to allow as much natural light and environmental influences to be present within the crop that is being protected by the greenhouse. One example of a retractable roof that fits this description is the Cravo retractable greenhouse system.

Global example: Cravo System

The predominate global example of a retractable roof greenhouse evident in the research was the Cravo system mentioned above in Culiacan, Mexico. Their company research and demonstration facility is situated in the same region as some of the leading global seed and Mexican horticultural industry research facilities, providing the perfect opportunity to compare the four main crops (capsicum, cucumber, eggplant and tomatoes) back to back with multiple different housing structures, growing techniques and system compositions. At the time of visiting their facility, the traditional local production was in the process of winding down the season, as crop quality and associated pack out yield was quickly heading to a point in which it was no longer viable. It was quickly evident however, that the Cravo house was different. Those crops, one being planted late in the season and just coming into production and the other from the start of the season, which traditionally would no longer to be considered to be commercially viable at this time, were both performing exceedingly well.

Figure 3: Cravo greenhouses research and development facility in Culiacan Mexico utilising their X frame structure, next to a traditional poly vented roof saw tooth greenhouse

The capital cost of a Cravo retractable greenhouse depends largely on which model is chosen, which in turn is dependant the level of environmental pressures the crop is being protected against. The four structure types offered by Cravo, delineated by price and protection from lowest to highest, outlining cost and an indicative Australian cyclone load capacity.

Flat Roof

The lowest cost and protection option, this design is only capable of medium wind loads (110 km/h) and has a porous roof covering. While this flat roof offers 100% protection from direct sunlight, during rain events water will flow through pre-determined slits in the covering partially wetting the plants. This minimally regulated water flow could pose limitations to production still operating in a soil based system, as foot or vehicle traffic may become restricted (http://www.cravo.com/en/house-models/flat-roof).

Figure 4: 17 ha flat roof Cravo in construction for blueberry production in tequila, Mexico

X Frame

The entry level completely sealed house, the X frame offers medium wind load ratings also (110km/hr) but with the distinct advantage of enabling complete sealing against environmental forces even with the roof retracted, as there is an option to have a secondary retractable insect net roof layer, below the traditional white/clear plastic roof covering. (http://www.cravo.com/en/house-models/x-frame).

Figure 5: (Left) X Frame construction showing cabling and main posts and gutter supports.

Figure 6: (Right) Example production of cucumber in Mexico research facility at the end of the season when no one else in the region is in production (Source: Author)

Rafter

The first of the more rigidly designed houses, the rafter's main differentiating aspects are an increased wind load rating of up to 177 km/hr and the ability to span distances of 14.6 metres. This improved spanning capability does however require the use of a centre bracing pole that has the potential to restrict operational movability. These features lead to an addition of a mid to high price per m2 capital investment that must to be taken into account when evaluating crops and target markets and the price those markets are willing to pay. (http://www.cravo.com/en/house-models/rafter).

A Frame

This is the most expensive but strongest version of the retractable Cravo greenhouse. It increases the maximum closed wind load ratings to 200 km/hr, and at the same time enabling a between post span of up to 14.6m. The highest rates of capital investment can include options such as a double retractable roof covering, which do add to the final cost, but in comparison to other real life applications, the total cost is somewhere in the vicinity of 50% or less than that of the industry standard high tech glass houses. (http://www.cravo.com/en/house-models/a-frame).

Operation

Due to the nature of the retractable roof greenhouses' ability to work with nature, the producer and computer expertise, workload and capital investment is kept to a minimum, and in most aspects works automatically, only needing adjustments with crop changes or in the event of power outages. This synergy is achieved by the implementation of indoor and outdoor sensors that monitor humidity, air temperature, surface temperature and available light. The computer software that is designed for the Cravo houses then continuously adjusts roof % opening, misting systems, irrigation systems and wall openings to keep environmental conditions within a set point of parameters.

Yield Potential

The limiting factors affecting yield potential, as witnessed in the Cravo demonstration house in Culiacan, Mexico mainly involve the capacity to work with weather conditions at high humidity times. The main function of removing humidity is to open or partly open the roof coverings allowing excess plant transpiration or water evaporation to be vented off. This cannot be done if the outside temperature and or humidity are at the same level or higher asthe negative effects of an open roof (high radiation levels/rain) are worse than the occurring humidity.

Figure 7: Late season tomato plants grown in Cravo house still in very good production condition (Source: Author)

Advantages

- Damage prevention for crops against rain, wind and high environmental temperatures.
- Low humidity regulation limiting plant transpiration.
- Completely sealed insect protection covering.
- Increased 1st grade pack outs to over 90%.
- Increased work force comfort and productivity.
- Extended growing seasons.
- Market short supply price capitalisations.
- Ability to fold up in the event of a cyclone or severe weather event.

Disadvantages

- High initial capital expense cost.

- Limitations in managing soil-borne diseases.
- Need for modification of current farming machinery and production infrastructure.

Retractable Roof Type	Flat	X Frame	Rafter	A Frame
Cost $ m2	$50-$60	$60-$70	$70-$80	$80-$100
Cyclone Rating Closed	CAT 1	CAT 1 / 2	CAT 2	CAT 2 / 3

Table 2: Estimated Ballpark Comparison of Cravo house models and their Australian cyclone rating load capacity

**Cyclone ratings and estimated costs vary depending on individual applications, locations and system options.*

Vented fixed Roof

The main vented fixed roof design used around the world is the saw tooth or the Israeli Azrom design. The design and shape of these structures is defined by an arching or angled roof line meeting at an acute angled, and then continuing back down the main structure to form a vertically situated face that acts as the vent. The main function of this vent when positioned downwind of the predominant wind direction is to passively vent excess heat and humidity to best suit crop target conditions.

Global Example: Azrom

A unique example of a fixed roof production facility in a tropical environment similar to what is present in tropical northern Australia is actually the very own Israeli Azrom saw tooth plastic covered greenhouse in Ayr Queensland Australia. With one full season of production the results, both good and bad have been surprising. Two keys points we have been able to pull away from the initial trial phase include the following:

- Cost – Apart from the capital expenditures that are obviously associated with the construction of any substantial structure, the operational cost created by the setup and different crop management procedures that are not present in field production are one very important point when considering any protected system. Unfortunately, these costs, as learned from this experience, are very hard to establish until actual completion of the project.

- Season length – The degree as to which a basic, and less than ideal, structure still enabled an extended season, both in terms of early and late production and was able to maintain the same yield and quality has been quite advantageous.

 

Figure 8: (Left) Inside our commercial trial facility on our property in Ayr, Queensland Australia

Figure 9: (Right) Research facility in Culiacan, Mexico utilising the saw tooth vented design greenhouse (Source: Author)

Capital costs

The capital costs of most fixed roof structures tend to be in the relative same price range, falling in the medium to high cost price bracket. Less flexible basic structures, such as the fixed roof, run into additional costs when trying to extend seasons longer or more specifically control the climate. These costs are due to the implementation of specific climate controls such as:

- Suction fans.
- Circulation fans.
- Dehumidifiers.
- Controllable vent openings.
- Humidity sprinkler systems.
- Roll up side curtains.

These then tend to add cost and complexity to the production system, which is determined on a specific crop and location case by case basis.

Operation

The varying layers of climate controlling/modifying technologies that are incorporated into a fixed roof design and to what degree these are automated and function in a compatible manner with weather stations greatly influences the degree of difficulty and man power involved in operating a fixed roof vented house.

Yield Potential

The yield potential of a fixed roof vented greenhouse is specifically influenced by the target growing season, the capacity of the greenhouse's passive and associated climate regulating capacities, the crop genetics and the operational experience specific to the area's climate.

Advantages

- Protection for mild weather events and most pest and fungal pressures.
- Ability to regulate climate conditions.
- Mildly extended growing season.

Disadvantages

- High capital expense cost.
- Risk of a virus or disease breakout affecting 100% of crop.
- Inability to withstand cyclones or severe weather events without de-skinning.

High-Tunnel

High tunnels are best described as three to four metre hooped steel tube framed tunnels with a plastic sheeted roof covering, usually with open side and end walls. Although simple and relatively cheap in construction, structural integrity is limited in adverse weather conditions. This was demonstrated in Mexico, at the end of every season, the same time our study group visited, all the rooves and walls were detached and rolled up on the hundreds of hectares of structures doted across the region.

Global Example

The main examples of high tunnel-type greenhouses encountered during the research were self-manufactured structures, which the basic design and construction tend to lend themselves to. It did not seem there was any industry standard present, but rather farmers, through trial and error tailored structure dimensions and functions to suit their specific crop and local climate.

Capital costs

The lowest cost of the three studied tropical protected cropping structures tend to offer a proportional level of protection and flexibility. This protection and flexibility is due to these systems relatively low cost construction, assembly methods and materials. This design may work well with specific crops, environmental or market conditions, allowing for a satisfactory return on investment both economically or as part of a strategic production insurance policy.

Figure 10: Examples of high tunnel structure protected cropping in Mexico (Source: Author)

These structures though basic in design and operation, were being used for blueberry production. A main disadvantage of this simple design is that in the event of severe weather events, all roof and wall coverings have to be removed manually, causing significant increases in labour costs.

Operation

Accompanying their lower cost and construction aspects, operations inside high tunnel structures tend to be very similar, if not the same as, traditional field production systems. The only consideration that has to be taken into account is the operation of bigger machinery, which may be limited due to width or height restrictions operating around tunnels poles and bracing.

Yield Potential

Yield potential, as seen in very sensitive crops such as blueberries and lettuce, have seen substantial gains in yield, or more specifically in first grade product pack out. This gain, when used in conjunction with other growing technologies, such as indoor specific genetics or hydroponics, enable a greater degree of gross yield or market accepted yield to be achieved quite rapidly.

Advantages

- Lowest cost alternative to field production.
- The biggest increase in protection per dollar spent.
- Mild ease in disassembly or maintenance.
- Existing field production methods and equipment can still be used.

Disadvantages

- Limited ability to withstand severe weather events.
- Very limited ability to withstand even mild cyclones.
- Can be restrictive in high growing or long-life cycle crops.

Fixed Roof Type	Vented	High Tunnel
Cost $ m2	$30-$50	$75-$100
Cyclone Rating Closed	N/A	CAT 1 / 2

Table 3: Estimated ballpark comparison of fixed-roof greenhouse designs and their Australian cyclone rating load capacity (Source: Author)

Chapter 3: Growing Medium

Of the countless applications of growing mediums observed, both at home and overseas, there are two main categories that have a practical base in production trials and commercialised farms with similar crops and conditions as tropical Australia. These can be summarised as soil and soil-less mediums, both of which can be broken down into countless variations and complexity levels specific to each individual application, with an overview of the price point, and observed potential yield variation on cucumber and tomato crops.

Soil

As evident from observations, and contrary to initial assumptions, the majority of global indoor production is still soil-based. The way in which different areas of the world approach indoor production are unique to their specific crops, climate and original soil base.

Global Example: Arava Valley

One of the prominent examples of a systematic approach to optimising a soil indoor farming system are the indoor farmers in the Arava Valley in southern Israel. Starting with a coarse rock/sand base the farmers of the region would first trench and export out the unsuitable original soil, replacing it with a more suitable sand/soil mix mined from another part of the desert. This replacement soil was then filled back into the trenched greenhouse beds. It is also important to add that that these same farmers would sink bores down to about a kilometre in places only to find salty water, which was then mildly desalinized before being used on the crops (capsicum, cucumber etc.). With this in mind proper, drainage and periodic flushing of the soil is of the utmost importance in order to avoid the accumulation of salt.

Figure 11: Greenhouses in the Arava desert valley Israel (Source: Author)

Capital costs

Depending on the starting soil condition and make up, generally speaking most arable land soils can be brought up to a standard with minimal cost to enable a consistent, uniform cropping base. Some of the key points considered in places such as Mexico, Israel and the USA include:

- Drainage.
- Carbon %.
- Salt concentration.
- Source water quality.
- Ability to flush soils, whether it be through rain or overhead irrigation.
- Nutrient level and ratios.

Operation

Figure 12: Protected capsicum crop starting to show signs of excessive salt build up in the soil, potentially leading to yield or quality problems in future crops – Mexico

In soil operations are the same in principle to most procedures and techniques that can be found in specific crop production operations. The key consideration, whether the crop is being grown in the Middle East or North America is the health of the crop be in the best possible state, through proper nutrient management and crop rotations to mitigate any biological hindrances.

Yield Potential

From initial data collection, as well as grower testimonies around the globe, it is apparent that while in principle it is possible to achieve yields on par with hydroponic systems, the variability associated with most soil profiles and distribution tends to lead to compromises being made.

Advantages

- Low setup cost.
- Big irrigation and fertigation buffer.
- Ability to scale quickly.
- Low management requirements when compared to hydroponic.

Disadvantages

- Moderate pathogen risk.
- Difficult to achieve extremely consistent yields.
- Possible product contamination (post-harvest cleaning necessary).

Soil-less medium

Soil-less growing medium and the technologies associated with its implementation are not a new occurrence by any means. More widespread adoption has led to an extensively diverse array of systems and key production components designed to cover any and every crop, geared to target market requirements. An example of this type of system includes shelf ready retail lettuce grown in a suspended water and nutrient only solution. This solution can be delivered by either high pressure intermediate misting technology or a semi submersed recirculating tray hydroponic system to ensure no foreign particles can ever enter the supply chain, eventuating in an inconsistent experience for the end consumer.

Global Example

One extreme example of a soil-less growing medium production operation is the indoor leafy green production facility in Japan, Spread Co. Their operation consists of a 2.8 ha factory facility with 2.5 ha of area under production. The difference with this production facility though is the implementation of true vertical farming setup on a 16-level tiered system with soil-less hydroponic water recirculation systems and artificial grow lights. This facility operates and is actively growing plants 24 hours a day 365 days a year. Due to the completely sealed and continuous plant growing environment, yields of over 7.7 million head of the 4 varieties on offer are produced every year (*http://www.spread.co.jp/en/technology/).*

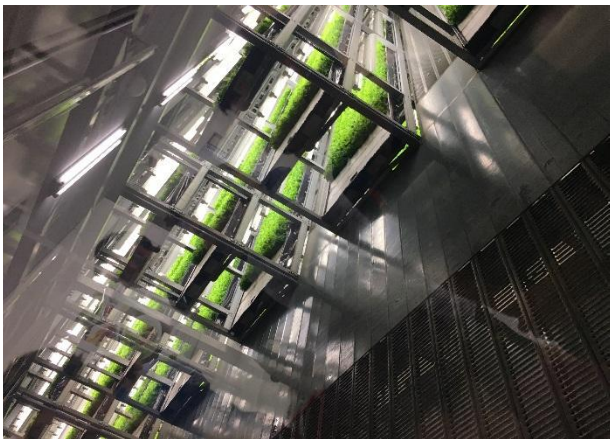

Figure 13: (Left) The tier system used by Spread Co. to maximise the number of plants per m2 in the leafy green factory in Japan.

Capital costs

The capital and maintenance cost of a soil-less medium is separated into two main components, growing medium and holding/drainage system.

Growing Medium

Depending on which crop and irrigation system is in place the choice of material that makes up the growing medium has a great influence on the capital cost. Growing materials most commonly used include coconut husks, pine mulch and vermiculite. Globally, growers tend to use a combination of two or more of these to take advantage of each medium's specific functions that support the production system and crop. The organic recycled materials tended to be at the lower end of the cost spectrum and routinely came pre-packed into a bag or box, whereas the high cost mined or manufactured products, such as pulverised porous rock or polymer products were at the higher end.

Holding/Drainage System

The main considerations regarding the medium holding and draining system that most growers stated as key points of consideration were:

- Drainage efficiency.
- Necessity to recycle or drain waste excess irrigation water.
- Whether growing medium is in disposable grow bags, or a long-life substrate.

Really understanding what is needed by the target crop and market is key to optimising the operational and capital cost of setting out the hydroponic media holding and drainage system.

Operation

The management cost and technical expertise involved in soil-less growing medium greatly increases when compared to in soil growing systems, even when compared in their most basic forms. For this reason, many of the farms visited stated that due to low commodity prices or lack of local management advice, they had stopped making the transition.

Yield Potential

The yield potential of soil-less growing mediums when operated correctly within specific crop nutrient and water requirements regularly showed higher yields, higher pack outs and an overall more consistent production output. While data on this is widely available and pushed by soil-less industry, it was repeatedly stated that gaining such a high level of control and consistency does come with the price of the system having very little buffering or margin for error if something was to fail or a operational human error is made.

Advantages

- Increased crop quality consistency.
- Increased yield consistency.
- Clean at pick product (no dust).
- The ability to adjust nutrient or irrigation conditions to provide a desired crop function instantly with no lag time, allowing for quick evaluation.

Disadvantages

- Higher capital expenditure.
- Higher cost of production.
- High technical attention and support needed.
- Low margin of error if mistakes are made.

Growing Medium	Soil	Basic Hydroponic / Soil-less
Initial Capital Cost m2	$0 - $5	$10-$30
Yearly Maintenance Cost	$2.5	$5-$10
Yield Potential Examples		
Cucumber	20 - 40 kg/m2	50 - 70 kg m2
Tomatoes	10 - 20 kg m2	60 – 75 kg m2

Table 4: Growing medium cost and basic average yield tendencies noted on my travels

Chapter 3: Irrigation and Fertigation

Mirroring the same application considerations and yield/cost advantages and disadvantages as growing medium choice (usually invariably linked), the two common system principals that all commercially applied fall under there two main categories of broad application drip tape and targeted applied hydroponics.

Drip Tape / Soil

Every example of the indoor use of drip tape used in soil production systems mirrors the common industry practices applied to field production both here and abroad. The main differentiating practice observed was the placement of the tape either above or below the ground, the number of drip lines and the place distance in relation to the plants.

Global Example

The most common example observed of in soil drip irrigation was also the lowest cost and technically simple irritation possible. Rarely used in Australia due to its lower water use efficiency and increased weed pressure attributes, the practice of a single or dual tape layer down on the surface between or besides plants without plastic or organic mulch was the layout of choice. With the low labour rates in countries such as Mexico that enable manual weeding to be done and the quick turnaround from land prep to crop planting if tape and plastic don't have to be buried it makes economic and operation sense to that this method is used.

Figure 14: (Left) Typical low-cost capsicum production system with above ground drip lines.

Figure 15: (Right) Bed setup is also a similar layout to field production but with a vee'd inner row

Capital Costs
Capital costs due to the widespread global use of drip tape technology and the number of companies now offering iterations of this product has led to the near commoditisation of scale and cost, enabling it to be applicable to even the lowest value product production system especially when it comes to the comparison against hydroponic or targeted water/fertilizer applications.

Operation
The application, retrieval and management of all iterations of drip tape systems have mostly become mechanised. The only main consideration through the production cycle is the ability of emitters to become blocked or restricted. This problem however, through proper water selection, routine flushing or the application of hydrogen peroxide or other acidic based cleaners can be avoided or reversed in most situations.

Yield Potential
The main sources of plant and production variability caused in crop cycles from farmer feedback and experience relate to problems with soil drainage or profile in isolated examples throughout a crop, and either tape blockages or uneven nutrient distribution when problems become more widespread or show distinct location pattern throughout the house.

Advantages
- Utilisation of existing equipment and operational procedures.
- Low cost.
- Easy of operation and monitoring.
- Large soil water holding capacity.

Disadvantages
- Hard to manage variations in soil profile in relation to water holding capacity.
- When leaks occur, soil conditions make it hazardous to operate work platforms, trolleys or spray equipment.

Hydroponics

Global Example
The prominent global example of a unique hydroponic indoor growing system was an alternating raise and lower strawberry system outside of Mexico City, Mexico. The system

consisted of long plastic troughs hung from the ceiling of a retractable roof greenhouse. In these troughs slabs of coco peat were placed with an individual emitter for every plant. The cables were then set at the ideal length to allow the excess irrigation solution to pass through the coco peat grow bags into the trough and continue to the end of the row. There it was collected, cleaned and recycled. The advantage of this system is that the hydroponics allowed the ability to utilize 100% of the available growing surface and sunlight while at the same time, not compromising on worker efficiency by lifting alternate rows, not shading out plants by bringing all rows to a level position quickly and with virtually no operating costs.

Figure 16: (Left) Hanging trough strawberry production system outside of Mexico City, Mexico.

Figure 17: (Right) Example of the drainage system and the mechanisms to allow the alternate rows of crop to be raised and lowered to allow for optimum growth and operational efficiencies (Source: Author)

Capital Costs

Depending on the complexity of a hydroponic system, costs can vary from a simple waste to ground system, to a completely recycling, self-purifying and monitoring Dutch operation. The many iterations and options seen incorporated into hydroponic systems on my research include:

- Auto nutrient monitoring and adjustment.
- Daylight hour referenced irrigation automation.
- Ultra violet or chemical sterilisation.

Operation

The complexity and operational cost of a hydroponic system once again depends on the level of complexity incorporated and the management capability present within the farming operation. For the large-scale hydroponic farms visited around the globe, the ability to have a dedicated irrigation manager as well as an in-house plant health specialist was a common aspect of a successful operation.

Yield Potential

The yield potential of hydroponic systems, when setup and operated correctly are the only way articulated by growers, to achieve the highest degree of crop uniformity and yield that the other main factors of crop genetics and greenhouse climate will allow. This though has to be weighted up when cash flow, cost per kg target market and management capabilities are taken into account.

Advantages

- Highest possible yield uniformity and volume.
- Dust and mud free working environment.
- Quick adjustments to plant nutrient composition.
- The theoretical ability to achieve 12 months' production in one location.

Disadvantages

- High capital cost.
- High operational cost.
- High maintenance costs.
- High level of operational expertise necessary.

Irrigation System	Drip Tape	Hydroponic
Cost m2	$1 - $5 m2	$5 - $15 m2
Irrigation Consistency	MED	HIGH
Fertigation Consistency	LOW	HIGH

Table 5: Irrigation System cost and consistency variation overview

Conclusion

Consumers, and by proxy retail and wholesale outlets are increasingly demanding high quality, consistent produce to be available at all times and at a reasonably affordable price point. This demand will inevitably lead to research, commercial implementation and eventual widespread adoption of new technologies on a farm-by-farm basis. After witnessing, first-hand, the production capacity and full commercialisation of the protected horticulture industry globally, in areas with the same climatic conditions that are present in northern Australia, it is highly likely, if not inevitable, that production systems in the future will adopt this production system in order to meet consumer demands. To direct future production towards this goal, a great deal of consultation and proof of concept trials will need to be conducted on the target farms or production regions in order to minimize the potential for loss of capital and misallocation of human resources on a larger scale. Due to the longer life-cycles of crops, such as tomatoes or capsicums, the time taken between the initial product design, implementation and final yield or efficiency analysis can lead to lengthy lag times, potentially up to a full season or year. Workable solutions to counter this lag-time and potential production mistakes have to be incorporated into the larger horticultural production system in order to minimize risk to individual farmers. Farm-to-farm collaboration, linking of whole national supply locations on a specific product line or supply amalgamations of multiple lines into a collaborative production entity with the ability to share or pool research data and resources can create an efficient way to fast-track the development of chosen protected technologies and will increase the likelihood of the project being successful.

What this has meant for the author's family operation has been a two to three-year research and development phase, trialling all the applicable technologies and techniques, such as hydroponics and different growing mediums in our current fixed-roof research facility to slowly but methodically arrive at simple yet detailed solution. Although completely tailored and unique to a crop, local conditions and target market this has paved the way and shown other growers and potential local and international customers that Northern Australia can, and will, offer not just a cheap high-volume production source of fruit and vegetables, but also a year-round, consistent and high-quality production base as well.

Recommendations

There are a number of recommendations that can be draw from this global investigation and subsequent report that drive the direction of which of the core building blocks of a greenhouse production system detailed above are fundamental in ensuring a cost and time positive result regardless of crop produced. These include:

- A solid understanding of the specific crop's environmental thresholds that will limit productivity in regard to temperature, transpiration, nutrition, through an in-depth investigation and consultation with an industry scientist or researcher.
- Open and direct market communication as possible to ensure costs and specifications of the crop that is being planned for production will line up in a mutually positive situation.
- A development time frame and budget that allows a smaller scale production facility to be constructed that has the personnel and the practical flexibility to test and evaluate different production inputs and techniques.
- Thorough on farm bio-security protocols to ensure the mitigation of an introduced pest or disease.
- Consultation with local council and government in the event of severe local flooding, storms or cyclones, and as to how that affects the production systems of local area and the capacity for roof drainage, and structural engineering specifications etc.

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Plain English Compendium Summary

Project Title:	Protected Cropping in Tropical Australia. Securing food production in Northern Australia.
Nuffield Australia Project No.:	1621
Scholar:	Ross Pirrone
Organisation:	Pirrone Brothers Produce Ayr, Queensland
Phone:	04 383 400 40
Email:	admin@pirronebrothers.com.au
Objectives	To provide a broad and simple overview of production systems and/or system components for the application of commercial greenhouse production in northern Australian (Tropical Environments)
Background	As a traditional but relatively new outdoor horticultural producer in North Queensland we set about trying to find a way to increase the quality and the consistent supply of produce but all the while keeping the cost as low as possible in line with current field production and market price rates.
Research	The research and evaluations centre around the technologies and techniques available to bring protected production to the tropics that is able to stand up to our server climate conditions at times.
Outcomes	The international investigation and subsequent report and evaluation provided a broad understanding on the key aspects and fundamental features of a successful protected cropping system and the ability and awareness to draw upon different resources to piece together a suitable system for every unique application.
Implications	The direct implications prevalent to ourselves and ultimately for the greater northern horticultural industry are evented in the initial commercial trials conducted on our farm, and the proven commercial viability these have now proven.
Publications	Nuffield Australia National Conference, Melbourne, September 2018.