Intensive Berry Production Using Greenhouses, Substrates and Hydroponics. Is this the Way Forward?

A report for

by Nicola-Anne Mann

2014 Nuffield Scholar

January 2015

Nuffield Australia Project No 1415

Sponsored by:

Horticulture Innovation Australia

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Executive Summary

Berries are fast becoming the number one sellers in the fresh produce section of supermarkets and berry growers all over the world are looking at all feasible options to increase the production of these so-called 'super-fruits'.

The report is aimed primarily at Australian and international berry growers who are considering their options in terms of intensifying their existing cultivation methods. However the report may also be used as a guide for:

- Those considering growing berry crops in the future, and
- Existing protected cropping and hydroponic growers who intend to diversify or transition to berry production utilising their existing infrastructure and skills.

Key findings

- High tunnel production is the most common form of low-tech protected cropping of berries around the globe at present. The level of sophistication is improving rapidly to high-tech Venlo glasshouses and retractable greenhouses to improve the quality, quantity and consistency of the supply of berries produced whilst minimising all risks.
- The focus is shifting to production efficiency by looking at the best ways to optimise labour, water, nutrients, energy, pollination, improved genetics and timing (for instance, producing berry fruit earlier and later in the season without interruption or to meet very specific supply gaps within the market).
- The world's most progressive growers are carefully selecting and blending substrates for specific berry crops and even including bio-stimulants such as *Mycorrhizae*, *Trichoderma*, *Bacillus subtilis* and other additives to optimise plant health, plant development and to maximise yields sooner.

- Intensive, trellised, containerised plant management systems with precision fertigation programs are being refined to create high yielding fruiting walls whilst leachate (containing nutrients and water) is captured, recirculated and re-applied.
- The pros of adopting protected cropping, substrates and hydroponics in the fresh berry industry outweigh the cons despite higher capital investment and the current limitations for mechanically harvested crops within protected cropping structures.
- Extensive outdoor berry cultivation will continue to exist as growers strive to produce the volume required by the market. However this trend will shift towards intensive production as land, water, labour, nutrients and energy become scarce commodities and the risks associated with unprotected cultivation become unviable.
- Genetic selection and improvement of the various berry varieties is advancing swiftly but so too is the control of a few powerful breeders and marketing companies – so when growers select good varieties to grow they are selecting their marketing avenue too.
- The protected cropping of berries in greenhouses using substrates and hydroponics is in its infancy. As a result, the early adopters of this sophisticated and innovative method of berry production are considered pioneers in the industry. They have no alternative but to experiment and work on a process of educated trial and error because every farm, region, grower, market, berry crop and variety differs enormously and demands a different solution.

This report demonstrates why protected cropping, substrates and hydroponic techniques must be considered as viable berry growing methods in order to intensify the cultivation and production of berry crops to meet the surging global demand and be a financially viable, sustainable and profitable solution for commercial berry growers.

Contents

Figures

Tables

Foreword

My husband Wade and I are hydroponic rose growers on the Central Coast of New South Wales in Australia. We own and operate a small business called Roses 2 Go Pty Ltd, which we began in 2002 after immigrating to Australia. Originally from Zimbabwe, our family was forcefully evicted from our farm, which had been in the Mann family for more than twenty years. Our background was in the production of tobacco, wheat, barley, soya beans, grass seed, beef cattle and six hectares of roses for exportation. With limited resources, Wade, myself, our three young children and extended family grouped together to start a business in Australia in order to fulfil the requirements of the 127 Sub-Class Visa; our 'golden ticket' to a new start in the 'lucky country'.

With high expectations from the Australian government and only 36 months to prove ourselves, we decided to draw upon our rose growing expertise gained in Zimbabwe, knowing we had successfully sold our roses globally at the VBA Flower Auctions in Aalsmeer, The Netherlands. Once we managed to secure a suitable greenhouse to lease, we began growing 3,000m² of hydroponic roses in coco-peat, using a closed irrigation system whereby all water and nutrients were recycled and reused. Right from the start we also adopted Integrated Pest Management (IPM) principles using little to no harmful chemicals on our crops. Our efforts were rewarded with high quality rose crops, which we wholesaled directly to florists on the Central Coast.

Within one year of production we could no longer keep up with the demand for our high quality roses and decided to double our operation to 6,000m2. The marketing of the roses extended to Sydney and Newcastle and before long we opened a small shop on the farm from which we sold our roses direct to the public and ran farm tours as a local tourism operator. More retail shops were added to the business and dispersed across the Central Coast region. An online store completed the mix. Suddenly the business was retailing more than it was wholesaling. By now we were also offering a full florist service, which included

same day deliveries for a range of events and celebrations, from weddings to funerals and everything in between. Incredibly, all this took place within just five years.

Roses 2 Go Pty Ltd won Florist of the Year in consecutive years from 2007 to 2010 and Business of the Year in 2014 for the Wyong Shire. I was personally awarded the accolade of Business Woman of the Year in 2012 in the Retail AND Tourism categories and Business Person of the Year for the Wyong Shire in 2014. I have served on the Protected Cropping Australia Board for the past four years and sat on the Board of the Central Coast Business Enterprise Centre. I was also recently invited to be Chairperson of the Local Organising Committee for the 2015 Protected Cropping Australia Conference.

In recent years, our company has been hit hard by the mounting pressure of imported roses entering the Australian market, causing prices to fall dramatically (largely below the Australian cost of production for hydroponic roses). As a result, Wade and I began looking for another crop, which we could potentially grow alongside our roses in their semi-high tech greenhouse environment. With increasing consumer interest in blueberries and raspberries, it seemed the logical choice to investigate the potential to grow berry crops in a greenhouse environment. When the opportunity to become a Nuffield Scholar presented itself, I knew the program would provide the ideal springboard from which to launch a detailed study into “Intensive Berry Production Using Greenhouses, Substrates and Hydroponics”. My goal as a scholar was to find the world’s best practice in berry production and replicate innovative ideas from other industries, which had the potential to be adapted and improvised as berry growers.

Wade and I planted our first raspberries in November 2013, two months after I was awarded my Nuffield Farming Scholarship and the blueberries were planted in February 2014. This provided me with the ideal opportunity to “learn by doing” and trial a few of the many ideas discovered on my travels around the globe.

The Nuffield Farming Scholarship has given me the unique opportunity to travel and study alongside industry colleagues and fellow scholars to countries all over the world, including New Zealand, China, Phillippines, USA including California and Maryland, Mexico, Canada, Ireland, Spain, Portugal, United Kingdom, France, Belgium and The Netherlands. During my travels, I observed and analysed everything from Wild Low Bush Blueberries in Nova Scotia, Canada to the sophisticated farming techniques used to produce strawberries in The Netherlands. Other countries like Chile, Argentina, Morocco, South Africa and Japan, all countries known for their innovative berry growing practices, are now on my radar to visit in the future.

My husband Wade is a current Nuffield Scholar and we are honoured to be the first Australian husband and wife business partnership to be awarded the scholarship in consecutive years. Wade is using his scholarship to research global best practice in Integrated Pest Management (IPM) strategies for the greenhouse hydroponic production of berry crops, hence his studies will perfectly complement my own. Together we hope our findings will benefit not only our own business, but also the Australian primary production industry as a whole.

I would like to sincerely thank my sponsors, Horticulture Innovation Australia, without whom none of this would have been possible. The Nuffield Scholarship program has planted the seed for a deeper interest in research and learning. The more I learn, the more I realise there is to learn. I truly believe this is just the beginning of the journey for me.

Figure 1 Nicky Mann Picking Raspberries at Roses 2 Go February 2014 (Source: N Mann)

Acknowledgments

First and foremost, taking part in the Nuffield Farming Study program would not have been possible without the amazing support and encouragement of my husband, Wade and my children Zinzan, Tayne and Oregan, for which I am eternally grateful. To my first class team of Roses 2 Go Pty Ltd employees, Tammy, Belinda, Katie, Lyn, Dianne, Annette, Bob, Eden, Debra and George who have kept the farm and shops running in my extended absences – thank you! Thank you to Tony and Merle who have been pillars of support to Wade and I in more ways than they will ever know. To my Dad, thank-you for being the only consistent reader of my blogs. To my three sisters for listening to me waffle on about my exciting Nuffield adventures whenever I phoned. To our close friends Warwick, Teena, Monique and Paul and our extended family members who stepped up to help us out, thank you. To our business coach, Marcus, who has always encouraged both Wade and I to keep developing professionally and extending ourselves beyond our comfort zones, thank you for believing in us and pushing us forward. To the many business groups I have been a part of, thank you to all the individuals who have inspired me to want more and be more.

A huge thank you to my inspiring, travelling companions on the Global Focus Program, Tania Chapman, Finola McCoy, Justine Dutheil, Aubrey Pellet, Greg Gibson, Nigel Corish, Paul Olsen and Steve Wolfgram. This was a trip of a lifetime for not only did we visit some amazing parts of the world, but we also formed lifelong friendships and with strong mutual professional respect along the way. I feel global agriculture is in very safe hands with people like you leading your respective industries forward.

Thank you to the countless farmers, allied businesses and researchers who allowed me to inspect their farms, businesses, research facilities and operations in minute detail. Thank you for your patience and for so openly sharing your knowledge with me. I am forever indebted to you all. I would especially like to personally acknowledge the following people for going above and beyond for me in terms of organising visits or introducing me to new contacts – Kim and Craig Reiche; Rowena Edge; Dan Peach; Peter Malloy; Lloyd Foss; Harvey Hall; Julian

Raine; Jo Stephens; Allan Bissett; Dr Mike Nicholls; Scott Lawson; the team at Haygrove® UK, including Laura; Cristian and Douw; Ross Mitchell; Gabby and the team at Driscolls® in Watsonville, USA; Mark Bolda; Craig Moriyama; Dan Crowley; Igor Chpak; Johan Otto; Marco Vaz; Hugo from Sunshine Fruit, Portugal; the team at Legro®, The Netherlands, including Jacco; Brenda and Ronnie; Bart and Peter from Trayplants®, The Netherlands; Bart from Van Gennip Kwekerijen, The Netherlands; Marcel A.G. de Jong; Jonathan Eccles; Sophie Parks; Jonathan Lidbetter; Len Tesoriero; and the Protected Cropping Study tour group – thank you to each and every one of you for teaching and inspiring me.

I would particularly like to acknowledge Nuffield Australia for seeing potential in me and bestowing this incredible opportunity on me. To my fabulous sponsor, Horticulture Innovation Australia and, in particular, to Sharyn Casey, thank you for your financial, professional and personal support. Thank you for investing in and continuing to support farmers from the horticultural sector. I will forever be indebted to you and it is my intention to share my knowledge as often and as freely as I can for the benefit of the industry and to help take Australia forward as a global leader in the sector.

Last but not least, a heartfelt thank you to Australia. If it weren't for this wonderful country taking my family in and giving us the opportunity to make a new start back in 2002, I believe I would not be here to share my research, let alone be an Australian rose and berry grower. Each and every day my family and I count our blessings and strive to repay the great honour bestowed upon us by the Australian government of the time. Thank you from the bottom of our hearts.

Figure 2 Wade and Nicky Mann in amongst the roses at Roses 2 Go May 2014 (Source: N Mann)

Abbreviations

ABGA – Australian Blueberry Growers Association

AQIS – Australian Quarantine and Inspection Service

EC – Electrical Conductivity

DPI – Department of Primary Industry

g - grams

Ha - Hectares

HIA – Horticulture Innovation Australia

IPM – Integrated Pest Management

IDO – Industry Development Officer

Kg – Kilograms

Kph – kilometres per hour

LB – Lowbush Blueberries

m^2 - square metres

NHB – Northern Highbush Blueberries

NFT - Nutrient Flow Technique

NSW – New South Wales

NT - Northern Territory

PCA - Protected Cropping Australia

pH – Power of Hydrogen

ppm – parts per million

QLD – Queensland

RABA – Raspberry and Blackberry Australia

RE – Rabbit Eye

SA – South Australia

SHB – Southern Highbush Blueberries

SWD – Spotted Wing Drosophila

t – tonnes

TAS – Tasmania

USA – United States of America

UK – United Kingdom

VIC – Victoria

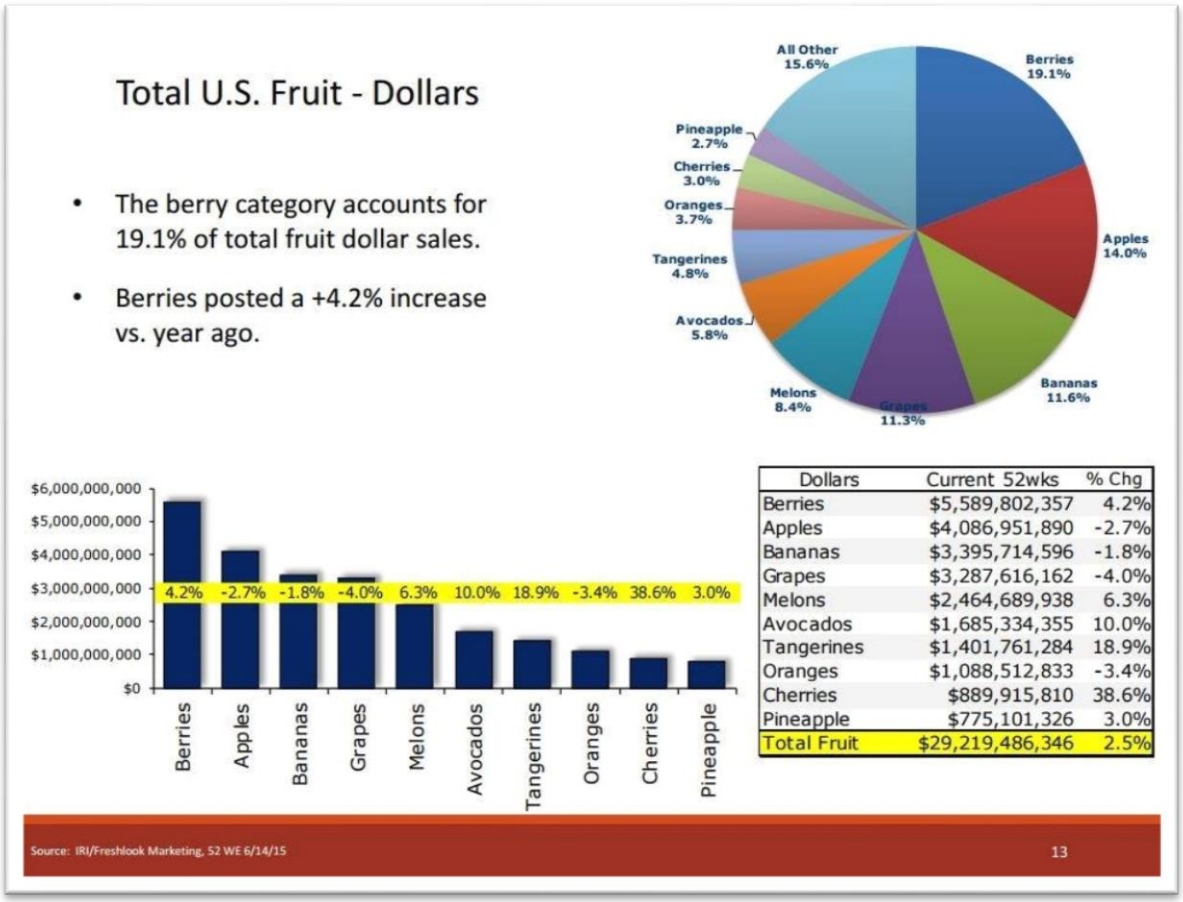
WA – Western Australia

Objectives

- To compare the various protected cropping structures currently utilised.
- To assess and compare the different substrates, containers and hydroponic systems used for intensive berry production.
- To take a closer look at the range of berry crops available with a specific focus on blueberries, raspberries, strawberries and blackberries in protected cropping environments and how crop management of these berry types occurs.
- To compare the pros and cons of protected cropping, substrates and hydroponics with traditional berry crop growing methods.
- To find the world's best practice in berry production and replicate innovative ideas from other industries, which have the potential to be adapted and improvised for berry growers.
- To make practical recommendations to growers considering adopting intensive greenhouse production of berries using substrates and hydroponics.

Introduction

The berry market is global. Berries are grown in all parts of the world with various geographic areas having their own unique varieties. Both the global production and consumption of berries are on the rise (Intelligence, 2008). During his presentation, 'The Global Berry Business within the Global Fresh Produce Market', Marco Luraschi from Rabobank Chile remarked, "Fresh berries are one of the fastest growing categories in terms of consumption within fruit." He added, "Berries have reached a significant share of retail fresh fruit sales, particularly in the USA where they have experienced approximately 4.7% year on year growth rate in context of growth of sales of the entire fruit categories" (Luraschi, 2013). The figure below shows the size of berry category in the USA which is indicative of where the global berry category is heading.



Dollars	Current 52wks	% Chg
Berries	$5,589,802,357	4.2%
Apples	$4,086,951,890	-2.7%
Bananas	$3,395,714,596	-1.8%
Grapes	$3,287,616,162	-4.0%
Melons	$2,464,689,938	6.3%
Avocados	$1,685,334,355	10.0%
Tangerines	$1,401,761,284	18.9%
Oranges	$1,088,512,833	-3.4%
Cherries	$889,915,810	38.6%
Pineapple	$775,101,326	3.0%
Total Fruit	$29,219,486,346	2.5%

Figure 3 USA Fresh Fruit Categories (Source: IRI/Freshlook Marketing, 52 Weeks 14/6/2015)

Why is berry consumption on the rise?

The growth in demand for and consumption of berries is foremost fuelled by the health trend sweeping the globe together with the growing demand for convenience and natural products. In addition to their proven health benefits, berries are convenient in that they require no peeling and are easy to carry and consume by hand. According to Cort Brazelton (2011) “the blueberry notably moves from its position as a niche product to that of a ‘must have’ commodity.”

Consumer expectations

Berries are expected to have excellent visual appearance (attractive, uniform in size and shape and have a glossy skin). Berries should also have good flavour, aroma and texture. Attributes such as a firm skin and even fruit size are considered essential for a pleasant eating experience (Intelligence, 2008).

Versatility driven by demand

If berries used to be about limited availability during a very short summer season, the reality today is very different. The berry industry has become increasingly versatile over time and today consists not only of fresh fruit, but also of frozen, dried, extracts, juices, pulps, beverages, oils and other highly specialised ingredients and/or products. A major goal of berry companies is to achieve year-round availability of fresh fruit at retail to service the demand for berries in all forms and variations. To achieve this goal, berries are either sourced from around the world or growers are encouraged to embrace new production techniques and varietal development(s). Cost of production is managed through the increased use of high yielding varieties, easier picking methods, more efficient use of water and fertilisers, and improved infrastructure like tunnels and greenhouses (Intelligence, 2008).

The Australian Berry Industry

According to Cort Brazelton "Australia has some of the highest per capita blueberry consumption in the world following American and English trends of consumption. The health message is firmly entrenched and the Australian consumer is an avid purchaser of blueberries for the same reasons of flavour, convenience, fun and health as in other established blueberry markets" (Brazelton, 2011).

The rate of production and consumption of berries within Australia is increasing in line with the rest of the world. The strict quarantine laws of Australia restricts the importation of fresh berries from around the world which fortunately allows local growers to expand their operations to meet the surging demand for fresh berry fruit across all berry sectors. New regions are emerging as potential berry growing areas as growers seek opportunities to find climates to either bring their berry harvest on earlier or later than the typical season.

The Australian berry industry consists of 4 main sectors:

- Strawberry
- Blueberry
- Rubus (consisting of the cane berries like raspberries, blackberries and boysenberries)
- Ribes (consisting of blackcurrants, redcurrants and gooseberries)

The Australian Strawberry Industry

Strawberries (*Fragaria ananassa*) are grown in most states of Australia and, due to the diversity of the Australian climate, fresh strawberries are available all year round for the consumer as depicted in Table 1 below:-

Table 7 Supply of Strawberries by State. (Source: Australian Strawberry Association Website July 2015)

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	% Total Production
Vic													32%
QLD													33%
WA													22%
SA													10%
TAS													2%
NSW													1%

Australia's main strawberry growing regions are the Sunshine Coast, Stanthorpe and Gatton in Queensland; Camden in NSW; the Yarra Valley in Victoria; the Adelaide Hills in South Australia, Wannaroo and Albany in Western Australia; and the northern part of Tasmania.

The number of strawberry growers in Australia has declined, however the growers that have remained have grown in size and become more efficient, as shown in Fig 4 below.

2001/02 STATE	Number, Serious Growers	Number Opportunistic Growers	Number Plants (millions)	Production Volume (t)	Value ($ mil)	Equivalent Punnet Value
QLD	290	85	24	18,000	104	1.44
VIC	160	35	10	12,000	52	1.09
Other States (WA, SA, NSW and TAS)	65	10	9	10,000	46	1.09
TOTALS	515	140	43	40,000	202	1.25

Most recent figures:

2007/08 STATE	Number, Serious Growers	Number Opportunistic Growers	Number Plants (millions)	Production Volume (t)	Value ($ mil)	Equivalent Punnet Value
QLD	250	75	32	26,000	122	1.28
VIC	120	5	14 *(+7*)*	21,000	136	1.80
WA	65	3	11	7,000	33	1.25
Other States (SA, NSW and TAS)	20	2	8	4,000	17	1.30
TOTALS	455	85	72	58,000	308	1.40

* *second year plants*

Figure 4 Comparison of growers from 2001/2 and 2007/8. (Source: Strawberry Industry Strategic Plan 2009-2013)

Increased production is mainly due to improved management practices and superior genetic material. However the downside of greater supply is that the price of strawberries has plateaued and drops significantly during peak season, indicating a marginal over supply in the Australian market. While strawberries are still the number one berry fruit in Australian supermarkets in terms of volume and sales, this popular berry has not enjoyed the level of growth experienced in the blueberry sector (HAL, 2009).

From a world perspective, Australia was the 28th largest strawberry producer by volume in 2002, with the USA, Spain and Japan the top three respectively (FAOSTAT, 2002). However, Australia ranks higher (17th) in production efficiency, producing an estimated 21 t/ha in 2002. The world leaders in production efficiency are the USA, Israel and Spain, with 46, 42.5 and 42 t/ha estimated for 2002 respectively (FAOSTAT, 2002). With the emergence of high-tech glasshouse production utilising substrates and hydroponic systems, strawberry yields have jumped to 15kg per m^2 which equates to 150 t/ha. This represents a vast improvement in yield by embracing the latest in advanced growing environments, precision fertigation, CO_2 injection, better genetics, improved pest and disease management and successful pollination (Kwekerijen, 2015). The increased yield and efficiency from sophisticated protected cropping of strawberries will have a key influence on the future of the strawberry industry in Australia. There will no doubt be an increasing number of growers adopting this form of production for a number of reasons. Firstly, as labour is a strawberry grower's highest production cost, table-top cultivation improves labour efficiency and productivity. Secondly, the off-the-ground production method produces a more favourable 'back friendly' work environment for employees than the production of strawberries grown in the ground. Lastly, the harvesting of strawberries can occur regardless of outside climatic conditions as fruit does not get wet or damaged and workers are able to work efficiently under the protection.

The Australian Blueberry Industry

Arguably one of the most notable things that stands the Australian blueberry (*Vaccinium*) industry apart from others is the fact that it is the only horticultural enterprise that has a younger grower demographic (NSW DPI Survey HAL Project, 2013/14). Forty nine percent of blueberry growers are aged 36 to 55. This is extremely encouraging for the blueberry

industry especially given the average age of growers in most other agricultural industries is 55+.

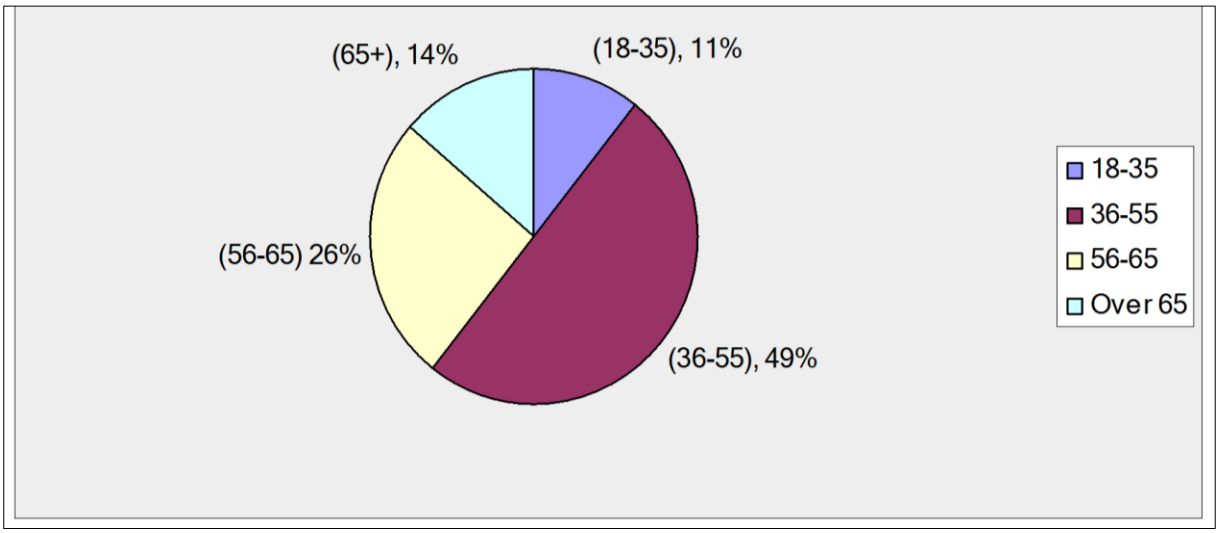


Figure 5 Age of the blueberry grower (Source: Phil Wilk, IDO, NSW DPI - November 2014 ABGA Conference)

The growth of the blueberry industry in Australia has tripled in 7 years, from 2000t in 2007 to 6100t in 2013. However the area planted has only doubled in that same period. It does need to be noted that some areas have recently been replanted with new varieties or new plants, which are higher yielding and this may explain why the overall production has increased compared to the area planted. There is an estimated additional 500ha either already planted or proposed to be planted within the next 4 years, which will add an additional 3000t of blueberries to the market.

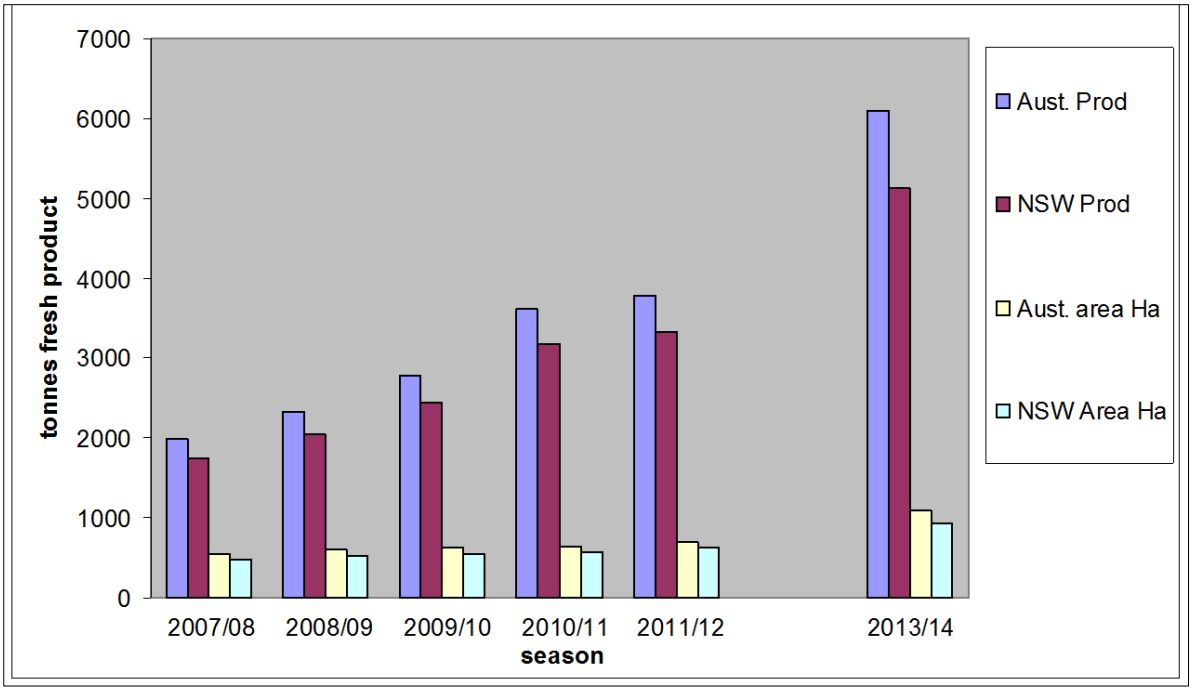


Figure 6 Australian Blueberry Production 2007-2013 (Source: Phil Wilk, IDO, NSW DPI, ABGA Conference Nov 2014)

There has been a trend towards expanding the growing regions into places like Atherton, Bundaberg, Munduberra and Childers in Queensland, inland to Casino, north of Woolgoolga to Ballina in NSW, Western Australia and Tasmania; in order to extend the season by producing fruit much earlier or later in the season and to find a niche timeslot in the market when prices are significantly better. The varying climates and latitudes within Australia offer different growing conditions/seasons from the traditional growing regions hence inducing earlier flowering, fruiting and harvest in the warmer climates or much later development of the berry crops in the cooler climates which results in very late season supply.

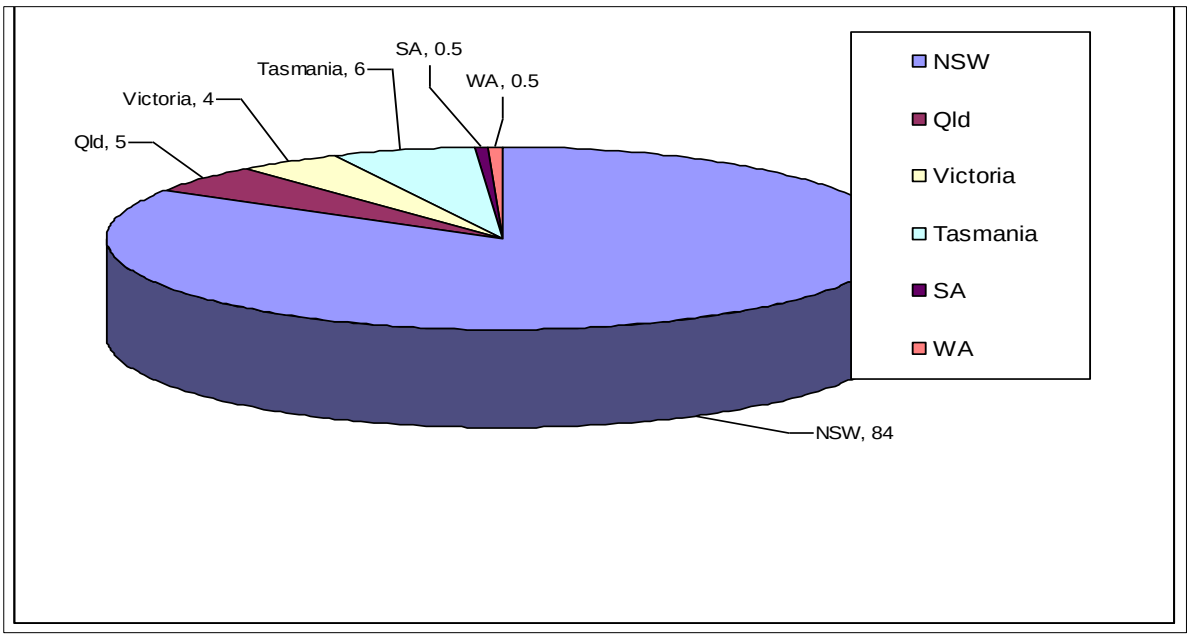


Figure 7 Blueberry Production by State 2013/14 (Source: Phil Wilk, IDO, NSW DPI - ABGA Conference November 2014)

While NSW remains the largest producer of blueberries in Australia, growth has jumped from 1% to 5% since 2011 in Queensland and from 2% to 6% in Tasmania within the same period. This demonstrates how optimising windows at the beginning and end of the traditional blueberry production period are attractive to the new growing regions and this trend is set to continue.

Table 8 Production area increase in blueberry plantings by states (hectares) including 1-4 year plants already planted in 2013/14 season. (Source: Phil Wilk - IDO, NSW DPI, ABGA Conference November 2014)

	NSW	QLD	VIC	TAS	WA	SA	TOTAL
HECTARES	256	90	30	60	60	2	498
PER CENT OF TOTAL	57%	20%	7%	13.4%	13.4%	1%	%100
FRUIT PRODUCTION INCREASE (t)	1792	315	480	960	960	32	4530

Table 9 Australian Blueberry Production (Source: Phil Wylk, IDO, NSW DPI, ABGA Conference November 2014)

YEAR	07/08	08/09	09/10	10/11	11/12	12/13	13/14
VOLUME (t)	1984	2330	2775	3615	3780	NA	6100
AREA (ha)	545	600	625	650	700	NA	1100
FRESH DOMESTIC (t)	1090	1360	1640	2320	2410	NA	5550
FRESH EXPORT (t)	450	320	270	320	320	NA	320
PROCESSED (t)	360	450	550	450	450	NA	450
HIGH CHILL	17%	25%	30%	33%	35%	NA	30%
LOW CHILL	83%	75%	70%	67%	65%	NA	70%
FARM GATE VALUE $/kg							
FRESH $/kg	20.9	21.24	21.55	18.98	19.65	NA	20
PROCESSED $/kg	5.76	5.45	3.95	3.03	3.83	NA	3.5
TOTAL VALUE OF AUSTRALIAN BLUEBERRY INDUSTRY $M	32.1	35.68	41.1	50.7	53.69	82 (ABS fig)	122.18

Table 2 clearly demonstrates how the blueberry industry is growing year on year and increasing its overall value as an industry.

The Australian Blueberry Industry is very well represented through its peak industry body, the Australian Blueberry Growers Association (ABGA), and has an active Industry Development Officer (IDO) in Phillip Wilk who is passionate and works very hard for the growers. There are a number of independent blueberry breeders concentrating on Southern Highbush varieties and we also have the Costa Group in conjunction with the global berry giant, Driscolls® active here. As a result there is no shortage of new and exciting varieties emerging that are suited to the various climatic conditions in Australia. These new varieties are also being sold around the globe and are highly sought after for their size, flavour and vigour.

The Australian Blueberry Industry is developing strongly in the area of protected cropping cultivation of blueberries under high plastic tunnel structures. Furthermore, some growers are also adopting hydroponic production systems. However, with a rapidly expanding industry, export markets will need to be established quickly in order to absorb the additional production and avoid prices dropping significantly, which would put growers under severe pressure.

The Australian Rubus Industry

The Australian Rubus Industryhas shown phenomenal growth in the past 10 years. The graph below shows the steady growth of rubus in overall tonnage in Australia.

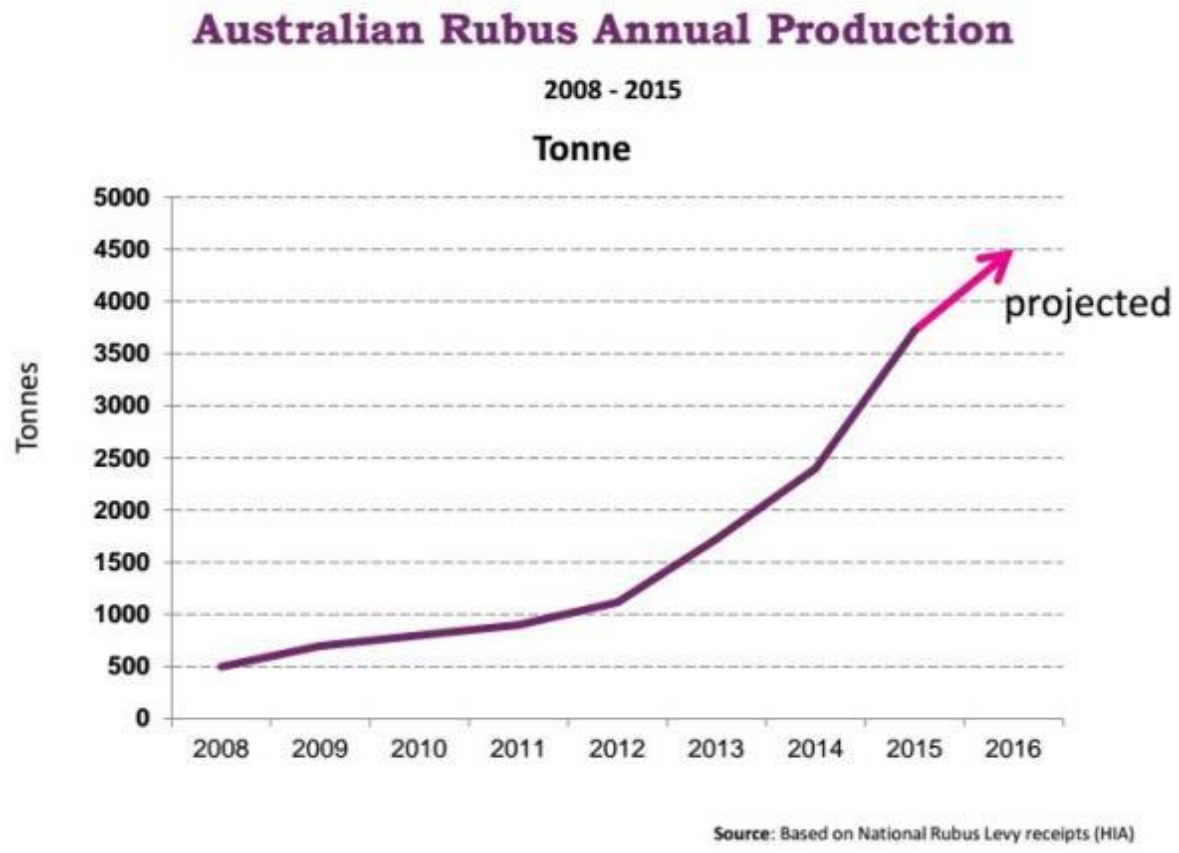


Figure 8 Australian Rubus Annual Production. (Source: J. Eccles, CEO, RABA at PCA 2015 Conference)

Improved varieties of primo-cane raspberries have arrived in Australia and this has enabled growers to produce higher yielding crops that have the capacity to travel well, have a superior shelf life and improved taste. These varieties may also be cropped twice per season with the first crops ready within the first year of planting, unlike floricane varieties which only crop in their second year. The raspberry industry is showing enormous potential as growers develop growing systems and perfect them in protected cropping environments.

Blackberries in Australia have huge potential as they are more tolerant of a warmer climate. Professor John Clark from the University of Arkansas has developed new primo-cane blackberry varieties, which are expected to make a significant impact on the Australian Rubus Industry once the Australian Quarantine and Inspection Service (AQIS) regulations have been satisfied and allows importation of the plant material.

The Australian Ribe Industry

The Australian Ribe Industry is considerably smaller than the Strawberry, Blueberry and Rubus sectors. Grown only in the cooler climates of Tasmania and Victoria, red currants and black currants are mainly produced for the juice market, whilst a small portion of the product also makes the fresh market. Due to increasing education and marketing about the strong health benefits of black currants as well as the growing popularity of Australian television cooking shows like Masterchef® and My Kitchen Rules®, these berries show great potential not only for their colour and distinct flavour, but also for their exclusivity and decorative value. Bringing new genetic strains into Australia that would allow the production of crops that are more tolerant of warmer temperatures could give this sector more opportunity for growth beyond the cooler growing regions.

The World Berry Industry

The berry industry is expanding and enjoying unprecedented growth on a global scale.

The world strawberry industry

Steady growth has been experienced in all berry categories with the exception of strawberries during the period between 2004 and 2008 (Figure 9).

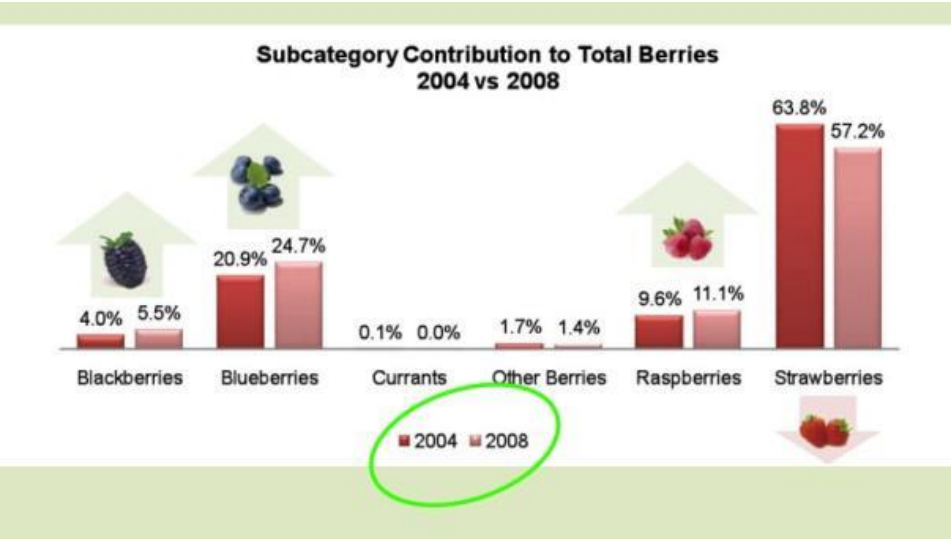


Figure 9 Subcategory Contributions to Total Berries 2004 vs 2008. (Source. Mark Gaskell Ph.D University of California Cooperative Extension.)

The strawberry category is experiencing a shift in its cultivation methods fuelled by 3 main factors; a) The Montreal Protocol – a world treaty regarding the phase out in the use of Methyl Bromide as a soil fumigant; b) Labour – the high cost and shortage of this vital resource; and c) Regulation of chemical residues and increasing with-holding periods.

The world blueberry industry

A report produced by Cort Brazelton (2011) shows exponential growth within the blueberry category around the globe. Brazelton writes "The world economy is becoming global and blueberry production and consumption is growing with it." (Brazelton, 2011).

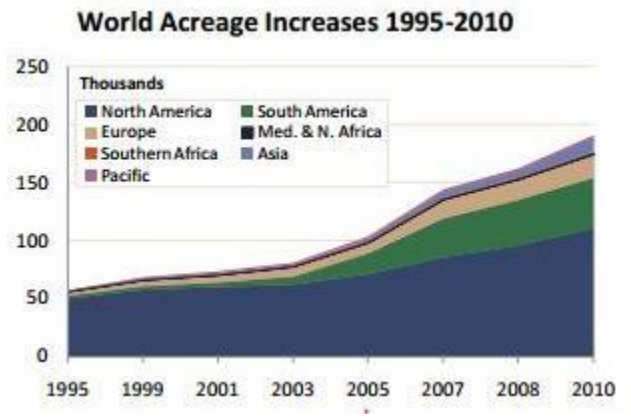


Figure 10 World Acreage Increases from 1995-2010. (Source: 2008 World Blueberry Acreage and Production Report by Cort Brazelton, February 2011)

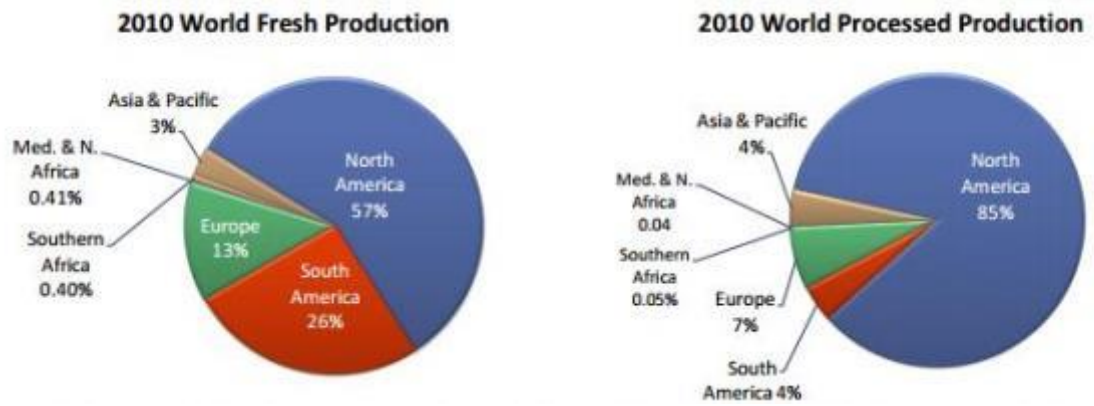


Figure 11 Comparison of World Fresh Blueberry Production vs Processed Production. (Source: 2008 World Blueberry Acreage and Production Report by Cort Brazelton, February 2011)

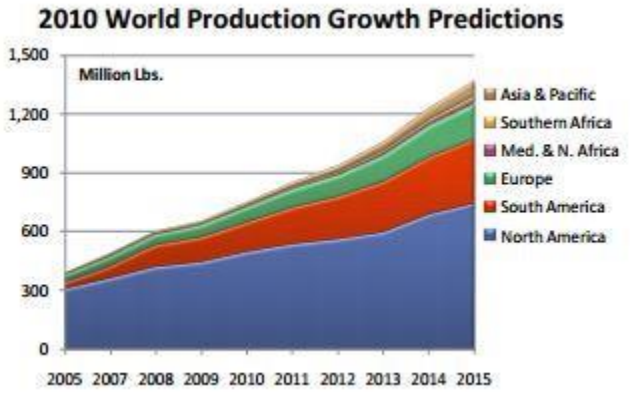


Figure 12 World Production Growth Predictions of Blueberries. (Source: 2008 World Blueberry Acreage and Production Report by Cort Brazelton, February 2011)

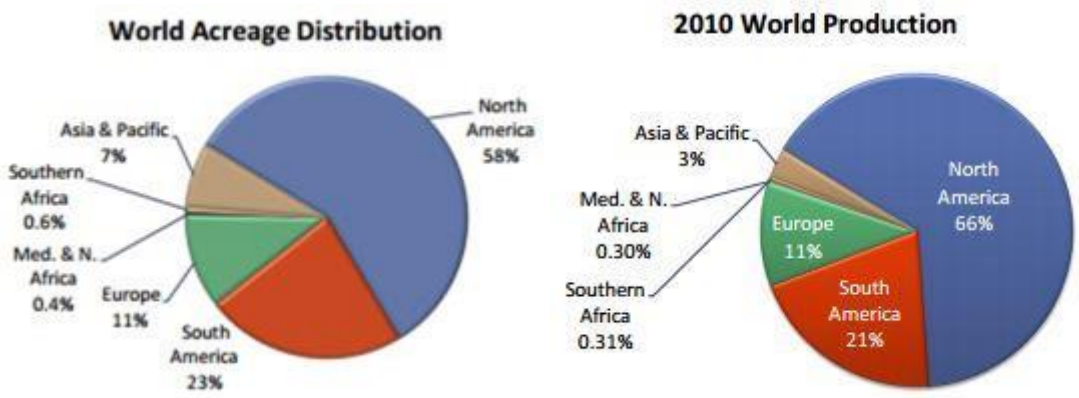


Figure 13 Comparing World Acreage Distribution vs World Production. (Source.2008 World Blueberry Acreage and Production Report by Cort Brazelton, February 2011)

Blueberries have seen unprecedented growth due to their "super fruit" status, which, according to Crawford and Mellentin, is "the result of a convergence of science and marketing in order to create a new, value-added niche in the nutrition market." (Crawford, 2008).

The world raspberry industry

World raspberry production - all volumes are in metric tons (MT)

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Russian Fed*	140 000	165 000	150 000	170 000	175 000	175 000	175 000	137 000	140 000	125 000
Serbia**	77 781	94 366	79 471	91 725	84 331	79 680	76 991	84 299	86 961	83 870
Poland	44 818	44 874	42 941	56 800	60 000	52 539	56 391	81 552	81 778	87 556
U.S.A.	51 982	51 710	62 142	71 941	82 826	74 843	64 773	28 667	33 838	31 207
Ukraine	19 137	18 100	19 700	25 300	20 500	27 200	24 600	26 100	27 700	25 700
Germany	29 200	29 700	20 000	20 034	7 000	7 196	6 191	5 334	5 068	5 212
Canada	11 658	14 880	14 236	13 828	14 152	12 442	11 517	11 825	12 607	11 864
United Kingdom	7 700	7 300	8 500	10 000	12 200	12 200	14 800	15 500	15 300	17 000
Hungary	13 306	9 847	9 258	8 470	6 724	11 900	6 166	6 304	4 967	3 184
Azerbaijan	1 100	2 300	4 800	10 000	10 000	13 700	8 000	9 500	10 000	10 000
Spain	3 200	4 500	5 029	6 000	7 000	7 500	10 000	12 000	12 000	10 000
Mexico	1 133	2 046	2 249	3 045	5 044	9 351	11 477	14 726	13 559	14 343
France	8 549	7 971	6 830	6 875	5 742	6 274	5 716	6 219	7 368	6 406
Bosnia***	3 372	2 500	1 719	1 700	1 289	6 452	8 032	7 483	8 487	7 937
Bulgaria	3 147	3 938	4 083	5 606	3 900	5 766	3 711	3 540	3 510	6 109
Kyrgyzstan	1 900	1 800	1 700	2 000	1 700	2 200	2 100	2 200	2 400	2 300
Norway	1 401	1 363	1 376	1 664	1 719	1 700	2 292	2 592	3 414	1 954
Italy	1 455	1 380	1 391	1 657	1 421	1 700	1 647	1 700	1 956	1 990
Romania	3 990	1 000	2 000	2 000	2 200	2 200	2 200	17	48	31
Switzerland	1 372	1 222	1 110	1 442	1 285	1 392	1 434	1 390	2 213	1 966

Russian Fed*= Russian Federaion, Serbia**= Serbia and Montenegro untill 2005, Bosnia***= Bosnia&Herzegovina

Figure 14 World Production of Raspberries 2001-2010. (Source: FAOSTAT 2010)

The acreage figures from the U.N. Food and Agriculture Organization (FAO) below show the 10 top raspberry producing countries in 2012. Notably, those countries with large acreages but a lower value of production generally produce primarily for the processing market.

Country	Acreage	Crop value (million $ U.S.)
Poland	28,423.00	82.57
Russian Federation	26,000.00	113.58
Serbia	21,952.00	n/a
United States	9,753.00	461.38
Ukraine	5,000.00	18.03
Azerbaijan	2,600.00	8.72
Canada	2,240.00	19.45
United Kingdom	1,616.00	67.22
Bulgaria	1,369.00	4.15
Lithuania	1,300.00	5.38

The world blackberry industry

FAO has no current statistics on blackberries and there is very limited data available. However, it was concluded from a review conducted in 2005 by means of a survey of worldwide blackberry production that there were an estimated 20,035 hectares of blackberries planted and commercially cultivated worldwide. This represents a 45% increase from the estimated area in 1995. Much of this product came from wild blackberries with 8,000 hectares producing 13,460 tons in 2004 (Strik, 2008). Current statistics would show a significantly different scenario with higher acreage and production especially given the increased blackberry production in Mexico alone in recent years (Brazelton, 2011). Blackberries seem to be following a similar growth pattern to raspberries. Their general hardiness and fruit size facilitates longer travel times to market showing potential for more export growth.

Analysing the Various Berry Crops

Strawberries – standout observations in the Nuffield study

Figure 15 Glasshouse strawberry production. (Source: N. Mann - The Netherlands March 2015)

There is incredible variation of production techniques from extensive field production in California to high-tech glasshouse production in Europe where state of the art structures and equipment optimise the conditions for the ultimate in yield and quality of strawberries.

The challenge arising from the phase out of Methyl Bromide as a soil fumigant in the USA

The imminent phase out of the use of Methyl Bromide (MeBr) as a soil fumigant resulting from the Montreal Protocol in the USA will mould the future as strawberry farmers, especially in California and Florida, will have to make drastic changes to their field preparation either by using different chemical fumigants or changing their growing methods.

“There is no known single alternative fumigant, chemical or other technology that can readily substitute for MeBr in efficacy, low cost, ease of use, availability, worker safety and environmental safety below the ozone layer” (Agriculture, 2005). There is great resistance to change and some strawberry farmers will not acknowledge there is a major problem looming if they do not accept new methods of cultivation, for example substrate production (Bolda, 2014).

Labour – a global challenge

With the expansion of the berry industry many of the farmers visited on the tour were concerned about getting enough regular labour to work on and harvest their berry crops. This was exemplified in the Watsonville area of California, which is considered the state’s ‘Berry Heartland’. Given the tighter migration laws and increased border patrols less illegal workers are entering the USA from Mexico. There is simply not enough labour to harvest the crops – it is not uncommon for farmers to leave 25% of their strawberry crop in the field unharvested due to labour shortages. Therefore, farmers are not able to capitalise on the better genetics and higher yields. The region’s labour force prefers to work with raspberries and blackberries, which are neatly trellised and planted at an easier height for working with compared to strawberries, which are planted at ground level (Larco, Senior Production Specialist, 2014).

Table-top production using substrates and high tunnels is an option for the strawberry growers in the Watsonville region into the future. The substrate means no more fumigation would be required; the table-tops are easier to work with and therefore more attractive to workers meaning more would be enticed to this type of work; and the high tunnels would result in higher yields in a smaller, more compact area, meaning the workers would no longer have to walk lengthy distances in the fields.

Glasshouse strawberry production in the Netherlands

The propagation of new strawberry stock from high hanging gutters in glasshouses as seen in the Netherlands allows five generations of runners to be harvested for propagation

purposes. New tissued cultured mother stock can then be re-planted, resulting in a system that is effective and delivering excellent results. This strict regime ensures fruit size is large, the new plants are productive and it allows them to experience sufficient chill to induce flowering once planted out (Bart, 2015).

Carbon dioxide (CO_2) injection is common in glasshouse production in the Netherlands. CO_2 is introduced at 450/500ppm in the young strawberry crop and gradually increased to 1000ppm. Two nurseries were visited and the first one had the CO_2 tubing within the strawberry canopy while the second nursery had the CO_2 tubing just beneath the gutter. The latter was seen to be more effective and increased yield by 2kg per m^2 (Kwekerijen, 2015). High CO_2 levels in the early growing crop were thought to make the crop very vegetative and lazy, making them slower to become generative.

Honey bees versus bumble bees for pollination of strawberries in high-tech glass houses

It was interesting to observe that in these high-tech glasshouses for strawberry production, European honey bees (*Apis mellifera*) were used for pollination alongside bumble bees. The reason for this was that a normal commercial bumble bee hive contains approximately 60 bumble bees (*Bombus terrestris*). Bumble bees are very efficient and effective pollinators. They start early and end late in the day and are rarely affected by light, humidity or temperature conditions. However, there is a substantial cost involved per hive, especially when compared to honey bee hives, which consist of around 10, 000 honey bees (potential pollinators) per hive. Therefore, when the conditions are perfect, that is when temperatures are above 15^{o}C and below 35^{o}C and humidity is less than 71%, the honey bees are highly effective, cheap and very efficient pollinators. Honey bees are also gentle insects, cross pollination is 100%, they are easier to handle than bumble bees and are structured and organised within their colony. Bumble bees on the other hand have messy hives, smaller numbers and are harder to handle than honey bees; they are considered “rude, stupid creatures” with no social interaction and no communication (Steen, 2015).

Costs and return on investment for greenhouse production of strawberries

It is common to see strawberries grown hydroponically in coco-peat slabs on table-tops or in troughs on suspended gutters and grown under high tunnels, which is a relatively expensive option for strawberry production. Most growers however feel the extra investment is viable, efficient and sustainable. (King, 2014) Taking it to the next level, high-tech glasshouse production requires large capital expenditure and there is an estimated 15-year return on investment, which is not an option for small to medium growers.

The following demonstrates the associated costs (Kwekerijen, 2015):-

- **Cost price** for greenhouse production is €40 (approximately A$60) per m² – they require €3 (approximately A$4.50) per kg return to make a profit i.e. (€3 per kg x 15kg/m2 = €45 (approximately A$68) return and cost is €40 (approximately A$60) /m2 = €5 (approximately A$7.50 per m² profit). Top glasshouse strawberry growers are returning 15kg per m² whereas good production of field strawberries is 5kg per m² per annum
- **Investment cost** is €300 (approximately A$453) per m² which includes hydronic heating, hanging gutters, pipe-and-rail, shade-screens, energy screens, supplementary lighting, CO_2 enrichment, foggers, precision irrigation, recirculating and recycling of water and nutrients, air-flow fans, energy buffer and storage tanks.

Sunlight and strawberries

Strawberries can tolerate a maximum of 14 hours of sunlight per day but prefer 10-12 hours for optimum quality and yield unlike tomatoes, which can tolerate up to 18 hours of sunlight each day. Therefore in some strawberry producing regions, the long summer days can have an adverse effect on the strawberries and the quality is compromised due to 14-16 hours of daylight, which is the case for example in far north Scotland. (Mitchell, 2015) This can be counter-acted by white-washing the high tunnels or covering them with 40% shade-netting. Another option is to plant a June Bearer like Elsanta, grow it for 60 days and then replant with new plants.

Using coco-peat in troughs on hanging gutters in single rows appeared to have the best results for plant development, ease of plant management and speed of harvesting. The strawberries can be planted at a slight angle to present the fruit to the harvester for easy and efficient picking, which is not possible in coir slabs. Planting in individual pots is another option, however, this option is not as efficient as the use of troughs.

Strawberries are from the same family as roses and raspberries, Rosaceae, which means fertigation and IPM is very similar for all three of these crops.

Reduction in chemical use and withholding periods for strawberries under protection

Protected cropping reduces pests and diseases meaning less use of pesticides and fungicides, which in turn facilitates the ability to adhere to the regulators' demands for low to zero residue levels. With minimal chemical use withholding periods before harvesting are shorter for these fresh berries. It is no surprise then that tunnel production is fast being adopted around the globe for the intensive production of strawberries.

LEDs in Glasshouse Cultivation of Strawberries

A study by Wageningen UR showed that LED light significantly improved production, flavour, refraction, titratable acid and the vitamin C content of strawberries. The study also showed that additional LED light on the fruits increased vitamin C content more than having LEDs on the leaves alone (Caroline Labrie, 2014/15). Another study by Wageningen UR using 12% blue light and 88 % red light again found a 13% increase in production with high flavour and vitamin C levels (Horticulture, 2014/15) . It was unclear if it was the temperature or the blue light that caused the increases in vitamin C, sugars and acids. If it was the result of the blue light, it may prove not be cost effective on a large scale as this spectrum of light generates a lot of energy and is therefore a costly option. It must be noted that LEDs are cheaper than High Pressure Sodium (HPS) lights and only produce 1% of heat compared to the HPS lamps. In conclusion, LEDs show great potential and positives for strawberry production within glasshouses. However the current cost for LEDs has not been proven to increase yield and

quality to a sufficient degree to attain higher prices and therefore make it a viable option; at least not at this time.

Raspberries - standout observations in the Nuffield study

Figure 16 Root tip propagation. (Source: N. Mann The Netherlands March 2015)

The primary observation during the Nuffield study in terms of raspberry production was that there is clearly potential to further develop the infrastructure and hydroponic growing systems for this berry crop. Adopting similar growing systems to those used for glasshouse capsicums or cucumbers is one possibility. Another is growing in a substrate so the raspberries can be continually cropped for four years before being re-planted. And yet another is the use of pipe and rails to allow the raspberries to grow taller in order to extend the fruiting capacity at the top of the plant and prune back in multiple stages rather than the two stages currently being done.

Genetic variations and breeding

There are exciting new developments in the genetics and varieties available for raspberries including black, white and yellow raspberries which show potential for small to medium greenhouse growers.

Soil pH requirement

It was noted that raspberries thrive in a soil or substrate with a pH level that sits between 6 and 6.5. (Hall, 2013)

Substrates

An increasing number of raspberries will be grown in substrate, especially with the phase out Methyl Bromide in the USA. The pull up of old plants and sterilization of the soil is a tedious and expensive process. Despite this however, it is necessary to prevent root borne diseases like *Phytophthora* and *Fusarium.* Substrate is quicker, cleaner and easier to grow in.

There are interesting and successful blends of substrates such as coco-peat and Irish peat blends with added *trichoderma* being utilized for propagation of raspberries.

Root Tip Propagation

The technique of root tip propagation has been perfected in the Netherlands with great success producing 400,000 plants per week in peak season. Root tip propagation is when the block of roots of the year-old raspberry plants is laterally cut in half and exposed to the sun whilst watering and feeding continues. The roots will sprout tiny little soft shoots which are harvested and planted out into seedling trays (refer to Figure 27). Root tip propagation can be manually intensive and fiddly but the results mean strong and uniform plants compared to the original root propagation where pieces of the raspberry roots are transplanted and allowed to grow. Root propagation is cheap and easy but creates an uneven crop which can be rectified by allowing all the shoots to grow and then applying a desiccant-type herbicide spray after a month, the new growth will then be even when they re-shoot.

Crop Management

The most successful crop management system was seen in Algave, Portugal at Sunshine Fruit managed by Hugo. He would let the raspberries grow until there were three strong nodes –

then the main stem would be pinched. The three shoots would be allowed to grow and they would be spread evenly across the linear trellis wires. Once the three stems reached the required height, they would be pinched again to prevent the canes from getting too tall for harvesting. When the crop was deemed to be in a strong healthy condition, watering would be decreased severely to stress the crop. This stress would force the plants to trigger a response to produce flowers and go into fruiting stage. The stress period would last two weeks, which is all it takes for raspberries to respond and start to produce flowering stems. This is also a valuable technique for those who wish to specifically time production. From the time the flowers are produced it takes approximately eight weeks for the fruit to be ready for harvesting in this region of Portugal.

Figure 17 Hydroponic Raspberry Production in square black pots using coco-peat in Portugal. (Source: N. Mann - March 2015)

Figure 18 Raspberry production in Belgium. (Source. W. Mann Belgium March 2015)

Blueberries - standout observations in the Nuffield study

Figure 19 Multi-span greenhouse production of blueberries. (Source: N. Mann NSW 2014)

"In terms of U.S. fruit consumption, blueberries rank only second to strawberries in popularity of berries. Blueberries are not only popular, but also repeatedly ranked in the U.S. diet as having one of the highest antioxidant capacities among all fruits, vegetables, spices and seasonings." (Mateljan, 2015).

Blueberries can be divided up into five sub-categories:-

- Lowbush Blueberries (Vaccinium angustifolium) – Grown wild on the prairies of Canada and North America; grown solely for processing; machine harvested; low inputs.
- Rabbiteyes Blueberries (Vaccinium ashei/virgatum) – High yielding smaller sized fruit but very vigorous and grown mainly because they can be harvested on the shoulders of the season.
- Northern Highbush Blueberries (Vaccinium corymbosum) – Grown in the cooler climates, these bushes are deciduous and require chill to initiate flowering.
- Southern Highbush Blueberries (Hybrids of Vaccinium corymbosum x Vaccinium darrowii x Vaccinium angustifolium) – Grown in the warmer climates, these

bushes are kept evergreen and growers try to keep them fruiting for longer periods and 2 harvest per season; require little to no chill.

- Half-Highbush Blueberries (Hybrid of the Highbush x Lowbush) – These compact bushes can be very high yielding to their proportional size and show potential for being grown on raised benches in greenhouses.

Soil pH requirements

The soil pH requirement for a highbush blueberry is between 4.5 and 5.5 and approximately 4.2-5.0 for a rabbiteye blueberry (Hancock, 2012).

Australia is performing well with protected cropping of blueberries

The writer has not travelled extensively and has not seen every blueberry farm around the world but the most advanced hydroponic blueberry production of any scale has been observed in Australia – this is changing dramatically now and projects are springing up everywhere across the globe.

The production of blueberries in greenhouses is an industry that is still in its infancy

Varying structures, media, pots, pruning, pinching, varieties, etc. have been observed by the writer of this report. Growers are still trialling and experimenting with techniques, as the use of greenhouses for blueberry production is a technique that is very much in its infancy. There is still a great deal to learn about the physiology of blueberries in these protected cropping environments and the physiology varies considerably between varieties as well. For example, some growers are still unsure of the exact temperature and duration required to initiate the flowering buds. They are also unsure about optimal day lengths; humidity and sunlight. This lack of knowledge and certainty differentiates the greenhouse blueberry industry from the glasshouse production of tomatoes, capsicums and cucumbers where most of this knowledge is known and implemented into the growing strategies.

The ability to control the timing of berries especially blueberry fruit production is paramount to growers

Being able to control the timing of the blueberry fruit production is paramount with vast expansion of cheap, outdoor and extensive production of blueberries around the globe, growers will have to perfect this in order for the higher cost of production to survive. For example, in Hamilton in New Zealand there were 14 year old blueberry bushes yielding 30 tonnes per hectare 25 year old blueberry bushes are producing 10-15kg of fruit each per season with very little to no money spent on the crop (extreme low cost of production) (Peach, 2014). Begs the question how do high tunnel and greenhouse blueberry producers compete with such low cost production? It comes back to TIME – what growers have 25 years to get to 15kg production unless they planted outdoor blueberries 25 years ago; however, this can be achieved in 5 years in tunnel production on substrate.

The greatest current global concern facing the entire berry category is the Spotted Wing Drosophila (SWD)

The Spotted Wing Drosophila (SWD) is extremely invasive and particularly difficult to control and detect and it can have catastrophic consequences. In the Netherlands a grower yielded 7kgs per blueberry bush in 2013 over a 15ha block and then did not yield one single berry the following year due to SWD (Dijk, 2015). Tunnel production is a slight deterrent whereas more sophisticated greenhouses and glasshouses equipped with insect screen would be a better protection from this pest. It was particularly evident on all travels around the globe the red SWD traps hanging around the berry crops.

Dust accumulation on the berry foliage

Dust accumulation on the leaves of tunnels in dry, arid climates is slowing the rate of photosynthesis down which adversely affects the plant's performance. This is a major disadvantage of tunnel production for some growers even here in Coffs Harbour, Australia.

NSW DPI Studies and current research

White weed matting has shown in preliminary results that sugar levels are increased compared to black weed matting. Limited consumer taste testing has also shown that people taste a more flavoursome fruit from the plants grown with white weed matting (Parks, 2014). A cheap alternative to mulching blueberries was observed in Hamilton and Hawks Bay, New Zealand by using old newspaper or cardboard which broke down in time but still retained moisture and stopped the weeds (Peach, 2014; Lawson, 2014).

The use of a native bee called *Tetragonula carbonaria* is being trialled in blueberry orchards in Coffs Harbour region. This is an exciting trial because this is a social bee that lives in a colony similar to the European Honey Bee. Being native to the area it is acclimatized and been noted for its ability to outperform the common bee in pollination.

Thinning of blueberry flowers does increase size of the fruit without loss of total yield, due to increased weight per individual berry (Parks, 2014). A trial using a foliar urea spray in Corrindi was not able to achieve the necessary flower drop required to thin the blossoms for positive results – therefore a repeat trial in the 2015 season will be undertaken.

Blackberries - standout observations in the Nuffield study

Figure 20 "The Watsonville Weave" Blackberries. (Source: N. Mann Driscolls USA October 2015)

Crop Management into the future with new varieties, new ideas and manipulating climate

Potential for blackberries in Australia

There are some exciting prospects with intensive blackberry production as new primo-cane varieties emerge – will growers be able to adopt the same crop management techniques from raspberry primo-canes? This will have to be trialled, although it does seem likely that this system will work on blackberries. The system therefore has great potential for the intensive greenhouse and substrate production of blackberries in line with the success shown with production of greenhouse primo-cane raspberries.

Blackberries are more suited to hotter climates, therefore there is potential in Australia for this berry crop.

The "Watsonville Weave" for flori-cane blackberry varieties is an extremely effective method of training blackberries and to ensure good production from the laterals. The "Watsonville Weave" is very labour intensive however and therefore expensive at £2000 (approximately A$4000) per hectare in the UK (Laura, 2015). Primo-cane blackberry production is an alternative to this expensive blackberry crop management technique.

Some novel ideas for growing long-cane blackberries for the manipulated production of fruit were observed.

In Hamilton, New Zealand, a grower had planted the blackberry plants in troughs filled with substrate and raised approximately 1.5m above the ground. This allowed the blackberry canes to grow downwards, reducing the need to trellis the stems, which saved time and money. Once these stems were mature, they could be up-rooted, de-foliated and put into cold storage until required. Another grower had allowed the canes to 'root-tip' into coir substrate. Once the roots were established, the cane would be cut from the base of the plant, the rooted stem up-lifted, defoliated and put into cold storage until required.

Techniques that manipulate a crop into early dormancy or delay its growth

Tunnel producers of blackberries around the world have perfected various means to manipulate a crop into early dormancy. One method observed was the removal of the plastic coverings over the high tunnels towards the end of the season to manipulate the crop into dormancy earlier as the temperature will drop significantly without the covers to maintain the warmth. In the same token, the growers use the plastic covers to induce faster growth at the beginning of season. They advance the blackberries' growth by putting the plastic covers on early in spring or at the end of winter to begin retaining any warmth within the structure.

Another technique applied is the application of lime sulphur spray on the blackberries at the end of the season to induce leaf drop and force the plant into dormancy. Lime sulphur also assists with killing any fungi and diseases over the winter (Larco, Senior Production Specialist, 2014).

Growers are also using methods such as 'set-back' to delay the crop. 'Set-back' is a method whereby the emerging eye is broken off, knowing that another will grow two weeks later. This is a useful technique to help time the harvest of the blackberries for preferable market prices.

Blackberries are generally larger than raspberries and therefore more cost effective to harvest in Australia, especially given Australia's high cost of labour. They also travel better and their shiny black colour is a major selling point (Nichols, 2009). To conclude, primo-cane varieties in particular show enormous potential for intensive protected cropping using substrates and hydroponics.

Traditional Methods Versus Protected Cropping, Substrates and Hydroponics – Pros and Cons

Table 10 The Pros and Cons of Protected Cropping

Pro's	Con's
Protection from birds and pests	Machinery cannot fit within the structures for machine harvesting which would have huge labour savings
Protection from hail and rain = less disease and spoilt/damaged fruit	Substrate is less forgiving than soil as a media for growing in so irrigation and fertigation needs to be exact
Guaranteed return on investment because risks are minimized	Slower return on investment particularly the more sophisticated the protection and hydroponic system
Employees and especially harvesters can work in all-weather conditions because they are undercover	High cost – the better the structure the more investment involved
Crops can be harvested when they are ready regardless of the weather conditions because they do not get wet so no need time to dry	Stifling heat in tunnels can have adverse effect on the labour, the berry crops and the pollinators – labour get uncomfortable and de-hydrate, plants can get stressed and scorched; pollinators will not perform in extreme heat
Higher yields and sooner Higher quality	Dust on leaves of plants in tunnels slows down rate of photosynthesis which affects plants performance
Better control of the crop = more precision growing and development of the crop; more control of the timing of fruiting	Wind and hail damage to plastic covers and glasshouses can be disastrous and very costly
Intensive production (fruit walls) makes optimum use of land plus labour more efficient and effective as they do not have to walk far between bushes	Plants have to be replaced more regularly due to intensive production over a shorter period of time

Rapid growth. Earlier fruit production. Shorter growth cycles. Multiple fruiting cycling in a season as crops are kept evergreen.	Protective covers may impact on navigation ability of pollinators due to UV stabilizers impregnated in the various types of covers.
More control of the plants can change feeds quickly to be generative or vegetative or stress plants to induce flowering. Substrate is very even compared to soil in large areas	Plastic tunnels may not vent adequately and quickly enough causing high humidity which in turn causes diseases like botrytis
Closed irrigation systems means water and nutrients are recycled and re-used which saves money as growers get more "crop per drop"	Need relatively level ground to erect greenhouse structures
Change varieties more regularly so growers can keep up-to-date with the latest genetics available	Disposal of plastic pots and plastic growing bags becomes a waste management issue
Can supply into niche time slots in the market for significantly better returns	Complete reliance on irrigation if the covers are fixed

Comparison of Substrate Production versus Conventional Soil Cultivation

Why growers are using substrate for growing blueberries, the following results of comparative yields between soil grown blueberries and those grown in substrate speak for themselves. These experiments were using the NHB variety "Aurora"

Table 11 Yield per plant Traditional versus Substrate. (Source: Peter van Dijk, Blueberry Consultant, The Netherlands. March 2015)

Year	Traditional Yield (kg/plant)	Substrate Yield (kg/plant)
1	0.5	1
2	1	2
3	1.5	3
4	2	4
5	2.5	5

Table 12 Comparative Results with "Aurora" (NH Blueberry Variety). (Source: Peter van Dijk, The Netherlands, March 2015)

Year	Conventional Yield (kg/ha)	Substrate Yield (kg/ha)
1	1650	7500
2	3300	15000
3	4950	22500
4	6600	30000
5	8250	37500

Unexpected Observations of the Nuffield study

Timing

Most of the progressive growers around the world that are using the latest protected cropping techniques are doing so to ensure very SPECIFIC TIMINGS of their crop into the market. This is to maximize return and minimize risk of losses of any kind such as quality of fruit, wrong timing - because if there is plenty of berry production coming from large extensive cropping, intensive protected cropping will not be able to compete on production costs during peak season. They have to come in early or late and to receive significantly better market prices– this is crucial for their survival for this type of high cost production growing system.

Consistency of Supply

In Australia growers are still trying to iron out steady/consistency of supply. Growers are still trying to work out how to manipulate the crops to get “out-of-season” production and higher prices. This is starting to happen by growers moving into different regions with different climate conditions to grow out-of-season berries and embracing more sophisticated protected cropping systems.

Market control

Some of the very best genetics of the different berry varieties around the world are controlled by a few very strong and powerful companies which are shaping the future of the industry whether growers like it or not – protected varieties versus public varieties – the gap is broadening quickly.

Supermarkets support high-tech berry production

The high tech strawberry production in The Netherlands equals the sophistication of some of the best and advanced tomato projects. The return on capital investment is approximately 15 years. Supermarkets are approving of the consistency of supply and quality of the fruit and encouraging more growers into this method of cultivation.

Breeding for size and machine harvesting

Breeders of berries for the fresh market are concentrating on developing berries that are tasty, vigorous, hardy, attractive, better shelf-life but are of a good size to assist with harvesting costs. That is, the bigger the berries the less that are needed to fill a punnet which means higher returns to farm. Breeders are also concentrating on bushes that have architecture that is suitable for machine harvesting which is berry growers' largest cost of production (Bell, 2015).

Mechanization

Developing harvesting and pruning machines that can fit within tunnels and greenhouse structures is an option to mechanize the protected cropping industry of berry production and must be explored.

Pollination

A critical factor in berry production is the necessity for successful and complete pollination of the berries. Some berry varieties do self-pollinate but to achieve better fruit size and weight pollination can assist (Rhodes, 2006; Parks, 2014). How the pollinators react to protected cropping is an important factor that must not be ignored.

Bumble bee - research and experience shows that Bumble Bee *(Bombus Terrestris)* are excellent pollinators as they are not as sensitive to plastic and glass cladding on tunnels and glasshouses, nor adversely affected by the increased temperature and humidity created in these confined growing spaces compared to the European honey bee *(Apis mellifera)*. The Australian government has got to consider allowing the greenhouse industry to utilize bumble bees in order for the Australian protected cropping industry to compete with the rest of the world. The model used in Canada for using bumble bees could be successfully adopted here in Australia with no adverse effect on the environment or natural eco-system. The queen bee restrictor on the nest would mean she cannot escape and form a rogue nest outside the greenhouse. Insect netting on the greenhouses would stop any stray bumble bees escaping. After 8 weeks the bumble bees are put to sleep in the coldroom and then destroyed and a new hive is brought in. It is controlled and monitored by outside providers to ensure growers are compliant. **IF** varroa mite lands on Australian shores and starts destroying the honey bee hives – there may be no choice but to allow bumble bees in.

The honey bee tends to struggle with its navigation in greenhouses and under plastic tunnels where the UV light is distorted or diffused by the protective material. This can be counter-acted with landmarks being erected around the greenhouse. That is, large shapes in bright blue and yellow suspended from the roof which will aid the honey bees to successfully navigate their way around the protected cropping structure. The other alternative is retractable greenhouse rooves to allow direct sunlight into the crop which will assist the honey bees and their effectiveness as pollinators for the berry crops. Honey bees need perfect conditions to be effective (temperatures above 15^{o}C and below 35^{o}C and humidity less than 71%). Then the honey bees are highly efficient, cheap and super-efficient pollinators – they are also gentle and cross pollination is 100% as opposed to the rough bumble bees (Steen, 2015). In the greenhouse environment the positioning of the hive is vital and the entrance to the hive should face the rising sun (east) (Steen, 2015). Feeding the honey bees whilst they are pollinating blueberries is essential as blueberry nectar is low in protein (Parks, 2014).

Humidity can have a severe impact on pollination and its effectiveness – high humidity (100%) in a greenhouse for 10-14 hours each 24 hour cycle can cause pollen to become too "sticky" to be adequately transferred by bees causing uneven and in some part incomplete pollination. Furthermore, low or lack of humidity can also affect pollination because the lack of moisture in the air prevents the pollen once transferred from germinating (Shloemann, 2012)

Solitary bees *(Hymenoptera)* – are being researched but only fly 25m from their nest; they do not work in colonies; Haygrove® UK are currently testing them in their cherry orchards and although results are still pending – they are not convinced of their effectiveness yet (Kruger, 2015).

Blowflies (*Calliphoridae)* – there is still research being done on the effectiveness of blowflies as pollinators because like Bumble Bees these insects pollinate by sonically vibrating the blossom which is essential for blueberry pollination in particular. Blowflies may show potential for the greenhouse industry as they may not be as sensitive to heat, humidity and UV distortion like honey bees and already available in Australia unlike bumble bees.

Conclusion

For passionate protected cropping advocates who believe in recycling of water and nutrients, IPM and using the latest environmentally-friendly strategies for the production of fruit, vegetables, flowers and herbs, etc., growing berries intensively, hydroponically, under protection and in substrates is a viable way forward to achieve the following:

- Maximise land-use, yield, water, nutrients
- Be highly efficient in terms of labour use
- Minimise risk and crop loss as a result of birds, pests, disease, rain, wind, hail, etc.

However, growers must first invest in the knowledge and/or consultants with knowledge in this area, and do the necessary calculations, cash flow projections and market research. The capital investment and time to recoup the investment must be conservative as future berry prices may not be as good as they were or are right now. When it comes to return on investment, there is never a guarantee.

The berry saturation point has not yet been reached in the market and does not seem to be close. However this situation can change quickly with market access being gained by exporting nations like Chile, Mexico, et al. In addition, prices could change overnight if these players gain more market access. There are vast quantities of berries being planted not only here in Australia but around the globe. As a result, production will increase. Will the consumer demand for berries continue to absorb the supply? That is the question that must be asked.

There are some outstanding examples of existing growers who work in teams using central processing facilities and are marketing in numbers. There are also growers (organic, conventional or hydroponic) that offer pick-your-own berry tours and/or have farm shops or a farmer's market presence that are doing exceptionally well. This is where the small to medium sized berry grower would be if they are not in a co-operative style grower-marketing group.

If growers feel safe in Australia because they are growing rubus, which is considered a softer fruit that does not travel well then they may be surprised to learn that raspberries are in fact airfreighted into the UK from South Africa and then packaged and re-distributed across the entire UK just six days after picking. Furthermore, the fruit is attractive and high quality, despite the process it has been through to get onto the shelves.

Above all it is important to learn, share and collaborate as an industry because whilst Australian growers are competing over the relatively small local market, the international competition is eyeing off excellent opportunities around the world, including the Australian market. Australian growers must work together and look outwardly to export markets around the globe. Our food is renowned as being safe for consumption and should be marketed as such, as opposed to marketing on price.

Recommendations

The Perfect Scenario Protected Cropping Berry Growing System in Australia

Strawberries:-

Venlo Glasshouse production unit with vertical-opening vents fitted with energy screens, shade screens, pipe and rail, hydronic heating, buffer tanks, foggers, misters, closed irrigation system, CO_2 injection in pipes underneath the gutter, single row table-top or on suspended gutters, white troughs filled with buffered coir blend – using IPM, honey-bees (hives rotated every 4/5 weeks) and bumble bees if allowed into Australia, twin supports – one for leaves and one for fruit.

Blueberries:-

Multi-Span Plastic Greenhouse with retractable roof and side opening vents for optimum humidity control and keeping the environment stable for the plants and bees, buffered coir blended with Irish peat, perlite and mycorrhizae, T-trellising support system, white weed-matting, 40l polyweave growbags (although the new containers from PlantLogic do show potential but no figures are available yet regarding improved yields or increased plant health), closed irrigation system and swap honey bee hives every 4/5 weeks.

Using fruiting walls, pinching and bending techniques to maximise fruiting laterals.

Potential to grow half-high blueberries on benches within this system.

The greenhouse industry could assist the outdoor/extensive growers by bringing on and advancing the normally slow growing blueberry bushes by starting them off in a greenhouse environment for 2 years – establishing a strong and healthy plant structure which could then be transplanted out into fields and they would yield more sooner.

Raspberries and Blackberries:-

Multi-Span Plastic Greenhouse with retractable roof and side opening vents for optimum humidity control and keeping the environment stable for the plants and bees, buffered coir blended with lots of fibres, Irish peat and *trichoderma*, linear trellising support system for 3 canes, white weed-matting, white shallow troughs or tubs, closed irrigation system and swap honey bee hives every 4/5 weeks.

All the above:-

Combination of solar energy, wind energy and a bio-digester (to consume waste) and create renewable source of energy to run the berry farm.

Bio-diversity with multi-floral crops within the greenhouse structures with lavender, marigolds, perennial basil, and a range of berries for the honey bees to forage on for strength, health and to keep as many bees within the structure as possible. If this is not possible the hives must be supplementary fed, rotated every 4-5 weeks and have 2 entries one inside the greenhouse and one outside the greenhouse, so that the honey bees can split their hive sending half the colony to forage outside the greenhouse and the other half to pollinate the berry crop inside the structure. This will enable the bees to keep the brood alive and keep a healthy hive. Successful pollination means improved yield and size of berries.

Fruiting walls with bending and pinching techniques to intensify plantings and make harvesting quicker and easier for the labour.

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Plain English Compendium Summary

Project Title:	**Intensive Berry Production Using Greenhouses, Substrates and Hydroponics.**

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Objectives	To compare the various protected cropping structures currently utilized. To assess and compare the substrates, containers and hydroponic systems used for intensive berry production. To take a closer look at the range of berry crops available with a specific focus on blueberries, raspberries, strawberries and blackberries in protected cropping environments and how crop management occurs. To compare the pros and cons of protected cropping, substrates and hydroponics with traditional berry crops growing methods. To make practical recommendations to growers considering adopting intensive greenhouse production of berries using substrates and hydroponics
Background	Hydroponic rose growers becoming hydroponic berry growers. To travel the globe looking at best practice greenhouse production and berry production and trying to marry the two
Research	Visiting farmers, researchers and attending conferences; reading books, journals, reports and research papers. Growing Southern Highbush blueberry bushes, raspberries and strawberries hydroponically in a multi-span greenhouse trialling and testing the research done around the globe.
Outcomes	Intensive Berry Production using Greenhouses, Substrates and Hydroponics is definitely a viable option for growers and must be considered with resources like land, water, nutrients and labour becoming expensive and scarce.
Implications	
Publications	Presented at Protected Cropping Australia Conference 2015 Presented at Australian Nuffield Conference 2015 Soilless Magazine December 2015