Australian Processing Tomato Grower

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Hort Innovation
Strategic levy investment

PROCESSING TOMATO FUND

AUSTRALIAN PROCESSING TOMATO GROWER

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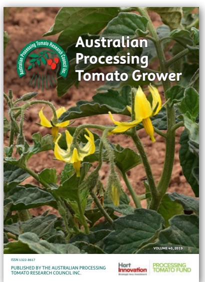
FINANCE REPORT - 2018/19	APTRC Account (Audited)	Hort Inn Account
Funds available 1 July 2018	***1,074,298***	***2***
INCOME		
Grower and processor levies	105,986	105,986
Horticulture Innovation Fund - insect traps	40,000	
TPP Surveillance	12,150	
GBCMA - From the Ground Up project	16,000	
Interest	18,907	21
Other Income		617
Total Income	***193,043***	***106,624***
EXPENDITURE		
Hort Innovation		130,327
Horticulture Innovation Fund - insect traps	40,000	
GBCMA - From the Ground Up project	4,516	
University of Melbourne - student project	10,000	
Global Tomato Foundation - Health Project	16,431	
Membership Fees	1,000	
Net Irrigation Project expenses	24,234	
APTRC Operating Expenses	20,783	
Total Expenses	***116,964***	***130,327***
Net Operating Surplus/(Deficit)	***76,079***	***(23,703)***
Purchase of ute	(22,727)	
Decrease/(Increase) in debtors	(9,990)	26,776
Increase/(Decrease) in liabilities	1,885	(2,449)
Funds available 30 June 2019	***1,119,545***	***626***



Cover Photo

Another Season Unfolds
Bill Ashcroft

Back Cover Photo

Chris Lloyd, Barmac

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EDITORIAL

The Australian Processing Research Council Inc (APTRC) is pleased to present the 2019 edition of the "Australian Processing Tomato Grower" magazine, describing the research and development outcomes and significant events that shaped the industry over the 2018/19 season. We also thank the businesses that support these activities.

Co-editors Bill Ashcroft
Peter Gray
APTRC Inc
Design and Printing
Willprint Shepparton

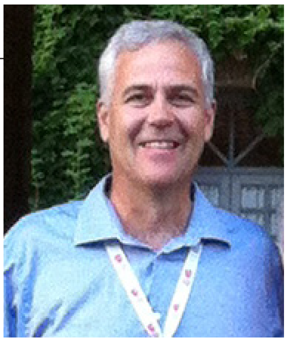
The project [Australian Processing Tomato Industry Capacity Building Program (TM17000)] which includes the production of this magazine has been funded by Horticulture Innovation Australia Limited with co-investment from Australian Processing Tomato Research Council Inc. and funds from the Australian Government.

Notice to Contributors:

Authors wishing to contribute articles to the next 'Australian Processing Tomato Grower' should submit copy to APTRC Inc., PO Box 2293, Shepparton, Victoria, 3632 NO LATER THAN June 30, 2020. Where possible, photographs should be supplied as hi-res digital images on disk or email. Graphs, charts, tables, etc. should be submitted electronically, with an accompanying print-out for confirmation of data.

APTRC – Chair Report 2019

Charles Hart, Chair, Australian Processing Tomato Research Council Inc.



The 2018/19 season is now a distant memory as our grower members are in the midst of dealing with the new plantings, the heat, the dry conditions, and excessively high water prices.

This season the growers delivered a total of 211,961 tonnes of tomatoes for processing. This represented a slight decline from the 2017/2018 season and equated to an average yield of approximately 90.3 tonnes per hectare, which was a good outcome having regard to the weather conditions for the season, particularly the December and January period. In December, the industry incurred possibly its worst outbreak of bacterial speck, and January produced record high temperatures.

Soluble solids averaged 5.2%, which was in keeping with the past few years where solids have been consistently above 5%.

It is interesting to note that imports of processed tomato products increased slightly compared to the previous year and exports declined slightly, albeit at a higher price point. Imports currently account for approximately two thirds of domestic demand for processed tomato products, with per capita consumption of processed tomato products by Australians being 23kg per person.

This year was the third year since the implementation of Horticulture Innovation Australia and I am pleased to advise that the new funding arrangements have now been successfully implemented and are working well.

We had a great attendance at the 2019 Tomato Forum and I would like to thank Peter, Bill and Ann for their contributions in arranging the Forum. The speakers and information disseminated was constructed around the general principle that the industry had managed to lift average yields from 50t/ha to 100t/ha over the period that Liz Mann had worked for the APTRC, and the APTRC Committee wanted to challenge the industry to take up the target of achieving crops producing 200t/ha.

Having regard to the immense experience of our growers, processors, suppliers of agricultural products and services, and our researchers, we asked them the question, "*what knowledge and practices do we need to adopt around the biology, chemistry, hydrology and physics of the growing environment to achieve 200t/ha crops on a sustainable basis?*"

The topics covered by the panels at the Forum included:

- Irrigation practices, chaired by Chris Taylor
- Soils structure, chaired by Jim Geltch
- Soils health and nutrition, chaired by Matt Wright
- Pests and diseases, chaired by Matt Wright; and
- Tomato cultivars, chaired by Tony Henry

The panel discussions at the Forum, followed later by a stakeholder workshop, produced good information that will be used by the Committee to plan future research which will assist us to achieve our goal of growing sustainable tomato crops that produce 200t/ha. We believe that soils-related research will make up a significant part of the immediate work that needs to be done.

We had very insightful and thought-provoking presentations by Jason Fritch, CEO of Kagome Australia, and Allan Findlay, GM Supply Chain & Operations at SPC. It was clear that the industry has significant challenges in being cost-competitive relative to imported tomato products. We were advised that both Kagome and SPC are looking to value-added tomato products to retain their market share in Australia. This will of course raise different challenges for the industry as it comes to terms with growing tomatoes that have the necessary attributes in order to differentiate Australian products from the mass-produced tomato paste products of the large overseas producers.

Dr Mark Bailey, Head of Water Resources at GMW provided us with his thoughts regarding the availability of water, which unfortunately suggested we are likely to remain in a dry period, with poor prospects of normal water allocations being reached. Further, Andre Henry presented the research work he undertook as a Nuffield scholar regarding the use of tomato plant waste to produce fuel and/or building products. We are hopeful that we will be in a position to pursue the good work that he has done thus far.

We also heard from Sophia Callaghan, Melbourne University, regarding the identification of fungal pathogens associated with poor growth of tomato plants, and from Ann regarding the industry capacity-building program which continued during the past season. This program encompasses the work that used to be conducted by Liz and Ann, and included the Annual Processing Tomato R&D Forum, the distribution of the Tomato Topics brochure, variety and on-farm trials and a field day. Ann has been ably assisted by Bill with this program.

2019 will be remembered as the year that Liz resigned from the APTRC. It would be remiss of me not to recognise her significant contribution to the industry during the nearly twenty years she held the Industry Development Manager ("IDM") position. Liz worked tirelessly for the betterment of the industry by developing exceptional expertise across all aspects of the industry and building strong industry relationships with researchers all over the world, government bodies and, most importantly, the growers and processors. Her immense knowledge of all aspects of growing tomatoes, and her presence, will be profoundly missed.

I would like to thank all the growers and processors for their assistance and cooperation in giving of their time and making their properties available to facilitate the trials; again we had unanimous support from the growers.

Finally, I take this opportunity to thank all the committee members as well as the grower group committee for their dedication and commitment to the industry. The year ahead will no doubt have its challenges, which I believe we are well equipped to meet with the assistance of Ann, Bill, Peter and the APTRC members at large.

Tomato Forum in Echuca

The End of an Era

APTRC

After nearly twenty years in the position, Liz Mann resigned as Industry Development Manager in January, having made a very significant contribution to the industry during her time in the role.

Liz started work with APTRC during the 1999-2000 season, following on from Lauren Thomson. Lauren had been a great contributor to industry development as the first IDM, and there was concern about a successor being able to fill her shoes. In the event, Liz was a standout candidate in the interview process and went on to provide the industry leadership and support that built on Lauren's work and helped take it to new heights (weather events allowing). Her work spanned a time when the industry was changing dramatically, but remaining at the cutting edge of global competitiveness, in one of the most challenging growing environments.

From an industry perspective, Liz hit the ground running in 1999 and proved to be a highly motivated and knowledgeable IDM, with a network that stretched across the globe. She was not scared of hard work and put the hours in to get the job done to best effect – including having the minutes completed by the time a meeting came to its close. In addition to the technical contribution she made to R&D, Liz did a great deal to foster positive industry relationships, with growers and processor staff having many opportunities to meet and discuss technologies, processes and seasonal conditions.

Liz quickly formed strong friendships across the industry and was instrumental in helping individual farm businesses meet challenges and take up opportunities; particularly through funding grants following floods, or grants which helped businesses to develop. Her initiative around the Commonwealth's On-farm Irrigation Efficiency Program was taken up by every processing tomato grower at the time, and the effects of that work benefited the industry for years. She led a Women in Horticulture group to South East Asia to encourage alternative sources of income for tomato growers; she led a young growers group to Kununurra which helped local discussion networks; she hosted international visitors and was a leading organiser of the Melbourne World Processing Tomato Congress in 2004. And the list goes on.

Her contribution to the industry was outstanding. In recognition of her service to processing tomato growers and the industry in general, Liz was awarded the prestigious John Clifford Award at her farewell dinner at Echuca in June.

Who is Hort Innovation?

Mark Spees

Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australia's horticulture sector. We exist to provide the knowledge and solutions needed to create a world-class horticulture industry, and to drive a prosperous and healthy Australia. Hort Innovation works with industry to invest levy, co-investment and Australian Government dollars into initiatives spanning research and development, extension and communication, trade, marketing and more.

Your industry's voluntary levy

The voluntary processing tomato R&D levy was established by the industry, for investment through the processing tomato collective industry fund (CIF) – otherwise known as the Hort Innovation Processing Tomato Fund. The processing tomato industry has set producer contributions to the CIF at a rate of 0.5 per cent of gross value of production. It's Hort Innovation's responsibility to work with the industry to invest the voluntary levy, together with Australian Government funds, into strategic R&D initiatives.

How are investment decisions made?

Investments specific to the Hort Innovation Processing Tomato Fund are guided by the industry's Strategic Investment Plan (SIP). This document has been developed by the industry to outline key priorities for investment. It's available to be used like a 'roadmap' by the processing tomato Strategic Investment Advisory Panel (SIAP) – a skills-based panel made up of growers and other industry representatives that is tasked with providing advice to Hort Innovation on potential levy investments.

What did we invest in this year?

The 2018/19 financial year saw the establishment of the first voluntary levy investment through the Hort Innovation Processing Tomato Fund. The project *Processing tomato industry capacity building* (TM17000) is delivered by the Australian Processing Tomato Research Council and facilitates an industry development program that's all about supporting awareness and adoption of R&D outcomes, delivering best practice information, enhancing skills of existing industry participants and encouraging new entrants. Specific activities of the project include but aren't limited to:

- Delivery of communication channels including the annual Australian Processing Tomato Grower Magazine and quarterly Tomato Topics newsletters
- Events including industry field days and annual R&D forums
- The collection of industry benchmark data and statistics, communicated to industry through annual data and statistics reports
- Supporting on-farm trials, including cultivar evaluation trials, and disseminating results to industry.

Find out more

Information on the Hort Innovation Processing Tomato Fund and the investments within it can be found at www.horticulture.com.au/processing-tomato. Hort Innovation also sends news and alerts to Hort Innovation members and contacts, so if you haven't already, be sure to sign up for free at www.horticulture.com.au/sign-up.

The processing tomato industry also has a dedicated Industry Strategic Partner, Mark Spees, who can keep you updated with information from your industry's levy investments. You can get in touch with him at mark.spees@horticulture.com.au or 0439 574 173

Financial operating statement 2018/19

OPENING BALANCE	**67,727**
Levies from growers (net of collection costs)	130,327
Australian Government money	157,876
Other income*	1,290
TOTAL INCOME	**289,493**
Project funding	278,109
Consultation with and advice from growers	-
Service delivery – base	11,052
Service delivery – shared	18,314
Service delivery – fund specific	8,278
TOTAL EXPENDITURE	**315,753**
Levy contribution to across-industry activity	7,186
CLOSING BALANCE	**34,281**

*Interest, royalties

Annual Industry Survey 2019

Peter Gray

Executive Summary

During the 2018/2019 season, thirteen growers produced 211,961 tonnes of processed tomatoes, a slight decline on the volume grown in 2017/18, and the crop was again processed by three companies.

Some 2,347 hectares were planted, with total use of sub-surface drip irrigation for the first time. Following a partial break from transplants after 2011/2012, this season witnessed yet another increase in the proportion of transplants being used by growers.

For only the second time in ten years all the planted area was harvested. Average yield was 90.3 tonnes per hectare, which might be considered a good outcome given the weather conditions during December and January especially. In December, the industry incurred possibly its worst outbreak of bacterial speck, and January produced record high temperatures.

Soluble solids averaged 5.21%, continuing outcomes in recent years where solids have been consistently above the 5.00% benchmark.

Imports of processed tomato products, in equivalent raw tonnes, increased slightly during 2018 compared to the previous year, with Italy continuing to be the largest supplier to the Australian market. Exports declined, albeit at slightly higher price points, with a general decline in the smaller markets; the main markets of Vietnam, New Zealand and Thailand bought a little more product in equivalent raw tonnes.

During the last five to seven years, imports have accounted for about two thirds of domestic demand for processed tomato products; prior to this period the ratio was closer to 50%. This change in market proportion may have been influenced by wholesale and retail strategic reaction to poor Australian harvests in 2008 and 2011.

Australians consume an average of 23 kilograms of processed tomato products, in equivalent raw weight. Americans consume a little more, Europeans consume a little less. Therefore, the potential domestic market growth for the Australian industry may be equivalent to the population growth rate of about 1.6% per year.

Comparative data indicates that California leads global field productivity, with Australia coming second in the field of leading tomato-producing nations. However, despite recording much higher individual paddock yields, it seems that Australian average field productivity has plateaued at 90 to 100t/ha.

Such an outcome is not sustainable:

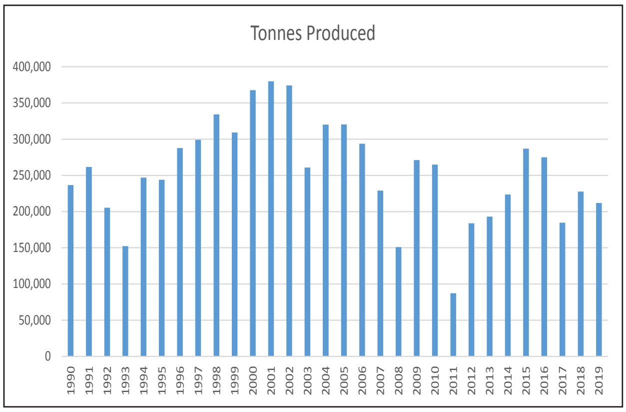
- For producers whose input costs (including that of irrigation water due to low rainfall and downstream demand) are increasing each season; and
- For processors competing with international products in a domestic market of static per capita demand.

Productivity elements that need to be continuously addressed include:

- Access to varieties that deliver optimum production and processing attributes. However, given we can achieve 150t/ha plus from current varieties, this is not the key productivity issue;
- Crop management practices that effectively monitor and control damaging pest and disease incursions. In particular, we need to ensure that incursions are recognized at a very early stage; and
- Flexible irrigation technologies and practices that are applied with a good understanding of variable soil physics and biology. Specifically, the industry must find solutions to successive seasonal yield reductions under sub-surface drip irrigation and improve the lifetime return on its irrigation infrastructure; and Industry profitability and competitiveness must rise significantly above their current status. Through a multi-disciplinary research project during 2019-2020, APTRC will be focusing on field information that could assist the industry to develop solutions to yield reductions and return on irrigation infrastructure.

1 Industry Size

1.1 Volume

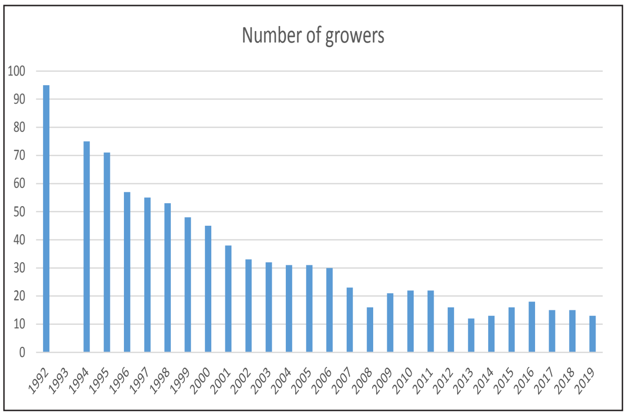


Graph 1-1: Paid tomato volumes delivered (tonnes)[1]

Growers delivered 211,961 tonnes of tomatoes during the 2018/19 season, a decrease of about 7% compared to the previous year. No fruit was supplied by fresh market growers.

Graph 1-1 indicates that the industry, in production terms, is still the same size it was in the early 1990s; successive strategic plans had been aiming for a better outcome than this. As will be noted later, implications of the 2008 and 2011 seasons, in particular, appear to have had a significant influence on domestic market demand.

1.2 Producers



Graph 1-2: Number of growers[1]

Thirteen specialist growing businesses supplied the 2018/19 intake, two less than in the previous season. This was the same number that delivered the 2014 volume.

While grower numbers have plateaued in recent years, it seems there is flexibility for additional growers to join a particular season if economic conditions prove attractive. This provides an opportunity for the industry to make the best of each season's potential.

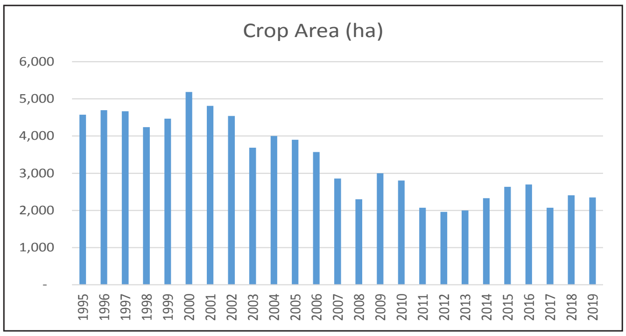
1.3 Processors

As in the previous season, the crop was processed by three businesses, with Kagome Foods and SPC Ardmona taking in the majority of the crop.

Presentations by Kagome and SPC at the 2019 Forum emphasised the ongoing competition they face in domestic and export markets, but tomatoes continued to be an important part of their product mix and strategies were in place to emphasise products that could deliver higher operating margins – not a quick road to success, but the building blocks for a successful future.

2 The Crop

2.1 Area and management



Graph 2-1: Planted crop area (ha)[1]

Some 2,347 hectares were planted to tomatoes, and the total area was harvested. The smaller areas planted in recent years are due to a combination of lower processor requirements and higher field yields.

Season	Drip %	Transplant %
1989/90	15%	
1998/99	48%	21%
2008/09	76%	57%
2008/09	76%	57%
2009/10	80%	65%
2010/11	88%	79%
2011/12	90%	81%
2011/13	98.5%	72%
2013/14	95.0%	59%
2014/15	99.9%	68%
2015/16	98.3%	69%
2016/17	99.6%	86%
2017/18	99.3%	88%
2018/19	100.0%	91%

Table 2-1: Proportions of drip and transplants[2]

For the first time, the Australian crop was fully grown under sub-surface drip irrigation.

However, a yield decline is typically observed with each successive year of tomato cropping under sub-surface drip. The general sense amongst the industry is that the yield reduction is due to soil factors, given that growers observe a return to first year yields following the ripping of paddocks. Some cracking soils naturally simulate this process.

It is imperative that growers can recoup the capital investment in sub-surface drip over a number of tomato crop seasons, and during 2019-2020 the industry will be conducting a detailed investigation into the behaviour and impact of this technology on a range of soils. The broad objective will be to match the optimum irrigation system to soil types. In some cases this might mean an alternative to sub-surface drip, and/or the use of low-pressure systems.

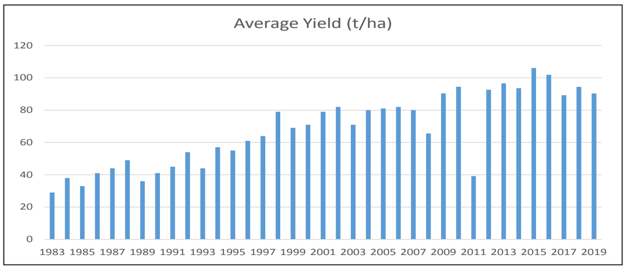
Following a partial break from transplants after 2011/12, recent years have witnessed a growing trend back to transplants.

2.2 Yield

				Average Yield (t/ha)		
Season	Planted Area	Harvested Area	Harvested Area %	Planted Area	Harvested Area	Comments
2010	3443	2806	81%	77	94.4	Wet harvest
2011	2850	2074	73%	28.5	39.2	Flooded crops
2012	2366	1962	83%	76.8	92.6	Wet harvest
2013	1999	1998	100%	96.6	96.6	Wet, late harvest
2014	2386	2330	98%	91.4	93.6	Wet, late harvest
2015	2700	2635	98%	103.5	106.1	Early crop failure
2016	2782	2697	97%	98.8	101.9	Poor crop stand, delayed harvest, over-contract fruit
2017	2183	2071	95%	84.6	89.2	Delayed harvest due to rain
2018	2457	2407	98%	92.5	94.4	Abandoned due to factory power outage and subsequent harvest delay
2019	2347	2347	100%	90.3	90.3	Extreme bacterial speck, high temperatures

Table 2-2: Average yield, harvest conditions (t/ha)[2]

Average yield in 2019 was 90.3 t/ha, with all planted area being harvested. This was yet another season where adverse conditions impacted on the crop. Weather events in mid-December created the conditions which encouraged possibly the industry's most extreme outbreak of bacterial speck. This was followed in January by some of the highest recorded temperatures in the tomato-growing regions.

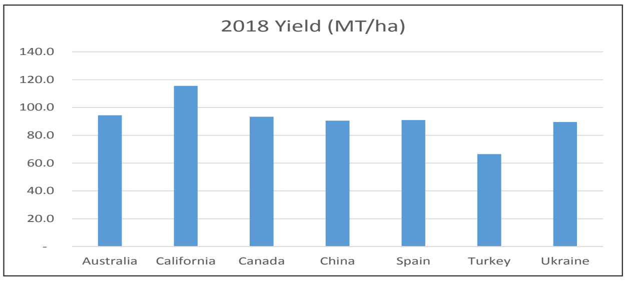


Graph 2-2: Average yield (t/ha)[1]

With average tomato prices remaining stable over many seasons, one of the factors which has mitigated this in maintaining grower profitability is the increase in average field yields.

Whilst Table 2-2, indicates some of the seasonal conditions that Australian growers must contend with, these are probably not totally dissimilar to conditions in seasons when yields were increasing. However, during the past ten years, average field yields have remained relatively static.

We know that yields up to 180 t/ha are being achieved from specific blocks, and it is critical that the industry continues working to drive average yields higher. This will require ongoing developments in cultivars, irrigation methodology, soil management, pest and disease management, and logistics.

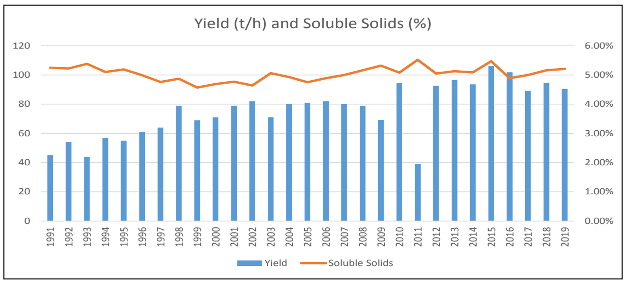


Graph 2-3: 2018 average yield (Mt/ha), by country[3]

Graph 2-3 presents the average yields for some countries during the development of the Australian industry. With California still showing the way, there is a group of countries challenging the 100t/ha benchmark. Data for Italy was not available for 2018, but its yields were 82.4 t/ha in 2017 and 75.6 t/ha in 2016.

In terms of international competitiveness, despite the specific challenges Australian growers face in one of the most volatile growing environments, the industry still rates very well compared to other countries.

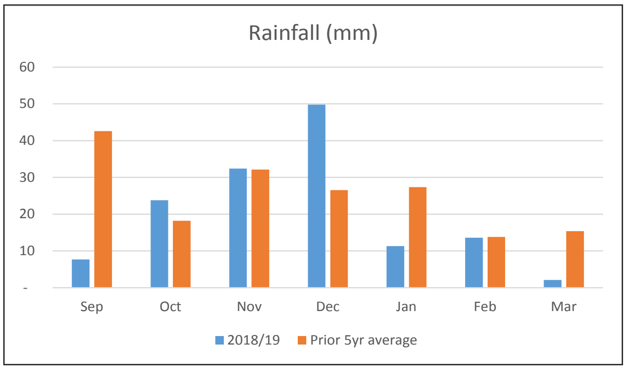
2.3 Soluble Solids



Graph 2-4: Soluble solids (%) and yield (t/ha)[1]

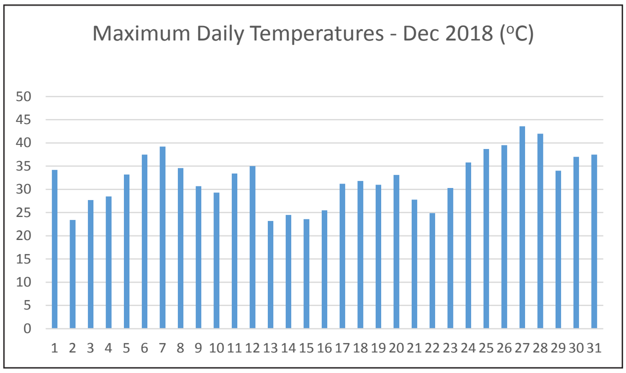
Average soluble solids for the season were 5.21%, above the minimum benchmark of 5.00% preferred by processors. The industry had been through a period in the 1990s when soluble solids were declining as yields increased. However, for the past ten years, soluble solids have only been less than 5.00% in one season. Previous annual surveys have noted that the improved solids performance may be due to factors such as tomato varieties and targeted crop nutrition, which emerged from the industry research program.

3 The Season



***Graph 3-1: Rainfall at Echuca (mm)*[4]**

Planting commenced in late September on the back of an extended dry period. This resulted in initial low soil-moisture levels. Frequent showers and strong winds set back planting schedules and slowed the growth of young plants, with planting completed by late November, early December.



***Graph 3-2: Maximum temperatures, Echuca*[4]**

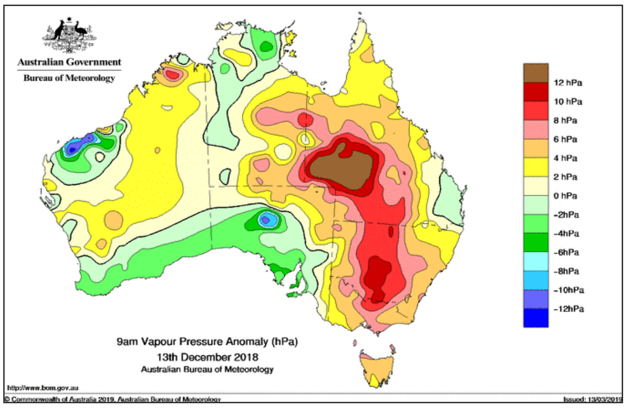
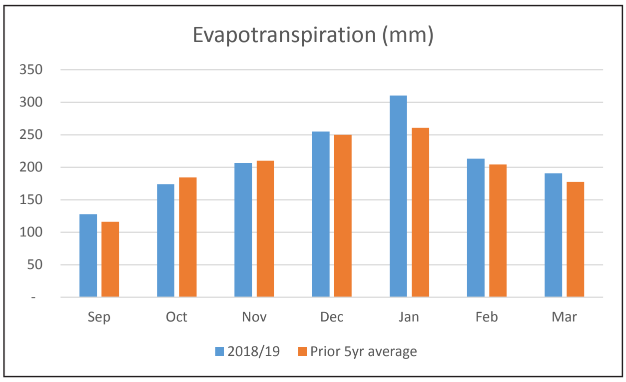


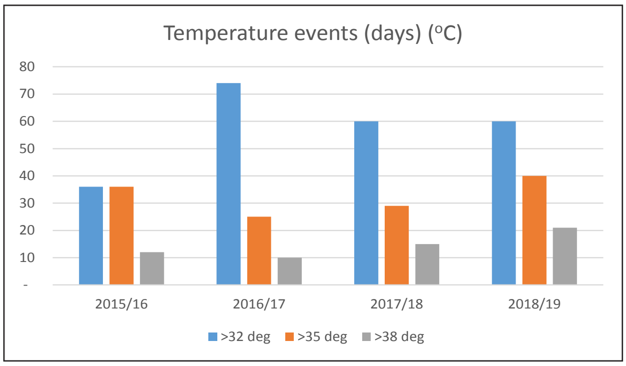
***Image 3-1: Vapour Pressure Anomaly*[4]**

Around 12mm of rain fell about 10 December. This event was followed by a significant increase in humidity (compared to the long-term average) on 13 December, and that was immediately followed by four days of relatively low temperatures during which another 25mm of rain fell.

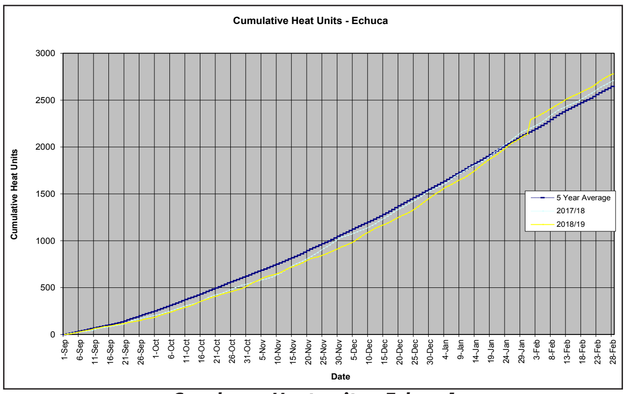
Shortly after these weather events, growers experienced possibly the worst outbreak of bacterial speck the industry has witnessed, badly affecting the most advanced crops at the time.



***Graph 3-2: Evapotranspiration, Swan Hill (mm)*[4]**

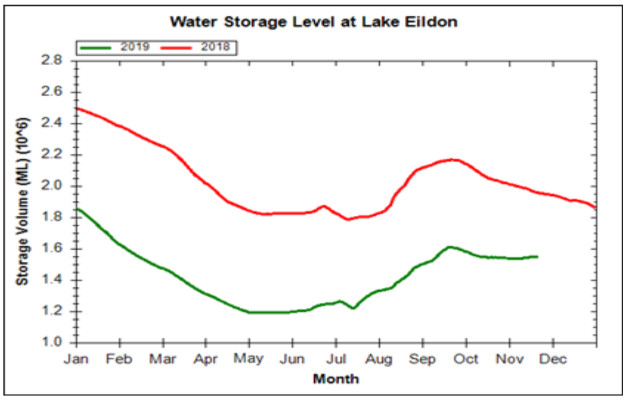


***Graph 3-3: Echuca temperature events*[4]**

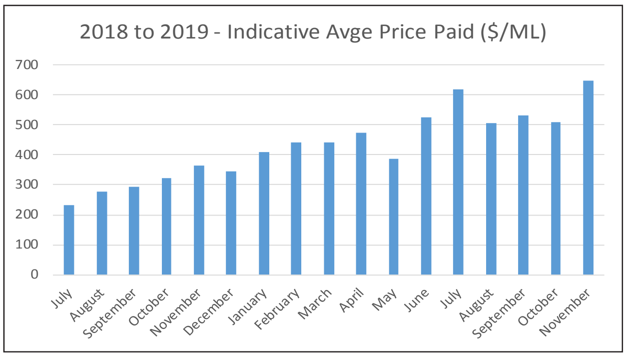


***Graph 3-4: Heat units – Echuca*[5]**

Harvest began in mid-January for SPC growers, with Kagome growers commencing at the end of that month. There was extremely hot weather through the end of December and during January and this further affected the condition and management of crops, which had not had a great season. Harvest was completed by mid-April. The recent trend in the number of days with temperatures in excess of 38°C bears consideration as to potential management issues in coming seasons.



***Graph 3-5: Level of Lake Eildon*[6]**



***Graph 3-6: Zone 1A water price ($/ML)*[7]**

With Eastern Australia in the grip of long-term drought, the regional effect was coming to bear on the industry through the season as temporary market water prices increased. The current outlook is for high water prices to continue unless there are significant rains, and the continuing investment in downstream horticultural plantings is a further factor which influences the price tomato growers must pay for irrigation water.

4 Trade

4.1 Imports

Product	Factor	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Dried/powder	20	35,720	36,291	54,358	39,155	39,125	35,940	26,875	34,506	37,934	37,660
Whole/pcs <1.14L	1.1	39,969	49,030	50,371	49,173	48,060	42,660	45,222	40,965	43,354	42,683
Whole/pcs >1.14L	1.1	12,137	14,790	19,445	18,661	18,911	28,402	28,088	22,997	24,002	24,275
Paste/puree<1.14L	6	54,301	70,232	64,835	73,484	80,602	83,976	153,210	102,733	107,923	109,578
Paste/puree>1.14L	6	110,332	107,112	242,310	148,728	145,214	109,242	102,866	130,171	140,532	144,906
Juice [1]	1.1	43	86	143	264	137	116	75	83	38	75
Sauce/ketchup	2	14,415	22,314	26,760	28,902	33,633	38,628	39,276	38,462	45,705	45,946
Total Tomato		**266,917**	**299,855**	**458,222**	**358,367**	**365,682**	**338,964**	**395,612**	**369,917**	**399,488**	**405,123**

Table 4-1: Imports of Tomato Products[8] *(equivalent raw tonnes)*

The volume of imports increased slightly compared to 2017, with most categories contributing to that increase.

Italy supplied 98% of whole/pcs<1.14L, 93% of whole/pcs>1.14L, and 79% of paste/puree<1.14L. The USA supplied 45% of paste/puree>1.14L, with China and Italy each supplying about 20% of that category. Italy supplied 50% of the sauce/ketchup category, with New Zealand being the next largest supplier at 17%. These proportions are similar to those comprising 2017 imports.

In summary, Italy remains, by far, the largest source of imported processed tomato products into Australia.

Product	Factor	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Dried/powder	20	5.02	5.28	3.81	5.04	5.30	5.67	6.28	5.54	5.72	5.77
Whole/pcs <1.14L	1.1	1.32	1.28	1.09	1.05	1.08	1.23	1.22	1.26	1.12	1.17
Whole/pcs >1.14L	1.1	1.04	0.88	0.82	0.81	0.91	1.05	1.04	0.95	0.90	0.97
Paste/puree<1.14L	6	1.71	1.48	1.23	1.18	1.24	1.44	1.42	1.39	1.29	1.27
Paste/puree>1.14L	6	1.24	1.12	0.95	0.95	0.94	1.12	1.33	1.18	1.10	1.15
Juice [1]	1.1	1.88	1.12	1.57	1.11	1.00	1.30	1.61	0.91	2.41	1.79
Sauce/ketchup	2	1.82	1.54	1.25	0.55	1.58	1.72	1.79	1.80	1.78	1.78
Total Tomato		**1.43**	**1.32**	**1.09**	**1.01**	**1.19**	**1.35**	**1.37**	**1.36**	**1.28**	**1.32**

Table 4-2: Average import prices ($/kg), at 2018 monetary value[8]

Except for dried/powdered products, there is generally a weak statistical correlation between imported volumes and price. That is, the variability in imported volumes does not appear to be price-driven – although each price point can still be lower than that at which Australian processors can supply product.

This issue will be considered further, below.

4.2 Exports

Product	Factor	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Whole/pieces	1.1	2,658	956	1,035	1,581	1,075	2,552	746	461	133	62
Paste/puree	6	4,810	3,900	3,248	11,492	14,987	33,800	43,747	104,518	21,852	16,402
Sauce/ketchup	2	8,888	10,532	9,334	4,134	3,218	3,524	8,196	4,039	8,799	11,636
Juice [1]	1.1	66	47	201	237	224	195	131	57	50	80
Total Tomato		**16,422**	**15,435**	**13,818**	**17,444**	**19,504**	**40,070**	**52,819**	**109,075**	**30,834**	**28,180**

Table 4-3: Exports of tomato products[8] *(equivalent raw tonnes)*

The volume of exports declined from that of 2017, with the increase in sauce/ketchup products not compensating fully for the reduction in paste/puree products.

Whole/piece exports were affected by the lack of volume to Japan. Although the paste/puree volume declined in total, this appears to have been due to a general decline in volume to lesser markets; the main markets of Vietnam, New Zealand and Thailand took in a little more than in 2017.

Product		2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Whole/pieces		3.10	4.63	3.12	2.93	3.28	1.29	4.04	5.03	6.55	4.66
Paste/puree		1.94	1.88	2.13	1.39	1.38	1.37	1.26	0.97	1.16	1.38
Sauce/ketchup		2.04	2.53	2.49	2.84	2.72	2.58	2.54	2.68	1.90	1.95
Juice [1]		1.45	1.26	1.18	1.44	1.20	1.21	1.26	1.58	1.11	1.70
Total Tomato		**2.35**	**2.73**	**2.51**	**2.31**	**2.14**	**1.56**	**1.85**	**1.23**	**1.64**	**1.79**

Table 4-4: Average export prices ($/kg), at 2018 monetary value[8]

Unlike import prices and volume variability, there is an expected strong statistical correlation between average export price and volume variability. For example, the volume of paste/puree sold in 2016 was double that of 2015, but the average price was also commensurately lower. Australian processors have indicated that future trade must be built on higher-margin, value-added products, and this strategy may be partially reflected in the higher average prices in 2018 for the two major categories.

4.3 Market Demand

Calendar	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	5 Yr	7 yr
Imports	266,916	299,855	458,223	358,367	365,682	338,964	395,613	368,918	399,488	405,123		
Net Australian	254,578	249,543	71,465	179,090	171,491	181,561	234,007	165,773	153,848	199,456		
Dom Demand	521,494	549,398	529,688	537,457	537,173	520,525	629,620	534,691	553,336	604,579		
Imported %	51%	55%	87%	67%	68%	65%	63%	69%	72%	67%	67%	67%
Local %	49%	45%	13%	33%	32%	35%	37%	31%	28%	33%	33%	33%
Per capita (kgs)	24	25	24	24	23	22	26	22	22	24	23	23

Table 4-3: Apparent domestic market demand[2] *(equivalent raw tonnes)*

For individual years, combining data can produce non-matched results; ABS data is based on a calendar year, rather than a seasonal year, and this survey is unable to account for year-end stocks. However, these factors should tend to be mitigated when viewed over time.

Table 4-3 presents the information relating to apparent Australian market demand for processed tomato products; net Australian production equates to tomatoes processed less exports. The following indicators emerge from this information;

- Prior to the flood season of 2011, imported and local products provided a more even proportion of apparent demand. However, after 2011, the proportion of demand moved decidedly in favour of imported product. Looking at five and seven year intervals, after 2011, imported product has provided two thirds of Australian apparent demand. Data for 2008 presents another year when Australian production declined dramatically (Graph 1-1). One conclusion is that Australian secondary processors (and retailers), suffering a second reduced year of supply from the local industry in 2011 decided there would have to be a higher imported buy in order to guarantee supply to their customers, and this decision would be a longer-term one;
- It was previously noted that there was a poor statistical correlation between imported volumes and average prices over time. This outcome may be influenced by the apparent long-term policy that secondary processors and retailers would strategically depend less on Australian production; and
- Regardless of annual variability in Australian consumption of tomato products, the longer-term data indicates that local per capita consumption has remained stable, at about 23 kilograms of equivalent raw tomatoes. (By comparison, US consumption is about 25 kilograms and EU consumption is about 20 kilograms). Given stable per capita consumption, the industry might expect market demand to increase at the same rate as population growth; for the eight years to 2019, the average growth rate was about 1.6%[9].

5 Global Production and Outlook

5.1 Production

In 2018, recorded global production totalled 34.830 million tonnes, a reduction of 7.8% compared to 2017. It is anticipated that production will increase in 2019, by about 7%, but still be short of the 2017 total.

In 2000, Australia contributed 1.35% of global production. By 2017, Australia contributed 0.49% of global production and ranked 23rd in industry volume; in 2018 these metrics improved, to 0.65% of global production and ranked 20th in industry volume. In 2018, Australia remained 4th in industry volume of those countries with a January-June harvest.

WPTC crop updates note the following about 2019 production:

- The Californian harvest is expected to be about one million short tons less than expected. Final factory inventory is also projected to be low, so there is an expectation that production in 2020 could increase to possibly 13 million short tons;
- The Northern Italy harvest experienced several hailstorms and extreme heat events, with production expected to be down 18% compared to 2018. Southern Italy had a bad start to the season, but their best September in twenty years. Although fruit quality was good, green fruit reduced factory yields and the volume of finished product is expected to be lower;
- Spain and Portugal had very good seasons, with expected appreciable increases in production compared to 2018;
- Turkish production is expected to increase significantly in 2019 under reasonable harvest conditions;
- Argentinian production was adversely affected by rain, and Chile experienced its most serious drought in fifty years. This is expected to result in a reduction of about 30% in Chilean plantings for 2020; and
- Australia is anticipating a modest rise in 2020 production;

Country	Season	2017	2018	2019E	% change 2018-19	Ranking 2018	% total 2018
USA	Jul-Dec	9,900	11,547	10,430	-10%	1	33.15%
Italy	Jul-Dec	5,200	4,650	4,800	3%	2	13.35%
China	Jul-Dec	6,200	3,800	4,500	18%	3	10.91%
Spain	Jul-Dec	3,350	2,800	3,200	14%	4	8.04%
Brazil	Jul-Dec	1,450	1,400	1,200	-14%	5	4.02%
Turkey	Jul-Dec	1,900	1,300	2,200	69%	6	3.73%
Chile	Jan-Jun	1,080	1,211	1,100	-9%	7	3.48%
Portugal	Jul-Dec	1,554	1,198	1,410	18%	8	3.44%
Iran	Jul-Dec	980	750	1,650	120%	9	2.15%
Ukraine	Jul-Dec	650	735	720	-2%	10	2.11%
Tunisia	Jul-Dec	643	618	807	31%	11	1.77%
Algeria	Jul-Dec	600	500	800	60%	12	1.44%
Russia	Jul-Dec	400	495	550	11%	13	1.42%
Canada	July-Dec	426	450	465	3%	14	1.29%
Argentina	Jan-Jun	488	427	395	-7%	15	1.23%
Egypt	Jul-Dec	300	400	400	0%	16	1.15%
Greece	Jul-Dec	400	320	400	25%	17	0.92%
Thailand	Jan-Jun	260	260	260	0%	18	0.75%
Dominican Republic	Jul-Dec	220	258	258	0%	19	0.74%
Australia	**Jan-Jun**	**185**	**228**	**212**	**-7%**	**20**	**0.65%**
Israel	Jul-Dec	200	200	200	0%	21	0.57%
Poland	Jul-Dec	200	200	200	0%	22	0.57%
France	Jul-Dec	195	139	150	8%	23	0.40%
South Africa	Jan-Jun	180	135	140	4%	24	0.39%
Morocco	Jul-Dec	130	130	130	0%	25	0.37%
India	Jan-Jun	130	130	130	0%	26	0.37%
Hungary	Jul-Dec	100	106	100	-6%	27	0.30%
Peru	Jan-Jun	110	100	100	0%	28	0.29%
Syria	Jul-Dec	70	70	70	0%	29	0.20%
Senegal	Jan-Jun	53	53	61	15%	30	0.15%
New Zealand	Jan-Jun	50	50	50	0%	31	0.14%
Mexico	Jan-Jun	40	40	40	0%	32	0.11%
Bulgaria	Jul-Dec	50	30	40	33%	33	0.09%
Japan	Jul-Dec	30	28	25	-11%	34	0.08%
Czech Republic	Jul-Dec	25	25	25	0%	35	0.07%
Venezuela	Jan-Jun	20	20	20	0%	36	0.06%
Slovakia	Jul-Dec	20	20	20	0%	37	0.06%
Malta	Jul-Dec	8	7	8	14%	38	0.02%
Total		**37,797**	**34,830**	**37,266**	7%		

Table 4-1a: World Production by Country ('000 metric tonnes)[3]

6 References and Sources

1. Previous survey data, B Horn and L Mann
2. Previous survey data, L Mann
3. World Processing Tomato Council
4. Bureau of Meteorology
5. Bureau of Meteorology, and previous survey data, L Mann
6. Goulburn-Murray Water
7. Victorian Water Registry
8. Australian Bureau of Statistics, and previous survey data, L Mann
9. Australian Bureau of Statistics

Bacterial Speck on tomato leaves
– Photo: Dr Margaret Tuttle McGrath, Cornell University

Effect of Soil pH on Infection of Tomato Plant Roots by Soilborne Pathogens

By Vikesh Ajith, University of Melbourne

Sub-surface drip irrigation has been linked to significant changes in the physical and chemical properties of soil near and away from sub-surface drip lines. One of these observed changes is a decrease in soil pH in areas directly adjacent to drip emitters. When we think of soil pH in agriculture, we are often concerned with its direct effects on the growth of our crops. It affects nutrient availability and aluminium toxicity, and optimum pH values for a variety of crops are well documented. However, less is known about the effects of soil pH on soilborne diseases. There are several plausible ways that soil acidity may affect soilborne diseases. It could reduce the fitness of the host, increasing its susceptibility to disease, or it could directly affect the survival of the pathogen by providing optimal or suboptimal pH conditions for its growth and development. Decreasing soil pH has also been related to changes in microbial community composition in the soil, potentially giving soilborne diseases a competitive edge.

The impacts of soil pH were studied on two soilborne diseases of tomato, *Fusarium oxysporum* and *Pythium irregulare*, which were both isolated from tomato roots by Sophia Callaghan in her field surveys in 2017 and 2018. Soil sampling was done in early 2019 from 3 tomato fields to establish the relationship between soil pH and distance from drip emitters (Figure 1). In each field, 3 areas were randomly selected, and soil samples were taken from directly adjacent to the emitter and 45 cm away at the same depth. Soil pH was measured in the lab and the results from a mixed model analysis showed a significant difference in soil pH_{CaCl_2} between the two positions ($p<0.05$), with a mean soil pH_{CaCl_2} of 6.6 away from the emitter, and pH_{CaCl_2} of 5 adjacent to the emitter. These results are consistent with the previous literature.

The next step was to determine if pH had a significant effect on the growth rates of *F. oxysporum* and *P. irregulare* in vitro. The pathogens were grown on artificial medium (potato dextrose agar) amended with NaOH and HCl to produce medium of varying pH of 4, 5, 6, 7 and 8. The experiment showed that the growth of the pathogens was consistent between the pH range of 5-8 but decreased significantly in highly acidic medium (pH 4). This suggests that pH may not be a significant factor affecting the mycelial growth of the two pathogens.

To detect broader interactions between soil pH and the infection process, a pot trial was set up with six treatments, soil pH (pH 5.5, 7, 8) and *P. irregulare* treatment (control, inoculated). Tomato seedlings (cv. H3402) were transplanted into the pots, and plant heights recorded each week. At 3 weeks, plants were harvested, and dry weights recorded.

A two-way ANOVA on dry root weights showed that while the pathogen and soil pH factor were significant ($p < 0.05$), there was no significant interaction effects between the pathogen and soil pH on the dry root weights (Figure 2). One possible explanation for the lack of interaction is the exclusion of the soil microbial community factor through steam sterilization of the potting mix, excluding the potential effects of soil pH on the soil microbiome, which could in turn affect the pathogen. This may suggest that while soil pH may not have directly affected the pathogenicity of *P. irregulare*, indirect effects may still exist.

Future directions of this research would involve further pot trials with *F. oxysporum* isolates causing chocolate streak, as well as investigating the effects of pH on fungal spore germination and development. Measurements of soil microbial activity would also be an added dimension to consider.

Vikesh Ajith is a Bachelor of Agriculture Honours student at the University of Melbourne. The project was supported by the Goulburn Broken CMA through funding from the Australian Government's National Landcare Program.

Figure 1. Collecting soil samples around the sub-surface irrigation tape for pH measurements

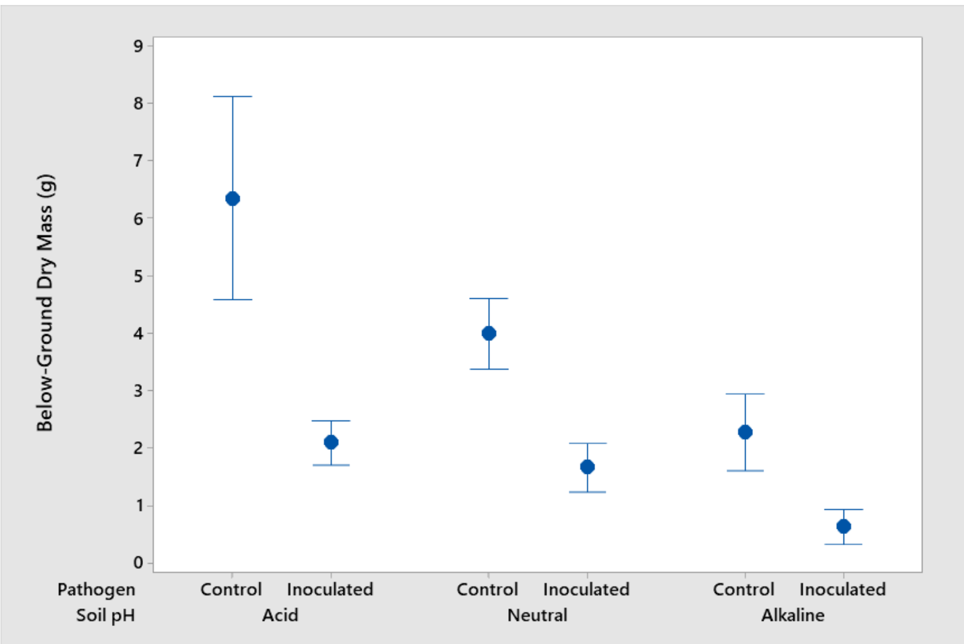


Figure 2. Mean below-ground dry mass of tomato plants in response to pH and P. irregulare inoculation. Error bars represent 95% confidence intervals for the means. N = 7 per treatment.

Association of Soilborne Pathogens with Poor Root Growth in Processing Tomatoes

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Introduction

The objective of this study was to identify and characterise the major soil pathogens associated with yield loss in the Australian Processing Tomato Industry. This final year of my PhD has been dedicated to replicating trials, looking more closely at the phylogenetics of some major pathogens, co-supervising 3 honours students who did small projects related to mine, and writing the thesis! Therefore, here I will present summaries of the key findings resulting from my work and some suggestions for future research directions. The methods and background to these experiments have been described in previous editions of this magazine (2017 and 2018) and various Tomato Topics articles.

Summary of findings

I. Soilborne Disease Surveys

Since the last major pathology surveys of processing tomato fields in the early 90s, the disease-scape seems to have changed significantly (Flett 1986; Washington et al. 2001). *Phyopththora nicotianae* no longer seems to be the most abundant or important soilborne pathogen contributing to yield loss in the industry (although it can be very aggressive when present). This is possibly due to the shift from furrow to sub-surface drip irrigation and an increased awareness of Phytophthora disease, leading to effective management in the form of phosphonate distributed via drip lines.

Surveys of stunted and diseased plants over three seasons have found *Fusarium oxysporum* and *Pythium spp.* to be the most frequent and important soil borne pathogens. Based on their limited abundance in surveys, some less important (putative) pathogens included *Phytophthora nicotianae, Phytophthora cajani, Colletotrichum coccodes, Rhizoctonia solani, Alternaria spp., Sclerotinia minor, Plectosphaerella cucumerina, Fusarium acuminatum and Fusarium solani.* Additionally, some non-fungal pathogens were monitored and noted during surveys; bacterial speck (*Pseudomonas syringae pv. tomato*), tomato spotted wilt virus, big bud disease (*Candidatus Phytoplasma aurantifolia*), root stunt nematode (*Tylenchorhynchus spp.)* and root lesion nematode (*Pratylenchus spp.*). These should all be considered potential threats and should be monitored.

II. Investigation into Phytophthora and Pythium species and their role in growth reduction and yield decline

In total, 13 species of *Pythium* and 2 species of *Phytophthora* were identified based on morphological examinations and sequencing of the functional genes ITS, Cox-1 and Cox-2.

As reported by Flett (1986), Phytophthora disease was caused by *Phytophthora nicotianae*. This species was highly aggressive in subsequent glasshouse trials, capable of causing damping-off, severe root and collar rot and plant death (cv. H3402). The second species, *Ph. cajani* appeared mild to non-pathogenic on tomato plants (cv. H3402) during greenhouse trials. In three years of surveys, Phytophthora disease was always more severe in the first two months of the season but was rarely found as plants matured. Overall, compared to the genus Pythium, Phytophthora was encountered relatively infrequently.

In the field, *Pythium spp.* were isolated from tomato plants throughout the season from the seedling stage through to harvest. *Pythium spp.* were associated with symptoms of stunting and root systems that were depleted and lacking rootlets. *Pythium dissotocum* was the most abundant and widespread species during the three years of surveys being identified at 70% of surveyed sites. Among the Pythium species were some well-known pathogens of tomatoes and other vegetables such as *P. aphanidermatum, P. irregulare* and *P. ultimum* (Robertson 1973, 1976; Jenkins and Averre 1983; Manorantitham et al. 2001; Lévesque and De Cock 2004; Deniel et al. 2011; Blancard 2012). Some other species have been reported on tomatoes very infrequently over time such as *P. catenulatum, P. inflatum* and *P. paroecandrum*. This is the first report of *Py. carolinianum, Py. heterothallicum, Py. hordeum, Py. recalcitrans* and a new *Pythium sp.* being isolated from field tomato crops anywhere in the world. None of the 13 *Pythium spp.* have previously been reported on field tomatoes in Australia.

Studies of the 13 Pythium species gave many interesting and surprising results. Firstly, Pythium is often thought of as a cold climate pathogen (Sauvageau et al. 2019), however the species in this study all had optimum growth temperatures (*in vitro*) between 25°C and 32.5°C and *Pythium aphanidermatum* was even higher, at 37.5°C (Fig. 1). Often, the optimum temperature for the growth of a pathogen in culture is a good predictor for the optimum temperature for disease development (Stirling et al. 2004; Miyake et al. 2014). The fact that the optimum activity temperature for these *Pythium spp.* matches that of tomato plants and the temperature averages for summer in the growing region, makes it probable Pythium disease is an issue for Australian processing tomato crops.

Pythium is well known as a seed and seedling pathogen, and this proved true in pre-germination *in vitro* trials which looked at the effect of 9 Pythium species and 5 processing tomato cultivars (H3402, H1175, H1015, H2401 and H4401). The aggressiveness of the species varied significantly ($p<0.0001$) (Fig. 2). The very aggressive pathogens were *Pythium aphanidermatum*, *P. ultimum var. ultimum, P. dissotocum* and *P. irregulare* and infection by these species was most likely to result in disease severity scores of 4 or above (pre-germination seed death) on all tomato cultivars. The rest of the species were moderate or mild pathogens that caused disease severity scores of 3 or less, meaning that although they could cause a degree of stunting and radicle damage, they were unlikely to cause death.

The 5 tomato cultivars differed significantly in their susceptibility to infection by Pythium ($p<0.0001$) (Fig. 2). The 5 cultivars were almost equally susceptible to the aggressive Pythium pathogens but varied in their response to infection by the mild or moderate pathogens. However, none of the cultivars were consistently better performing. The implications of this finding are of limited value from a management perspective at this stage, although it would depend on what Pythium species predominated in the field. We recommend further studies into the potential tolerance of processing tomato cultivars to Pythium disease are performed, including pot and field trials.

Glasshouse trials revealed more about the pathogenicity of these Pythium species (Figs 3&4). Firstly, the damping-off assessment showed that many species can still cause the death of seedlings, even when inoculated post-germination, when the seedlings were 3 weeks old (Fig. 3). This finding is relevant to the many growers who have opted to use seedling transplants rather than direct seeding. The pattern of aggressiveness mirrored that of the *in vitro* test, with the same species appearing as highly aggressive, moderately aggressive, and non-pathogenic (Fig. 3).

However, as expected, the severity of disease was lower overall when seedlings were inoculated after germination (as for the pot trial) rather than before germination (as for the *in-vitro* trial). This is in line with the general understanding that the younger the plant, the more vulnerable it is to Pythium and other seedling pathogens (Chun and Schneider 1998).

The glasshouse trials also showed that some Pythium spp. can also cause stunting and root rot of mature plants (Fig. 4). Generally, the same species which were problematic at the seedling stage were also problematic at the mature plant stage, i.e. *Pythium aphanidermatum, P. ultimum var. ultimum, P. dissotocum* and *P. irregulare*. One exception was *Pythium recalcitrans* which was surprisingly virulent on mature plants though only mild to moderately aggressive at the seedling stage (Figs. 2-4). *Pythium recalcitrans* was only discovered recently on grapevine roots in Spain (Moralejo et al. 2008). It has since been reported as pathogen of other crops including cucumber (Tesoriero 2011), carrot (Lu et al. 2013), tobacco (Bian et al. 2016), alfalfa (Berg et al. 2017) and soybeans (Radmer et al. 2017) but the true extent of its host range is yet to be uncovered. Although reports of Pythium causing disease of mature tomato plants are uncommon, the genus is reported as a pathogen of many other vegetable and horticultural crops beyond the seedling phase, including other solanaceous species (Stirling et al. 2004; Pivonia et al. 2012). Overall, the glasshouse trials provided important evidence that *Pythium spp.* could indeed be contributing to the problem of poor growth in mature plants observed by growers.

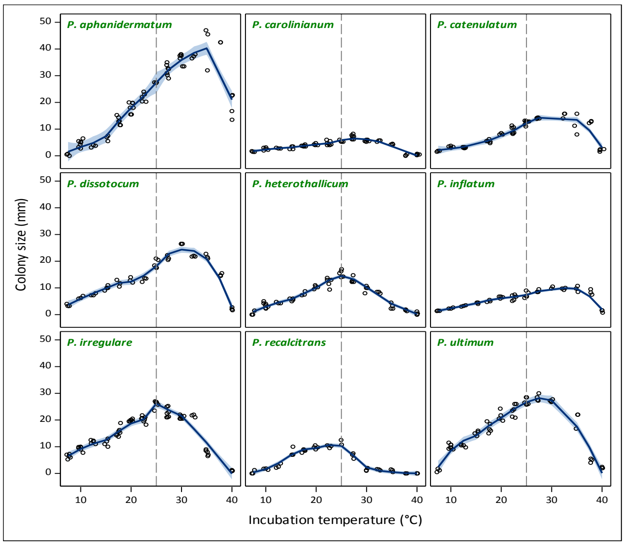

Figure 1. Mean Pythium radial growth rates between 24-48 h on Potato Dextrose Agar (PDA) growing media recorded at 2.5°C intervals from 7.5-40°C with confidence intervals shaded in blue. The dotted reference line runs through 25°C. This trial was run twice and each consisted of at least three replicate plates per isolate.

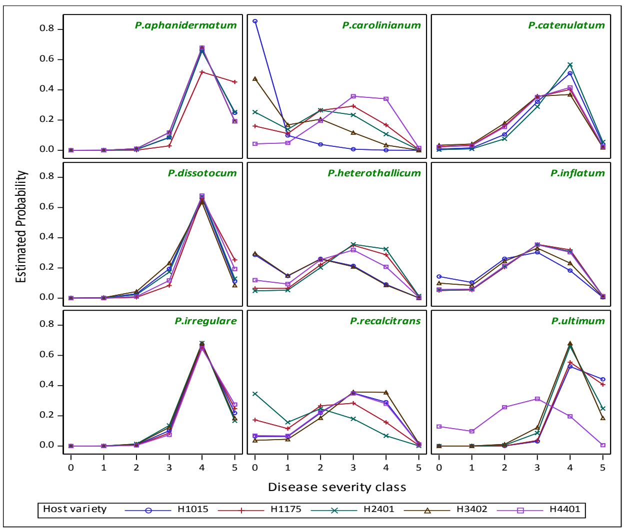

Figure 2. Predicted probability of disease severity scores (0-5) ordered according to Pythium species, as calculated by the adjacent categories logistic model. This in vitro assay involved inoculation of 5 processing tomato cultivars (H1015, H1175, H2401, H3402 and H4401) with 9 Pythium spp. The severity rating score was based on a 0 to 5 scale, where 0 = seed germinated and healthy; 1 = seed germinated and seedling showed few light brown lesions on the radicle, shoot asymptomatic or slightly stunted; 2 = seed germinated and seedling showed brown, enlarging and/or coalescing lesions on radicle, shoot present but clearly stunted and unthrifty; 3 = seedling died after germination, radicle length > 3 mm, radicle brown and necrotic, shoot not emerged or partially emerged but leaves still encased in seed; 4 = seedling died shortly after germination, radicle < 3 mm, radicle dark brown and shoot not emerged; 5 = seed failed to germinate and discoloured.

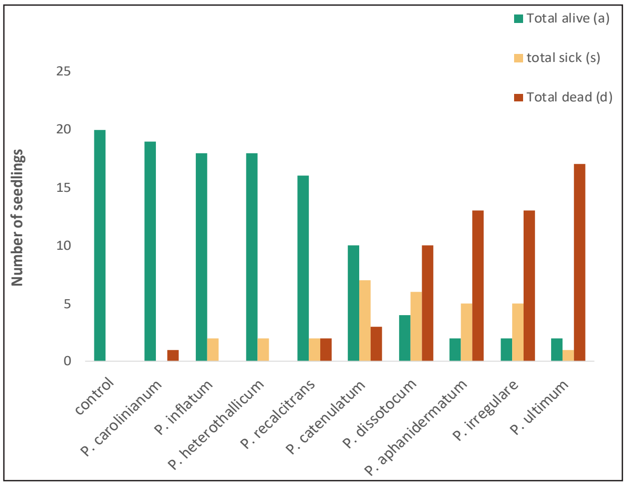

Figure 3. Number of healthy (green columns), unhealthy (yellow columns) and dead (red columns) 4-week-old tomato seedlings (n =20), 1 week after inoculation with different Pythium species.

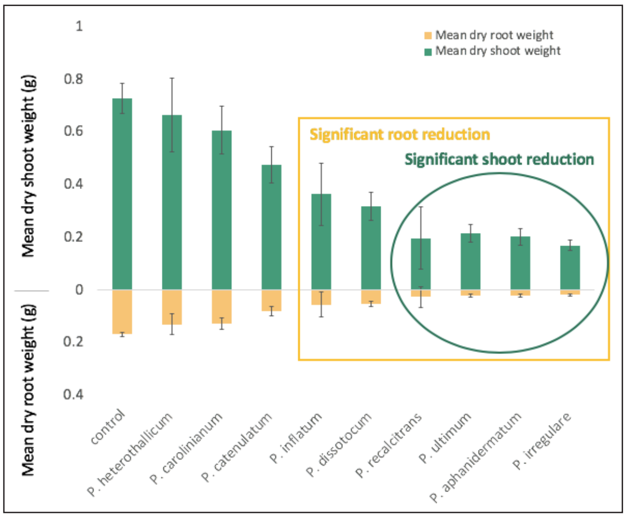

Figure 4. Mean dry shoot (green columns) and root (yellow columns) weights (g) of 8-week-old tomato plants, 1 month after inoculation.

III. *The chocolate streak disease*

During surveys, *F. oxysporum* was the most commonly isolated putative pathogen often associated with stunted plants which had chocolate brown vascular streaks in the crown and upper tap root region (Fig 5). These plants usually occurred in small groups of 1-3 in a row, though occasionally there would up to 10 or more infected plants along the row. Chocolate streak disease was observed across the growing region in three seasons of surveys, and was observed on different soil types, direct seeded and transplanted crops, and early and later season cultivars.

These field symptoms matched those of Fusarium crown and root rot (FCRR) disease which is caused by *Fusarium oxysporum f. sp. radicis-lycopercisi* (Forl) (Yamamoto et al. 1974; Jarvis and Shoemaker 1978). However, this pathogen and disease have not been confirmed in Australia, hence further work aimed to investigate the etiology of the disease.

Firstly, glasshouse trials confirmed the *F. oxysporum* isolates could cause disease in the form of significant root weight reduction, stunting, root and collar browning and seedling death in tomato plants (Fig. 6). This symptomology matched that described for FCRR.

Next, the host range of *F. oxysporum* isolates was assessed by inoculating 6 key rotation crops (rye, barley, maize, clover, wheat and faba bean) in pot trials. After two months, the inoculated tomato plants had significantly reduced root systems whereas the key rotation crops showed no disease symptoms. Nevertheless, *F. oxysporum* was re-isolated from the crowns of all plants. This result contrasted with reports of FCRR which is said to cause disease in a broad host range including faba bean and clover (Menzies et al. 1990).

Another diagnostic indicator for FCRR is its optimal growth temperature, which is reportedly low (18-22°C). However, the chocolate streak disease occurs during Australian summer, and the *F. oxysporum* isolates grew best at 30°C on artificial medium *in-vitro* (Fig. 7). This result indicates a biological difference between the chocolate streak causal organism and *Forl*.

Finally, phylogenetic analysis was performed on 3 gene regions (ITS, ef1 and Pgx4) in an attempt to confirm the taxonomic identity of the *F. oxysporum* causing chocolate streak. Although the pathogen was confirmed to be *F. oxysporum*, the *formae speciales* could not be identified. Chocolate streak isolates did not form one group in the phylogenetic cladogram and also did not cluster with *Forl* isolates. However, international *Forl* isolates also do not cluster together, as the group is polyphyletic (O'Donnell et al. 1998; Lievens et al. 2009). Based on these patterns, authors hypothesise that *Forl* probably evolved pathogenicity several times. Given the polyphyletic nature of *Forl* and the results reported above, it is plausible that the Australian population of *F. oxysporum* is genetically and biologically unique from international *Forl* populations.

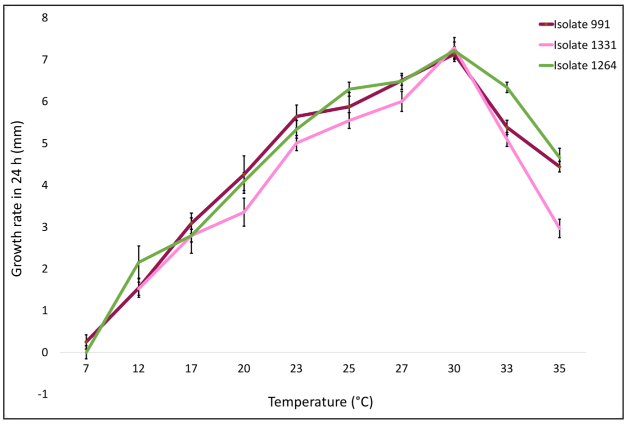

Figure 7. The growth rate of 3 F. oxysporum isolates (991, 1264, 1331) on an artificial medium (PDA) at temperatures between 7 and 35°C (error bars = ± standard error).

Fig 5. Examples of the chocolate streak symptom in the tap root and crowns of two processing tomato plants.

Fig 6. Tomato plants (cv. H3402) from the control treatment (left) and the treatment inoculated with F. oxysporum (right), 2 months after inoculation.

Conclusions

This project successfully identified many of the major and minor soilborne pathogens which are likely to be contributing to poor growth and yield loss of processing tomatoes. The study also illustrated the complexity of diagnosing soilborne diseases when the web of other biotic and abiotic interacting factors must also be considered. Unfortunately, but unsurprisingly, there is not a sole cause of yield decline, and so no "silver bullet" for management.

Accurate pathogen identification and confirmation is the backbone of disease management and this has been achieved through this project. Further work will continue to build on this foundation. Once the identity of the major pathogens is established, efforts can be directed towards management approaches which take the biology and epidemiology of the causal pathogens and disease into account. Hence, the suggestions for future studies in the next section largely relate to exploring management strategies.

This study was also a good reminder that regular disease monitoring is critical for the quick detection of emerging or introduced pathogens. Increasingly intensive farming, globalisation and the movement of humans, plants and animals, and a warming world are all factors which are contributing to the introduction and emergence of novel plant pathogens (Callaghan and Guest 2015). Industries have a need and a responsibility to stay vigilant when it comes to disease detection.

Suggestions for future studies

1. A review of chemicals used for disease management by the Australian Processing Tomato industry.
   - Are the fungicides and fumigants currently being used by the industry effective against the major pathogens?
   - Have the major pathogens developed resistance to the important fungicides?
2. Biological control
   - As both *Forl* and *Pythium spp.* are reported to be weak competitors, would disease incidence be reduced in the field by the use of organic amendments which increase microbial activity?
   - And/or, would organically run fields suffer less from these pathogens which are weak competitors?
3. Pythium
   - As *Pythium* and *F. oxysporum* were often isolated from the same plants, could they be involved in a disease complex of some sort?
   - Would crop rotation be an effective measure to minimise Pythium infection when most species have broad host ranges? Or, have isolates developed a degree of host specificity over time (e.g. Harvey et al. 2008) and therefore crop rotation could indeed be useful?
   - Why does *P. recalcitrans* behave differently to other Pythium species, being only a mild pathogen at the seedling stage but a severe stunting and root rot pathogen on more mature plants?
   - Considering the optimal temperature for these Pythium species is between 25 and 37.5°C, is Pythium disease likely to worsen as our climate warms?
4. Fusarium
   - Where did the chocolate streak *F. oxysporum* come from? Is it a native strain that has evolved pathogenicity towards tomatoes (e.g. Fusarium wilt of cotton in Australia (Davis et al. 1996))? Or, has it been introduced via contaminated transplants (which come from interstate) or via seed or another means?
   - Is there a gene region which can differentiate *Fusarium oxysporum* crown and root strains from *Fusarium oxysporum f. sp. lycopercisi* (*Fol*), the tomato wilt pathogen?

References

Berg, L. E., Miller, S. S., Dornbusch, M. R., and Samac, D. A. 2017. Seed rot and damping-off of alfalfa in Minnesota caused by pythium and Fusarium species. Plant Dis. 101:1860–1867 Available at: https://apsjournals.apsnet.org/doi/10.1094/PDIS-02-17-0185-RE [Accessed December 12, 2019].

Bian, C., Zhao, S., Jang, K., and Kang, Y. 2016. First report of Pythium recalcitrans infecting flue-cured tobacco. Australas. Plant Dis. Notes. 11 Available at: https://link.springer.com/content/pdf/10.1007%2Fs13314-016-0195-4.pdf [Accessed December 10, 2019].

Blancard, D. 2012. *Tomato Diseases: Identification, Biology and Control: A Colour Handbook, Second Edition*. 2nd ed. Available at: https://books.google.com/books?id=_Sc6_-OjjXUC&pgis=1 [Accessed May 20, 2019].

Callaghan, S., and Guest, D. 2015. Globalisation, the founder effect, hybrid Phytophthora species and rapid evolution: new headaches for biosecurity. Australas. Plant Pathol. 44:255–262.

Chun, S. C., and Schneider, R. W. 1998. Sites of infection by Pythium species in rice seedlings and effects of plant age and water depth on disease development. Phytopathology. 88:1255–1261 Available at: https://apsjournals.apsnet.org/doi/pdfplus/10.1094/PHYTO.1998.88.12.1255 [Accessed October 29, 2019].

Davis, R. D., Moore, N. Y., and Kochman, J. K. 1996. Characterisation of a population of Fusarium oxysporum f. sp. vasinfectum causing wilt of cotton in Australia. Aust. J. Agric. Res. 47:1143–1156.

Deniel, F., Vallance, J., Barbier, G., Benhamou, N., Le Quillec, S., and Rey, P. 2011. CONTROL OF PYTHIUM SPP. ROOT COLONIZATION IN TOMATO SOILLESS CULTURE THROUGH CHLORINATION OF WATER STORAGE TANK. Acta Hortic. :1293–1299 Available at: https://www.actahort.org/books/893/893_152.htm [Accessed June 20, 2019].

Flett, S. 1986. Phytophthora Nicotianae Var. Nicotianae Causing Root and Crown Rot of Direct-Seeded Tomatoes in Victoria. Australas. Plant Pathol. 15:11 Available at: http://link.springer.com/10.1071/APP9860011 [Accessed May 20, 2019].

Harvey, P. R., Warren, R. A., and Wakelin, S. 2008. The Pythium - Fusarium root disease complex - an emerging constraint to irrigated maize in southern New South Wales. Aust. J. Exp. Agric. 48:367 Available at: www.publish.csiro.au/journals/ajea [Accessed May 28, 2019].

Jarvis, W. R., and Shoemaker, R. A. 1978. Taxonomic status of Fusarium oxysporum causing foor ans root rot of tomato (Letter to the Editor). Phytopathology. :1679–1680 Available at: https://www.apsnet.org/publications/phytopathology/backissues/Documents/1978Articles/Phyto68n12_1679.PDF [Accessed July 18, 2019].

Jenkins, Jr., S. F., and Averre, C. W. 1983. Root Diseases of Vegetables in Hydroponic Culture Systems in North Carolina Greenhouses. Plant Dis. 67:968–970 Available at: https://www.apsnet.org/publications/PlantDisease/BackIssues/Documents/1983Articles/PlantDisease67n09_968.PDF [Accessed June 18, 2019].

Lévesque, C. A., and De Cock, A. W. A. M. 2004. Molecular phylogeny and taxonomy of the genus Pythium. Mycol. Res. 108:1363–1383 Available at: https://linkinghub.elsevier.com/retrieve/pii/S0953756208604724 [Accessed June 18, 2019].

Lievens, B., van Baarlen, P., Verreth, C., van Kerckhove, S., Rep, M., and Thomma, B. P. H. J. 2009. Evolutionary relationships between Fusarium oxysporum f. sp. lycopersici and F. oxysporum f. sp. radicis-lycopersici isolates inferred from mating type, elongation factor-1α and exopolygalacturonase sequences. Mycol. Res. 113:1181–1191 Available at: http://dx.doi.org/10.1016/j.mycres.2009.07.019.

Lu, X. H., Jiang, H. H., and Hao, J. J. 2013. First Report of *Pythium recalcitrans* Causing Cavity Spot of Carrot in Michigan. Plant Dis. 97:991–991 Available at: http://apsjournals.apsnet.org/doi/10.1094/PDIS-10-12-0977-PDN [Accessed December 12, 2019].

Manorantitham, S. K., Prakasam, V., and Rajappan, K. 2001.

Biocontrol of damping off of tomato caused by Pythium aphanidermatum. Indian Phytopath. 54:59–61 Available at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.993.2773&rep=rep1&type=pdf [Accessed June 18, 2019].

Menzies, J. G., Koch, C., and Seywerd, F. 1990. Additions to the host range of Fusarium oxysporum f. sp. radicis-lycopercisi. Plant Dis. 74:569–572.

Miyake, N., Nagai, H., and Kageyama, K. 2014. Wilt and root rot of poinsettia caused by three high-temperature-tolerant Pythium species in ebb-and-flow irrigation systems. J. Gen. Plant Pathol. 80:479–489 Available at: http://link.springer.com/10.1007/s10327-014-0542-2 [Accessed December 10, 2019].

Moralejo, E., Clemente, A., Descals, E., Belbahri, L., Calmin, G., Lefort, F., et al. 2008. Pythium recalcitrans sp. nov. revealed by multigene phylogenetic analysis. Mycologia. 100:310–319.

O'Donnell, K., Kistlerr, H. C., Cigelnik, E., and Ploetz, R. C. 1998. Multiple evolutionary origins of the fungus causing panama disease of banana: Concordant evidence from nuclear and mitochondrial gene genealogies. Proc. Natl. Acad. Sci. U. S. A. 95:2044–2049 Available at: http://www.ncbi.nlm.nih.gov/pubmed/9482835 [Accessed September 30, 2019].

Pivonia, S., de Cock, A. W. A. M., Levita, R., Etiel, E., and Cohen, R. 2012. Low temperatures enhance winter wilt of pepper plants caused by Pythium sp. Phytoparasitica. 40:525–531 Available at: http://link.springer.com/10.1007/s12600-012-0254-0 [Accessed December 10, 2019].

Radmer, L., Anderson, G., Malvick, D. M., Kurle, J. E., Rendahl, A., and Mallik, A. 2017. Pythium, Phytophthora, and Phytopythium spp. associated with soybean in Minnesota, their relative aggressiveness on soybean and corn, and their sensitivity to seed treatment fungicides. Plant Dis. 101:62–72 Available at: http://apsjournals.apsnet.org/doi/10.1094/PDIS-02-16-0196-RE [Accessed December 12, 2019].

Robertson, G. I. 1973. Pathogenicity of pythium spp. to seeds and seedling roots. New Zeal. J. Agric. Res. 16:367–372 Available at: https://www.tandfonline.com/action/journalInformation?journalCode=tnza20 [Accessed June 18, 2019].

Robertson, G. I. 1976. Pythium species in market gardens and their pathogenicity to fourteen vegetable crops. New Zeal. J. Agric. Res. 19:97–102 Available at: https://www.tandfonline.com/action/journalInformation?journalCode=tnza20 [Accessed June 18, 2019].

Sauvageau, A., Gravel, V., and Van der Heyden, H. 2019. Soilborne Inoculum Density and Environmental Parameters Influence the Development of Pythium Stunt Caused by Pythium tracheiphilum in Head Lettuce Crops. Plant Dis. 103:1685–1692 Available at: https://apsjournals.apsnet.org/doi/10.1094/PDIS-09-18-1486-RE [Accessed July 15, 2019].

Stirling, G. R., Eden, L. M., and Ashley, M. G. 2004. Sudden wilt of capsicum in tropical and subtropical Australia: A severe form of Pythium root rot exacerbated by high soil temperatures. Australas. Plant Pathol. 33:357–366 Available at: www.publish.csiro.au/journals/app [Accessed December 14, 2019].

Washington, W. S., McGee, P., Flett, S. P., Jerie, P. H., and Ashcroft, W. J. 2001. Cultivars and fungicides affect Phytophthora root rot in processing tomatoes. Australas. Plant Pathol. 30:309 Available at: http://link.springer.com/10.1071/AP01040 [Accessed May 20, 2019].

Yamamoto I., Konad H., Kuniyasu M., Saito M., Ezuka A. 1974. A new race of *Fusarium oxysporum* f.sp. *lycopersici* including root rot of tomato. Proc. Kansai Plant Proc. Soc. 16: 17–29.

Biological Trials, 2018-2019 Season

Ann Morrison and Liz Mann

Over the past couple of seasons APTRC have been trialling several commercial biological products containing various plant growth promoting rhizobacteria (PGPR) and a fungal inoculant (VAM).

The products used last season were:

- NitroGuard DEFENDER - *Diazotrophs* plus *Bacillus* microbes (Mapleton Agri Biotec Pty Ltd)
- CataPult - Vesicular Arbuscular Mycorrhizae plus 2 species of *Bacillus* microbes (Mapleton Agri Biotec Pty Ltd)
- Serenade Prime - *bacillus subtilis* strain QST 713 (Bayer CropScience Pty Ltd)
- Tri-Culture - *Bacillus licheniformis, Bacillus methylotrophicus, Bacillus subtilis* (SLTEC Fertilizers)

The products were applied to the transplant seedlings by root dipping just prior to transplanting with the aim of enabling the microorganisms to colonise the plant root surfaces and the surrounding soil.

A range of microbes were applied, including diazotrophs (nitrogen-fixers) as well as phosphate-solubilisers, which may enhance the availability of nitrogen and phosphorus to the tomato plant.

Some *Bacillus* species have also been reported to secrete metabolites that can trigger plant growth and prevent pathogen infection (Radhakrishnan, Hashem and Abd Allah, 2017), which may translate to improved crop yields.

The Vesicular Arbuscular Mycorrhizae (VAM), after colonising plant roots, can develop a large network of hyphae extending well beyond the root hair zone. These hyphae can extract phosphorous, nitrogen and other nutrients and deliver them back into the plant, effectively increasing the soil volume the plant roots can access.

The 2018/19 season's trials were held at three sites: Rorato Nominees at Jerilderie, Geltch Investment's Castle Rd and Kagome Jennison's (Tri-Culture was only trialled at the Castle Rd and Jennison's sites).

The plant population at each trial site was assessed within 4 weeks of transplanting. There were no significant differences in the plants per hectare between the control and the different treatments.

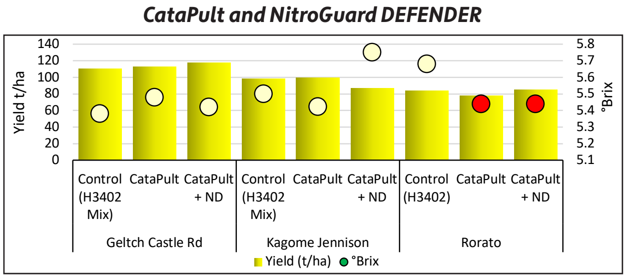

Figure 1. CataPult and NitroGuard DEFENDER (ND) yield and °Brix results

No significant differences in yields were found between the control and Mapleton products at any of the trial sites, though the CataPult and CataPult + NitroGuard DEFENDER treatments had slightly higher yields than the control in two out of three trials (*Figure 1*).

The °Brix values for the two Mapleton products in the trial at Rorato's were significantly lower that the control.

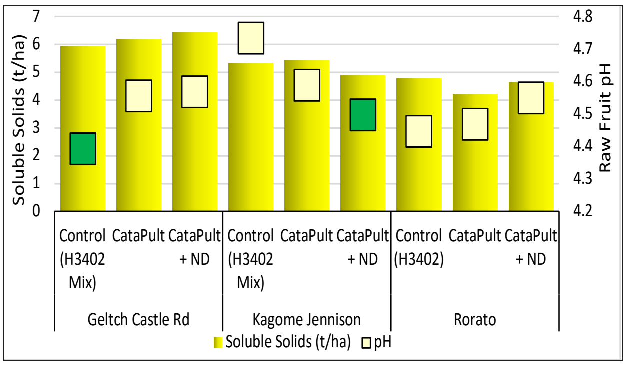

Figure 2. CataPult and NitroGuard DEFENDER (ND) tonnes per hectare of soluble solids and raw fruit pH results

There were no significant differences in tonnes per hectare of soluble solids between the control and the Mapleton products, in addition, the treatment with the highest soluble solids was different at each trial site.

The control at Castle Rd had a significantly lower pH than the two treatments, whereas the CataPult + NitroGuard DEFENDER treatment had a significantly lower pH than the control at Jennison's (*Figure 2*).

Serenade Prime

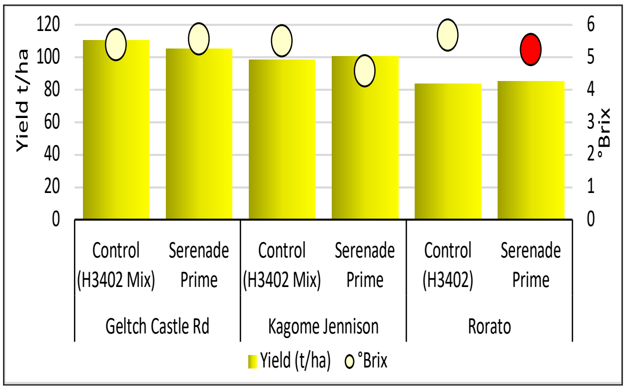

Figure 3. Serenade Prime yield and °Brix results

Comparison of the yields between the Serenade Prime treatments and the control did not show any significant differences at any of the trial sites. In the trial at Rorato's, Serenade Prime had a significantly lower °Brix than the control (*Figure 3*).

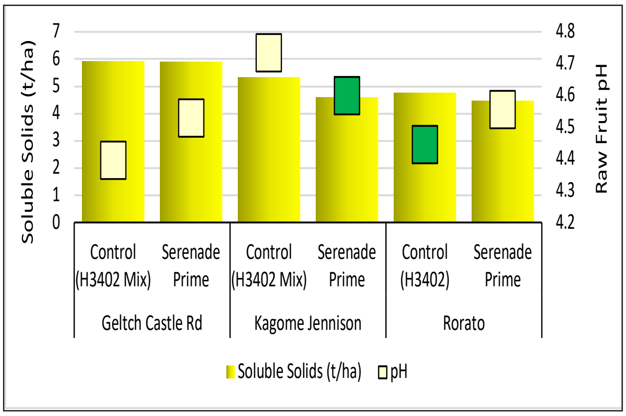

Figure 4. Serenade Prime tonnes per hectare of soluble solids and raw fruit pH results

No significant differences in the calculated tonnes per hectare soluble solids were found at any of the trial sites, the control had slightly higher soluble solids at Jennison's and Rorato's.

The raw fruit pH was significantly lower with the Serenade Prime treatment compared to the control at Jennison's, whereas the control had a significantly lower pH at Rorato's (*Figure 4*).

Tri-Culture

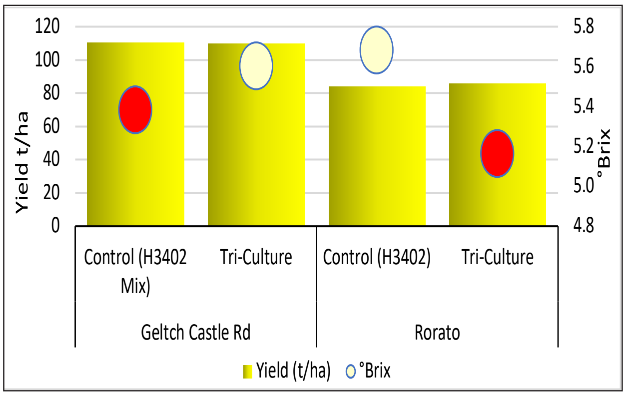

Figure 5. SLTEC Fertilizers Tri-Culture yield and °Brix results

Once again there was no significant difference in yields between the control and the Tri-Culture treatment at either trial site. However, at the Castle Rd trial site, the control had a significantly lower °Brix and slightly higher yields, whereas at Rorato's the results were the opposite with the control having significantly higher °Brix and slightly lower yields (*Figure 5*).

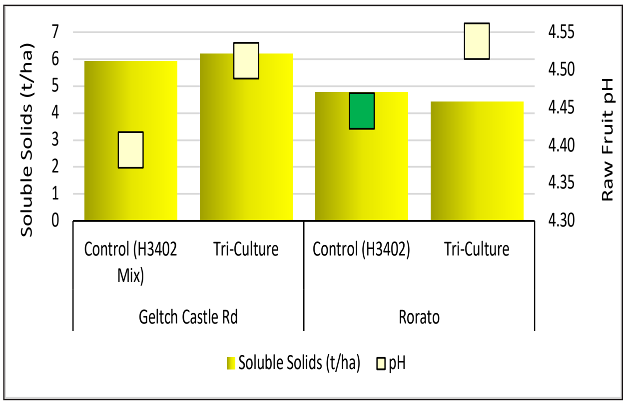

Figure 6. SLTEC Fertilizers Tri-Culture tonnes per hectare of soluble solids and raw fruit pH results

There were no significant differences in tonnes per hectare soluble solids between the treatments, with the control having slightly lower soluble solids in one trial and slightly higher in the other.

In the trial at Rorato's, the control had a significantly lower pH then the Tri-Culture treatment. The pH of the control was also lower at Castle Rd, but this difference was not significant (*Figure 6*).

Summary

There was no clear benefit shown by any of the treatments, none of the applications resulted in a significant improvement in fruit yields. In the trial at Rorato's, the control had a significantly higher °Brix value than all the treatments, but this was not replicated at other sites. There were no obvious trends in fruit pH, with some treatments having either significantly lower or higher pH than the control at different sites.

Only one application of each product was made at planting, and perhaps repeat applications during the growing season may have changed the results.

Radhakrishnan R, Hashem A, Abd Allah EF., *Bacillus*: A Biological Tool for Crop Improvement through Bio-Molecular Changes in Adverse Environments. Front Physiol. 2017. (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5592640/)

Processing Tomato Cultivar Trials 2018-2019

Ann Morrison, Liz Mann and Bill Ashcroft

Introduction

In an ongoing effort to reduce the industry reliance on a limited range of cultivars, the Australian Processing Tomato Research Council is continuing its cultivar evaluation program. The aim of these trials was to assess if any of the tested cultivars out-performed the current industry standards of H1015 in the early season trials, H3402 Mix in mid-season trials and TCP 93800 or 94829 in the cherry tomato trials.

A range of machine-harvested trials consisting of one early season, five mid-season transplant, five mid-season direct seeded and one cherry tomato transplant trial were established. In addition, two small-plot observational trials were transplanted in October.

In all, sixteen different cultivars or variations of current mixes were assessed in the machine harvested trials (seven of which were cherry tomato cultivars) and twelve cultivars were included in the observational trials.

Materials and methods

Cultivars

Machine harvested trial cultivars

		Cherry	Early	Mid season					Mid season				
		Transplant	Transplant	Transplant					Direct seed				
	Grower	Kennedy	Kagome - Hibma North	Kilter - D.Brawn	Kagome - Jennisons	Weeks - Watsons	Rorato	Geltch - Castle Rd	Lehmann	Wakeman	Chirnside	Lawrence	Henry
	Bed Width (m)	1.52	1.52	1.52	1.52	1.52	1.67	1.52	1.67	1.67	1.67	1.67	1.67
	Planting Date	1/10/18	29/9/18	8/10/18	9/10/18	19/10/18	26/10/18	14/11/18	2/10/18	14/10/18	25/10/18	1/11/18	3/11/18
	Plant count date	30/10/18	23/10/18	22/10/18	29/10/18	30/10/18	13/11/18	26/11/18	22/10/18	7/11/18	20/11/18	20/11/18	20/11/18
	Harvest Date	17/1/19	5/2/19	28/2/19	25/2/19	12/3/19	1/3/19	5/4/19	6/3/19	19/3/19	29/3/19	3/4/19	6/4/19
	No. Days	108	129	143	139	144	126	142	155	156	155	153	154
Heinz	H1015		✓										
	H1765		✓										
	H1766		✓										
	H1175 Mix			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	H1538 Mix			✓	✓	✓	-	✓	-	-	-	-	-
	H3402			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	H3402 Mix			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
United Genetics	UG15212			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	UG16112			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Lefroy Valley	TCP 93800	✓											
	TCP 94829	✓											
	TCP 94902	✓											
	TCP 94903	✓											
	TCP 94904	✓											
	TCP 94905	✓											
	TCP 94906	✓											

Table 1: Cultivars evaluated during the 2018-19 processing tomato season

The breakdown of the mixes used in the trials were as follows:

- *H3402 Mix = 50% H3402 + 50% H2401*
- *H1175 Mix = 50% H1175 + 50% H3402*
- *H1538 Mix = 50% H1538 + 50% H1175*

Observational trial cultivars

		Enza Zaden	Enza Zaden	Enza Zaden	Seminis	Seminis	Seminis	Seminis	Seminis	Seminis	Seminis	South Pacific Seeds	South Pacific Seeds	HM Clause
Location	Planting Date	E15M.70088	E15M.70084	E15M.70077	SVTM9007	SVTM9000	SVTM9008	SVTM9003	SVTM9015	SVTM9016	SVTM9016	306-7	272-6	HMX 58811
Kagome Jennison	13/10/18	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Geltch Carinya	20/10/18	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	-	-	✓

Table 2: Cultivars assessed in the 2018-19 transplanted observational trials

Cultivar Characteristics

The tables below list the main characteristics of the machine harvested cultivars.

Variety	Extended Field Storage (EFS)	Maturity	Disease Resistance	Fruit Shape/Size	Plant Size	Colour	Firmness	°Brix	Juice Bostwick (cm)	Predicted Paste Bostwick (cm)
H1015	yes	early-mid	VFFNPAS Cm	blocky M	medium	normal	high	high	12.5	4.54 (Inter)
H1175	yes	full	VFFNAS	blocky/oval M	large	high	v. high	low	9.9	2.26 (Thick)
H1538	yes	full	VFFNPAS LbSwXc	Pear L	large	normal	med	med	13.4	4.33 (Inter)
H1765	yes	early	VFFNPSw	-	MED/LG	high	-	5.23	-	5.65 (Thin)
H1766	yes	early	VFFNSw EbLbCmXc	-	MED/LG	normal	-	5.32	-	2.64 (Thick)
H2401	yes	full	VFFNPAS	blocky/oval M	med	normal	high	med	10.8	2.61 (Thick)
H3402	yes	mid	VFFNPAS	blocky/oval M	med	normal	v. high	med	12.9	-

Table 3: Summary of Heinz cultivar characteristics
(from Heinz Seed 2019 International Variety Catalogue and AgSeed 2019 Processing Tomato Variety Guide)

Disease resistance, V - Verticillium wilt, FF - Fusarium races 1&2, N - root knot nematode, P - bacterial speck, A - Alternaria stem canker, S - stemphylium spp. (grey leaf spot) Disease tolerance - Cm - bacterial canker, Eb - early blight, Lb - late blight, Sw - tomato spotted wilt, Xc - bacterial spot

Variety	Extended Field Holding (EFH)	Maturity	Disease Resistance	Fruit Shape/Size	Plant Size	Colour	Firmness	°Brix	Juice Bostwick (cm)	Predicted Paste Bostwick (cm)
UG 15212	yes	mid	VFFNPtsw	Square Round 69 gm	med	good	good	med	11.67	Thick
UG 16112	yes	full	VFFNPtsw	70 gm	med		good	med	11.68	Thick

Table 4: Summary of United Genetics cultivar characteristics from the UG Global Variety Program 2018

Disease resistance, V - Verticillium wilt, FF - Fusarium races 1&2, P – Bacterial speck, Race 0, tsw - Tomato spotted wilt

Trial Design and Assessment

Machine harvest trials

The machine harvested cultivar trials were laid out in a randomised complete block design (RCB), which is a standard design for agricultural experiments. This design is used to help mitigate the impact of variations in trial results due to spatial effects in the paddock e.g. variations in soil type or irrigation.

The trials were all planted with five blocks (replicates), repeating along the rows, except for the transplant trial at Kagome Jennison's site, which was restricted to four replicates due to the short row length. Cultivars included in a trial were assigned at random across each block (*Table 5*). All trial sites were drip irrigated single row beds. Due to limited seed availability the H1538 Mix was only included in four of the transplant trials.

Block\Row	Row 1	Row 2	Row 3	Row 4	Row 5	Row 6
Rep 5	H3402	UG15212	H1175 Mix	H1538 Mix	UG16112	H3402 Mix
Rep 4	UG15212	UG16112	H1538 Mix	H1175 Mix	H3402 Mix	H3402
Rep 3	UG16112	H1538 Mix	H3402	H3402 Mix	H1175 Mix	UG15212
Rep 2	H1175 Mix	H3402 Mix	UG15212	UG16112	H3402	H1538 Mix
Rep 1	H1538 Mix	H1175 Mix	H3402 Mix	H3402	UG15212	UG16112

Table 5: An example of a randomised complete block trial layout used

A hand-held GPS unit was used to measure and peg out the machine harvest trial rows. These plots ranged in length from 60 to 100 metres depending on the total row length at the trial site. During planting, the cultivar was swapped at each peg in accordance with the trial plan. The weight of fruit produced from each trial plot was measured using load cells on the bulk harvester trailers.

Plant counts were performed on all machine harvest trials within a month of crop emergence or transplanting. The number of plants within a two metre section was counted in five locations spread evenly across a trial plot and then used to estimate the plant population within that plot.

All machine harvested trials were visually assessed prior to harvest. Twenty healthy red fruit were randomly sampled from each treatment plot and taken to the Kagome Laboratory for °Brix, pH and colour testing. A refractometer and a pH meter were used to test °Brix and pH respectively, using a pureed sample of the raw fruit. A hand-diced fruit sample was also tested for colour, using a Hunter Lab Colorimeter.

Colorimeters provide numerical colour values along the black to white axis (colour L), the green to red axis (a) and the blue to yellow axis (b). The higher the value for the individual colour axis, the lighter the colour (higher L), the more red (higher a) and the more yellow (higher b) the fruit.

The preferred raw fruit pH is around the 4.3-4.4 range or lower, and the minimum a/b colour score (obtained by dividing colour a by colour b) needs to be 1.9 or higher.

Treatment plot fruit yields (tonnes per hectare) were calculated using trial plot weights together with the treatment plot row length and width.

Yield and °Brix results were multiplied together to determine the tonnes per hectare of soluble solids (labelled as soluble solids (t/ha)).

Cherry tomato trial

As the number of seedlings available was limited, the cherry tomato trial was restricted to three 20 metre replicates. A visual assessment of each cultivar was made six days prior to harvest and two cherry tomato cultivars were immediately rejected as being unsuitable for canning.

Each cherry tomato trial plot was harvested into a separate 400 kilogram bin, which was then weighed on a free standing two tonne scale. For the five cultivars which passed the initial screening, a random sample of fruit was collected from each bin and tested at the SPC laboratory for °Brix and pH. An additional random sample of 100 healthy ripe fruit was taken from each bin and used to calculate the percentage of fruit with retained calyx. The fruit were also measured to obtain the diameter of the ten smallest and ten largest fruit as well as the overall weight of the 100 fruit sample.

Observational trials

Two transplanted observational trials were also established, each consisting of four seven metre replicates. The cultivars in these trials were assessed by Bill Ashcroft prior to the paddock being harvested. Indicative yields were estimated by hand harvesting a two metre length of the cultivars which passed the initial visual screening at the Kagome Jennison's site.

Results And Discussion

Cool wet conditions in late 2018 led to the development of widespread bacterial speck and canker across many of the trial sites.

Fruit puffiness, incomplete locule development with the fruit containing only a few seeds and little gel, was found across a lot of the mid-season trial sites. This disorder is thought to be exacerbated by extremes in temperature and soil moisture ("Tomato disease field guide"), so is perhaps more a seasonal effect than a specific cultivar characteristic.

Visual Assessment

The machine harvested cultivars were visually assessed within two weeks prior to harvest (Table 6).

Variety	Vine	Fruit
Early Season		
H1015	Medium compact vine, dark foliage, good cover	Medium size, blocky egg-plum shaped, ok/good colour, firm fruit, ok wall thickness, small core
H1765	Medium compact vine, dark leaves, good cover	Medium large plum fruit, very good colour, fruit a bit softer, ok wall thickness, small core, slightly harder separation - odd calyx retained when shaken off vine, some bleaching, BER
H1766	Medium compact vine, med dark leaves, good cover	Medium large plum fruit, ok colour, firm fruit, ok wall thickness, some yellow shoulder and bleaching.
Mid-Season		
H1175 Mix	Medium vigorous vine, not much foliar disease, cover ok	Slightly larger, medium firm round plum fruit, colour ok, good wall thickness, small core, some bleaching and puffiness.
H1538	Medium vigorous vine, good cover, less foliar disease	Very elongated fruit, medium firmness. Colour ok - good, small core, thinnish walls, some BER and breakdown
H3402	Medium compact vine, good cover, slightly less foliar disease.	Blocky medium plum, firm, ok colour & wall thickness, some puffiness
H3402 Mix	Med vigorous vine, compact, some foliar disease, ok cover	Medium firm plum fruit, colour ok, some puffiness, small core
UG15212	Medium vigorous slightly ragged vine, bit more foliar disease, cover ok.	Large blocky plum fruit, some pointed, colour ok, very firm, thick walls, some bleaching and puffiness, some smaller greens, concentration not quite as good.
UG16112	Medium vigorous vine, bit ragged & tending to fall open, ok cover, bit more foliar disease, sits on beds ok.	Large plum fruit, slightly blocky. Colour ok, very firm thick walled fruit, some a bit puffy, better concentration than UG15212.

Table 6: Pre-harvest cultivar assessment

Note that in the graphs and tables in the body of the report, green values were statistically higher than the industry standard and red values were significantly lower. Data which has been excluded from analysis is coloured grey. The letters in the graphs correspond to those in the ANOVA tables. Except for Figures 1 and 2, where there were only 3 replicates, the box and whisker plots show the range in the data, dividing it into quartiles. Mean values are designated with an X.

Early Season Trials

Due to limited seed availability, only a single early season trial was planted at Kagome Hibma North. This trial initially consisted of four 60 metre replicates, but the fourth replicate results were discarded as there was a wheel track running up an outside row of the trial. Using the data from three replicates meant each cultivar was equally penalised by having one replicate in the spray row.

Table 7 shows the analysis of variance (ANOVA) table for the Kagome Hibma North early season trial.

In the table, average values which are followed by the same letter do not significantly differ (P=.05, Tukey's HSD).

Variety	Plants/ha		Yield (t/ha)		°Brix		Soluble solids (t/ha)		pH		Colour L		Colour a		Colour b		Colour a/b	
H1015	19298	a	77.49	a	6.07	a	4.70	a	4.74	a	27.23	a	32.30	a	13.98	a	2.31	a
H1765	19079	a	79.68	a	5.73	a	4.57	a	4.65	a	30.41	a	31.28		14.91	a	2.10	a
H1766	19737		76.39	a	6.13	a	4.67	a	4.67	a	27.40	a	31.82	a	14.12	a	2.25	a
Tukey's HSD (P=.05)	943		11.867		0.689		0.769		0.204		3.543		6.485		1.722		0.311	
Treatment Prob (F)	0.423		0.6369		0.2015		0.8271		0.3759		0.056		0.7819		0.2348		0.1542	
Replicate Prob (F)	0.5		0.378		0.7452		0.4504		0.1887		0.679		0.7322		0.9436		0.6758	

Table 7: Kagome Hibma North transplant trial ANOVA results

H1766 was excluded from Plants per hectare to correct skewness/kurtosis.
H1765 was excluded from Colour a to correct heterogeneity of variance.

The early season trial at Kagome Hibma North was relatively low yielding, with average yields ranging from around 74 to just under 80 tonnes per hectare. There were no statistically significant differences between the cultivars, although H1765 had the highest yields (*Table 7*).

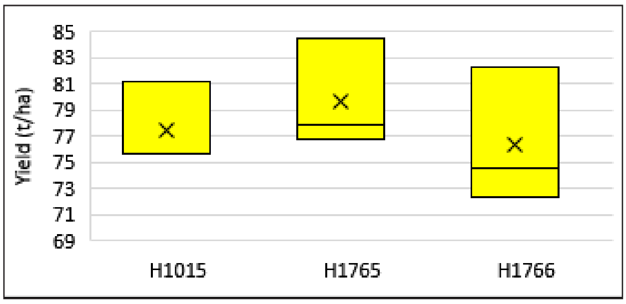

Figure 1: Box and whisker plot of Hibma North yields (t/ha)

The cultivar H1015 showed more consistent yields across the three replicates with a difference of around 5.5 tonnes per hectare between its highest and lowest yielding replicates. In comparison, H1766 showed around ten tonnes per hectare variation between replicates and H1765 just under eight (*Figure 1*).

There were no statistically significant differences in the °Brix between the three cultivars (*Table 7*), with the measured °Brix ranging from 6.13 (H1766) to 5.73 (H1765).

The cultivar H1766 showed the largest variation in °Brix across the three trial replicates, with a 0.6 variation in °Brix values compared to 0.1 and 0.4 for H1015 and H1765 respectively (data not shown.

On a percentage basis, H1766 had around a one percent higher °Brix than H1015 and one and a half percent lower fruit yield. Whereas H1765 had a two percent higher yield and around five percent lower °Brix (*Figure 2*).

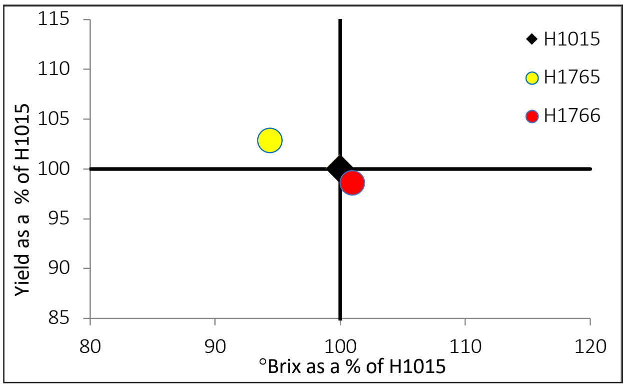

Figure 2. Average fruit yields &°Brix as a percentage of H1015

There were no statistically significant differences in the calculated tonnes per hectare of soluble solids, all three cultivars performed equally well.

Similarly, there were no significant differences in the average raw fruit pH values between the three cultivars and all were higher than the preferred maximum of 4.3. H1765 had the lowest pH of 4.64 (*Table 7*).).

There were also no statistically significant differences in the colour a/b values between the three cultivars, and all were higher than the minimum acceptable level of 1.9.

Mid-Season Trials

Analysis of Variance Tables

The analysis of variance tables for the ten mid-season trials detail the results for last season (Tables 8-17). For the trials at Chirnside's and Lehmann's, only data from four replicates were analysed due to faulty load cells at one site and missing laboratory data at the other. Results with the letter highlighted in red are significantly worse than the industry standard cultivar (H3402 mix), and those with a green highlighted letter significantly better than the standard for that parameter.

Variety	Plants/ha		Yield (t/ha)		°Brix		Soluble Solids (t/ha)		pH		Colour L		Colour a		Colour b		Colour a/b	
H1175 Mix	52695	a	134.28	a	5.10	a	6.99	a	4.44	b	27.69	a	33.46		13.91	a	2.41	a
H3402	56887	a	142.90	a	5.22	a	7.50	a	4.39	ab	27.26	a	31.75	a	13.35	a	2.39	a
H3402 Mix	55838	a	132.69	a	5.36	a	7.25	a	4.41	ab	28.15	a	31.73	a	13.39	a	2.38	a
UG15212	64371	a	105.02	b	5.05	a	5.44	b	4.44	b	29.28	a	33.91	a	14.91	a	2.28	a
UG16112	54341	a	137.23	a	5.06	a	7.07	a	4.38	a	27.93	a	33.17	a	13.64	a	2.43	a
Tukey's HSD (P=.05)	12190		19.76		0.38		1.10		0.05		3.71		3.86		2.35		0.31	
Treatment Prob (F)	0.0762		0.0005		0.0969		0.0005		0.009		0.521		0.2753		0.2622		0.5712	
Replicate Prob (F)	0.2344		0.1014		0.0025		0.0808		0.0029		0.4553		0.9483		0.7511		0.4074	

Table 8: Chirnside direct seeded trial ANOVA results (4 replicates only)
NB. H1175 Mix was excluded from colour a to correct heterogeneity of variance/skewness.

Variety	Plants/ha		Yield (t/ha)		°Brix		Soluble Solids (t/ha)		pH		Colour L		Colour a		Colour b		Colour a/b	
H1175 Mix	19211	a	110.28	a	5.38	a	5.92	a	4.38	b	28.87	a	34.75	a	14.29	a	2.44	a
H1538 Mix	18947	a	123.58	a	5.28	a	6.54	a	4.36	b	28.27	a	35.15	a	13.94	a	2.52	a
H3402	18684	a	108.98	a	5.34	a	5.80	a	4.43	b	28.79	a	35.25	a	14.13	a	2.50	a
H3402 Mix	19211	a	110.48	a	5.38	a	5.93	a	4.39	b	29.39	a	34.49	a	14.82	a	2.33	a
UG15212	17369	a	108.32	a	5.20	a	5.62	a	4.32	b	29.58	a	34.65	a	14.43	a	2.40	a
UG16112	18816	a	102.49	a	5.68	a	5.81	a	4.16	a	29.62	a	34.13	a	14.26	a	2.39	a
Tukey's HSD (P=.05)	3478		26.26		0.63		1.57		0.15		2.00		1.78		1.00		0.21	
Treatment Prob (F)	0.5787		0.2698		0.2823		0.5617		0.0003		0.2673		0.3953		0.1608		0.1003	
Replicate Prob (F)	0.5333		0.1153		0.0793		0.6789		0.2108		0.6365		0.0469		0.1623		0.3921	

Table 9: Geltch Castle Rd transplant trial ANOVA results

Variety	Plants/ha		Yield (t/ha)		°Brix		Soluble Solids (t/ha)		pH		Colour L		Colour a		Colour b		Colour a/b	
H1175 Mix	81785	a	175.78	bc	5.32	a	9.35	a	4.37	b	27.07		35.38	a	13.44	a	2.64	a
H3402	86463	a	182.69	ab	5.22	a	9.52	a	4.37	b	27.54	a	34.68	a	13.57	a	2.56	a
H3402 Mix	84363	a	186.14	ab	5.24	a	9.76	a	4.33	ab	27.98	a	34.70	a	13.94	a	2.49	a
UG15212	74139	a	166.65	c	5.26	a	8.78	a	4.26	a	27.77	a	34.54	a	13.14	a	2.63	a
UG16112	77022	a	188.37	a	5.16	a	9.70	a	4.30	ab	28.24	a	34.91	a	13.82	a	2.53	a
Tukey's HSD (P=.05)	0.11t		11.98		0.63		1.33		0.10		0.81		1.51		0.79		0.0219t	
Treatment Prob (F)	0.3388		0.0003		0.9557		0.2128		0.0225		0.1139		0.4921		0.0515		0.096	
Replicate Prob (F)	0.3345		0.0006		0.5329		0.401		0.1087		0.0049		0.0883		0.0494		0.028	

Table 10: Henry direct seeded trial ANOVA results
NB. H1175 Mix was excluded from Colour L analysis to correct skewness/kurtosis.
Plants/ha and Colour a/b had a 'Log(n+1)' transformation applied to correct skewness/kurtosis.

Variety	Plants/ha		Yield (t/ha)		°Brix		Soluble Solids (t/ha)		pH		Colour L		Colour a		Colour b		Colour a/b	
H1175 mix	17434	ab	113.75	a	5.78	a	6.57	a	4.63	a	28.42	a	31.73	a	14.28	a	2.23	a
H1538 mix	17105	ab	100.39	a	5.40	a	5.45	ab	4.68	a	26.85	a	30.19	a	13.18	a	2.29	a
H3402	17763	a	92.93	a	5.33	a	4.93	ab	4.72	a	28.28	a	32.10	a	13.85	a	2.32	a
H3402 mix	17434		98.50	a	5.55	a	5.33	ab	4.73	a	28.45	a	30.98	a	14.03	a	2.21	a
UG15212	15954	b	81.93	a	5.18	a	4.20	b	4.57	a	28.30	a	31.51	a	14.29	a	2.21	a
UG16112	16447	ab	102.95	a	5.33	a	5.45	ab	4.62	a	25.58		30.56	a	14.26	a	2.15	a
Tukey's HSD (P=.05)	1797		33.971		0.628		1.990		0.257		3.646		4.610		1.756		0.346	
Treatment Prob (F)	0.0441		0.1293		0.0028		0.0245		0.3401		0.6009		0.7489		0.3267		0.6459	
Replicate Prob (F)	0.4504		0.0065		0.1803		0.0401		0.6771		0.3008		0.2022		0.8304		0.4947	

Table 11: Kagome Jennison transplant trial ANOVA results
NB. H3402 Mix was excluded from plants/ha analysis to correct heterogeneity of variance.
UG16112 was excluded from Colour L to correct heterogeneity of variance/skewness/kurtosis

Variety	Plants/ha		Yield (t/ha)		°Brix		Soluble Solids (t/ha)		pH		Colour L		Colour a		Colour b		Colour a/b	
H1175 Mix	18816	b	86.20	a	5.38		4.61	a	4.43	a	26.40	a	30.78	a	12.37	a	2.50	a
H1538 Mix	19868	a	95.69	a	5.72	a	5.47	a	4.46	a	28.25	a	30.12	a	13.31	a	2.26	a
H3402	19342	ab	88.07	a	5.58	a	4.94	a	4.50	a	27.90	a	30.82	a	12.85	a	2.40	a
H3402 Mix	19605	ab	87.45	a	5.58	a	4.89	a	4.41	a	28.33		31.39	a	13.64	a	2.31	a
UG15212	19079	ab	94.57	a	5.50	a	5.19	a	4.41	a	26.95	a	31.74	a	12.83	a	2.50	a
UG16112	18816	b	88.54	a	5.56	a	4.92	a	4.46	a	28.05	a	31.34	a	12.83	a	2.45	a
Tukey's HSD (P=.05)	971		36.058		0.475		2.029		0.176		2.320		3.291		2.035		0.300	
Treatment Prob (F)	0.0128		0.9381		0.707		0.8322		0.5333		0.1128		0.6925		0.4769		0.1082	
Replicate Prob (F)	0.9842		0.2757		0.1939		0.1919		0.9698		0.0119		0.1321		0.0496		0.2633	

Table 12: Kilter transplant trial ANOVA results
NB. H1175 Mix was excluded from °Brix to correct kurtosis.
H3402 Mix was excluded from Colour L to correct skewness.

Variety	Plants/ha		Yield (t/ha)		°Brix		Soluble Solids (t/ha)		pH		Colour L		Colour a		Colour b		Colour a/b	
H1175 Mix	79042	ab	147.04	a	4.92	b	7.22	a	4.29	b	28.55	a	34.43	a	14.33	a	2.40	a
H3402	84791	a	146.60	a	4.90	b	7.18	a	4.29	b	28.44	a	33.57	a	13.83	a	2.43	a
H3402 Mix	79880	ab	149.04	a	4.94	b	7.35	a	4.26	ab	29.18	a	34.10	a	14.41	a	2.37	a
UG15212	75928	b	108.89		5.46	a	5.95		4.13	a	28.47	a	34.01	a	13.95	a	2.44	a
UG16112	73892	b	148.81	a	4.64	b	6.90	a	4.26	ab	29.02	a	34.81	a	14.57	a	2.39	a
Tukey's HSD (P=.05)	7090		9.920		0.480		0.662		0.131		1.238		1.470		0.901		0.185	
Treatment Prob (F)	0.0027		0.844		0.0015		0.2738		0.009		0.2723		0.1662		0.1067		0.8096	
Replicate Prob (F)	0.8042		0.0065		0.1624		0.1311		0.3912		0.0716		0.2047		0.0508		0.1414	

Table 13: Lawrence direct seeded trial ANOVA results
NB. UG15212 was excluded from Yield to correct skewness.
UG15212 was excluded from °Brix to correct heterogeneity of variance/skewness.

Variety	Plants/ha		Yield (t/ha)		°Brix		Soluble Solids (t/ha)		pH		Colour L		Colour a		Colour b		Colour a/b	
H1175 Mix	66467	a	159.37	a	5.33	a	8.50	a	4.43	a	28.70	a	32.74	a	14.39	a	2.28	a
H3402	68713	a	156.96	a	5.23	a	8.20	a	4.45	a	29.04	a	32.67	a	14.24	a	2.30	a
H3402 Mix	67665	a	155.59		5.23	a	8.13	a	4.42	a	29.54	a	31.81		14.09	a	2.28	a
UG15212	70659	a	146.49	b	5.35	a	7.83	a	4.43	a	29.84	a	32.79	a	15.15	a	2.17	a
UG16112	65719	a	155.87	ab	5.35	a	8.34	a	4.44	a	29.11	a	32.07	a	14.52	a	2.19	a
Tukey's HSD (P=.05)	22537		10.368		0.391		1.007		0.109		2.270		1.564		1.460		0.219	
Treatment Prob (F)	0.9588		0.0175		0.6983		0.3468		0.9212		0.5517		0.4848		0.2388		0.2519	
Replicate Prob (F)	0.7981		0.0022		0.7154		0.1018		0.0209		0.7434		0.4525		0.1129		0.5265	

Table 14: Lehmann direct seeded trial ANOVA results (four replicates only)
H3402 Mix was excluded from Yield to correct kurtosis.

Variety	Plants/ha		Yield (t/ha)		°Brix		Soluble Solids (t/ha)		pH		Colour L		Colour a		Colour b		Colour a/b	
H1175 Mix	16647	a	76.65	a	5.26	a	4.01	b	4.53	b	27.99	a	34.31	a	14.71	a	2.35	a
H3402	16407	a	83.83	a	5.68	a	4.77	a	4.45	ab	27.96	a	33.00	a	14.04	a	2.35	a
H3402 Mix	17006	a	75.73	a	5.62	a	4.26	ab	4.41	a	30.04	a	31.36	a	14.88	a	2.12	a
UG15212	16168	a	78.49	a	5.36	a	4.20	ab	4.39	a	29.30	a	32.17	a	14.46	a	2.23	a
UG16112	15689	a	84.05	a	5.32	a	4.46	ab	4.45	ab	28.80	a	32.15	a	14.00	a	2.30	a
Tukey's HSD (P=.05)	1415		8.751		0.48		0.58		0.10		3.76		2.93		2.29		0.35	
Treatment Prob (F)	0.1026		0.0228		0.0544		0.0108		0.0067		0.4192		0.0658		0.7005		0.2499	
Replicate Prob (F)	0.1979		0.0002		0.0916		0.0082		0.0071		0.1951		0.5089		0.4374		0.8098	

Table 15: Rorato transplant trial ANOVA results

Variety	Plants/ha		Yield (t/ha)		°Brix		Soluble Solids (t/ha)		pH		Colour L		Colour a		Colour b		Colour a/b	
H1175 Mix	59401	a	122.66	a	5.10	a	6.26	a	4.44	a	30.81	a	34.00	a	14.79	a	2.30	a
H3402	57246	ab	112.32	a	5.08	a	5.70	a	4.41	a	29.17	a	33.56	a	14.79	a	2.28	a
H3402 Mix	58084	a	110.69	a	5.00	a	5.53	a	4.37	a	28.58	a	33.24	a	13.88	a	2.42	
UG15212	42635	c	108.15	a	4.68	a	5.05	a	4.40	a	28.40	a	33.92	a	14.38	a	2.36	a
UG16112	44671	bc	113.05	a	5.00	a	5.65	a	4.42	a	30.19	a	32.68	a	14.48	a	2.26	a
Tukey's HSD (P=.05)	13043		33.739		0.636		1.770		0.108		3.656		5.048		2.404		0.308	
Treatment Prob (F)	0.0017		0.7344		0.301		0.3826		0.3786		0.2426		0.9265		0.7688		0.7728	
Replicate Prob (F)	0.8154		0.2354		0.0094		0.1763		0.6642		0.2919		0.805		0.8582		0.2009	

Table 16: Wakeman direct seeded trial ANOVA results
NB. H3402 Mix was excluded from Colour a/b to correct kurtosis.

Variety	Plants/ha		Yield (t/ha)		°Brix		Soluble Solids (t/ha)		pH		Colour L		Colour a		Colour b		Colour a/b	
H1175 Mix	16842	a	114.16	a	5.26	a	6.00	a	4.45	a	27.11	a	31.43	a	13.36	a	2.36	a
H1538 Mix	16842		113.77	a	5.22	a	5.94	a	4.41	a	29.34	a	32.32	a	14.35	a	2.25	a
H3402	16711	a	117.22	a	5.32	a	6.25	a	4.43		26.72	a	32.27	a	13.39	a	2.42	a
H3402 Mix	16579	a	111.35	a	5.42	a	6.03	a	4.44	a	28.22	a	32.34	a	14.25	a	2.29	a
UG15212	16579	a	112.57	a	5.20	a	5.85	a	4.39	a	27.49	a	31.10	a	13.30		2.34	a
UG16112	16711	a	113.87	a	5.32	a	6.04	a	4.40	a	29.47	a	30.01		14.54	a	2.07	a
Tukey's HSD (P=.05)	914		27.483		0.379		1.446		0.093		3.048		3.371		2.150		0.380	
Treatment Prob (F)	0.8918		0.9907		0.5009		0.9711		0.2675		0.0429		0.6918		0.3188		0.1097	
Replicate Prob (F)	0.0924		0.9806		0.2799		0.889		0.0194		0.8512		0.9598		0.4144		0.5261	

Table 17: Weeks transplant trial ANOVA results
NB. H1538 was excluded from Plants/ha to correct skewness/kurtosis.
H3402 was excluded from pH to correct heterogeneity of variance.
UG16112 was excluded from Colour a to correct skewness/kurtosis.
UG15212 was excluded from Colour b to correct heterogeneity of variance.

Plants per hectare

The plant population at each trial site was assessed within 24 days of emergence or planting. There were no significant differences in plant populations compared to the H3402 Mix in any of the transplant trials (*Figure 3*). However, in the direct seeded trial at Wakeman's site (*Table 16*), both United Genetic cultivars had significantly lower populations.

In general, the two United Genetics varieties (UG15212 and 16112) tended to be slower to emerge (around five days slower in the first mid-season direct seeded trials) and were found to be noticeably smaller seedlings coming from the nursery.

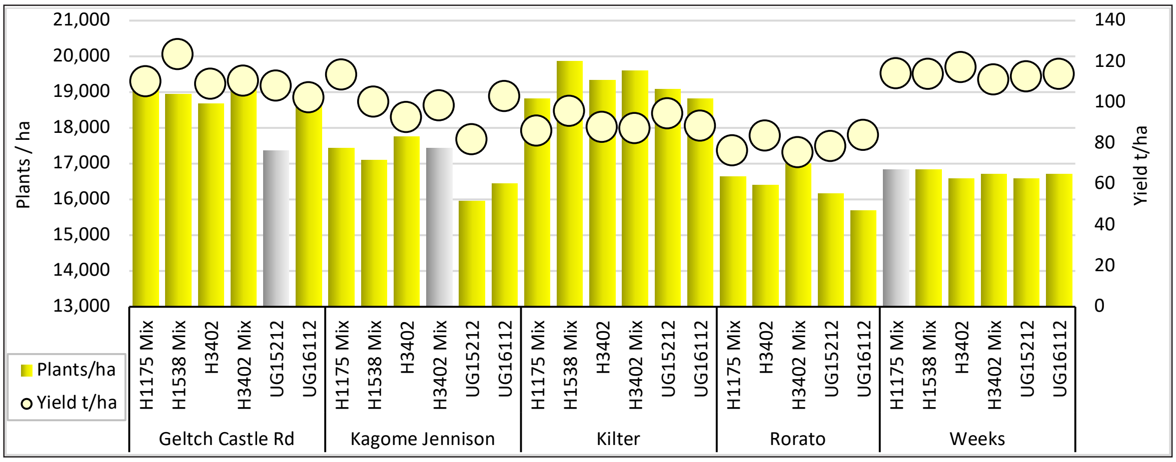

Figure 3: Transplant trial plant populations and yields

A higher plant population may not necessarily translate into higher yields for that cultivar. The cultivar's vine characteristics may counteract the effect of a lower plant population, with larger vines being able to support more fruit and potentially yielding well at lower plant densities compared to more compact cultivars.

UG15212, for example, had the lowest yields in both Chirnside's & Henry's trials, but it had the highest plant density at one site and lowest at the other. In the trial at Wakeman's both United Genetics varieties had significantly lower plant populations, but their yields were close to that of the H3402 Mix (*Figure 4*).

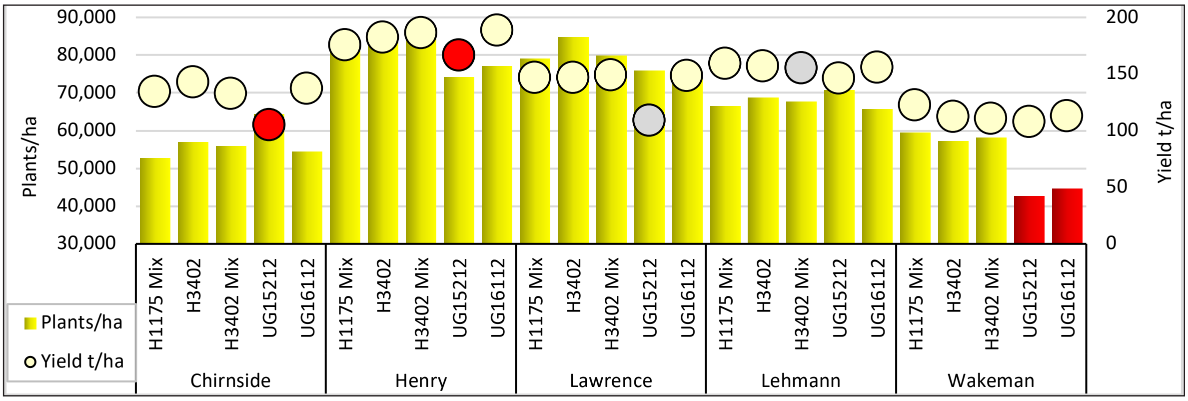

Figure 4: Direct seeded trials: plant population and yields

Yield and °Brix

There were no significant differences between the yields in any of the transplanted trials (*Figure 5*), however in the direct seeded trials at Chirnside's and Henry's UG15212 had significantly lower yields. (*Figure 6*).

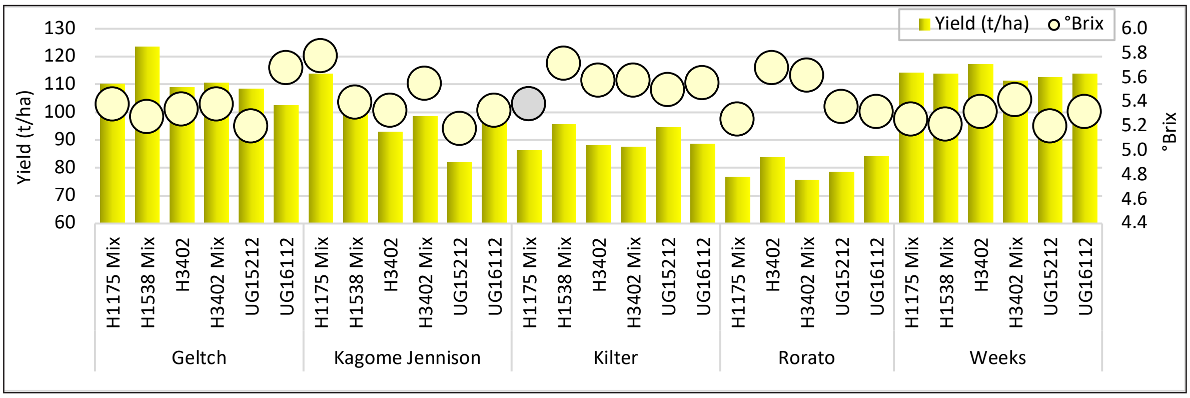

Figure5: Mid-season transplant trials: average yield and °Brix compared to H3402 Mix

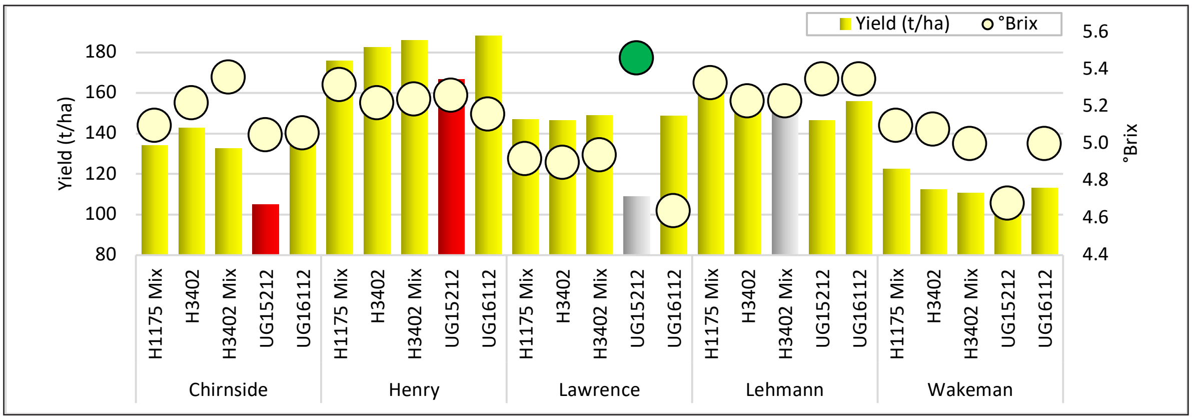

Figure 6: Mid-season direct seeded trials: average yield and °Brix compared to H3402 Mix

In general, UG15212 tended to be the lowest yielding cultivar whilst UG16112 tended to have mid to higher range yields (*Table 18*). The remaining cultivars seem to be quite variable in their ranking on average yields.

There were no significant differences between the °Brix values of any of the cultivars in the five transplant trials (*Figure 5*). However in the direct seeded trials. UG15212 had a significantly higher °Brix at Lawrence's (*Figure 6*).

While there is usually an inverse relationship between yield and °Brix, UG15212 had both the lowest yields and lowest brix in the trials at Chirnside's, Jennison's and Wakeman's (*Tables 18 and 19*).

Yield (t/ha)	Highest →				Lowest
Chirnside	H3402	UG16112	H1175 Mix	H3402 Mix	UG15212	
Geltch Castle Rd	H1538 Mix	H3402 Mix	H1175 Mix	H3402	UG15212	UG16112
Henry	UG16112	H3402 Mix	H3402	H1175 Mix	UG15212	
Kagome Jennison	H1175 Mix	UG16112	H1538 Mix	H3402 Mix	H3402	UG15212
Kilter	H1538 Mix	UG15212	UG16112	H3402	H3402 Mix	H1175 Mix
Lawrence	H3402 Mix	UG16112	H1175 Mix	H3402	UG15212	
Lehmann	H1175 Mix	H3402	UG16112	H3402 Mix	UG15212	
Rorato	UG16112	H3402	UG15212	H1175 Mix	H3402 Mix	
Wakeman	H1175 Mix	UG16112	H3402	H3402 Mix	UG15212	
Weeks	H3402	H1175 Mix	UG16112	H1538 Mix	UG15212	H3402 Mix

Table 18: Ranking of mid-season cultivars on average yield for each trial site

°Brix	Highest →				Lowest
Chirnside	H3402 Mix	H3402	H1175 Mix	UG16112	UG15212	
Geltch Castle Rd	UG16112	H3402 Mix	H1175 Mix	H3402	H1538 Mix	UG15212
Henry	H1175 Mix	UG15212	H3402 Mix	H3402	UG16112	
Kagome Jennison	H1175 Mix	H3402 Mix	H1538 Mix	UG16112	H3402	UG15212
Kilter	H1538 Mix	H3402	H3402 Mix	UG16112	UG15212	H1175 Mix
Lawrence	UG15212	H3402 Mix	H1175 Mix	H3402	UG16112	
Lehmann	UG16112	UG15212	H1175 Mix	H3402	H3402 Mix	
Rorato	H3402	H3402 Mix	UG15212	UG16112	H1175 Mix	
Wakeman	H1175 Mix	H3402	UG16112	H3402 Mix	UG15212	
Weeks	H3402 Mix	H3402	UG16112	H1175 Mix	H1538 Mix	UG15212

Table 19: Ranking of mid-season cultivars on average °Brix for each trial site

Tonnes per hectare soluble solids

There were no significant differences in the tonnes per hectare of soluble solids in the transplant trials compared to the H3402 Mix. There were however some significant differences between other cultivars at two transplant trial sites. At Kagome Jennison's, UG15212 had significantly lower soluble solids than the H1175 Mix, and at Rorato's, the H1175 Mix had significantly lower soluble solids than the straight H3402.

In the direct seeded trials, UG15212 had significantly lower soluble solids than H3402 Mix at Chirnside's. UG15212 also had the lowest soluble solids in all the other direct seeded trials, though that difference was not statistically significant (*Figure 7*).

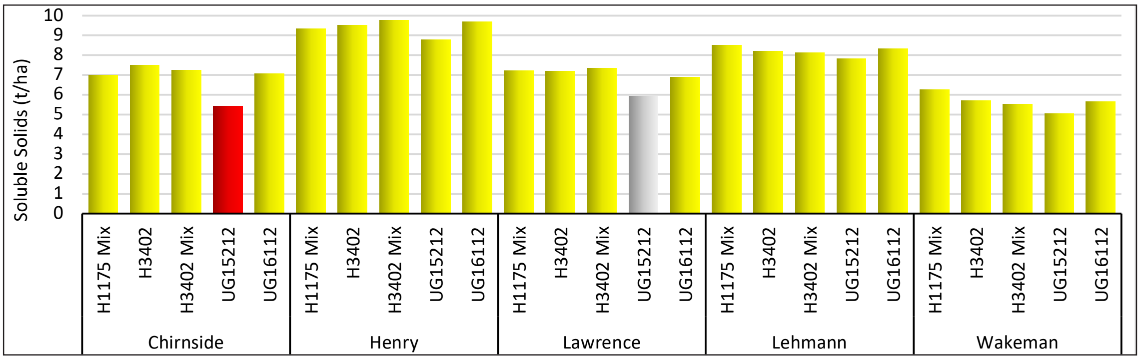

Figure 7: Mid-season direct seeded trials average tonnes per hectare solids compared to H3402 Mix

Soluble Solids (t/ha)	Highest →				Lowest
Chirnside	H3402	H3402 Mix	UG16112	H1175 Mix	UG15212	
Geltch Castle Rd	H1538 Mix	H3402 Mix	H1175 Mix	UG16112	H3402	UG15212
Henry	H3402 Mix	UG16112	H3402	H1175 Mix	UG15212	
Kagome Jennison	H1175 Mix	H1538 Mix	UG16112	H3402 Mix	H3402	UG15212
Kilter	H1538 Mix	UG15212	H3402	UG16112	H3402 Mix	H1175 Mix
Lawrence	H3402 Mix	H1175 Mix	H3402	UG16112	UG15212	
Lehmann	H1175 Mix	UG16112	H3402	H3402 Mix	UG15212	
Rorato	H3402	UG16112	H3402 Mix	UG15212	H1175 Mix	
Wakeman	H1175 Mix	H3402	UG16112	H3402 Mix	UG15212	
Weeks	H3402	UG16112	H3402 Mix	H1175 Mix	H1538 Mix	UG15212

Table 20: Ranking of mid-season cultivars on average tonnes per hectare soluble solids produced for each trial site

On ranking, UG15212 had the lowest soluble solids in eight out of ten trials, whereas UG16112 tended to have mid-range soluble solids (*Table* 20).

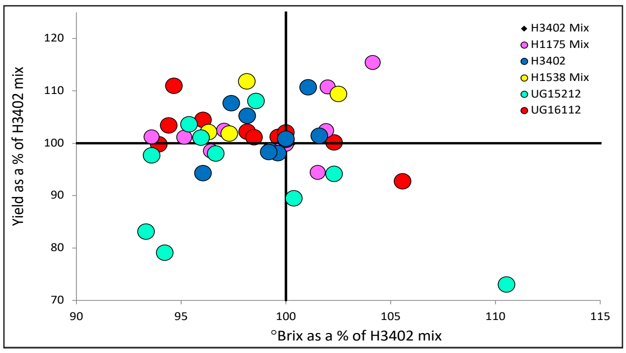

Figure 8: Average yields and °Brix as a percentage of H3402 Mix

When comparing yield and °Brix values in the mid-season cultivars as a percentage of those for the H3402 Mix, H1538 had higher yields in its four trials and higher °Brix in one out of the four trials. The cultivar UG16112 had equivalent or higher yields in nine out of ten trials and higher brix in three trials, UG15212 had higher yields in three trials and higher Brix in another three trials (*Figure 8*).

Summary of trial results across all sites

Across all trial sites, H1175 Mix had the highest grand mean (124.02 t/ha) followed by UG16112 (123.52 t/ha) and then H3402 (*Table 21*).

For °Brix values, the grand means ranged from 5.41 to 5.22, with UG15212 having the lowest value of 5.22 followed by UG16112 with the second lowest of 5.24.

The highest grand mean for tonnes per hectare of soluble solids was from the H1175 Mix, with a value of 6.54. UG16112 had the fourth highest soluble solids at 6.43 and UG15212 had the lowest at 5.81.

Variety	Yield (t/ha)	°Brix	Soluble Solids (t/ha)
H1175 Mix	124.02	5.28	6.54
H1538 Mix	108.36	5.41	5.84
H3402	123.25	5.29	6.48
H3402 Mix	121.77	5.33	6.45
UG15212	111.11	5.22	5.81
UG16112	123.52	5.24	6.43

Table 21: Summary of all mid-season trial results (grand means)

H1538 Mix showed the smallest range in average fruit yields across the trials, but it was only included in four transplant trials. The H3402 Mix showed the largest variation in average yields between the different trial sites at 110 tonnes per hectare followed by UG16112 at around 104 tonnes per hectare.

Across the five transplant trials, UG16112 had a significantly lower pH at Geltch's Castle Rd site, and the H1175 Mix had significantly higher pH at Rorato's (*Tables 9 and 15*).

In general, as tomatoes mature there is an increase in the sugar content and a decrease in acidity (increase in the pH) as citric acid stored in the fruit is used for respiration during the ripening process (Anthon et al. 2011). However, there was no obvious correlation between fruit pH and days to harvest in the transplant trials, with the trial at Rorato's having the shortest growing season but no corresponding reduction in fruit pH.

There were no statistically significant differences in raw fruit pH in any of the direct seeded trials compared to that of the H3402 Mix. However, looking at significant differences between the other cultivars, UG15212 had the lowest pH in the trials at Henry's and Lawrence's, significantly lower than both the H1175 Mix and H3402 (*Tables 10 and 13*). At Chirnside's, UG16112 had significantly lower pH than both the H1175 Mix and UG15212 (*Table 8*).

There was perhaps some correlation seen between the days in the field and fruit pH for the direct seeded crops, with the trial at Lawrence's having the lowest pH and the shortest time in the paddock. All the direct seeded crops were grown in the Boort area which perhaps minimised the effect of location on the fruit pH between these trials.

pH	Lowest →					Highest
Chirnside	UG16112	H3402	H3402 Mix	H1175 Mix	UG15212	
Geltch Castle Rd	UG16112	UG15212	H1538 Mix	H1175 Mix	H3402 Mix	H3402
Henry	UG15212	UG16112	H3402 Mix	H3402	H1175 Mix	
Kagome Jennison	UG15212	UG16112	H1175 Mix	H1538 Mix	H3402	H3402 Mix
Kilter	H3402 Mix	UG15212	H1175 Mix	UG16112	H1538 Mix	H3402
Lawrence	UG15212	H3402 Mix	UG16112	H3402	H1175 Mix	
Lehmann	H3402 Mix	H1175 Mix	UG15212	UG16112	H3402	
Rorato	UG15212	H3402 Mix	H3402	UG16112	H1175 Mix	
Wakeman	H3402 Mix	UG15212	H3402	UG16112	H1175 Mix	
Weeks	UG15212	UG16112	H1538 Mix	H3402	H3402 Mix	H1175 Mix

Table 22: Ranking of mid-season cultivars on average pH values for each trial site

On ranking, UG15212 tended to be in the lower range of pH values for a trial, while UG16112 tended to be in the low to mid-range (*Table 22*).

There are a range of factors that influence fruit pH aside from cultivar, including maturity stage, cultural practices as well as growing location and seasonal variations. The main agro-environmental factors thought to have the most impact on fruit acidity are mineral fertilization, water supply, and temperature (Etienne et al. 2013).

The trial data seems to support the suggestion of location having some influence on raw fruit pH. Comparing the raw fruit pH of a cultivar across the various trial sites, Kagome Jennison's had the highest raw fruit pH for each cultivar, whilst the trial at Lawrence's produced the lowest pH fruit in all but one trial.

There were no statistically significant variations in the average colour a/b scores at any of the trial sites and all the colour values were above 2.1, which is above the minimum requirement (1.9).

On ranking, the H3402 Mix tended to be in the lower range of a/b scores across most trial sites, while the H3402 and H1175 Mix (H1175 normally has good late season colour) tended to have higher scores. UG16112 tended towards the mid to lower end of the range as well.

Variation within cultivars

There were large differences in replicate yields for some cultivars within a trial. The range in fruit yields across replicates ranged from ten to fifteen tonnes up to 70 to 75 tonnes per hectare. The most common variation in replicate yields within a cultivar was between 20 – 25 tonnes per hectare (*Figure 9*).

The trials at Jennison's and Kilter had the widest range of replicate yields. This may partially be due to the high population of volunteer tomato plants at Jennison's, and patches of high weed pressure at the Kilter trial site.

There was more variation in replicate yields in the direct seeded trial at Wakeman's compared to the other direct seeded trials. This was possibly due to uneven water distribution down the trial rows during the growing season (*Figure 10*).

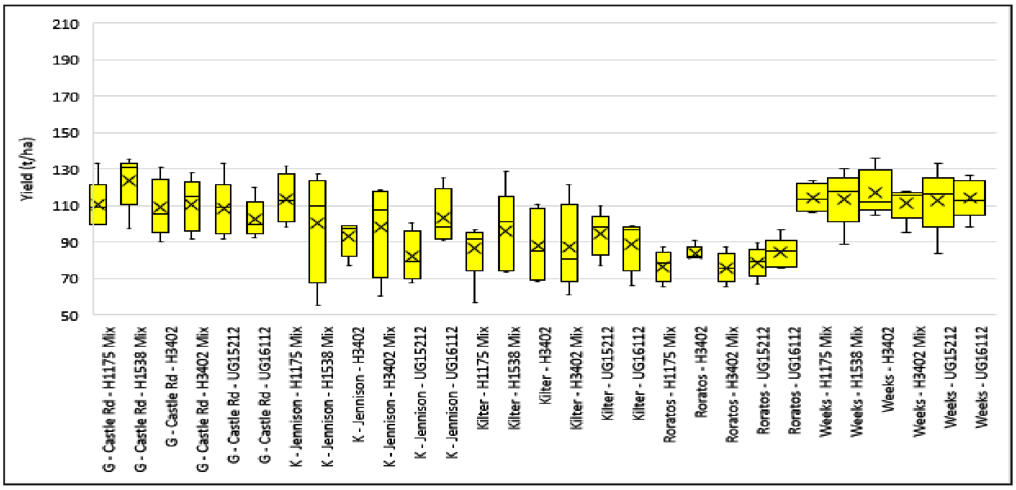

Figure 9: Box and whisker plot of mid-season transplant replicate yields grouped by grower

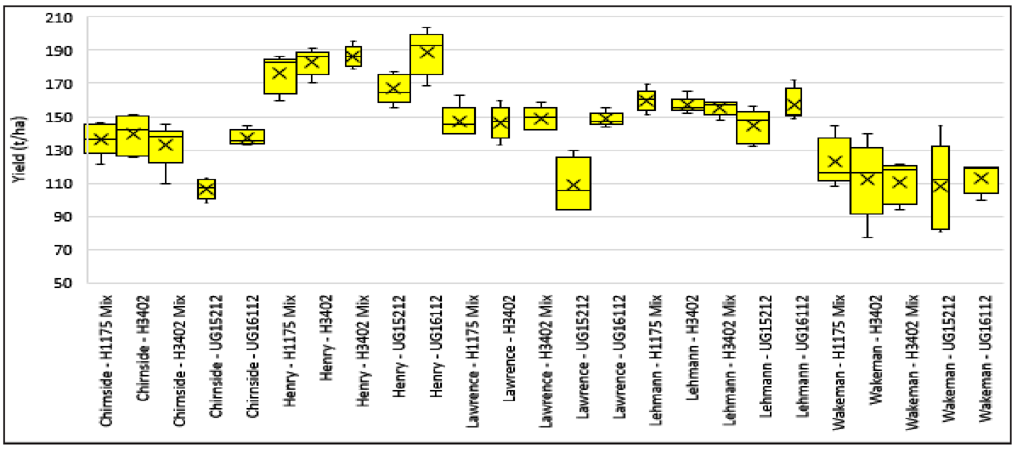

Figure 10: Box and whisker plot of mid-season direct seeded replicate yields grouped by grower

Observational trials

Two transplanted observational trials were established, one at Kagome Jennison's and the other at Geltch's Carinya. The trials were transplanted on 13th and 20th of October 2018 respectively.

Both trial sites were assessed on 13th February 2019 (*Table 23*). Assistance with harvesting promising cultivars was provided by the seed suppliers.

Seed Supplier	Trial line	Comments (combined over two sites) [a] Include in machine harvest trials next season, [b] Include in observational trials next season, pending seed availability	Site 1 Indicative yield t/ha [SS%/pH]	Rating* Site 1/2
Site 1 Control	Heinz 3402/2401 mix	Medium-vigorous vines covering the bed well but exposing some fruit to a bit of bleach. Some fruit in furrows, good yield, firm, egg-blocky pear-shaped fruit, medium size. <10% green.	160.6 [4.9/4.49]	7.5
Site 2 Control	Heinz 3402/2401 mix	Very good vine, med/vigorous on the bed, a little bit of bleach but ok. Good yield, Medium-small, firm, plum-egg fruit.		8
		Note that a second control row, beside the trial at Site 2, produced a smaller vine and seemed more prone to leaf disease – although yield still good.		6.5
Enza Zaden	E15M 70088	Large vine that can fall open, secondary growth on top at site 1. Mid-season, dark foliage, yield ok, fruit firm medium-large blocky plum-eggs, colour variable, core at site 1. Bit of breakdown and bleach also		5/5.5
	E15M 70084	Medium vine, tall and falling open. Medium/firm blocky plums, some breakdown evident. Lacking yield. Dropped by the seed company.		3/4
	E15M 70077 [b]	Spreading med/vigorous vine, medium-dark foliage, on the bed. Concentration and yield good – looks early (Site 1). Very firm, solid fruit with thick walls and good colour although a bit of core at site 1 and a bit puffy at site 2. Medium blocky plum-egg shape. A little foliar disease at both sites.	147 [4.5/4.51]	6.5/7
HM Clause	HMX 58811 [b]	Medium-vigorous vine falling open with fruit breakdown evident in the assessed rep – better in other reps. Medium sized blocky plum-pear shaped fruit. Very firm, colour ok although a bit puffy at site 1. Not bad at site 2 although cover still an issue.	155.3 [5.0/4.37]	5/6.5
Seminis	SVTM 9000 [a]	Medium vine on the bed looks early – good concentration. Bit of foliar disease at both sites. Firm, medium sized, blocky egg-plum-pear shaped fruit – some dimpled, good colour. Puffy at site 1. Yield good. Lack of EFS could be the problem.	166.6 [4.6/4.41]	6.5/7
	SVTM 9003 [a]	Medium-compact vine, smaller dark leaves providing good cover. Good yield of medium-large blocky plum-pears. Medium firmness, thick walls and colour ok but a bit puffy and a few radial cracks evident at site 1.	202.3 [5.7/4.36]	6/6.5
	SVTM 9007	Upright spreading vine that can flop open (site 2) – not so bad at site 1. Dark foliage – looks to be a bit later. Firm, small-medium plum-pears. Colour ok, core at site 2. Average yield and some canker evident at site 2.	162.3 [4.8/4.53]	6/5
	SVTM 9008	Vigorous vine that can open up, fruit bleach and breakdown evident at site 1. Vine much better at site 2. Very firm medium blocky eggs. Some splitting at site 1. Not worth the risk despite appearance at site 2.		4/7
	SVTM 9015 [b]	Medium/vigorous vine on the bed, a bit upright. Yield ok-good, medium sized blocky eggs, very firm – and a touch hollow. Touch of bleach and breakdown evident. Colour ok and good concentration.	182 [4.9/4.43]	6.5/7
	SVTM 9016 [b]	Medium-vigorous tall vine a bit floppy in places. Dark foliage. Yield ok, some greens at site 1. Very firm, medium large blocky plum fruit with a slight dimple. Holding. Yield and vine?		5.5/6.5
SPS (Site 1 only)	272-6	Bush on bed with some good cover and larger leaves. Large egg-plum fruit, colour and firmness ok. Looks a bit later, although some breakdown evident also. Not enough yield.		4
	306-7	Good cover although vine a bit tall/floppy – variable. Fruit medium-large, some pointy with a bit of bleach. Firm, blocky plum-pears, Colour ok but a bit puffy. Good concentration – looks a bit early. Yield down a bit. Too open and breaking down in some spots.		4

Table 23. Observational trial assessments (made by Bill Ashcroft)

**Ratings are a score out of 10, based on a visual assessment of the vine and fruit, taking account of vine type, cover, severity of any plant or fruit disease, fruit holding, concentration and yield.*

Two of the Seminis cultivars, SVTM9000 and SVTM9003, will be included in machine harvested trials next season. In addition, the Enza Zaden cultivar E15M 70077, HM Clause's HMX 58811 and two Seminis varieties - SVTM 9015 and 9016 - will be reassessed in the observational trials.

Heinz Quarry Park harvest results

A non-replicated trial was transplanted at Weeks' Quarry Park by the grower in conjunction with Heinz, with a single row for each cultivar. APTRC staff assisted in obtaining harvest yields and testing fruit for °Brix.

There were four new varieties included in the trial with control (H3402) yields obtained from an adjacent row of the commercial crop. Indicative harvest yields were taken on 11th April 2019 from approximately 230 metres of each trial row (*Table 24.*).

Cultivar	H3402	H5408	H3406	H1307	H4007
t/ha	119.49	136.08	122.30	112.74	121.46
°Brix	5.8	5.9	5.2	5.6	5.8
Soluble Solids (t/ha)	6.93	8.03	6.36	6.31	7.04

Table 24. Indicative Yield, °Brix and Soluble Solids results from Quarry Park

The cultivars H5408 and H4007 produced yields and °Brix as good or better than H3402 and, based on these results, APTRC is hoping to include them in machine harvest trials next season.

Summary

Early Season

Whilst there were no significant differences between the cultivars in the early season trial at Hibma, H1766 had slightly lower yield, but higher brix than H1015. This cultivar also performed well in the Heinz adaptor trials and has a broader range of disease tolerances than H1765. APTRC hopes to continue trialling H1766 in machine harvested trials this coming season.

Mid -Season

UG15212 showed significantly lower yields in two trials as well as significantly lower soluble solids in a single trial (*Table 25*). On ranking, it also tended to have lower yields across most of the trials and will not be continued with next season.

UG16112 while not showing significant improvements over H3402 Mix, displayed slightly higher yields in eight out of the ten trial sites. APTRC intends to continue trialling this cultivar alone and in a 50:50 mix with UG19406 next season.

Unfortunately, the H1538 cultivar is no longer commercially available and will be dropped from the trial program.

Trial	Plants /ha	Yield	°Brix	Soluble Solids (t/ha)	pH	Colour a	Colour b	Colour a/b
Chirnside	-	UG15212	-	UG15212	-	-	-	-
Geltch	-	-	-	-	-	-	-	-
Henry	-	UG15212	-	-	-	-	-	-
Kagome Jennison	-	-	-	-	-	-	-	-
Kilter	-	-	-	-	-	-	-	-
Lawrence	-	-	UG15212	-	-	-	-	-
Lehmann	-	-	-	-	H1175 Mix	-	-	-
Rorato	-	-	-	-	-	-	-	-
Wakeman	UG15212 UG16112	-	-	-	-	-	-	-
Weeks	-	-	-	-	-	-	-	-

Table 25: Mid-season cultivars showing a statistically significant difference to H3402 Mix (red is lower, green is higher)

Observational Plots

APTRC hopes to include the two Seminis cultivars, SVTM9000 (early season) and SVTM9003 (mid-season), in the machine harvested trials next season. In addition, the Enza Zaden cultivar E15M 70077, HM Clause's HMX 58811 and the Seminis varieties SVTM 9015 and 9016 will be included again in next season's observational trials.

Cherry Tomato Trial

Six determinant cherry tomato varieties supplied by South Pacific Seeds were trialled against the current commercial standard cultivar TCP 93800 in a replicated transplant trial at Kennedy's.

Due to limited seedling numbers the trial was restricted to a randomised complete block trial design of three replicates, with each plot being 20 metres in length. The trial was planted on 1st October 2018 in a single row on 1.52 metre wide beds with a plant density of approximately 23,000 plants per hectare. The crop was harvested on 17th January 2019, 108 days after transplanting.

Four of the seven varieties trialled had small round fruit, whilst another had larger round fruit and two cultivars had large elongated grape shaped fruit. The larger fruit while not being suitable for canning may have alternative uses in the future, so their assessment was included.

Variety	Fruit Shape	Assessment
93800	Small round	Original commercial cultivar - problem with calyx retention
94829	Small round	Bit more breakdown than 93800, but better calyx release
94902	Small round	Lot of breakdown, didn't handle early the wet conditions - bush collapsed, poor taste
94903	Large grape	Healthiest looking bush, some pale shoulder on fruit and colour more orange than red, some fruit too big, taste not as good as 94904's
94904	Small round	Some calyx retention, variable fruit size with some too big, tough skin, tastes better than 94906, question on holding ability, good colour
94905	Large round	Large fruit - too big for canning, fair bit of calyx retention, vine is good
94906	Large grape	Fair bit of breakdown, bland flavour, inconsistent fruit size with some fruit too big, vine okay compared to 93800

Table 26: Pre harvest assessment of cherry tomato cultivars

Two cultivars were rejected during pre-harvest assessment, both cultivars 94902 and 94906, showed excessive fruit breakdown. Harvest yields were obtained for these two cultivars, but no further testing was carried out.

Variety	Fruit Shape	Plants/ha		Yield (t/ha)		°Brix		Soluble solids (t/ha)		pH	
93800	Small round	22587.72	a	30.21	bc	5.27	a	1.577	c	4.387	a
94829	Small round	23026.32	a	29.11	bc	5.30	a	1.524	c	4.467	a
94902	Small round	23026.32	a	22.53	c	-		-		-	
94903	Large grape	22807.02	a	58.72	a	6.30	a	3.706	a	4.52	a
94904	Small round	22807.02	a	37.34	bc	6.07	a	2.226	bc	4.493	a
94905	Large round	23026.32	a	42.27	ab	6.10	a	2.548	b	4.42	a
94906	Large grape	22807.02	a	42.82	ab	-		-		-	
Tukey's HSD P=.05		767.58		19.36		1.62		0.938		0.14	
Treatment Prob(F)		0.3957		0.0006		0.1664		0.0002		0.0627	
Replicate Prob(F)		0.178		0.4196		0.8755		0.2863		0.1293	

Table 27a: Harvest assessment of cherry tomato cultivars with ANOVA results

Variety	Fruit Shape	% Fruit with calyx		Average diameter 10 largest fruit (cm)		Average diameter 10 smallest fruit (cm)		Difference in average diameter (cm)		Average fruit weight (gm)	
93800	Small round	11.8	ab	2.597	c	1.833	b	0.763	c	6.99	b
94829	Small round	2.6	c	2.687	c	1.847	b	0.840	bc	7.54	b
94902	Small round	-		-		-		-		-	
94903	Large grape	4.2	bc	3.183	b	2.167	ab	1.017	bc	18.48	a
94904	Small round	30.8	a	2.840	bc	1.770	b	1.070	ab	7.76	b
94905	Large round	21.5	a	3.663	a	2.370	a	1.293	a	18.35	a
94906	Large grape	-		-		-		-		-	
Tukey's HSD P=.05		0.43t		0.47		0.44		0.26		0.0833t	
Treatment Prob(F)		0.0003		0.0003		0.0057		0.0009		0.0001	
Replicate Prob(F)		0.7609		0.7801		0.8247		0.3716		0.3053	

Table 27b: Cherry tomato trial -fruit size and calyx retention with ANOVA results

There was no significant difference in the number of plants per hectare between the various cultivars. The average plant population across the trial cultivars ranged from 22,588 to 23,807 plants per hectare (*Table 27a*). There was also no correlation between plant population and yields in this trial.

The commercial cultivar yields for cherry tomatoes in 2018-2019 were almost half of those of the previous season. Some of this yield reduction may be due to the crop being sown as a single row on 1.52 metre beds as opposed to the double row trial on 1.83 metre beds last year. However, the grower also noted that after the heavy rains earlier in the season, plant growth slowed dramatically. Fruit breakdown was also more widespread this season.

The three cultivars with the largest fruit size also showed the highest fruit yields, with 94903 (a large grape cultivar) having significantly higher yields than the others. Of the small round cultivars, 94904 had higher yields than the others, although this difference was not significant (*Table 27a*).

The two cultivars with the largest fruit also produced statistically significantly higher tonnes per hectare of soluble solids than 93800 (*Tables 27a and b*).

Comparing the tonnes per hectare of soluble solids produced by the cultivars with small round fruit, 94904 had the most, but this difference was not statistically significant even when the data from the three small round cultivars was analysed separately.

There were no statistically significant differences between the raw fruit pH of the various cultivars. The commercial cultivar 93800 had the lowest pH and the large grape sized cultivar 94903 had the highest (*Table 27a*).

The cultivar 94829 had significantly lower calyx retention on healthy ripe fruit than the other four cultivars (*Table 27b*).

Although there were no statistically significant differences between the calyx retention of the commercial cultivar 93800 and 94904, the percentage of attached calyx increased from around 12 to just below 31 percent. SPC's Raw Fruit Specifications for cherry tomatoes list fruit with attached stems as defects. These would be included in culls, and the combined total net weight of culls should be under 15 percent (Ferrier, 2019).

These specifications also list the acceptable range of fruit diameter as being from 1.5 to 3.0 centimetres. All the small round cherry cultivars fit this criterion, but the average of the largest ten fruit from the cultivars 94903 and 94905 were greater than three centimetres.

The average diameter of the smallest ten fruit from each of the cultivars was greater than 1.5 centimetres.

The cultivar 93800 had the most consistent fruit size, but there was no statistically significant difference in the range of fruit diameters between 93800 and 94829. Both the cultivars 94904 and 94905 had a significantly larger range of fruit sizes than 93800 (Table 27b).

There were no significant differences in average fruit weight between the three small round fruit cultivars, all were less than eight grams per fruit. The two cultivars with larger fruit had average fruit weight over 18 grams which was significantly heavier than the small round fruit cultivars. The varieties with heavier fruit had correspondingly higher yields (*Table 27b*).

Summary of Cherry Tomato Trial results

Overall there was more fruit breakdown this season compared to last season.

A summary of the various cultivars in comparison to 93800 follows:

- 94829 (small round) - slightly lower yield than 93800 and statistically significantly lower calyx retention
- 94902 (small round) - poor vine and too much breakdown
- 94903 (large grape) - too large for canning but calyx release okay
- 94904 (small round) - highest yields of small rounds but too much calyx retention (over 30 percent)
- 94905 (large round) - too large for canning
- 94906 (large grape) - too large for canning, too much breakdown

SPC also ran a half paddock yield comparison test between the 93800 and 94829 cultivars in the same paddock as the replicated trial. The yields obtained were 29.2 tonnes per hectare for 94829 and 30.9 tonnes per hectare and higher calyx retention for 93800 (Ferrier, 2019 pers. comm.).

In the past two seasons the cultivar 94829 displayed statistically significant improvement in calyx release and slightly lower (though not statistically significant) yields than the current commercial cultivar 93800. None of the other cultivars trialled matched all the criteria for canning due to problems with fruit size, calyx retention or poor holding ability.

Acknowledgements

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References

Anthon GE, LeStrange M, Barrett DM. Changes in pH, acids, sugars and other quality parameters during extended vine holding of ripe processing tomatoes. J Sci Food Agric. 2011 May;91(7):1175-81. doi: 10.1002/jsfa.4312. Epub 2011 Mar 7.

A. Etienne, M. Génard, P. Lobit, D. Mbeguié-A-Mbéguié, C. Bugaud, What controls fleshy fruit acidity? A review of malate and citrate accumulation in fruit cells, *Journal of Experimental Botany*, Volume 64, Issue 6, April 2013, Pages 1451–1469, https://doi.org/10.1093/jxb/ert035

Ferrier A. (2019). SPC Cherry Tomato Specifications Tomato disease field guide, July 2017, De Ruiter & Seminis, https://www.deruiterseeds.com/en-us/resources/disease-guides/tomato-disease-guide.html

TM17000: Processing Tomato Industry Capacity Building

Peter Gray, Ann Morrison, Bill Ashcroft and Liz Mann

Introduction – Industry Strategic Plan

The 2018-2023 Strategic Plan identifies three key outcomes for the industry. These are:

- Building skills, capacity and knowledge in the industry so that the capability exists to implement Research, Development and Extension (RD&E) and marketing outcomes and deliver the supply and quality improvements needed by the industry;
- Provide support for new or enhanced market opportunities, both domestically and increasingly for export, in order to increase demand and support processing tomato prices; and
- Undertake RD&E to improve product quality (including new varieties) and increase productivity/reduce yield variability in order to support the industry's future viability and sustainability.

Commencing during the 2018/19 season, TM17000 is jointly funded by levy funds through APTRC and Commonwealth funds through Hort Innovation. It is the key industry strategy to deliver most of the outcomes described above. Specifically, its objectives are to:

- Co-ordinate information delivery to the industry;
- Increase industry understanding of the latest relevant R&D outcomes and the adoption of R&D by processing tomato businesses;
- Increase the reach of the industry R&D program by engaging stakeholders in the R&D process, including on-farm trials;
- Collect industry benchmark data and statistics to help identify gaps and direct industry development efforts;
- Provide an accurate representation of the industry with stakeholder groups, such as Plant Health Australia; and
- Identify and secure other funding sources to support RD&E aimed at industry development.

TM17000 continues a long history of RD&E activity by the APTRC. Commencing under initial IDM, Lauren Thompson, this activity was ably continued over many years by Liz Mann. Liz completed her employment with APTRC at the end of this 2018/19 season (see further article).

TM17000 activities and outcomes

Cultivar Evaluation

During the 2018/19 season APTRC conducted 12 machine-harvested cultivar trials looking at seven cherry tomato varieties, three early-season and six mid-season varieties or mixes thereof. Twelve additional varieties were also assessed in two observational trials (see further article).

The machine-harvested trials were planted as randomised complete block trials with statistical analysis (ANOVA) performed on the results.

One early season cultivar (H1766) showed promise as a potential replacement for the existing commercial cultivar with a better range of disease tolerances and similar yields. We are keen to continue trialling this cultivar in the future subject to seed availability.

In the mid-season trials, the cultivar UG16112 showed slightly higher yields than the commercial H3402 mix in eight trials. Further testing of this cultivar by itself and in various mixes will continue in next season's trials.

Two Seminis cultivars performed well in the observational trials and have been included in the 2019/20 machine harvested trials.

Difficulty in obtaining statistically significant results is an ongoing problem in the cultivar evaluation program, and in agricultural trials in general. After discussions with an agricultural consultant, APTRC have decided that in addition to our usual trial program, three small plot will be included nearest- neighbour cultivar trials in the 2019/20 season.

On-Farm Trials

Four commercial biological products were trialled during the season; each containing various rhizobacteria to promote plant growth (see further article). The products used were:

NitroGuard DEFENDER – *Diazotrophs* plus *Bacillus* microbes;

CataPult – Vesicular Arbuscular Mycorrhizae, plus two species of *Bacillus* microbes;

Serenade Prime – *bacillus subtilis* strain QST 713; and

Tri-Culture – *Bacillus licheniformis*, *Bacillus methylotrophicus*, *Bacillus subtilis*.

The first three products were part of continuing trials commenced in 2017/18.

Unfortunately, this season there was no clear benefit shown by any of the treatments over the control.

Trials of commercial products will continue to be part of R&D in a bid to mitigate some of the conditions produced by the extreme variability in the Australian agricultural environment.

Identify new crop threats

Biosecurity remains a high priority for the industry, and through continuing liaison with state and federal authorities the Industry Development Manager maintains a watching brief on potential threats emerging from overseas and elsewhere in Australia.

As a signatory to the Emergency Plant Pest Response Deed (EPPRD) and industry member of the Consultative Committee on Emergency Plant Pests (CCEPP), the APTRC has a chair at the table of regular national discussions on biosecurity issues. Liz was particularly active in this area, as well as engaging with other horticultural industries in biosecurity planning and surveillance. Field monitoring for the Tomato Potato Psyllid for example, was conducted in tomato crops last season in conjunction with monitoring in potato crops. No psyllids were detected.

Pest alerts, disseminated through the CCEPP, are communicated to industry members through Tomato Topics and extension activities. Over the past twelve months, brown marmorated stink bug, brown fruit rugose virus and fall army worm have all featured in biosecurity discussion related to processing tomatoes.

Industry Development

In addition to RD&E projects instigated by APTRC, which aim to deliver the objectives of the industry strategic plan, industry development also covers the capacity to capture funding grants from government programs for complementary RD&E, and Liz had been very successful at doing so. During the season, the following projects were undertaken through grant funding.

Two Regional Land Partnership 'From the Ground Up' projects through Goulburn Broken Catchment Management Authority. The first project assisted an understanding of the impact of sub-surface drip irrigation on soil compaction. Under Dr Richard Doyle from the CRC for Soils, pits were dug at three sites and the results presented at a workshop on 16 October. The observations and discussions from this project were presented at the 2019 Industry Forum, developed in a follow-up workshop, taken up in developing the 2019/2020 soils project under Sam North.

The second project studied the relationship between soil pH and pathogenic Fusarium and Pythium. Conducted by Dr Paul Taylor's team from The University of Melbourne, soil pH measurements were taken at various distances from irrigation emitters (see further article). Generally, the pH at the emitters was found to be more acid than in the shoulders of the rows. The growth rates of pure cultures of *Fusarium oxysporum* were then measured under controlled conditions. There was no significant difference in growth of *F. oxysporum* between pH of 5, 6, 7 and 8, although it was felt that actual field conditions may present

s different result. Again, this work will be incorporated into the 2019/2020 soil project.

Again through Liz, a Horticulture Innovation Fund project through the Victorian Department of Economic Development, Jobs, Transport and Resources was undertaken in conjunction with the seed potato industry. This project was intended to lead to a new and improved insect surveillance system by establishing insect traps in processing tomato and seed potato regions. Information from the traps will be used to monitor endemics, and provide a monitoring tool for biosecurity. At the time of writing the insect traps have been manufactured and will be distributed and monitored during the 2019/2020 season.

Disseminate information to the industry

Information is disseminated to the industry through a range of events and media. These include; the Industry Forum, crop inspections, a quarterly newsletter and an annual magazine. In addition, materials and information are emailed to stakeholders as specific matters arise.

It was decided to upgrade the APTRC website, to introduce contemporary web software and improve the capacity to upload a range of information more effectively. This work will be completed in 2019/2020.

APTRC will be undertaking further work on the evaluation of various development methods through a specific session at the 2020 Industry Forum. Although evaluation responses at Forums have typically produced high levels of stakeholder satisfaction with presentation and content, responses to other events have been less forthcoming and APTRC must persist in ensuring that stakeholders are given the most appropriate opportunities to assist their understanding of potential development gains.

Collate annual industry statistics

The 2019 Annual Industry Survey (see further article) continues a multi-year series of reports which are recognised for their high degree of accuracy. Born out of the critical 1996 Industry Benchmarking Report, the annual surveys present each season's data as a guide to how the industry has developed since the initial benchmarking work. Now that a significant body of statistics has been gathered over many seasons, this year's report has attempted to identify some of the key messages that are underpinned by the data and will help to inform future industry strategies.

Industry publications

There are two industry publications; the quarterly *Tomato Topics* newsletter, and this *Australian Processing Tomato Grower* magazine. The four editions of *Tomato Topics* included subjects such as:

- IPM for processing tomatoes
- Updates from Sophia Callaghan on her project work (see further article)
- Biosecurity updates, including the principles of farm hygiene
- Reports on the cultivar and small-plot trials of commercial products
- Regional pest and disease pressures, including bacterial speck by Margaret Tuttle McGrath from Cornell University
- Drip irrigation; observations from California
- An overview of the 2019 Industry Forum
- Tomatoes and health
- Cost of Production, sample costs from California
- WPTC global production data

Annual Industry Forum

The Industry Forum was held in Echuca on 13 June, attended by 61 stakeholder representatives. Typically, the annual Forum provides an opportunity for researchers to present and discuss their season's work. For the 2019 Forum the opportunity was taken to invite a number of stakeholder speakers with commercial backgrounds, enabling broader discussions on some key topics, including:

Water availability and pricing – Mark Bailey from Goulburn-Murray Water, and consultant Andrew Bomm

The processor view – Jason Fritsch from Kagome and Andrew Findlay from SPC

New irrigation trials – Chris Taylor from Kagome and Andrew Pollard from Netafim

Soils – Sam North from NSW DPI and consultant Christian Bannan

Pest and disease control – Sophia Callaghan from The University of Melbourne and Keith Fallow from Bayer

Cultivars – Ann Morrison and Bill Ashcroft from APTRC

The evaluation follow-up indicated that attendees appreciated the industry scope covered during the day. Discussion during and after the Forum then led to the planning and implementation of the multi-disciplinary soils project in 2019/2020.

Field Days

Two field days were held last season, both of which were well supported by growers, agronomists and industry representatives.

The Lake Boga/Boort region crop inspection tour was held on the 19th December, starting with a visit to an organic processing tomato block, followed by inspections of a number of tomato crops in the Boort area. The afternoon ended with a dinner held at a local grower's property.

The annual drip irrigation crop inspection and dinner was held under very hot & windy conditions on the 18th January. The tour covered a diverse range of enterprises including carrots grown under pivot irrigation, high amylase maize and a dual lateral line tomato trial. Dinner following the tour was held at a processor representative's property.

In addition to the Industry Forum, the Field Days provide an opportunity for networking and collegiate contact. The Australian processing tomato industry is comparatively small, but it punches above its weight on the global scene and stakeholders benefit from quality opportunities to get together.

Harvesting Observational Trials

Conclusion

TM17000 continues a long-line of capacity-building projects that have brought immense benefit to the industry. Acknowledged in a number of strategic plans, these projects provide a key platform for producers to consider and implement tested technologies, products and practices, the combination of which has maintained our competitive position.

As noted in the Industry Survey, agronomic, climatic and competitive pressures don't disappear; once a solution is found for one issue, a new one arises. The APTRC Committee continues to see the capacity-building projects as being vital to the long-term success of the industry by assisting stakeholders to meet new challenges.

2019 SPC Tomato Field Report

Andrew Ferrier, Field Manager SPC

Tough domestic market conditions in canned tomatoes led to a slight reduction in tonnage contracted to SPC for season 2019. With two growers retiring from the industry, 46,850 tonnes were contracted with 7 growers across 469 hectares (81% transplant; 19% direct seed). For 2019, H3402 remained the main variety grown for SPC (324 Ha) with H1015 (72 Ha), H1175Mix (62 Ha), trials of H1538 (1.1 Ha) and UG19406 (2.2 Ha) as well as 8 Ha of cherry tomatoes making up the balance.

Bed preparation was hampered by the extended dry conditions, the low soil moisture levels forcing growers to use more water than anticipated to prepare blocks for planting, which began in late September and continued largely uninterrupted until late-November. A cool start to the growing season and seemingly endless wind throughout the September – December period slowed the growth and development of young tomato crops. A hail storm on November 20th in the Rochester area resulted in a small area being replanted. With an eerie similarity to the previous season, albeit a couple of weeks later, a significant 4-day rain event occurred in mid-December with 35-80 mm recorded across the growing regions. This was followed by several days of high humidity and with growers unable to traffic paddocks to spray, an incredibly high incidence of Bacterial Speck, at levels not seen before, ravaged the developing crops. The disease pressure severely set back early crops, with growers doing all they could in the ensuing months to revive their crops and maximise their recovery. Extreme temperatures in late December and a January which saw the highest monthly mean temperature recorded at the Echuca Aerodrome (36.8°C) contributed to an extended heatwave in which maximum temperatures averaged 38°C, affecting plant development with many crops unable to recover fully from the multiple setbacks. The result was low vigour, split sets and poor yields, especially in early crops.

Harvest began for SPC on the 14th of January with the cherry tomatoes; the main processing crop beginning on the 29th of January and continuing through until the 14th of April. Favourable conditions prevailed for most of the harvest period with the only rain interruption occurring on the 7th of February. Harvest was delayed in part due to the rain but also due to green fruit. A second maturity delay in mid-March also stopped production as the impacts of the rain and heat events during the growing season were felt. Ethrel was again widely used during the harvest period to try to minimise the delays and enable SPC to continue harvest operations whilst optimising fruit quality and maximising fruit yield.

More consistent, reliable factory throughputs were a feature of the 2019 processing season, as the SPC plant continues to show improvement year on year. For season 2019 SPC processed 38,957 (paid for) tonnes at an average yield of 84T/ha. Average brix for the season across all varieties was 5.24°Bx. Average canning percentage was 80%, non-canning 13% with 7% Cull/Reject. H3402 (70%) again accounted for the majority of the tonnes processed. Along with H1015 (15%) and H1175Mix (13%), the remainder comprised of Cherry tomatoes and the variety trials.

Whilst water allocations reached 100% by February and Lake Eildon remained at moderate levels, the nature of an unfair water market meant that water prices were at artificially inflated levels throughout the season, with no relief in sight. Rainfall for the first half of 2019 is well below average following on from a dry 2018, causing a great amount of uncertainty in the processing tomato industry and the agricultural sector in general. Processors and growers will need to continue to work together to ensure the survival of the processing tomato industry through these troubling times and secure a strong future for all involved.

Kagome Field Report

Matt Wright, Field Manager, Kagome

The 2018-2019 season commenced with planting on September 24th. The mid and later windows of planting were affected by frequent showers and strong winds which delayed completion until December 2nd, 14 days past the original target.

November and December also presented less than ideal growing conditions with frequent wet weather igniting higher than average levels of bacterial disease through all plantings, with the most advanced crops being heavily penalised.

January's maximum temperature was six degrees above the long-term average, placing a lot of pressure on irrigation systems which we haven't seen for a number of years.

Harvest commenced on January 31st, with the early crops slightly down on yield as a result of November weather conditions. But as harvest progressed, yields slightly increased and as a result a total of 171,461 gross tonnes, 85% of contract, was harvested with a grower average of 95t/ha.

The factory had 3 stops during the season, but overall the conditions during the entire harvest window were rather forgiving, resulting in high quality of the finished product.

There were nine varieties selected to deliver the overall volume, targeting viscosity and good colour throughout the various stages of the harvesting window. All varieties were put to the test with the high incidence of bacterial diseases. The varieties combined delivered an average of 5.2 brix which was slightly up on the previous season and the long-term average.

The grower group had a yield spread ranging from 68t/ha to 167t/ha, with rotational programs being the biggest influence on the yield results. New fields and fields that had a long rotation were the most productive, while the shorter rotations netted the least desirable outcome.

The winter months were dry as was spring and, with the season underway, water allocations are still low and temporary market prices are rising. As a result, this has caused a lot of uncertainty for Australian farmers across a variety of industries. Many growers are currently reviewing their season's strategies and adjusting their plans to get the best outcome from their own situations.

Kagome's estimated requirements for the 2020 season will be down slightly on 2019 due to the drought, limitations on water availability and cost, and an overall reduced grower area.

The varietal selection did not differ from the previous season, however H1175mix (50% H3402: 50% H1175) proved to be strong, with good placement noted for the entire delivery window.

The 2018 winter has been extremely dry with little rainfall received across the catchment, causing a sharp spike in water price. The outlook for the 2019 season is warm and dry and, as history would suggest, a prediction like this normally means clear skies and a positive tonnage outcome.

Australian Processing Tomato Research Council Inc.

Hort Innovation
Strategic levy investment

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