Australian Processing Tomato Grower

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Hort Innovation
Strategic levy investment

PROCESSING TOMATO FUND

AUSTRALIAN PROCESSING TOMATO GROWER

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INTRODUCTION

The APTRC is once again pleased present this publication as a record of the industry's research and development program and major events. We also thank all the businesses and agencies that support these activities.

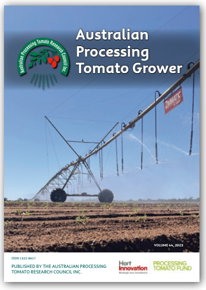
APTRC Committee members 2023.

Left: Charles Hart.
Middle: Tony Henry.
Right: Matthew Stewart.

Left: James Weeks.
Middle: David Chirnside.
Right: Nick Raleigh.

Left: Andrew Ferrier.
Middle: Chris Taylor.
Right: Stuart McColl.

Profit and Loss - Australian Processing Tomato Research Council Inc **For the year ended 30 June 2023**	**Hort Innovation**	**Research**
INCOME		
Levies	55,169.95	110,339.90
Interest Received	517.29	10,776.14
Total Income	***55,687.24***	***121,116.04***
EXPENSES		
Accounting	-	636.36
Audit	-	977.27
Biosecurity	-	2.74
Depreciation	-	8,165.08
Grower Levies - Hort Innovation	125,285.00	55,169.95
Memberships & Subscriptions	-	1,500.00
Project - Melbourne University PhD Hanyue	-	20,000.00
Study Tour (USA) - Expenses	-	6,135.00
Travel Expenses	-	2,859.78
WorkCover	-	118.92
Total Expenses	***125,285.00***	***95,565.10***
Net Surplus/(Deficit)	***(69,597.76)***	***25,550.94***



Cover Photo

Kagome tomatoes growing in sand with Pivot Irrigation

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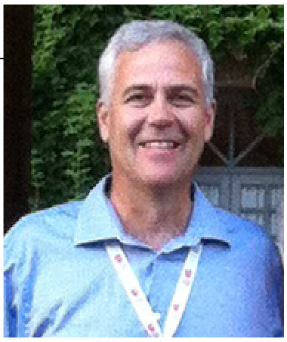
The project [Australian Processing Tomato Industry Development and Extension Program (TM20000)] which includes the production of this magazine has been funded by Horticulture Innovation Australia Limited with co-investment from Australian Processing Tomato Research Council Inc. and funds from the Australian Government.

Notice to Contributors:

Authors wishing to contribute articles to the next 'Australian Processing Tomato Grower' should submit copy to IDM, Matthew Stewart at APTRC Inc., aptrc.idm@outlook.com NO LATER THAN June 30, 2024.

APTRC – Chairman’s Report 2022/23

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



As we reflect on the 2022/23 season, the numerous challenges faced by the entire processing tomato industry come to the forefront. Our members were faced with challenges from the outset, with significant and widespread rainfall that impeded field preparation efforts. Subsequently, during October, our members had to deal with the potential and realised effects of rising river levels and damaging floodwaters on properties.

For those growers who managed to make progress later in the planting season, most achieved only about half of their initial contracted planting area. Cool temperatures and localised hailstorms further hampered crop development and productivity across the regions. Consequently, the 2022/23 season saw growers delivering a total of 110,621 tonnes of processing tomatoes, representing just under half of the pre-season forecast estimates. Yields were notably suppressed, averaging 67.9 tonnes per hectare. This outcome, in an extremely challenging season, required all the skill and resilience our members could muster. Despite their efforts the average yield fell below the high averages that our members typically achieve.

The extension efforts led by our IDM Matt Stewart, and Research Manager Ann Morrison, played a pivotal role this year, extending beyond information and technology transfer. The December Boort Region and February Netafim Field Days provided growers with a welcome opportunity to step away from their own farms, connect with peers, and share valuable experiences from the challenging season.

The APTRC Annual Forum, held at the Moama Bowling Club, witnessed significant attendance and featured a diverse range of speakers. Highlights included insights from CEO Jason Fritsch into Kagome Australia’s current challenges, and the strategies the company has in place to improve resilience both for itself and the industry as a whole. We also heard from Kagome’s senior agronomist, Stuart McColl on their challenging, innovative and ultimately successful transition to sand-grown tomatoes in NSW. Stuart and his colleagues have pushed the boundaries on when, where and how tomatoes can be grown in our region. Agriculture Victoria’s Nick O’Halloran and Joe Braden shared findings from irrigation surveys conducted during the season, exploring ways to help industry enhance design and better manage irrigation systems in the future.

A noteworthy presentation by Matt Stewart on behalf of the Tomato Foundation, a cause we’ve been supporting in recent years, promises to reshape the global perspective on processed tomato products and their positive effects on human health. Ann Morrison, with assistance from Bill Ashcroft updated us on the cultivar trial programs, revealing several new cultivars on the horizon that hold promise to bolster our resilience against local pest and disease pressures into the future.

In the realm of research and development, our collaboration with the University of Melbourne on soil-borne disease work, led by PhD student Hanyue Feng, provided a very important finding. Hanyue’s identification of *Fusarium oxysporum* Race 3 in our seasonal samples, previously thought to be present only in Queensland Fresh Market tomatoes, underscores the importance of partnering with specialized departments to advance our knowledge.

In other research, the Australian National University concluded their study on tomato vine gasification, and their detailed report is available elsewhere in this publication.

Regarding our major funding partner Hort Innovation, we were informed that our regional manager, Adrian Englefield, was being moved to a new portfolio, and we extend our best wishes to him. With this change, we welcomed Mark Spees *(mark.spees@horticulture.com.au)* in the role of Industry Services and Delivery Manager (ISDM), serving as our go-to person for overall industry consultation regarding the investment of our Collective Industry Fund (CIF). Also, welcomed was Susie Murphy-White (*susie.murphy-white@horticulture.com.au)* who is now our Hort Innovation project manager/process owner, responsible for receiving and reviewing our Milestone reports and assisting with project inquiries. Matt has already established strong working relationships with these HI staff and is working closely with them to advance our industry agenda.

While 2022 saw the absence of several experienced growers due to personal or environmental reasons, there is optimism ahead and we look forward to those growers growing and delivering tomatoes in the upcoming 2023/24 season.

In 2023, our committee has welcomed David Chirnside and Nick Raleigh to the APTRC, both serving as grower representatives. Both have material, very broad and relevant experience in the industry. We look forward to their involvement and contribution on the committee.

On behalf of the committee, and in my personally capacity, I wish to thank Tony Henry who has played a pivotal role on the committee and who has been of great support to me. Tony’s exceptional attention to detail, his enthusiasm and vast knowledge on all things scientific has been invaluable in assisting the committee in its role. Despite having decided to no longer grow tomatoes we are hopeful that he will remain an active participant in the industry as his vast experience and expertise will be sorely missed. We wish him and Ro all the very best as they try and “slow” down.

In conclusion, the committee and I extend our sincere thanks to the growers and processors for their assistance and cooperation in facilitating the APTRC trial program, particularly under some of the most challenging conditions possibly ever experienced during a planting period. Special appreciation goes to Matt and Ann, with assistance from Bill and the volunteer committee members, for their continued enthusiastic support of our industry members.

Hort Innovation update

Susie Murphy White, Industry Development and Innovation Manager

In 2022/23, the Hort Innovation Processing Tomato Fund continued to invest in the project *Processing tomato industry development and extension* (TM20000). This project is delivering effective research, development and capacity building solutions to Australian processing tomato businesses, to improve profitability and sustainability.

Led by Matt Stewart and Ann Morrison with support from Bill Ashcroft, the *Processing Tomato industry development and extension* (TM20000) project is the only processing tomato project funded by Hort Innovation, using the voluntary research and development levy, funds from the Australian Government and in-kind contributions from the APTRC.

On the Hort Innovation website at [Hort Innovation | Processing tomato industry development and extension (TM20000) (horticulture.com.au)] you can read about how the extension project has built capacity in the industry. Delivering *Tomato Topics* quarterly newsletters, field days, industry events, annual magazine and the completed industry survey on production and consumption. It is always a pleasure to review Matt's milestone reports as he is delivering a very worthwhile project for industry. It is pleasing to see that the industry is a resilient and robust industry after facing some challenging conditions. I look forward to meeting the members of the processing tomato industry in 2024.

The Hort Innovation Processing Tomato Fund financial forecast for 2023/2024 is showing a deficit for the coming financial year. The plan to extend the project over the next financial year will bring the project funds into the black for the final milestone payment in 2027/2028.

Table 1. Processing tomato financial forecast statement for 2023/2024.

Processing Tomatoes Fund	**R&D** **2023/2024** Forecast from actuals 27/11/23
Opening Balance	-131,284
Levies from growers	120,000
Commonwealth funds	50,829
Other Income	-500
Total Income	170,329
Project funding[1]	87,426
Available for Investment	0
Grower Consultation & Advice[2]	0
Service delivery	14,232
Total matched expenditure	101,658
Closing balance	-62,613

The 2022/23 Fund Annual Report that covers all of Hort Innovation's 37 industry funds is also available on the **Hort Innovation website**.

I encourage you to have a read of the 2022/23 Fund Annual Report as it includes a background to Hort Innovation – who we are and how we operate, consult, invest, work with our partners and report. Last year, Hort Innovation invested over $139M in levies, Australian Government contributions, grants and co-investment. Our role is to capture value from the investments we make to benefit all levy payers. We look forward to a great year ahead of investment on behalf of the horticulture sector.

If you have any questions or would like to discuss anything with Hort Innovation, please feel free to call Susie Murphy White Industry Development and Innovation Manager **Susie.Murphy-White@horticulture.com.au** about the industry development and extension project and Mark Spees Industry Services and Delivery Manager **Mark.Spees@horticulture.com.au** about R&D advisory panel and new investment priorities.

Annual Industry Survey 2023

Matthew Stewart

Executive Summary

The annual industry survey provides a year-on-year comparison, detailing industry performance in the current year compared with the previous one.

The data also tells the 'story' of Australian production and international trade over a longer period of time, supporting analysis of where the industry is headed, for example in terms of grower numbers, production, and location.

The 2022/23 season presented significant and unique challenges with major flooding and widespread rain affecting both the total area planted and the total yield delivered. The planted area in 2022/23 was below original forecasts due to flooding and weather delays that occurred prior to or during typical field preparation timeframes.

During the 2022/2023 season, twelve growers produced 110,621 tonnes of processing tomatoes, a significant decrease compared to the volume grown in 2021/22, and the crop was again processed by three companies.

Some 1733 hectares were planted, with total use of sub-surface drip irrigation. The use of transplants was significantly high at 94% of the total area under production, with seeded tomatoes making up the remaining 6%.

In 2022/23, the Australian processing tomato industry achieved an average yield/ha of 67.9 tonnes and 95% of planted area was harvested

Soluble solids averaged 5.3%, which is the highest figure in over 10 years. However, this is likely due to the fact that crop yields were down and what we're observing is the typical inverse relationship between yield and solids.

On the international scene, imports and exports are reviewed and discussed in the context of the previous calendar year (2022), not the abovementioned processing season (2022/23).

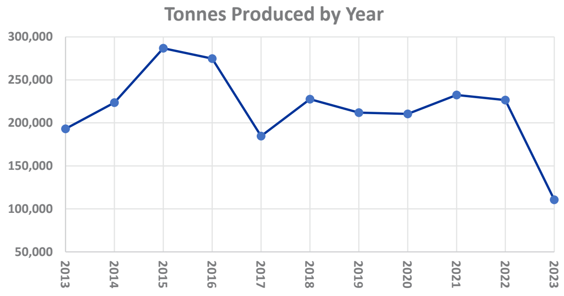
The importation of processed tomato products into Australia increased during the 2022 calendar year, continuing a slow but clear trend upwards. Exports of Australian processed tomatoes on the other hand dropped by a significant figure of 36% in 2022. This export figure won't likely improve for another year or two given the lower than ideal harvest from the 2022/23 season.

Total Australian domestic consumption increased in 2022, however it was supplied by imports rather than local product. An ideal situation would be to see increased consumption being also supplied by a higher proportion of domestic production.

Australian domestic per capita consumption increased again, and Australia remains one of the highest consumers of tomato products per capita in the world.

Industry Size

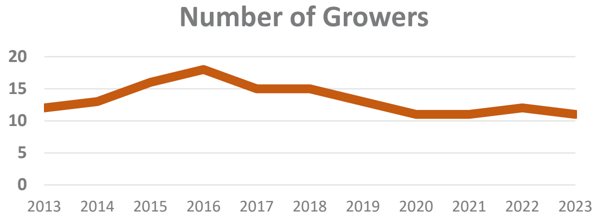
Volume



Paid tomato volumes delivered (tonnes) (APTRC)

Growers produced 110,621 tonnes of processing tomatoes during the 2022/23 season, with the bulk of demand coming from the two major processing operations in Australia. Contained in the total production figures are organically grown tomatoes, which contributed 282 tonnes of produce (a significant decrease on the previous season).

Producers



Number of growers (APTRC)

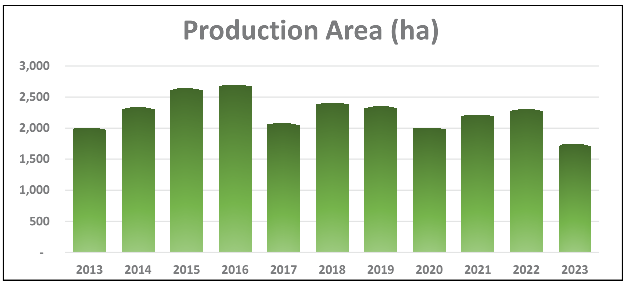
The grower number fell to 11 specialist businesses for the 2022/23 processing tomato season, spread mainly across Northern Victoria, with a lesser number growing in Southern NSW.

Processors

As in the previous season, the entire crop was processed by three organisations, with Kagome processing 81.5%, SPC 14.3% and Billabong Produce 4.2%.

The Crop

Area and management



Planted production area (ha) (APTRC)

The area under production decreased to 1733 hectares, of which 95% was harvested. The smaller area planted (or successfully established) this season was a direct result of the effects of excess rainfall and flooding early in the season.

Season	Transplanted	Seeded
2010/11	79%	21%
2011/12	81%	19%
2011/13	72%	28%
2013/14	59%	41%
2014/15	68%	32%
2015/16	69%	31%
2016/17	86%	14%
2017/18	88%	12%
2018/19	91%	9%
2019/20	86%	14%
2020/21	90%	10%
2021/22	85%	15%
2021/23	94%	6%

Proportions of transplants Vs seed by area grown (APTRC)

This season, the crop was again fully grown under sub-surface drip irrigation, which is likely to remain the status quo for the Australian industry.

There was a decrease in the proportion of direct seeded crop grown this season. This was due to a crop being wiped out by floods and also because of one grower exiting the industry entirely and another grower opting to step out for just this past season. The Boort region is still the only area direct-seeded and represented 6% of the total industry by area in 2022/23.

Area and Production by State	VIC	NSW
Area Planted	65.0%	35.0%
Tomato Volume Processed	65.0%	35.0%

Production by State (APTRC)

In the 2022/23 season, the relative planted area (%) and production amount (%) by state aligned perfectly. This suggests that the area planted and yield per hectare from those areas is relatively stable (on the average at least) across not just states, but different water, soil and climatic conditions.

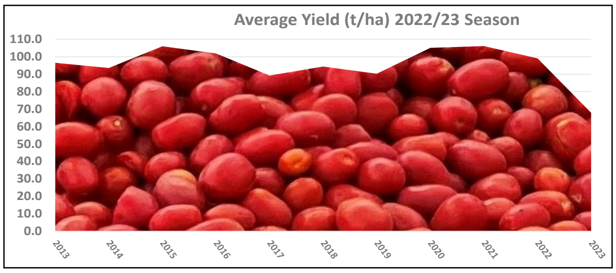
Yield

Season	Area (ha)	Area (ha)	Harvested	Average Yield	Seasonal Comments
	Planted	Processed	Area %	t/ha	
2012/13	1999	1998	100%	96.6	Wet, late harvest
2013/14	2386	2330	98%	93.6	Wet, late harvest
2014/15	2700	2635	98%	106.1	Early crop failure
2015/16	2782	2697	97%	101.9	Poor crop stand, delayed harvest, over-contract fruit
2016/17	2183	2071	95%	89.2	Delayed harvest due to rain
2017/18	2457	2407	98%	94.4	Some crop abandoned due to factory power outage and resulting delay
2018/19	2347	2347	100%	90.3	Extreme bacterial speck, high temperatures
2019/20	2073	2003	97%	105.1	Hot and windy during growing; late harvest rains
2020/21	2215	2215	100%	106.13	Dry start, strong winds mid spring, some hail, mild summer
2021/22	2480	2300	93%	99.1	Delays from staff scarcity and crops abandoned due to wet finish
2022/23	1733	1643	95%	67.9	Excess early rainfall & flooding caused planting delays and losses.

Average yield, harvest conditions (MT/ha) (APTRC)

The excess early rainfall and flooding events hampered efforts to adequately prepare fields for planting. Also, the flooding completely wiped out 75 ha of early production in the Boort region and later, 15.5 ha was ploughed in after poor early performance due to adverse weather conditions in the North Central region.

The 2022/23 season saw a significant decrease in yield average, resulting mostly from growers having inadequate time to prepare fields to their usual high standards; from planting outside of the ideal timeline; and from poor weather conditions, including severe hail and wind events and persistent low temperatures.



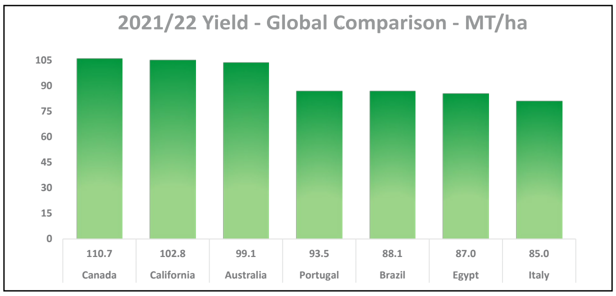
Average yield (t/ha) (APTRC)

The industry recorded an average yield of only 67.9 tonnes per ha for season 2022/23, which by global standards is a lower than ideal outcome. However given the extreme constraints of the season, the figure is quite explainable.

The industry had to adapt to the season by planting many weeks outside the usual schedule, by working intensely with nurseries to alter transplant orders and by trialling alternate soil preparation methods for planting.

The major grower last year, Kagome Farms even utilised their knowledge in growing other processing crops in sand under a combination of pivot and drip irrigation to achieve whatever tonnes they could late in the season to help satisfy buyer demand. Planting on sand may now become a standard practice for a portion of the crop in future to help mitigate risk and widen the planting/harvest window for industry.

Additionally, the ongoing annual industry cultivar evaluation trials and research into root disease are some of the current actions the APTRC and the Australian processing tomato industry are undertaking to help achieve higher yield outcomes under adverse climatic conditions.

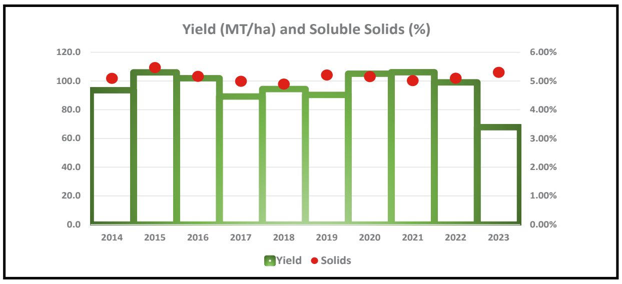


2022 average yield (MT/ha), by country (Colvine)

Note: To get the most accurate global comparison, data for international production is a season behind and in this report, represents the previous season (2021/2022). This is due to the offset availability of data from the Northern Hemisphere.

In the 2022 processing year, Australia achieved an average yield of 99.1 tonnes per ha. This result is slightly lower than ideal and was due primarily to delayed harvests. The causal factors for this were in the first instance, stilted processing operations and harvesting complications from a lack of available staff due to carry-over affect from the pandemic. In the second instance, rainfall from mid-April onwards further delayed harvest operations and ultimately left 180 ha of crop in the field.

Soluble Solids



Soluble solids (%) and yield (t/ha) (APTRC)

Average soluble solids for the season were 5.3%, which is well above the minimum benchmark of 5.0% preferred by processors. The past decade of results shows that the minimum soluble solids benchmark is being met (or very close to it) every season.

Cultivar

CULTIVARS	Percentage of Total Area Grown	
	2022/23	2021/22
H3402	24.3%	35.0%
H1015	18.4%	8.2%
H1014	14.4%	4.6%
UG19406/UG16112	12.4%	16.1%
H1301	7.8%	2.0%
H1311	5.8%	2.5%
UG4014	5.4%	4.0%
SVTM9000	4.7%	1.0%
UG16112	2.5%	0.5%
SVTM9024	2.0%	3.3%
H3406mix	0.9%	7.6%
H3406	0.6%	1.5%
H1311mix	0.4%	8.1%
HM58811	0.3%	0.2%

Cultivar by proportion of total area

When comparing the 2021/22 and 2022/23 seasons, there were some significant shifts in the balance of cultivars grown by area. Many factors influence the mix of cultivars grown from season to season including changing customer requirements, upgrading of processing infrastructure, new market access or loss of previous markets, seasonal harvesting logistics and agronomic suitability to growing region and soil type.

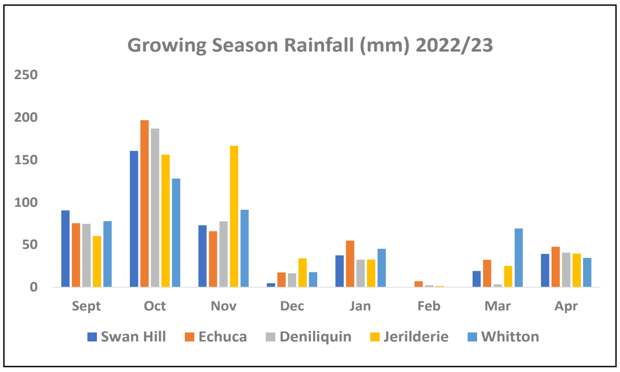
The trend away from the blending of cultivars in-field to obtain a desirable processing outcome is a noticeable progression in industry, with the introduction of alternative processing techniques making the mixing of cultivars less important.

There were no new cultivars commercially grown this past season either, which given the extreme challenges is not surprising.

The APTRC are hoping to re-establish the normal cultivar evaluation program this coming season and explore cultivars with improved genetic resistances to soil and foliar diseases.

The Season

Rainfall

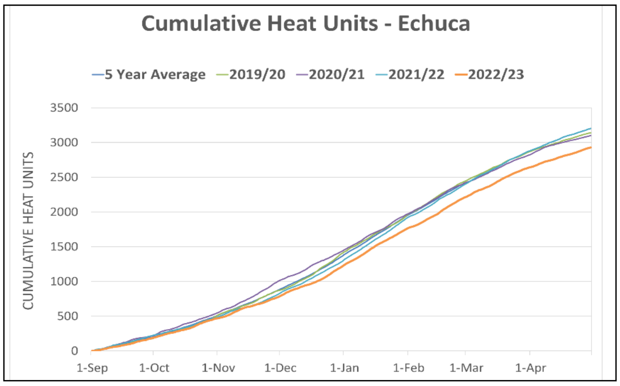


Rainfall across the major growing regions (mm) (BOM)

As seen in the above chart, for most regions, rainfall was extreme for the start of the season, particularly in October 2022 and as such planting and sowing operations were severely compromised. Planting is usually completed prior to December, however in the 2022/23 season, planting continued well into January 2023!

A few crops suffered hail damage early, which was highly unfortunate for those growers in the path of these storm events and led to some crop being ploughed in. Thankfully, the rainfall was more moderate for the rest of the season, allowing a relatively smooth (but late) harvest period.

Heat Units



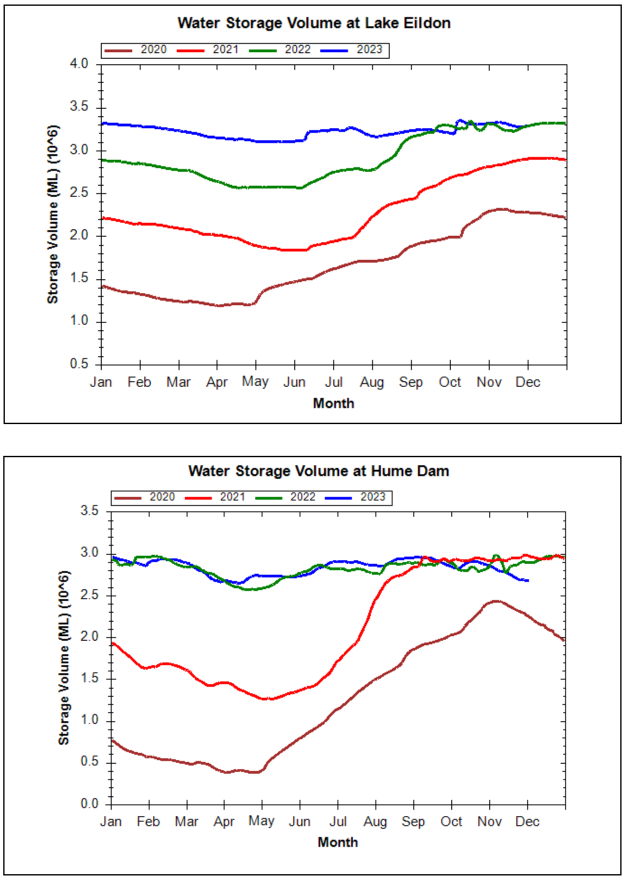
Heat units – Echuca (BOM)

The heat units recorded during the major crop growth period demonstrate that the season was cumulatively much cooler than the previous 5-year average and the most recent season.

This cool weather severely hampered growth in young transplants and most crops never achieved their full potential.

Although this graph uses data from Echuca, it's a central point for industry and can be generally considered indicative of what was experienced by growers in surrounding regions.

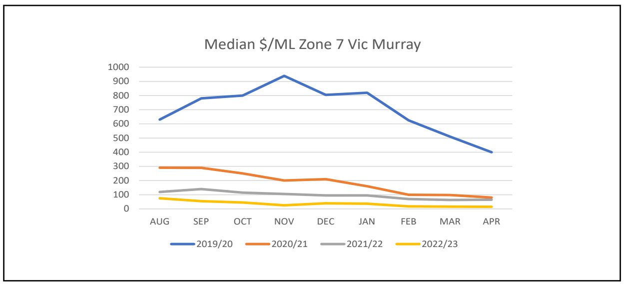
Water Storages

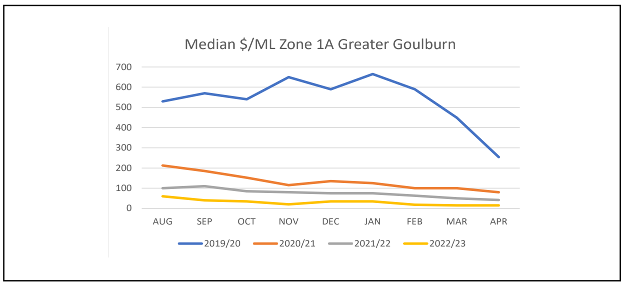


Storage Volume, Lake Eildon and Hume Dam (GMW)

The water storage levels across all catchments have remained high or increased significantly throughout the calendar year due to high inflows from last season's persistent La Niña climate conditions. The cost of water will be moderate to low throughout the 2022/23 growing season and due to the quantum of water in storages, availability should be relatively stable for at least the next season.

Water Price





Zone 1A and Zone 7 median water price ($/ML) (Registry)

The price of water during 2022/23 remained low and is a direct reflection of higher allocations and inflows into major water storages for Victoria and NSW during this period.

Water prices are predicted to remain supressed for at least another season.

Trade

Imports

Product	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Dried/powder	39,125	35,940	26,875	34,506	37,934	37,660	34,880	28,017	29,143	34,263
Whole/pcs <1.14L	48,060	42,660	45,222	40,965	43,354	42,683	41,799	51,121	36,356	45,488
Whole/pcs >1.14L	18,911	28,402	28,088	22,997	24,002	24,275	22,369	21,129	21,316	24,029
Paste/puree<1.14L	80,602	83,976	153,210	102,733	107,923	109,578	110,328	159,447	137,971	125,751
Paste/puree>1.14L	145,214	109,242	102,866	130,171	140,532	144,906	133,524	143,118	140,502	187,046
Juice [1]	137	116	75	83	38	75	50	30	17	47
Sauce/ketchup	33,633	38,628	39,276	38,462	45,705	45,946	47,050	48,375	45,788	51,585
Total Tomato	**365,682**	**338,964**	**395,612**	**369,917**	**399,488**	**405,123**	**389,999**	**451,236**	**411,093**	**468,210**

Imports of Tomato Products (equivalent raw tonnes) (ABARES)

The volume of imports rose significantly during 2022, with increases in all import categories, except for small pack 'Paste/puree'. Imports for 2022were the highest in well over 10 years.

The largest sources of these imports, sorted by category were as follows (where the major importer supplied less than 90% of the total, the next most significant supplier/s are also included).

- **Dried/powder** – Turkey 57.13%, Israel 12.14%, New Zealand 11.18%
- **Whole/pcs <1.14L** – Italy 96.46%
- **Whole/pcs >1.14L** – Italy 97.61%,
- **Paste/puree<1.14L** – Italy 83.76%, China 12.51%
- **Paste/puree>1.14L** – USA 51.32%, China 24.11%, Italy 18.26%
- **Juice** – Mexico 29.18%, UK 28.06%, USA 20.59%
- **Sauce/ketchup** – Italy 40.83%, New Zealand 19.39%, China 11.37%

At 67% of total volume (last year 68%), Italy remains the dominant source of imported processed tomato products into Australia. The next largest suppliers were USA and China, supplying 12% and 10% respectively into Australia.

Product	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Dried/powder	5.92	6.33	7.01	6.18	6.39	6.44	6.25	6.85	5.97	6.05
Whole/pcs <1.14L	1.22	1.38	1.37	1.41	1.25	1.30	1.38	1.53	3.33	1.58
Whole/pcs >1.14L	1.02	1.18	1.16	1.06	1.01	1.08	1.10	1.10	2.27	1.24
Paste/puree<1.14L	1.38	1.61	1.60	1.56	1.44	1.41	1.54	1.73	1.70	1.75
Paste/puree>1.14L	1.06	1.24	1.49	1.32	1.23	1.28	1.36	1.44	1.32	1.47
Juice [1]	1.12	1.45	1.80	1.02	2.70	2.00	2.05	3.40	3.65	2.85
Sauce/ketchup	1.76	1.93	2.01	2.01	1.99	1.99	2.09	2.41	2.37	2.22
Total Tomato	**1.33**	**1.51**	**1.54**	**1.52**	**1.44**	**1.47**	**1.56**	**1.70**	**2.33**	**1.70**

Average import prices ($/kg), in 2022 monetary values (ABARES)

Correlation between Imports and Price

- The overall price for imports during 2022 dropped significantly from the previous year's high of $2.33, to the same level as 2020 ($1.70/kg). However, despite this, the average price for Dried/powder and Paste/puree categories actually increased.

- The correlation across the past 10 years for Juice and price appears to be strengthening.

- Juice exhibits a strong negative correlation, meaning as price goes down, imports go up.

- The correlation across the past 10 years for Sauce/ketchup and price appears to be only moderate.

- Sauce/ketchup exhibits a moderate positive correlation, meaning as price goes down, imports go down.

- The correlations for imported product are quite varied and swing from moderately positive to moderately negative and deviate within different package sizes within category groups. Therefore, it suggests that overall, the variability in imported volumes does not appear to be strongly price driven for most categories (except for Juice).

Exports

Product	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Whole/pieces	1,075	2,552	746	461	133	62	139	623	273	417
Paste/puree	14,987	33,800	43,747	104,518	21,852	16,402	11,695	32,766	38,323	22,032
Sauce/ketchup	3,218	3,524	8,196	4,039	8,799	11,636	13,227	14,788	17,986	13,660
Juice [1]	224	195	131	57	50	80	106	52	47	118
Total Tomato	**19,504**	**40,070**	**52,819**	**109,075**	**30,834**	**28,180**	**25,167**	**48,228**	**56,629**	**36,227**

Exports of tomato products (ABARES) (equivalent raw tonnes)

The overall volume of exports decreased substantially in 2022, most noticeably in the paste/puree and sauce/ketchup categories. Juice and whole/pieces categories increased; however, they represent a small portion of total exports.

The largest export markets, sorted by category and then by country were as follows:

- **Whole/pieces –** Philippines 33%, Thailand 10%, Papua New Guinea 10%
- **Sauce/ketchup –** New Zealand 38%, Japan 33%, China 20%
- **Paste/puree –** Japan 43%, Vietnam 28%, New Zealand 15%
- **Juice –** New Zealand 40%, Singapore 15%, Fiji 14%

At 35% of all products, Japan remains the major export destination for Australian processed tomato produce, with New Zealand close behind at 29% and China at 13% of total exports.

Product	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Whole/pieces	3.67	1.45	4.52	5.62	7.31	5.20	2.86	1.84	3.21	3.61
Paste/puree	1.55	1.54	1.41	1.09	1.30	1.54	1.96	2.46	2.30	2.46
Sauce/ketchup	3.05	2.88	2.84	2.99	2.13	2.18	2.22	2.55	2.19	2.25
Juice [1]	1.35	1.36	1.41	1.76	1.24	1.89	1.14	1.17	1.08	1.19
Total Tomato	**2.25**	**1.65**	**1.95**	**1.30**	**1.73**	**1.88**	**2.03**	**2.34**	**2.12**	**2.35**

Average export prices ($/kg) (ABARES), in 2022 monetary values

The real price of exports increased slightly in 2022, which is beneficial for the Australian processing industry.

The data suggests a moderate negative correlation between average export price and volume exported, meaning that as price goes up, volume exported goes down. This applies to all product categories, except for Juice, which consistently appears to have no correlation to export price whatsoever.

It's worth noting that there is a moderate, but not a strong, negative correlation between export volumes and the USD exchange rates across the last 10 years, meaning that as exchange rates decrease, exports increase and vice versa. The fact that it is only a moderate correlation may suggest that exports from Australia aren't heavily dictated by exchange rates and that other market forces are having more influence on annual export opportunities.

Market Demand

Calendar Year	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	5 yr	10 yr
Dom. Demand	537,173	520,525	629,620	534,691	553,336	604,579	576,793	613,485	587,025	658,422	608,061	581,565
Imports	365,682	338,964	395,613	368,918	399,488	405,123	389,999	451,236	411,093	468,210	425,132	399,433
Net Australian	171,491	181,561	234,007	165,773	153,848	199,456	186,794	162,249	175,933	190,212	182,929	182,132
Imported %	68%	65%	63%	69%	72%	67%	68%	74%	70%	71%	70%	69%
Local %	32%	35%	37%	31%	28%	33%	32%	26%	30%	29%	30%	31%
Per capita (kgs)	**23**	**22**	**26**	**22**	**22**	**24**	**22**	**24**	**23**	**25**	**24**	**24**

Apparent domestic market demand (ABARES) (equivalent raw tonnes)

Table 5.4.1. The above table represents the Australian market demand for processed tomato products and shows how this demand is being met from local or imported products.

For individual years, combining data can produce non-matched results; ABARES 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, such as through the 5-year or 10-year averages.

Considering this data, the following may be noted:

Imports: Imports decreased quite significantly in the 2021 calendar year but have since surged back to the highest levels in over 10 years.

Net Australian: The net Australian figure was higher for the third year running and equates to tomatoes processed, less exports. This increase means that a greater volume of locally grown and processed product was used for domestic consumption than in the previous year.

Domestic Demand: After a dip in domestic demand for 2021, the total demand for processed tomato products in Australia is at the highest level in over 10 years.

Imported %: The imported percentage of processed tomato products stayed almost the same as 2021. Ideally, we would like to see the imports decrease, as more Australian produce meets local demand.

Local %: The percentage of local product sold in the Australian market decreased only by 1% in 2022.

Per Capita kgs: The average per capita consumption rose to 25 kilograms of equivalent raw tomatoes. This is a positive result and sits the 2022 consumption just slightly above the 5yr and 10yr averages.

Global Industry

Production

In 2022, the recorded global production totalled 38.449 million tonnes, compared to 39,184 million tonnes for the previous year; a decrease of 2%.

In 2022, Australia contributed 0.6% of global production and moved its ranking up one position to 17th for industry volume. This move in position however was only due the fact of Ukraine having a low production year, resulting from the current war.

Country	Season	2021	2022	*2023E*	% Change 2022-23E	Ranking 2022	% Total 2022
USA	Jul-Dec	10,223	9,964	11,920	20%	1	26.1%
China	Jul-Dec	4,800	6,200	8,000	29%	2	12.2%
Italy	Jul-Dec	6,059	5,476	5,400	-1%	3	15.5%
Turkey	Jul-Dec	2,200	2,350	2,700	15%	4	5.6%
Spain	Jul-Dec	3,185	2,125	2,600	22%	5	8.1%
Iran	Jul-Dec	1,300	1,800	2,000	11%	6	3.3%
Brazil	Jul-Dec	1,525	1,632	1,650	1%	7	3.9%
Portugal	Jul-Dec	1,596	1,414	1,500	6%	8	4.1%
Algeria	Jul-Dec	1,000	1200	1350	13%	9	2.6%
Chile	Jan-Jun	1,174	971	1150	18%	10	3.0%
Tunisia	Jul-Dec	940	649	675	4%	11	2.4%
Russia	Jul-Dec	523	638	660	3%	12	1.3%
Argentina	Jan-Jun	596	626	586	-6%	13	1.5%
Canada	July-Dec	399	548	530	-3%	14	1.0%
Egypt	Jul-Dec	440	456	600	32%	15	1.1%
Greece	Jul-Dec	420	340	390	15%	16	1.1%
Australia	Jan-Jun	233	227	110	-52%	17	0.6%
Dominican Republic	Jul-Dec	227	227	227	0%	18	0.6%
Israel	Jul-Dec	200	200	200	0%	19	0.5%
Poland	Jul-Dec	175	175	250	43%	20	0.4%
India	Jan-Jun	162	162	162	0%	21	0.4%
France	Jul-Dec	164	142	160	13%	22	0.4%
Peru	Jan-Jun	120	125	150	20%	23	0.3%
Ukraine	Jul-Dec	800	120	500	317%	24	2.0%
South Africa	Jan-Jun	125	120	160	33%	25	0.3%
Morocco	Jul-Dec	100	100	100	0%	26	0.3%
Hungary	Jul-Dec	115	80	110	38%	27	0.3%
Senegal	Jan-Jun	73	73	73	0%	28	0.2%
New Zealand	Jan-Jun	50	52	25	-52%	29	0.1%
Syria	Jul-Dec	40	40	40	0%	30	0.1%
Thailand	Jan-Jun	40	40	40	0%	31	0.1%
Mexico	Jan-Jun	40	40	40	0%	32	0.1%
Bulgaria	Jul-Dec	40	40	37	-8%	33	0.1%
Japan	Jul-Dec	23	27	26	-4%	34	0.1%
Czech Republic	Jul-Dec	25	25	25	0%	35	0.1%
Venezuela	Jan-Jun	20	20	20	0%	36	0.1%
Slovakia	Jul-Dec	20	20	20	0%	37	0.1%
Malta	Jul-Dec	8	5	8	60%	38	0.0%
Total		**38,402**	**38,449**	**44,194**	**15%**	**38**	**100.0%**

World Production by Country ('000 tonnes) (Colvine)

Outlook

- It is currently anticipated that production in Australia will increase significantly in 2023/24 (by 15% over the 2022/23 figure), due to large planting areas and favourable weather forecasts for major production regions. This is in part to make up for stock depletion due to the poor 2022/23 season, and equates to a preliminary estimate of 260,000 MT, which includes a small quantity of organic tomatoes.

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** n.d. denotes where 'no date' could be found for publishing.*

TM20000: Processing tomato industry development and extension

Matthew Stewart, Industry Development Manager

Introduction

The overall objective of this project is to deliver effective research, development, and capacity building solutions to the Australian processing tomato industry, with the goal of improving profitability and sustainability.

The opportunities for this project encompass to following:

1. Increasing the reach of the processing tomato industry R&D program by engaging stakeholders in the R&D process, including on-farm trials.

2. Effectively communicating R&D outcomes and applicable industry information to Australian processing tomato businesses and assisting with adoption of relevant R&D.

3. Being actively involved with the relevant stakeholders, including seed suppliers into Australia, to facilitate the importation process.

4. Collecting industry benchmark data and statistics to track changes, help identify gaps and direct industry development efforts.

5. Identifying, and securing where possible, other funding sources (including through cross-industry projects) to support R&D and extension aimed at industry development. Given the challenges with October floods in the growing regions and the subsequent delayed planting program for tomato crops, it was decided that there would be no additional seasonal activities beyond the normal scope of the project.

The target audience for these activities is primarily the processing tomato growers and farm managers. However, the project is also very active in engaging advisors and professional industry stakeholders, due to their extension roles in industry.

2023 Annual Processing Tomato Forum

APTRC IDM - Matthew Stewart

TM20000 activities and outcomes

Annual APTRC Forum

The largest item on the annual extension program is the APTRC Forum, which was successfully held on Friday 16th June 2023 at the Moama Bowling Club 'Venue'.

The forum was attended by 57 delegates and the follow-on dinner and drinks at Junction Restaurant were attended by 44 members and partners.

A total of 13 different and interesting speakers, presented on a range of topics throughout the day over three sessions, categorised as 'TM20000, 'Industry Insights' or 'Into the Future'.

The evening dinner provided a further opportunity to consolidate the learnings from the day by allowing growers, processors, suppliers, and academics to continue the discussions into the night.

Forum attendees commented that the quality of presenters and presentations was above expectations. The annual forum is experiencing excellent year on year support and participation.

The full listing of presentations from the day can be found at https://www.aptrc.asn.au/info-for-industry

Field Days

In the course of the 2021/22 season, both scheduled crop inspection days were successfully held.

On December 16th, the Boort & Boga crop inspection day saw the active participation of 11 individuals, followed by an evening dinner at the Kerang Hotel. The decline in participant numbers, deviating from typical seasons, directly stemmed from uncontrollable events affecting the industry—specifically, flood delays impacting tomato planting and extended broad acre harvest schedules.

On February 3rd, the Netafim sponsored Rochester Tour attracted 39 participants. Post-tour, an Industry Dinner at Moama Bowling Club 'Greens' welcomed 65 members, including children. Across the two field days, the APTRC facilitated on-site discussions on cultivating strategies in challenging conditions, managing late planting schedules, and optimizing production in sandy soils using a combination of pivot and drip irrigation.

A comprehensive record of these discussions is available in the December 2022 Tomato Topics and March 2023 Tomato Topics.

Darcy Kirchhofer presenting at the Netafim Irrigation Crop Inspection Day in January.

Gus Tall with Nick O'Halloran and Joe Braden, assessing irrigation systems

Processing Tomato Cultivar Evaluation

Operating exclusively on growers' properties, our trials encountered the same challenges as the broader industry in the 2022-23 season. Despite Research Manager Ann Morrison's commitment to a comprehensive program, usable data was only successfully extracted from two screening trials and three replicated transplanted machine harvest trials.

Ann also managed the inclusion of six cultivars in the screening trials this past season. With collaborative support from Bill Ashcroft, these cultivars were meticulously assessed based on visual evaluations of vine and fruit characteristics. These evaluations continue to play a crucial role in identifying potential cultivars for inclusion in the upcoming season's machine harvest trials.

The replicated machine harvest trials yielded limited statistically significant results. However, the assessment of the 18 trialed cultivars still contributed to our narrative of long-term averages versus our industry standard. This insightful perspective enables a comprehensive understanding of how cultivars perform across diverse conditions over time, further detailed in the cultivar report (herein).

Despite the inherent unpredictability of nature, the cultivar program still provided valuable insights that continue to inform industry decision-making. The availability of seed remains of concern to the industry however, as import conditions continue to restrict which cultivars we can include in the program. We are working with seed industry (see below) and regulatory authorities to try and overcome this issue and ensure we have access to the latest and most relevant material for the Australian industry.

Industry Publications

The enduring industry newsletter, "Tomato Topics," has long been an integral aspect of capacity-building projects delivered by the APTRC. Accessible issues are available via the APTRC website (https://aptrc.asn.au/). Additionally, past editions of the "Processing Tomato Grower" Magazine, offering a detailed account of APTRC work each season, can be accessed online.

The online R&D database, meticulously established and maintained by Ann Morrison, serves as a robust and searchable platform for industry researchers, growers, and service providers. This resource facilitates a comprehensive review of past findings, adding value to previous R&D endeavors.

Annual Industry Statistics

The data generated for the annual report serves as a pivotal industry reference, essential for monitoring, evaluation, and project planning based on local and global trends. This information is formally published as a standalone document, accessible on our website, and prominently featured in the annual Processing Tomato Grower magazine. Further details are available in the corresponding article within this magazine.

Assessment of Emerging Crop Threats and Industry Communication

In addition to collaborating with regulatory bodies, the APTRC maintains its active membership in the Australian Seed Federation (ASF), fostering connections through the ASF network and annual business convention.

This engagement aims to enhance our comprehension of challenges associated with seed imports and explore effective solutions. Collaborating with processors, growers, and Hort Innovation remains integral to our collective pursuit of managing risks and enhancing national seed security.

This year, the APTRC welcomed John Marchese, Heinz Seed Head of Global Agriculture - Commercial Seed & Operations, to Australia. John orchestrated a meeting with key imports and biosecurity personnel in Canberra, facilitating discussions on current tomato seed regulations. The objective is to work collaboratively on a comprehensive systems approach involving DAFF (Department of Agriculture Fisheries and Forestry), the USDA (United States Department of Agriculture), and Heinz Seed.

The industry actively monitors recently established pests such as Fall Army Worm and Serpentine Leaf Miner, while staying updated on the latest management recommendations for Silverleaf White Fly and Tomato Yellow Leaf Curl Virus. The

APTRC is also keeping a watchful eye on Guava Root Knot Nematode following recent detections in the Northern Territory and Queensland while maintaining links with organisations undertaking surveillance for potential incursions of Brown Marmorated Stink Bug. Currently none of these new threats have been identified in the processing tomato industry.

Pest & Disease Updates

In the 2022-23 season, the APTRC successfully transitioned its Pest & Disease update system to utilize a text messaging service, aligning with planned objectives. The industry responded positively to this service, with 102 members subscribing. Preliminary feedback indicates that industry members received information more directly and were more inclined to read the communications.

Promoting Awareness of the Australian Processing Tomato Industry Locally and Internationally

The IDM role serves as a pivotal point of contact for the processing tomato industry, consolidating information, coordinating activities, and fostering innovation. Locally, this entails active involvement in relevant industry networks, including the annual Hort Connections event (Adelaide 2023), Horticultural Industry Network (HIN), APEN (Austral-Asia Pacific Extension Network), and Plant Health Australia (PHA). APTRC staff also engage proactively with researchers from Australian universities, including The University of Melbourne, Deakin University, and Australian National University.

The APTRC maintains robust linkages with departmental institutions, including state Departments of Primary Industries (DPIs) and Biosecurity Australia.

Projects Extended During TM20000 and Funded by APTRC or External Sources

While much of the RD&E conducted in the processing tomato industry is directly funded through APTRC committee projects, extension of information from these initiatives is vital for industry development and constitutes a significant part of TM20000 activity. This extension is made possible with the support of the Hort Innovation TM20000: Processing tomato industry development and extension project.

Extension activities cover results from various projects, including ongoing research at the University of Melbourne and via Agriculture Victoria, as well as recently completed projects at the Australian National University.

Acknowledgments

The APTRC extends sincere gratitude to processing tomato growers and processors for their unwavering support. Special appreciation goes to Ann Morrison and Bill Ashcroft, as well as the dedicated APTRC committee members who consistently step forward to undertake diverse duties essential for project success.

The author acknowledges the support of Hort Innovation and the continued collaboration delivering effective and relevant projects in the future.

John Marchese, Chris Taylor, Matt Stewart and Bryce Merrett visiting the imports and biosecurity team in Canberra to discuss seed importation

Producers David & Emily Chirnside at Hort Connections Adelaide, with Matt Stewart.

Ausveg led American Grower Tour visit farms in Rochester

PhD Hanyue Feng and Dr Niloofar Vaghefi inspecting crops for disease.

Tomato waste to profit: converting harvest and processing waste into green energy, fuels and fertiliser

Vivienne Wells

APTRC Grower Summary

The APTRC commissioned the Australian National University to undertake research on gasification of tomato vines. The objective of this study for industry was to quantify the potential hydrogen yield from tomato vines and show if it was a cost-effective means of extracting hydrogen for fuel, fertiliser or energy.

Once the Hydrogen yield figures were known, on request from the APTRC, Andre Henry (author of the Nuffield report on Gasification) generously offered his time and knowledge on this topic to review these findings for industry and compare them against alternative hydrogen generating technologies.

What Andre found was that in recent years, technologies for production of hydrogen by electrolysis (using solar electricity to split water) have improved significantly. At the time of reporting, these operating systems already had a production cost close to or under what the tomato gasification process can produce. These simpler, greener, faster methods will only improve in efficiency, whereas the tomato vine hydrogen yield is more or less set.

Taking into account the extra issues associated with transport and logistics of moving vines out of paddocks and also the competing technologies, APTRC have decided that further work on vine gasification is not warranted.

The following report gives a detailed account of the ANU research project and the final report can be found on the APTRC website www.aptrc.asn.au by navigating to "Information for Industry" and selecting the "Growers Resource Centre" icon.

Introduction

The current energy crisis highlights the need to transition to clean and secure energy and process inputs. Whilst the agricultural industry is considered a hard-to-decarbonise sector in the energy transition, it also holds significant potential to contribute to a clean-energy future. Of particular interest is the use of waste streams such as renewable biomass, which can provide Australian producers with both an on-farm energy source and a potential income stream.

Waste tomato vines, a source of renewable biomass, contain roughly 14.8 GJ/ton, which can be harvested in various ways to provide useful energy [1]. Whilst the organic waste is often burnt in the paddock to prevent disease propagation through subsequent crops, this contributes to global greenhouse gas (GHG) emissions and does not allow any of the energy in the biomass to be transformed into useful forms. Collection and combustion of the biomass is a well-known and commercial process but is an inefficient way of converting the biomass into energy as much of it is lost to waste heat. Additionally, the raw biomass is an inconvenient form of energy to transport as it has a comparative low energy density.

It is possible to process the vine waste to 'upgrade' the energy in the carbohydrates into more useful forms of energy. One way to do this is gasifying the vines; that is heating them in a controlled atmosphere to liberate the carbon (C), hydrogen (H_2) and oxygen (O_2) from the biomass. There are a range of methods to undertake gasification, both in terms of the process heat source used and the gases that are fed into the reaction chamber during the process, but the end product desired is a mixture of H_2 and carbon monoxide (CO) called synthesis gas (syngas) [2]. Syngas is of particular interest currently and can be used in a downstream process to synthesis liquid hydrocarbon fuels like methanol, kerosene (jet fuel) and diesel. It can also be used as a source of H_2, which is both a highly efficient energy carrier and vital for industrial processes and inputs, including ammonia and other synthetic fertilisers [4].

An additional product of gasification is a high-value carbon char that has potential as an organic soil amendment, which can increase soil-moisture retention and improve soil structure. Harvesting waste tomato vines and processing them via gasification would therefore close the loop for carbon waste during growing processing tomatoes, potentially allowing for improved sustainability and cash-flow outcomes. A schematic of the potential closed loops is shown below in Figure 1

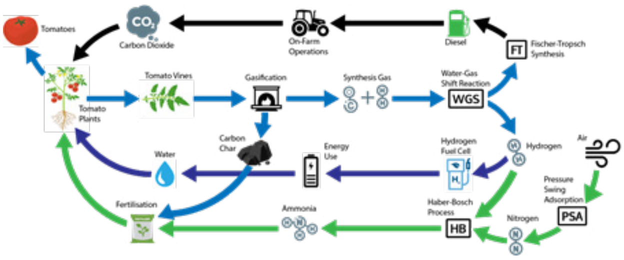


Figure 1: Recycling carbon and hydrogen through tomato production. Showing synthetic fuel production (top), hydrogen use as an energy carrier (second from bottom), and fertilisation with ammonia (bottom)

Whilst there is significant development of gasification technologies being undertaken, the technical and economic feasibility of any pilot plant is influenced by the volume of waste that is available in specific regions. Thus, the potential yield of syngas and its composition must be determined to further assess the viability of a gasification system utilising tomato vine waste.

In this project, tomato waste was analysed to determine its physical properties, including moisture content and elemental constituents. The samples were then pre-processed and gasified in a lab-based reactor under a carbon dioxide (CO_2) atmosphere, with the composition of the liberated gasses measured and recorded at small time intervals. This was used to calculate the amount and composition of syngas produced during the gasification process under various biomass-to-oxidiser ratios and the energy contained in this gas. The total energy availability for the processing tomato industry was then calculated using as estimate of the mass of vine waste available each season.

The outcomes of this project will be an important contribution to understand the potential for converting waste agricultural streams into high-value, carbon neutral products for the Australian processing tomato industry to diversify income streams and increase their overall profitability and resilience.

Background

Competition with cheaper, imported tomato products means that Australian growers have faced shrinking market share at the same time as production costs have significantly increased [1]. Whilst increasing the efficiency of fruit production volumes is a topic of interest in the industry, it does not sufficiently increase the competitiveness of farmers in the Australian market and so the addition of other income streams for farmers should be investigated [1].

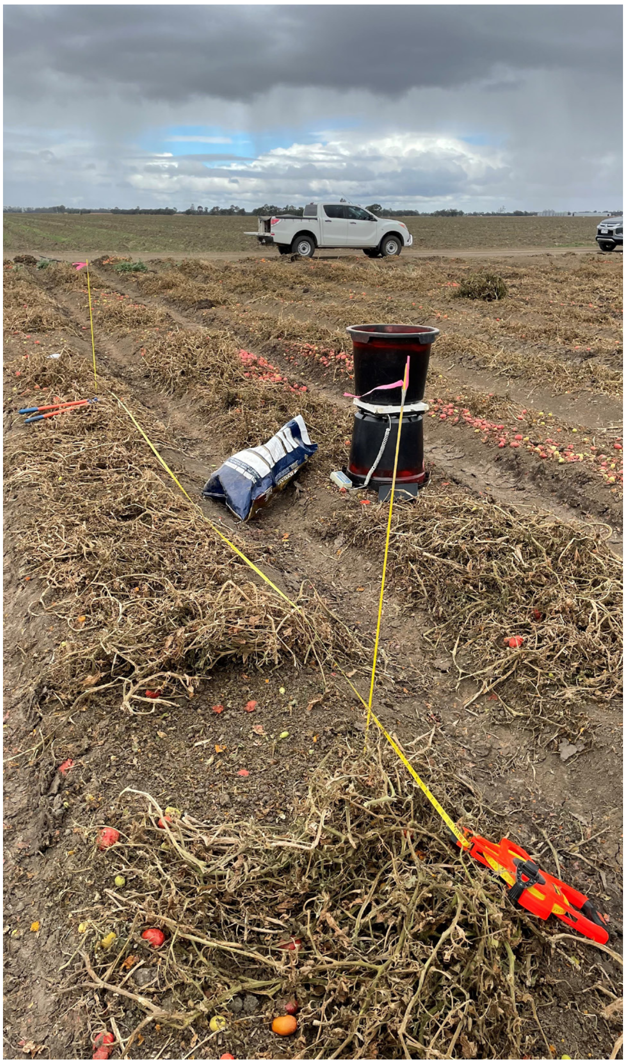
2018 Nuffield scholar Andre Henry, identified a viable pathway to explore the revenue opportunities from harvesting tomato vine waste through gasification [1]. In order to explore a pathway toward a viable commercial venture where farmers could monetise tomato vine waste, the APTRC has funded this project to quantify the resource level that would be obtained from gasifiying the waste at the end of a harvest.

Gasification

Gasification of carbon-rich materials is a common procedure to produce hydrogen as an industrial feedstock. It is usually done with coal. The reaction is performed at temperatures above 600° C using either steam or CO_2 as an oxidising agent, which drives the reaction towards carbon monoxide and hydrogen. Whilst these are the end products of the reaction, there are several intermediate reactions that occur, producing other products that may not be converted to carbon monoxide and hydrogen during the time spent in the reactor [2]. The most notable of these is methane. Whilst methane is a widely-used energy carrier (natural gas is made up of methane), its presence in the syngas is undesirable for downstream processing. Thus, the methane present during gasification should be reformed to create additional carbon monoxide and hydrogen. Whilst methane reforming is also a topic of great research interest, for the purposes of this study it can be assumed that complete conversion of the methane to carbon monoxide and hydrogen is achieved [4].

During steam gasification – where steam is used at the gasifying agent – higher amounts of hydrogen are produced due to the addition of the hydrogen to the reaction in the form of the water (H_2O) vapour when compared with dry gasification where CO_2 is the oxidiser [2].

However, depending on the desired product of the gasification process, the amount of hydrogen produced can be increased by reacting the carbon monoxide in the product gases with water vapour, which creates a larger amount of hydrogen, with CO_2 as a by-product [2]. As this CO_2 is derived from the waste tomato vines, the emission of this stream into the atmosphere would be carbon neutral as it was initially harvested from the atmosphere during photosynthesis undertaken by the tomato plant [3].



Post-harvest sample collection for ANU

Gasification is undertaken at high temperatures, with the necessary heat normally provided by burning a portion of the feedstock in industrial plants [5]. This decreases the overall yield of syngas, and so other sources of renewable heat are being investigated to provide this process heat. Concentrating solar energy is of particular interest in this field as it is able to provide the very high temperatures that are needed for these reactions [2].

Concentrating Solar Energy Systems

The two forms of solar energy concentrating systems could provide the required heat for gasification reactions are heliostat field collectors and parabolic dish collectors. Heliostat field collector systems consist of a large number of mirrors that reflect the sun onto a receiver atop a fixed tower. The heat is collected at the top of the tower and can reach operating temperatures of between 300 and 2000° C. These systems are usually very large in size to achieve economies of scale as they are very expensive to install [6].

Parabolic dish collectors are also able to reach high enough temperatures for gasification reactions and are much more modular in their construction. They consist of a parabolic mirror, the same shape as radio telescopes, that reflect sunlight onto a single point above the dish's centre. Whilst the manufacturing costs of these systems can be high as the mirror has to be free of imperfections, they can operate between 150 and 1500° C, providing a modular alternative to heliostat field collector systems [6].

Whilst the specifics of any commercial plant involving the gasification of tomato vines have yet to be determined, these concentrating solar energy systems are important to consider as they mean that no biomass needs to be burnt to provide the heat of the gasification reaction, maximising the yield of the process.

Uses of Gasification Products

The desired products of the gasification reaction are hydrogen and carbon monoxide, which is referred to as syngas. The ratios of these two gases in the product gas are both dependent on the type of biomass used as well as the process used during gasification (for example whether steam or CO_2 gasification was undertaken) [5]. This ratio can be partially controlled by an additional reaction called the Water Gas Shift (WGS) reaction where water vapour and carbon monoxide is converted into hydrogen and CO_2 [3]. This is important as the syngas can be used without separation as a feedstock to the Fischer-Tropsch process or separated to obtain the hydrogen as either an energy carrier or chemical feedstock [4].

The Fischer Tropsch process is used to create synthetic fuels with the same chemical composition as the fossil-derived liquid fuels that are currently widely used. This is a well-known commercial process, with the largest contributor to its cost being the production of the feedstock hydrogen, highlighting the potential market for cost-effective sources of syngas [8].

Hydrogen is a zero-emission fuel where the only product from its use is water, and as such it is of particular interest for the energy transition. There are currently technical challenges around its use to replace liquid fuels in heavy industry, but the market for hydrogen is forecast to grow significantly to make it a key commodity in a decarbonised future [8].

Whilst hydrogen is of interest as an energy carrier, the wide scale use of the technology is not commercially viable at present due to high costs associated with storing and transporting hydrogen. However, hydrogen can also be used to produce ammonia, which is predominantly used in agriculture as a fertiliser. Hydrogen molecules are transferred into ammonia through the Haber-Bosch Process, which takes nitrogen gas (N_2) from the air and combines it with hydrogen at high pressures [9]. Nitrogen makes up approximately 80% of the earth's atmosphere and

thus is relatively easy to extract, meaning that the bulk of the production cost of creating ammonia is from obtaining hydrogen [10]. Due to local demand for ammonia in Australian agriculture, and a desire to shift away from dependence on imported sources of the fertiliser, there is significant interest in increasing local production of ammonia using renewable sources of hydrogen ("green ammonia"), such as that generated from gasification of renewable waste streams.

Methodology and Results

Samples were collected from post-harvest fields and sent for lab analysis in airtight containers to minimise microbial decay and ensure that the moisture content of the plant material was conserved. One sample set was sent for ultimate and proximate analyses to determine the physical properties of the vines, and the other was sent directly to the gasification lab for pre-processing and gasification.

Ultimate and Proximate Analysis

Before any analysis was undertaken, the free moisture in the samples was removed by drying the samples at 40° C until no further change in mass was observed. This indicates that all the moisture not contained within the samples has been removed.

Ultimate analysis determines the percentage of moisture, volatile matter, fixed carbon and ash content in a biomass sample. This is done by heating the material under an inert atmosphere to high temperatures and observing the change in mass of the sample over this period. At the beginning of the heating period, the inherent moisture contained in the vines is vaporised, showing a decrease in the mass up to around 100° C. The total moisture content of the material is the free and inherent values combined.

The temperature is continually increased, and after the initial loss of mass due to drying there is a continued reduction in the mass of the sample. This decrease in the mass is caused by the volatile matter in the biomass decomposing due to the high temperature and entering the gas phase.

The remaining material, which is a mixture of the fixed carbon and ash, is then kept at high temperatures, but oxygen is also fed into the chamber. The oxygen reacts with the fixed carbon in the solid state and creates gaseous carbon monoxide or CO_2. Once again, the change in the mass of the sample during this phase indicates the fixed carbon present in the original biomass. The remaining material in the solid state is ash, an inorganic waste material that does not contribute to syngas production.

Proximate analysis finds the elemental composition of the biomass material, including the carbon, hydrogen, nitrogen and sulphur content. These results were used to inform the flow rate of oxidising gases needed during gasification to achieve various biomass to oxidiser ratios.

The results of the ultimate and proximate analysis are shown below in Table 1.

	Sample 1	Sample 2	Sample 3
Ash yield, % (db)	16.8	10.6	10.8
Total moisture, % (db)	17.7	19.3	16.3
Volatile matter, % (db)	68.6	72.4	72.8
Fixed carbon, % (db)	14.6	17.0	16.4
Carbon, % (db)	36	39.9	40.9
Hydrogen, % (db)	5.2	5.4	5.6
Nitrogen, % (db)	1.53	1.08	2.05
Sulphur, % (db)	0.36	0.25	0.20

As can be seen in the table above, there is quite a variation in the composition of the samples supplied. This indicates that sourcing material from different growing locations may cause variations in the amount and composition of syngas produced. Whilst taking an average of the composition is sufficient for lab-based experiments, this would need to be monitored during operation of a commercial plant to ensure that the desired products are obtained.

Of particular note is the relatively low levels of sulphur in the samples. Sulphur is especially aggressive to materials and poses health concerns when occurring as sulphur dioxide, which is produced during gasification. Whilst even with low levels of sulphur in the sample, gas scrubbing would be necessary to ensure that it was not harmful, the low levels present in the samples are favourable to economically operating a gasification plant with the tomato vine feedstock.

Biomass Preparation for Gasification

The second batch of tomato vine samples were cut into short lengths and weighed. They were then dried at 80° C until no mass change was observed, indicating that the material was fully dry. The moisture content was then calculated using the formula:

$$\mathrm{MC}\,(\%) = \frac{m_i - m_f}{m_i} \times 100$$

Where MC is moisture content, m_i is the initial mass of the vines and m_f is the final mass after drying.

The moisture content of the samples measured in the ANU lab had a small level of discrepancy with that measured in the commercial lab. The moisture contents were 20.0%, 22.2% and 20.3% for samples 1, 2 and 3, respectively. The discrepancy between the measurements was likely does to heterogeneity in the samples. The moisture content of the samples is important as gasification of wet materials requires additional energy input to heat up the water contained in the samples and can cause temperature inconsistencies within a reactor. Thus, pre-processing of the biomass material is necessary to reduce the moisture content and therefore the heat requirement for the gasifier.

The dry biomass sample was then ground to produce a uniform powdered sample. Whilst particles of different sizes were initially investigated, the heterogenous nature of the vine samples meant that grinding to different sizes would cause different types of the biomass to be in different samples. As the vines are considerably tougher than the leaf material contained in the sample, smaller particle size samples would predominantly consist of leaf material and thus the syngas production rates obtained from experiments with those samples would not be representative of the yield from the biomass as a whole.

Gasification

Precisely 1 gram of each ground sample was placed between two highly porous refractory aluminosilicate mats within an alumina tube reactor. The mats acted as a sample stage and upper protective layer for the powdered vines. The tube was centred inside the furnace with the sample bed in the middle of the heating zone to ensure uniform heating in the gasification zone. The temperature of this zone was recorded using a thermocouple, which controlled the output of the furnace to ensure the target temperature of 900° C was achieved.

Each end of the reactor tubes was placed in-line with gas flow pipes, where input gases were controlled by mass-flow controllers (MFC) and the composition of the product gases were recorded with a mass spectrometer. A schematic of the reactor tube set-up is shown in Figure 2.

The tube was purged with argon to eliminate any gas species from the reactor and gas lines at ambient temperature. Once purged, the furnace was heated to 900° C, with CO_2 at various rates being fed into the reactor from 400° C. Once the furnace reached 900° C, it was kept there for 40 minutes, with the gas composition being recorded at small intervals. The furnace was then cooled, with the CO_2 flow being shut off when it reached 400° C.

The gas flow rates recorded for the gasification run with Sample 1 and 15 ml/min of CO_2 is shown in Figure 3

Figure 3 shows a large spike in the amount of CO_2 present in the product gases during the first part of the experiment. This is due to the temperature of the reactor not being sufficient to convert the CO_2 into carbon monoxide and shows that this begins to happen around 650° C, as was expected. The flow then gradually increases once again through the experiment as the amount of biomass depletes and therefore there is nothing for the CO_2 to react with.

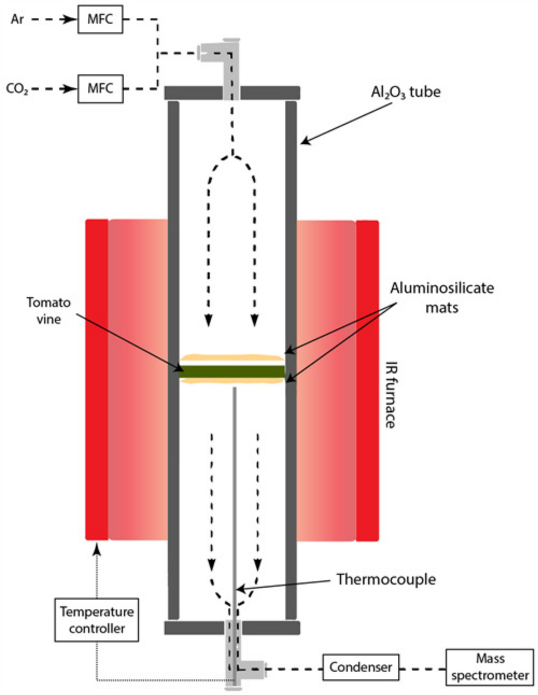
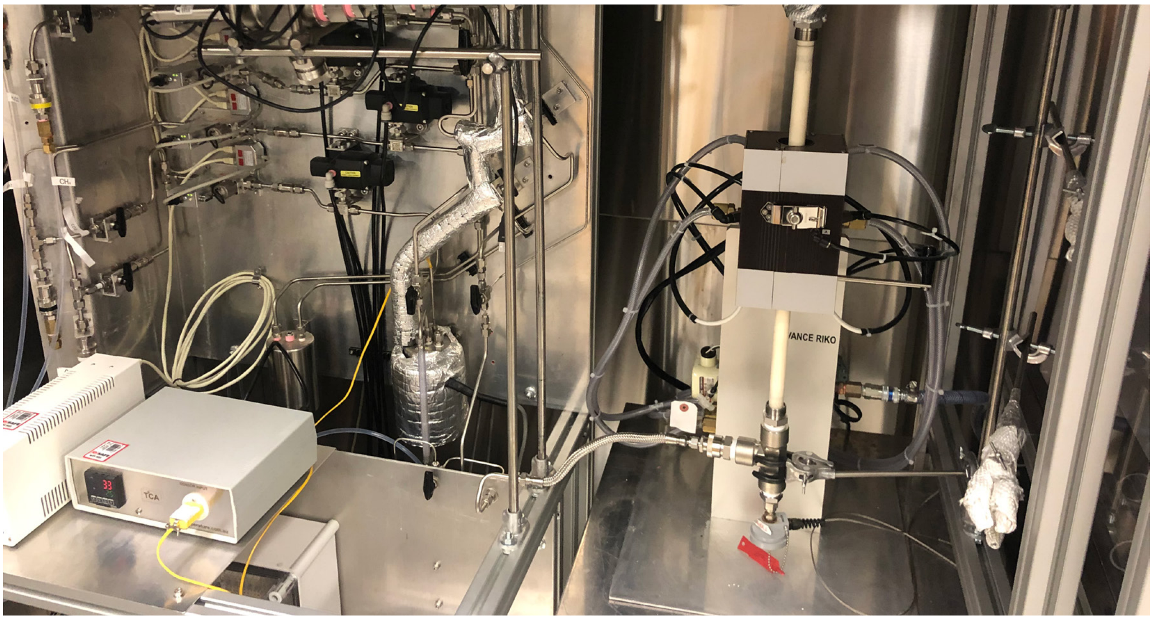


Figure 2: Reactor tube setup in lab furnace



ANU lab equipment for Gasification project

Carbon monoxide, hydrogen and methane production also peaks early in the run as the bulk of the biomass reacts.

The hydrogen, carbon monoxide and methane production during gasification are shown (in Figures 4, 5 and 6) as a function of the carbon dioxide flow rate.

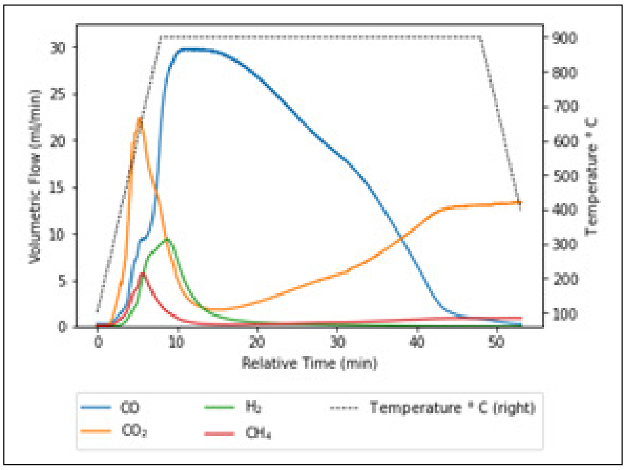


Figure 3: Gas flow rates during gasification of Sample 1 with 15 ml/min of CO_2

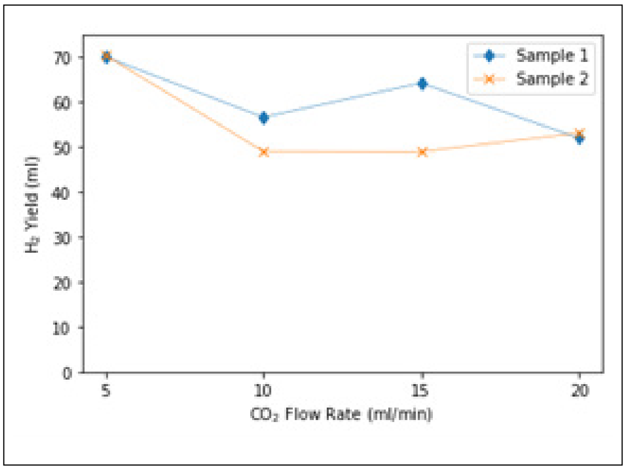


Figure 4: Hydrogen production as a function of oxidiser flow rate

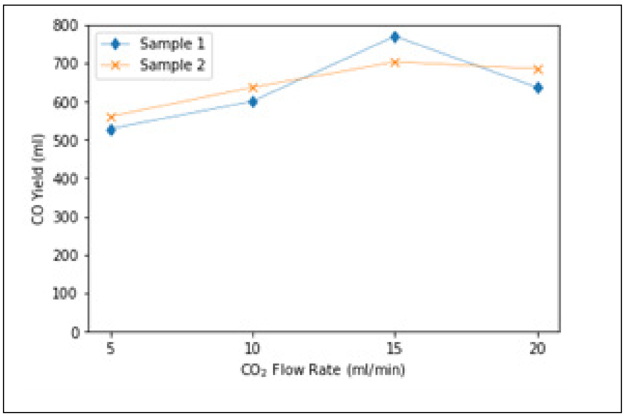


Figure 5: Carbon monoxide production as a function of oxidiser flow rate

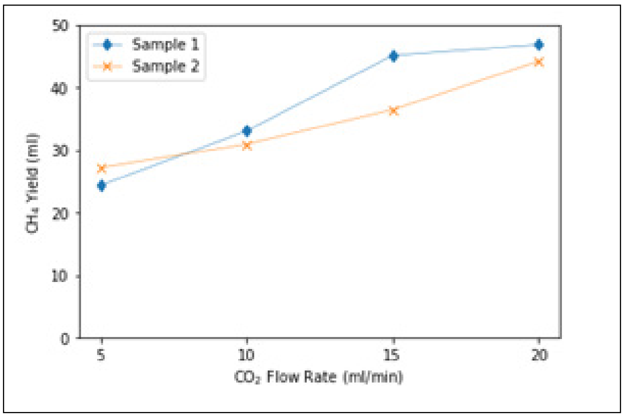


Figure 6: Methane production as a function of oxidiser flow rate

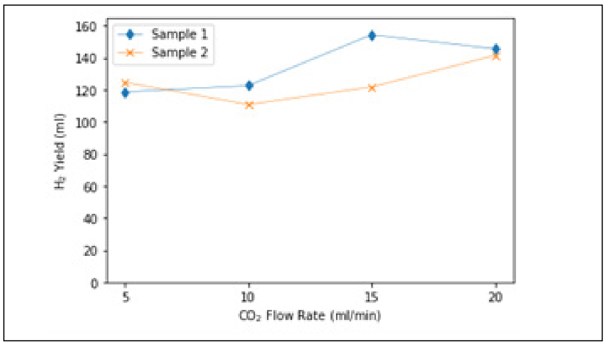


Figure 7: Hydrogen production calculated when complete conversion of methane with CO_2 is assumed

The maximum hydrogen production is obtained with 5 ml/min of CO_2 as the oxidising gas. However, the trend of the methane production during gasification increases with increased CO_2 flows. As the methane can be reformed to create more syngas with the addition of appropriate catalysts in the reaction chamber, the additional yield can be calculated from this amount of methane. The hydrogen production including this conversion is shown in Figure 7.

In this circumstance, the maximum hydrogen is produced with CO_2 flow rates of 15 ml/min and 20 ml/min. This is likely due to the increase in the amount of matter that is liberated from the biomass due to the higher concentration of the oxidiser.

The annual harvest potential for tomato vines in the processing industry is 25,000 tonnes per harvest [1]. This means that the potential hydrogen yield from the gasification of these vines is 348 tonnes, with an additional 26,900 tonnes of carbon monoxide being produced. The potential energy of this hydrogen is 49.3 terajoules (TJ), with the carbon monoxide representing 272 TJ. However, this carbon monoxide can be converted into hydrogen and CO_2, with an additional 1,940 tonnes of hydrogen being produced (when assuming 100% conversion of the carbon monoxide). This means that the total energy potential for the hydrogen produced during gasification and the water gas shift reaction (conversion of the carbon monoxide) is 323 TJ.

This hydrogen could then be used in a fuel cell, with a conversion efficiency of 60% – that is, 60% of energy is converted into electricity, generating 54 GWh of electricity.

Whilst this is the total energy potential of the hydrogen yield through the gasification of these vines, energy is needed at each stage of the reaction to produce this hydrogen. Based on rough calculations that can be undertaken with these data, the energy required for the gasification would be around 190 TJ. As the water-gas shift equation releases energy, which could be used to get the water needed to the reaction temperature, the

Vivienne Wells and Rebecca Craine from ANU on the Annual January Crop Inspection.

energy required would only be that to keep the reactor at about 300 degrees and therefore would be much less. Whilst the energy required for gasification seems like a very large proportion of the harvested energy, it is in the form of heat energy, and would not need to be stored and thus can have a lower value than the energy in the produced hydrogen. For example, the sun's energy, which can be provided at low operational costs during the day can be used to produce the hydrogen at a single, which is then transportable and able to be stored until needed. Whilst this can be provided with small operational costs, the trade-off is the infrastructure associated with the systems, which has a significant start-up cost. When considering non-renewable sources of energy, the supply costs of this energy is still less than the market value of the hydrogen produced.

Conclusion

Samples of tomato vine waste were analysed and gasified under CO_2 atmospheric conditions in order to obtain the potential energy yield of producing hydrogen from the waste. The ratio of oxidiser to biomass during the reaction has a direct effect on the rates of carbon monoxide, hydrogen and methane production. Much larger amounts of carbon monoxide than hydrogen were produced during the gasification process. This is to be expected as there is no additional hydrogen input into the system through the oxidising gas to be changed under steam gasification conditions.

In order to obtain the maximum potential hydrogen yield, complete conversion of methane to carbon monoxide, and complete conversion of carbon monoxide (in the presence of water) to hydrogen and CO_2 was assumed. The energy input needed for each stage of the reaction is not insignificant, but could be provided by concentrating solar energy.

Further Work

Further gasification experiments could be undertaken in order to obtain the same yield calculations for Sample 3, as well as under steam gasification conditions. Additionally, the composition of the residue from the samples after gasification should be measured to be able to estimate its usefulness as an organic fertiliser.

Additionally, further experiments could be undertaken using a catalyst in the reaction chamber in order to understand the empirical conversion rate of the methane present in the sample into syngas.

More in depth research into the potential economic outcomes of a gasification plant would have to be done in order to understand the scale needed for the plant to be profitable. This would look at the potential of incorporating other agricultural waste streams into the process, comparing technologies for providing process heat, as well as competing processes including biodigestion.

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Identification of *Fusarium oxysporum* isolates associated with yield decline of Australian processing tomatoes

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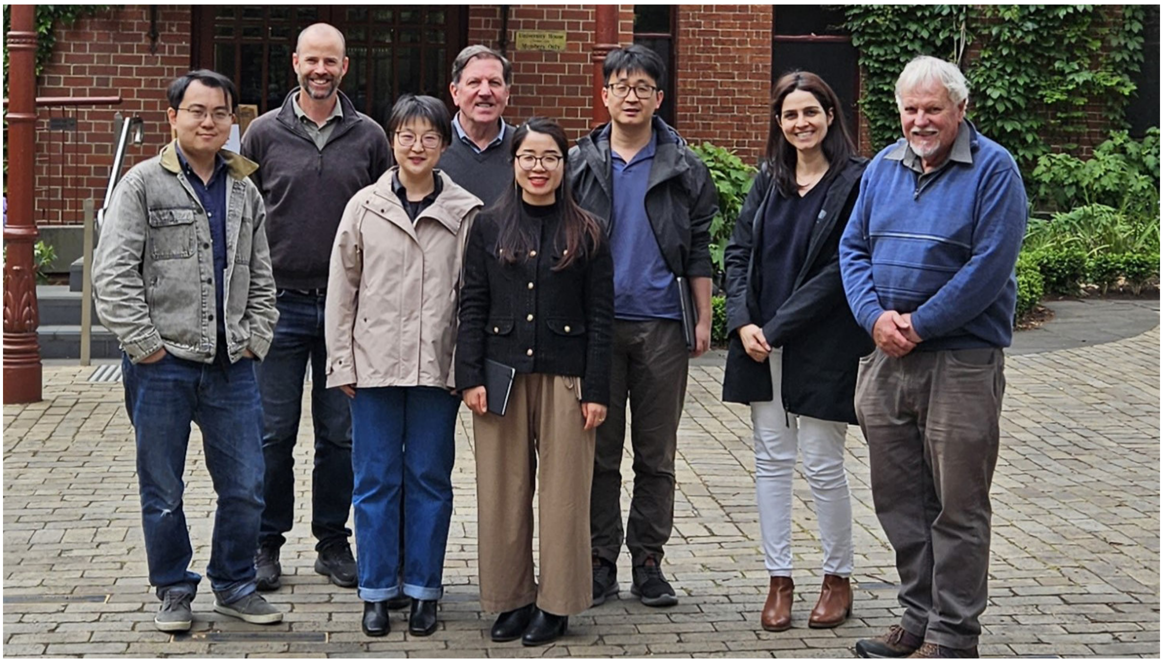
Grower summary of MU study

Previous work by Melbourne University identified the fungal pathogen *Fusarium oxysporum* (*Fol*) as a principal cause of root disease and subsequent yield decline in Australian processing tomato crops. PhD candidate Hanyue Feng has continued these studies, examining the genetic make-up of 20 *Fol* isolates, sampled from diseased tomato plants at various locations from 2017-2023. Three races of *Fol* are currently recognized globally, and races 1 and 2 were thought to be prevalent in Australian processing tomato crops. Hanyue's study showed that the 20 isolates were genetically diverse, and that most were closest in genetic makeup to *Fol* Race 3, which was first identified in fresh tomato crops in Queensland and now poses a major problem overseas. She also looked at the effects of 8 of these fungal isolates (including races 1, 2 and 3) on Heinz 3402 seedlings in a glasshouse study, finding that all of them significantly reduced plant growth. Heinz 3402 reportedly has resistance to Fol races 1 and 2, so this raises the question of whether we are dealing with a slightly different pathogen in Australia, and if so, we need to look for cultivars with resistance to it. Similarly, if these isolates have significant impact on other agricultural crops there may be implications for our rotation strategies. These are priorities for Hanyue's future studies.



APTRC meeting with the team from The University of Melbourne

Introduction

The fungal pathogen *Fusarium oxysporum* has been found to be associated with yield decline of Australian processing tomatoes [1-3]. Globally, tomatoes can be affected by different Fusarium diseases, the most common being Fusarium wilt caused by *F. oxysporum* f. sp. *lycopersici* (*Fol*) and Fusarium collar and root rot caused by *F. oxysporum* f. sp. *lycopersici-radicis* (*Forl*). *Forma specialis* (f. sp.) is an informal taxonomic grouping that is applied to a fungal pathogen that only causes a unique disease on a specific host [4-8]. Therefore, *Fol* and *Forl* are considered as specific pathogens of tomato worldwide that cause wilt and collar/root rot diseases, respectively. In Australia, Fusarium wilt (caused by *Fol*) has been reported as a serious disease of field grown tomatoes whereas Fusarium collar and root rot (caused by *Forl*) has not been detected.

Isolates identified as *Fol* may belong to different physiological races depending on their ability to cause disease on different tomato cultivars. Three races of *Fol* have thus far been described globally [9, 10], *Fol*-resistant tomato cultivars carrying the Immunity gene 1 (*I1*) were then developed. However, in 1945 in Ohio *Fol* isolates capable of breaking *I1* resistance were detected and described as race 2 [10]. Subsequent to the development and release of race 2-resistant tomato cultivars carrying the *I2* resistance gene, isolates capable of breaking both *I1* and *I2* resistances were identified and described as race 3, first in Australia, in 1978 [12], and subsequently in the USA and other parts of the world. Today, *Fol* races 1, 2, and 3 isolates are widespread in all tomato growing regions in the world; however, studies have shown that these three races of *Fol* in different regions have evolved separately from each other [11, 13-16]. For example, it has been shown that *Fol* race 3 isolates in Australia and the USA are genetically distinct and have evolved separately from different genetic backgrounds [4, 11, 13, 17, 18] thus raising the possibility that the USA race is in effect a new Race 4.

Fusarium oxysporum exhibits extraordinary genetic plasticity [19-22] and its genome is compartmentalised into a core genome and adaptive (or accessory) chromosomes [6, 7, 23-25]. The core genome includes housekeeping genes which are essential for survival and function and is therefore, conserved between different *formae speciales*. The adaptive genome, however, includes pathogenicity-related genes and is therefore variable in content and size among different *formae speciales* of *Fusarium oxysporum*. Hence differentiation of tomato *formae speciales* and *Fol* races cannot be achieved by sequencing based on the conserved housekeeping genes [26-30] as *Forl* and *Fol* races do not correlate with their phylogenetic background based on the conserved genes in the core genome [6, 7, 26, 27]. Instead, characterisation of tomato *formae speciales* and *Fol* races requires additional pathogenicity-related molecular markers. As a result, *F. oxysporum* isolates can be identified based on conserved genes including translation elongation factor (*tef1-a*), second largest subunit of RNA polymerase II (*rpb2*), calmodulin (*cmdA*) and tubulin (*tub2*) [4, 6, 7, 29, 31, 32]. However, identification of *formae speciales* and races will need to focus on pathogenicity genes/ effector genes in the adaptive genome.

Pathogenic fungi contain a suite of genes (pathogenicity factors) that produce enzymes that enable the pathogen to recognise specific hosts and initiate infection. These pathogenicity factors include cell wall degrading enzymes such as polygalacturonases, which are important in the process of the hyphae penetrating the host epidermal cells [33-35]. Comparison of polygalacturonase gene (PG) sequences are useful for analysing the genetic diversity within certain fungal species [36-38]. Previous studies in Japan on *Fol* and *Forl* isolates from tomatoes compared the nucleotide sequences of *pg1*, *pg5* and *pgx4* derived from PG gene to successfully differentiate *Forl* from *Fol* [26], and further molecular markers were then developed to differentiate *Forl* and *Fol* races [27].

This report presents results for molecular characterisation of *F. oxysporum* isolates, collected during the 2017-2023 growing seasons from symptomatic processing tomato plants from various locations in VIC and NSW. The identifications were based on core genomic loci as well as pathogenicity-related genes. Further, the pathogenicity of eight isolates is reported, in which plant height, dry weight and physiological responses to *F. oxysporum* inoculation were measured in glasshouse pathogenicity bioassays.

Summary of findings

Disease collection and confirmation of phylogeny

From December 2021 to June 2023, 17 putative pathogenic *F. oxysporum* isolates were collected and isolated from symptomatic plants from diseased tomato fields across VIC and NSW. Diseased processing tomato plants are characterised by poor development, leaf discolouration and stunting. Isolates UM991, UM1264 and UM1390 previously collected in 2017 and 2018 (Sophia Callaghan, 2021) were also included. Phylogenetic analyses based on the sequences of *tef1-a*, *rpb2*, *cmdA*, and *tub2* confirmed identity of all isolates as *Fusarium oxysporum*.

Identification of *Fol* races

Most of the UM isolates belong to *Fol* race 3 based on presence and absence of certain PG gene fragments, no band from the last row (*sprl*) indicated no *Forl* was observed. UMT01, UMT02, UMT06 and UMT08 were identified as *Fol* race 1, whereas isolates UMC01 and UM1390 were identified as *Fol* race 2 (Fig 1 and Table 2).

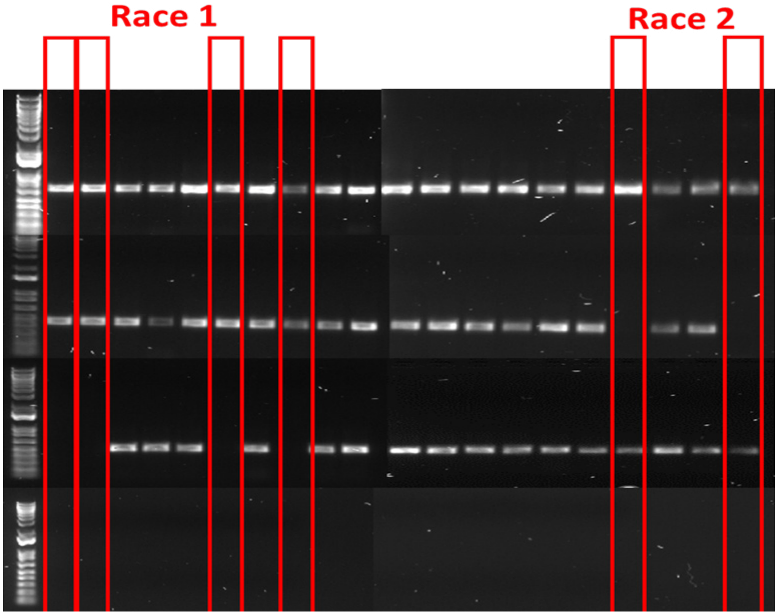


Figure 1. Identification of Fusarium oxysporum f. sp. lycopersici (Fol) races by polymerase chain reaction (PCR) using the uni, sp13, sp23, and sprl primer sets [26, 27, 33-38]. PCR products were electrophoresed in a 1.0% agarose gel.

Table 1. Summary of collection dates and locations of** F. **oxysporum isolates

Isolate Name	Location	Year
UMT01	Himba East VIC	2022
UMT02	Himba East VIC	2022
UMT03	Himba East VIC	2022
UMT04	Jennisons NSW	2022
UMT05	Jennisons NSW	2022
UMC01	Jennisons NSW	2022
UMT06	Nanneella VIC	2023
UMT07	Nanneella VIC	2023
UMT08	Nanneella VIC	2023
UMT09	Nanneella VIC	2023
UMT10	Nanneella VIC	2023
UMT11	Smitts VIC	2023
UMT12	Smitts VIC	2023
UMT13	Moonswest VIC	2023
UMT14	Moonswest VIC	2023
UMT15	Moonswest VIC	2023
UMT17	Birganbigil NSW	2023
UM991	Henry 1 VIC	2017
UM1264	Ken 1 VIC	2018
UM1390	Wakeman VIC	2018

Table 2. Identification of *Fusarium oxysporum formae specilales* ***and races based on presence (+) or absence (-) of PG gene fragments.***

Isolate Name	uni	sp13	sp23	sprl	race
UMT01	+	+	-	-	1
UMT02	+	+	-	-	1
UMT03	+	+	+	-	3
UMT04	+	+	+	-	3
UMT05	+	+	+	-	3
UMC01	+	-	+	-	2
UMT06	+	+	-	-	1
UMT07	+	+	+	-	3
UMT08	+	+	-	-	1
UMT09	+	+	+	-	3
UMT10	+	+	+	-	3
UMT11	+	+	+	-	3
UMT12	+	+	+	-	3
UMT13	+	+	+	-	3
UMT14	+	+	+	-	3
UMT15	+	+	+	-	3
UMT17	+	+	+	-	3
UM991	+	+	+	-	3
UM1264	+	+	+	-	3
UM1390	+	-	+	-	2

In addition, the pathogenicity related genes *pg1*, *pg5* and *pgx4* were amplified and sequenced and a genetic distance network including reference sequences of *Fol* races from overseas was produced. In general, results from phylogenetic analysis of the three PG genes (Fig 2) were consistent with the results from the indicator primer sets (Fig 1 and Table 2). However, UM1264, UMT12, UM991 and UMT04 were identified as *Fol* race 3 using the indicator primer sets but did not cluster with known *Fol* races in the genetic distance network. Based on the sequence analysis of the PG genes, UMT12, UM1264 and UM991 were found to be more closely related to wilting disease of bean and cowpea caused by *F. oxysporum* f. sp. *phaseoli*, f. sp. *trachephilum*, f. sp. *niveum* and f. sp. *colocasiae,* whereas UMT04 was an outlier that was clustering away from *Fol* race 3 but closely related to *F. oxysporum* f. sp. *raphani* instead. More importantly, many of the UM isolates formed the same clade with *Fol* race 3, followed by *Fol* race 1 and lastly *Fol* race 2. No *Forl* was found.

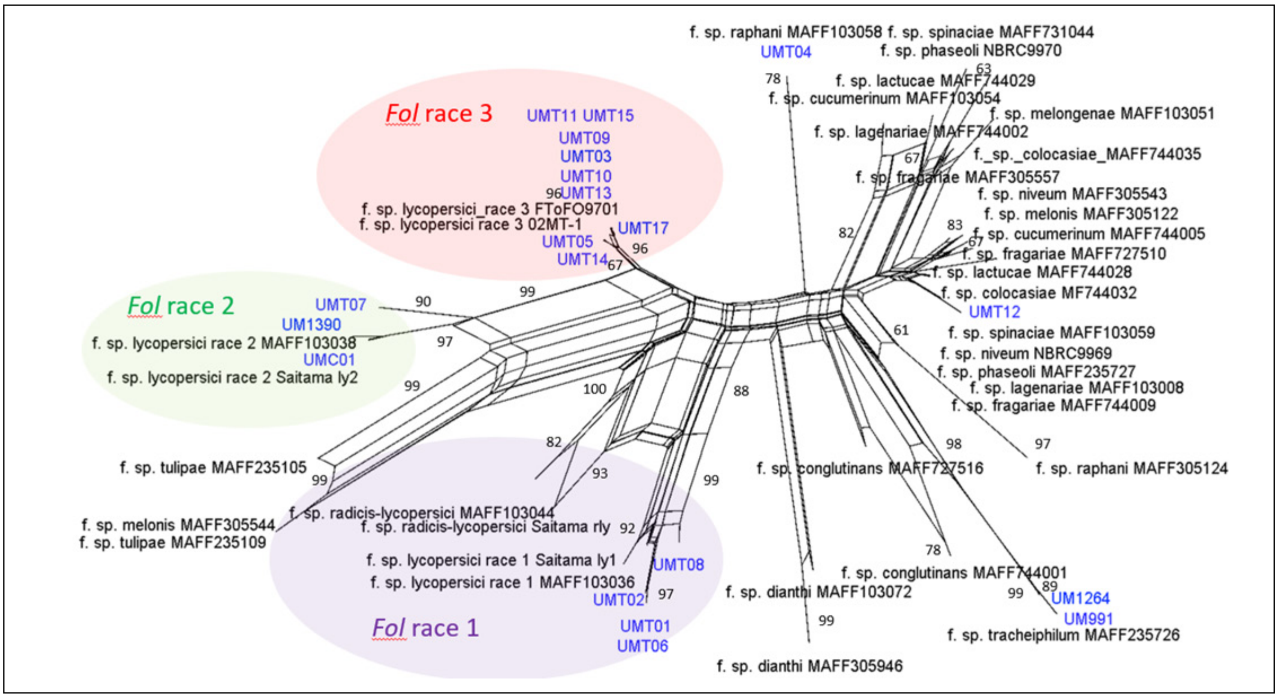


Figure 2. Phylogenetic relationships among 20 F. oxysporum species collected from symptomatic plants from NSW and VIC. Sequences were obtained after concatenation of three loci (pg1, pg5 and pgx4). The split network estimated in Splitstree (Huson and Bryant, 2006) using uncorrected p distance indicated reticulate branching among Fusarium species, UM isolates are in blue. The scale bar represents the expected changes per site.

High genetic diversity of *Fusarium oxysporum* was observed in processing tomato fields. Our results were in line with previous findings that differentiation of *formae speciales* cannot rely on phylogenetic relationships based on conserved genes, as *F. oxysporum* species complex (FOSC) has been reported to have multiple origins in terms of phylogeny and pathogenicity [6, 27, 31, 39, 40]. The clustering of tomato *F. oxysporum* isolates with other previously reported *formae speciales* indicated strong polyphyletic origin of this pathogen in Australia (Fig 2), which describes a group of organisms derived from more than one common evolutionary ancestor or ancestral group, hence having multiple phylogenetic origins [14, 31].

Glasshouse bioassay of *Fol* races

Strains UMT01, UMT02, UMT03, UMT04, UMT05, UM991, UM1264 and UM1390 isolated from diseased plants collected from processing tomato fields were used to infect tomato seedlings of cultivar H3402, a cultivar with reportedly high resistance to *Fol* races 1 and 2, at the two-leaf stage.

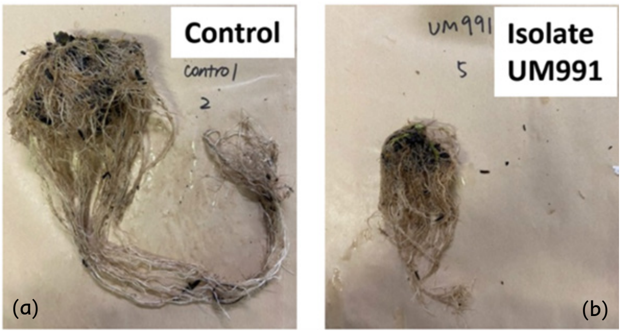


Figure 3. Comparison of healthy (a) and inoculated tomato root tissues (b) at the end of the pathogenicity bioassay.

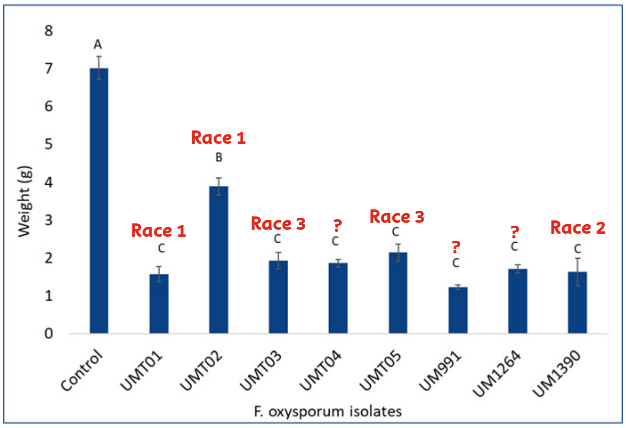


Figure 4. Root dry weight of processing tomatoes eight weeks after inoculation with Fol isolates, questions marks denote F. oxysporum isolates that do not cluster with known Fol races, error bars represent standard error of the means.

All isolates of *F. oxysporum* used in the glasshouse bioassay were able to cause significant growth reduction compared to the control, healthy treatment. UMT02 was the least aggressive isolate, which was classified as *Fol* race 1, the same as UMT01. However, the latter showed significantly higher aggressiveness (Fig. 4). The host cultivar H3402 has been reported to have high resistance to *Fol* races 1 and 2 in the USA, however it did not exhibit any significant resistance against the Australian *F. oxysporum* isolates. Disease aggressiveness was not correlated with *Fol* race, i.e., no race was found to be more aggressive than the others, yet *Fol* race 3 was found to be the most prevalent. Processing tomato cultivars with resistance to races 1 and 2 originated from breeding programs in the USA [10, 15, 17, 42, 43] and hence may have been assessed against different pathogen types that are found in Australia. Host cultivar H3402 was susceptible to Australian *Fol* races 1 and 2, suggesting that these two Australian isolates may have virulence factors different from the US *Fol* races [6, 7, 11, 13-16, 28, 30]. Therefore, further assessments are required testing imported processing tomato cultivars for resistance to Australian *Fol* isolates.

Conclusion

High genetic diversity was observed among the 20 *F. oxysporum* isolates based on the core genomic loci and pathogenicity-related genes. Although processing tomato cultivar H3402 was reported to have high resistance to US *Fol* races 1 and 2, it was susceptible to infection by the Australian *F. oxysporum* isolates, regardless of the *formae speciales* or races. *Fusarium oxysporum* isolates caused significant growth reduction and root loss of processing tomatoes in the glasshouse bioassay. Future studies will focus on screening more processing tomato cultivars for identification of putative sources of resistance to the Australian *F. oxysporum* pathogen and correlating disease aggressiveness with resistance genes to Australian *F. oxysporum* strains.

Acknowledgement

This project is funded by the Australian Processing Tomato Research Council, the first author is granted with a Melbourne Research Scholarship.

Future studies

Host cultivar screening

Future experiments will focus on screening processing tomato cultivars grown in the Australian industry for potential resistance to *F. oxysporum*. A current glasshouse bioassay is testing H1014, H1015, H3402, SVTM9000 and SVTM9025. More host cultivars will be screened using the most prevalent *Fol* race 3 isolates. Host cultivars will be screened for resistance against Australian *Fol* pathogens, and possible resistance genes or mechanisms of resistance could be further investigated.

Host range studies

From the phylogenetic analysis based on the pathogenicity-related loci, not all UM isolates formed the same clade with known *Fol* races, hence further glasshouse bioassay studies will assess pathogenicity of UM isolates, especially those that did not cluster with known *Fol* races on different hosts other than processing tomato. Information on pathogenicity and host range of isolates will help better understand the host-pathogen interactions and the concept of *forma specialis* and provide further information on the effectiveness of crop rotation for disease management.

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Assessment of the biocontrol potential of *Pythium oligandrum* UM202001 against selected soil pathogens of Australian processing tomatoes

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Introduction

Field surveys conducted in 2018-19 found several soilborne pathogens affecting field-grown processing tomatoes in Victoria and the most aggressive pathogens were identified as *Pythium* spp. and *Fusarium oxysporum* (Callaghan et al. 2019). The *F. oxysporum* strains induced collar and root rot symptoms (Figure 1) and later were identified as different races of the Fusarium wilt pathogen *F. oxysporum* f. sp. *lycopersici* (see report herein by Hanyue Feng et al.). Also, among the pathogenic *Pythium* species causing seedling damping-off and root rot, pathogenicity tests suggested that *P. irregulare* and *P. ultimum* were the most aggressive.

Figure 1. Symptom of* Fusarium oxysporum *infected tomato plants showing necrosis of the internal tissue of the collar, tap roots and lateral roots (Callaghan 2020).

Antagonistic microorganisms (biocontrol agents) have been proposed as economical and effective alternatives to chemical control for managing plant diseases (Ab Rahman et al. 2018). Compared with chemical control, biocontrol has the advantages of minimising environmental, legal and public safety concerns, high sustainability, target specialisation and cost-efficiency (Rechcigl & Rechcigl, 1999). Due to the unique environment and climatic conditions of Australia, native organisms may be more appropriate choices for biocontrol agents than imported formulations for better establishment and minimized environmental impacts.

Pythium oligandrum has been reported as an antagonistic microorganism that is able to colonize plant roots without causing symptoms (Le Floch et al. 2005), parasitise other microorganisms for nutrition (Benhamou et al. 2012), produce antibiotic compounds (Smith et al. 1991), enhance plant growth (Gerbore et al. 2014) and mediate induced resistance in plants (Benhamou et al. 1997). In 2020, a *Pythium oligandrum* strain (UM202001) was isolated from the soil of diseased tomatoes in Melbourne. This study aimed to assess the biocontrol potential of this strain against the soilborne pathogens of processing tomatoes and is part of a PhD project to identify and assess the efficacy of biocontrol agents for managing soil-borne diseases of processing tomatoes.

Materials and methods

Pythium oligandrum UM202001 was tested for its biocontrol capabilities in a dual-culture plate test and in glasshouse trials. *Pythium ultimum* strain UM915 and *Fusarium oxysporum* strain UM991 were selected based on their high aggressiveness on tomato plants in previous studies.

In-vitro interaction test

A glass microscope slide was coated with a 1 mm thick layer of water agar. An agar plug colonised by *P. oligandrum* mycelia was placed on the left side of the slide and an agar plug colonised by one of the pathogens was placed on the right side of the slide, at a 4 cm distance. Three replicates were set up each for *P. oligandrum* against *F. oxysporum* and *P. ultimum*, with a control group of three slides loaded with *P. oligandrum* agar plugs and plugs from autoclaved Potato Dextrose Agar. The slides were contained in Petri plates on top of moist filter paper and incubated at 25°C with continuous lighting. The growth of the hyphae of the microbes was monitored every day, and one day after the contact, the interaction between the hyphae of the two microbes was observed under an optic microscope (1000× magnification) with Trypan blue dye and a cover slip added.

Glasshouse protective and curative trials

After verification of the *in-vitro* antagonistic behaviour against the pathogens, UM202001 was tested on tomato seedlings infected with the two pathogens in glasshouse trials in a completely randomised design with five internal replicates, four treatment groups and four control groups. The control groups contained one non-inoculated control, with other groups each inoculated with only one of the microorganisms. The inoculum of *Pythium* species consisted of mycelium grown on autoclave-sterilized millet seed while *F. oxysporum* inoculum consisted of a spore suspension at a concentration of 10^6 spores/ml.

UM202001 was tested both for protective and curative properties (Figure 2). For the protective treatments, two test groups were transplanted into 1.5 L pots filled with sterilized potting mix inoculated with 5% (v/v) UM202001 inoculum, and after four days, 5% (v/v) of UM915 inoculum and 20 mL UM991 spore suspension were added to each treatment group. For curative treatments, two test groups were firstly inoculated with 5% (v/v) of UM915 inoculum and 20 mL UM991 spore suspension at transplanting, and 5% (v/v) of UM202001 inoculum was added to the pots after four days. The non-inoculated control group was grown in potting mix only.

Plant height and aboveground symptoms were measured every week for eight weeks. At harvest, root symptoms and height were assessed, and plants were oven-dried at 70°C for root and shoot dry mass measurement. Height and weight data were analysed with one-way analysis of variance. All pots receiving UM915 were planted with one additional seedling to determine the damping-off rate represented by the number of seedlings deaths at the first week after transplanting, with extra seedlings removed afterwards. The trial was repeated a second time.

Glasshouse trial for the potential pathogenicity of UM202001

To be used as a biocontrol agent, further evidence was required to confirm *P. oligandrum* was not pathogenic to tomato seedlings. In a completely randomised design with five internal replicates,

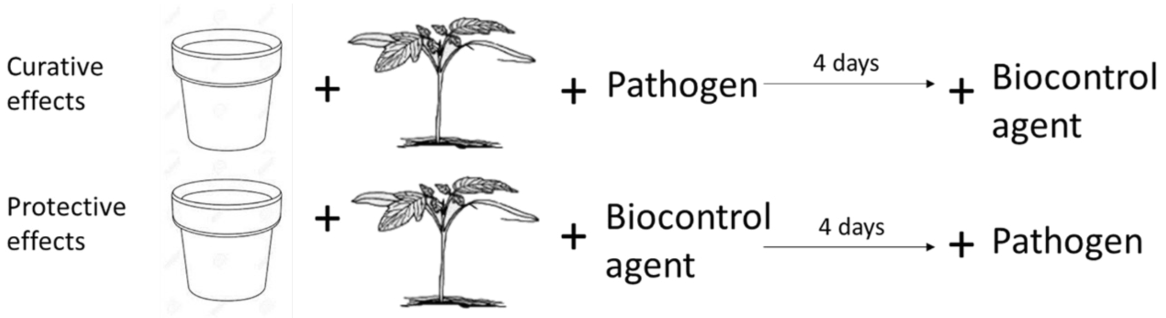

***Figure 2. The setup of the glasshouse trial to assess potential curative and protective effects of* Pythium oligandrum *UM202001 against tomato pathogens* Fusarium oxysporum *and* P. ultimum.**

three-week-old tomato seedlings were transplanted into 1.5 L pots filled with sterilized potting mix mixed with 2.5%, 5%, 7.5% and 10% (v/v) UM202001 inoculum, with a control group incubated with pure potting mix.

Results and discussion

In-vitro interaction test

Hyphae of UM202001 were attracted to and eventually coiled around the hyphae of both UM991 and UM915 (Figure 3), hence, demonstrating the microparasitic activity of UM202001 against both *P. ultimum* and *F. oxysporum*. Microscopic observations (Figure 3) were in line with previous studies, which reported that *P. oligandrum* hyphae recognize the cell surface of its host and coil around the hyphae of the host (Benhamou et al. 2012). Mycoparasitism also involves the destructive invasion and extraction of nutrition from the host (Benhamou et al. 1999), hence, results suggested that UM202001 may stunt and even kill the pathogens when contested directly.

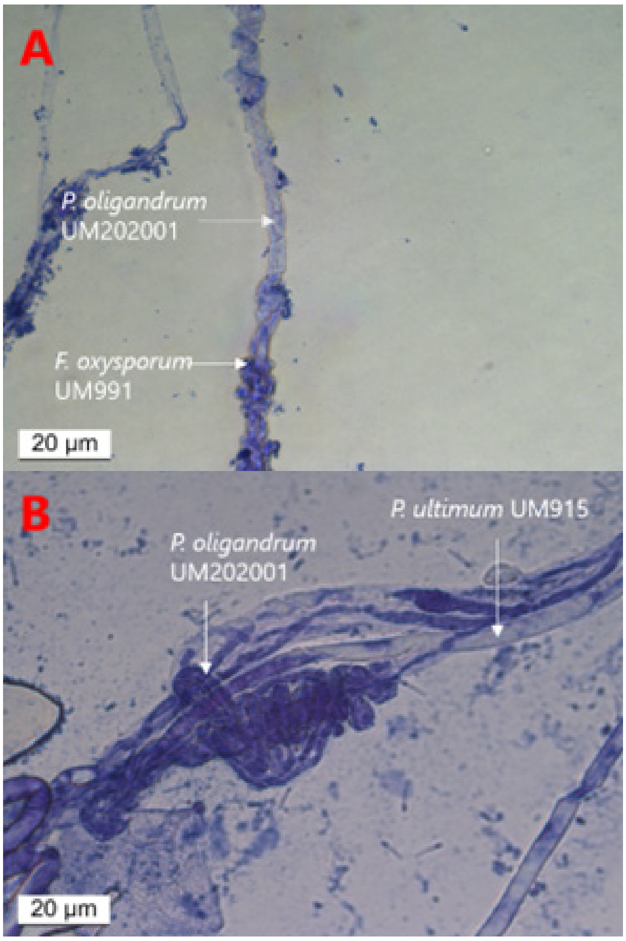

Figure 3. Microscopic image of the in-vitro interaction between hyphae (stained with Trypan blue). (A) The coiling of* Pythium oligandrum *UM202001 hyphae around those of the pathogen* Fusarium oxysporum *UM991. (B) The coiling of* P. oligandrum *UM202001 hyphae around those of the pathogen* P. ultimum *UM915.

Glasshouse protective and curative trials

Crown and root infection

There were no symptoms identified in the collar and root tissue of non-inoculated control plants (Figure 4B). *Fusarium* inoculation led to discolouration of tomato plants (indicative of infection, Figure 4A) and slight necrosis of collar tissues of two out of 15 inoculated plants from the first trial (Figure 4C) and three plants from the second trial. *Fusarium oxysporum* was cultured from the root fragments of all *Fusarium*-inoculated plants from both trials and the collar tissue samples from the five tomato plants with collar symptoms. No collar symptoms were observed in plants treated with *P. ultimum*, with their roots being darker in colour compared with the non-inoculated control (Figure 4D).

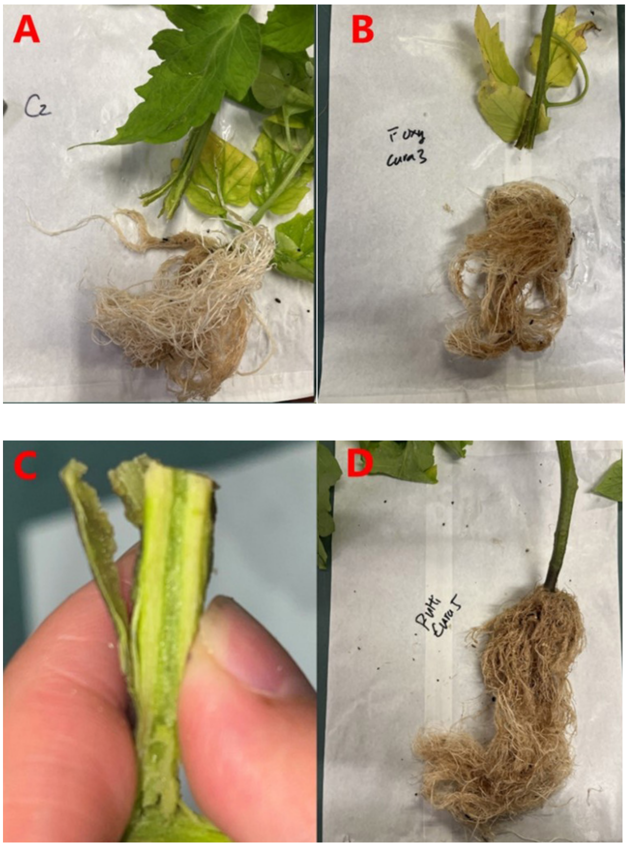

***Figure 4. Harvested tomato roots and collar tissue at eight weeks after inoculation. (A) Roots of a control plant inoculated with* F. oxysporum. *(B) Roots of a non-inoculated control plant. (C) Collar tissue of a plant infected with* F. oxysporum *showing slight browning (circled). (D) Roots of a control plant inoculated with* P. ultimum.**

Plant height

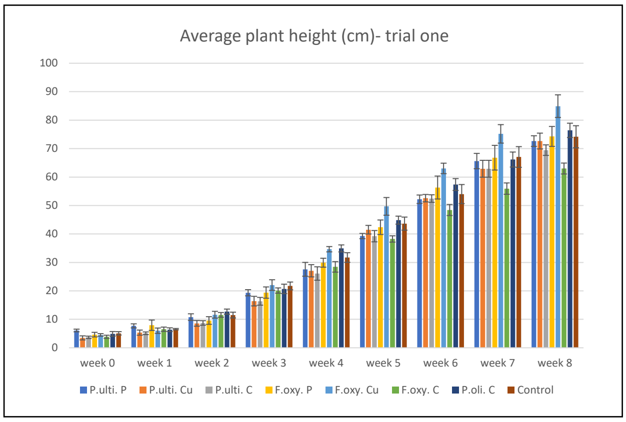

Figure 5. The average tomato plant height of the protective treatment groups (P. ulti. P and F. oxy. P), the curative treatment groups (P. ulti. Cu and F. oxy. Cu), the disease controls (P. ulti. C and F. oxy. C), the UM202001 control (P. oli. C) and the non-inoculated control (Control) of trial one.

The plant height measurement results showed that tomato plants treated with *F. oxysporum* UM991 had significantly reduced height from week seven in both trials (Figure 5), suggesting that the pathogen negatively affected the growth of the glasshouse plants although visual symptoms were not as severe (Figure 4C).The protective and curative treatments with UM202001 of tomato plants under *F. oxysporum* inoculation had no significant effect on plant height when compared with the non-inoculated control, while sometimes being significantly higher than the disease control, which seemed to suggest that the plant growth under disease pressure was improved with the introduction of UM202001.

Pythium ultimum is generally considered as an early-stage pathogen, which can cause damping-off of young tomato seedlings, with the pathogenicity gradually decreasing as the tomato cell wall becomes lignified as the plant matures (Sealy et al., 1990). This may explain why the plant height of the disease control was generally only significantly lower than the non-inoculated control at the very early growth stage in the first trial (Figure 5).

Dry weight

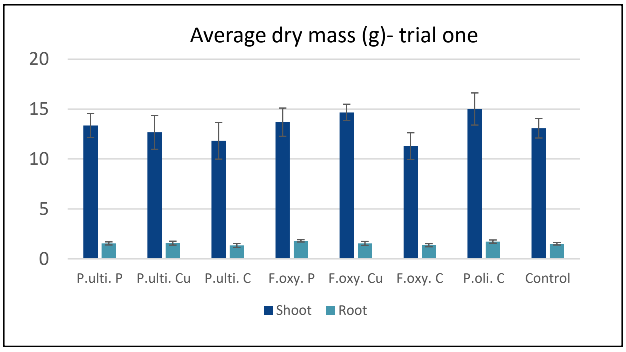

Figure 6. The average shoot and root dry mass of tomato plants in the protective treatment groups (P. ulti. P and F. oxy. P), the curative treatment groups (P. ulti. Cu and F. oxy. Cu), the disease controls (P. ulti. C and F. oxy. C), the UM202001 control (P. oli. C) and the negative control (Control) of trial one.

Based on these results, both protective and curative treatment of UM202001 against *F. oxysporum* led to higher average shoot and root dry mass production compared with the disease controls (Figure 6), which was significant in the first trial. Thus, the tomato plants receiving UM202001 inoculation under *F. oxysporum* pressure were able to have larger dry mass production, indicating better plant health status. This finding further suggests that the introduction of UM202001 may improve plant growth and performance, even after the establishment of *F. oxysporum*.

Damping-off of seedlings

At the one-week mark, all pots inoculated with *Pythium* were examined for seedling damping-off. In the first trial, three seedlings in the *P. ultimum* treatment groups (2 in the curative and 1 in the disease control) died from damping-off, making the damping-off rate of trial one 10%. In the second trial, two seedlings in the *P. ultimum* disease control died from damping-off, making the damping-off rate of trial two 6.7%. *Pythium ultimum* was cultured from root fragments of the dead seedlings. These results showed that no seedlings died when infected with UM915 and with UM202001 inoculum applied four days earlier. Thus, it seems that the pre-established UM202001 may prevent UM915 from killing the seedlings, as no seedlings died in the protective treatment of UM202001 against UM915.

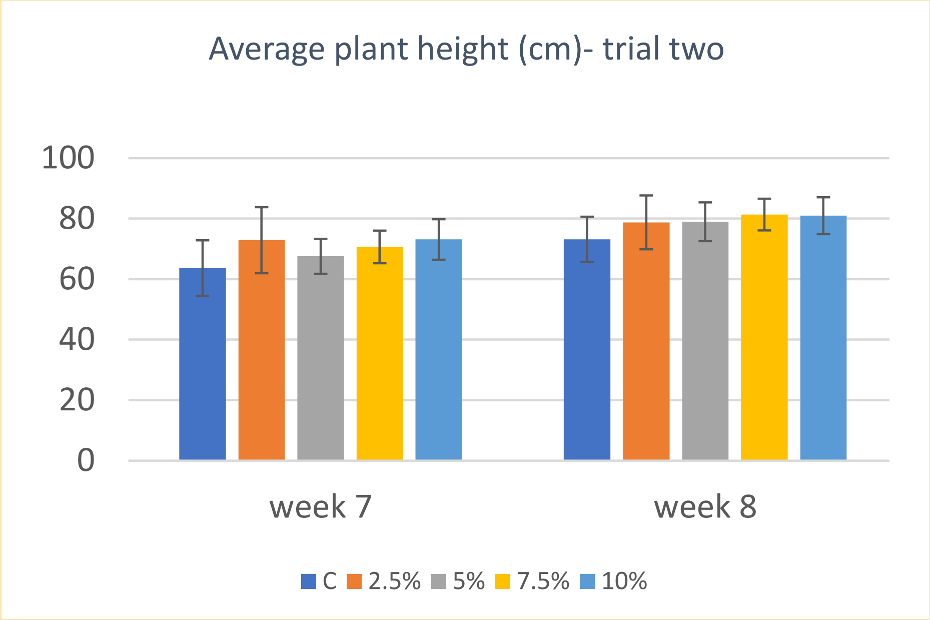

Figure 7. The average height of the tomato plants of the treatment groups inoculated with 2.5% v/v (2.5%), 5% v/v (5%), 7,5% v/v (7.5%) and 10% v/v (10%) of UM202001 millet inoculum at week 7 and 8 in trial two of the glasshouse trial for the potential pathogenicity of UM202001.

Glasshouse trial for the potential pathogenicity of UM202001

In both trials (Figure 7), no significant difference was found between the plant height of any treatment and the control.

In both trials, only the shoot and root DM of the 10% treatment group from trial two was significantly higher than those of the control group and 2.5% treatment group (Figure 8). Other than this, no significant differences were found between the DM of any two groups in both trials. This indicates that that even when applied at a very high rate (10% v/v), the biocontrol agent *P. oligandrum* had no adverse effects on plant growth and development, but sometimes improved growth after application (Figures 7 and 8).

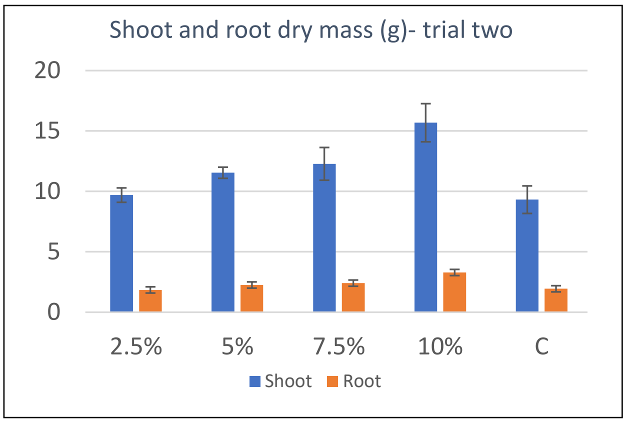

Figure 8. The average root and shoot dry mass of tomato plants in the treatment groups inoculated with 2.5% v/v (2.5%), 5% v/v (5%), 7.5% v/v (7.5%) and 10% v/v (10%) of UM202001 inoculum at harvest of trial two from the glasshouse trial for potential pathogenicity of UM202001.

Conclusions

Based on the preliminary results of these experiments, the application of *P. oligandrum* improved the growth and dry mass production of tomato plants both before and after the inoculation of *F. oxysporum* in glasshouse pot trials. *P. oligandrum* was also able to protect the seedlings from damping-off caused by *P. ultimum*. Moreover, even when applied at a high concentration, *P. oligandrum* inoculum did not have an adverse effect on the growth of tomato plants in glasshouse pot trials. Hence, *P. oligandrum* may have the potential to be applied as a biocontrol agent for Australian tomato soilborne diseases.

Future directions

These preliminary results suggest that *P. oligandrum* is able to prevent the pathogens from inducing severe reduction in the growth and development of tomato plants under the disease pressure of *P. ultimum* UM915 and *F. oxysporum* UM991. However, several factors limit the large-scale application of *P. oligandrum*. Firstly, as an oomycete, *P. oligandrum* does not produce airborne spores, instead, it produces water-borne zoospores and thick-walled oospores, but only in relatively small numbers, making it slow to establish in soil. The inoculation method in these bioassays involved growing the mycelium of *P. oligandrum* on sterilized millet, making the inoculum bulky and hard to handle.

Therefore, the future direction of this project is to investigate other biocontrol properties of *P. oligandrum*. *Pythium oligandrum* is known to produce the protein secondary metabolite oligandrin, which can trigger the defence mechanisms of tomato plants against *Phytophthora parasitica* and *Fusarium oxysporum* f. sp. *radicis-lycopersici* (Benhamou et al. 2001) and in grapevines against *Botrytis cinerea* (Mohamed et al. 2007). Oligandrin has not been tested with *P. ultimum* and *F. oxysporum* f. sp. *lycopersici* yet, so the next step of the project is to verify the production of oligandrin, extract it from the UM202001 culture, and test it against the pathogens on tomato plants in glasshouse trials.

Another potential limiting factor in application of *P. oligandrum* as a biocontrol agent is lack of knowledge on its adaptation to field conditions. Therefore, I am also planning to test the effectiveness of *P. oligandrum* in actual production sites, preferably affected by soilborne pathogens. If successful, the biocontrol potential of *P. oligandrum* can be further confirmed with sufficient levels of plant growth improvement in the field as a result of its application.

Acknowledgement

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Australian Processing Tomato Cultivar Trials 2022-2023

Ann Morrison And Bill Ashcroft

Introduction

The 2022-23 season was marked by an extremely wet and cool spring and summer, with large areas of the processing tomato growing region in northern Victoria and southern NSW being negatively impacted by flooding and wet weather.

The APTRC's cultivar assessment program proceeded on a limited basis due to the conditions. While five screening trials and five replicated transplanted machine harvest trials were established only two screening trials and three replicated trials yielded useable data. They were located near Rochester and Tresco (near Lake Boga) in northern Victoria, and Thyra in southern NSW.

Six cultivars were included in the screening trials where they were rated by visual assessments of vine and fruit characteristics. These ratings are then used to identify potential cultivars to be included in the following season's machine harvest trials.

A total of 18 cultivars were included in replicated machine harvest trials this season. All trials were established with transplanted seedlings as the Boort region, where traditionally direct seeded crops are sown, was too wet to access during sowing time.

Ann Morrison at screening trial field day

Materials and Methods

Cultivars

Cultivars included in the 2022-23 screening and machine harvest trials are listed in *Table 1*.

Processors and Seed Representatives assessing new cultivars at screening trial

Bill Ashcroft discussing cultivars at Screening Trial Day

Cultivar Hand Planted Screening Trial at Jennisons block

Table 1. Cultivars evaluated during the 2022-23 growing season

	Screening (transplants)			Replicated Machine Harvested (transplants)		
	Early		Mid-Season	Early	Mid Season	
	Kagome (Thyra NSW)	**Go Farms (Tresco Vic)**	**Kagome (Thyra NSW)**	**Go Farms (Tresco Vic)**	**Kagome (Thyra NSW)**	**Campaspe Ag (Timmering Vic)**
H1015	✓	✓	-	✓	-	-
HM Encina	✓	✓	-	-	-	-
HM Enotrio	✓	✓	-	-	-	-
HM Pumatis	✓	✓	-	-	-	-
SVTM 8840	-	-	-	✓	-	-
SVTM 9000	-	-	-	✓	-	-
Syngenta BQ390	✓	-	-	✓	-	-
Syngenta BQ403	✓	-	-	✓	-	-
H3402	-	-	✓	-	✓	✓
H1884	-	-		-	✓	-
HM 58811	-	-	-	-	✓	✓
HM 58841	-	-	-	-	✓	✓
HM 6856	-	-	✓	-	-	-
HM Aprix	-	-	✓	-	-	-
HM Nava	-	-	-	-	✓	-
HM 5558 (Orsorosso)	-	-	-	-	✓	✓
NUN 239	-	-	-	-	✓	-
NUN 241	-	-	-	-	✓	-
NUN 507	-	-	-	-	✓	-
SVTM 8840	-	-	-	-	✓	-
SVTM 9008	-	-	-	-	✓	-
SVTM 9023	-	-	-	-	✓	✓
SVTM 9025	-	-	-	-	✓	✓
SVTM 9334	-	-	✓	-	-	-

H - Heinz, HM - HM Clause, NUN - Nunhems, SVTM - Seminis

Trial Design and Assessment

Preliminary Screening trials

Screening trials were established using transplanted seedlings and consisted of two six metre plots per cultivar planted on adjacent rows. These trials were visually assessed and rated prior to the paddock being harvested.

Machine harvested trials

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

The trials were set out with five replicates (blocks) repeating along the rows. Plots ranged from 60 to 70 metres in length and all sites were drip irrigated single row beds of 1.52 metre width. The trial cultivars were assigned at random across each block.

A hand-held GPS unit was used to measure and peg out the machine harvest trial rows. During planting, cultivars were swapped at each peg in accordance with the trial plan. The weight of harvestable fruit produced from each trial plot was measured using load cells on the bulk harvester trailers.

Prior to harvest, twenty healthy red fruit were randomly sampled from each trial plot and taken to the Kagome Laboratory for Brix, pH, and colour testing. A pureed sample of raw fruit was used for Brix and pH testing using a refractometer and a pH meter. A hand diced fruit sample was also tested for colour using a Hunter Lab Colorimeter.

From a processing point of view, the preferred raw fruit pH is less than 4.35 and the desirable a/b colour score (obtained by dividing colour a by colour b) is 2.0 or higher.

Red fruit yields (tonnes per hectare) from trial plots were calculated using trial plot weights together with the 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)).

Statistics

Trial results were analysed using the ARM 9 statistical program to perform analysis of variance (ANOVA), comparing the differences between group means. Whether the difference between means was significant or not was determined using Tukey's HSD (honest significant difference) P = 0.05.

Results and Discussion

The main feature of the start of the 22-23 growing season was high rainfall across large parts of the growing region and surrounds, resulting in widespread flooding. Trial sites at Tresco and Rochester were also badly affected by heavy rain and hail during the growing season causing considerable flower and fruit loss and subsequent foliar disease outbreaks. In general, below average summer temperatures combined with delayed plantings contributed to a late harvest.

This season, several growers agreed to include new cultivars, which are in commercial use overseas, directly into machine harvest trials. One of these cultivars, SVTM8840, was classed as early and a main variety in Italy. As such it was included in both early and mid-season trials to maximise information on its performance under Australian conditions.

Early Season Trials

An early season replicated trial was established at Tresco, near Lake Boga in northern Victoria, on 12th October 2022, the day before a major rain and flooding event which stopped all planting for several weeks.

This trial contained five cultivars, including H1015 as the commercial standard, and was harvested on the 20th of February 2023 after 131 days in the field.

The statistical analysis (ANOVA) of trial results is shown in *Table 2*, where average values followed by same letter do not significantly differ (P=.05, Tukey's HSD).

Table 2. ANOVA results for the Tresco, Vic early season transplant trial (131 days in the field).

Cultivar	Yield (t/ha)		°Brix		Soluble solids (t/ha)		pH		Colour a/b	
BQ390	45.29	a	5.26	ab	2.36	a	4.56	a	2.10	a
BQ403	44.77	a	5.80	a	2.60	a	4.31	b	2.11	a
H1015	48.21	a	5.30	ab	2.56	a	4.53	a	2.17	a
SVTM8840	49.04	a	5.16	b	2.53	a	4.38	ab	2.06	a
SVTM9000	47.66	a	5.20	ab	2.47	a	4.45	ab	2.08	a
Tukey's HSD (P=.05)	9.79		0.63		0.614		0.22		0.47	
Treatment Prob (F)	0.614		0.042		0.777		0.016		0.961	

This early season trial yielded an average of around 47 tonnes per hectare, which is much lower than normal, reflecting the tough seasonal conditions.

No significant differences in red fruit yields were found, and there was only a 4.3 tonne per hectare difference between the highest and lowest yielding cultivars (BQ403 and SVTM8840).

Similarly, there were no significant differences in Brix compared with that of the commercial standard H1015. However, BQ403 had a Brix of 5.8 which was significantly higher than SVTM8840's Brix value of 5.16.

Figure 1 shows the trial's yield and Brix as a percentage of the control (H1015). SVTM8840 had higher yields and lower brix than H1015 and BQ403 had lower yields and higher brix.

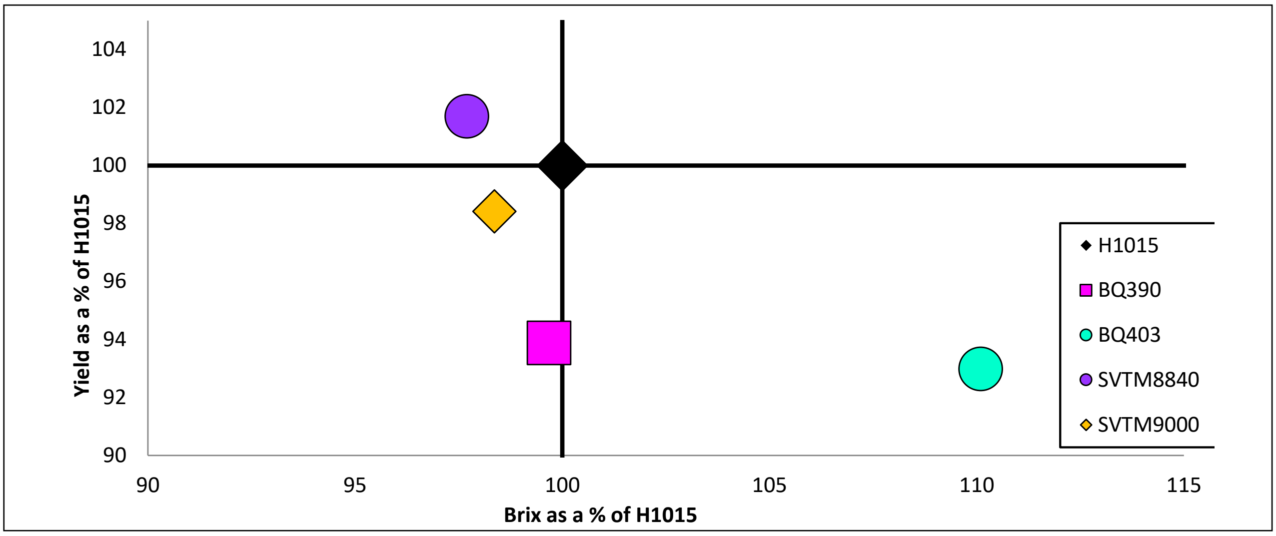

Figure 1. Tresco early season cultivars yield and Brix as a percentage of H1015.

The tested raw fruit pH ranged from 4.31 for BQ403 to a high of to 4.56 for BQ309. BQ403 was the only cultivar with a pH below the maximum preferred value of 4.35 and it also had a significantly lower pH than that of H1015. The later than ideal harvest at 131 days could have contributed to the higher raw fruit pH values across this trial.

All cultivars in the trial showed a higher colour a/b score than the minimum preferred reading of 2.0. Readings ranged from 2.06 for SVTM8840 to a high of to 2.17 for H1015, however, there were no statistical differences in colour a/b between any of the five cultivars.

Mid-Season Trials

Four mid-season transplant trials were established but one trial site was cultivated out by the grower due to poor plant establishment across the field. Another trial was harvested (not reported) but was extremely low yielding due to rain and hail damage, which resulted in fruit and flower loss and the development of foliar diseases.

The two mid-season trials which yielded useable results were planted on the 8th of November (Thyra NSW) and 16th of November (Timmering Vic). These trials were harvested after 146 and 160 days in the field respectively.

Analysis of Variance Tables

In the ANOVA results tables, numbers in green font signify results that are significantly better than the mid- season industry standard cultivar (H3402) for that parameter. Data which has been excluded from analysis is highlighted grey with the reason for exclusion listed below the table.

Table 3. ANOVA results for the Thyra, NSW transplant trial (146 days in field).

Variety	Yield (t/ha)		°Brix		Soluble solids (t/ha)		pH		Colour a/b	
H3402	87.24	a	5.87	ab	5.11	a	4.66	abc	2.36	a
HM58811	125.51	a	6.09	ab	7.62	a	4.56	bcd	2.31	a
HM58841	78.03	a	6.27	ab	4.90	a	4.55	cd	2.39	a
HM Nava	103.22	a	6.56	a	6.77	a	4.47	d	2.35	a
HM5558	100.97	a	5.84	ab	5.91	a	4.67	ab	2.41	a
NUN 241	97.14	a	5.92	ab	5.77	a	4.69	a	2.40	a
SVTM8840	90.98	a	5.51	b	5.02	a	4.49	d	2.45	
SVTM9008	102.07	a	6.28	ab	6.44	a	4.51	d	2.28	a
SVTM9023	110.26	a	5.75	ab	6.35	a	4.55	cd	2.31	a
SVTM9025	89.06	a	6.29	ab	5.47	a	4.47	d	2.22	a
Tukey's HSD (P=.05)	0.2159t		0.94		0.1871t		0.11		0.37	
Treatment Prob (F)	0.149		0.023		0.092		0.0001		0.732	

Applied automatic data correction transformation 'Log(n+1)' to Yield to correct skewness.
Applied automatic data correction transformation 'Log(n+1)' to Soluble Solids to correct skewness.
Excluded SVTM8840 from Colour a/b to correct heterogeneity of variance

Table 4. ANOVA results for the Timmering, Vic transplant trial (160 days in field).

Variety	Yield (t/ha)		°Brix		Soluble solids (t/ha)		pH		Colour a/b	
H3402	100.97	a	5.77	a	5.64	a	4.59		2.28	a
HM58811	97.14	a	5.97	a	5.50	a	4.45	ab	2.27	a
HM58841	90.98	a	6.78	a	4.13	a	4.42	ab	2.30	a
HMX5558	102.07	a	5.93	a	3.77	a	4.36	b	2.22	a
SVTM9023	110.26	a	6.32	a	3.46	a	4.53	a	2.34	a
SVTM9025	89.06	a	5.97	a	3.69	a	4.37	b	2.25	a
Tukey's HSD (P=.05)	0.2159t		1.46		3.148		0.13		0.38	
Treatment Prob (F)	0.149		0.308		0.144		0.0070		0.931	

Excluded HM58841 from Yield to correct heterogeneity of variance.
Excluded H3402 from pH to correct heterogeneity of variance/skewness/kurtosis .

Yield and Brix

Figures 2-6show data from the two mid-season trials in graphical format for ease of comparison. In these, the bars or circles coloured grey indicate data which has been excluded from analysis.

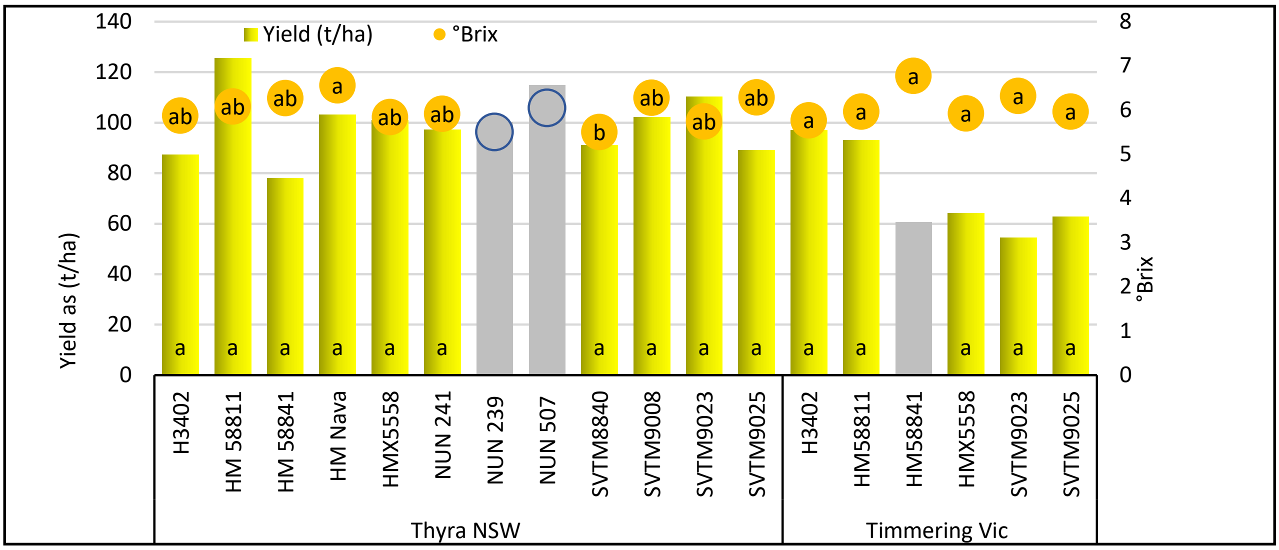

Figure 2. Mid-season red fruit yields and Brix

Yields

There were no significant differences in yields in any either of the mid season trials. At the Thyra trial site, a number of replicates were lost due to a harvesting error. This left insufficient replicates to perform statistical analysis on the cultivars NUN 239 and NUN 507, however the yield data from the remaining two replicates has been included in *Figure 2* (coloured grey) for reference.

Average trial yields ranged from 98 tonnes per hectare at Thyra and 72 tonnes per hectare at Timmering. Only four replicates were harvested at Timmering as one replicate was badly impacted by root disease resulting in significant seedling loss. The four remaining trial replicates were probably also affected to a degree by root disease, and this combined with the late harvest at 160 days, would have contributed to the lower than normal yields.

Brix

Raw fruit Brix readings averaged 5.99 across the Thyra trial and 6.12 at the Timmering trial site.

Tonnes per hectare soluble solids

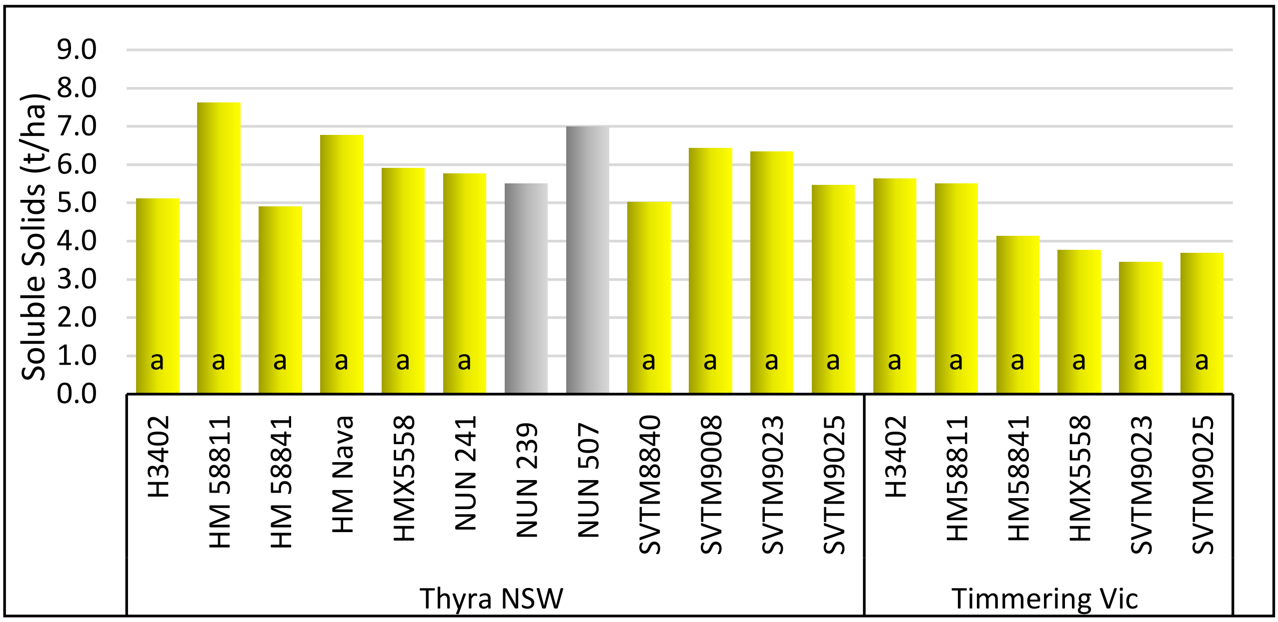

Figure 3. Mid-season trials tonnes per hectare of solids.

There were no significant differences between H3402 and the other trial cultivars in the two trials. However, HM Nava had significantly higher Brix than SVTM8840.

There were no significant differences in soluble solids at either trial site, with results ranging from a low of 3.46 for SVTM9023 at Timmering to a maximum of 7.62 from HM58811 in the trial at Thyra (*Figure 3*).

Figure 4 shows a comparison of average trial yields and Brix of each cultivar expressed as a percentage of H3402 (represented by the black diamond in the cross hairs). The cultivars HM58811, Nava, NUN 241 and 507, SVTM9008 and 9025 all showed both higher yields and Brix in at least one trial, however these are not a statistically significant improvement on H3402's performance.

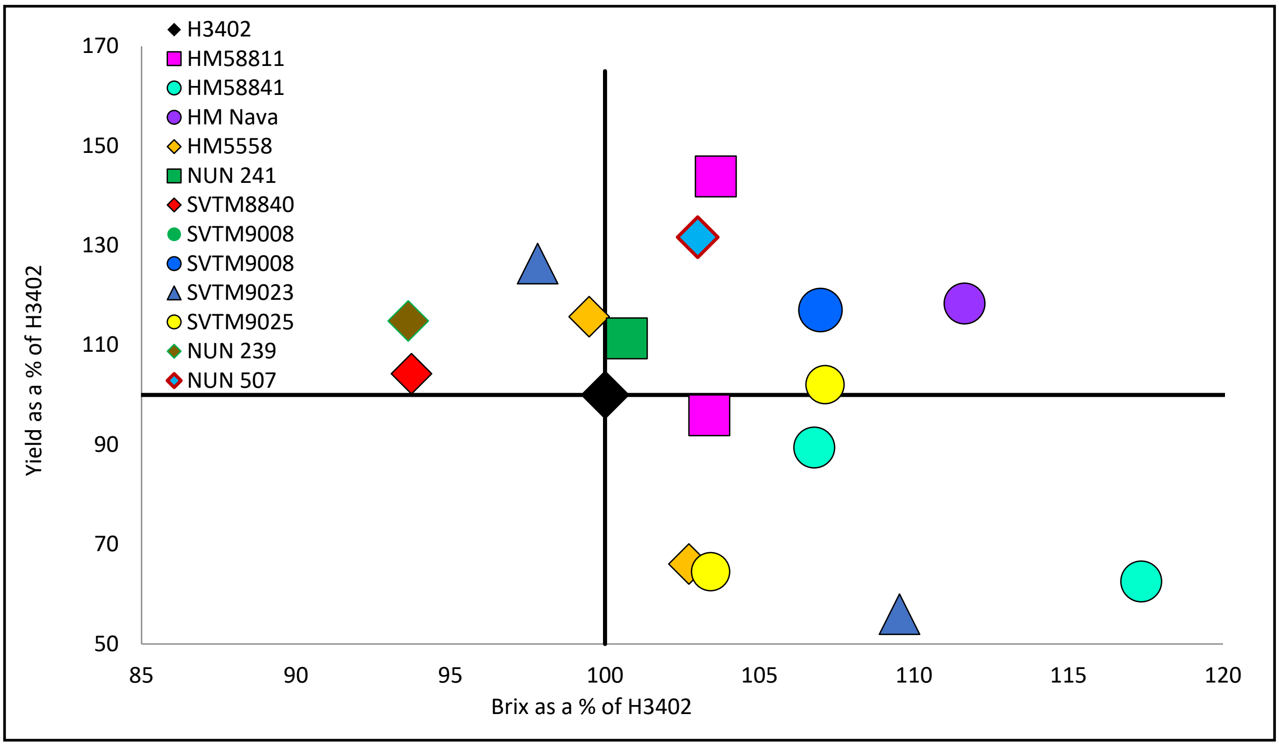

Figure 4. Average yields and Brix as a percentage of H3402.

pH

All raw fruit pH readings across both trials were higher than the processors' preferred maximum pH of 4.35 (Tables 3 and 4). The pH ranged from 4.47 and 4.69 at Thyra and four cultivars (HM Nava, SVTM8840, SVTM9008 and SVTM 9025) had a significantly lower pH than H3402. The Timmering trial raw fruit pH ranged from 4.36 to 4.5

Once again, the trials were harvested later than expected which may have contributed to the higher pH values as pH tends to increase the longer fruit are left on the vine.

Colour

All colour a/b values were higher than the minimum preferred limit for processing of 2.0. Colour scores across the two trials ranged from 2.22 to a high of 2.45, but there were no statistically significant differences between the cultivars (Tables 3 and 4). HM5558 had one of the lowest colour scores of 2.22 at Timmering and had the second highest colour score of 2.41 at Thyra, suggesting that other environmental factors are having an impact on colour.

Yield variation within mid-season cultivars

The largest range in red fruit yields for an individual cultivar across its replicates within a trial was of just over 97 tonnes per hectare for SVTM9008 at Thyra, this was also the highest yielding replicate across both trials of 172 tonnes per hectare (Figure 5).

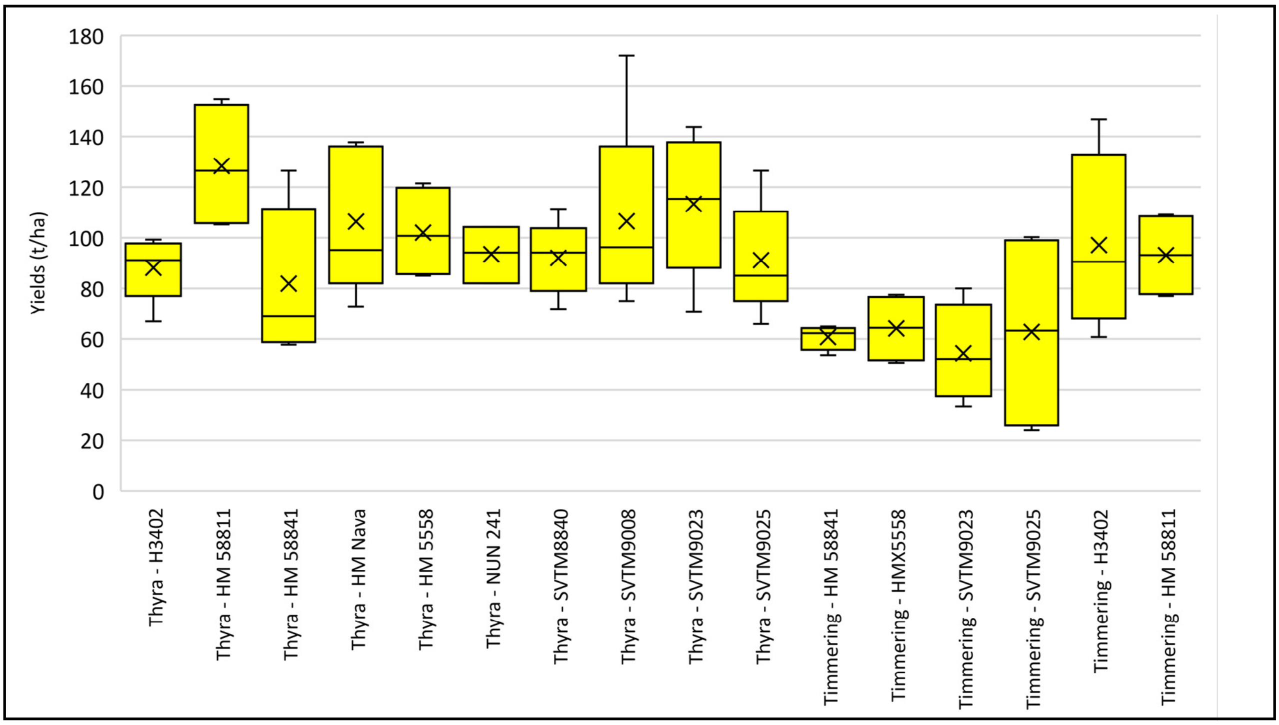

Figure 5. Box and whisker plot of mid-season replicate yields grouped by grower

Yearly average yield and Brix over four seasons

Figure 6 shows the yearly average red fruit yield and Brix as a percentage of H3402 for the last four seasons. These results are not necessarily statistically significant but show a range of cultivars which consistently perform "as well as" the industry standard over several seasons. These longer term results give confidence that these varieties will hold up under a range of seasonal conditions.

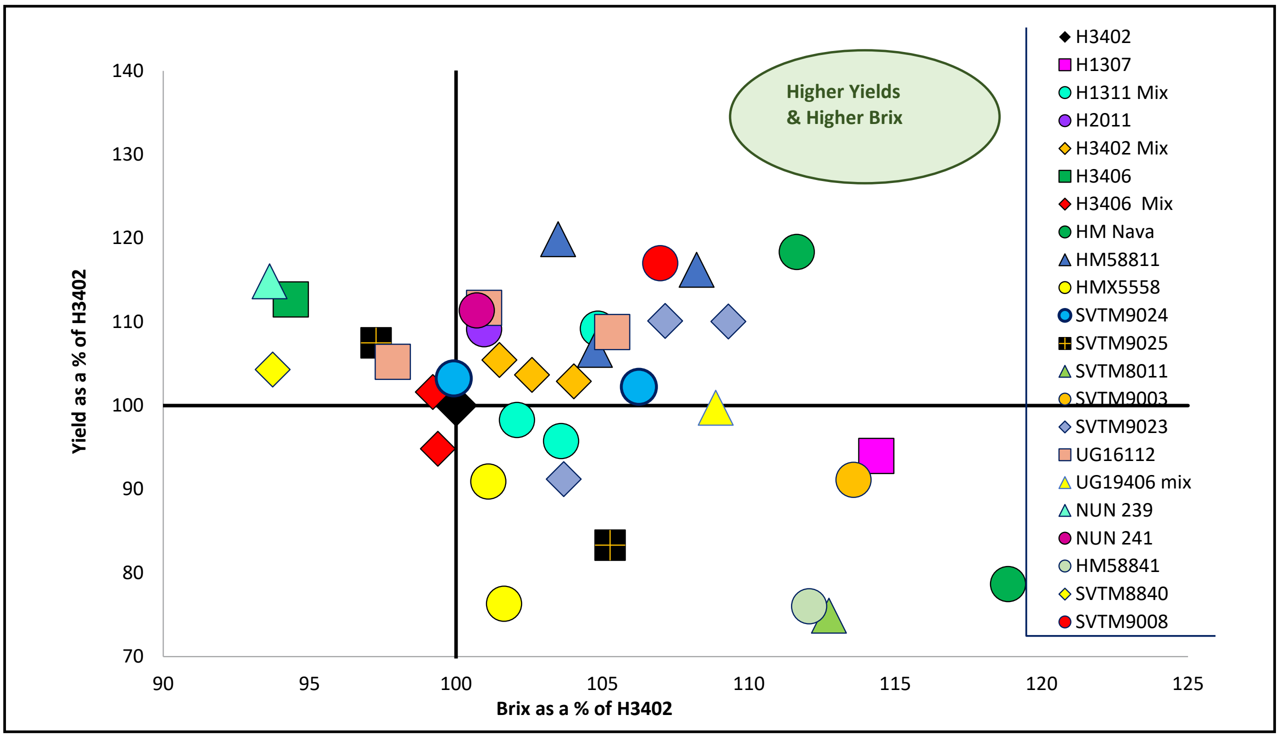

Figure 6. Yearly average mid-season trial results as a percentage of H3402 for the past 4 years

Screening Trials

Whilst two early and three mid-season screening trials were initially established, only one early and one mid-season trial at Thyra were assessed whilst the other trials were disregarded due to poor plant stands, health and production.

Cultivars in the remaining two screening trials as well as the larger machine harvest trial at the Thyra site were assessed on 7th of March 2023 after 119 days in the field. A brief description and a rating score out of 10 for each cultivar can be found in Tables 5 and 6.

Table 5. Early season screening trial assessment

Cultivar	Comments	Rating (-/10)
H1015	Medium-compact vine on the bed with dark foliage. Bit of leaf roll and disease on top but not bad. Small-medium sized, firm, blocky plum-egg shaped fruit with good colour. A few dimpled and a hint of bleach. Yield quite good although some greens still (10%?). Second-early?	**7**
HM Encina	Medium-vigorous vine – a bit upright but on the bed with large, dark, leaves -some rolled. Good sized (some large) blocky plum-pear fruit – a few puffy, medium firmness with a bit of grey-wall and veining detracting from good colour. Good concentration but question over holding – breakdown evident at both sites. Some patches of leaf disease also. Good yield – holding so far. Again greens 10% +. Fruit quality an issue. Regarded as second early.	**6.5**
HM Enotrio	Medium-vigorous vine – upright and flopping over a bit. Medium sized plum-egg fruit, firm with very good colour, small core and medium yield. No bleach to speak of so good fruit but yield and vine type mark it down. Greens 10%+	**6**
HM Pumatis	Medium/compact vine on the bed with some leaf roll. Foliage lighter and showing a bit of disease but cover still ok. Yield and concentration good. Fruit a bit variable but mostly medium egg-plum fruit, firm with good colour although a little bleach and shoulder discoloration noted. A few dimpled and yellow-eye too. Pretty good compared with others for early yield.	**7.5**
Syngenta BQ390	Vigorous/medium vine with dark foliage showing less disease than surrounds. Firm egg-pear shaped fruit of good size but a bit puffy. Medium colour with some core. Total yield looks ok but many (30%?) greens – looks later. Hence very little foliar disease or breakdown.	**6**
Syngenta BQ403	Medium-vigorous vine on the bed still providing reasonable cover. Medium leaf colour with a bit of disease (speck) evident. Firm blocky egg-plum shaped fruit, good colour and concentration relative to others (<10% green). Yield also good – so rates well for early production.	**8**

Table 6. Mid-season screening trial assessments

Cultivar	Comments	Rating (-/10)
	MACHINE HARVEST TRIAL	
H3402	Medium/vigorous vine – a bit ragged at this site. Fruit firm with good colour, blocky egg-plum shaped with some smalls. Good yield but greens >10%. A few bleached fruit also.	7
HM 58811	Upright medium-vigorous vine – falling open a bit - with medium/dark foliage. A bad bit of mite damage but otherwise not much foliar disease. Blocky egg-pear shaped fruit with good size (some large) and a few pointed. Very firm but a bit puffy. Colour medium only with some fence posting. Yield ok but 20%+ green.	6.5
HM 58841	Medium-vigorous vine – a bit upright and flopping. Elongated egg-shaped fruit – some with slight point. Medium colour and a bit of core and bleach. Very firm and medium size. Some foliar disease and 10%+ green.	6
HM Nava	Medium vine, a bit upright but on the bed – with dark foliage providing mainly good cover. Medium-large egg-pear shaped fruit showing just a hint of breakdown. Medium-firm with thick walls and a bit puffy with medium colour (some core). Yield ok-good but 20% green and breakdown could still be an issue as noted last season.	6
HMX 5558 (Orsorosso)	Medium vine on the bed – next to a spray row unfortunately. Medium-dark foliage. Medium-large elongated plum-egg shaped fruit, very firm but a bit puffy. Colour variable. Yield ok. Green 10% + A bit later	6.5
Nun 239	Medium-vigorous spreading vine with medium-dark foliage. Lots of green fruit still (50%). Colour average with fence posting and core. Medium sized blocky plum fruit, very firm. A few with points and some dimples. Lacking yield and a hint of breakdown. Later.	6
Nun 241	Medium-vigorous vine a bit floppy with medium-dark leaves. Fruit of variable size, very firm and a bit puffy. Medium sized blocky egg-plum fruit with average colour again – fence posting and core evident. Some smalls and only medium yield, although green only about 10%.	6
Nun 507	Medium/compact vine on the bed with good concentration and very little green. Yield ok. Medium blocky plum/egg shaped fruit. Size a bit variable, medium firmness and colour ok (small core). A bit of foliar disease but not too bad. Earlier – try in early observation.	7
SVTM 8840	Medium/vigorous vine with large, rolled leaves. Few greens (< 10%) and a hint of breakdown in exposed fruit. Firm, large/medium blocky plum-egg shaped fruit. Colour ok and yield could also be good. Earlier?	7
SVTM 9008	Medium-vigorous vine opening up here and showing some bad foliar disease. Fruit very firm blocky plum-eggs, a bit puffy and small-medium (variable) size. Some bleach and colour medium only. Medium-poor yield. Not much green either. Discontinued by the seed company.	5
SVTM 9023	Vigorous vine with dark leaves, falling open. Large, blocky egg-pear fruit – a few dimpled. Very firm, medium colour and yield with a bit of bleach also. Try on older ground.	5
SVTM 9025	Medium/vigorous sprawling vine with medium foliage and a fair bit of foliar disease. Medium sized blocky plums with a few points. Very firm and a few puffy. Colour ok and medium yield. Vine opening up a bit, some bleach but not much breakdown.	6
	MID-SEASON OBSERVATION TRIAL	
SVTM 9334	Medium/vigorous vine a bit floppy. Medium/dark foliage providing good cover in the absence of mite damage. Small-medium round-plum fruit – good set and yield. Medium firmness and colour ok. Some bleach and heat damage in exposed fruit but most holding. Fruit size an issue here.	6
HM Aprix	Medium-compact vine – small plants with small, dark, rolled leaves. Medium blocky eggs, firm with good colour. A few dimples. Yield medium only, although ok for plant size. Greens maybe 15%. Double row?	6

HM 6856 (Adenda)	Medium vine, low and on the bed, with small dark leaves showing little sign of disease and providing good cover. Fruit medium sized blocky egg-plums. Very firm with thick walls, good colour although a bit of shoulder bleach. Some greens still. Yield ok.	**7**
HM 6856 (Adenda)	Medium vine, low and on the bed, with small dark leaves showing little sign of disease and providing good cover. Fruit medium sized blocky egg-plums. Very firm with thick walls, good colour although a bit of shoulder bleach. Some greens still. Yield ok.	**7**
H 3402	See above. Larger vine and fruit size evident in these plots.	**7**

Summary

The exceptional weather conditions had a severe impact on our cultivar trial program this season, as they did on commercial crops. Results could not be considered typical although they provide some indication of how plants withstand a cool, wet season. On the other hand, the cooler summer weather did not fully test the resistance of cultivars to sunburn and bleaching, and field holding capabilities under more extreme temperatures could not be assessed.

In the early season screening trial, BQ403 and Pumatis both received higher field rankings than H1015, however in terms of yield, BQ403 produced slightly less tonnes of red fruit in a single low yielding trial. Nevertheless, the APTRC would be keen to continue assessing both cultivars in larger scale trials in the upcoming season. SVTM9000 also continued to be a consistent performer, and while SVTM8840 yielded well it will not be available for ongoing assessment.

A number of promising mid-season varieties including HM 6856 and 58841, Nun 239 and 507, and SVTM 9025 will be included in next season's machine harvested trial program subject to availability. APTRC will also continue to assess, along with the current commercial standards, mid-season varieties such as HM58811 and SVTM 9023 to provide additional points of comparison.

Acknowledgements

We are very grateful to participating growers, seed companies and processors for their co-operation and interest in the conduct of these trials, particularly in light of the trying seasonal conditions.

2023 SPC Field Report

Andrew Ferrier: Field Manager, SPC

The 2022-2023 season will be remembered as one of the toughest in recent memory. From record spring rainfall, floods and damaging hailstorms to ever increasing input costs, the challenges were many and significant.

With a delayed finish to the 2022 harvest and protracted grower negotiations which saw two growers retire from the industry, preparations for the 2023 season were already disrupted, but the ensuing weather conditions would prove a test of everyone's resilience - with some growers questioning whether to abandon the 2023 season altogether. Wetter conditions throughout the Autumn and Winter months, when it seemed like every time growers tried to work paddocks it rained again, continued to hamper preparations. Fortunately, a window of fine weather in June/July allowed bed forming and ground preparation to commence. The fine weather was short-lived however, as the wet Winter led into a cool and extremely wet Spring, resulting in record flooding in mid-October. River levels exceeding the 2011 event in Rochester and equalling the 1974 levels in the Shepparton area, impacted many properties throughout Rochester, Echuca, Shepparton and Mooroopna as well as inundating tomato paddocks. A slightly drier start to Spring in the Boort area enabled them to begin direct seeding from mid-September through until mid-October, when further rains put a halt to any further plantings. Wetter conditions in the Rochester area prevented any planting until a two-week opportunity between the 10th and the 24th of November. Due to the delays, early transplants were lost, further adding to the already burgeoning cost burden on growers. The season was now effectively split between the two growing districts, beginning in the Boort area and then, after an expected gap of around three weeks, picking up again in the Rochester area.

SPC initially contracted 38,500 tonnes of tomatoes with four growers, but less than half the intended area was planted, split evenly between the Rochester and Boort districts. Plans for cherry tomatoes were abandoned due to the seasonal difficulties and the need to maximise available land for conventional fruit. As only half the tonnes were planted, only half the scheduled tonnes would be available to process daily, restricting SPC's production flexibility and adding further complexity to an already difficult season.

The cool, wet conditions extended into December, inhibiting plant growth and restricting weed control, with bacterial speck also becoming an issue. So diseases, due in part to the excessive Spring moisture, led to two paddock failures in the Rochester district. It would be mid-December and into January before tomato plants would begin to develop and grow. As if Mother Nature hadn't already done enough, a hailstorm on the 22nd of January severely damaged crops in the Rochester area. Most blocks recovered, including those affected by the hail, and grew well through February but a late start to harvest was inevitable.

Harvest began in the Boort area four weeks later than expected on the 1st of March, continuing uninterrupted until the 23rd of March with yields exceeding expectations. Harvest in the Rochester area began a week after that on the 30th of March. Upon completion of the first Rochester paddock and with later crops slow to ripen, the decision was made to pause harvest until after the Easter break. Unfortunately, 18mm of rain fell on the tomato paddocks on the 6th & 7th of April. Then, after restarting on the 11th, another rain event on the 12th kept harvesters off the paddocks until the 20th. Harvest conditions were extremely difficult from then on with the late crops suffering some yield losses in the wet conditions.

15,829 nett tonnes were processed through the SPC facility with the last on the 4th of May. H1015 accounted for 36% of the intake, H3402 33%, UG16112 27%, with HM58811 (3.5%) and H3406 making up the balance. Average brix was 5.27°Bx with an average yield from harvested paddocks of 96T/Ha which was quite pleasing considering the difficult growing season.

Significant input cost pressures continue to plague growers and processors. A full soil moisture profile and full water storages, combined with fruit price rises, will give growers some confidence moving into the 2023-2024 season, despite a predicted El Nino event looming. With demand high for Australian products, SPC will look to increase tonnage significantly in 2024 to make up for supply shortages in 2023. Here's hoping for a much-improved year for the Australian Processing Tomato Industry.

2023 Kagome Field Report

Chris Taylor: General Manager, Field Operations, Kagome

The 2022-2023 season will be etched into Kagome's history, and notably, within the broader industry, as an exceptionally demanding/devastating period for tomato production. In my 17 years in the industry, this season stands out as the most challenging. It appeared destined to set records, but unfortunately, for all the wrong reasons.

From July 1st to May 27th, 2023 (*our final processing day*), an astonishing 600mm of rainfall inundated our fields, making gumboots a staple for all growers. Regrettably, growers across various regions – Boort, Lake Boga, Rochester, and NSW – bore the brunt, experiencing substantial losses, and in some cases total wipeouts due to severe flooding and rainfall.

Initially, Kagome set out for the 2022-2023 season with a goal of contracting 198,363 payable tonnes. However, that soon became unachievable with extensive rainfall preventing growers from accessing their fields and preparing for tomato cultivation. Kagome typically commences planting around September 26th, but this season saw the first tomatoes not planted until November 9th in Mathoura, a six-week delay. This setback had profound implications for transplants, affecting their size, quality, and health. The nurseries played a crucial role, demonstrating remarkable flexibility and commitment under such challenging circumstances, ensuring the production of plants despite adversity.

Unfortunately, due to such a delayed start and ongoing interruptions, the Kagome grower group had to discard over 7 million transplants that had grown too big and old, commanding a replanting process in the nursery. This added significant costs to an already financially demanding program.

Kagome's conventional tomato volume settled at 77,081 payable tonnes, falling significantly short of our initial target. To address this shortfall, the Kagome Farms group devised a plan to grow tomatoes on sand, recognizing the criticality of harvest feasibility. This initiative contributed an additional 12,795 tonnes, ensuring the continued presence of some Australian brands on supermarket shelves.

I want to express my gratitude to everyone involved in making the late-season "tomatoes on sand" project a success – from irrigation suppliers, nurseries, seed companies, contractors and in particular the Kagome Farming Team, who committed themselves to the project with failure not an option. We went from an idea in late November to fully develop 167Ha of irrigation, to finish planting on the 18th of January, *(As previously stated, breaking records for all the wrong reasons).*

Amidst an intensely cold, wet growing season, frequent rain interruptions, and hail in some areas, below-average yields and delayed harvest were inevitable. The tomato harvest commenced on February 15th, presenting a slow and prolonged process, concluding on May 27th. Harvest conditions were far from ideal, and retaining staff posed significant challenges.

Kagome's final volume stood at 89,911 payable tonnes, boasting an average Brix of 5.21, covering a total of 102 season days, with 62 days dedicated to paste production and 40 downtime days.

Looking ahead to the 2023-2024 season, we all harbor hope for vastly improved growing conditions and outcomes. Despite the industry and producers facing high input costs, particularly for energy, the promising prospects of full water storages, anticipated drier conditions forecasted by the Bureau of Meteorology, and a surge in tomato base price to record levels signal a positive opportunity on the horizon.


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