RMCG

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Reuse and recycling of substrate for hydroponic strawberries

Stage 3 Report

Fruit Growers Tasmania

Final

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ACKNOWLEDGEMENT OF COUNTRY

Tasmania is Aboriginal land. We acknowledge the palawa and pakana, the Tasmanian Aboriginal peoples, as the Traditional Owners and continuing custodians of the lands, seas, and waterways of lutruwita, Tasmania, on which this project will be conducted. We recognise their ongoing connection to the land, waters, and culture, and pay our respects to their Elders, both past and present, acknowledging emerging leaders. Additionally, we express our gratitude for the knowledge and insights that Traditional Owners and other Aboriginal and Torres Strait Islander peoples contribute to our shared work in Australia.

We pay our respects to all Aboriginal and Torres Strait Islander communities. We acknowledge that Australia was founded on the genocide and dispossession of First Nations peoples and affirm that sovereignty was never ceded in this country. We embrace the spirit of reconciliation, striving toward self-determination, equitable outcomes, and an equal voice for Australia's First Peoples.

Executive summary

The 'reuse and recycling of substrate for hydroponic strawberries' project ran for three years, from late 2022 until 2025. The project was developed in response to increasing costs and accessibility issues of sourcing coir, the primary growing substrate for hydroponic berry production.

The project worked with three project partner farms and utilised a combination of desktop research, laboratory testing and industry consultation and on-farm trials to improve understanding of substrate behaviour in hydroponic strawberry production in particular. The purpose of the project was to improve the resilience of hydroponic berry production in Tasmania. The project had two key aims:

- To identify and investigate methods to reuse coir as a substrate after the first strawberry growing season
- To investigate suitable alternative substrates for hydroponic strawberry production, either in a mix with coir, or as stand-alone substrate.

INTERPRETATION OF RESULTS

Results from the Stage 3 trials varied substantially between farms and are not directly comparable across sites. Results should be interpreted as site-specific explorations, not scalable industry averages.

For all changes to the commercial production system, whether it be reusing coir, adding composted pine bark as an amendment or changing substrate container, there are production system management changes that could be employed to improve performance (fertigation, plant management adjustments). Such changes should reduce the yield gap to the existing commercial production system (fresh coir, fresh plants in bags). Due to limitations around farm infrastructure, logistics and trial design, such changes weren't able to be tested and trialled – all treatments were tested under the management conditions of the existing commercial production systems. Greater knowledge around how to manage changed substrate or containers requires development over time.

The Stage 3 trial results must therefore be interpreted with this in mind.

This report documents the results of the Stage 3 commercial scale trials and Stage 4 economic assessment component of the project, drawing on findings from Stages 1 and 2 of the project.

REUSING COIR

Summarised results from Stage 3 trials showed that:

- There was a substantial yield decrease growing in 2nd year coir bags (-27% than commercial control)
- There was a substantial yield decrease growing 2nd year coir in troughs – both compared to fresh coir in troughs (-19%) and fresh coir in bags (commercial control) (-31%)
- Growing fresh plants in composted coir (sourced from stockpile) in troughs (agitated) yielded 5% less than fresh coir in troughs (one farm only) – but yielded better (+15%) than 2nd year coir substrates left in situ.

Reasons for yield results:

- A decline in drainage characteristics of used coir substrates, particularly when left in situ (unagitated) for two seasons, was determined to be the primary cause of the yield decline.
- The settling of coir fines and the presence of dead plant roots (from first year of production) reduced porosity and inhibited drainage in used coir substrates, causing water-logging and anaerobic root zone conditions, which impacted plant health.

- The drainage issues were likely to have caused increased *Pythium* levels observed in used coir substrates.
- Agitating/mixing used coir substrates prior to planting (composted coir treatment) improved the performance in comparison to used coir substrates left in situ between seasons. Agitating/mixing improved substrate porosity and, therefore drainage.

ALTERNATIVE SUBSTRATES – COMPOSTED PINE BARK

- The composted pine bark and coir mixes on average performed -6% to -15% compared to commercial control treatment (fresh coir in bags).
- Adding composted pine bark to 2nd year coir prior to planting improved 2nd year coir performance (18% to 25% yield improvement relative to 2nd year coir-only treatments).
- The mix of 40:60 2nd year coir and composted pine bark was found to be the optimal mixed substrate ratio (only 6% yield reduction compared to fresh coir substrates). This aligned with existing literature.
- This result indicates that there is potential to utilise composted pine bark as an amendment to improve 2nd year (reused) coir. Given the differences in commercial hydroponic strawberry production systems, individual businesses will have to evaluate the suitability of using pine bark in their specific system on a small scale first.
- It is assumed that the process of mixing 2nd year coir with composted pine bark improves the substrate drainage characteristics and porosity relative to used coir substrates (both in situ and agitated).

CONTAINER TYPE (BAGS/TROUGHS)

There was an observed yield decrease in troughs, when comparing the same substrate grown in both bags and troughs (-12% for fresh coir, -4% for 2nd year coir). This was likely caused by:

- Increased early-season fruit losses in troughs, due to fruit rot
- The bags providing a preferable ‘tighter’ root zone environment, which reduced coir settling
- Greater uniformity of substrate density in bags, versus in troughs.

TRIAL INTERPRETATION CONSIDERATIONS

- Trials were not able to be completely aligned and replicated between farms.
- Block sizes, irrigation and operational constraints differed between farms.
- Due to irrigation line set up limitations on farms, each substrate treatment was subject to the same fertigation regime which were optimised for the existing commercial production system. Ideally, fertigation regimes would have been adjusted and optimised for each treatment to better understand comparative potential yield performance.

ECONOMIC ASSESSMENT AND CONSIDERATIONS

Fruit yield and income are fundamentally critical for the sustainability and viability of berry production systems. However, changes in substrates also have an impact on the overall cost of production; therefore, understanding the impact on overall profitability is important.

The economic assessment compared the following substrate treatments:

- Base case – fresh coir in plastic wrapped slabs with fresh plants replaced annually
- 2nd year coir in bags (fresh plants)
- 2nd year coir and composted pine bark mix, in troughs (fresh plants).

The comparative gross margin analysis, for the full 2-year production scenario, under existing market and substrate price conditions showed that:

- Fresh coir in bags, replaced annually, remains the most profitable. This is driven by increased yield compared to the reused coir substrates modelled, despite having higher substrate, labour and disposal costs.
- The 2nd year coir and composted pine bark treatment was more profitable than the 2nd year coir in bags treatment, due to its increased yield.
- Both reused coir production systems had lower variable costs (5% and 10%) than fresh coir, due to reduced substrate, substrate handling (labour) and disposal costs.

Sensitivity analysis showed that:

- If reused coir yields can be improved (by 100g per plant) through management adjustments to improve production, both reused coir substrate treatments could meet a similar profitability to fresh coir production.
- Any reductions in fruit price improve the relative profitability of the reused substrates, due to their lower cost structure. Conversely, increases in fruit price mean that the existing production system will increase in relative profitability.
- Increases to coir pricing between 10–30% would mean that reusing coir substrates would be relatively more profitable than the existing production system, demonstrating the importance of reviewing market conditions ahead of establishing production for each season.

The overall economic assessment suggests that any work undertaken to reduce the yield gap between fresh coir and reused coir substrates will be worthwhile, and that any decreases to fruit price or increases to coir price will relatively favour the profitability of systems utilising reused coir.

> An important caveat: the economic model and sensitivity analysis is undertaken on the average fruit price achieved over a season. Therefore, it does not consider the dynamic nature of fruit pricing through the season and the impact of timing fruit production with periods of higher prices. Understanding different substrate systems and how their fruit production varies through the season requires close consideration for growers.

KEY TAKEAWAYS

- Fresh coir in bags was the best-yielding substrate. This is unsurprising given the existing production system (fertigation, plant management) is optimised for these substrates' characteristics.
- Agitating/mixing used coir prior to reuse (as opposed to leaving in situ) improved the structural characteristics (water drainage, porosity) and therefore yield performance of used coir.
- Mixing composted pine bark with used coir further improved the performance of used coir.
- Based on disease testing results, sterilisation of used coir substrate prior to reuse in strawberry or other berry hydroponic production is not warranted. Production decreases observed in used coir substrates are largely due to drainage issues, rather than other factors.
- Producers should consider mitigations (mixing, adding composted pine bark) to improve structural characteristics in used coir substrates prior to reuse.
- Microbial activity can increase in used substrates over time, which may impact nutrient availability and productivity.
- Plants grown in bags yielded more than in troughs, however fine-tuning production strategies in troughs should improve performance over time. There are substantial disposal and handling cost and plastic waste reductions by growing in troughs. These need to be considered against yield differences.

- Fine-tuning fertigation and plant management strategies to different substrate and container types is required, and must be done progressively over time, to improve production performance of used coir substrates and production in troughs.
- Profitability of the production system needs to be considered, not just yield. Cost savings by reusing coir, if strategies to improve the management of the drainage issues of used coir are found, could improve profitability.

RECOMMENDATIONS

While coir prices and accessibility have normalised after COVID-19-associated supply-chain interruptions, the hydroponic berry industry should continue individual on-farm trials to improve reuse of coir as a risk-minimisation strategy. The economics assessment, demonstrating the sensitivity of fruit price and coir price changes to profitability, supports this.

As with any substantial change to a production system, it can take several growing seasons to fine-tune the system to its best potential. A key challenge is developing fertigation strategies for new substrates and container types to match their different drainage, chemical and biological characteristics.

Suggestions for further trials/research can be undertaken by industry and include:

- Further on-farm trials investigating different fertigation strategies for mixed-use coir and composted pine bark amendments to improve knowledge are recommended.
- Investigating cost-effective methods of ‘mixing’ used coir (and adding composted pine-bark) in situ is also recommended.
- Further work to understand substrate microbial activity changes in used coir and composted pine-bark and production impacts would also be of benefit. Composting coir during stockpiling without plastic wrap may improve its performance when reused. The reasons for this should be further investigated.
- Optimising production in troughs should continue to be a focus, given the disposal and handling costs and plastic waste reductions compared to grow bags. Further work to trough design, considering substrate characteristics and uniformity to improve yield performance, is required.
- Aeration and (uncontrolled) composting of the used coir between seasons by putting it in loose stockpiles, utilising coarser coir. These should also be further investigated to determine whether they can reduce the yield gap or reduce production costs.
- Investigating composted pine bark and disease suppression.
- Investigating the origins of disease in hydroponic production systems.
- Investigating the reuse of coir from strawberry production in other berry crops, e.g. raspberries or blackberries. Such crops may be better suited to used substrates.
- The sharing of research and findings between farms is enormously important to furthering the resilience of the industry. Any future projects should be coordinated between farms.

ACKNOWLEDGEMENTS

RMCG thanks Fruit Growers Tasmania for engaging RMCG and their support during the project.

A huge thank you goes to the three project partners who provided directions and insights for the project. They conducted the trials on their busy commercial farms, collected samples, data and observations. Without the commitment of farm management and diligence of their staff, this work would not have been possible.

1 Introduction

1.1 BERRIES IN TASMANIA

Tasmania's berry industry has rapidly expanded over the past 10–15 years. Berry farmgate value has increased by an annual average of 14% between 2012–13 and 2023–24[1]. This has been largely driven by increasing hydroponic production under poly-tunnels, allowing for increased production in Tasmania's relatively cool, Mediterranean climate.

Tasmania produces approximately 45% of Rubus berries (raspberries and blackberries) grown in Australia, valued at $103m. Approximately 15% of Australian strawberries (valued at $79m) and 10% of blueberries (valued at $34m) are produced within Tasmania[2]. The proportion of berries grown under protected cropping systems in Tasmania has been steadily increasing over the past 10-15 years.

Approximately 90% of strawberry production in Tasmania is grown hydroponically under poly-tunnels, and relies on coconut fibre (coir) as the growing substrate. Coir is sourced from coconut-producing countries in South-East Asia (including but not limited to India, Sri Lanka and the Philippines). Hydroponic strawberry producers are particularly reliant on the continual supply of fresh coir substrate, as they are annual crops that require fresh plants and substrate each year.

1.2 PROJECT BACKGROUND

Price increases and shipping delays of coconut coir during the COVID-19 pandemic (2020–2022) impacted accessibility to hydroponic substrates for growers. The reliance on coir as the only substrate for hydroponic strawberry production (and its use in raspberry, blueberry and blackberry hydroponic production also) in Tasmania was identified as a key risk for future production, particularly if the cost and accessibility issues for coir were to escalate further. Growers, therefore, identified a need for the investigation of possible solutions, such as reusing coir for at least one year and alternative substrates.

Growers were concerned about potential issues with soilborne diseases if reusing coir and were interested in sterilisation options to mitigate this risk.

A project was proposed to the Department of Natural Resources and Environment (DNRE) for funding via the Agricultural Development Fund. Fruit Growers Tasmania (FGT) and three project partner berry farms: Costa Berries, Hillwood Berries and Tasmanian Berries submitted the proposal to DNRE in late 2021. FGT received funding mid-2022 and subcontracted RMCG in October 2022 as the research partner for the project. This project was funded through the Tasmanian State Government's (DNRE) Agricultural Development Fund.

1.3 THE PROJECT

The coir reuse/replacement/recycling project had two key aims:

- To identify and investigate methods to reuse coir as a substrate for more than one growing season
- To investigate suitable alternative substrates for hydroponic strawberry production, either in a mix with coir, or as stand-alone substrate.

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1 https://www.rabobank.com.au/media-releases/2025/tasmania-stand-out-success-story-of-australian-agriculture-gearing-up-for-mature-growth-ahead-industry-report
2 https://tasmaniangrown.au/what-we-grow/fruit/

The project began in late 2022. The project, in response to changing economic factors and market accessibility of coir substrates, has evolved since the submission of the project proposal. Coir prices, shipping times and supply returned to pre-COVID levels during 2023 and have since stabilised.

The focus for the project shifted once prices stabilised in 2023. The focus was on investigating the viability of using coir for more than one growing season. However, the project still considered and investigated standalone alternatives.

1.3.1 PROJECT STRUCTURE AND REPORTING

The stages of the project, including their production seasons, are shown below:

- Stage 1 – Defining the characteristics of alternative substrates, including exploratory trials guided by project partners (2022/23)
- Stage 2 – Small-scale trials (2023/24) on three project partner farms, greenhouse and laboratory (UTas support)
- Stage 3 – Larger-scale trials (2024/25) on three project partner farms
- Stage 4 – Economic Assessment (2024/25) based on information from stages 1–3 and project partner input, and a comparative review of emissions from substrates identified in this research.

The project partners provided guidance on trial focus and set up, ran trials on their farms, supported data collection and provided their observations made during trials through each production season.

The final reports for Stages 1 and 2 of the projects were reported to FGT at milestones 5 (April 2024) and 6 (October 2024) respectively. Report summaries from these stages of the project can be found in Appendices 1 and 2.

This report covers Stages 3 and 4 as well as the comparative emission assessment.

This report presents data and information from the final growing season (Stage 3) of the project 'Reuse and recycling of hydroponic substrate to enable the growth of high-value agricultural production in Tasmania' (Stage 3 and 4, project milestone 8). Reports on the preceding two growing seasons were produced and submitted to FGT for milestones 5 and 6 in 2023 and 2024, respectively.

1.3.2 PREVIOUS STAGES FINDINGS

Stage 1 of the project identified:

i. Wood-fibre-based substrates as an available and practical alternative to coir substrates, produced in Australia. Processed wood-fibre substrates (various products) and composted pine-bark were trialled on a small-scale during Stages 1 & 2.

Stage 2 identified composted pine-bark as the preferred alternative substrate or 'additive' to coir. There were two primary reasons:

ii. It is widely available and cost-competitive in Tasmania
iii. The literature review and small-scale trials identified it as a possible viable alternative to coir, with similar physical characteristics (e.g. porosity, structural stability).

2 Stage 3 – Methodology

2.1 TRIAL DESIGN INFORMATION

ON-FARM TRIAL DESIGN INFORMATION: COMMERCIAL RELEVANCE

All trials were co-designed with the commercial hydroponic strawberry businesses prior to the season, with the explicit objective that results would be commercially meaningful and directly observable within operating farms to allow commercial adoption.

As a result, these trials were intentionally at a commercial practice-scale, i.e. on-farm practice demonstrations, not small-plot, replicated research trials conducted under controlled conditions. This distinction is critical when interpreting performance metrics such as yield.

Our commercial partners were clear that trial designs had to:

- Align with current and future commercial practice
- Occur with their existing commercial production system (irrigation, fertigation, plant management)
- Avoid disrupting normal harvesting, grading, irrigation, and nutrition systems
- Generate information that could realistically support industry adoption, rather than scientific publication alone

The trial designs ensured that, under the existing commercial production system, qualitative information about substrate behaviour (drainage, aeration, plant management) was able to be collected to further improve management of these substrates and container options into the future.

The 'traditional' production system on hydroponic farms is set up for using fresh coir in bags (a polyethylene wrap) growing system. Hence, yield results may favour the existing production system.

The trials focused on developing a better understanding of substrate behaviour, and what management changes would be required to ensure an alternative substrate could be effectively managed in the future. This included using troughs to replace polyethylene for practical and environmental reasons. Yield information was collected and this provided an important relative indicator of performance. However, the qualitative results about substrate behaviour will provide the greatest value to inform future work and extension to industry.

Commercial control data could not be obtained from all trial sites. Where possible, we have included the % difference to commercial control (fresh coir in bags). Results are reported as relative performance indicators and are to be interpreted alongside surrogate productivity measures such as crown number and diameter, and the commercial production system context, rather than looking at standalone comparative yield results across all trials, which were not uniformly set up as explained in Section 2.4. Absolute yield performance should therefore not be interpreted in isolation to the context of these trials.

2.2 PROJECT GOALS – STAGE 3

Based on the findings from Stage 1 and 2 of the project; and the return of coir price and accessibility to pre-COVID conditions, the research goals were refined utilising the original goals listed in the project plan. This was necessary to ensure the relevance of the project's research and findings aligned with current and commercial market conditions in the industry, whilst remaining aligned with the project goals to build a better understanding of substrate behaviour.

Using the findings and learnings on substrate behaviour, crop performance and required management approaches from Stage 2, the key aims of the Stage 3 hydroponic strawberry commercial-scale trials were to:

1. Compare and evaluate production performance of fresh coir and 2nd year coir (both immediate re-use and post-stockpile) substrate treatments
2. Compare and evaluate production performance of fresh coir and wood-fibre-based (composted pine-bark) substrate treatments
3. Compare and evaluate different combined substrate mix ratios (coir combined with composted pine-bark)
4. Evaluate the impacts of substrate packaging – plastic wrapped coir (slabs) versus reusable troughs, considering yield and quality impacts, substrate performance and operational changes
5. Provide recommendations for next steps.

The trials were designed to be replicated at each project partner farm, as much as practically possible given their differing farm systems, locations and climate, production areas and management strategies.

This approach, whilst not a controlled replicated trial held at each farm, aimed to ensure that the trial data generated provided answers to the four key aims above.

2.2.1 RESEARCH QUESTIONS FOR STAGE 3

Key research questions under consideration for Stage 3 were:

- How does strawberry productivity (total yield, timing of fruiting and fruit size) in alternative substrates (2nd year coir or composted pine bark) compare against those grown in fresh coir substrates?
- Does the substrate type influence fruit size and quality characteristics or labour efficiency?
- How does the productivity performance of different substrates affect the overall financial return (gross margin) per area of production (considering factors including substrate cost, fruit yield and quality, handling and management activity changes)?
- For each substrate/blend, what changes are required to existing management systems to optimise plant performance for each blend, if necessary? Do they need to be trialled further, via on-farm trials? If yes, how, i.e. by each commercial company or via a new project?
- Which substrate options provide the best productivity (considering total yield, timing of fruiting, fruit size/quality, cost of production inputs and labour efficiency) for producers?
- How does growing in troughs impact substrate performance and overall fruit yield and quality characteristics, compared to growing in slabs?

Primary research focus

- Strawberry plant performance/productivity in different substrate blends compared to fresh coir
- Economics of using different substrates
- Optimisation options of substrates/blends and plant management practices, including operational activities.

Secondary research focus

- Environmental impact of using different substrates and systems (reusable troughs, imported plastic wrapped coir slabs, water, nutrients), e.g. emissions, resource use efficiency/waste.

2.3 RESEARCH PLAN – OVERVIEW OF STAGE 3

The three substrate types trialled in Stage 3 were:

- Fresh coir (commercial control substrate)

- Used (2nd year and stockpiled) coir
- Composted pine bark (8mm-hammermilled fines).

Stage 3 of the project also trialled combined (or mixed) substrates (fresh/used coir and composted pine bark mixes) in different ratios (70:30, 50:50, 40:60). The coir and composted pine bark mixed substrate was selected by the project partners based on the results from Stages 1 and 2 of the project. Economic factors including the cost and accessibility of alternative substrates were also considered.

The project partner farms collected data and observations on several key variables (including yield, quality, plant health, substrate drainage characteristics) as outlined in the Stage 3 project plan document (Appendix 2). These key variables include:

- Plant performance:
  - Plant vigour: measured as individual plant crown numbers and crown diameters (reported at specific stages through the growing season)
  - Overall fruit yield (grams per plant) (reported at the conclusion of the growing season)
- Observations:
  - Visual plant observations such as plant health, vigour, start and development of harvest, fruit size and fruit quality)
  - Substrate attributes, especially physical structure influencing porosity, water infiltration, lateral water movement, drainage and water use, as well as required changes in nutrition (e.g. of pine bark mix substrates or straight reused coir compared to fresh coir) and changes in and substrate attributes over time
- Substrate disease loading – analytical data:
  - Pathogen loading: Quantitative DNA PCR testing for soil borne diseases – conducted at the middle and end of the season
- Additional testing of substrates or plants was made available to project partner farms as required to investigate any plant health issues identified.

The commercial-scale trial findings were used to inform the Stage 4 economic analysis.

Stage 3 results, the economic analysis in Stage 4 and the industry outlook at the time of the final analysis will determine the commercial feasibility of the mixed substrate(s) and reused substrates. Further RD&E needs may be identified during Stage 3.

2.4 STAGE 3 – TRIAL TREATMENT DESIGN

Substrates

The substrate treatments trialled were:

- Fresh coir
- 2nd year coir
  - In this instance: coir used for strawberry production for one growing season at the time of planting – unprocessed (old plants removed, fresh plants planted)
  - Old plants were removed via circular drill bit (removing crown and canopy), with fresh plants planted
  - 2nd year coir was left in situ – undisturbed and unmixed – prior to replanting of fresh plants
- Stockpiled used coir (composted coir) (Hillwood only)
- Mixed substrate (fresh or 2nd year coir and composted pine bark (8mm hammermilled fines) in 40:60, 50:50 and 70:30 ratios).

Coir substrate variation

Coir substrates can vary substantially; some have more coco pith and are finer, whilst some have greater proportion of coir chips and are coarser. Observations from Stage 2 suggested that coarser coir has greater structural durability than finer coir and performs better over a second year of use. Project partners aimed to source coir with a greater proportion of chips than in Stages 1 and 2 of the project to enhance substrate suitability for a second season of use. However, the 2nd year coir tested in these trials was the finer coir, given it would take a year of use to be able to trial the coarser coir substrate as a 2nd year substate.

Individual farms each used their standard coir mix for the trials. This means that not all farms may use the same type/mix of coir. Each farm uses the coir that best suits their production environment and system to ensure optimal productivity. This approach enabled a true comparison of alternative substrate treatments to their commercial production system.

Container type

Container treatments included:

- Troughs (0.5m or 1m length)
- Polyethylene wrapped coir substrate (1m bags/slabs).

There is an ongoing shift by the industry towards using troughs instead of bags to reduce soft plastic waste. However, this is a gradual change, and most commercial production is still occurring in the bags.

Fresh coir and 2nd year coir substrate treatments were trialled in both bags and troughs (0.5m or 1m length, depending on each farm's preference). Composted pine bark treatments were trialled only in troughs (not bags).

The trial design intended to ensure that differences in substrate behaviour in fresh and 2nd year coir can be observed in both container types, ensuring industry knowledge is developed on what, if any, management changes were required to ensure optimal production in troughs.

A secondary benefit of using troughs is to change the irrigation systems from individual drippers to drip lines. This change would reduce labour costs for installing and removing several irrigation drippers between seasons. However, troughs require labour for filling them with substrate. Both systems required substrate removal at the end of the season. Disposing of used coir bags is more challenging than coir in troughs, given the plastic needs to be separated from the coir if the coir is to be reused or recycled.

Tasmania currently does not have a facility that recycles polyethylene (slab bags). Used slab bags must be shipped to Victoria for processing.

Plant varieties

Each of the project partner farms grows for Driscoll's and therefore uses Driscoll's varieties for production. The plant variety 'Zara' was selected for trials across all farms. Zara is the primary Driscoll's strawberry variety, so its use in the trials was relevant for commercial production systems for at least the medium-term. Table 2-1 below shows the trial outline for each farm.

Table 2-1: Trial treatments for 2024/25 commercial scale trials

TREATMENT #	SUBSTRATE	CONTAINER	FARMS
1 (commercial control)	Fresh coir	Bags (1m)	All
2	Fresh coir	Troughs (1m)	All
3	2nd year coir	Bags (1m)	All except Costa
4	2nd year coir	Troughs (1m)	All except Hillwood
5	Composted coir (Hillwood pile)	Troughs (1m)	Hillwood
6	40% 2nd year coir, 60% composted pine bark	Troughs (1m)	All except Costa
7	50% 2nd year coir, 50% composted pine bark	Troughs (1m)	All except Costa
8	50% **fresh coir**, 50% composted pine bark	Troughs (1m)	Costa
9	70% 2nd year coir, 30% pine bark	Troughs (1m)	All except Costa

Additional information concerning management practices and data collection protocols can be found within the Stage 3 Project Plan (Appendix 1).

Trial size

Each project partner farm was able to dedicate slightly different areas of its farm to the trials.

- **Costa Berries**: Each of their four trial treatments was each a full production block in size
- **Hillwood Berries**: Their six trial treatments were across two tunnels (two rows per treatment)
- **Tasmania Berries**: Their seven trial treatments were across two tunnels (two rows per treatment).

3 Stage 3 – Individual farm trial results

Results are shown below for each of trials held at the three project partner farms including:

- Plant growth measurements (crowns per plant, and crown diameter): taken at three different points over the growing season: early October, early December and early February
- Yield results: average fruit yields per plant for each treatment across the 2024–25 growing season
- Substrate pathogen loading testing: Two rounds of substrate sampling and DNA pathogen testing by SARDI were completed:
  1. February 2025 (mid-season) and;
  2. April 2025 (end-season).

Details and information on key pathogens identified and results can be found in this section, however Appendix 3 displays the full raw test results.

Each farm's production results have been presented individually – comparisons between treatments can only be made within each farm, due to climatic, management and planting date differences between each farm.

3.1 COSTA BERRIES

3.1.1 PLANT MEASUREMENT RESULTS

Table 3-1: Average crown diameter (mm) measurement results – Costa Berries

TREATMENT	PLANTING DATE	OCTOBER	DECEMBER	FEBRUARY
Fresh coir – bags	10th June 2024	52	83	100
Fresh coir – troughs	3rd July 2024	55	83	101
2nd year coir – troughs	26th June 2024	50	69	93
50:50 fresh coir, composted pine bark	12th July 2024	50	73	102

Table 3-2: Average crown number (no.) measurement results – Costa Berries

TREATMENT	PLANTING DATE	OCTOBER	DECEMBER	FEBRUARY
Fresh coir – bags	10th June 2024	2.1	2.8	5.0
Fresh coir – troughs	3rd July 2024	2.3	2.8	5.2
2nd year coir – troughs	26th June 2024	1.8	2.9	4.2
50:50 fresh coir, composted pine bark	12th July 2024	2.2	3.2	5.6

Each of the treatments at Costa performed reasonably similarly – particularly by the February measurement time. It appears the planting date has less of an impact on the results, as later planted treatments 'catch up' to earlier ones.

The 2nd year coir treatment is the exception – with less plant vigour in terms of both crown diameter and number.

3.1.2 YIELD RESULTS

Table 3-3 displays the average saleable yield achieved for each of the four treatments trialled by Costa. Each treatment was across a whole production block at Costa and represents a large sample size.

Table 3-3: Average saleable fruit yield (grams per plant) for each treatment across the whole growing season

TREATMENT	CONTAINER	YIELD (G/PLANT)	% DIFFERENCE TO FRESH COIR IN BAGS (CONTROL)
Fresh coir	Bags (1m)	1301	
Fresh coir	Troughs (1m)	1119	- 14%
2nd year coir	Troughs (1m)	767	- 41%
50% fresh coir, 50% composted pine bark	Troughs (1m)	1052	- 19%
Average (all treatments)		**1060**	

The commercial control (fresh coir in bags) treatment had yielded greater than all other treatments.

The 2nd year coir treatment was the poorest yielding – almost 300g less per plant than the composted pine bark and coir mix, and 540g less per plant than the commercial control. This aligned with anecdotal observations from farm agronomists, which suggested that plant yield for the 2nd year coir treatment declined substantially as the season progressed, particularly later in the season.

3.1.3 DISEASE – SUBSTRATE PATHOGEN LOADING RESULTS

Table 3-4: February testing – Costa Berries – Substrate pathogen results

SUBSTRATE	CONTAINER	PYTHIUM CLADE F (PG DNA/G SAMPLE)	OTHER PATHOGENS PRESENT
Fresh coir	Bag	0	Nil
Fresh coir	Troughs	0	Nil
2nd year coir	Troughs	107	Nil
50:50 fresh coir, composted pine bark	Troughs	0	Nil

Table 3-5: April testing – Costa Berries – Substrate pathogen results

SUBSTRATE	CONTAINER	PYTHIUM CLADE F (PG DNA/G SAMPLE)	OTHER PATHOGENS PRESENT (PG DNA/G SAMPLE)
Fresh coir	Bag	0	Nil
Fresh coir	Troughs	0	Nil
2nd year coir	Troughs	34	*Meloidogyne fallax*
50:50 fresh coir, composted pine bark	Troughs	0	Nil

As displayed in Table 3-4 and Table 3-5, for both testing periods, the only substrate treatment that had presence of soil-borne pathogens at Costa Berries was the 2nd year coir substrate. Compared to the other project partner farms, their overall levels of pathogens were substantially lower.

3.2 HILLWOOD BERRIES

3.2.1 PLANT MEASUREMENT RESULTS

Table 3-6: Average crown diameter (mm) measurement results – Hillwood Berries

TREATMENT	OCTOBER	DECEMBER	FEBRUARY
Fresh coir (troughs)	50	65	86
2nd year coir (bags)	48	50	62
Composted coir	37	63	81
40:60 2nd year coir, composted pine bark	49	62	85
50:50 2nd year coir, composted pine bark	47	58	73
70:30 2nd year coir, composted pine bark	45	73	98

Table 3-7: Average crown number (no.) measurement results – Hillwood Berries

TREATMENT	OCTOBER	DECEMBER	FEBRUARY
Fresh coir (troughs)	2.0	2.3	3.4
2nd year coir (bags)	2.1	2.3	2.8
Composted coir	1.5	3.3	3.7
40:60 2nd year coir, composted pine bark	2.1	2.3	3.7
50:50 2nd year coir, composted pine bark	2.2	2.7	4.1
70:30 2nd year coir, composted pine bark	2.1	3.3	4.3

2nd year coir (bags) was the worst performing treatment – based on both crown numbers and diameter. The remaining treatments all performed relatively similarly. Interestingly, the composted coir performed much better than the 2nd year coir, in line with other treatments. The 70:30 2nd year coir, composted pine bark treatment was the most vigorous treatment.

Root zone observations

Root zone observations were undertaken by Hillwood Berries during each of the plant measurements (complete descriptions are shown in Appendix 3). Composted coir and 70:30 2nd year coir, composted pine bark were the two treatments with the roots perceived to be in the best condition at the February measurements by farm staff. This aligns with the plant measurements that identified the 70:30 2nd year coir, composted pine bark treatment as the best performing treatment. However, there was a greater variation between these treatments during October and December.

Figure 3-1: Comparative root conditions of different substrate treatments (taken April 2025)

Table 3-8: Hillwood Berries root zone observations – February measurements

TREATMENT	FEBRUARY DESCRIPTION OF ROOT ZONES
Fresh coir (troughs)	▪ Ok root distribution patchy in places, new white root growth occurring
2nd year coir (bags)	▪ Poor root distribution, roots mainly formed in bottom half of bag ▪ More caramel roots to white in bag ▪ Canopy is smallest in size out of all trials
Composted coir	▪ Good root distribution, roots are compact, new white root growth occurring
40:60 2nd year coir, composted pine bark	▪ Ok root distribution, patchier compared to 70% 2nd yr coir, 30% pine bark and composted coir trials
50:50 2nd year coir, composted pine bark	▪ Ok root distribution, patchier compared to 70% 2nd yr coir, 30% pine bark and composted coir trials. New white root growth is occurring
70:30 2nd year coir, composted pine bark	▪ Good root distribution, roots are compact, new white root growth occurring.

3.2.2 YIELD RESULTS

Table 3-9 displays the overall yield results for each of the treatments across the whole growing season at Hillwood Berries.

Hillwood Berries were not able to provide fresh coir in bags yield information, so the control comparison is to fresh coir in troughs.

Table 3-9: Average saleable fruit yield (grams per plant) for each treatment across the whole growing season – Hillwood Berries

TREATMENT	CONTAINER	YIELD (G/PLANT)	% DIFFERENCE TO FRESH COIR IN TROUGHS
Fresh coir	Troughs	918	
2nd year coir	Bags	666	-27%
Composted coir	Troughs	876	-5%
40:60 2nd year coir, composted pine bark	Troughs	888	-3%
50:50 2nd year coir, composted pine bark	Troughs	791	-14%
70:30 2nd year coir, composted pine bark	Troughs	857	-7%
Average		**833**	

The fresh coir in troughs treatment was the best yielding treatment. Interestingly, the composted coir in troughs yield much higher (210g per plant) than the 2nd year coir in bags. This aligned with the plant measurement and root zone observation results.

Of the composted pine bark mixes, 40:60 2nd year coir, composted pine bark was the best yielding only 3% less than fresh coir in troughs. The fresh coir yield results are greater than expected based on the plant measurement results (February was the last plant measurement date), suggesting that the fresh coir substrate treatments may better maintain fruit production as the growing season progresses.

3.2.3 DISEASE – SUBSTRATE PATHOGEN LOADING RESULTS

Table 3-10: February testing – Hillwood Berries – Substrate pathogen results

SUBSTRATE	CONTAINER	PYTHIUM CLADE F (PG DNA/G SAMPLE)	OTHER PATHOGENS PRESENT
Fresh coir	Troughs	0	Nil
2nd year coir	Bags	1935	*Common Scab, Phoma terrestris*
Composted coir	Troughs	362	Nil
40:60 2nd year coir, composted pine bark	Troughs	1027	*Pythium clade I*
50:50 2nd year coir, composted pine bark	Troughs	1435	*Pythium clade I*, *Macrophomina phaseolina* (Charcoal Rot)
70:30 2nd year coir, composted pine bark	Troughs	513	*Pythium clade*

Table 3-11: April testing – Hillwood Berries – Substrate pathogen results

SUBSTRATE	CONTAINER	PYTHIUM CLADE F (PG DNA/G SAMPLE)	OTHER PATHOGENS PRESENT
Fresh coir	Troughs	0	Nil
2nd year coir	Bags	12,763	Nil
Composted coir	Troughs	3,738	Nil
40:60 2nd year coir, composted pine bark	Troughs	4,599	Yes – *Pythium clade I*
50:50 2nd year coir, composted pine bark	Troughs	1333	Yes – *Pythium clade I*
70:30 2nd year coir, composted pine bark	Troughs	675	Yes – *Colletotrichum coccodes*

As displayed in Table 3-10 and Table 3-11, fresh coir was the only treatment that did not have any presence of *Pythium clade F* across both of the testing periods. The second-year coir treatment had the highest level of *Pythium clade F* during both February and April testing. Pythium levels increased on average overall between the February and April testing periods.

3.3 TASMANIAN BERRIES

3.3.1 PLANT MEASUREMENT RESULTS

Table 3-12: Average crown diameter (mm) measurement results – Tasmanian Berries

TREATMENT	OCTOBER	DECEMBER	FEBRUARY
Fresh coir (bags)	41	49	63
Fresh coir (troughs)	38	40	49
2nd year coir (bags)	31	36	50
2nd year coir (troughs)	31	35	46
40:60 2nd year coir, composted pine bark	41	40	51
50:50 2nd year coir, composted pine bark	41	40	48
70:30 2nd year coir, composted pine bark	40	31	46

Table 3-13: Average crown number (no.) measurement results – Tasmanian Berries

TREATMENT	OCTOBER	DECEMBER	FEBRUARY
Fresh coir (bags)	4.0	3.3	3.1
Fresh coir (troughs)	3.4	2.3	2.6
2nd year coir (bags)	2.8	2.0	2.3
2nd year coir (troughs)	2.9	2.1	2.3
40:60 2nd year coir, composted pine bark	3.9	2.1	2.5
50:50 2nd year coir, composted pine bark	3.6	2.5	2.2
70:30 2nd year coir, composted pine bark	3.5	2.3	2.1

The measurements taken at Tasmanian Berries, unfortunately, appear to have been performed inconsistently between each of the measurement stages. This is evidenced by decreased readings in crown number and some crown diameter results. As such, it is difficult to interpret these results, particularly the crown number results.

Based on the crown diameter measurements, it appears the fresh coir in bags was the most vigorous treatment. The remaining treatments were relatively evenly performing.

3.3.2 YIELD RESULTS

Yield results for the whole growing season are shown in Table 3-14 below.

Table 3-14: Average saleable fruit yield (grams per plant) for each treatment across the whole growing season – Tasmanian Berries

TREATMENT	CONTAINER	YIELD (G/PLANT)	% DIFFERENCE TO FRESH COIR IN BAGS (CONTROL)
Fresh coir	Bags	1016	
Fresh coir	Troughs	879	-13%
2nd year coir	Bags	916	-10%
2nd year coir	Troughs	917	-10%
40:60 2nd year coir, composted pine bark	Troughs	1057	4%
50:50 2nd year coir, composted pine bark	Troughs	1044	3%
70:30 2nd year coir, composted pine bark	Troughs	990	-3%
Average		**974**	

Tasmanian Berries was the only farm where the fresh coir treatment was not the highest yielding (bags or troughs). Both the 40:60 and 50:50 2nd year coir, composted pine bark mixes outperformed the fresh coir treatments. There was a large yield decrease between fresh coir grown in bags and troughs, however, the 2nd year coir in bags vs troughs did not have any difference in yield. Filling of troughs, e.g. too loose or too tight, may have affected plant performance.

3.3.3 DISEASE – SUBSTRATE PATHOGEN LOADING RESULTS

Tasmanian Berries substrate treatments unfortunately were not tested during February.

Table 3-15: April testing – Tasmanian Berries – Substrate pathogen results

SUBSTRATE	CONTAINER	PYTHIUM CLADE F (PG DNA/G SAMPLE)	OTHER PATHOGENS PRESENT
Fresh coir	Bags	0	Yes – *Macrophomina phaseolina*
Fresh coir	Troughs	0	Yes – *Pythium clade I*
2nd yr coir (old bags)	Bags	0	Yes – *Macrophomina phaseolina, Sclerotinia, Phome terrestris*
2nd yr coir	Troughs	7011	Yes – *Macrophomina phaseolina*
40:60 2nd yr coir & pine bark	Troughs	103	Yes – *Macrophomina phaseolina*
50:50 2nd year coir & pine bark	Troughs	147	Yes – *Macrophomina phaseolina*
70:30 2nd yr coir & pine bark	Troughs	1249	Yes – *Macrophomina phaseolina*

Both fresh coir treatments (bags and troughs) did not have any *Pythium clade F* detected (however fresh coir in troughs did have traces of *Pythium clade I* detected). Interestingly, only the 2nd year coir in troughs was detected with *Pythium clade F*. Strawberry charcoal rot (*Macrophomina phaseolina*) was detected in almost all samples from Tasmanian Berries.

4 Stage 3 – Overall trials discussion

4.1 YIELD RESULTS

The overall yield performance considering results from the three trial farms is discussed below.

Fresh coir substrates (bags or troughs) were the best performing overall – being the highest performing treatments at Costa (fresh coir in bags) and Hillwood (fresh coir in troughs). Fresh coir in bags was the third best performing treatment at Tasmanian Berries.

Standalone 2nd year coir substrate was the poorest yielding substrate overall – being the lowest yielding treatment at Costa and Hillwood, and 2nd lowest at Tasmanian Berries.

Composted pine bark and 2nd year coir mixes ranged from approximately 10 - 30% better relative to standalone 2nd year coir substrates. At Tasmanian Berries, the 40:60 2nd year coir and composted pine bark was the best yielding treatment overall. Overall, composted pine bark and 2nd year coir mixes yielded less than fresh coir but more than 2nd year coir substrates.

At Hillwood, composted coir yielded 32% higher than 2nd year coir in bags, and only 5% less than fresh coir in troughs. This likely points to the benefits of mixing used coir prior to reuse, and potentially also the benefits of a composting process prior to reuse.

In summary, fresh coir in bags can be considered the best yielding treatment. Composted pine bark and 2nd year coir mixes were the next best yielding substrate grouping, with 2nd year coir standalone substrates the lowest yielding. The yield results demonstrate the value of adding composted pine bark to 2nd year coir to improve yield performance.

The results at Tasmanian Berries for composted pine bark and 2nd year coir mix, which outperformed the commercial control, demonstrate the potential for a mixed substrate in the future, particularly as management practices specific to this substrate can be refined over time.

However, interpreting the yield data requires caution because the trial design may not translate to commercial production system and their context.

4.2 PATHOGEN PRESENCE AND YIELD IMPACTS

Table 4-1 shows the average *Pythium clade F* quantity detected for each substrate group.

Table 4-1: Average *Pythium clade F* quantity for different substrate groups

SUBSTRATE GROUP	AVERAGE PYTHIUM CLADE F (PG DNA/G SAMPLE)
Fresh coir	0
2nd year coir	3642
Composted pine bark mixes	1007

Pythium clade F was not detected in any fresh coir substrate treatments (in either the February or April testing). *Pythium clade F* was most prevalent in 2nd year coir substrates overall. Only one standalone 2nd year coir sample had no *Pythium* detected (out of six 2nd year coir samples). There appeared to be a direct relationship between reused coir substrates and *Pythium* presence.

Some 2nd year coir sample with poor yield had almost no *Pythium clade F* detected (Costa Berries), whilst some had relatively higher *Pythium* levels (Hillwood). There were also some treatments that had high *Pythium* detections, which still outperformed farm trial averages (composted coir, 40:60 2nd year coir and composted pine-bark).

Costa Berries had almost no pathogens detected in their substrates, which was consistent with testing from Stage 2. Further investigation is required to determine why Costa Berries consistently has a lower pathogen profile in all of its substrates compared to the other project partner farms.

4.3 DISCUSSION – REUSING COIR AND YIELD OUTCOMES

Why were 2nd year coir substrates lower yielding than fresh coir, and composted pine bark mix substrates?

Combining information from trial yield results, disease testing and anecdotal farm observations, it's suspected there are multiple factors impacting the yield performance of 2nd year substrates.

The composted coir treatment was only trialled at one farm (Hillwood Berries), however, it provides a useful comparison between a used coir substrate that has been separated from plastic slabs and left to compost prior to planting and therefore mixed in between plantings, and to 2nd year coir substrates, left in situ undisturbed in slabs between growing seasons. The exact age of the composted coir was not known given it came from a stockpile continually topped up. The composted coir had been used for strawberry production for one year, then left in the compost stockpile for a period of time, which could have ranged from a few months up to several years.

Composted coir outperformed the 2nd year coir treatment at Hillwood by approximately 210g per plant. It is suspected that the process of 'agitating' and thus aerating the used coir when stockpiling substrate and again when filling troughs before planting is a reason for the positive yield performance in comparison to 2nd year coir substrates (which are left in situ in plastic wrap after the first year of use). There may be other unknown characteristics of the composted/stockpiled coir, e.g. microbial activity, that may have caused the positive yield impact. The relatively higher yielding performance of the composted pine bark mixes against standalone 2nd year coir may also be explained by the mixing of the substrate ahead of planting and introducing a beneficial microbial population.

Observations from farm staff, during this and previous stages of the project, indicate that the longer coir substrates are left in situ (in bags or troughs), the more there is a 'clogging-up' effect – whereby smaller particles within the coir substrate move down the substrate profile, clogging up pore spaces and therefore reducing porosity and drainage. 2nd year coir substrates were observed to have poor drainage. This led to difficulties in irrigation and fertigation scheduling, causing waterlogging of the substrate and poor root growth (as shown in Figure 4-1). This clogging up of pores also reduced the air-filled porosity of the substrate - essential for oxygen supply of roots. As such, an anaerobic environment in the bottom half of the substrate profile was observed, with apparent negative plant health impacts noted.

The 2nd year coir substrates also contained dead plant roots from their first year of production (only the crown and canopy of first year plants are removed between seasons). Farm staff have hypothesised that the dead roots also fill pore spaces within the substrate – further reducing porosity and inhibiting drainage. The old roots may also have harboured *Pythium*.

Figure 4-1: 2nd year coir substrate root zone profile (bags and troughs)

This double effect of the ‘clogging-up’ of coir substrates over time when left in situ, and the dead roots reducing pore spaces and potentially carrying diseases, is assumed to be the primary cause of the root health and yield decline observed in standalone 2nd year coir substrates with fresh plants.

Observations from Costa and Hillwood Berries indicated that 2nd year coir substrates performed particularly poorly later in the season, as drainage issues compounded over time. Growers often target production during the shoulder periods for higher pricing as national supply drops off. Therefore, a reduction in marketable, especially grade 1, yield differences between treatments in this period can have a double economic impact – less fruit, lower proportion of grade 1 fruit and missing out on good market demand. As yield data was only available at a season timeframe, this has not been fully examined.

Whether the increased *Pythium* levels or the poor structural characteristics of 2nd year coir treatments is the primary causal factor negatively impacting yield cannot be fully determined by this trial. *Pythium* species are opportunistic plant pathogens and typically thrive in wet, poorly drained and anaerobic soil/substrate conditions. The substrate conditions observed in 2nd year coir substrates align with *Pythium*’s preferred conditions.

There is a stronger relationship between negative yield outcomes and 2nd year coir, than there is between negative yield outcomes and *Pythium* detection. This is evidenced by the composted pine bark and 2nd year coir mixes yielding relatively well, despite moderate levels of *Pythium* pathogens being detected within the substrate. Given the variation in yield results of those substrates detected with *Pythium clade F*, it is hypothesised that the primary cause of the poor yield results is the poor substrate structural characteristics exhibited in 2nd year coir substrates – with *Pythium* species likely having a secondary negative yield impact once it establishes.

4.3.1 COMPOSTED PINE BARK AS AMENDMENT

Composted pine bark mixes

The yield results of the composted pine bark mixes were more consistent than those of both fresh and 2nd year coir substrate mixes.

40:60 2nd year coir and composted pine bark was the best yielding mix ratio at both of the farms that trialled all ratios (Hillwood and Tasmanian Berries). Figure 4-2 displays the substrate root profile of this mix compared to 2nd year coir bags and demonstrates the improved drainage and root distribution of the composted pine bark mix substrate.

Figure 4-2: 40:60 2nd year coir and composted pine bark substrate root profile (left), compared to 2nd year coir in bags (right)

Mixing 2nd year coir with composted pine bark improved yield across all farms, when compared to standalone 2nd year coir substrates. This suggests that the addition of composted pine bark to coir-based substrates improves plant growth, particularly as the season progresses. The composted pine bark, with its larger particle sizes, may act in a complementary way to 2nd year coir, potentially assisting in providing structure and increasing porosity of the substrate profile. This assists in maintaining optimal drainage and air-filled porosity characteristics. Composted pine bark may also release compounds that suppress pathogens. *Pythium* levels in composted pine bark substrate mixes were lower than those in 2nd year coir substrates.

Composted pine bark and 2nd year coir substrates were mixed before planting. Therefore, it is not completely clear whether the characteristics of composted pine bark, or the mixing process, or a combination of both, caused the improved performance compared to standalone 2nd year coir substrates. It seems likely that the composted pine bark physical and biological properties had the positive impact.

Composted pine bark in a mix with used coir substrate shows promise for future opportunities to allow for greater reuse of coir. Given composted pine bark has only been trialled for two seasons in hydroponic strawberry systems, improving understanding of its characteristics to be able to fine-tune irrigation and fertigation management strategies should allow for better yield performance.

4.4 DISCUSSION – CONTAINER TYPE AND YIELD OUTCOMES

The average relative yield performance and *Pythium clade F* substrate pathogen levels by container type can only be compared for the substrate treatments which were trialled in both bags and troughs (fresh coir and 2nd year coir only).

Table 4-2: Relative yield differential of fresh and 2nd year coir substrates grown in troughs compared to bags

SUBSTRATE	YIELD DIFFERENTIAL TO SAME SUBSTRATE IN BAGS
Fresh coir	-12%
2nd year coir	-4%

The results show that fresh coir in troughs yielded 12% less than when in bags. 2nd year coir yielded 4% less when grown in bags.

Composted pine bark mixes in troughs were the best performing trough treatments on average – the 40:60 2nd year coir and composted pine bark mix out-yielded both fresh and 2nd year coir in troughs (Table 4-1).

Table 4-3: Average *Pythium* levels in different container types – Fresh and 2nd year coir

SUBSTRATE	CONTAINER	AVERAGE PYTHIUM CLADE F LEVELS (PG DNA/G SAMPLE)
Fresh coir	Bags	0
Fresh coir	Troughs	0
2nd year coir	Bags	6381
2nd year coir	Troughs	3523

There was no trend between container type and *Pythium* levels. *Pythium* levels were on average higher in bags than in troughs, however this average is skewed by one very high result of 2nd year coir grown in bags.

Container type - observations

- In some trials, increased early-season plant growth was observed in troughs. Farm staff hypothesised this was due to the black material of the troughs absorbing heat and creating a warmer substrate environment compared to bags during cool weather, increasing the rate of root development. This hypothesis has not been tested.
- Increased early-season fruit losses occurred in trough treatments across each of the project partner farms. This was due to early-season fruit lying directly on the wet substrate material, which caused fruit rot. Once the plant canopy developed further, there was no issue, as fruit started to hang outside of the trough substrate surface. The exact quantity of fruit loss was not measured and was said to be relatively minimal compared to overall fruit yield.
- Mitigations to reduce early fruit loss to decay in troughs were tested. The use of coir toppers was trialled which succeeded in reducing early-season fruit losses (Figure 4-3). However, there were issues in ensuring placement of these around the plants to neatly sit on the substrate as well as material and labour costs.

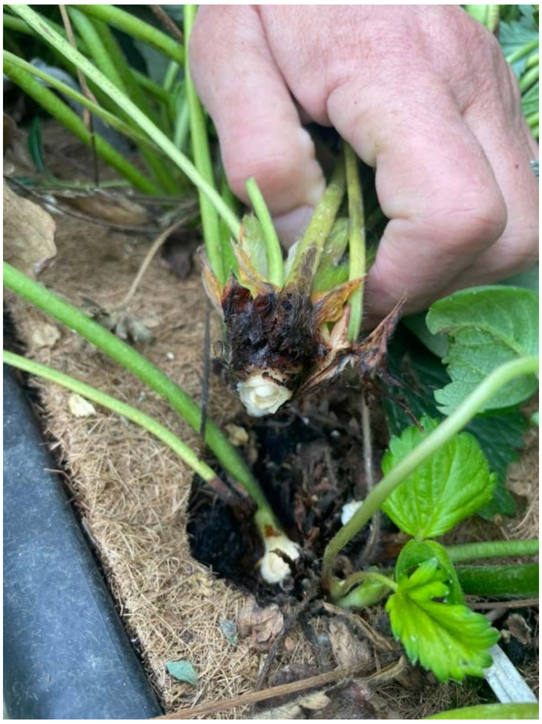

Figure 4-3: Coir toppers placed on top of substrate to reduce fruit losses

- It was hypothesised by farm staff that the bags had a positive yield impact by creating a tight root-zone environment, which may reduce the 'pugging-up' effect seen in the 2nd year coir substrate treatment which had a negative yield impact. This has not been extensively tested but should be considered in any future trials. Plastic wrapped slabs are produced by machine and are therefore uniform and tightly packed. Troughs were hand filled and likely not evenly compacted to mimic the packing of coir in slabs. Mechanical filling of troughs or filling them to a consistent coir weight would overcome the issue.

The production/yield differences between bags/slabs and troughs need to be weighed up against other economic and environmental considerations:

- The use of troughs reduces plastic waste considerably, as they do not need to be replaced for at least 5 years and the plastic can be recycled, as opposed to bags being disposed of each season. Depending on how the plastic bag waste is handled by each farm, troughs would have a benefit in reducing waste disposal costs.

- Troughs allow for the use of drip-tape, which replace individual drippers. Drippers often are knocked during picking and fall out of the substrate, leading to increased labour costs to re-insert, or potential yield impacts if they are not re-inserted. Inserting and removing them at the start and finish of each cropping cycles incurs high labour costs.
- Growers have indicated that handling the grow bags (separating used coir from the plastic) is labour-intensive, representing a significant cost impact. Growing in troughs allows for the simpler handling of spent substrate and also allows for the use of used coir or composted pine bark.

Composted pine bark and 2nd year coir showed most promise out of the substrate types in troughs. Optimising management practices (fertigation, plant management) to its specific characteristics, should further reduce the yield gap to the existing commercial production system over time. As the characteristics of troughs and alternative substrates are better understood as they become more familiar, this should also improve the relative performance of this substrate.

KEY TAKEAWAYS

Fresh coir substrates grown in bags remained the best yielding substrate. This is not surprising given this is the preferred commercial production system. Management strategies are designed around this substrate and slab type and have been refined over many years.

The use of 2nd year coir with fresh plants, left in situ (without mixing and leaving the substrate to ‘compost’ in between growing seasons), resulted in a substantial negative yield impact. This is thought to be primarily caused by structural decline of the substrate in situ, through ‘pugging up’ and dead plant roots decreasing porosity and reducing drainage.

The process of mixing used coir prior to reuse appeared to improve structural characteristics and yield performance (composted coir treatment at Hillwood). The composting process was not managed like it is done in commercial composting operations. It is rather a way stockpiling that leads to composting. This may further improve the quality of used coir.

Reusing coir, after stockpiling for some time and agitation, may be a viable way of reusing coir from a yield perspective (considering cost savings).

Composted pine bark performed very well in complementing both fresh and 2nd year coir as a substrate for strawberry production. Across each of the three project partner farms, plant growth from mixed composted pine bark and coir substrates is similar or greater than standalone fresh coir substrates in troughs.

For production in troughs in future, composted pine bark should be considered in a mix with coir.

40:60 mixes of 2nd year coir and composted pine bark was the best-yielding ratio.

Pythium pathogen load increased in 2nd year coir-based substrates, compared to fresh coir. This is likely due to poorer structural characteristics creating favourable conditions for pathogens to thrive, or pathogens accumulating over time in year 1 on roots which remain in the used slabs while they would break down in the composted coir (or, more likely, a combination of both).

Other soil-borne pathogens such as *Macrophomina phaseolina* and *Phoma terrestris* were found in the substrate of some treatments. This did not appear to be causing disease in the plant. It is uncertain how these pathogens entered the substrates.

5 Economic assessment

5.1 METHODOLOGY

‘A Gross Margin (GM) comparative analysis was undertaken, comparing economic costs and benefits between the:

- ‘Base case’ – fresh coir in plastic-wrapped slabs with fresh plants replaced annually.

Two alternative reuse substrate production scenarios:

- 2^{nd} year coir in bags (fresh plants)
- 2^{nd} year coir and composted pine bark mix, in troughs (fresh plants).

The substrate scenarios were modelled over a two-year production period, ensuring the overall economic change is captured. For all scenarios, the first year of production is fresh coir in bags, and the second year of production utilises the used coir as part of the alternative reuse substrates.

The analysis was based on assumptions utilising data generated from trial results (yields from different substrate treatments), an understanding of management changes required for different substrates, as well as pricing and costing information from growers and industry as of the Stage 3 trials time-period (2024-25).

It was assumed that 2^{nd} year coir substrates yielded 20% less than fresh coir substrates, and 2^{nd} year coir and composted pine bark mixed substrates yielded 10% less than fresh coir substrates. Whilst these trial results varied substantially from farm to farm, these are reasonable approximations of relative yield performance recorded during the Stage 3 trials.

Factors such as fruit price, coir price, alternative substrate costs, labour costs and efficiency are all dynamic. The presented analysis is based on pricing at the time of report writing. The Excel-based model has been developed so that it can be updated in the future with new data as required.

A sensitivity analysis has been completed to assess the potential impact of changes in yields, fruit price and coir price on the profitability of each production scenario.

The aim was to determine how coir replacement or reuse might affect the overall economic feasibility of the production system, from a gross margin perspective. A detailed costing of substrate changes for each project partner has not been conducted because individual business data was not available. Therefore, the model is designed to provide a comparative guide, given the currently known yield and cost differences between treatments. Each farm has unique characteristics and differences and must undertake its own analysis.

5.1.1 ASSUMPTIONS

Table 5-1: Assumptions included in comparative gross margin model

CATEGORY / ACTIVITY	VALUE	PER UNIT	COMMENT
Yield (base case)	1.2	kg per plant	Based on stage 3 trial results
Yield (2nd year coir in bags)	1.0	kg per plant	Based on stage 3 trial results
Yield (2nd year coir and composted pine bark mix)	1.1	kg per plant	Based on stage 3 trial results
Average fruit price	$8.80	kg	Varies, based on farm information
Fresh coir cost	$4.00	bag	Information from project partners suggested $3–4 per bag, dependent on coir type. $4 used to reflect predicted increase in prices due to weather damage in coir producing regions.
Composted pine bark price	$80.00	cubic metre	Information from manufacturer
Bag volume	0.02	cubic metre	Known specification
Trough volume	0.02	cubic metre	Known specification
Trough cost	$1.00	trough	Existing manufacturer
Plants per bag/trough (1m)	6	Plants per metre length	As per farm trials
Labour cost	$40.00	hour	Based on minimum wage (casual) of $32 per hour, plus super and other costs
Planting, including substrate placement	$1.33	1m bag/trough planted	Assumes 1 bag/trough substrate placed and planted per minute (2 workers)
Dripper placement/removal (labour cost)	$0.17	Labour costs per metre length	Assumes drippers placed in 240 x 1m bags/troughs per hour (15 seconds per 1m length)
Harvesting (labour costs)	$2.00	per kilogram picked	Assumes 20kg harvested per worker per hour
Fertigation (nutrient costs)	$9,000.00	per hectare	No fertigation/nutrient difference between treatments (as per Stage 3 trials)
Irrigation requirement	9	ML per year	
Substrate removal and separation	100	Labour hours per hectare	The model assumes this is handled under substrate removal costs of 100 hours per hectare
Plastic and used coir waste disposal costs	$4,750.00	Cost per hectare	Disposal costs to organics processor as per multiple farms (this will differ for each farm based on proximity to processor) Depending on the method and farm location, it was noted that bag and substrate separation could be up to $8,000 per hectare (200 labour hours) alone – not including bag disposal For fresh coir production systems, this is an annual cost. For both modelled reused coir scenarios, this cost occurs every 2nd.
Mixing costs (2nd year coir and composted pine bark)	$4,000.00	Per hectare	Assumes 100 labour hours per hectare. Mixing occurs of 2nd year coir whilst adding composted pine bark in between seasons. (No mixing assumed for 2nd year coir scenario).

5.1.2 OTHER CONSIDERATIONS

This economic assessment is only considering the gross margin impacts of the various scenarios. Overhead costs are not included in the analysis – therefore the gross margin analysis does not consider overall profitability, but rather a component of it.

Growers have indicated that maintaining current yields is important to maintaining their market relationships with key marketers, wholesalers and retailers. Modelled yields for alternative substrates are based on those of the Stage 3 trials, which are lower than in the existing commercial production systems. This analysis does not consider the impact of reduced yields on market relationships and selling product.

Labour costs have been estimated for various activities (harvesting, substrate placement and planting, dripper placement, substrate removal). These will be different for each farm. The economic assessment does not consider variations within each farm's specific production system.

An average fruit price has been selected and modelled for over the entire production season. Therefore, this model does not consider the seasonality of fruit prices. Additionally, the model does not consider the impact of changes in the timing of fruit harvest volumes through the season.

Disposal costs of spent substrate and bags have been estimated based on costs incurred by one farm in sending grow bags to an organics processing facility. Some farms process waste (separating plastic from coir and plants) on-farm, sending plastic to landfill and allowing for alternative uses of coir. There is considerable variation between farms about how bag/coir removal, however this cost modelled was agreed by farms to be reasonable estimate for disposal costs in all cases.

Comparing emissions from different substrate is important, given the associated transport emissions from sourcing coir. Whilst this economic assessment did not consider greenhouse gas emissions, this may be something industry need to report on and possibly offset in future. Further information for industry in comparing emissions can be found in Appendix 4.

MANAGEMENT CHANGES

The economic analysis is based on the management of substrates and subsequent yields achieved during the Stage 3 trials. During the Stage 3 trials, infrastructure limitations meant that individual substrate treatments could not be irrigated and fertigated individually (separately from commercial crops) as they were on a fertigation regime for an entire production block.

The yield results used for this analysis reflect this. The implementation of some management changes (i.e. tailoring fertigation and irrigation to each substrate's characteristics) should reduce the yield gap, however these have not been modelled due to lack of data. As an example, composted pine bark substrate is known to lead to nitrogen drawdown, meaning that more nitrogen is required to be added to the substrates compared to fresh coir. This could not occur for the composted pine bark treatments because they were not on a separate fertigation line. Management changes adjusted to optimise each substrate and how it is used would change variable costs.

RISK

Any horticultural system operates within the confines of a risk profile, risk being the 'normal' fluctuations in economic performance over a period of time. The main types of risk that are commonly associated with production systems are business risk and financial risk:

- **Business risk** – including:
  - Production (climate, pests, genetic variation and disease)
  - Prices (product sale, output - and input prices)
  - Institutional settings (legislation that impacts production e.g. marketing, workplace health and safety, biosecurity and environmental regulation).
- **Financial risk** refers to the variability in returns to owner's equity resulting from meeting interest charges, financial obligations or from servicing debt. Financial risk is a direct result of gearing, the higher the proportion of debt to total capital, the higher the financial risk.

Different factors, some within a manager's control and some outside a manager's control, will influence the success of an individual business over time. Changing substrate may be a small part of the total cost of production; however, the result of interrupted supply could have significant impacts to the long-term success of a production system. The extra costs associated with changing substrates (from an international supply chain to a locally sourced product) can be thought of, in an economic sense, as the cost of reducing the risk profile of a production system. The right decision for an individual farm business manager will come down to an individual's preference for risk over time and the projection of market supply and demand.

5.2 COMPARATIVE GROSS MARGIN RESULTS

Table 5-2 below shows the comparative gross margin analysis for the current commercial production system (fresh coir in bags) compared to 2nd year coir in bags (fresh plants, in situ) and the 2nd year coir mix with composted pine bark (40:60 ratio). The analysis is based on current average known pricing conditions (fruit price, substrate price, labour costs) and yield differences based on results from the Stage 3 trials. This is only for a single year of production using these substrate treatments.

Table 5-2: Comparative gross margin analysis – single year of production (per m^2 production area)

	BASE CASE	2ND YEAR COIR (FRESH PLANTS, IN SITU)	2ND YEAR COIR, COMPOSTED PINE BARK (TROUGHS)	REASON FOR DIFFERENCE
Yield	1.2kg per plant	1kg per plant	1.1kg per plant	
Gross income per m^2				
Income	$74.5	$62.1	$68.3	Yield
Variable costs per m^2				
Substrate and containers	$4.71	$0.00	$1.65	No new substrate
Crop management	$6.82	$6.82	$6.82	
Packing and transport	$18.26	$15.96	$17.11	Yield
Infrastructure repairs & disposal	$1.18	$0.70	$0.70	
Picking labour	$16.94	$14.12	$15.53	Yield
Other production labour	$5.67	$4.85	$5.67	Reduced substrate changeover costs (left in situ)
Total variable costs	$53.58	$42.45	$47.27	
Gross margin	**$20.97**	**$19.67**	**$20.86**	

The comparative gross margin analysis based on a single year of production using these substrates shows that, under the pricing and yield assumptions modelled, the 2nd year coir and composted pine bark substrate was slightly more profitable than fresh coir. The 2nd year coir treatment was approximately 6% less profitable than the base case production scenario, driven by the 200g reduction in yield per plant.

The variable costs for 2nd year coir and the composted pine bark treatment are roughly 20% and 10% lower than the base case, respectively. This is due to substrate input savings, reduced labour requirements and no disposal costs (from reduced substrate handling costs and also less fruit to handle).

Modelling only a single year of production does not, however represent the true profitability of the modelled production scenarios, given that for the two reused coir treatments, the first year of production is still utilising fresh coir. Table 5-3 below shows the average gross margin over a two-year period.

Table 5-3: Average gross margin ($/m^2) over two-year production period for each modelled substrate scenario

	BASE CASE	2ND YEAR COIR (FRESH PLANTS, IN SITU)	2ND YEAR COIR, COMPOSTED PINE BARK (TROUGHS)
Yield (kg per plant)	1.20	1.10	1.15
Income and costs (per m^2 production area)			
Income	$74.54	$68.33	$71.44
Variable costs			
Substrate and containers	$4.71	$2.35	$3.18
Crop management	$6.82	$6.82	$6.82
Packing and transport	$18.26	$17.11	$17.68
Infrastructure repairs & disposal	$1.18	$0.94	$0.94
Picking labour	$16.94	$15.53	$16.24
Other production labour	$5.67	$5.26	$5.67
Total variable costs	$53.58	$48.01	$50.62
Gross margin	**$20.97**	**$20.32**	**$20.91**

The results over a two-year period show that the fresh coir treatment is the most profitable under the current production scenario.

Whilst the fresh coir treatment is most profitable across the full production time frame, the relatively similar gross margin results align with anecdotal profitability results from a project partner farm during the Stage 2 trials. During these trials, their 2nd year coir, fresh plants in troughs treatment yielded 15% less than the farm average. However, due to substrate cost, substrate placement and handling (labour) and disposal cost savings, it was the second most profitable block on the farm. Notably, this occurred in a season where fruit price was low (the modelled fruit price in this scenario is $8.80 per kg). It demonstrated the importance of considering cost and labour savings associated with substrate handling. In years with lower fruit prices, as is becoming more common with increasing fruit supply on the market, increasing focus on controlling costs whilst minimising yield differential will be critical to maintain profitability. Reusing substrates can assist with this. The sensitivity analysis below highlights the impact of changing fruit price on profitability of the modelled production scenarios.

5.3 SENSITIVITY ANALYSIS

Fruit yield, fruit pricing and coir pricing are all relatively dynamic components within this production system. Sensitivity analysis was undertaken to understand the impact that changes in these parameters have on the profitability of the different modelled substrate options.

Sensitivity analysis is based on the average profitability of the **two-year** production system (as opposed to the individual year of production using alternative substrates).

Yield impacts on average gross margin ($/m^2)

The comparative gross margin analysis was based on yields achieved in Stage 3 as below:

- Base case – fresh coir: 1,200g per plant
- 2nd year coir in bags: 1,000g per plant
- 2nd year coir and composted pine bark (CPB) 40:60: 1,100g per plant.

Table 5-4 below displays the average gross margin for each production scenario under different yields (1000, 1100 and 1200 g per plant). The sensitivity analysis has been included to show what impact increasing the yields of the substrate reuse treatments has on comparative gross margins. The bolded figures represent the gross margin from the Stage 3 trials analysis.

Table 5-4: Yield impacts on average gross margin – Two-year production period (assuming first year, using fresh coir, is 1,200g per plant. Bolded figures are modelled scenario yields)

	2ND YEAR PRODUCTION – YIELD PER PLANT (G)		
	1,000	1,100	1,200
Base case			**$20.97**
2nd year coir	**$20.32**	$22.15	$23.97
2nd year coir and CPB (40:60)	$19.08	**$20.91**	$22.74

The analysis shows that if management changes can be implemented to improve the yields using either 2nd year substrate, by 100g, profitability will be higher than the existing fresh coir production system ($21.45 per m^2). While unquantified in this work, the cost change would see a reduction or removal of the substrate cost which is 8.9% of current variable costs, with an increase in the fertigation costs which is 1.7% of the variable costs. It is unlikely that the fertigation cost would overtake the cost of the substrate replacement, in targeting yields closer to the base case scenario. Given the potential upside in improved management identified, the results show that further work investigating management changes to improve yield from using alternative substrates is justified and could result in greater profitability.

Fruit price impacts on gross margin ($/m^2)

The comparative gross margin analysis was based on an average fruit price of $2.20 per punnet ($8.80 per kg).

Fruit pricing received by farms varies substantially due to overall market supply and demand and timing of production across growing regions. Farms have noted that there is increasing supply in the market, which long-term has been reducing prices achieved.

Table 5-5 below displays the gross margin achieved for each of the substrate scenarios under a range of average fruit prices across the two-year production system. The bolded numbers represent the modelled price.

Table 5-5: Fruit price impacts on average gross margin – Two-year production system (assuming first year is fresh coir. Bold is gross margin at price modelled)

PRICE PER PUNNET	$1.80	$2.00	$2.20	$2.40	$2.60
Base case	$7.41	$14.19	**$20.97**	$27.74	$34.52
2nd year coir	$7.90	$14.11	**$20.32**	$26.53	$32.74
2nd year coir and CPB (40:60)	$7.92	$14.42	**$20.91**	$27.41	$33.90

The analysis shows that if fruit price decreases, the profitability of the systems reusing coir improves relative to existing commercial production. At $1.80 per punnet, both the 2nd year coir and composted pine bark mix treatments are more profitable than the base case, despite having less yield, due to their lower costs of production.

Conversely, if fruit price was to increase, the existing commercial production system becomes even more profitable than those reusing coir.

Growers should consider overall market pricing trends to understand how it may impact their profitability when using new substrates or reusing substrates.

An important caveat: the economic model and sensitivity analysis is undertaken on the average fruit price achieved over a season. Therefore, it does not consider the dynamic nature of fruit pricing through the season and the impact of timing fruit production with periods of higher prices. Understanding different substrate systems and how their fruit production trends within season is important and has not been considered as part of this analysis.

Coir price impacts on gross margin ($/m^2)

The comparative gross margin analysis was based on coir pricing of $4 per 1 metre slab.

Coir price has varied over the past 5 years, increasing mainly due to shipping issues associated with the COVID-19 pandemic, before returning to a similar price to pre-covid. This project was established because of concerns over the reliance of the industry on coir if prices continued to increase or remained high.

Table 5-6 shows how changes to coir pricing impacts the comparative profitability of the different substrate systems.

Table 5-6: Coir price changes impact on average gross margin – Two-year production system (assuming first year is fresh coir. Bold figures are gross margin at existing coir price modelled)

PRICE PER METRE (BAG/TROUGH)	$3.00	$3.50	$4.00	$4.50	$5.00	$5.50	$6.00
Base case	$22.14	$21.55	**$20.97**	$20.38	$19.79	$19.20	$18.61
2nd year coir	$20.91	$20.61	**$20.32**	$20.02	$19.73	$19.44	$19.14
2nd year coir and CPB (40:60)	$21.50	$21.21	**$20.91**	$20.62	$20.32	$20.03	$19.73

The sensitivity analysis shows that if the coir price increased to $4.50 per slab or more, the 2nd year coir and composted pine bark treatment would have a similar or higher gross margin to the existing production system. 2nd year coir would also be equivalent to the commercial production gross margin at $5.50 per slab. Conversely, decreases in coir pricing improve the relative gross margin of the existing production system.

Any future price increase of coir, therefore, improves the economic feasibility of reusing coir.

5.4 ECONOMIC SUMMARY

The comparative gross margin analysis undertaken based on the Stage 3 trial results shows that the existing production system (fresh coir in bags) is the most profitable under modelled current market and substrate price conditions. This is driven by the increased yield over the reused coir substrates modelled, despite having higher substrate and labour costs.

The 2nd year coir and composted pine bark treatment was more profitable than the 2nd year coir in bags treatment, driven by its greater yield.

Both reused coir production systems had lower variable costs per m^2 than the fresh coir, due to reduced substrate and substrate handling (labour) costs.

The sensitivity analysis showed that if yields can be improved through management changes to both the 2nd year coir and 2nd year coir / composted pine bark substrates by 100g per plant (approximately 10%), they could be more profitable than the fresh coir production system.

Changes to fruit pricing impacts the relative profitability of the production systems substantially. Any reductions in fruit price improve the relative profitability of the reused substrates, due to their lower cost structure. Conversely, increases in fruit price mean that the existing production system will increase in relative profitability.

Increases to coir pricing between 10–30% would mean that reusing coir substrates would be relatively more profitable than the existing production system – demonstrating the importance of reviewing market conditions ahead of establishing production for each season.

The overall economic assessment suggests that any work undertaken to reduce the yield gap between fresh coir and reused coir substrates will be worthwhile, and that any decreases to fruit price or increases to coir price will relatively favour the profitability of systems utilising reused coir.

6 Overall project findings

6.1 STAGE 3 RESEARCH QUESTIONS AND FINDINGS

- How does strawberry productivity (total yield, timing of fruiting and fruit size) in alternative substrates (2nd year coir or composted pine bark) compare against those grown in fresh coir substrates?
  - Fresh plants grown in 2nd year coir substrates had a lower yield on average compared to fresh coir substrates. There was a large yield decline towards the end of the season.
  - Composted pine bark and 2nd year coir substrates were slightly lower yielding than those in fresh coir but were quite consistently performing.
- Does the substrate type influence fruit size and quality characteristics or labour efficiency?
  - Fruit size and quality were not assumed to be impacted by substrate type. Labour efficiency did not appear to be impacted by substrate type.
- How does the productivity performance of difference substrates affect the overall financial return (gross margin) per area of production (considering factors including substrate cost, fruit yield and quality, handling and management activity changes)?
  - Labour requirements and waste disposal costs are lower when utilising 2nd year substrates in situ, and can lead to cost savings, potentially offsetting any lower yield performance. This was demonstrated in the Stage 2 trial results, where one trial using 2nd year coir yielding 15% less than farm average was the 2nd most profitable block on farm – due to cost savings.
  - The overall financial return is dependent on individual farm cost structure – and a model has been developed for individual farms to input their own costs to consider substrate changes to their production system.
- What changes are required to existing management systems to optimise plant performance for each substrate or blend/mix, if necessary? Do they need to be trialed through further on-farm trials? If yes, how i.e. by each commercial company or via a new project?
  - If planting fresh plants in 2nd year coir substrates, the substrate will require mixing i.e. removal from bags or troughs to enhance its structural properties.
  - Further refinement of irrigation and fertigation strategies are required for composted pine bark and 2nd year coir mix substrates. It is recommended that individual farms conduct trials to continue developing knowledge over time – as a risk mitigation against any possible coir supply chain interruption or pricing shock.
- Which substrate options provide the best productivity (total yield and or timing of fruiting and or fruit size/quality, cost of production inputs and labour efficiency) for producers?
  - Fresh coir provided the greatest yielding substrate in trials, and at current prices, this provides the best profitability for growers (however, this will differ based for each individual farm).
  - Composted pine bark mixed with 2nd year coir (60:40) is the best alternative reuse option for coir and is cost-competitive (if not cheaper) than fresh coir. If management strategies can reduce the yield gap to fresh coir substrate production, this is an appealing alternative for growers.
- How does growing in troughs impact substrate performance and overall fruit yield and quality characteristics, compared to growing in slabs?
  - Growing in troughs reduced yield for both fresh coir and 2nd year coir treatments, but this may be rectified by packing troughs at the same density as slabs and doing that consistently to avoid difference between troughs.
  - Composted pine bark and 2nd year coir mixes were the best performing substrate type in troughs.

6.2 REUSE AND RECYCLING OF HYDROPONIC SUBSTRATE

The project has demonstrated that coir can be reused for hydroponic strawberry production, despite yield decreases. The Stage 2 trials demonstrated that the cost-savings from reusing coir (inputs, labour, disposal costs) can, in some scenarios outweigh any decrease in yield and improve profitability. In addition, information from Stage 1 trials suggests that leaving plants and coir in situ for a 2nd year of production is also economically feasible. However, there are management challenges that need to be worked through to overcome production issues when used as a standalone substrate to reduce the yield gap to production in fresh coir.

A settling effect occurs in coir substrates left in situ for 2 years, which reduces their structural characteristics, leading to drainage issues that impact plant health. The project has, however, shown that 2nd year coir, when mixed as a standalone substrate, or with composted pine bark is vastly improved reduces the yield gap to commercial production (approximately within 10%). Further trials investigating reused coir substrate mixes should focus on refinement of fertigation and irrigation management strategies to improve production performance.

Cost savings from reusing coir, either as standalone or in a mix with composted pine bark, may outweigh any potential yield declines. There may be other considerations including risk, disease and commercial arrangements, which may impact decision-making.

Project partners have indicated that used coir may be well-suited for use in other hydroponic berry crops produced on-farm, such as raspberries or blackberries.

6.2.1 END OF LIFE SUBSTRATE REUSE/RECYCLING OPTIONS

The project identified the following potential reuse opportunities for spent substrates.

Table 6-1: Reuse options

REUSE OPTION	COMMENTS
Use in other berry crops	Used coir could be used in mix for raspberry or blackberry hydroponic production.
Addition to commercial compost	Logistics and arrangements with local compost producers need to be established; composting on farm is possible – training of interested growers required.
Composting on farm	Should be done as per composting guidelines (active composting) or in vessel composting to kill pathogens or left for a long time to passively compost. Composting can occur together with other organic residues or on its own. If on its own, the C/N ratio needs to be suitable.
Mulch or soil amendment	Potential to supply local garden centres or landscaping operations or local organic recycling business. Potential to control pathogens via solarisation or fumigation.
Activated carbon / biochar	If economical e.g. a biochar producer is in the region and prepared to take the used substrate, or a new biochar plant can be set up to run profitably in the region (by a group of growers).
Mushroom cultivation	As additive or 'capping' if free of pathogens and foreign matter, and consistent – trials required.
Biogas production	May be viable on its own or mixed with other materials, if biogas is already generated close to the hydroponic production area and the resulting gas / electricity and process residues e.g. ash can be used efficiently and profitably – research required.

6.3 CHALLENGES

The following challenges have been identified for recycling/reuse:

- Time required to deal with a solution and associated costs
- The need to separate coir, if used, from plastic wraps for many reuse options, and the technology and cost of doing this
- The need to sterilise/compost the spent substrates for some reuses and the technology and cost of doing this
- The costs of handling and transport of used substrates, if the berry producer must pay for it all
- No reliable data on the ‘make up’ of spent substrates from different production systems (i.e. typical chemical and biological properties) and therefore its value
- Potential lack of communication between those who want to get rid of the ‘waste’ and those who can put it to good use as well as across industries with similar waste challenges.

7 Conclusion

The ‘reuse and recycling of substrate for hydroponic strawberries’ project ran for three years from late 2022 until 2025. The project was developed in response to increasing costs and accessibility issues of sourcing coir, the primary growing substrate for hydroponic berry production.

The project worked with three project partner farms and utilised a combination of desktop research, laboratory testing and industry consultation and on-farm trials to improve understanding of substrate behaviour in hydroponic strawberry production in particular. The purpose of the project was to improve the resilience of hydroponic berry production in Tasmania. The project had two key aims:

- To identify and investigate methods to reuse coir as a substrate after the first strawberry growing season
- To investigate suitable alternative substrates for hydroponic strawberry production, either in a mix with coir, or as stand-alone substrate.

INTERPRETATION OF RESULTS

Results from the Stage 3 trials varied substantially between farms and are not directly comparable across sites. Results should be interpreted as site-specific explorations, not scalable industry averages.

For all changes to the commercial production system, whether it be reusing coir, adding composted pine bark as amendment or changing substrate container, there are production system management changes which could be employed to improve performance (fertigation, plant management adjustments). Such changes should reduce the yield gap to the existing commercial production system (fresh coir, fresh plants in bags). Due to limitations around farm infrastructure, logistics and trial design, such changes weren’t able to be tested and trialled – all treatments were tested under the management conditions of the existing commercial production systems. Greater knowledge around how to manage changed substrate or containers requires development over time.

The Stage 3 trial results must therefore be interpreted with this in mind.

This report documents the results of the Stage 3 commercial scale trials and Stage 4 economic assessment component of the project, drawing on findings from Stages 1 and 2 of the project.

REUSING COIR

Summarised results from Stage 3 trials showed that:

- There was a substantial yield decrease growing in 2nd year coir bags (-27% than commercial control)
- There was a substantial yield decrease growing 2nd year coir in troughs – both compared to fresh coir in troughs (-19%) and fresh coir in bags (commercial control) (-31%)
- Growing fresh plants in composted coir (sourced from stockpile) in troughs (agitated) yielded 5% less than fresh coir in troughs (one farm only) – but yielded better (+15%) than 2nd year coir substrates left in situ.

Reasons for yield results:

- A decline in drainage characteristics of used coir substrates, particularly when left in situ (unagitated) for two seasons, was determined to be the primary cause of the yield decline.
- The settling of coir fines and the presence of dead plant roots (from first year of production) reduced porosity and inhibited drainage in used coir substrates, causing water-logging and anaerobic root zone conditions which impacted plant health.

- The drainage issues were likely to have caused increased *Pythium* levels observed in used coir substrates.
- Agitating/mixing used coir substrates prior to planting (composted coir treatment) improved the performance in comparison to used coir substrates left in situ between seasons. Agitating/mixing improved substrate porosity and, therefore drainage.

ALTERNATIVE SUBSTRATES – COMPOSTED PINE BARK

- 2nd year coir performance was greatly improved when mixed with composted pine bark prior to planting (+18–25% yield – relative to 2nd year coir-only treatments)
- The mix of 40:60 2nd year coir and composted pine bark was found to be the optimal mixed substrate ratio (only 6% less yield compared to fresh coir substrates), which aligned with existing literature
- Based on this result, there is considerable potential in utilising composted pine bark as an amendment to 2nd year coir
- It is hypothesised that the process of mixing 2nd year coir with composted pine bark improves the substrate drainage characteristics and porosity relative to used coir substrates (both in situ and agitated)

CONTAINER TYPE (BAGS/TROUGHS)

There was an observed yield decrease in troughs, when comparing the same substrate grown in both bags and troughs (-12% for fresh coir, -4% for 2nd year coir). This was likely caused by:

- Increased early-season fruit losses in troughs, due to fruit rot
- The bags providing a preferable 'tighter' root zone environment, which reduced coir settling
- Greater uniformity of substrate density in bags, versus in troughs.

TRIAL INTERPRETATION CONSIDERATIONS

- Trials were not able to be completely aligned and replicated between farms
- Block sizes, irrigation and operational constraints differed between farms
- Due to irrigation line set up limitations on farms, each substrate treatment was subject to the same fertigation regime, which were optimised for the existing commercial production system. Ideally, fertigation regimes would have been adjusted and optimised for each treatment to better understand comparative potential yield performance

ECONOMIC ASSESSMENT AND CONSIDERATIONS

Fruit yield and income are fundamentally critical for the sustainability and viability of berry production systems. However, changes in substrates also have an impact on the overall cost of production; therefore understanding the impact on overall profitability is important.

The economic assessment compared the following substrate treatments:

- Base case' – fresh coir in plastic wrapped slabs with fresh plants replaced annually, and
- 2nd year coir in bags (fresh plants)
- 2nd year coir and composted pine bark mix, in troughs (fresh plants).

The comparative gross margin analysis, for the full 2-year production scenario, under existing market and substrate price conditions showed that:

- Fresh coir in bags, replaced annually, remains the most profitable. This is driven by increased yield compared to the reused coir substrates modelled, despite having higher substrate, labour and disposal costs.

- The 2nd year coir and composted pine bark treatment was more profitable than the 2nd year coir in bags treatment, due to its increased yield.
- Both reused coir production systems had lower variable costs (5% and 10%) than fresh coir, due to reduced substrate, substrate handling (labour) and disposal costs.

The sensitivity analysis showed that if reused coir yields can be improved (by 100g per plant) through management adjustments to improve production, both reused coir substrate treatments could meet a similar profitability to fresh coir production.

Changes to fruit pricing impact the relative profitability of the production systems substantially. Any reductions in fruit price improve the relative profitability of the reused substrates, due to their lower cost structure. Conversely, increases in fruit price mean that the existing production system will increase in relative profitability.

Increases to coir pricing between 10–30% would mean that reusing coir substrates would be relatively more profitable than the existing production system – demonstrating the importance of reviewing market conditions ahead of establishing production for each season.

The overall economic assessment suggests that any work undertaken to reduce the yield gap between fresh coir and reused coir substrates will be worthwhile, and that any decreases to fruit price or increases to coir price will relatively favour the profitability of systems utilising reused coir.

AN IMPORTANT CAVEAT

The economic model and sensitivity analysis are undertaken on the average fruit price achieved over a season. Therefore, it does not consider the dynamic nature of fruit pricing through the season and the impact of timing fruit production with periods of higher prices. Understanding different substrate systems and how their fruit production varies through the season requires close consideration for growers.

KEY TAKEAWAYS

- Fresh coir in bags were the best-yielding substrate. This is unsurprising given the existing production system (fertigation, plant management) is optimised for this substrates' characteristics.
- Agitating/mixing used coir prior to reuse (as opposed to leaving in situ) improved the structural characteristics (water drainage, porosity) and therefore yield performance of used coir.
- Mixing composted pine bark with used coir further improved the performance of used coir.
- Based on disease testing results, sterilisation of used coir substrate prior to reuse in strawberry or other berry hydroponic production is not warranted. Production decreases observed in used coir substrates are largely due to drainage issues, rather than other factors.
- Producers should consider mitigations (mixing, adding composted pine bark) to improve structural characteristic in used coir substrates prior to reuse.
- Microbial activity can increase in used substrates over time, which may impact nutrient availability and productivity.
- Plants grown in bags yielded more than in troughs, however fine-tuning production strategies in troughs should improve performance over time. There are substantial disposal and handling cost and plastic waste reductions by growing in troughs. These need to be considered against yield differences.
- Fine-tuning fertigation and plant management strategies to different substrate and container types is required, and must be done progressively over time, to improve production performance of used coir substrates and production in troughs.

- Profitability of the production system needs to be considered, not just yield. Cost savings by reusing coir, if strategies to improve managing the drainage issues of used coir are found, could improve profitability.

RECOMMENDATIONS

While coir prices and accessibility have normalised after COVID-19 associated supply-chain interruptions, the hydroponic berry industry should continue individual on-farm trials to improve reuse of coir as a risk-minimisation strategy. The economics assessment, demonstrating the sensitivity of fruit price and coir price changes to profitability, supports this.

As with any substantial change to a production system, it can take several growing seasons to fine-tune the system to its best potential. A key challenge is developing fertigation strategies for new substrates and container types to match their different drainage, chemical and biological characteristics.

Suggestions for further trials/research can be undertaken by industry and include:

- Further on-farm trials investigating different fertigation strategies for mixed used coir and composted pine bark amendments to improve knowledge are recommended.
- Investigating cost-effective methods of ‘mixing’ used coir (and adding composted pine-bark) in situ is also recommended.
- Further work to understand substrate microbial activity changes in used coir and composted pine-bark and production impacts would also be of benefit. Composting coir during stockpiling without plastic wrap may improve its performance when reused. The reasons for this should be further investigated.
- Optimising production in troughs should continue to be a focus, given the disposal and handling costs and plastic waste reductions compared to grow bags. Further work to trough design, considering substrate characteristics and uniformity to improve yield performance, is required.
- Aeration and (uncontrolled) composting of the used coir between seasons by putting it in loose stockpiles, utilising coarser coir. These should also be further investigated to determine whether they can reduce the yield gap or reduce production costs.
- Investigating composted pine bark and disease suppression.
- Investigating the origins of disease in hydroponic production systems.
- Investigating the reuse of coir from strawberry production in other berry crops, e.g. raspberries or blackberries. Such crops may be better suited to used substrates.
- The sharing of research and findings between farms is enormously important to furthering the resilience of the industry. Any future projects should be coordinated between farms.

ACKNOWLEDGEMENTS

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A huge thank you goes to the three project partners who provided directions and insights for the project. They conducted the trials on their busy commercial farms, collected samples, data and observations. Without the commitment of farm management and diligence of their staff, this work would not have been possible.

Appendix 1: Stage 1 project summary

DEFINING THE CHARACTERISTICS OF ALTERNATIVE SUBSTRATES, INCLUDING OPPORTUNISTIC TRIALS (2022/23)

This summary was generated from the complete Stage 1 Project Report (available separately from this report).

STAGE 1 OVERVIEW

Stage 1 of the project aimed to define the characteristics of alternative substrates and undertake desktop research into the feasibility of reusing coir, prior to undertaking trials as part of Stages 2 and 3 of the project.

Stage 1 investigated sterilisation options for reusing coir substrates. Additionally, testing was undertaken to test the assumption that disease load in used substrates is the limiting factor to reuse.

Wood fibre substrates were identified as the most suitable alternatives to coir, however, there were some production differences to be examined more closely during Stages 2 & 3.

STAGE 1 ACTIVITIES

Small-scale trials were undertaken (ahead of the project schedule) by project partners during Stage 1. These trials investigated ‘GrowFibre’, produced by Australian Growing Solutions, a newly available processed wood-fibre substrate, as a standalone substrate, as well as 2nd year coir with 2nd year plants.

Structural and soil-borne pathogen testing was undertaken to understand the performance and disease-loading differences between fresh, used coir and also alternative wood-fibre substrates.

- Dr Marcus Hardy from the University of Tasmania (UTAS) undertook an initial investigation (under laboratory testing conditions) into the hydraulic properties of substrates and how these might change as the substrate ages
- Pathogen testing of substrates was completed by Dr Michael Rettke at SARDI.

The hydraulic testing showed that used coir appeared feasible as there was a lack of degradation of key substrate characteristics, including water-holding capacity and air-filled porosity compared to fresh coir under laboratory conditions.

The substrate pathogen testing did not reveal significant differences between fresh coir, used coir and alternative-woodfibre pathogen profiles. Trials in Stage 2 were then designed to build on these findings to determine whether there are any other factors that might impact using coir for more than one season.

Sterilisation options for substrates identified as the most suitable were microwaving, using ozone gas and composting. Each of these options requires further economic and technical analysis if it is determined that sterilisation is required to manage substrate disease levels.

An economic framework was developed to allow berry producers to compare gross margins as influenced by different substrates, their cost and their use (1 year, 2 years, in grow bags, in troughs). It found that wood fibre substrates may be economically feasible, assuming any production differences are able to be managed effectively to ensure similar yields (this was based on substrate pricing during Stage 1).

STAGE 1 RESEARCH QUESTIONS AND ANSWERS

The Stage 1 research questions and findings were:

- What are the desired attributes in a substrate?
  - Adequate water-holding capacity, air-filled porosity, compressibility, sustainable recovery of spent materials and the ability to be produced locally are the key desired characteristics of substrates
- What are the characteristics of alternative substrates?
  - Alternative substrates were identified, and their characteristics examined by SWOT analysis. Alternate substrate characteristics varied substantially between substrates.
- What are the preferred alternative substrates to coir?
  - Wood fibre products were identified as the most suitable alternatives, especially when mixed with coir
  - Wood fibre products possess advantages over other identified substrates
  - Composted pine-bark substrates also warrant further investigation in the next stages of the project
- What are the characteristics of used (spent) coir (after one growing season)?
  - The characteristics of used coir was found to be similar to that of fresh coir, both from a physical and biological (pathogen load) perspective. More research is required to further examine the characteristics of used coir.
  - The results demonstrated the potential in using coir substrates for more than one growing season.
- What sterilisation options are available for substrate?
  - Microwaving, using ozone gas and composting were identified as the most suitable sterilisation options for substrate
  - Chemical options are not preferred by project partners due to WH&S issues
  - Each of these sterilisation options will require further technical and economic analysis, if it is determined that sterilisation is required
- What are the baseline costs of sourcing coir for single-use hydroponic production systems?
  - Baseline costs of sourcing coir (at the time of research in late 2022) was between $180 and $220 per cubic metre, delivered on-farm. Coir prices have since decreased, driven by reduced shipping costs.
  - Research showed that coir costs (including freight) fluctuate substantially due to various factors, including global economic conditions, fuel prices, trade policies, and shipping industry dynamics. Global shipping prices are the key price contributor to coir prices in Australia. For instance, in 2021–22, when the project was conceived, costs were extremely high and freight times unpredictable and longer than before the Covid pandemic. This correlated with decreased shipping availability and increased shipping prices.
  - The recent decrease in coir price has influenced the view of some berry producers on the need for immediate coir replacement. Others believe that an alternative should be investigated further as a risk management strategy to mitigate against any possible future interruptions or cost increases in coir supply.
- How resilient is the cost of coir substrate materials to different price shocks and or supply chain/availability shocks?
  - Freight and transport costs are the key price contributor to coir landed in Australia and vary more than the price of coir itself as a raw material. Any global supply chain shocks which impact shipping prices will inevitably have a substantial impact on the price of coir delivered to Australia, given coir originates in coconut-producing countries within Asia. Timing of supply is also a concern when there are interrupted supply chains.

- What suitable materials are available in Tasmania which can be used to augment coir as a hydroponic substrate?
  - A wood fibre product and composted pine bark were identified during Stage 1 as possible options, and these may be suitable when mixed with coir. A wood fibre product is currently produced (pilot commercialisation stage) in Victoria, and a second wood fibre option is under development in Queensland.
  - The coarser wood fibre (GrowFibre) product is available in Tasmania and is shipped from Victoria.
  - A pine bark substrate is currently produced in Northeast Tasmania from forestry ‘waste’ and is under investigation to be trialled in Stage 2.
- What is the cost of accessing alternative materials, and how does this change with location and freight costs?
  - Wood-fibre products range from $40 – $130 per cubic metre, excluding freight (Refer to SWOT in Appendix 1).
  - Products that are able to be compressed are lower cost to ship and may remain viable against coir if not produced in Tasmania.
  - Some wood-fibre products are able to be compressed (Australian Wood Fibre product), whilst others cannot. Decompressing product however, requires specialised equipment.
- Which materials should be trialled in the formula of the mixed substrate in stage 2 of the project?
  - It is recommended to continue with forestry ‘waste’ based (wood fibre and composted pine bark) alternative substrates in Stage 2 and refine the physical properties by mixing optimum proportions of coir and alternative substrate.
  - During stage 2, it will need to be determined whether mixing wood fibre or pine bark with spent coir results in better substrate performance than that of spent coir alone. If this is the case, stage 3 will aim to identify the optimal mixing ratio.
  - The trialling of substrates must consider changes in the production system such as troughs, different irrigation applications, mixing and potentially sterilising of substrates and ‘end of life’ solutions for spent substrates. The effect of different substrates on crop performance must be monitored throughout the season for Stage 2. Further investigating substrate properties is required for Stage 2 as well as providing feedback to alternative substrate producers.

Next steps for the project include:

- Further research on using spent coir for hydroponic strawberry production
- Determining the feasibility of hydroponic strawberry production using wood fibre and pine park substrate materials
- Considering the transition from grow-bags to troughs in the above.

Appendix 2: Stage 2 project summary

STAGE 2 – SMALL-SCALE TRIALS

OVERVIEW

The purpose of Stage 2 was to undertake small-scale trials across each of the project partner farms to ground-truth findings from Stage 1 of the project. Whilst Stage 1 was originally planned to not involve any on-farm trials, project partners were keen to opportunistically trial some substrate mixes (GrowFibre and 2nd year coir) in their operations. These therefore, were medium scale trials. Hence, the Stage 2-planned small scale trials were also on-farm and therefore were of medium scale size. They were designed to provide additional and more robust data on the previously trialled mixes, as well as testing some additional options.

The findings of Stage 2 were used to inform treatment selection for the larger, commercial scale trials occurring in Stage 3 of the project (2024/25).

Key observations that were common across each of the three project partner farms are detailed below:

Used coir

Drainage in 100% used coir treatments (both 2nd year coir and composted coir) was substantially inhibited, particularly later in the growing season. The bottom half of the substrate profile stayed saturated and created anaerobic root growing conditions.

- It is thought that as coir ages and breaks down within the bags/troughs, the finer particles move down the substrate profile and 'clog up' pore spaces, restricting drainage in the bottom half of the substrate profile. This issue was not picked up during the physical structure investigation by Dr Marcus Hardie as he worked with a 'disturbed' sample (not in situ) which had not been used for an entire season.
- The lack of drainage is thought to be the primary reason for poor plant growth and yield results in the back half of the season.

EC levels in the 100% reused coir treatments crept up during the season, and became somewhat difficult to manage, particularly in the corners of the troughs where it was difficult to flush with irrigation. This is presumed to be due to the inadequate drainage characteristics as outlined above

100% wood fibre substrates (GrowFibre)

100% GrowFibre substrates did not perform as well as fresh coir or mixed substrates. GrowFibre was observed to dry out at the top layer of the substrate and did not hold enough moisture at the start of the season. It showed poor lateral moisture movement. For these reasons, greater irrigation (via increased number of drippers) was required.

As the season progressed, the bottom half of the substrate profile of the GrowFibre treatments became clogged, waterlogged and anaerobic. This again was thought to be due to smaller particles of the fibre moving down and clogging pore spaces. This was also not picked up by the physical structure investigation by Dr Marcus Hardy.

Hence, 100% wood fibre substrates were observed to turn from being free draining, with insufficient water holding capacity, to the opposite quite quickly.

Mixed substrates (coir and wood fibre)

- The mixed substrates appeared to perform quite well relative to other substrate treatments on both Costa and Hillwood farms.
- The combination of the used coir with high water holding capacity, with the GrowFibre with relatively low water holding capacity, appeared to be beneficial to plant growth. Interestingly, waterlogging in the lower part of the substrate later in the season did not appear to be a major issue.

Disease testing

The aim of the disease testing was to confirm or otherwise the relationship between soil-borne pathogen prevalence and coir age.

The main pathogen detected overall was *Pythium clade F.*

Pythium was detected in several of substrates sampled. It did not appear to be associated with the age or type of the substrate. This aligned with testing results from Stage 1 of the project.

Macrophomina phaseolina (charcoal rot) was detected in very low quantities in three substrate treatments:

- **TasBerries**: Fresh coir (misted tip plants)
- **TasBerries:** Fresh coir (bare-rooted plants)
- **Hillwood:** Composted coir.

Pythium clade I, Pythium violae and Phoma terrestris were all detected in just one substrate sample each (not both the same sample).

Pathogen levels were very low and did not appear to affect the plants.

KEY FINDINGS

Whilst there was a 15% yield decrease in the reused coir trial treatment at Costa (compared to the control), it was anecdotally noted that despite this, it was one of the most profitable blocks on the farm overall. This was due to the savings in coir inputs and associated labour, as well as reduced coir disposal costs. That the fruit price was, on average, quite low across the season meant that these cost savings improved profitability, despite the negative yield impact. In seasons with higher fruit prices, the additional yield may be more important in overall profitability.

This was a key finding from Stage 2 and demonstrates that overall profitability must be considered, not only yield. Commercial scale trials in Stage 3, and the economic analysis in Stage 4, will further examine this, including a sensitivity analysis around the impact of changing average fruit prices.

Both GrowFibre and composted pine-bark, in mixes with fresh or used coir, were reasonably successful – showing similar plant growth to fresh coir. Whilst there were changes in management required (greater number of drippers, increased irrigation frequency), plant growth was equivalent to the commercial control across most farms.

Given the lack of local production of GrowFibre and the freight costs in supplying it from Victoria to Tasmania, GrowFibre was not currently deemed to be an economically competitive substrate for use. As such, by the conclusion of Stage 2, composted pine bark (produced by Padgett's Nursery in Scottsdale) emerged as a more economic and suitable alternative, local and sustainable wood-fibre substrate. The cost of supplying composted pine bark to project partner farms was cheaper or roughly equivalent to that of coir.

The obvious drawback in using composted pine bark is that, given it is not heat-treated like GrowFibre, there may be potential for nitrogen drawdown (nitrogen being taken up by composted pine bark and reducing plant available nitrogen). However, project partners believe that this could be managed by amending fertigation regimes. Composted pine bark will be trialled on each of the project partner farms as part of Stage 3 of the project and this will be further investigated.

Based on the DNA pathogen testing results of the substrate mixes, there did not appear to be any difference in disease prevalence between coir and wood-fibre substrates.

Appendix 3: Stage 3 trials & results information

Table A3-1: Root zone observations – Hillwood Berries

SUBSTRATE	OCTOBER	DECEMBER	FEBRUARY
Fresh coir (troughs)	Some healthy white root growth with more caramel roots. ▪ Substrate fall apart easily when taken out of trough ▪ Root distribution is patchy.	Substrate falls apart a lot when taken out of trough. ▪ Patchy root distribution.	Ok root distribution patchy in places, new white root growth occurring
2nd year coir (bags)	Good root distribution throughout bag. ▪ Healthy white root growth with caramel roots ▪ Substrate is very compact due being second year bags.	No observation	Poor root distribution, roots mainly formed in bottom half of bag. ▪ More caramel roots to white in bag ▪ Canopy is smallest in size out of all trials.
Composted coir	Really good root distribution throughout trough. ▪ Healthy white root growth with some caramel roots ▪ Fell apart slightly on the corners when taken out of trough.	Good root distribution, more brown to white roots. ▪ Substrate held together when taken out of trough.	Good root distribution, roots are compact, new white root growth occurring.
40:60 2nd year coir, composted pine bark	Healthy white root growth with some caramel roots. ▪ Substrate is very compact and didn't fall apart when taken out of trough ▪ Root distribution mainly around the base of the trough and patchy at the top.	Good root distribution, white root growth occurring. ▪ Substrate falls apart slightly when taken out of trough.	Ok root distribution, patchier compared to 70% 2nd yr coir, 30% pine bark and composted coir trials.
50:50 2nd year coir, composted pine bark	Lots of white healthy root growth. ▪ Good root distribution throughout the trough ▪ Substrate falls apart slightly when taken out of trough.	Good root distribution, white root growth occurring. ▪ Substrate falls apart slightly when taken out of trough ▪ Some roots are starting to brown.	Ok root distribution, patchier compared to 70% 2nd yr coir, 30% pine bark and composted coir trials. New white root growth is occurring.
70:30 2nd year coir, composted pine bark	Substrate has the poorest roots with roots mainly distributed at the base of trough. ▪ Substrate is quite compact and doesn't fall apart when taken out.	Good root distribution, white root growth occurring. ▪ Substrate held together when taken out of trough D15.	Good root distribution, roots are compact, new white root growth occurring.

Table A3-2: February substrate pathogen testing results (only pathogens detected shown)

FARM	SUBSTRATE	CONTAINER	*Macrophomina Phaseolina* KDNA COPIES/G SAMPLE*	*Pythium Clade F* PGDNA/G SAMPLE*	*Pythium Clade I* PGDNA/G SAMPLE*	*Phoma Terrestris* KDNA COPIES/G SAMPLE*
Costa	Fresh coir	Bag	0	0	0	0
Costa	Fresh coir	Troughs	0	0	0	0
Costa	2nd year coir	Troughs	0	107	0	0
Costa	50:50 fresh coir, pine bark	Troughs	0	0	0	0
Hillwood	50:50 2nd year coir, pine bark	Troughs	2	1435	2	0
Hillwood	40:60 2nd year coir, pine bark	Troughs	0	1027	3	0
Hillwood	2nd year coir	Bags	0	1935	0	2
Hillwood	Composted coir	Troughs	0	362	0	0
Hillwood	Fresh coir	Troughs	0	0	0	0
Hillwood	70:30 2nd year coir & pine bark	Troughs	0	513	6	0

Table A3-3: April substrate pathogen testing results (only pathogens detected are shown)

FARM	SUBSTRATE	CONTAINER	*COLLETOTRICHUM COCCODES* PGDNA/G SAMPLE*	*MACROPHOMINA PHASEOLINA* KDNA COPIES/G SAMPLE*	*PYTHIUM CLADE F* PGDNA/G SAMPLE*	*PYTHIUM CLADE I* PGDNA/G SAMPLE*	*MELOIDOGYNE FALLAX* PGDNA/G SAMPLE*	*SCLEROTINIA SCLEROTIORUM/S MINOR* KDNA COPIES/G SAMPLE*	*PHOMA TERRESTRIS* KDNA COPIES/G SAMPLE*	BLACK ROOT ROT KDNA COPIES/G SAMPLE*
Costa	Fresh coir	Bags	0	0	0	0	0	0	0	0
Costa	Fresh coir	Troughs	0	0	0	0	0	0	0	0
Costa	2nd year coir	Troughs	0	0	34	0	4	0	0	0
Costa	50:50 fresh coir, pinebark	Troughs	0	0	0	0	0	0	0	0
Hillwood	50:50 2nd year coir, pinebark	Troughs	0	0	1333	46	0	0	0	0
Hillwood	40:60 2nd year coir, pinebark	Troughs	0	0	4599	2	0	0	0	0
Hillwood	2nd year coir	Bags	0	0	12763	0	0	0	0	0
Hillwood	Composted coir	Troughs	0	0	3738	0	0	0	0	0
Hillwood	Fresh coir	Troughs	0	0	0	0	0	0	0	0
Hillwood	70:30 2nd year coir & pine bark	Troughs	9	0	675	0	0	0	0	0
Tasmanian Berries	Fresh coir	Bags	0	1	0	0	0	0	0	0
Tasmanian Berries	Fresh coir	Troughs	0	0	0	1	0	0	0	0
Tasmanian Berries	2nd yr coir (old ba)	Bags	0	1	0	0	0	2	4	0
Tasmanian Berries	2nd yr coir	Troughs	0	2	7011	0	0	0	0	9
Tasmanian Berries	40:60 2nd yr coir & pinebark	Troughs	0	6	103	0	0	0	0	2
Tasmanian Berries	50:50 2nd year coir & pinebark	Troughs	0	0	147	0	0	0	0	0
Tasmanian Berries	70:30 2nd yr coir & pine bark	Troughs	0	2	1249	0	0	0	0	0

Appendix 4: Comparing emissions from using coir and pine bark as substrate

RATIONALE

There is increasing scrutiny and interest by the public in embedded emissions within the food supply chain, both on-farm and from farm inputs. Carbon emissions policy is likely to tighten on agricultural production (and other industries) in the coming years. Given that coir is transported from other countries in Asia, there are high carbon emissions associated with transporting this substrate to Australia. This represents a risk if alternative carbon pricing policies are implemented. Additionally, maintaining social licence to operate is crucial for community support and marketability of food products, and there is increased interest in how food is produced. Identifying a substrate with a lower emissions profile than coir is, therefore, alongside the circular economy principle, preferable and can represent a key consideration in selecting alternative substrates.

EMISSIONS ASSESSMENT APPROACH

A single 'hydroponic substrate emission calculation tool', does not exist. Relevant tools can be found on platforms like the AIA Environmental Accounting Platform (EAP)[3] for broader agricultural emissions or the Cool Farm Tool[4] for estimation of GHG emissions and water-use impacts. To calculate emissions specific to individual hydroponic systems' substrate(s), their origin, generation and components, as well as inputs and use data have to be assessed using general calculators. The HortCarbon Info tool[5] for horticultural operations, the NGER threshold calculator[6], and the GHG baseline tools[7] may be adequate to assess emissions for reporting obligations.

Steps to estimate hydroponic substrate emissions are:

- Identify emission sources and types (carbon dioxide, nitrous oxide, methane) for the substrate
- Collect data on the type and quantity of materials used in the substrate, energy and water consumption, and any other inputs or outputs related to production using the substrate
- Use relevant calculators.

For detailed and accurate substrate emission calculations, especially if the operation requires specific reporting or compliance, experts may be required to utilise advanced carbon accounting software.

In an emission Lifecycle Analysis (LCA), the entire production process (cradle to grave) of the substrate and of the hydroponic operation has to be included.

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3 https://aginnovationaustralia.com.au/aiaeap/
4 https://coolfarm.org/
5 https://www.longpaddock.qld.gov.au/dcap/horticulture-industry/hortcarbon/)
6 https://cer.gov.au/schemes/national-greenhouse-and-energy-reporting-scheme/report-emissions-and-energy/nger-calculators#:~:text=Emissions%20and%20energy%20threshold%20calculator,Show
7 https://www.cefc.com.au/pathfinder/baselining-ghg-emissions/ghg-baselining-tools/#:~:text=Cool%20Farm%20Tool,and%20improvement%20for%20Australian%20conditions

LIFECYCLE ANALYSIS (LCA)

Conducting a detailed LCA can provide a full comparison of emissions by including all stages from production to disposal. Steps include:

- Define the functional unit (e.g. o cubic meter of substrate)
- Determine the boundaries of the analysis (e.g. cradle-to-gate, cradle-to-grave)
- Collect data on all inputs and outputs for each stage of the substrates' life cycles
- Include raw material extraction, production, transport, and processing
- Use LCA software or databases to quantify emissions and environmental impacts
- Analyse the results to identify the substrate with the lower overall emissions and environmental impact.

A detailed LCA including the end-of-life phase (cradle-to-grave) involves:

- Collection of data on emissions for the production, transport and decomposition of coir and pine bark, as well as reuse, composting, and landfill scenarios
- Modelling using LCA software to determine emissions for both substrate options
- Quantification of the global warming potential (GWP) of CO2, NOx and CH4 emissions.

Emission factors for composting and landfill scenarios from databases like the Intergovernmental Panel on Climate Change (IPCC) guidelines or local environmental agencies can be used.

For an ‘end of life’ emissions comparison, modelling emissions for different reuse scenario involves calculating/estimating the reduction in CO_2, NOx and CH_4 emissions due to multiple reuse cycles and its impact on reducing emissions. Following that, emissions per kg of coir and pine bark composted and or deposited in landfill need to be determined.

Conducting emissions (lifecycle) calculations for substrates used in strawberry production trials in this project and including associated operations for each partner organisation, was far beyond the scope of this project. Therefore, information is provided about production processes and inputs to consider when conducting an individual company’s emissions assessment focused on substrates only.

Only comparing the greenhouse gas emissions from the use of coir and pine bark substrate in a partial emissions assessment involves considering several factors such as substrate production methods, transport, decomposition, and use after the substrate is not suitable for crop production anymore (reuse, recycling).

An overview of key factors is presented in the following sections.

PARTIAL EMISSION ASSESSMENT OF HYDROPONIC SUBSTRATES

A partial emissions assessment is just looking at emission associated with the substrates’ production, transport and ‘end of life’.

In the following, factors to be included in a partial assessment of substrate emissions are presented. For a high-level comparison of substrate emissions, the assumption can be made that emission on farm do not differ widely based on substrates. Differences, that relate to differences in inputs such as water, fertilisers, energy and chemicals would have to be included in a full farm emissions audit or lifecycle assessment.

PRODUCTION PROCESSES

Coir substrate production details

Coconut trees absorb carbon dioxide during their growth, contributing to carbon sequestration. However, if coir production leads to deforestation or unsustainable agricultural practices, it could negate some of these benefits.

Coir is a natural fibre extracted from coconut husks. The production process involves soaking the husks, separating fibres, and often involves minimal processing. This process typically requires less energy and fewer emissions compared to synthetic substrates such as rockwool or perlite.

Types of coco coir products that can be used individually or blended for specific hydroponic needs are:

- Coco Pith: Fine particles, high water retention
- Coco Fiber: Stringy, improves aeration
- Coco Chips: Chunky, balances water retention and aeration.

Process

- After harvest, the fibrous outer husks are manually or mechanically removed from the nuts and collected for processing. Husks are sun-dried for several weeks to reduce moisture and prepare for fibre extraction.
- Dried husks are fed into a decorticator, a machine that separates coir fibres (long strands used for mats, ropes, etc.) and coir pith (also called coco peat, the fine material used in hydroponics).
- Coir pith and fibres are soaked and washed in fresh water to remove salts (sodium and chloride) and reduce electrical conductivity (EC) as well as dust/ debris.
- Coir is spread on racks and turned regularly for sun drying or dried within bunkers to avoid contamination (e.g. bird droppings, dirt).
- Dried coir is sieved to remove fine dust and ensure uniform particle size. This improves aeration and consistency in hydroponic systems.
- Coir is treated with calcium and magnesium solutions to replace residual sodium and potassium ions and improve nutrient exchange capacity (buffering). Buffered coir has more stable properties compared to non-buffered coir and reduces nutrient lockout in hydroponics.
- Some manufacturers perform an additional wash after buffering to remove displaced salts. This results in 99.9% salt-free coco coir, ideal for sensitive hydroponic crops. Buffering and washing are optional steps that are recommended but not standard.
- Finally, coir is compressed into blocks, bricks, or bales and packaged for transport. Blocks, slabs or bricks are often wrapped in plastic (in bulk) to maintain cleanliness and moisture levels. Slabs and blocks are often wrapped and made ready for planting.

Pine bark substrate production details

Pine trees also sequester carbon dioxide during their growth. Using pine bark as a substrate may contribute to carbon sequestration if sourced from sustainably managed forests.

Pine bark is a byproduct of the timber industry. The production process involves harvesting and processing pine trees, which can cause emissions from logging equipment.

Pine bark is obtained as a byproduct from sawmills. Debarking methods (e.g., drum, ring, or chain flail debarkers) affect the quality and composition of the bark, including how much wood is mixed in as well as energy use. The raw bark is ground or hammer-milled to reduce particle size. It may be screened to separate coarse chunks from finer particles, depending on the intended use (e.g., nursery applications, hydroponics).

Bark is then windrowed and left to age (compost) for 3 to 12 months. During the process it is moistened and turned regularly to promote aerobic microbial activity. Aged bark is often blended with sand, peat moss, or coir to adjust water holding capacity, air porosity and bulk density. Temperatures are monitored to avoid overheating or anaerobic conditions. Optional nitrogen additives (e.g. urea or ammonium nitrate) may be used to accelerate decomposition.

The substrate is screened again to achieve desired particle size distribution. It is then packaged or delivered in bulk to nurseries or hydroponic growers.

PARTIAL EMISSION COMPARISON

OVERVIEW

Comparing the emissions of hydroponic substrates such as imported coir and locally produced composted pine bark for Tasmania involves assessing the carbon footprint and environmental impact of each option. The primary factors to consider have been described above.

Overall, while both coir, wood-fibre and pine bark substrates have environmental impacts including emissions, coir substrate may have a slight advantage in terms of lower emissions during production and potentially greater carbon sequestration benefits, if transport is not included. However, the specific environmental impact will depend on factors such as sourcing practices, transportation distances, and end-of-life management.

PRODUCTION AND PROCESSING EMISSIONS

As explained above, imported **coir emissions** include those from harvesting coconuts, processing coir fibres, any inputs and machinery used during production and initial transportation within the producing country. Coir needs to be processed to remove salts and other impurities, which involves energy use and thus emissions. Packaging e.g. plastic, for long-distance shipping will also contribute to emissions.

Locally produced composted **pine bark emissions** include those from sourcing and stockpiling pine bark, hammermilling, screening, and composting processes, and any production-related transport, inputs and machinery used during production. The pine bark composting process itself generates emissions, particularly methane if not managed properly. If nitrogen is added, NO_2 emissions are likely to occur due to denitrification. Local processing typically involves less, or no packaging and handling compared to imported products.

TRANSPORT EMISSIONS

Shorter transport distances reduce the overall carbon footprint.

Transport emissions from **imported coir** are significant due to the long distances involved in shipping coir from countries like India or Sri Lanka to Tasmania. Emissions are generated from ocean freight, followed by land transportation to the final destination.

Pine bark can be sourced locally in Tasmania, reducing transport emissions compared to coir substrate sourced from distant locations. Transportation emissions from locally produced composted pine bark are relatively low as the pine bark is sourced and processed locally within Tasmania.

REUSE OR DISPOSAL EMISSIONS

Factors to consider are decomposition rate, reuse potential and disposal methods.

Coir decomposes slowly, which means it releases carbon dioxide (CO_2) over a longer period. This slower decomposition can result in lower immediate emissions but sustained emissions over time. **Coir can often be reused** for one to two growing cycles before it needs to be disposed of or composted. Reusing coir reduces the need for new materials and associated emissions.

Pine bark decomposes at a moderate rate. It may release CO_2 and methane (CH_4) more quickly than coir, depending on conditions. **Pine bark can also be reused**, but its structure might degrade faster than that of coir, depending on the composting process and conditions. However, it can be composted and used as organic matter in soil.

The decomposition rate for **both substrates** will also vary depending on factors such as particle size and environmental conditions. Both coir and pine bark can be composted. Composting produces CO_2 and CH_4, with the latter gas having a higher global warming potential than CO_2. Disposal in a landfill can lead to anaerobic decomposition, which produces methane (CH_4).

COMPARISON

Locally produced substrates like composted pine bark are likely to have lower emissions compared to imported coir, especially when considering transport emissions. Pine bark substrate could be considered a more environmentally friendly choice compared to imported coir.

However, coir's slower decomposition rate and reuse opportunities might give it an advantage in certain disposal scenarios. Conducting a detailed LCA with specific data and conditions for the Tasmanian strawberry industry will provide the most accurate comparison.

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