

Final Report

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Optimising cover cropping for the Australian vegetable industry

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- No
 Yes (whole report)
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Summary

Cover crops are one of the most useful tools for managing intensive vegetable growing soils. The integration of cover crops into vegetable production can improve soil health by building soil structure and condition, reducing erosion, adding nitrogen, improving nutrient recycling, and contributing to weed and soil-borne disease control.

The project Optimising cover cropping for the Australian vegetable industry project, ran from July 2017 to 2020, involving both research and delivery activities. The field research generated new information on the use and agronomy of cover crops to manage soil structure, soil microbial communities, specific beneficial microbes, and soil-borne diseases under Australian conditions.

The new information was combined with practical industry knowledge and international research to deliver, information on cover crops to the vegetable industry. This included 11 farm walks and two Cover Crop Coaching Clinics covering the selection, establishment, management, and termination of cover crops, and the management of soil-borne diseases and weeds.

The project also produced seven articles, 20 factsheets, six guides, four research reports, six webinars, five podcasts, and five videos which are housed on the on the Soil Wealth website www.soilwealth.com.au/my-topic/cover-crops-and-biofumigation.

These outputs are an important legacy of the project, which will continue to deliver useful information on using cover crops to restore or maintain healthy soil for profitable and sustainable vegetable growing. The knowledge, skills and experienced developed across the three partner organisations, Applied Horticultural Research, Queensland Department of Agriculture and Fisheries, and the Tasmanian Institute of Agriculture, are an important additional legacy produced by the project to ensure the vegetable industry has the capability to further develop the use of cover crops.

But the best summary left to a leading vegetable grower

“The advancements in cover cropping have been the most advanced single change to farming that I’ve seen for 30 years. It’s an absolute game-changer”

Keywords

Cover crops; biofumigation; vegetables; microbial community; mycorrhizae; soil-borne disease; agronomy; herbicides; termination; soil structure; glucosinolates

Introduction

Cover crops are one of the most useful tools for managing intensive vegetable growing soils. The integration of cover crops into vegetable production can improve soil health by building soil structure and condition, reducing erosion, adding nitrogen, improving nutrient recycling, and contributing to weed and soil-borne disease control (Larkin, 2015; Murphy, 2015).

Much of the health of soil is driven by its microbial communities. Cover crops can impact directly on soil microbial communities through the input of organic matter from the cover crop and through root activity during the growth of the cover crop, both of which boost the soil's biological activity. There is a growing interest in soil health and managing beneficial biological soil microbes in vegetable production. Arbuscular mycorrhizae fungi are the “flagship” of beneficial fungi, with wide general understanding of them by vegetable growers. An increasing number of mycorrhizae inoculum products are available on the market and used by growers. There is a need to improve understanding on how cover crops can be managed to optimise the overall soil microbial community and specific beneficial microbes such as mycorrhizae fungi.

Soil-borne diseases are also part of the microbial community of vegetable soils. Biofumigation is a process where specialised cover crops are grown, mulched and incorporated into the soil to release glucosinolates, which can be toxic to many soil-borne pests, diseases and weed seedlings (Kirkegaard and Sarwar, 1998). Critical to the effectiveness of biofumigants is the production of a high plant biomass and the production of high levels of glucosinolates. Under Australia's warm to sub-tropical conditions there is little information on the growth of various biofumigation cover crops, the amount of biomass and glucosinolates, and their efficacy against soil-borne disease.

The general principles of cover crop use in vegetable production are well understood. Cover crops are being encouraged in a broad range of vegetable growing areas and production systems, but there is a need for new information on how to manage cover crops to ensure they fit with current intensive production systems and integrate with other changes in production e.g. strip tillage. A key requirement is to adapt the international research and practical knowledge to Australia's climate and intensive vegetable production systems. For example, cover crops in Australia are more likely to be limited by water shortages than cold temperatures experienced in many northern hemisphere areas where cover crops are widely used. This “Australianisation” of leading overseas work is an important step so optimal use of cover crops in local conditions can enhance farm-level profitability and sustainability.

This project, which ran from July 2017 to 2020, had the following objectives;

- Deliver “Australianised” information on cover crops specific to the vegetable industry covering cover crop selection, establishment, management, and termination, and on the management of soil-borne diseases and weeds.
- Generate new information on the use of cover crops to manage soil structure, soil microbial communities, specific beneficial microbes, and soil-borne diseases under Australian conditions.
- Develop knowledge and capacity to promote the continual improvement of cover crop use in the Australian vegetable industry.

Methodology

The cover crops project involved both research and delivery activities from July 2017 to 2020.

Research

The location of trials and demonstration plantings across Australia and details of the main focus and cover crops trialed at these sites is provided in Table 1. Full details of the research sites are provided in the research reports.

Table 1. **Cover crop field sites and their main focus.**

Site	State	Cover crops	Focus
Bundaberg	Qld	15 biofumigants cultivars	Biofumigant growth, glucosinolate production different times of the year
Gatton	Qld	15 biofumigants cultivars, sorghum, lablab, fallow	Biofumigant growth, glucosinolate production different times of the year and efficiency against soil-borne diseases and soil microbial community
Cowra	NSW	Cereal rye, fallow	Cover crops and strip tillage, hay removal and microbial community
Bathurst	NSW	Oats, cereal rye, fallow	Cover crops and strip tillage
Yarramundi	NSW	Oats, Ryegrass, Oats/ryegrass/vetch, fallow	Cover crops and mycorrhizae
Richmond	NSW	Cereal rye, sorghum, sunn hemp, buckwheat, tillage radish, nemat, fallow	Cover crops and weed management and mycorrhizae
Lindenow	Vic	Sorghum, sunn hemp, sorghum/sunn hemp/tillage radish, Japanese millet, French millet, barley, cereal rye, Saia oats, ryegrass/clover, nemat, BQ mulch, caliente rojo, buckwheat	Demonstration planting for East Gippsland Vegetable Innovation day
Maffra	Vic	Oats/ryegrass	Cover crops and strip tillage
Devon Meadows	Vic	Cereal rye/vetch/peas, fallow	Cover crops and mycorrhizae
Forthside	Tas	Caliente, ryegrass, fallow	Long-term trial, soil structure and soil microbial communities, soil-borne-diseases
Richmond	Tas	Ryegrass, oats, millet, tillage radish, oats/tillage radish, fallow	Soil structure, soil-borne disease and soil microbial community
Virginia	SA	Sorghum, Nemat, fallow	Root knot nematodes in tunnel house
Manjimup	WA	Sorghum/lablab/cowpea/vetch/linseed, fallow	Cover crops and strip tillage
Myalup	WA	Cereal rye, field pea, ryegrass, caliente, BQ mulch, biofumigation mix	Cover crops and weed management and mycorrhizae

In addition to the research sites, the project sampled 57 vegetable crops for mycorrhizae associations on cover crops and vegetable crops, taking root samples to determine mycorrhizae colonisation levels, and soil samples to determine mycorrhizae inoculum levels. These were taken from commercial farms in Queensland, New South Wales, Victoria, Tasmania, South Australia and Western Australia.

Extension

The cover crop project delivered new information, knowledge, and tools to industry through two Cover Crop Coaching Clinics, a number of field walks, and presentations at industry forums. Due to COVID-19 restrictions during the last six months of the project, there was a greater reliance on webinars and podcasts.

The cover crop project built a wide range of legacy outputs including articles, factsheets, guides, webinars, podcasts, and videos. These are housed on the Soil Wealth Websites.

Partnerships

Partnerships were built with four other projects to effectively cover the areas of interest and the delivery of extension and training activities. The key partnerships were:

- A Strategic Approach to Weed Management for the Australian Vegetable Industry (VG15070). VG16068 shared research sites across Australia with the University of New England-run project.
- Soil Wealth and Integrated Crop Protection (VG16078). VG16068 contributed cover crop expertise to Soil Wealth demonstration sites and worked closely with the project on the integration of strip tillage and cover crops. The outputs from the project are housed on the Soil Wealth website (www.soilwealth.com.au/my-topic/cover-crops-and-biofumigation/)
- Queensland Government's Resilient Rivers project. VG16068 expanded the range of biofumigants and soil-borne diseases and included a site at Bundaberg.
- DPIPWE AgriVision 2050. VG16068 expanded the length and scope of the long-term field trial at Forthside.

Outputs

The cover crops project contributed to 11 farm walks and industry events, ran two Cover Crop Coaching Clinics, produced seven articles, 20 factsheets, six guides, four research reports, six webinars, five podcasts, and five videos. The outputs from the project are detailed below.

Events

Farm walks

1. Summer Cover crops farm walk, Richmond **NSW** 16 February 2018 (27 participants). Led by Gordon Rogers (AHR) and Adam Harber (Greensill Farming Group), the farm walk covered what can cover crops do, choosing a cover crop, how to manage cover crops and included viewing of cover crops on-site.
2. Can cover crops reduce Sclerotinia in lettuce? Richmond **Tasmania** 31 May 2018 (14). Led by Kelvin Montagu the farm walk focused on cover crops and their role in disease management. The field walk presented results on Sclerotinia in the lettuce crop following on from annual ryegrass, oats, tillage radish and Japanese millet cover crops.
3. Cover crops for managing root knot nematodes in tunnel houses, Virginia **South Australia** 3 September 2018 (32). Thirty participants from the Soil-borne Disease masterclass (VG15010 and VG15009) visited the trial and discussed the role of cover crops in managing soil-borne diseases.
4. Vegetable Centre field day, Forthside **Tasmania** 10 October 2018 (48). Robert Tegg and PhD student Brianna Walker presented results on the long-term cover crop/biofumigant site, with a demonstration of the incorporation process.
5. Cover crops and soil & tissue testing workshop, Orrvale **Victoria** 7 November 2018 (6). Kelvin Montagu covered what can cover crops do, choosing a cover crop and how to manage cover crops, at a packing shed talk.
6. Biofumigant cover crops, Bundaberg **Queensland** 21 March 2019 (26). John Duff hosted participants from the Cover Crops Coaching Clinic at the Bundaberg biofumigant trial.

7. Cover cropping: Implications for weed management field day, Myalup **Western Australia** 20 June 2019 (33). Marc Hinderager presented on the agronomy of managing cover crops and integrating cover crops and strip tillage.
8. Cover crops and soil biology, Richmond **NSW** 31 July 2019 (53). Kelvin Montagu presented at the Western Sydney University Soil Biology Masterclass and took participants on a farm visit to the mycorrhizae trial at Yarramundi.
9. Cover crop management, Virginia **South Australia** 23 October 2019 (29). Kelvin Montagu presented at the VegNET forum on cover crop selection and management.
10. Cover crops and strip tillage, Richmond **NSW** 25 October 2019 (38). Kelvin Montagu talked about cover crop management and strip tillage.
11. Vegetable Centre field day, Forthside **Tasmania** 5 December 2019 (59). International guest speaker Dr Adrian Newton from the Hutton Institute UK, presented on sustainable cover cropping systems with a farm walk, covering the pros and cons of different systems, including biofumigants.



Figure 1. Caliente cover crop being incorporated at the TIA field day

Cover Crop Coaching Clinic

The project delivered two Cover Crop Coaching Clinics in NSW and Queensland. The clinics, attended by 58 growers, brought cover crops into the 21-century through the combination of new science, machinery and management practices to make them work on today's farms. The coaching clinics were run by Kelvin Montagu, Adam Harber from Greensill Farming Group, and Darren Long from MG Farm, Tasmania, who is one of the leading cover crop innovators in vegetable production. Together they provided a wealth of practical and research knowledge to the growers, who rated the day well.

A third clinic to be held in western Australia was postponed due to COVID-19 restrictions.

Articles

A series of seven articles involving the cover crops project were produced. These included three articles in which leading vegetable growers outlined the benefits of the project (Appendix 3, Appendix 4, Appendix 5).

- **Cover Crop Coaching Clinic Bundaberg March 2019** (Appendix 1)
- **Winter cover crops' effects on weeds: Results from TAS and WA trials** (Appendix 2)
- **Deon Gibson Covered in glory - Grower Success Stories – Real results from the vegetable R&D levy** (Appendix 3)
- **Opening the doors to a sustainable farming future** (Appendix 4)
- **Cover cropping pioneer aiming to educate others** (Appendix 5)
- **Should you be making hay from your cover crop?**

www.soilwealth.com.au/resources/articles-and-publications/should-you-be-making-hay-from-your-cover-crop/

- **Forthside Open Day focusses on crop and soil health for greater productivity**

<https://ausveg.com.au/articles/forthside-open-day-focusses-crop-soil-health-greater-productivity/>

Fact sheets

Twenty fact sheets were produced, including 15 fact sheets detailing the current commercially available biofumigant cover crops.

1. **Quantifying Soil Health after Long-Term Cover Crops** (Appendix 6) Fact sheet summarises the measurable impact of long-term cover crops on soil health.
2. **Integrated Weed Management on a Bathurst pumpkin farm** (Appendix 7) Fact sheet outlines the advantages & drawbacks of cover crop, strip tillage and residual herbicide use in pumpkins.
3. **Cover crop + Rolled ground cover + Strip till = Record farm cucumber yield** (Appendix 8) Case study highlighted how cover crops together with strip tillage produced a big yield benefit.
4. **Cover crop + Strip till: A Winning Combination for Soil Health** (Appendix 9) Case study outlined the soil health benefits of combining cover crops and strip tillage.
5. **Soil Loss in Vegetables** (Appendix 10) Outlines how replacing fallow with a cover crop is one of the easiest and most affordable options to reduce soil loss and for soil health benefits.

A series of 15 factsheets summarising growth period and incorporation for brassica biofumigation cover crops in Queensland for the following cultivars. These factsheets summarise biofumigant management, potential uses, and pest and disease issues for each cultivar or mix:

6. **Caliente** (Appendix 11)
7. **Tillage Radish**
8. **Terranova Radish**
9. **Blackjack Radish**
10. **Caliente Rojo**
11. **Nemat**
12. **Mustclean**
13. **Cappuccino**
14. **BQ Mulch**
15. **Biofum**
16. **Fungisol**
17. **Nemcon/Nemclear**
18. **Nemsol**
19. **Black mustard**
20. **White mustard**

Guides

The cover crop project produced the following six guides. **Cover Crops in the Wider Bay Burnett** (Appendix 12) Guide was produced summarising cover crop selection, biofumigants, termination and incorporation for the Wide Bay Burnett region.

1. **Guide to Brassica Biofumigant Cover Crops** (Appendix 13) provides comprehensive information on the use of biofumigant cover crops for managing soil-borne diseases in vegetable production systems
2. A series of guides have been produced summarising information in easy to use tables. The tables cover 52 warm and cool season cover crops. These tables will be distributed in the *Vegetables Australia* magazine as A3 inserts.
3. **Cover Crop Agronomy** (Appendix 14) Summarises the relative environmental tolerances, soil conditions, sowing information, and growth characteristics.
4. **Cover Crop and Soil-borne Disease** (Appendix 15) Summarises the potential impact of cover crops on some key soil-borne diseases.
5. **Cover Crops and Herbicides** (Appendix 16) Summarises herbicides which may be used in cover crops, and how residue herbicides from vegetable crops may affect the following cover crops.
6. **Cover Crop Termination** (Appendix 17) Summarises the options for terminating cover crops, resulting biomass and its speed of breakdown.

Reports

Four research reports detail the research undertaken by the project.

1. **Effect of cover crops on soil biological communities** (Appendix 18) Details how soil biological communities respond to the use of cover crops.
2. **Cover crops to manage mycorrhizae for vegetable crops** (Appendix 19) Details the levels of mycorrhizae associations in commercial vegetable and cover crops and boosting mycorrhizae using cover crops.
3. **Long-term impacts of cover crops** (Appendix 20) Details the impact of more than ten years of cover crop use on soil properties and soil-borne disease levels.
4. **In vitro studies to determine the biofumigant effectiveness of Brassica cover crops on mortality of soil microorganisms** (Appendix 21) Assesses the impact of biofumigant from a range of cover crop varieties on a range of common soil pathogens and beneficial microorganisms.

Webinars

Six webinars were produced.

1. Biofumigation Cover Crops PART 1: What variety and when?

In this webinar John Duff (QDAF) and Kelvin Montagu (AHR) summarise the results of trials growing more than 12 different biofumigants at different times of the year in Gatton and Bundaberg.

www.soilwealth.com.au/resources/webinar-recordings/biofumigation-and-cover-crops-part-1-what-variety-and-when/

2. Biofumigation Cover Crops PART 2 Pest & diseases & impact on soil-borne diseases

Part 2 of the webinar looks at potential pest and disease issues while growing cover crops and the potential impact on soil-borne diseases (*Sclerotium rolfsii*, *Sclerotinia sclerotiorum* & *Macrophomina phaseolina*) following incorporation.

www.soilwealth.com.au/resources/webinar-recordings/biofumigation-cover-crops-part-2-pest-diseases-impact-on-soilborne-diseases/

3. Using cover crops to manage mycorrhizal fungi in vegetable crops

The webinar presented by Dr Kelvin Montagu (AHR) covers the biology of mycorrhizal fungi, the prevalence in more than 50 vegetable crops and vegetable growing soils, and how cover crops and mycorrhizae inoculants might be managed to increase crop-mycorrhizae associations.

www.soilwealth.com.au/resources/webinar-recordings/using-cover-crops-to-manage-mycorrhizal-fungi-in-vegetable-crops/

4. Cover crops and soil biology in vegetable soils

Dr Shane Powell (University of Tasmania) and Dr Kelvin Montagu (AHR) look at diversity of biological communities in vegetable soils across five sites and the impact of cover crops on the microbial communities.

www.soilwealth.com.au/resources/webinar-recordings/cover-crops-and-soil-biology-in-vegetable-soils/

5. East Gippsland Vegetable Innovation Days - Cover Crops and Strip Tillage live webinar panel session

Presented by Dr Kelvin Montagu, the panel discussion involves the experience of leading growers Michael Evans, Mulgowie Farms; Adam Schreurs, Schreurs & Sons; Jake Ryan, Three Ryans; Pete Shadbolt, Scotties Point Farms and Michael Nash, Agnova, as they introduce cover crops + strip tillage into vegetable production

www.soilwealth.com.au/resources/webinar-recordings/east-gippsland-vegetable-innovation-days-cover-crops-and-strip-tillage-live-webinar-panel-session/

6. Cover crop trial discussion: East Gippsland Vegetable Innovation Days

Dr Kelvin Montagu (AHR, Soil Wealth ICP team), John Duff (Queensland Department of Agriculture and Fisheries) and Carl Larsen (RMCG, Soil Wealth ICP team) discuss the results of a cover crop trial at the East Gippsland Vegetable Innovation Days (EGVID) 2020.

www.soilwealth.com.au/resources/videos-and-apps/cover-crop-trial-discussion-east-gippsland-vegetable-innovation-days/

Podcasts

Five podcasts were produced covering the basics of cover crops, an overview of the project, and cover crops trials at Cowra and Bathurst. These podcasts were produced in partnership with Hort Innovation and the Soil Wealth & ICP project (VG16078).

Two “Growing Matters” podcasts were produced jointly with Hort Innovation.

1. Basics of cover crops

[Growing Matters - #1 Basics of cover cropping with Dr Kelvin Montagu \(9min listen\)](#)

2. Link between cover crops and soil health: An outline of the cover crop project

[Growing Matters - #2 Link between soil wealth and cover cropping with Dr Kelvin Montagu \(12min listen\)](#)

A series of three podcasts was developed in partnership with Soil Wealth (VG16078) drawing on the cover crop information from the project.

3. Integrated Weed Management: Using cover crops and strip till

www.soilwealth.com.au/resources/podcasts/integrated-weed-management-using-cover-crops-and-striptill-6-minutes/

4. Cover crop trials at Cowra NSW, with Marc Hinderager

www.soilwealth.com.au/resources/podcasts/podcast-cover-crop-trial-at-cowra-nsw-with-marc-hinderager-6-minutes/

5. Benefits of cover crops and strip-till for pumpkin production: Interview with Michael Camenzuli from Bathurst

www.soilwealth.com.au/resources/podcasts/benefits-of-cover-crops-and-striptill-for-pumpkin-production-interview-with-michael-camenzuli-from-bathurst-6-minutes/

Videos

Five videos were produced covering two specific cover crops (buckwheat and sunn hemp); how cover crops and strip tillage work together; impact of cover crops on soil erosion and the use of biofumigation in vegetable production. These videos were produced in partnership with the Queensland Government's Resilient Rivers project, the Soil Wealth & ICP project (VG16078) and A strategic approach to weed management for the Australian vegetable industry (VG15070).

There is increasing interest in using different cover crop species to improve soil health and productivity in the Australian vegetable industry. The project produced two videos providing guidance on sowing, management, and termination of the buckwheat and sunn hemp cover crops.

1. Cover crop spotlight on Buckwheat

www.soilwealth.com.au/resources/videos-and-apps/cover-crop-spotlight-on-buckwheat/

2. Cover crop spotlight on Sunn hemp

<https://www.soilwealth.com.au/resources/videos-and-apps/cover-crops-the-advantages-of-sunn-hemp/>

3. Cover crops and strip tillage vegetable grower Ed Fagan (Cowra, NSW) explains how strip-tillage and cover cropping complement each other for a successful cucumber crop.

www.soilwealth.com.au/resources/videos-and-apps/ed-fagan-explains-why-his-initial-reservations-about-striptill-and-cover-crops-were-dispelled/

Two videos are in final stages of production and will be available on the Soil wealth website

4. Cover crops and erosion

www.soilwealth.com.au/my-topic/cover-crops-and-biofumigation/

5. Biofumigation: A cover crop option for the Australian vegetable industry

www.soilwealth.com.au/my-topic/cover-crops-and-biofumigation/

Outcomes

The project addresses farm productivity, resource use and management, within the Vegetable Strategic Investment Plan 2012–2017. Specifically, the cover crop project contributed to 1. developing innovative techniques to improve on-farm productivity, and 2. increasing growers' ability to defend themselves against rising costs of inputs, the effect of variable climates, water and soil shortages, and diseases.

The project had the following outcomes:

1. Increased use of cover crops in vegetable production underpinned by robust Australian research on the benefits and agronomy.
2. Vegetable growers and advisers using new regional- specific cover-crop information and coaching to restore or maintain healthy soil for profitable and sustainable vegetable growing.

Outcome 1 - Increased use of cover crops in vegetable production underpinned by robust Australian research on the benefits and agronomy.

Darren Long, MG Farms

"I think the biggest advantage of these cover crop coaching clinics and Hort Innovation projects is that you get to talk to other growers. You can bounce some ideas off each other and that's what I've found – I get to go away and meet growers all around Australia who are like-minded, and we can actually talk about how they do things and what they see"

The cover crops project has delivered to vegetable growers and advisers a wide range of information to facilitate greater use of cover crops. Partnering with leading cover crop user Darren Long on the Cover Crop Coaching Clinics delivered information to growers, underpinned by the research knowledge generated by the project. This co-delivery approach proved popular with growers and was a driver of changes in practice following the clinics.

For example, there was increased adoption of cover crops in the Bundaberg region after the Cover Crop Coaching Clinic. Several producers planted cover crops as a direct result, with consultation from the project team. Cover crops planted include oats, tillage radish, nemat and millet.



Figure 2. Grower submitted pictures of tillage radish, Nemat and Millet cover crop planted in Bundaberg following the Coaching Clinic.

The project has delivered Australian cover crop research to growers and advisers (participant numbers in brackets) via webinars (190) and farm walks (332). These face-to-face and online events have covered all aspects of cover crop management and benefits – soil health, soil biology, structure improvements, weed management, soil-borne-diseases and biofumigant cover crops.

Andrew Johanson, Sustainable Farming Practices Manager, Mulgowie Farming Company (Appendix 4)

“Through my involvement, I’ve learnt a lot about soil biology and how microbes are helping to build a resilient plant”

Outcome 2 - Vegetable growers and advisers using new regionally specific cover-crop information and coaching to restore or maintain healthy soil for profitable and sustainable vegetable growing.

Tasmanian grower Deon Gibson, Premium Fresh farm manager (Appendix 3)

“It has been a revelation for us. We’ve never had such healthy-looking carrots. There are no nematodes, the crops have beautiful green, healthy tops and they’re in free-draining soil. And in terms of cultivation, the soil breaks down very easily and has plenty of organic material, worms and dung beetles,”

Two coaching clinics were run in NSW and Qld, and a third postponed due to travel restrictions because of COVID-19. These Cover Crop Coaching Clinics allowed road testing of information and resulted in a shift in focus from regional guides to the comprehensive cover crop tables on cover crop agronomy, soil-borne disease, herbicides and termination. These tables split cover crops into cool and warm seasons, and allow growers to select cover crops most suited to their region’s growing conditions.

Case studies have highlighted both the profitability and sustainability of using cover crops. For example, Cover crops + roller crimper + strip tillage proved a winning combination. Cucumber yield and gross income more than doubled, with many soil and weed control benefits adding up to produce impressive yield and quality results (Appendix 8, Appendix 9).

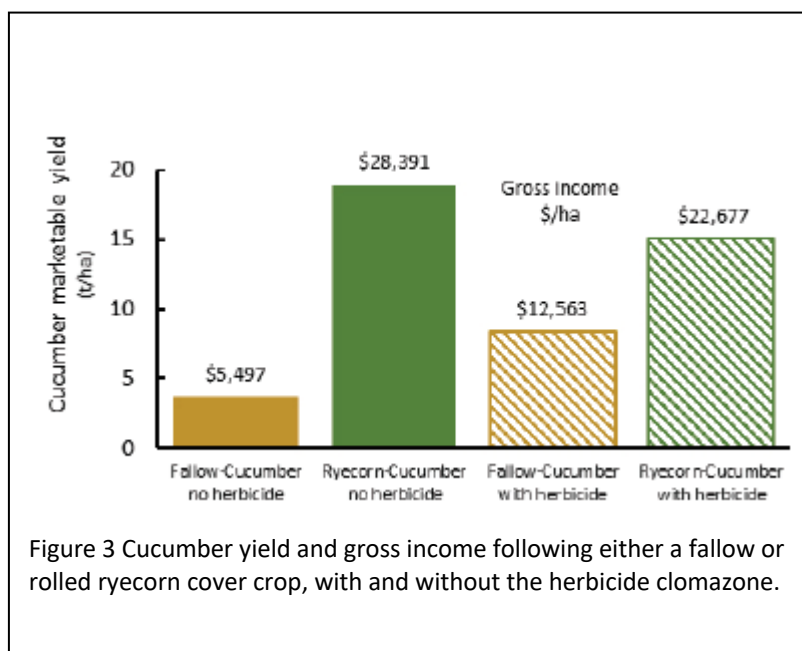


Figure 3 Cucumber yield and gross income following either a fallow or rolled ryecorn cover crop, with and without the herbicide clomazone.

In another case study, the reduction of erosion due to cover crops was highlighted (Appendix 10).

Andrew Johanson, Sustainable Farming Practices Manager, Mulgowie Farming Company (Appendix 4)

“With controlled traffic farming, cover cropping and minimum tillage, we have seen our soil water infiltration and holding capacity increase, the soil become less compacted and more friable, and yield increase, with plants showing more resilience to weather extremes”

The projects guidelines leave the vegetable industry with a strong legacy. These will help encourage and guide growers to make the most of cover crops.

Monitoring and evaluation

The cover crop project delivered beyond the planned activities and outputs detailed in Table 2. This was achieved through effective partnerships with other projects, allowing more integrated project outputs, for example, cover crops and strip tillage, and cover crops and weed management.

Partnerships with the communication channels of AUSVEG, Hort Innovation’s Growing Matters podcasts and the Soil Wealth 7 integrated crop projection project allowed the project to respond to industry needs. For example, five podcasts were produced that had not been planned.

The project was also able to respond to changing environment and industry needs to produce outputs relevant to industry. For example, during the drought the project produced an article on making hay from a cover crop in response to rising hay prices.

Table 2. Assessment of project effectiveness based on M&E Plan.

Evaluation Question	Achievement	Project learnings
Have the four research reports been produced?	Four research reports were produced covering the major areas of the project (Appendix 18, Appendix 19, Appendix 20, Appendix 21)	Research reports were produced for the end of the project. These reports will form the basis of scientific publications to be published.
Have the three regional guides been developed?	Six guides replaced the regional guides covering specific cover crop topics of biofumigants, agronomy, soil-borne diseases, herbicides and termination (Appendix 12, Appendix 13, Appendix 14, Appendix 15, Appendix 16, Appendix 17)	The project reviewed the appropriateness of region guides and determined that guides specific to topics were more useful for growers.
Have the three webinars been delivered?	Six webinars were produced as detailed in the outputs section.	A greater number of webinars were produced due to travel restrictions associated with COVID-19. The webinars were popular with industry and well attended. They represented a good way to deliver research results to industry.
Have the three Coaching Clinics been delivered?	Two Cover Crop Coaching Clinics have been delivered (NSW & Qld) with the third clinic in WA postponed due to COVID-19. This will be delivered when travel restrictions are lifted.	The partnership between the project researchers and Darren Long of MG Farms, a leading grower and cover crop user, proved an effective delivery method. Participants were presented with practical how-to strategies and research results in the one-day session.
Were the demo farm walks conducted?	Eleven farm walks and industry presentations were conducted as detailed in the outputs section. The events were well attended with 332 participants.	Three farm walks were cancelled and replaced with online events due to COVID-19.

Have the four factsheets been produced?	Twenty-one fact sheets were produced covering a wide range of topics.	The greater number of factsheets was due to successful partnerships with other projects, allowing integration on topics such as strip tillage and weed management.
Have Facebook pages been established for new Demo Sites?	Facebook pages were used for the demo sites	
Have the six videos been produced?	Five videos were produced as detailed in the outputs section.	The videos are an important legacy output from the project. The buckwheat video has had almost 10,000 views in two years, with positive feedback on the information contained.
Additional outputs	Five podcasts and seven articles were produced covering outputs from the project.	Additional outputs were produced in response to conditions or industry needs. For example, during the drought hay prices were high so the project produced an article: Should you be making hay from your cover crop?

Effectiveness, Appropriateness & Legacy

The cover crop project outputs have aligned strongly with growers and advisers’ needs and expectations. Both quantitative and qualitative feedback from events has been strong. Participants thought the events were relevant to their business (7.3 out of 10) and rated the topic, content, and delivery at (7.7 out of 10).

The webinars proved popular with growers and advisers and were a good way to deliver research findings on biofumigation, soil biology and mycorrhizae.

The output from the project has produced a strong legacy. Already the recorded webinars have had more than 500 views, with the videos exceeding 12,000 views.

The project will be distributing the four tables on cover crop agronomy, soil-borne diseases, herbicides, and termination through inserts in *Vegetables Australia* magazine over the coming year. These tables have a strong practical focus and will help growers select the most appropriate cover crop for their vegetable production system.

The knowledge, skills and experience developed across the three partner organisations are an important additional legacy produced by the project. These, together with the PhD produced, will help ensure the vegetable industry has the research capability to draw on to further develop the use of cover crops.

Table 3. Appropriateness of project activities based on M&E Plan

Evaluation Questions	
Have training and extension activities increased the skills and knowledge of growers and advisers?	Across the training and extension activities (webinars, Cover Crop Coaching Clinics and farm walks) 92% of participants considered that they would be able to make more informed decisions about cover crops following the events. When asked how likely they were to change farm practices or advice following the event a score of 6.7 was given out of 10. Participants thought the events were relevant to their business (7.3) and rated the topic, content and delivery at 7.7.
Have the communication activities reached the audience?	Unsolicited articles produced by AUSVEG provide qualitative evidence that growers have been reached and value the information (e.g. Appendix 3, Appendix 4, Appendix 5) Also the project team has received regular contact from growers after events and other communications, such as webinars.
Have the factsheets, how-to-guides and reports been used?	The majority of outputs have been produced at the end of the project and form a strong legacy. Where early outputs were produced these have proved popular. For example, the buckwheat video has recorded almost 10,000 views, while Benefits of combining cover crops and strip tillage has had more than 1,800 views.
Has new information from the research component been incorporated into delivered activities?	Research undertaken by the project has been included in all outputs detailed in the Outputs section. The factsheets and guides will form an important legacy for the project ensuring information is available to the industry.

Recommendations

Cover crops are one of the most useful tools for managing intensive vegetable growing soils. Their importance is increasing as vegetable production systems move to “softer” more biological approaches to tillage, integrated crop protection, weed control and nutrition.

Darren Long, MG Farms

“The advancements in cover cropping have been the most advanced single change to farming that I’ve seen for 30 years. It’s an absolute game-changer”

This project has filled an important gap, bringing cover crop information together and modifying it specifically for the Australian vegetable industry. This has also occurred across other horticultural and agricultural sectors, e.g. vineyards and broad-acre cropping. There is an ongoing need to periodically update these guidelines based on grower experience and new research findings.

Recommendation 1 – Continuous improvement

Consideration be given to fund the ongoing delivery of the Cover Crop Coaching Clinic. These clinics are an important pathway delivery to the industry and for the continuous improvement of cover crop practices in the vegetable industry. Combining growers and researchers’ experience would also allow rolling updates to the guideline, including the ongoing “Australianising” of new cover crop information, most of which is generated in the northern hemisphere.

Recommendation 2 – Cross-sector research opportunities

Consideration be given to development of a cross-sector approach for future cover crop research. This may be across all horticulture crops or in partnerships with agriculture crops. Cross-sectoral cover crop issues could include:

1. Mixed cover crops are topical among growers, largely based on the assumption that increased diversity is better. Research is required to understand the role mixed species cover crops can play in delivering cover crop benefits and to help overcome some of the management issues e.g. termination.
2. Water limitations are a key issue in Australian production systems, restricting both the growth of the cover crop as well as impacting on stored water for the subsequent cash crop. Research is required to guide growers on species selection to minimise water use, and management practices to maximise stored soil water.
3. Terminating cover crops is highly reliant on glyphosate. Alternatives are required, which may need to integrate rolling/mulching with non-glyphosate herbicide alternatives, or other options for organic growers.
4. Cover crops have traditionally been sourced from broad acre crops and pasture species and selected mainly because of the availability of cheap seed. The selection of specific traits for cover crops is only now emerging e.g. tillage radish, root max ryegrass. This an area that would benefit from a cross-commodity approach.
5. Soil biology remains an emerging area of importance where cover crops can potentially play an important role. A cross-sectoral approach would be useful in building a better understanding on the role of cover crops in managing soil biology. For example, what does it take to permanently change soil microbiology? Can this be somewhat controlled or manipulated, and what represents a healthy system? What role does long term use of cover crops have in this?
6. Biofumigant cover crops require further development. In this project we demonstrated that their efficiency varies with the time of year and growing conditions. Further work on additional soil-borne pathogens and nematodes is required, as it has become evident each biofumigant variety has a different glucosinolate makeup and effectiveness at different times of the year.

Recommendation 3 – Integration

Applied research, working closely with growers, is required to develop new integrated approaches using cover crops. A good example from this project was the combination of cover crops and strip tillage, with both practices providing additional benefits when combined. Integration of different practices could include:

1. Cover crops and treatments for soil-borne diseases
2. Subsoil ripping and cover crops
3. Cover crops in organic production need an integrated approach to develop termination approaches that work.
4. Cover crops and beneficial biology
5. Cover crops to manage beneficial insects

Recommendation 4 – Cover crop – vegetable sequencing

One aim of this project was to collate information on the best cover crop – vegetable crop sequence to deliver the best outcomes. However, apart from the impacts of sequencing on soil-borne diseases, there was little solid information on the most beneficial sequences.

This approach may initially focus on the influence of cover crops on diseases and pathogens of different species, and on cover crops and mixes on pathogen inoculum.

Recommendation 5 – Long-term rotation trials

Long-term approaches to managing soil health would be beneficial to Australian vegetable growers. A series of longer-term rotation trials have been established in the US, and in the UK at the James Hutton Institute. The development of a series of linked rotation trials in Australia, under differing production systems examining some of the fundamental questions around soil health in cropping systems, including cover crops, would be beneficial to producers in this sector.

Refereed scientific publications

Paper in conference proceedings

Montagu, K., Harber, A., Walker, B., Lucas, D., Tegg, R., Powell, S., Tesoriero, L., Rettke, M., Wilson, C., Doyle, R., 2018. How do cover crops reduce soilborne disease in vegetable production, via influence on specific pathogens or changes in general soil microbial communities? National Soil Science Conference.

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Intellectual property, commercialisation and confidentiality

No project IP, project outputs, commercialisation or confidentiality issues to report.

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On farm trials

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Growers survey

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Appendices

Appendix 1. Cover Crop Coaching Clinic Bundaberg March 2019

Appendix 2. Winter cover crops effects on weeds: Results from TAS and WA trials

Appendix 3. Deon Gibson Covered in glory -Grower Success Stories – Real results from the vegetable R&D levy

Appendix 4. Opening the doors to a sustainable farming future

Appendix 5. Cover cropping pioneer aiming to educate others

Appendix 6. Quantifying Soil Health after Long Term Cover Crops

Appendix 7. IWM on a Bathurst pumpkin farm: Advantages & drawbacks of ground cover use, tillage and residual herbicides

Appendix 8. Cover crop + rolled ground cover + strip till = record farm cucumber yield

Appendix 9. Cover crop + Strip till a winning combination for Soil Health

Appendix 10. Soil loss in vegetables

Appendix 11. Brassica Biofumigant Cover Crop - Caliente

Appendix 12. Cover crops in the Wide Bay Burnett

Appendix 13. Guide to Brassica Biofumigant Cover Crops

Appendix 14. Cover crop agronomy summary

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Appendix 16. Cover crops and herbicides

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Appendix 18. Effect of cover crops on soil biological communities

Appendix 19. Cover crops to manage mycorrhizae for vegetable crops

Appendix 20. Long-term impacts of cover crops

Appendix 21. In vitro studies to determine the biofumigant effectiveness of Brassica cover crops on mortality of soil microorganisms

Appendix 1

Cover Crop Coaching Clinic, Bundaberg, March 2019

On 21st March, 28 vegetable growers and agronomist from the Bundaberg region attended the Cover Crop Coaching Clinic. The clinic was run through the vegetable levy funded project VG16068 Optimising cover cropping for the Australian vegetable industry. The practical workshop demonstrated the latest cover crop species, the benefits and how best to integrate cover crops into their vegetable production systems. Presenters included Kelvin Montague (applied Horticultural Research), Darren Long (MG farm produce), John Duff (QDAF) and Adam Harber (VegNET IDO). Darren is a vegetable farmer from Tasmania that demonstrated best management practices of biofumigant cover crops. Participants also visited a biofumigant trial featuring 12 different species of biofumigants. Producers gained first-hand knowledge on agronomic performance, pest and disease pressure and benefit of incorporation biofumigants. The trial was also funded through the project. Since the coach clinic, adoption of cover crops has increased with several producers planting cover crops as a result and with consultation from the project team. Cover crops planted include oats, tillage radish, nemat and millet.

In collaboration from AHR and the VegNET IDO (BFVG), a factsheet with information from the workshop was produced on cover crops in the Wide-Bay Burnett area which can be found on the Soil Wealth website.



Tillage radish, Nemat and Millet crop planted in Bundaberg following the workshop.

Appendix 2

R&D | WEED MANAGEMENT |



Caliente cover crops at Forthside, Tasmania.



Italian ryegrass at Forthside, Tasmania. Images courtesy of M. Coleman.

WINTER COVER CROP EFFECTS ON WEEDS: RESULTS FROM TAS AND WA TRIALS

Many growers are now including cover crops in their annual cycle to improve the quality of their soil, and information about soil health benefits will often influence which cover crop type (or mix of types) is selected. But what about their effects on weeds? The project team from the University of New England (UNE) investigates.

In 2018, a team from the University of New England (UNE) monitored two winter cover crop trial sites to understand the impact of several cover crop types on weed germination and growth.

The two winter cover crop sites included a long-term trial at the Tasmanian Institute of Agriculture (TIA) Vegetable Research Facility near Forthside, and a newly-established trial hosted by Ivankovich Farms near Myalup, Western Australia.

The TIA trial comprises four replicated plots each of Italian ryegrass (*Lolium multiflorum*) and Caliente (*Brassica juncea*) cover crops, as well as four fallow control plots for comparative analysis. These fallow plots received one extra herbicide treatment during the fallow period.

Cover crops were grown for 145 days before incorporation. The Myalup replicated trial includes six cover crop types, grown for 90 days before incorporation: field peas (*Pisum sativum*), cereal rye (*Secale cereale*), Italian ryegrass, Caliente, BQ Mulch (25 per cent *Brassica nigra*, 75 per cent *Brassica abyssinica* or *Brassica carinata*), and a biofumigant mix provided by David Grays (comprising *Brassica juncea* and *Eruca sativa*).

All cover crops were monitored regularly after sowing to measure the growth and canopy cover of each type, and the number and species of weeds present. Immediately prior to incorporation, final cover crop biomass and ground cover data were collected, as well as weed biomass and counts by species.

This research was undertaken as part of the three-year project *A strategic approach to weed management for the Australian vegetable industry* (VG15070), a strategic levy investment under the Hort Innovation Vegetable Fund.

INITIAL RESULTS

A faster-establishing, competitive cover crop can be more effective in suppressing both weed germination (by shading the ground and making it difficult for seed which requires light to germinate) as well as growth (by out-competing weeds that have germinated for resources and space). Figures 1 and 2 show the percentage of ground cover observed in the cover crops across both sites.

As Figure 1 shows, Caliente established more quickly than Italian ryegrass at Forthside, being at approximately 50 per cent ground cover some 50 days after sowing. Italian ryegrass established more slowly, but by the time the cover crops were incorporated (145 days after sowing), ground cover was close to 100 per cent for both.

At Myalup, cereal rye covered the ground considerably faster in the first 14 and 28 days after sowing compared with the other

cover crops, and field peas were relatively slow (see Figure 2). However, by the time of incorporation into the soil (90 days after sowing), all cover crops had similar ground cover.

WEED DENSITY AND BIOMASS

Many common weeds in vegetable production were observed at the two sites including fat hen (*Chenopodium album*), chickweed (*Stellaria media*), milk thistle (*Sonchus oleraceus*) and wild radish (*Raphanus raphanistrum*).

Table 1 shows more weeds were present within Caliente at Forthside than within the Italian ryegrass and fallows, while a higher weed biomass was also found. The very thick canopy of Italian ryegrass at 145 days after sowing means that it may have been more effective at intercepting light at ground-level compared to Caliente at this late stage, where diffused light reached the ground level within the two metre high stalks. To explore the impact of light interception on weeds, this will be measured in year two for both trials.

Caliente also featured uncovered and partially-shaded wheel tracks which did not occur in the Italian ryegrass. In Caliente, this may have allowed weeds such as chickweed, commonly observed at Forthside and capable of growing in moist, partially-shaded conditions, to establish and grow well within the taller stature of this crop.

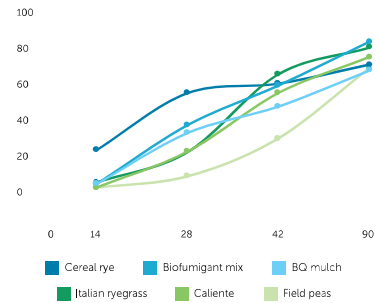
Table 1 also shows that the rapid ground cover establishment of cereal rye in Myalup correlated with a considerably reduced weed burden in the cereal rye plots at the end of the trial, both in terms of the number of weeds per square metre and the weed biomass. This shows that early ground cover establishment is important for cover crops to suppress weeds.

Biofumigant crops such as Caliente can have additional benefits including soilborne disease suppression, and anecdotal evidence suggests that its allelopathic effects (the chemical inhibition of one species by another) may also reduce the weed seed bank and suppress recently-germinated weeds after the crop has been incorporated into the soil. However, like selective herbicides, this effect may only inhibit seeds and seedlings of some weed species and not others. To explore the impact of the cover crop types on the weed seed bank at different depths, soil samples were collected for germination and counting of weed seeds at UNE. Analysis is ongoing, and full results will be published in the project's final report.

Each cover crop species is also likely to establish and perform differently with regard to suppressing weed growth and seed production depending on seasonal variation, local climate, paddock history, time of planting and incorporation, and weed species present.

Both the Forthside and Myalup trials will be replicated identically in 2019. Team members from the Hort Innovation-funded project

FIGURE 2: COVER CROP GROUND COVER PERCENTAGES, 14 TO 90 DAYS AFTER SOWING, MYALUP, APRIL-JULY 2018



Optimising cover cropping for the Australian vegetable industry (VG16068) are evaluating beneficial mycorrhiza and crop yield on these trial sites. Two similar summer cover crop trials are planned for Richmond, New South Wales, and the Lockyer Valley in Queensland (also a Hort Innovation-funded trial site).

The UNE team is very grateful to Hort Innovation for funding this research. In Western Australia, the team was supported by Peter and Anthony Ivankovich (Ivankovich Farms, Myalup), Ian Guthridge and Graham Blincoe (Western Australian Department of Primary Industries and Regional Development), Grant Swan, John Cross and Bruce Shaw (David Grays), and Dave Stewart (Elders). In Tasmania, Philip Beveridge and Robert Tegg (TIA) provided generous support of the project and access to the TIA site at Forthside. Doris Blaesing (RM Consulting Group) and John Duff (Queensland Department of Agriculture and Fisheries) provided expert advice on cover crop variety selection.

INFO

For more information, please visit une.edu.au/wmvegetables, or contact Michael Coleman at m20@une.edu.au or 0-37 403 644 or Chris Fry at c15@une.edu.au or 0191 220 916.

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Project Number: VG15070

Hort Innovation | **VEGETABLE FUND**
through levy investment

FIGURE 1: COVER CROP GROUND COVER PERCENTAGES, 20 TO 145 DAYS AFTER SOWING, FORTHSIDE, MAY-OCTOBER 2018

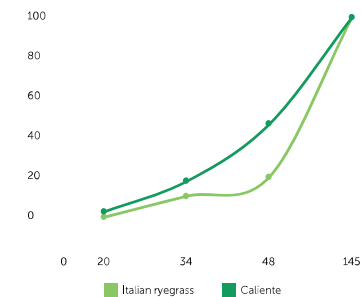


TABLE 1: WEED DENSITY AND WEED BIOMASS, MYALUP (WA) AND FORTHSIDE (TAS), 2018

TREATMENT	WEED DENSITY FORTHSIDE plants per m ²	WEED BIOMASS FORTHSIDE grams per m ²	WEED DENSITY MYALUP plants per m ²	WEED BIOMASS MYALUP grams per m ²
FIELD PEAS	-	-	13.5	17.7
CEREAL RYE	-	-	7.8	0.4
ITALIAN RYEGRASS	189.8	55.1	10.5	3.1
CALIENTE	262.3	125.9	15.5	2.7
BQ MULCH	-	-	18.5	2.6
BIOFUMIGANT MIX	-	-	14.5	2.5
FALLOW	22.3	26.1	-	-



DEON GIBSON

COVERED IN GLORY

Award-winning carrots are just one sign for Deon Gibson that patience has its own rewards when using covercropping.

Inspired by 2015 Farmer of the Year Grant Sims, local Tasmanian grower Darren Long and various field days and walks, the Premium Fresh Tasmania Farm Manager started to revive cover cropping on his property. Deon is now working with others from Queensland and Victoria on a three-year project with Applied Horticultural Research scientist Dr Kelvin Montagu entitled *Optimising cover cropping for the Australian vegetable industry* (VG16068), a strategic levy investment under the Hort Innovation Vegetable Fund.

For this project, Deon has set up his

damage to the surface. The same applies in winter. That's where cover cropping maintains the consistency."

PATIENCE PAYS OFF

Deon says sticking with covered cropping beyond "trying one year and not the next" was netting excellent results in terms of better yields and premium prices.

"You still have to grow the cover crop – not just put it in and forget about it. I've found to get the best out of it, you give it that little bit more and you get twice the result. It's really about keeping your cool and not using your soil when it's not fit to be used," he says.

and greater analysis by agronomists is deepening the physiological understanding of cover crops.

The project's end goal is to create a range of templates, such as booklets or guides, that highlight the estimated costs of what to grow, which cover crops and practices work best with different crops, and the expected results.

"It's my hope to follow through and produce long-term results that will benefit all. Everyone's back pocket will be helped. At the end of it, I'm sure I'll be really proud of this."

SUMMARY

- Project VG16068 aims to combine new science, machinery and management practices that growers, such as Premium Fresh Tasmania Farm Manager Deon Gibson, can use to improve their yields and ultimately increase prices.
- For this project, Deon has established a four- or five-year paddock rotation, giving selected paddocks a 12-18 month rest with selected cover crops. He has seen promising signs such as weed suppression and improved protection of soil as a result.
- A range of materials will also be released, including on the Soil Wealth and ICP website (soilwealth.com.au) that identify the approximate costs of what to grow and which cover crops and practices work best.
- *Optimising cover cropping for the Australian vegetable industry* has been funded by Hort Innovation using the vegetable research and development levy and contributions from the Australian Government.

"It has been a revelation for us. We've never had such healthy-looking carrots"

300-hectare farm at Forth on a four- or five-year paddock rotation, giving selected paddocks a 12-18 month rest with selected cover crops. The emphasis on quality over quantity has suppressed weeds, improved operational efficiencies and protected the soil rather than leaving the paddocks exposed to the elements.

"It has been a revelation for us. We've never had such healthy-looking carrots. There are no nematodes, the crops have beautiful green, healthy tops and they're in free-draining soil. And in terms of cultivation, the soil breaks down very easily and has plenty of organic material and worms and dung beetles," Deon says.

"Your soil is a living organism and you don't want it to die, so you want something growing in there – even if it's only a short-term cover crop, you're protecting that soil.

"Doing so over summer means you're not getting all the extremes with a 30-degree sun hitting the bare soil and doing lots of

"Because of financial imperatives there's often too much of a push on the soil but, where possible, I'd rather be rejuvenating the soil than just have a marginal crop on it.

"I've seen that one bad decision can undo a paddock for four or five years where a harvest has depleted and destroyed the soil structure. Yet after cover cropping, our horsepower, fuel and irrigation requirements are reduced, and our soil isn't as tight and bashed down as we're not trying to turn it to plant a crop in the next day.

"Likewise, with strip plots all the natural drain and nutrients are still there because you haven't smashed it up. We're back on it in no time, and there's no erosion because the water filters down from the harder bits where you've worked before."

LONG-TERM GOALS

Deon says the scientific tools available are improving, such as penetrometer readings,