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Investment Roadmap for Enhancing Yield Consistency in the Australian Avocado Industry

Developed in partnership with industry through project AV23014

Hort Innovation AVOCADO FUND

Wilkie Horticulture

Queensland Government

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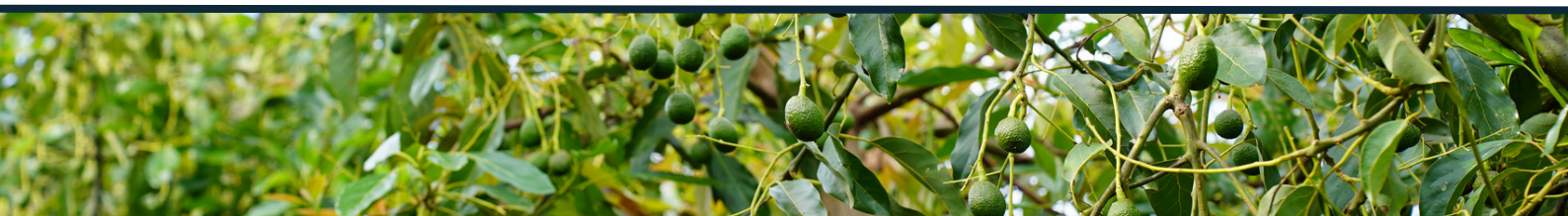
The project 'Workshop and roadmap for the way forward for irregular bearing' (AV23014) has been funded by Hort Innovation, using the avocado research and development levy, co-investment from the Queensland Department of Agriculture and Fisheries, and contributions from the Australian Government. Hort Innovation is the grower-owned, not-for-profit research and development corporation for Australian Horticulture



Introduction

The Australian avocado industry is undergoing a period of significant growth in production, which has changed the dynamics of markets and industry profitability. It is widely accepted that inconsistent production and availability of fruit to markets has significant negative impacts on profitability.

This Roadmap was developed because there was a perception that there were wide-ranging views within the industry on the direction future investments to improve yield consistency should take. A Workshop and co-design process exposed participants to high quality scientific information, encouraged rigorous discussion and was successful in generating consensus on the critical issues for yield consistency in Australia.

This Roadmap will inform and support avocado industry investments aiming to improve yield consistency (minimise the effects of irregular and alternate bearing). It is anticipated that this Roadmap should have a lifespan of at least 10 years. These investments will help achieve:

- The Hort Innovation avocado industry strategic plan (Outcome 2)
- Avocados Australia strategic plan (1.1 Encourage consistent supply to the domestic market)
- Australian Avocados Export Strategy (Section 2)
- Australian Avocado Extension Strategy (High priority practice change area 12)

The intended users of the Roadmap are those evaluating investment decisions, including the avocado Strategic Investment Panel and Hort Innovation. It is also intended that the Roadmap be used by research providers designing projects aimed at improving yield consistency.

The Roadmap has been developed with two key principles in mind. First, that the process be undertaken with high levels of industry input and consultation. Second, that strong and broad scientific expertise be used to develop the Roadmap.

The Roadmap is a research strategy that has identified key issues, likely strategies to overcome these issues and potential deliverables. The Roadmap is not intended to be a research proposal.

Project summary

This roadmap is part of the Hort Innovation-funded project (AV23014), which aims to develop a comprehensive and actionable roadmap for research, development, and extension focused on irregular and alternate bearing in the Australian avocado industry, guiding future industry investments.

The Roadmap development process began with a literature review, to provide a strong scientific foundation, and an industry survey, to gain grower insights and understand their perceptions of the issues.

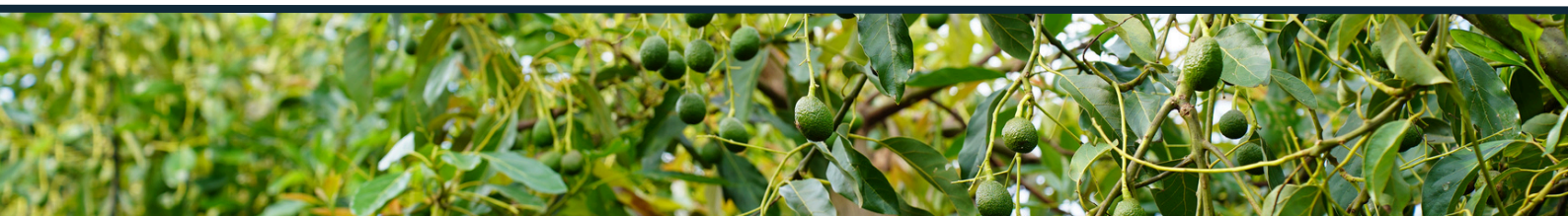
The primary activity was the Workshop in Brisbane, which was attended by leading scientists, advisers and producers from diverse growing regions that represented 14% of Australian production. The program was designed to provide the participants with current scientific information on critical issues around alternate and irregular bearing in avocado, and to allow the group time to absorb and discuss this information. There were a range of important outcomes from the discussion and co-design sessions at the Workshop. First, the group agreed that the traditional terms of 'irregular bearing' and 'alternate bearing' may be leading to confusion and that talking of the issue as one of yield consistency would be more useful.

Second, the factors affecting yield consistency were separated into four clear crop production impact areas. This aided the co-design process and is intended to aid investment decisions:

1. Floral initiation and development
2. Pollination and fruit set
3. Fruit development and retention
4. Vegetative growth and canopies

Third, there was consensus that for many of the issues affecting yield consistency, scientific understanding is in its infancy and many areas require research to develop underlying principles, knowledge and understanding before grower tools and management packages could be developed. There are a broad range of issues within the identified Investment Priorities which further demonstrates the breadth of the challenge in improving yield consistency. Some issues were identified to be more severe in certain growing regions, however, many of the issues were accepted to be in common across the industry.

Extensive feedback on versions of the draft Roadmap has been sought, via an additional information session in Western Australia, an industry wide webinar and an opportunity for written responses following online access to the draft roadmap.



Purpose and scope of the Roadmap

The purpose of the Roadmap is to inform and guide future avocado industry investment decisions aimed at improving consistency of production.

These investments will help achieve:

- The Hort Innovation avocado industry strategic plan (Outcome 2)
- Avocados Australia strategic plan (1.1 Encourage consistent supply to the domestic market)
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Many factors affect yield in avocado orchards. We are not including certain aspects of avocado production systems in the investment priorities of this Roadmap:

- Factors that indirectly affect avocado reproductive development via tree health or by inducing stress in the tree, are not considered in this Roadmap.
- Examples of factors that are not included in the investment priorities are Phytophthora and irrigation. We are not saying these issues are unimportant, they are not included as areas for research in this Roadmap because research on these issues is conducted in other programs.

The terms 'irregular bearing' and 'alternate bearing' have traditionally been used to describe different forms of variability in avocado yield. The workshop participants agreed that these terms may be leading to confusion and are not ideal. The group instead agreed to refer to impacts on:

1. Floral initiation and development – including the induction, initiation and development of inflorescences and flowers up until the point that the flowers open.

2. Pollination and fruit set – encompassing all of the processes from flower opening until a fruit has been set. This includes the quality of the flowers, the transfer of pollen and all of the processes affecting successful fertilisation of the ovary and resultant fruit set.

3. Fruit development and retention – this encompasses the entire period of fruit development from the point of initial fruit set until maturity and includes the processes of fruit growth and fruit abscission.

4. Vegetative growth and canopies – this includes the factors affecting the development of the canopy, ranging from the scale of individual shoot growth up to the whole tree and orchard scale.

The Australian avocado industry operating environment in 2024

- Inconsistent supply of fruit to markets is having a strong negative impact on profitability in all growing regions.
- There has been a significant increase in plantings with some of these plantings yet to come into production.
- The industry is aiming to drive domestic consumption and increase export, both at profitable farm gate prices, but inconsistent fruit supplies are hindering this market development.
- Wide range of growing environments (tropical to temperate), with an associated range of crop phenology.
- The climate is changing. The overall impacts on avocado yield through direct impacts to crop development processes are not fully understood. Nor are the impacts for the different growing regions.

Australian annual avocado production and price

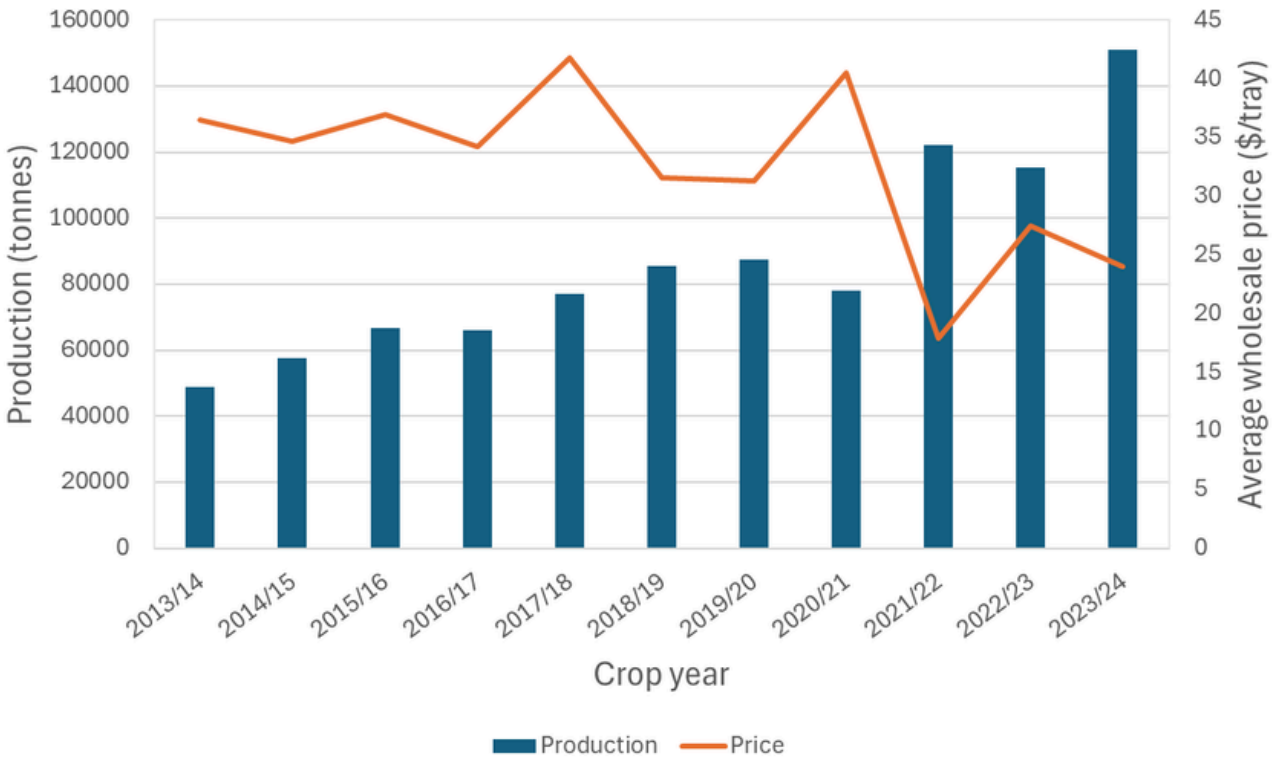


Figure 1: The relationship between Australian national avocado production and average wholesale avocado prices
Source: Data provided by Avocados Australia Limited

Where are we and where do we want to be?

Current state

- Lack of consistency in yield and low productivity is a significant issue in Australian avocado orchards.

- Improved understanding of avocado physiology, factors affecting crop load development and responses to management.
- Better management tools and strategies.
- Greater ability of managers to generate improved crop resilience against severe weather events.

Desired state

- Australian avocado orchards with greater productivity and improved yield consistency
- Greater grower confidence in ability to achieve consistent yields.

The Roadmap development process

Broad industry and scientific contributions were a feature of the Roadmap process:

- A Project Reference Group consisting of growers and scientists was engaged to guide the Roadmap development.
- The Roadmap design workshop was attended by growers representing 14% of Australian avocado production and leading domestic and international scientists.
- The survey had responses from more than 50 avocado businesses with representation from all Australian growing regions.

LITERATURE REVIEW

- Reviewed the factors affecting alternate and irregular bearing, including the influence of growing regions
- Areas that were reviewed in great detail in AV12030 were not duplicated, resulting in a review with a significant focus on tree physiology and resource allocation

PRE-WORKSHOP SURVEYS

- Domestic survey gained an understanding of grower experiences and perceptions across all production regions
- International consultation provided input from researchers worldwide regarding their experiences and perspectives

WORKSHOP

- Featured guest international and domestic speakers and facilitated discussion sessions
- Participants engaged in a co-design process to develop the R,D&E investment priorities

R,D&E ROADMAP

- Information gathered from the literature review, surveys, presentations, workshop discussions and co-design sessions were integrated
- The Roadmap will provide a pathway for future investments in this area, validated through extensive industry consultation
- It is worth noting, however, that the Roadmap is not a research proposal

POST-WORKSHOP FEEDBACK OPPORTUNITIES:

- Webinar
- Feedback session in Western Australia
- Written responses to draft Roadmap

FINAL REPORT

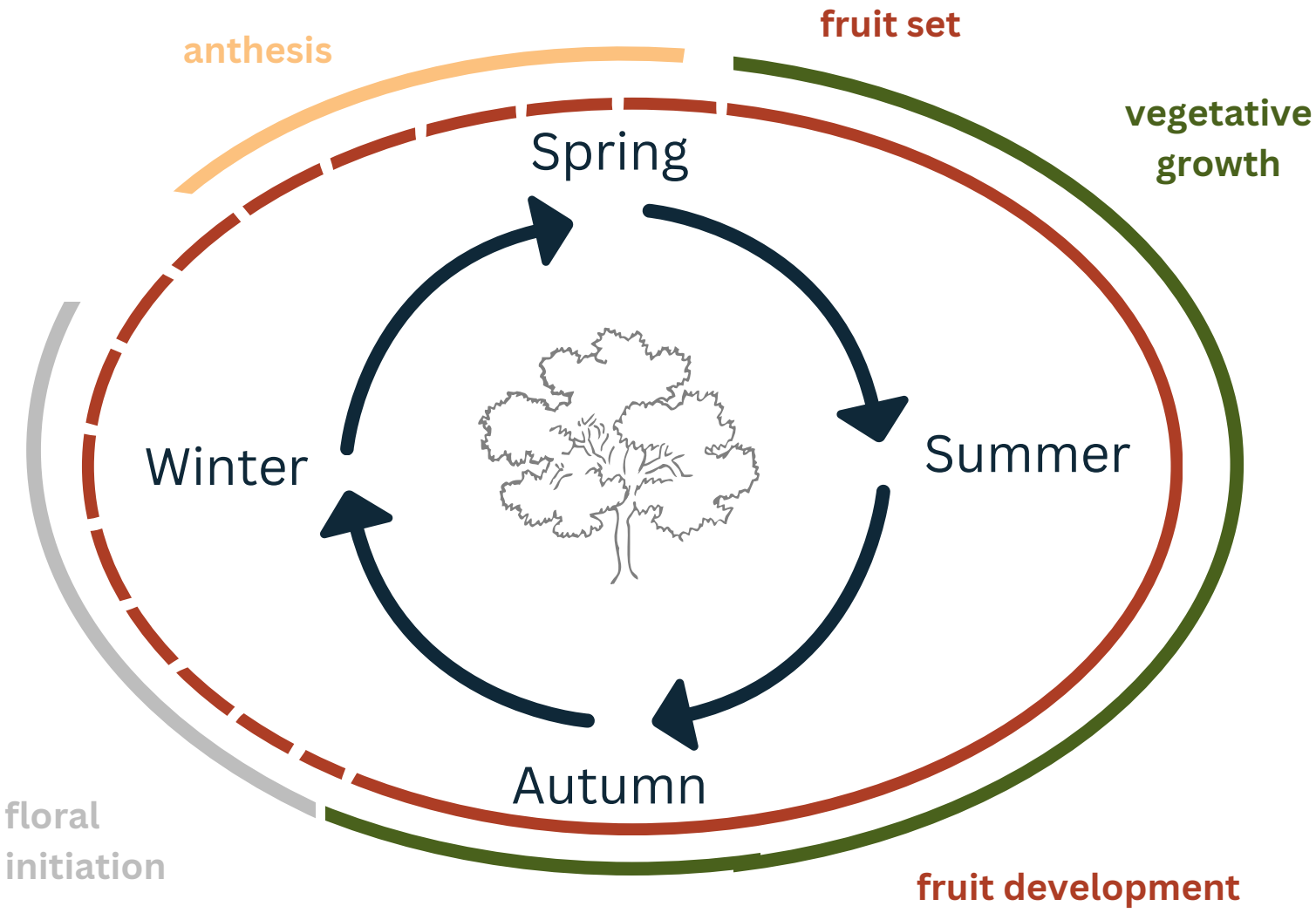
- Summary of all outputs
- Outputs added to Best Practice Resource
- Industry article on the project
- Final Roadmap submitted to Hort Innovation

A note for users of the Roadmap

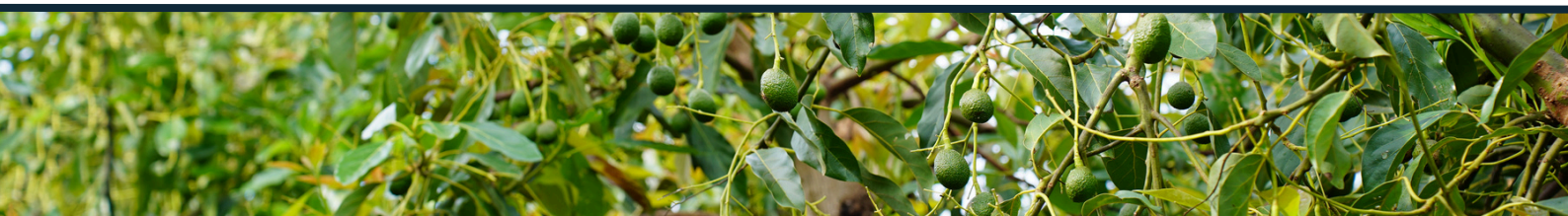
Reproductive development in avocado is complex, because it is a multi-step process, is affected by processes occurring within the tree and by the external environment. Additionally, the previous crop affects the development of the current crop.

This means that critical crop development processes such as floral initiation and development, fruit set and fruit development can be affected by each other or by vegetative growth.

It is therefore important for Roadmap users to consider how their issue of interest may interact with issues in the same or other Impact areas.



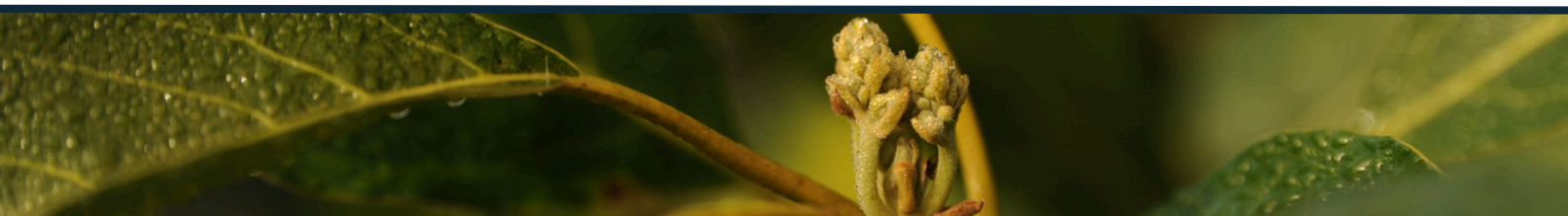
The avocado crop development cycle varies with growing environment. The initiation of flowers occurs when temperatures are cool enough for the expression of flowering genes, and these flowers bloom during late winter or spring. Fruit set and development follow flowering, with fruit maturity and harvest times varying with growing regions, sometimes overlapping floral initiation and bloom, sometimes not. Vegetative growth often occurs in spring, summer and autumn flushes but sometimes these flushes become indistinct.



Investment priorities
Impact 1: Floral initiation and development

Problems/Issues	Strategies	Deliverables
-Poor ability to manage carbohydrate availability and/or allocation.	Improve understanding of carbohydrate partitioning in trees and how it can affect initiation, development and quality of flowers.	New knowledge on carbohydrates to support consistent flowering, including measurement protocols and tissue carbohydrate thresholds (**M**).
Poor flowering: -Insufficient tools and knowledge to manage the impact of high crop loads and late harvesting causing poor flowering.	Investigate strategies to improve regularity of flowering under varying crop loads, including interactions with vegetative growth, timing of harvest, carbohydrate status of the tree and other signals.	New knowledge and tools to support consistent flowering (**M**), including the effects of crop load on vegetative growth, carbohydrates, hormones and other signals.
-Insufficient canopy management strategies.	Improve understanding of canopy architecture and complexity and its impact on flowering and crop production. E.g. light and production of shoots for flowering.	Canopy management strategies and principles to support consistent flowering and production (**S-M**).
	Improve understanding of pruning on subsequent flowering.	Same as above (**S-M**).

Investment time frame:
***E** = extension; **S** = short, up to 3 years; **M** = medium, 3 to 6 years; **L** = long term, more than 6 years*



Investment priorities
Impact 2: Pollination and fruit set

Problems/Issues	Strategies	Deliverables
Poor flower quality leading to poor fruit set: –Beyond the role of carbohydrate and Boron, there is little understanding of what determines flower quality –Unknown effect of flowering intensity on flower quality –Limited understanding of flower quality at grower level.	Investigate opportunities to manipulate carbohydrate partitioning to improve flower quality, including manipulating flowering intensity.	Understanding of desired carbohydrate levels in flowers and management options to influence this (e.g. via crop load management)
	Develop understanding of what makes a good pollen grain • Attractiveness • Viability • Likely to produce strong fruit	Definition of desirable traits for pollen and management options to influence it (**S–M**).
Negative effect of cool and hot temperatures at flowering. The impact of temperatures at flowering are well understood but there is a lack of tools to manage it.	Investigate the possibility of increasing the length of time flower pistils are viable.	Understanding and management tools to increase flower pistil viability, if possible (**S–M**).
	Investigate options to modify orchard microclimate, including cover crops or other methods.	Understanding of the changes to orchard microclimate achieved through different options (**S–M**).
Insufficient understanding of the impact of pollenisers on productivity and profitability.	Investigate productivity and profitability aspects of polleniser distribution and the best cultivars for each region.	Quantitative understanding of the productivity and profitability impacts of pollenisers (**E,S**).
	Encourage documentation and sharing of local pollination events in relation to climate (e.g. VPD).	Extension of industry standard methods to document pollination events (**E**).
Sub optimal pollen transfer.	Investigate factors affecting nectar and pollen attractiveness and how to influence it.	Understanding and management tools to influence avocado flower attractiveness (**M**).
	Investigate ideal pollinator stocking rates per hectare and ideal hive distributions.	Decision tools on when and how many hives to introduce (**S – M**).
	Investigate options to attract alternate pollinators, including cover crops to promote a habitat and food source.	Understanding and management guidelines on options to increase pollinator diversity for improved pollination, including regional understanding on floral competition and supporting plants (**S – M**).
	Investigate artificial methods of pollination or transfer of cross-pollen.	Proof of concept of artificial pollination/pollen transfer methods in avocado orchards (**S–M**).

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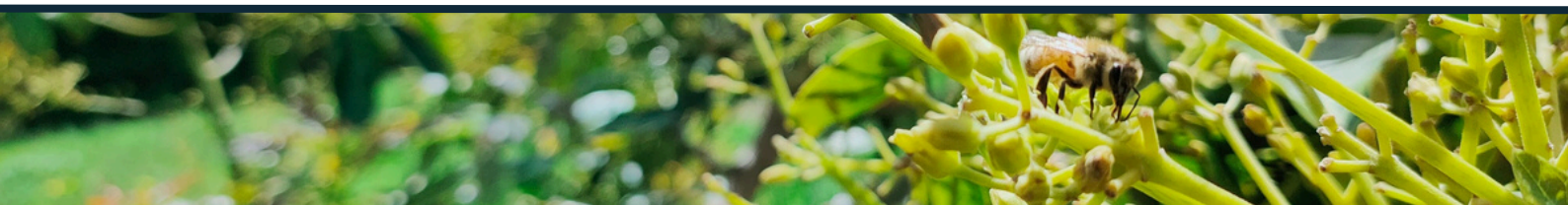

Investment priorities
Impact 3: Fruit development and retention

Problems/Issues	Strategies	Deliverables
Limited ability to manage fruit retention and development: –Lack of understanding of the relationships between flowering, fruit set and abscission (crop load development cycle).	Develop understanding of reproductive development and the crop load development cycle in different growing regions.	New knowledge on reproductive development (**S**). Foundation for pathway to manage crop load through various methods (**S–M**).
–Lack of tools to manage abscission.	Investigate new tools to manage abscission (e.g. PGR management of abscission currently underway in AV23000).	Management tools developed through AV23000 and beyond (**M–L**).
–Lack of understanding of carbohydrate partitioning, signalling and storage across the phenological cycle.	Develop understanding of these cycles across different growing regions and their relationship with fruit development.	New knowledge and pathway for management of carbohydrates for improved and consistent production (**M–L**).
–When carbohydrate benchmarks are developed, a rapid carbohydrate measurement tool would be needed.	Develop a rapid, scalable, non–destructive carbohydrate measurement method to quantify partitioning of carbohydrates (progress toward this in AV19006).	Carbohydrate measurement method – a tool for management and research (**M**).
–Unknown yield potential (carrying capacity) for each region. Varied grower and regional expectations.	Determine sustainable yield potential/carrying capacities for different growing regions that do not lead to alternation of bearing. Understanding of the physiology underlying regional differences may lead to management strategies to improve yield and consistency.	Sustainable yield potentials (crop loads) identified for differing growing regions, along with an understanding of differences in the underlying physiological drivers of productivity.
Considerable yield variation and production problems with 'Hass'.	Undertake DNA–free gene editing to improve reproductive success of 'Hass'	Proof of concept (**S**). New Hass clones that exhibit more consistent production (**M**).

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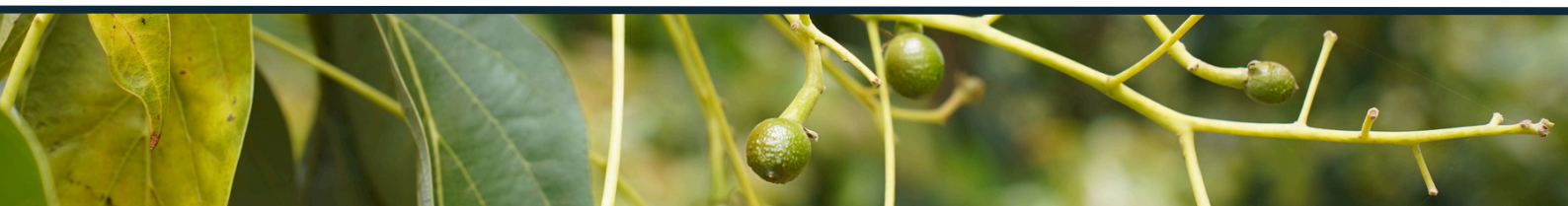

Investment priorities
Impact 4: Vegetative growth and canopies

Problems/Issues	Strategies	Deliverables
Canopy management and light environment impacts on regularity of bearing not well understood. A wide range of current pruning practices.	Develop understanding of pruning strategies for high and consistent production, potentially through better orchard light environment and canopy structures. Develop understanding of effects of canopy structure and light availability on pollinator activity.	Greater understanding of the principles of light, canopy structures and responses to pruning (**M**) Orchard light model and best management practice and solutions for rapid light measurement (**S-M**) Pruning strategies that promote balanced vegetative growth and fruiting (**S-M**)
The effect of nitrogen nutrition on vegetative growth and subsequent reproductive development is poorly understood. Grower nitrogen nutrition practices vary regionally.	Investigate the ability to use nitrogen nutrition to manipulate spring and summer flushes and subsequent floral initiation.	Greater understanding of the effect of nitrogen on the balance between vegetative and reproductive development, with a goal of leading to more consistent production (**S-M**).
	Investigate the effect of crop load on nitrogen requirements in different growing regions. A range of tools are available including isotope studies.	Updated nitrogen guidelines that consider growing environment, crop load, vegetative growth and genetics (**S-M**).
	Investigate the effect of nitrogen nutrition on competition between shoot growth and fruiting	New knowledge on factors affecting fruit to shoot competition to feed into nitrogen guidelines.
Limited ability to manipulate carbohydrate partitioning for desired balance between vegetative growth and reproductive development	Investigate methods to modify allocation of carbohydrate resources with the aim of improving productivity. E.g. PGRs, pruning techniques, nutrition, crop load manipulations.	Improved understanding of factors affecting allocation of resources and competition between sinks in avocado orchards. Improved ability to alter partitioning (**M**).
PGR potential not maximised	Further studies on PGR use strategies to optimise their use.	Updated principles for PGR usage (**S**).
Lack of understanding of leaf function over time, including across the season and during shoot development.	Investigate leaf function and photosynthetic rates, including the effect of light intensity and photoinhibition, during shoot development and as leaves age.	New knowledge on leaf function and carbohydrate production (**M**). Improved understanding of energy production by avocado trees and interactions with reproductive development (**M**).

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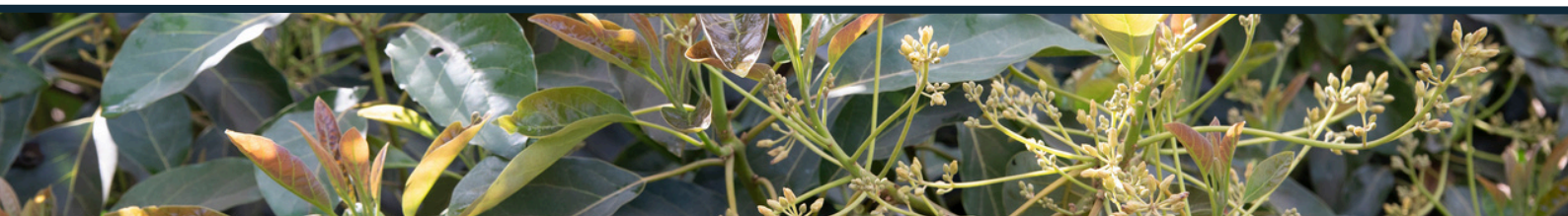

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AV23014 Project Reference Group:

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