How can we make macadamia orchards more friendly to beneficial insects?

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Summary:

- An inter row insectary consists of a diverse suite of flowering plants that are either self-seeded or purposefully and selectively planted within the inter row.
- An inter row insectary needs to be monitored and managed, however, it also requires minimal disturbance to maintain populations of beneficial arthropods (which can be done using alternate row mowing).
- An inter row insectary can be designed, with careful plant selection, to improve farm productivity, profitability and sustainability by improving both soil health and increasing the 'ready army' of beneficial insects within the orchard.

For the past 3 years, BioResources has been running a research project funded by Horticulture Innovation Australia (HIA) (project code MC16008) with in-kind contributions from BioResources Ltd and Coates Horticulture, that has provided 11 macadamia growers from mid-coast NSW up to Bundaberg QLD with the practical experience of growing and maintaining an inter row insectary. BioResources then monitored these inter row insectaries in terms of their vegetation composition and insect community composition in comparison to industry standard mown areas within these farms for 2.5 years.

Aside from the practicalities learnt about maintaining an inter row insectary in macadamia orchards, the most significant finding for this project is that insectaries in the inter-row can increase species diversity of arthropod communities and in turn create a more complex food web, benefiting the health of the macadamia orchard without any corresponding increases in pests of macadamias.

What is an inter row insectary?

An inter row insectary is a place of increased plant species diversity, with increased (year-round) floral resources, reduced physical disturbance and improved habitat complexity that provides beneficial insects with the resources and shelter to maintain healthy populations within the orchard. The presence of beneficial insects means that pest control (predation) is occurring continually in the background all the time. It is estimated that beneficial insects provide 5-10 times the pest control in agricultural ecosystems compared to chemical applications[1]

The benefits of changed inter row management for the purposes of an insectary and conservation biological control are further amplified when the potential for multiple ecosystem services are taken into consideration. While specific quantification of these services has been beyond the scope of this project, it is worth noting that managed vegetative diversity in the inter row, and other areas on-farm, can contribute to ecosystem services specific to insects including pollination, food provisioning, recycling organic matter, and other services.[2] Beyond insect services, managed vegetative diversity can improve soil structure, soil microbiology, nutrient cycling, water storage, carbon sequestration, and biodiversity, and this has been quantified in other studies.[3]

An inter row insectary can be grown in most orchards, providing there is sufficient light within the inter row for plant photosynthesis.

Strategies

There are different strategies that can be used to achieve an insectary in an orchard, and the suitability of the strategy will depend on many factors, including the maturity of trees, available light, available machinery, budget and time to manage the insectary. The most important factor for growing an inter row insectary is the willingness of the grower/manager to change existing management practices, and this can be done to different degrees.

Insectaries can be as basic as allowing the existing inter row vegetation to grow and maintain it as a '**mohawk'** down the centre of the inter row. This strategy relies on naturally present weed, grass and native plant species that are likely to establish in the absence of regular mowing. This can work well depending on the composition of the naturally present seed bank, and the willingness of the grower/manager to monitor the mohawk so as not to allow one or two plant species to dominate (this can be managed by mowing alternate row mohawks as needed).

Photo 1. Example of alternate row mowing at one of the case study orchards. This is a young orchard and unmown strips could span the majority of the inter row.

Planting seeds for insectaries and cover crops

With a bit more effort, the inter row insectary can be designed to specifically attract parasitoid wasps and pollinating insects as well as to improve soil quality with the aim of improving overall tree health. This method, based on selecting specific compositions of plant seed and either direct drilling or hand casting seed over prepared ground in the inter row, can be incorporated with existing inter row vegetation and can be done to differing degrees depending on budget and need. This type of '**cover crop**' insectary has potentially much greater benefits for overall orchard and soil health compared to a mohawk of existing inter row vegetation, however, there are often practical and logistical issues in establishing and maintaining cover crops that need to be worked through, especially in dryland situations.

Photos 2 & 3. Cover crops at one of the case study orchards - (left) emerging seedlings, (right) at maturity.

Rats, weeds, pest reservoir and harvesting nut- will inter row insectaries lead to other problems?

Rats

The idea of growing an inter row insectary can be challenging for growers who have had rat problems in the past. The industry standard close mown orchard is promoted to alleviate rat problems, however, for many growers who follow industry mowing guidelines, rats are still an issue. For growers who have rat issues, increased monitoring and targeted action is undertaken. This same systematic approach to rat management applies to growers who have increased inter row vegetation. *Managed* vegetative diversity is the key to successfully incorporating an inter row insectary into an orchard, and spot mowing and spot herbicide spraying within the inter row vegetation are additional tools that can be used if necessary.

Within the research project, the presence of an inter row insectary was not found to exacerbate rat problems on the majority of trial farms that had existing issues with rats, and by the end of the project any rat problems within insectaries had been resolved. Those growers who had initial concerns in regards to insectaries exacerbating rats within their orchard quickly gained confidence in their ability to manage rat problems if and when they emerged.

Weeds and plant dominance

Within an inter row insectary, locally present (and occasionally seeded) insectary plant species can become dominant in some situations where management of the insectary is not undertaken or left too long between monitoring. During the project, some of the participating farms who grew mohawk type insectaries from existing seed banks observed that one locally present species had become very dominant (mostly Setaria grass, Kikuyu grass, Rhodes grass, Cobbler's Pegs and Paddy's Lucerne). In all these cases, this was easily managed with either intermittent mowing/slashing or spot herbicide applications. Alternate row mowing is a good way to minimise issues with weedy species.

Pest reservoir

In this project we sampled arthropods using yellow sticky traps, which are particularly attractive to wasps, flies, thrips and some of the smaller true bugs (hemiptera). Whilst yellow sticky traps were not targeted at monitoring pest insect populations, major insect pests of macadamia were not found in the inter row vegetation. This was not unsurprising as macadamia pests are tree and nut pests as opposed to herbaceous pests. We did find small numbers of macadamia pests in the trees however there wasn't enough caught to evaluate treatment effects. Our data did validate that the aphids, leafhoppers and thrips of the herbaceous inter row are mostly different to that found the macadamia tree. For example, one of the predominant aphids in macadamia is the Black Citrus Aphid (*Toxoptera citricida*) which we did not observe in the inter row vegetation. However, we found several aphid species in the inter row which were not found in the macadamia tree, and therefore is a good food source for beneficial insects such as the larvae of lacewings and ladybeetles.

Harvesting macadamia nut

Where macadamia orchards are on sloping land, harvestable nut may roll into inter row insectaries, making it difficult to harvest. In these cases, inter row vegetation should either by reduced in width or entirely removed during the harvest period.

Main findings from project MC16008

From the 11 participating farms, four of the farms were chosen as 'case studies' to examine their results to a finer level because their experimental protocols were able to be consistently applied throughout the life of the project. The other seven farms experienced, in varying degrees, challenges that inhibited them from applying consistent experimental protocols over the life of the project (i.e. new mow/slasher operator who didn't apply/understand experimental protocols correctly, extreme weather and other environmental events). The results of these four 'case study' farms are summarised below.

Photo 4: Inter row insectary at one of the case study orchards in Bangalow, northern NSW. Row width: 10m, tree age: 18 years. Inter row insectary species here included sorghum and sunflowers.

Insect community composition

When compared with the industry standard mown areas, insectary vegetation (various degrees of mohawk and cover crop vegetation) maintained an increased abundance and diversity of arthropods (**Figure 1**) within both the inter row vegetation and macadamia tree throughout the project life. In this project we proposed that as management decisions are iteratively developed and improved for the macadamia inter row insectary, the abundance and diversity of beneficial arthropod populations will increase, while the food web will become more ecologically complex and self-regulating for conservation biological control and other ecosystem services.[4]

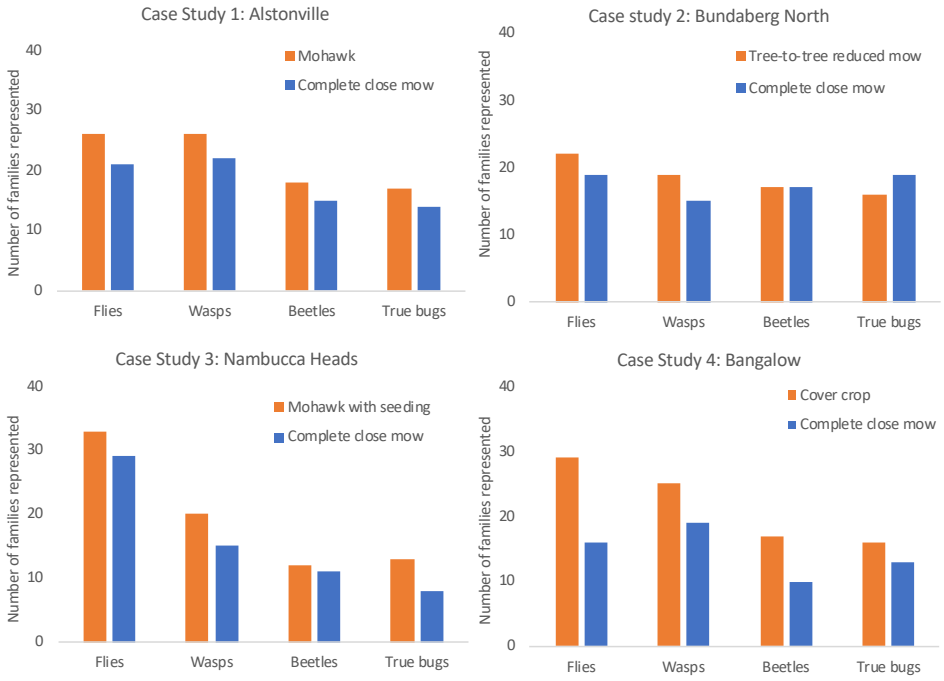
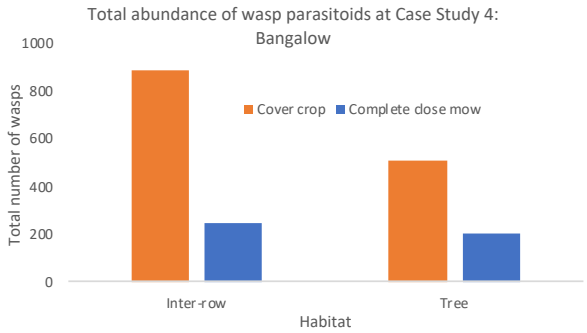


Figure 1. Comparison of insect diversity between control (complete close mow or 'industry standard') and insectary treatments at the four case study farms, using the commonly identified insect groups (flies, wasps, beetles and true bugs). Diversity is measured as a function of the number of insect families (taxa) identified.

Where insectaries were present, arthropods were proportionally higher in predators and parasitoids compared to arthropods within industry standard mown areas of the crop (see **Figures 3 & 4**). Higher trophic levels such as predators and parasitoids are more sensitive to changes in the environment by virtue of being dependant on lower trophic groups, hence they are more adversely affected by intense inter row management than, for example, herbivorous insects.



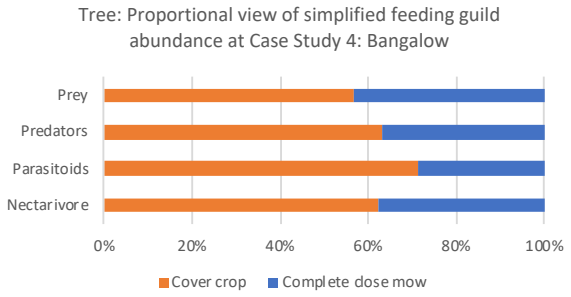


Figure 2 (left). Comparison of the total abundance of wasp parasitoids in both inter row and tree at Case Study 4 with respect to control (complete close mow or 'industry standard') and insectary treatment (cover crop) areas of the orchard.
Figure 3 (right). Proportional view of simplified feeding guilds in the tree at Case Study 4 with respect to control (complete close mow or 'industry standard') and insectary treatment (cover crop) areas of the orchard.

Industry standard mown areas within the orchard were more prone to spikes in populations of thrips within the macadamia trees when compared with insectary areas of the orchard (**Figure 5**). This instability in lower trophic level arthropods such as thrips in areas without inter row insectary vegetation relates to the higher frequency in disruption to the inter row areas via more frequent mowing, as well as having less resources necessary to maintain stable populations of predatory and parasitic arthropods.

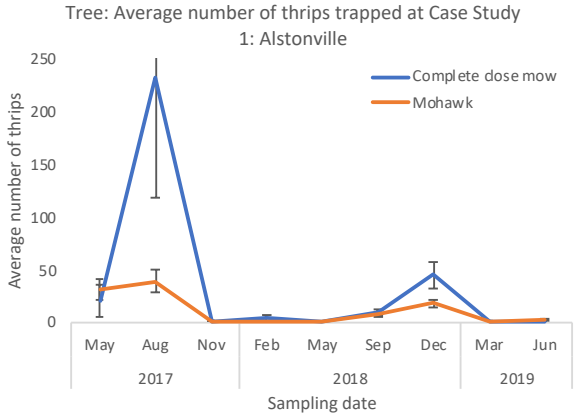


Figure 5. The relative average abundance of thrips within trees (± standard error) at Case Study 1 with respect to control (complete close mow or 'industry standard') and insectary treatment (mohawk) areas over the entire sampling period.

These important findings from project MC16008 relate closely to the food web theory, which considers trophic interactions among species (who eats who). Where there is an increase in biodiversity, and hence an increase in complexity within the food web, this results in a more stable and better functioning ecosystem with multiple services such a pollination, natural pest suppression and even nutrient cycling in the soil.

This project was in-field for a total of 2.25 years for the mohawk, tree-to-tree no mow, and mohawk with seeding case studies; and 1 year for the cover cropping case study. Similar studies find that improvements in arthropod abundance and diversity using insectaries for the purposes of conservation biological control are best understood as cumulative and as developing trends through time. Given the lack of macadamia pests in the inter row at all case study farms, we suspect that inter row vegetation might offer some protection for prey and beneficial arthropod diversity in the event that chemical controls in the crop are needed, allowing populations of beneficial arthropods to quickly re-establish. It would be pertinent for future studies to address this.

What is next in terms of research for BioResources?

Two new projects, funded by The National Landcare Program- Smart Farms Small Grants, are underway that will lead on from this initial work on inter row management in macadamia orchards. One project will focus on the common 'dark orchard' scenario in northern NSW, where one 'best-practice' grower is mid-way through rehabilitating his dark orchard by removing rows and planting inter row cover crops. BioResources will document this process and deliver it to macadamia growers via extension activities as a means of increasing their capacity

to practice similar techniques. The second project in Bundaberg focuses on new orchard development and the decisions required in relation to cover cropping and insect pest management utilising a more ecologically sound approach. These two projects will provide a 'how-to' in terms of setting up inter row insectaries and will help work through the various issues that are likely to arise during the process.

See the BioResources website for Inter row management Project Reports as well as links to sites of interest:
http://www.bioresources.com.au/inter_row_project/index.html (homepage)
http://www.bioresources.com.au/inter_row_project/publications.html (reports and links)
http://www.bioresources.com.au/inter_row_project/seedstoplant.html (list of seeds and their uses)
http://www.bioresources.com.au/inter_row_project/directseeders.html (direct drill seeding)

The following table provides options of methods for establishing inter row insectaries within an orchard. These options are neither extensive nor exclusive and combinations of options may be used within the one orchard. For example, alternative row mowing (at a reduced rate) can be used in conjunction with cover cropping or mohawk insectaries so as to provide a place of reduced disturbance for insects.

MOW OPTION	DESCRIPTION
MOHAWK	*Reduced mowing leaves a central mohawk strip down the row, with more regular mowing under the drip-line of the trees.*
	A mohawk can be retained year-round, including throughout harvest. Row width of minimum 10m. Mohawk strip width to be calibrated against width of harvester, slasher and mower.
ALTERNATE ROW MOW	*Mow every second row on a rotating schedule, allowing all rows to "grow out" somewhat across the year and all rows to be mowed alternately, outside of harvest.*
	This approach provides opportunities to more regularly encourage rejuvenation and flowering of vegetation in the inter row while managing dominant vegetation and areas of potential rat activity. A good option for young tree blocks where there is very limited ongoing access and management. It is also a good option where row width less than 10m and during non-harvest.
REDUCED MOWING WITH SEEDING	*Decide on a preferred reduced mowing strategy. Incorporate seeding into the inter row to improve vegetative diversity.*
	Intermittent seeding with seed mixes suitable specifically for the macadamia inter row to improve quality of the insectary and other ecosystem services.
COVER CROPPING	*Intensive management of the inter row with cover crops that improve multiple ecosystem services including insect pest suppression and crop pollination, nutrient cycling and soil health, carbon sequestration, and water and erosion control.*
	This is a dedicated system and detailed recommendations are beyond the scope of this project. Further information with be available from Bioresources in 2020-21.

	A valuable management approach for new blocks, young tree blocks, and blocks where row removal is underway. Also suitable in mature orchards where row width is greater than 10m and good light is available.

Table 1: Inter row insectary options – mohawk, alternate row mow, reduced mowing with seeding, and cover cropping.

References

1. Pimentel D., Stachow U., Takacs D. A. *et al.* Conserving biological diversity in agricultural/forestry systems. *Bioscience* **42**, 354–362 (1992).
2. Noriega, J. A. *et al.* Research trends in ecosystem services provided by insects. *Basic Appl. Ecol.* (2018).
3. Hillemann, P. Prairie strips transform farmland conservation. *Science Daily* (2019)
4. Herz, A. *et al.* Managing Floral Resources in Apple Orchards for Pest Control: Ideas, Experiences and Future Directions. *Insects* **10**, 1–24 (2019)