Final Report

"Bevan & Willemse" – Macadamia Inter-row Trial Results

Hort Innovation program title: The IPM program for the macadamia industry – BioResources

Hort Innovation project code: MC16008

Date: February 2020

Summary

This project investigates the potential for the development of insectaries through vegetation changes in the inter-row via reduced mowing. Adoption of reduced mowing where possible is expected to increase the abundance and diversity of beneficial arthropods by creating more complex food-webs that are vital to pollination and pest suppression. Our aim is to optimise macadamia orchards for the self-regulation of pests by supporting beneficial arthropods with shelter, breeding areas, nectar, alternative hosts/prey and pollen.

You worked with the BioResources team to investigate these ideas from early 2017 to mid 2019.

Your reduced mowing trial has provided several useful insights into the practicalities of reduced mow options in macadamia orchards and especially the mohawk. Industry has been particularly concerned that reduced mowing of the inter-row may lead to significant problems such as increased rat activity, invasive weeds and/or increased insect pests. Your trial gives other growers reassurance that a mohawk can be incorporated into existing orchard inter-row management and with basic monitoring and management will not lead to other problems.

The most significant benefits to having a mohawk vegetation inter-row on your farm is an increase in species richness (diversity) of arthropod communities particularly those that benefit the health of your macadamia orchard. The most distinct trend we observed overall was double the number of parasitoids and predators in the block where there was mohawk vegetation. In comparison the block with no mohawk had lower diversity of arthropods and higher presence of herbivorous insects such as thrips which were three times more numerous in the macadamia trees. Predators and parasitoids are ecosystem regulators providing virtually free pest control. The increase of predators and parasitoids on your farm is providing an economic benefit in terms reduced pest control inputs but also may be increasing other ecosystem services such as pollination via flies, wasps and beetles, leading to enhanced productivity overall.

The results for your trial are likely to be enhanced farm-wide and into the future where you can maintain a commitment to insectaries throughout your entire orchard. You have developed your own innovative strategies for harvesting and inter-row management, which are compatible with standard orchard operations while allowing retention of some vegetation year-round. Your farm enjoys an unusually diverse mix of naturalised weeds and natives in the inter-row with desirable characteristics for an insectary and that are also reasonably easily managed for weediness. You can consider some seeding with cover crops if you wish to use their features for more targeted benefits from the inter-row including improved seasonally-specific resources for pollinators and parasitoids, along with other ecosystem services (see below).

The BioResources team encourages you to read the final report for the *Macadamia IPDM Program - Inter-row Project (MC16008)*, which is available via *Hort Innovation*. Here you will find out more on the benefits of insectaries for macadamia orchards and also the experiences of other trial farms in implementing and managing insectaries. There is also an exploration of the multiple ecosystem services known to flow from reduced mow inter-row management practices along with improved arthropod biodiversity, including benefits for soil organic matter, nutrient cycling, water management, erosion control, weed suppression, soil carbon storage, soil microbiology and more.

Introduction

This project proposes that reduced mowing in the macadamia inter-row may increase vegetative diversity, increase floral resources and reduce habitat disturbance. This may in turn increase the presence of beneficial arthropods in the orchard. More broadly, the proposed changes in plant ecology may increase arthropod populations in general, leading to more complex food webs and better orchard self-regulation of economic pests. Furthermore, this enhanced nutritional food-web will benefit birds and micro-bats, which also have a role in pollination and pest suppression. In comparison it is estimated that beneficial insects provide 5-10 times the pest control in agricultural ecosystems compared to chemical applications[1], as these processes are occurring all the time. By encouraging more diverse ecosystems within the orchard the likelihood and/or intensity of pest outbreaks decreases.

You worked with the BioResources team in this investigation from early 2017 to mid 2019. We compared two (approximately) 1 Ha blocks. A control block was managed as industry standard with regular mowing (**Photo 1**, below). A treatment block was managed with reduced mowing, sustaining a centre mohawk for most of the trial period (**Photo 2**, below).

Photo 1: "Bevan & Willemse" complete close mow 1 May 2017

Photo 2: "Bevan & Willemse" mohawk 1 May 2017

As you will recall, with each site visit the BioResources team sampled each block for arthropods in three separate rows using yellow stick traps (YSTs), placing one YST in the inter-row and one YST in a tree. We assessed the vegetation in the inter-row at those three points (a quadrant of approximately 10m x 20m). The three data collection points were at least 30m apart and 50m from any block edge. We also spent time with you discussing the trial and any observations that you may have made in relation to rats, weeds, insect pests in the inter-row vegetation and/or any challenges with reduced mowing.

The objective of the trial has been to provide growers with practical experience in reduced mowing options on-farm with monitoring to quantify results.

BioResources first worked with growers to consider practical options for reduced mowing that are compatible with the seasonal demands of orchard management. It has then sought to provide information on any relationship between reduced mowing and the potential for increased rat, invasive weed and/or arthropod pest presence. Finally, the trial has sought to monitor association between changes in inter-row vegetation management and changes in orchard beneficial/pest arthropod ecology.

[1] Pimentel, D., Stachow, U., Takacs, D.A., Brubaker, H.W., Dumas, A.R., Meaney, J.J., Onsi, D.E., Corzilius, D.B., 1992. Conserving biological diversity in agricultural/forestry systems. BioScience 42, 354-362.

Reduced mowing in the inter-rowat "Bevan & Willemse"

Reduced mowing and potential problems

	Throughout the trial, BioResources regularly monitored for and consulted with Jenny and Bob Willemse, on the following issues:
Rats	The project team did observe evidence of rat activity in the mohawk during one site visit. This was quite late in the life of the trial. You reported the same observations. Alternate row mowing was organised in response to enable monitoring and management and discourage the rats from continued digging of nests in the area. No further problems were reported after this.
Problem weeds	The project team did observe a potentially "woody weed" in the mohawk during one site visit. This was Paddy's Lucerne. You reported the same observations and it was decided to spot slash and spot spray this weed. No further problems were reported.
Major insect pests of macadamias	The project team monitored vegetation in the inter-row for the presence of major macadamia pests including Macadamia Seed Weevil, Macadamia Nut Borer, Green Veggie Bug and Fruit Spotting Bug. Plant species typically found in the inter-row trial blocks at your farm were not observed to host these pests. You did not report observations of insect pests in the inter-row vegetation.
Management of the inter row	No issues were observed by the project team during site visits. No issues were reported by you. A number of different machinery options were available for slashing and harvesting, which suited straightforward inclusion of a mohawk in the trial block year-round.

Outcomes

Your trial has provided several useful insights into the practicalities of reduced mow options in macadamia orchards and especially the mohawk. Industry has been especially concerned that reduced mowing of the inter-row may lead to significant problems with increased rat activity, invasive weeds and/or insect pests. Your trial gives other growers reassurance that a mohawk can be incorporated into existing orchard inter-row management and with basic monitoring and management will not lead to other problems.

Management of your trial blocks for the life of your trial was very strong and consistent. Furthermore, your inter-row management practices can be defined as "best practice" in both the complete close mow block (which is the current industry standard) and the mohawk block (which is a new proposed industry alternative). Unlike several of our other trial farms, your trial blocks were not adversely impacted by extreme weather or environmental events. For this reason, the results from your trial are especially robust.

The most profound change we observed in arthropod assemblages was double the number of predators and parasitoids in the mohawk block vs the complete close mow block. We also found a moderate increase in nectivorous (pollinator) insects such as flies, wasps and beetles, in the mohawk block. Furthermore, there was a higher diversity (species richness) of arthropods in the mohawk block with overall increase of approximately 30% in the amount of arthropod families represented. In comparison the block with no mohawk had lower diversity of arthropods and higher presence of herbivorous insects such as thrips which were three times more numerous in the macadamia trees.

Proportionally there was more food (prey) available for beneficial insects in the mohawk block and subsequently we observed more predators and parasitoids. This was more pronounced in the inter-row than in the macadamia trees.

Whilst thrips have not been an economic issue for your farm, we did find in the macadamia trees of the complete close mow block that there were three times as many thrips. Although the data on egg parasitoids is potentially confounded by releases of *Trichogrammatoidea cryptophlebiae* (MacTrix), we did record an increase in the presence of egg parasitoids in the mohawk row block. Subsequently this modestly increased egg parasitoid presence/visitation in the macadamia trees.

For an overview of the potential for inter-row insectaries in macadamia orchards, the BioResources team urges you to read the project’s final report, *Macadamia IPDM Program - Inter-rowProject (MC16008),* which will be available via *Hort Innovation*.

Results of reduced mowing in the inter-row

Vegetative diversity

Vegetative diversity refers to the number of plant species present. Changes to regular mowing can change plant species diversity. This can in turn be associated with diversity of arthropod species. **Chart 1** presents an average count of plant species observed in the inter-row by treatment through time.

In this trial we anticipated that reduced mowing will increase the number of plant species present in the orchard. As we can see in **Chart 1**, this is consistently the case for the life of your trial, where reduced mowing and the retention of a mohawk result in an inter-row with more plant species. This can be characterised as an area with "managed vegetative diversity".

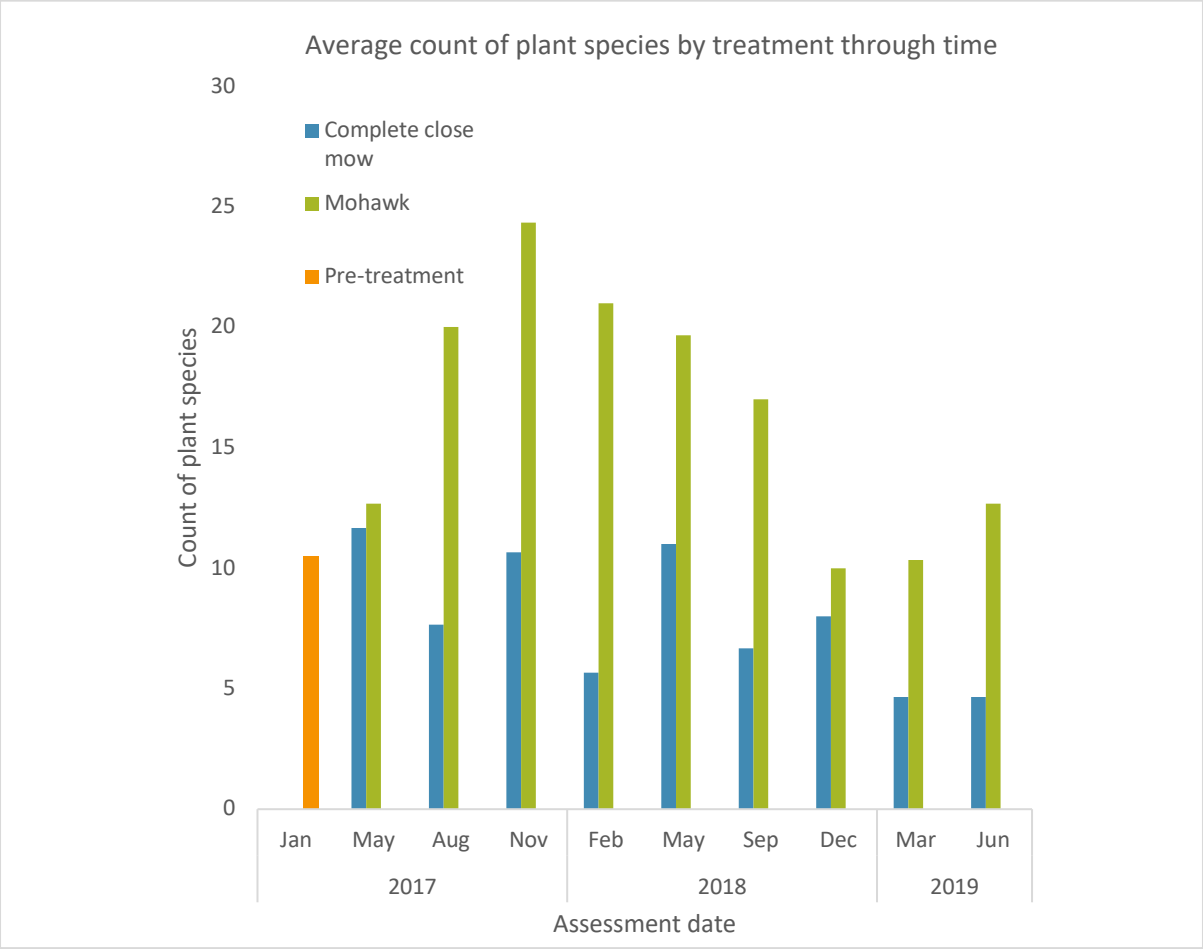

Chart 1: Average count of plant species by treatment through time. This is an average of counts taken at the three assessment points on each block.

Floral resources

Floral resources provide a food source for many beneficial arthropods and will encourage them to remain active in the orchard. **Chart 2** provides an average count of the plant species flowering at the time of the site visit. There were always flowering plant species in the mohawk block. In conjunction with this, we also see that these flowering species always produced a larger volume of flowers as a percent of biomass in the mohawk block as compared to the complete close mow block (**Chart 3**). These results are a

consequence of the mix of "naturalised weed" species present in the trial block, which demonstrate a number of favourable characteristics for plants in an insectary. By contrast, the complete close mow block could sustain only occasional and very limited floral resources (**Charts 2 and 3**).

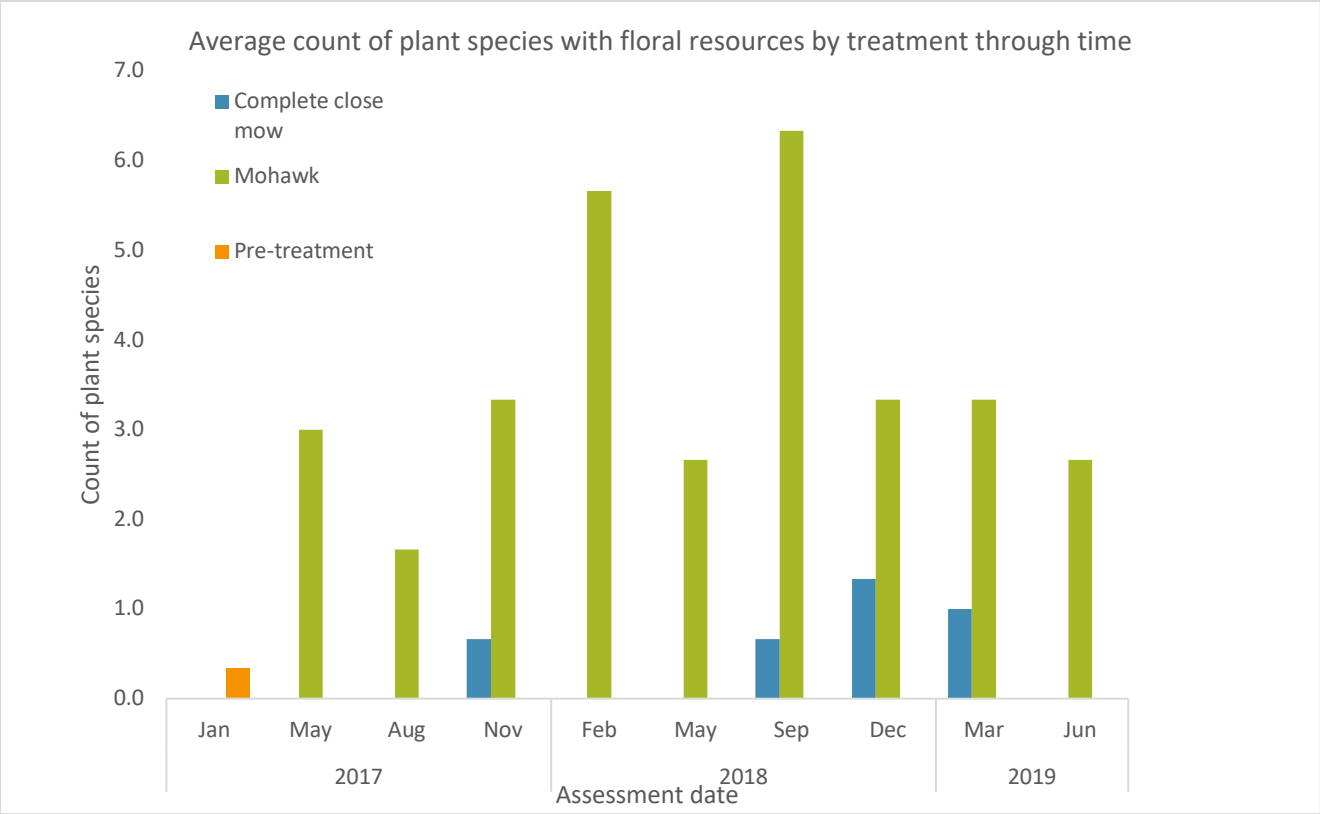

Chart 2: Average count of plant species with floral resources by treatment through time. This is an average of counts taken at the three assessment points on each block.

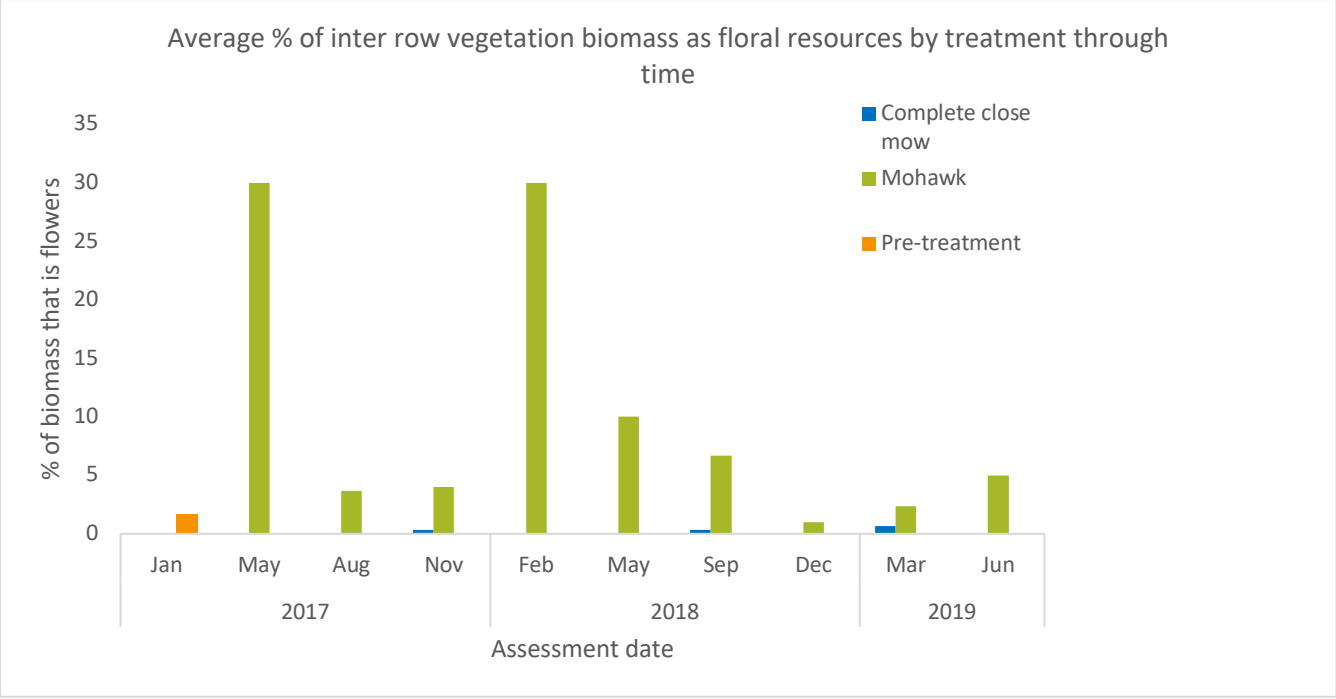

Chart 3: Average percentage of inter-rowvegetation biomass as floral resources by treatment through time. This is an average of counts taken at the three assessment points on each block.

Habitat disturbance

Areas of reduced mechanical and chemical disturbance can serve as favourable habitat for beneficial insects. Undisturbed areas may also provide a refuge for beneficial arthropods for faster recovery after spraying. The measurement of height provides a good indication of rates of mechanical disturbance. **Chart 4** reports the height in centimetres (cm) of vegetation in the inter-row by treatment through time. Retention of a central mohawk on your farm allowed for greater height of vegetation, and hence less disturbance in the inter-row for the life of the trial. By contrast, the complete close mow block was regularly and heavily disturbed.

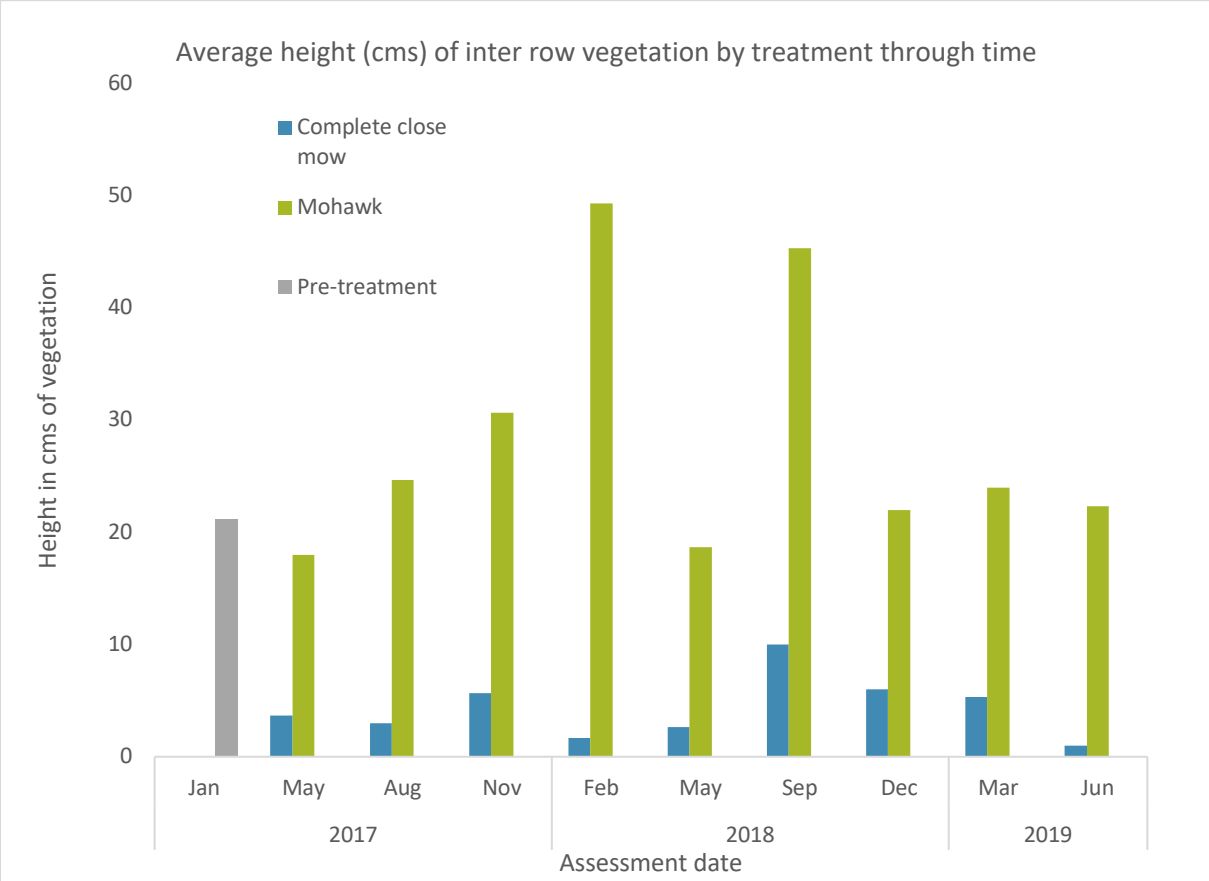

Chart 4: Average height (cm) of inter-row vegetation by treatment through time. This is an average of counts taken at the three assessment points on each block.

Results of arthropod evaluation

General arthropod abundance

From January 2017 to June 2019 we conducted 10 arthropod assessments (1 approximately every 3 months). In total, we collected and identified 10,553 arthropods using yellow sticky traps (YSTs). YSTs best capture flying insects such as flies, true bugs (including aphids), wasps and thrips. However non-flying insects and those not attracted to yellow are seldom caught (e.g. ants and spiders for instance). In **Chart 5** we have collated all the arthropods over the sampling period into broad order level classification. Both flies and wasps were more abundant in the mohawk treatment block than in the complete close mow block**.** Wasps were twice as likely to occur in the mohawk compared to the complete close mow block. Comparatively there are more thrips in the complete close mow block.

To examine more closely these broad arthropod order groupings, we identified the main arthropod groups (except thrips) to family level. We identified 4748 specimens of flies (Diptera) on your farm, comprising of 30 families out of 111 found in all Australian environments. Most adult flies require only nectar or pollen as their primary food source and only recently have flies been recognised in their importance as pollinators. As more fly behaviour observations are studied it is likely we will better understand their specific roles in pollination better. As part of a wider food web they are also important food source for beneficial insects such as spiders and vertebrate animals.

We identified 2133 specimens of wasps (Hymenoptera) on your farm, comprising of 28 families out of 77 families found in Australia, almost all of which were parasitoids. Consequently, your farm can be considered to have good biological diversity of this group.

In the complete close mow, we found nearly three times more thrips caught on the YSTs than in the mohawk (**Chart 5**). In the mohawk an even number of thrips were found in the row and trees (326 & 312 thrips respectively), as compared to the complete close mow area (617 & 945 thrips respectively). This three-fold increase of thrips in the trees could be further investigated as close mowing seems to have increased thrips in the trees and row compared to the mohawk block on your farm. It should be noted however, given the ubiquitous nature of this group, large numbers of thrips can be caught on individual YSTs traps leading to biases in population estimates. In theory given the increase in predators and parasitoids in the mohawk block we can hypothesize that this may help decrease thrip populations in macadamia trees on your farm.

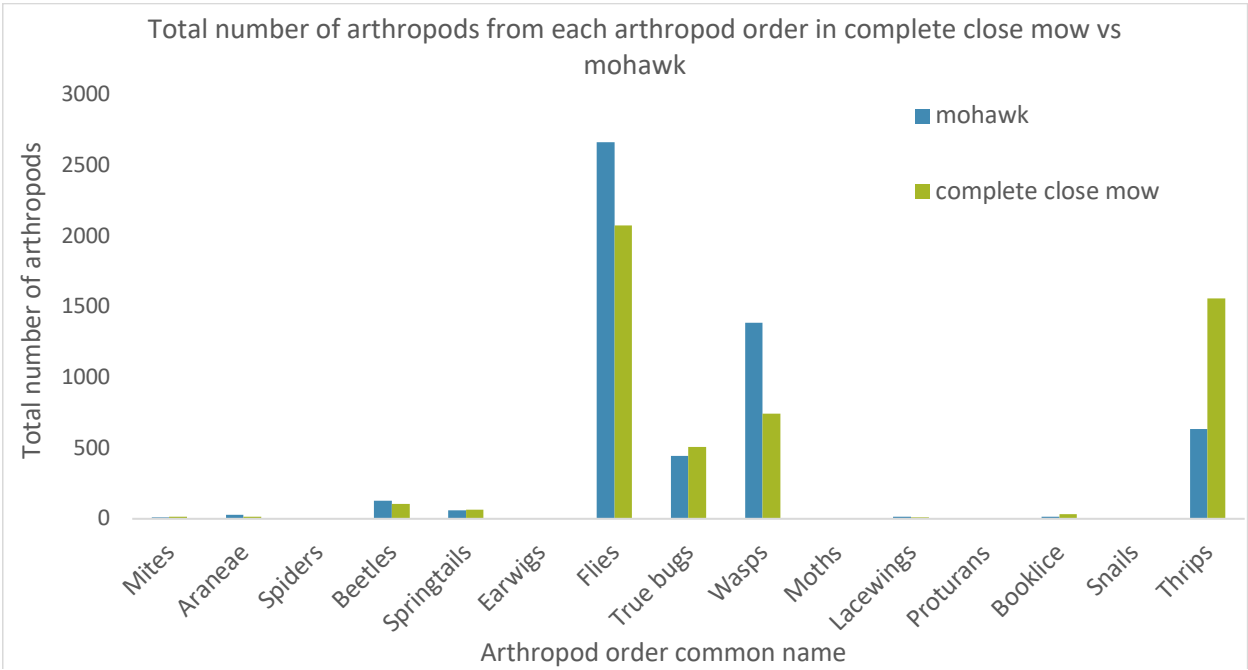

Chart 5: Total number of arthropods in order grouping caught in YSTs from January 2017 to June 2019 on Bevan and Willemse's farm comparing mohawk and complete close mow treatments.

Overall insect abundance was higher in the mohawk than in the complete close mow in both the row and tree, except for in 2017 in the macadamia tree, when thrips dominated the complete close mow samples (**Chart 6**).

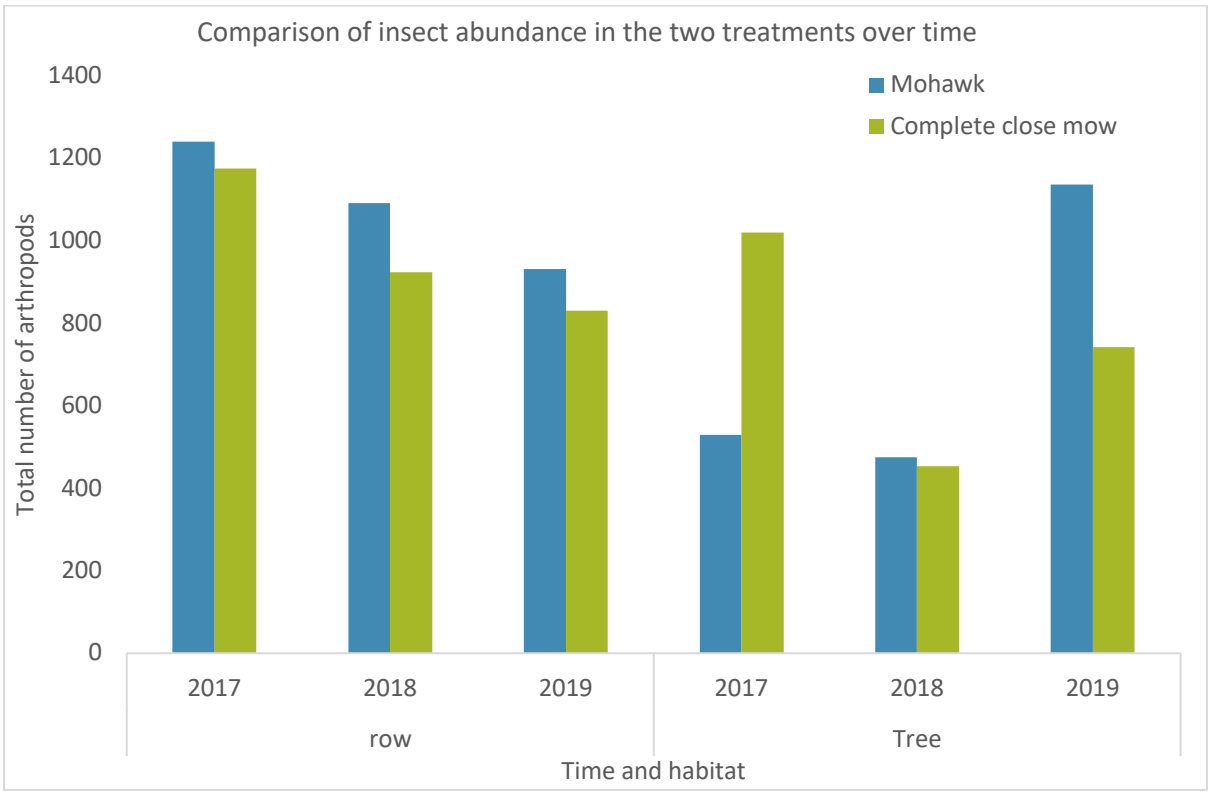

Chart 6: Number of arthropods identified on YSTs comparing treatments across time in the row and tree

Feeding Guilds

To better understand the nature of food webs on macadamia farms we have identified most insect species to family level classification, allowing us to determine the feeding guild structure of insect assemblages. The guild concept has been widely utilised by ecologists; a guild is any group of species that exploit the same resources. For instance, most insect herbivores are selective feeders, they may be specialised as leaf chewers, sap suckers, stem borers, root borers, gall formers, leaf miners etc. Beneficial insects feed as predators and parasitoids. Other important arthropod feeding groups are pollinators via nectar feeding (nectarivores). This is a good way of examining species richness and how it relates overall to farm food webs.

On your farm the mohawk block had comparatively greater number of nectarivores (primary food source - flower nectar) and twice as many predators and parasitoids when compared to the complete close mow block (**Chart 7**). Detritivores (which feed on dead plant and animal material) were almost double in number as well. However, in the close mow block, sap suckers (mainly thrips) were double as abundant when compared with the mohawk block. Other groups were less numerous as they are not as well represented by YSTs collection methods.

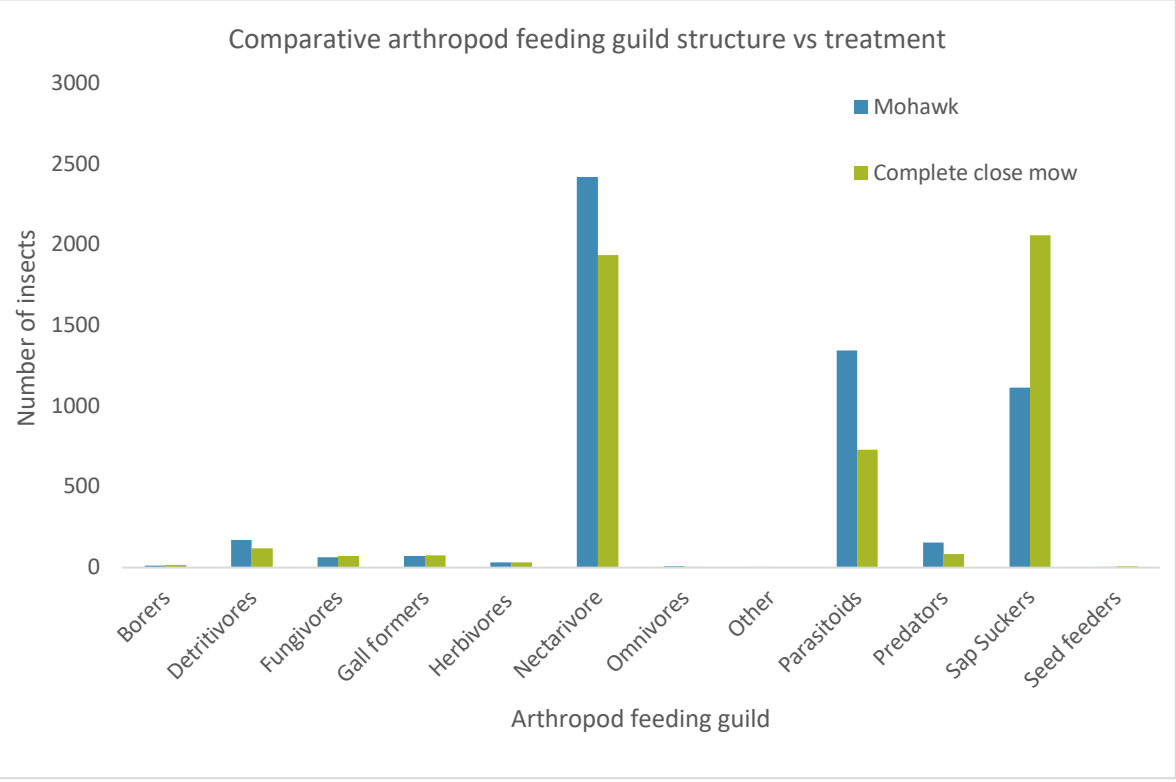

Chart 7: The number of insects and their respective insect assemblages (feeding guilds) caught on YSTs from January 2017 to May 2019.

To simplify our results, by classifying all insects as prey and then separating nectivores (potential pollinators), predators and parasitoids, as four broad categories, we can compare treatments comparatively in proportions. By combining tree and inter-row abundance counts between mohawk and complete mow treatments (**Chart 8**), there is a greater proportion of prey in the mohawk (57%). The proportion of predators and parasitoids in the mohawk block is far greater (63%) than in the complete

close mow block (37%). Nectivores are only modestly greater in the mohawk (55%) compared to the complete close mow block (45%).

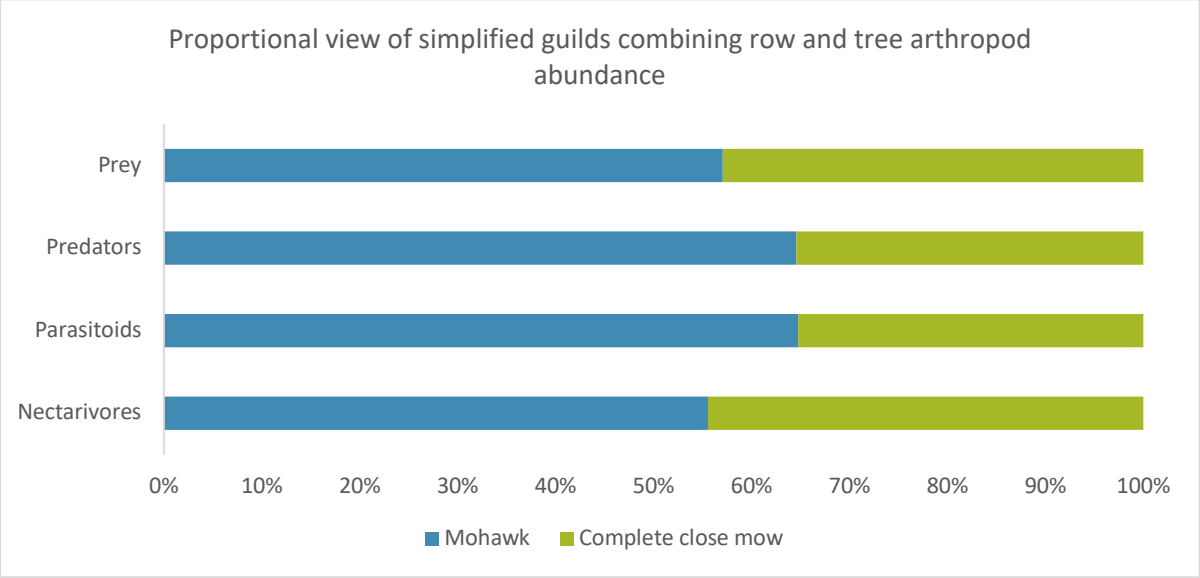

Chart 8: Representation of simplified feeding guilds in macadamia tree and inter-row habitats combining all abundance data.

When we examine this ratio comparing the row habitat in mohawk and complete close mow (**Chart 9**), nectarivores have similar proportions (51% and 49% respectively). There is however proportionally greater abundance of prey in the mohawk (56%). This may account for the greater proportions of predators (65%) and parasitoids (67%) in the mohawk compared to the complete close mow block.

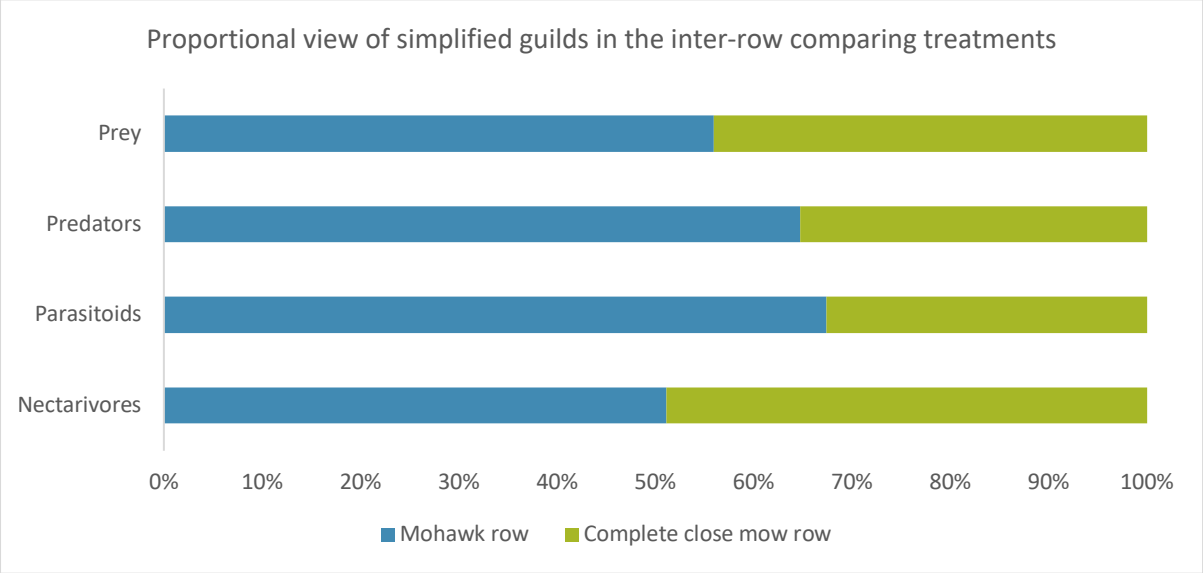

Chart 9: Representation of simplified feeding guilds in the inter-row comparing the mohawk and complete close mow treatments.

In the macadamia tree we found a higher proportion of all broad feeding guild groups in the mohawk (Chart 10). The prey ratio in the mohawk was 59% to that of the complete close mow (39%), and this was similar for the nectivores. In the mohawk predators and parasitoids had higher proportional ratios (64% & 56% respectively).

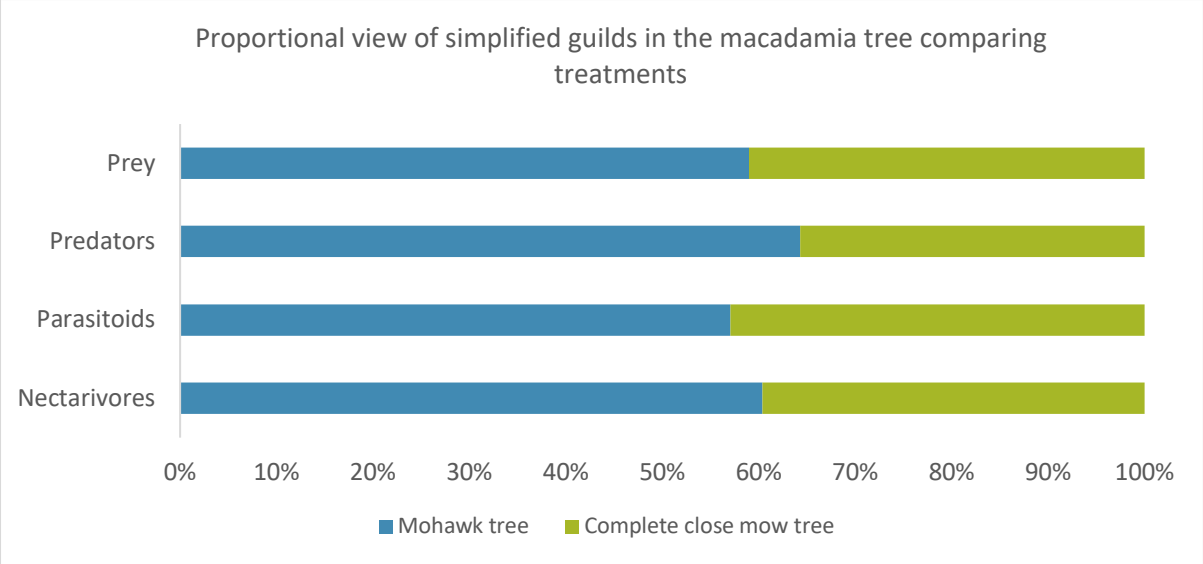

Chart 10: Representation of simplified feeding guilds in macadamia trees comparing mohawk and complete close mow treatments

Pollination

In many ecosystems, including agricultural ones, flies are very important pollinators. Of the 150 families of flies worldwide, almost half, 71, have been shown to feed from flowers (mainly nectar) and thus in principle transmit pollen from one plant to another. This is currently an expanding area of behavioural research as we discover more about their pollinating abilities. A famous example is that we would be a world without chocolate without pollination by the chocolate midge (family Certopogonidae). Of the fly families that dominate the nectarivores on your farm, they are from three main families: the Sciarids (fungus gnats), Chironomids (non-biting midges), and to a lesser extent Phorids (scuttle flies). Some Sciarid species are known to be pollinators however they are generally poorly studied in Australia, as they are particularly difficult to observe in the field, and thus their roles as pollinators are probably not fully appreciated. However, they are one of the most numerous specimens caught on YSTs on your farm. In certain environments like the artic, Chironomids are the most important pollinators of plants. Phorids are a very diverse family and many are important pollinators particularly in forest habitats. The most numerous Phorid genus on your farm was *Megaselia* which has over 1500 species worldwide. Some Phorids species are also known to be aphid predators. Phorid species have also been identified in northern NSW that parasitise macadamia seed weevil and fruit spotting bug.

The detritivores were substantially more dominant in the mohawk (**Chart 11**). They consist of the fly families Calliphoridae, Ephydridae, Psychodidae and Muscids. They are important for the recycling of nutrients back into the soil, as they feed on dead leaves, twigs and subsequent decaying mould.

The mohawk also had a greater number of predatory flies, mostly Dolichopodidae (long legged flies) and other families included Asilidae (Robber flies), Micropezidae (stilt legged flies) and Syrphids (hoverflies). Hover flies are second only to solitary bees in their value as commercial pollinators worldwide. Phorids where not collectively placed in the predatory guild as they are very diverse and occupy various feeding guilds as adults and larvae including scavengers, predators, herbivores, fungivores, parasitoids, and true parasites.

Fly parasitoids were absent from the complete close mow macadamia trees and in small number in the row. However, parasitoids were more abundant in the mohawk and at greater numbers in the adjacent trees than the row of the close mow block (**Chart 11**). A similar pattern was revealed in the fungivore guild. There was an increase in dipteran gall formers (family Cecidomyiidae) in the mohawk trees compared to the close mow trees (**Chart 11**). Overall, there was a greater diversity of family level flies and their feeding guilds in the mohawk trees.

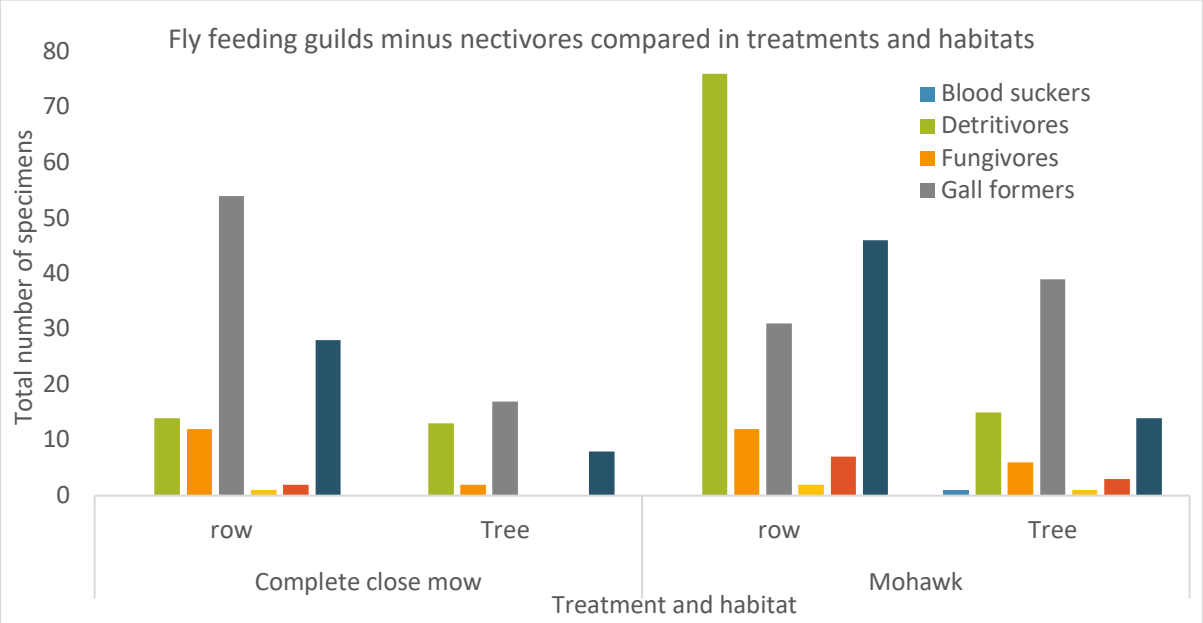

Chart 11: Dipteran (fly) feeding guilds with nectivores removed demonstrating smaller guild structure in mow treatments in the row and trees.

Parasitoids

One of the main treatment differences on your farm was a substantial increase in wasp parasitoids in the mohawk block compared to the complete close mow block in the three years of combined abundance data (**Chart 12**). When we examined differences between the row and tree, we found that there were less differences in parasitoid abundance in the tree, although mohawk trees had somewhat higher numbers.

The main parasitoid differences were recorded in the row, which had three times higher parasitoid abundance in the mohawk in the 2017 seasons and double as many parasitoids in 2019. If we examine more closely the families represented (**Chart 13**) we find that the mohawk has significantly more Chalcidoidea[2], Encyrtidae and Eulophidae. Chalcidoidea are very important in biological control of herbivorous crop pests because they are predominantly parasitoids of lepidoptera, aphids and beetles. Many other families were also better represented in the mohawk, with only the Diapriidae (parasitoids of flies) twice as high in the close mow treatment. Groups like the Ichneumonoids however, were four times more abundant in the mohawk macadamia trees. The Ichneumonoids are large wasps that commonly parasitise the larvae and pupae of Coleoptera (beetles), Hymenoptera (bees & wasps), and Lepidoptera (moths & butterflies) and they play an essential role in most ecosystems. Ichneumonids have been used

[2] It should be noted here that Chalcidoidea is a superfamily and was used for identification purposes in 2017 with only the Trichogrammatidae separated, but in 2018 and 2019 YST samples the Chalcidoidea was further identified to families within that group to better understand this significant group.

successfully as biocontrol agents however, not enough ichneumon species have been studied and further comprehensive research is needed.

Overall increased parasitoid abundance in the mohawk block fitted with our hypothesis as parasitoids need nectar to thrive. This may be better provided by the mohawk. Furthermore, the mohawk also provides more ecological niche space in terms of plant height/architecture, which is known to increase species richness.

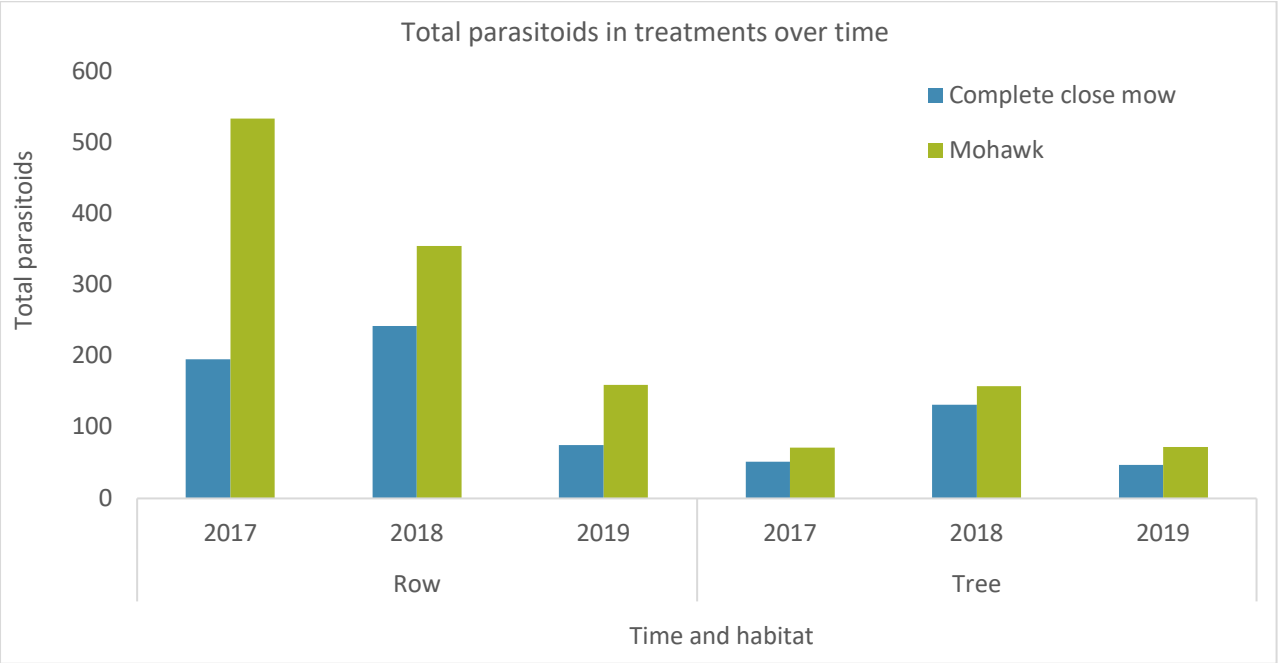

Chart 12: Comparison of the number of parasitoids caught on YSTs from January 2017 to May 2019 in row and tree.

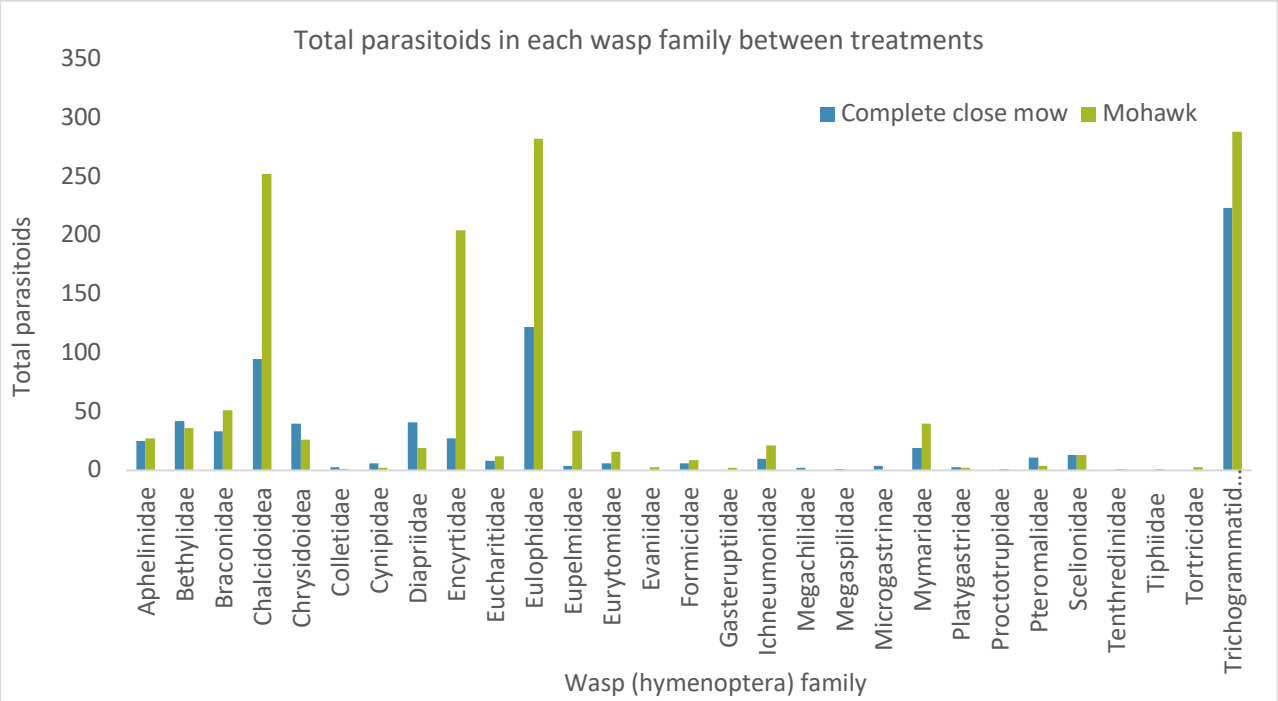

Chart 13: Numbers of Hymenoptera families (parasitoids) caught on YSTs from January 2017 to May 2019 comparing mow treatments.

Turning now to examine the parasitoids that you release on your farm, we saw interesting variations between treatments. **Chart 14** details the seasonal variation in tree and row habitats for each sampling period (e.g. May to June) that we took samples (10 consecutive seasons). The Trichogrammatidae (egg parasitoids) comprise mostly of *Trichogrammatoidea cryptophlebiae* (MacTrix) in summer when releasing them. However, there are also other egg parasitoids that parasitise moths and other arthropod eggs, which is why they can be found on your farm overwintering in small populations including *Trichogrammatoidea bactrae* and not *Trichogrammatoidea cryptophlebiae*. In 2018 there is approximately double Trichogrammatidae and triple the abundance in 2019 in the trees where there is a mohawk although there is little differentiation in 2017. Numbers are not so clear in the row habitat, with slightly more Trichogrammatidae in 2017 in the mohawk and three times more Trichogrammatidae in the complete close mow in 2018. In 2019, twice as many Trichogrammatidae are caught in the mohawk. However, the release points of MacTrix in summer will have confounded the results in both treatments during this period. Interestingly there is a small peak in 2018 in the complete close mow treatment in the tree habitat during winter. We can theorise there might have been a spike in moth egg laying by pyralids (grass moths) in the complete close mow that laid eggs in smother grass, to warrant this modest population increase.

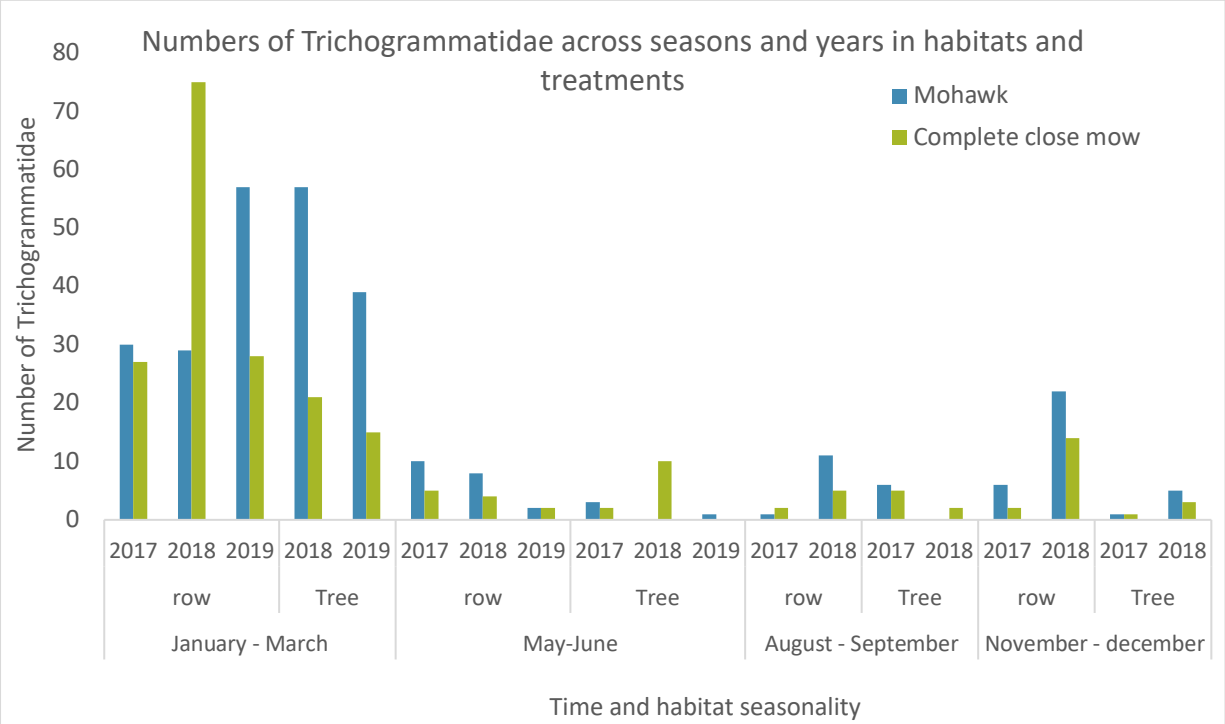

Chart 14: Seasonal abundance of Trichogrammatidae between habitats, treatments and time caught on YSTs from January 2017 to May 2019.

Findings and recommendations

Mohawk worked very well for your trial block, given the 10m rows and availability of machinery of a suitable configuration. Retaining a mohawk year-round, including during harvest, proved to be relatively straight-forward. The principal advantage of the mohawk reduced mow approach is that it can be sustained during harvest. This can be especially advantageous during winter, and particularly in dry years, because it keeps an insectary viable during slow growth periods. Other trial farms that removed the mohawk during harvest took many months to re-establish insectary vegetation when compared to yours. Optimal benefits from insectaries are possible when they are in place ahead of macadamia flowering and the annual intensification of crop pest pressure.

It is worth noting that findings from other trial farms and other industries indicate that alternate row mow may be another management strategy for you to consider. This involves mowing every second row on a rotating schedule, allowing all rows to “grow out” somewhat across the year but providing opportunities for mowing and management as required. This reduces the overall disturbance of beneficial arthropods, ensuring a refuge remains in place at all times for them. It ensures that beneficial arthropods will always have undisturbed areas around your farm for habitat. But it also provides opportunity to schedule removal of vegetation for rat monitoring and management. Likewise, there is opportunity to monitor and manage any “weediness” or dominance of vegetation and encourage regrowth and flowering.

On your farm our results have shown that arthropod abundance is clearly higher in the mohawk area than in the complete close mow. The mohawk was not shown to increase any macadamia pests. However, we found double the abundance of parasitoids and predators in the mohawk and greater species richness in terms of arthropod families represented both in the row and trees. There was also small increase in the presence of parasitoids and predators in the macadamia trees as a result of the mohawk vegetation compared to the complete close mow area of the orchard (particularly the Ichneumonoids). We also found a three-fold increase in thrips compared to the mohawk block over the season sampling period in the complete close mow treatment in the macadamia trees. Thrips were not however reported as much of an issue on your farm during our site visits and in information from bug checking by consultants. However, with increased predators and parasitoids when having a mohawk of vegetation we anticipate a reduction overall pest numbers and coupled with increased pollination. The economic benefit of increased beneficial arthropods could be measured in future studies. It is worth noting that our trial was conducted over 2.25 years, if these practices continue its likely arthropod diversity will increase further.

When the findings from all of the farms that participated in this project are taken into consideration, it is clear that insectaries have meaningful influence on orchard ecology when growers can commit to inclusion of the insectary in the orchard in terms of space allocation and long-term management. The mohawk in the inter-row worked very well on your farm given row width. There are other areas on-farm worth considering, including headlands, field margins and so on where changes to management can allow for habitat suitable for beneficial arthropods. Decisions to improve plant diversity with seeding, well-timed seeding and mowing to limit dominance of one species while encouraging new growth and flowering and so on are also very influential.

Finally, the BioResources team encourages you to read the final report for the *Macadamia IPDM Program - Inter-row Project (MC16008)*, which is available via *Hort Innovation*. Here you will find out more on the benefits of insectaries for macadamia orchards and also the experiences of other trial farms in implementing and managing insectaries. There is also an exploration of the multiple ecosystem services known to flow from reduced mow inter-row management practices along with improved arthropod biodiversity, including benefits for soil organic matter, nutrient cycling, water management, erosion control, weed suppression, soil carbon storage, soil microbiology and more.

Acknowledgements and thanks

The project team wishes to thank the Bevan & Willemse families for their participation, and particularly Jenny and Bob for their contributions and support in the field.