Macadamia Nut Orchard Modification Strategies for Reducing Macadamia Felted Coccid (*Eriococcus ironsidei*) Populations in Hawai‘i

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Introduction

The macadamia felted coccid (MFC), *Eriococcus ironsidei* Williams (Hemiptera: Eriococcidae) is originally from Australia and was first detected in South Kona on the Big Island in 2005 (Gutierrez-Coarite et al. 2017). MFC (Fig. 1) is currently the most important insect pest of macadamia (*Macadamia integrifolia*) orchards in Hawai‘i. This insect infests all above-ground parts of macadamia trees to feed and reproduce. Its feeding activity can deform and stop the development of new growth and cause yellow spotting on older leaves. When population densities are high, branch dieback can occur (Jones 2002), resulting in yield and tree losses. Dense plantings of macadamia trees with contiguous canopies decrease sunlight penetration to the ground. This problem leads to reduced understory plant growth and lower beneficial insect diversity in an orchard. While MFC management requires complete, thorough spray

Figure 1. (A) MFC adult, (B) macadamia tree trunk infested with MFC, (C) branch dieback on macadamia tree due to MFC.
coverage, dense canopies make application of pesticides difficult and expensive. Hence, pruning is often critical for pest management.

Regular hedging of lateral branches on macadamia trees can help maintain light dispersion and ventilation to the lower canopy and orchard floor between tree rows (McFadyen et al. 2004). In addition, a diverse array of flowering non-crop plants in macadamia orchards can assist with pest control by providing pollen and nectar sources necessary to support natural enemy populations (Landis et al. 2000, Jonsson et al. 2008). Further, Rusch et al. (2016) found that diversifying production systems with non-crop plantings, can help to reduce pest colonization and population growth rates by increasing the abundance of their natural enemies. Therefore, we investigated the practice of pruning to thin macadamia tree canopies to facilitate MFC management and enhance plant and insect diversity. We also looked at the impacts of pruning on macadamia nut yields and quality.

This publication provides growers with a summary of pruning and MFC research conducted by Gutierrez-Coarite et al. (2018) on “canopy management of macadamia trees and understory plant diversification to reduce macadamia felted coccid (Eriococcus ironsidei) populations.” We also provide recommendations on applying the results of this research. For complete details and access to this study, see the reference section below.

Tree Description and Location
This research project involved mature, 20-year-old ‘508’ and 34-year-old ‘344’ varieties of macadamia nut trees grown at two different commercial macadamia orchards in Pahala, Hawai‘i. These trees were exposed to three treatments: 1) pruning plus tillage, 2) pruning only, and 3) control. Sixteen trees per treatment were evaluated at each site.

Initially, the diversity and density of the understory plant species in the treatment and control plots were similar. All other cultural methods (fertilization, irrigation, etc.) practiced by the farm remained consistent. MFC populations were not controlled using any pesticide applications and were therefore at the naturally occurring rates.

The Treatments Used for Comparison
Treatment #1: Pruned and tilled
Using a tractor-mounted circular-saw hedge cutter and a pole saw, lateral branches were pruned during the second week of December 2014 for ‘344’ and the first week of

Figure 2. Treatment plots of modified canopy trees and unmodified canopy trees. (1) Pruned and tilled, (2) pruned only, and (3) control.
February 2015 for ‘508’. Hedging, while angled slightly toward the center of the tree row, removed approximately three feet of canopy from each side of the hedgerow. In addition, the ground between rows was tilled approximately six inches deep with a rotary tiller attached to a tractor. Rocks were removed and three flowering plant species, coreopsis (*Coreopsis lanceolata*), (yarrow) *Achillea millefolium*, and verbena (*Verbena x hybrid*), were seeded between the rows. These species were selected for high nectar production, fast regrowth rate after being cut or mowed, and tolerance to drought. They were also incorporated to increase plant abundance and diversity and to potentially enhance natural enemy populations. However, none of these seeded species became established in the orchard.

**Treatment #2: Pruned only**
Lateral branches were hedged similar to treatment #1; however, no tillage or seeding of flowering plants was done.

**Treatment #3: Control**
These trees remained in their present state. No pruning, tilling, or seeding of flowering plants were done in these plots.

**Data Collected for Each Treatment**

**Determining understory plant species diversity**
Three times a year, vegetation was sampled and collected from the middle of each row. All plant species were identified, and total biomass was recorded.

**Monitoring the abundance of MFC and beneficial insects**
MFC crawler (immature) populations were monitored, collected, and recorded monthly using double-sided sticky tape wrapped around two branches per tree. To evaluate the effects of macadamia tree canopy modification on the abundance of beneficial insects—predators and parasitoid of MFC, a yellow sticky card was hung in each tree and monitored monthly for predatory beetles including *Curinus coeruleus, Halmus chalybeus, Rhyzobius forestieri, Sticholatus ruficeps*, and *Scymnodes lividigaster* (Fig. 3A, B, C, D, and E), as well as a parasitoid, *Encarsia lounsburyi* (Fig. 3F).

![Figure 3. Predatory and parasitoid insects of MFC trapped with yellow sticky cards in macadamia trees. A) *C. coeruleus*, B) *H. chalybeus*, C) *R. forestieri*, D) *S. ruficeps*, E) *S. lividigaster*, and F) *E. lounsburyi*.](image)

![Figure 4. Each white speck within this section of branch designated by the sampling device is an adult MFC that was counted and inspected for predation or parasitism.](image)

![Figure 5. (left) Sign of predation by a beetle and (right) sign of parasitism by *Encarsia lounsburyi* wasp on MFC adults.](image)
Assessing predation and parasitism of MFC
The number of live MFC adults and the proportion of predated and parasitized MFC were recorded three times per year from a small section of branch (Fig. 4). Predation (Fig. 5A) by beetles resulted in a chewed, ragged hole on the adult coccid. Parasitism (Fig. 5B) by E. lounsburyi resulted in a neat, round exit hole on the MFC body (Gutierrez-Coarite et al. 2017).

Yield and nut quality
Yield data were collected between September and May for two seasons. Nuts were hand-picked from the orchard floor at 6- to 8-week intervals, and wet-in-husk nut weights were recorded per treatment. Nut quality was evaluated for defects, No. 1 kernel weight, and kernel recovery rate in the second harvest season only. There were four harvests for ‘508’ and three harvests for ‘344’.

Results and Discussion
Ground cover plant species diversity
Over the course of this two-year study, both pruned treatments resulted in greater species diversity (Table 1) and fresh plant understory biomass than were found in unmodified, control plots. Over 43% more plant species grew under pruned trees. In addition, pruned-and-tilled and pruned treatments had 10.7 to 28.8 times and 3.7 to 15.8 times more fresh plant understory biomass, respectively, than the control.

Macadamia growers typically mow and/or blow their orchard prior to harvest. The understory plants identified by this trial did not affect the ability to harvest and presented little to no danger to field staff and harvesters. White albizia, a leguminous plant, is considered an invasive species in Hawai’i. While this tree can provide a benefit of nitrogen-fixation, these trees can grow taller than macadamia trees and compete for light and soil nu-

Table 1. Understory plant species diversity (presence/absence) between rows of macadamia trees, in control and treatment plots.

<table>
<thead>
<tr>
<th>Common name</th>
<th>Scientific name</th>
<th>Pruned &amp; Tilled</th>
<th>Pruned</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goat weed</td>
<td>Ageratum conyzoides</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Spanish needle</td>
<td>Bidens pilosa</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Button weed</td>
<td>Borreria laevis</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Macadamia</td>
<td>Macadamia integrifolia</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Mullumbimby couch</td>
<td>Cyperus brevifolius</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Jelly leaf</td>
<td>Sida rhombifolia</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Carabao grass</td>
<td>Paspalum conjugatum</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Indian goose grass</td>
<td>Eleusine indica</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Barbed wire grass</td>
<td>Cymbopogon refractus</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Fleabane</td>
<td>Conyza canadensis</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Torpedo grass</td>
<td>Panicum repens</td>
<td>x</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>White albizia</td>
<td>Paraserianthes falcataaria</td>
<td>x</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Little hogweed</td>
<td>Portulaca oleracea</td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hairy crabgrass</td>
<td>Digitaria sanguinalis</td>
<td>x</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
rients if not controlled; however, the usual mowing was able to control them. In general, understory plants are beneficial because they can reduce soil erosion, increase organic matter to the soil when mowed or weed-whacked, and attract beneficial insects to an orchard.

**Abundance of MFC**

During this study, MFC populations fluctuated throughout the season and from year to year. However, peaks in MFC population trends were observed for both varieties. The first increase in MFC crawlers was observed from spring through summer (around April to August). The next, often larger, increase in population began around September, peaked in November/December, and then dropped off in January/February. By understanding these types of MFC population trends, growers may be better able to time spray applications for coccid management. Overall, greater numbers of MFC crawlers were captured on branches of ‘344’ than ‘508’. These results suggest that ‘344’ has greater susceptibility to MFC than ‘508’, an observation also mentioned by Reimer in a 2006 report. Results (Fig. 5) of this study show that by not pruning or tilling, MFC populations were increased on both varieties. Meanwhile, efforts to prune and increase understory plant species reduced MFC abundance by up to 50% without the application of pesticides.

*Statistically higher numbers of MFC on control versus pruned and/or pruned-and-tilled plots.

**Figure 5.** Monthly average of MFC per treatment over a 12-month period for pruned-and-tilled, pruned, and control treatments in Pahala macadamia orchards, showing overall greater numbers of MFC in unpruned plots during peak population.
Branch dieback caused by MFC was observed only in control plots and in those, only on the lower limbs. It was estimated that up to 25% of the canopy was affected by dieback.

**Abundance of beneficial insects**

The abundance of predatory beetles and parasitoids varied. More predatory beetles and parasitoids were captured in pruned and pruned-and-tilled plots than in control plots. From fall to spring, both pruned plots often contained significantly more beetles and parasitoids than control and pruned (treatment #2) plots. Control plots had 34–71% fewer beetles and 50–73% fewer parasitoids than plots that were pruned and modified.

In general, a rise in population of MFC crawlers was followed by a rise in population of beneficial insects. This trend was observed in both years and varieties, and amongst all treatments.

**Predation and parasitism of MFC**

Predation by beetles and parasitism by *E. lounsburyi* on MFC was observed in both pruned plots to a greater extent than in control plots. As beetle and parasitoid populations increased, predation and parasitism of MFC increased.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Treatment</th>
<th>Kernel Recovery (%)</th>
<th>Individual Nut Weight (g)</th>
<th>Nut Defect (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>'508'</td>
<td>Pruned and Tilled</td>
<td>31.8a</td>
<td>7.2a</td>
<td>10.5a</td>
</tr>
<tr>
<td></td>
<td>Pruned</td>
<td>31.6a</td>
<td>6.9b</td>
<td>8.7a</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>32.9a</td>
<td>7.3a</td>
<td>8.7a</td>
</tr>
<tr>
<td>'344'</td>
<td>Pruned and Tilled</td>
<td>29.8a</td>
<td>7.8a</td>
<td>26.7a</td>
</tr>
<tr>
<td></td>
<td>Pruned</td>
<td>30.6a</td>
<td>7.7a</td>
<td>20.0a</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>28.1a</td>
<td>7.5b</td>
<td>29.3a</td>
</tr>
</tbody>
</table>

Figure 6. Mean macadamia nut yield (wet in husk) per treatment in varieties ‘508’ and ‘344’ for two harvest seasons. Means for each year with the same letters did not differ significantly.

Table 2. Percentage of kernel recovery, nut defects, and individual nut weight of ‘508’ and ‘344’ varieties. Means for each variety with different letters differ significantly.
also increased. In both years, 54–59% of MFC juveniles were predated on, suggesting that beetles like *H. cha-
lýbeus*, *R. forestieri*, *C. coeruleus*, and *S. lividigaster*, are significant biocontrols. Although parasitism of MFC by *E. lounsburyi* was less than 5%, parasitoids may still be considered an important control tool, particularly if augmentative mass-releases are available.

**Yield and nut quality**

On average, yields of ‘344’ were over 72% lower than ‘508’ in years one and two (Figure 6). While ‘344’ trees produced larger individual nuts than ‘508’, ‘344’ had a higher defect rate (20.0–29.3% versus 8.7–10.5%). As a result of lower yields and higher defect rates, ‘344’ had up to 14.6% lower kernel recovery than ‘508’ (Table 2). Kernel recovery is often a factor used by processors to determine the farmer’s price per pound for macadamia nuts sold.

In year two, yield was 455 to 2,320 lbs per acre greater in the pruned and pruned-and-tilled treatments compared to control plots. While statistically insignificant by scientific terms, for a macadamia nut grower, this small increase in yield could still have important financial impacts. For example, an increase of one ton of wet-in-husk nuts per acre at $1.10 per pound, could equate to an increase of about $10,010 to $51,040 in gross revenue for a 20-acre farm, depending on the macadamia variety.

Yield, defect percentage rate, and kernel recovery were not significantly affected by any treatment in this study on either variety, which may be explained by Nagao et al. (1994), who suggest that following pruning, yield increases can be delayed by two to three seasons. Additional years of data might better assist in understanding and determining the long-term benefits of pruning on yield, nut quality, and kernel recovery rates.

**Conclusions**

Tree pruning reduces current canopy cover, encourages new growth and plant vigor, and increases sunlight exposure to the ground. In addition, soil tillage uncovers and exposes dormant seeds to sunlight and provides other factors needed for germination. Pruning and the combination of pruning plus tillage offered several benefits to ‘508’ and ‘344’ macadamia orchards infested with macadamia felted coccid (MFC) compared to trees left unpruned. Benefits noted by this study include 1) an increase in understory plant diversity and biomass, 2) a greater abundance of predatory beetles and parasitoids, and 3) an increase in predation and parasitism of MFC by these beneficial insects.

Fluctuations in MFC population were noted within seasons and from year to year, but results suggest that MFC populations can be reduced by up to 50% with pruning and by encouraging habitat for natural enemies.

Observations of greater MFC susceptibility of ‘344’ over ‘508’ were also affirmed with this study. Higher overall populations of MFC on ‘344’ likely reduced yield and increased kernel defects. In the presence of MFC, growers may consider replanting with varieties other than ‘344’.

While there were no statistically significant differences in yield or kernel recovery within the first two years after pruning, a small increase in yield during year 2 for both varieties provides encouragement for future studies on the long-term effects of macadamia nut tree pruning in MFC-infested and non-infested orchards.

Tree pruning and the combination of pruning and tillage are therefore recommended for orchards with dense closed canopies where MFC are a problem. Pruning increases beneficial insect numbers, reduces MFC populations, and provide good yields. Pesticide applications may be avoided using this practice.

Farm recordkeeping and field monitoring are recommended to track MFC numbers and assist with decision-making for farm-economic sustainability. We are currently developing action threshold recommendations for MFC to further improve IPM options. In addition, the timing of farm cultural practices and MFC management applications such as fertilization, pruning, and spraying can be critical for maintaining tree health and productivity. Confer with your local Cooperative Extension agent for current recommendation practices.

**References**


Gutierrez-Coarite, R., J. Mollinedo, A. Cho, and M.G. Wright. 2018. Canopy management of macadamia
trees and understory plant diversification to reduce macadamia felted coccid (*Eriococcus ironsidei*) populations. *Crop Protection* 113: 75–83.


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