



Recommendations for Coffee Berry Borer Integrated Pest Management in Hawai'i 2016

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The following document is a collaborative effort between the University of Hawai'i at Mānoa - College of Tropical Agriculture and Human Resources, Hawai'i Department of Agriculture, United States Department of Agriculture ARS DKI PBARC, Synergistic Hawaii Agriculture Council, and coffee grower groups.

Coffee berry borer (CBB) integrated pest management (IPM) recommendations were previously issued in 2013 and 2015. The current edition represents the most up-to-date information available for controlling CBB. Highlights of this version include updated information on the new formulations of Mycotrol®, flat bark beetles for field augmentation, and a decision tool for the Thirty Trees sampling method for CBB monitoring. Our goal is to provide coffee farmers with clear, concise, and up-to-date general guidelines to better manage CBB. More comprehensive information about CBB biology and its relationship to coffee tree biology can be found in Jarmillo et al.'s [7] and Aristizábal et al.'s [1] publications. These publications can help you understand the importance of the recommendations in this publication.

Research in foreign coffee-producing regions has proven that no single approach will control CBB. Not all recommendations will apply to all farmers, but we recommend following an integrated pest management approach, using as many of the suggestions as possible, in the order listed, for maximum effect. Keeping population levels low is key to effective CBB management. This document does not include an economic analysis of the recommendations. Producers should decide the most cost-effective methods for their farm with available information and business/financial records.

TABLE OF CONTENTS

SECTION I: FIELD SANITATION.....	3
A. Coffee Cherry and Raisin.....	3
B. Pruning.....	3
SECTION II: FIELD MONITORING.....	3
A. Recordkeeping.....	4
B. Monitoring.....	4
SECTION III: CBB CONTROL.....	4
A. Spraying <i>Beauveria</i>.....	4
B. Other Products Approved for Coffee.....	6
C. Biocontrol Agents.....	6
SECTION IV: HARVESTING.....	6
A. Pre-Harvest Strip-Pick.....	6
B. Main Harvest.....	6
C. Post-Harvest.....	7
SECTION V: SHIPPING.....	7
APPENDIX A: FARM RECORD LOG FOR CBB- CONTROL ACTIVITIES.....	8
APPENDIX B: REVISED THIRTY TREES SAMPLING METHOD FOR CBB MONITORING – 2016.....	13
APPENDIX C: TRAPS.....	17
APPENDIX D: SUMMARY OF TESTED INSECTICIDES AND REPELLENTS FOR CBB CONTROL IN COFFEE – 2016.....	19
APPENDIX E: FURTHER READING.....	23

This management document is recommended by the following groups (alphabetically):

CBB Task Force
Hawaii Coffee Association (HCA)
Hawaii Coffee Growers Association (HCGA)
Hawaii Department of Agriculture (HDOA)
Kau Coffee Growers Cooperative (KCGC)
Kona Coffee Council (KCC)
Kona Coffee Farmers Association (KCFA)
Kona Young Farmers
Maui Coffee Association (MCA)
Palehua Ohana Farmers Cooperative
Synergistic Hawaii Agriculture Council (SHAC)
University of Hawai'i at Mānoa - College of Tropical
Agriculture and Human Resources (UHM CTAHR)

For additional coffee and CBB information, visit
<http://hawaiicoffee.weebly.com>.

*Note: Numbers in brackets, i.e., [1], refer to publications in **Appendix E: Further Reading**.*

SECTION I: FIELD SANITATION

Field sanitation and strip-picking are proactive approaches that all coffee farmers in Hawai'i should apply at the end of the harvest season. They are the MOST IMPORTANT CBB-control activities.

A. COFFEE CHERRY AND RAISIN

1. *How and when do I strip-pick my coffee?*

- Strip-pick all (green, ripe, over-ripe, and raisin) cherry at the end of harvest and prior to pruning.
 - Avoid allowing coffee to fall to the ground or remain on trees or pruned branches.
 - Remaining cherry and raisin are potential breeding sites for CBB.
- Process or destroy all coffee from this picking.
- If you have continuous, year-round harvesting, consider strip-picking after the peak harvest season, or
 - Harvest every three weeks and remove all raisin and ripe and over-ripe cherry at each harvest.
- A pre-harvest-season strip-pick is effective at reducing CBB populations in the field.

2. *How do I dispose of CBB-infested cherry?*

CBB-infested cherry and raisin must be disposed of to prevent re-infestation of your coffee farm.

- Completely enclose CBB-infested coffee in containers or bags.
 - CBB can chew through many types of plastic bags.
 - Use double heavy-duty, industrial-strength black trash bags.
 - Buckets or drums with lids can be used to contain and kill CBB, and they can be reused. Do not reuse any container that previously contained pesticides, as this is a federal violation.
 - If using burlap bags, place a trash bag inside and then tie tightly to prevent tearing of the trash bag and escape of CBB through the burlap weave.
 - Leave bags and buckets in direct sunlight for at least 2 weeks.

- Bury infested cherry and raisin under at least 6 inches of compact soil, or
- Compost infested coffee with cherry skins.
 - Cover the pile with a tarp and secure the edges.
- Freeze small amounts of infested coffee to at least 5°F (-15°C) for at least 48 hours to kill CBB [6].
- Once CBB are killed, return cherry to the field, use as compost, or remove from your farm and dispose of in an appropriate manner.

B. PRUNING

Stump-pruning by block is currently the only pruning method for establishing a large area without food or shelter for CBB. Pruning can help to make other activities easier or more effective (e.g., ease of harvest, achieving better spray coverage and penetration into the interior of the tree, etc.)

- Prune trees AFTER strip-picking all (green, ripe, over-ripe, and raisin) cherry.
- Stump-pruning in blocks or areas may control CBB infestations within an orchard during the first year of production.
 - Avoid stump-pruning during drought. Trees need rainfall or irrigation and proper nutrition to recover.
 - If you must stump-prune during a drought, retain a “nurse vertical” to reduce tree shock and losses from stumping. The nurse vertical can be removed after new shoots emerge, and new shoots should be thinned to 3 or 4 main verticals [2].

If not actively farming coffee, consider stump-pruning your coffee trees when neighbors are pruning their trees to help neighboring farms in their attempts to control CBB.

SECTION II: FIELD MONITORING

Use the “Thirty Trees Sampling Method,” traps, visual monitoring, or a combination of these methods on your farm to help determine the most effective times to control CBB. Several times throughout the year CBB activity may increase, so intermittent sampling may miss

significant CBB movement. Year-round monitoring will lead to a better understanding of your operation and will help you to assess beetle activity.

A. RECORDKEEPING

Noting major farm events, such as your first and main flowering; spray dates, times and rates; harvesting; pruning dates and descriptions; etc. on a calendar or notebook, or in Appendix A for your individual farm(s), is highly recommended. Recordkeeping of all farm activities and major observations makes activities like spraying, fertilizing, sampling, etc. easier to schedule, organize, and accomplish. As a result, you may gain a better understanding of your farm, farm needs, and the relationship between CBB behavior and events on your farm. It is also recommended that you save the records of each sampling (pages 15 and 16 of Appendix B) for future reference.

B. MONITORING

In August 2012, Luis Aristizábal presented the “Thirty Trees Method for Monitoring and Control” to Kona and Ka‘ū coffee farmers. This method has been revised to more accurately suit the needs of coffee farmers in Hawai‘i and to address questions about the specific sample size per area being sampled (see Appendix B). Individual farmers may need to make further changes based on their particular situation and needs.

1. Why, when, and how do I sample and monitor for CBB?

Early detection of CBB and well-timed sprays will help to reduce infestations before populations explode. Although sampling is vital to determining spray intervals and locations of “hot spots,” sanitation is by far the most important control method.

- Follow the “Revised Thirty Trees Sampling Method for CBB Monitoring - 2016” to determine CBB infestation and position of CBB in the berries (Appendix B).
- Traps may be used as an additional tool in the CBB monitoring program but should not be used to replace the “Thirty Trees Method,” nor as a control mechanism (Appendix C).

SECTION III: CBB CONTROL

Do not use any pesticide not approved for use on coffee in Hawai‘i. Read and follow all label instructions before spraying *Beauveria* or any other pesticide or surfactant. The label is the law!

A. SPRAYING *BEAUVERIA*

Beauveria bassiana strain GHA is the active fungal ingredient in the commercial *Beauveria* products approved for use to spray and kill CBB in coffee orchards:

- BotaniGard® ES (EPA Reg. No. 82074-1) – conventional
- BotaniGard® 22 WP (EPA Reg. No. 82074-2) – conventional, NOT FOR SOIL APPLICATION
- Mycotrol® WPO (EPA Reg. No. 82074-2) – organic, OMRI™ approved
- Mycotrol® ESO (EPA Reg. No. 82074-1) – organic, OMRI™ approved
- BotaniGard® MAXX (EPA Reg. No. 82074-5) – conventional

1. How and at what rate do I apply Beauveria?

For tree applications:

- Spray coffee trees with 32 ounces (1 quart) or 1 pound of *Beauveria* per acre; **plus**
- At least 30 gallons of water per acre.
 - Use as much water as possible per acre, but use ALL 32 oz. of BotaniGard® ES or Mycotrol® ESO, and ALL 1 lb. of BotaniGard® 22 WP or Mycotrol® WPO.
 - Optional: Surfactant (Silwet L-77® Surfactant, Widespread®Max, Nu Film, etc.) at label rates.
 - BotaniGard® and Mycotrol® products contain surfactants and, as indicated on the product labels, are designed for application without additional wetting agents and spreaders. However, added surfactants and spreader/stickers may improve performance by increasing rain-fastness and penetration into damaged berries.
- Spray the entire tree, including the trunk, base of tree, and underside of leaves and berries.

- Spray to wet, but avoid excess runoff.
- Taking into account the type of sprayer, tree size and density, and plant spacing, calculations of water rates per acre and the amount of *Beauveria* product per gallon must be tailored to each farm.
- BotaniGard® MAXX has not been tested under Hawai‘i conditions. Follow label rates (overuse may lead to pyrethrin resistance).

2. When should I spray Beauveria?

- Spray *Beauveria* when % CBB infestation and % A/B alive levels are over your thresholds as determined by the “Revised Thirty Trees Sampling Method for CBB Monitoring – 2016.”
- Calculations and Table 1 from Appendix B may be used to aid in decision-making.
- Spray in the mid-afternoon or on cloudy days under conditions of low UV and high humidity for best *Beauveria* activity and persistence.
 - Beetle activity is most often observed in the afternoon, and beetle mortality may be higher if sprays contact the beetles directly and are made during this time of day.
 - Avoid spraying during bloom and when bees are actively foraging. *Beauveria* is reasonably safe to bees; however, avoid spraying pesticides while bees are foraging.

3. How often should I spray?

Spray as often as sampling and monitoring warrant, or at least once a month. When sprayed, *Beauveria* conidia or spores (the active ingredient of BotaniGard® and Mycotrol® products) contact the insect’s cuticle or exoskeleton. The spores then adhere to the cuticle, germinate within 6–9 hours, and penetrate the cuticle within 24 hours. The insect is killed within 3–10 days depending on the dose of spores and the size of the insect. Best *Beauveria* growth occurs above 74°F (23°C) with proper humidity but declines quickly as temperature increases above 82°F (28°C) [8,9].

- Spray *Beauveria* when CBB % infestation and % A/B alive levels exceed thresholds (Appendix B).
- Spray *Beauveria* when there is mass movement of CBB as indicated by trap catch and verified by visual observations and in-field sampling methods.

- Early-season control of CBB populations may require more frequent sprays.

4. Should I spray the ground and in rock crevices around infested coffee trees?

Fallen or dropped cherry and raisin on the ground may contain live CBB, so spraying *Beauveria* on the ground may help to kill CBB when they emerge. Field sanitation is still extremely important to reducing CBB populations on the farm and should be practiced. Follow the label for ground application.

5. Can I add other solutions to Beauveria sprays?

Other solutions can be mixed with *Beauveria*, but do not combine any pesticides not labeled for coffee. Fungicides may negatively affect *Beauveria* efficacy. Consult the compatibility chart created by the product’s exclusive distributor, BioWorks, Inc., prior to mixing pesticides with BotaniGard® and Mycotrol® products. This compatibility chart can be downloaded at <http://www.bioworksinc.com/products/shared/BotaniGard-es-tank-mix-compatibility.pdf>, or visit <http://www.bioworksinc.com> for additional product information. Also, test any mixed solutions on a small scale for phytotoxic effects, and avoid combining herbicides like Roundup® with *Beauveria*, as current studies show a negative effect on spore growth.

6. Spraying tips for growers using Beauveria

- Review and follow all pesticide labels for BotaniGard® and Mycotrol® products.
- Before adding to the spray tank, shake biopesticide containers vigorously. In the case of liquid formulations (BotaniGard® ES, Mycotrol® ESO, and BotaniGard® MAXX), make sure that all materials settled on the bottom of the container have been re-suspended.
- Spores are alive in suspension, so store in a cool, dry place and avoid storage and transport at temperatures below freezing or above 85°F.
- Shake stored pesticide bottles as often as possible to keep spores from settling over time.
- Use tank mix immediately and avoid storing for more than 24 hours.
- Do not “sprout,” modify, or otherwise adulterate *Beauveria* prior to application, as this will

minimize effectiveness of sprays.

- Provide enough time for leaves to dry after spraying and avoid heavy rain.

B. OTHER PRODUCTS APPROVED FOR COFFEE

A list of pesticides and repellants approved for use on coffee can be found in Appendix D: Summary of Tested Insecticides and Repellents for CBB Control in Coffee – 2016. Determinations of efficacy on CBB as a result of scientific research are also provided.

C. BIOCONTROL AGENTS

Research on the potential for importing biological control agents (e.g., parasitic wasps) against CBB is underway. Current biocontrol options are limited to existing predators, flat bark beetles.

- Flat bark beetles are the only significant biological control agents of CBB in Hawai'i coffee at present. These predators are widely distributed in Big Island coffee-growing areas and are numerous, but they feed mainly in raisin on the tree rather than in ripening cherry where initial crop damage occurs. The predators are not susceptible to *B. bassiana*, so they integrate well into the CBB-control program described above. Flat bark beetles can be raised on a diet of cracked corn and cornmeal to augment existing populations on farms [4,13].
- Learn more about these predators and how to rear and release them at <http://hawaiiicoffee.weebly.com/predators-of-cbb.html>

SECTION IV: HARVESTING

A. PRE-HARVEST STRIP-PICK

Often, the first round of coffee harvested will yield very little marketable coffee and is of lesser quality than main-round harvested coffee. Avoid leaving this first-round cherry and raisin on the trees. These materials will serve as a reservoir from which CBB will emerge and infest subsequent rounds.

- The first round of harvest often has a high level of CBB and may be treated as a sanitation strip-pick if all mature green, color-break, ripe, over-ripe, and raisin cherry are picked.
- Process or destroy all fruit from this first-round harvest.

B. MAIN HARVEST

1. Picker training

Coffee cherry and raisin left in the trees and on the ground could harbor CBB and become reservoirs for the next season. Coffee farmers should supervise pickers and impress upon them the importance of efficient harvesting and removing all ripe and dropped fruit. Farmers may combine performance goals with economic incentives such as not hiring the picker again, paying for greens and raisin, and hourly pay.

- Pick any over-ripe and raisin cherry when harvesting.
- Pick up dropped cherry from the ground, if possible.
- Avoid discarding green berries, over-ripe cherry, and raisin from the picking basket onto the ground.
 - Leave in the picking basket or discard in a separate container.
 - Small amounts may be discarded in a container with soapy water.
- Harvests can be pre-processed by adding a sorting stage, such as floating to remove reject coffee, before delivery to the mill.

2. Harvest interval or frequency

Interrupt the CBB breeding cycle with frequent and complete harvests. Coffee farmers are encouraged to avoid a harvesting interval of more than a month, which will allow CBB in berries to mature and escape.

- A harvest interval of 2–3 weeks is ideal for CBB control.
 - A longer harvest interval will increase the number of remaining raisin and over-ripe cherry.
 - Harvest color-break to red, raisin, and over-ripe cherry.
- Harvest promptly and as often as possible.

- Avoid an interval length that would allow over-ripe cherry to fall to the ground.

3. Harvest bags

When infested cherry are placed in bags, CBB will escape and can be transferred back to the field. Lining the inside of the burlap bag with a plastic bag is effective at minimizing the number of escapes.

- Tie bags shut at harvest to avoid the escape of CBB and re-infestation of the field.
- Avoid keeping bags in the field in the sun all day.
 - Take bags to the wet mill as soon as possible.
 - Do not move cherry in bags to clean areas within the farm, especially if bags are not closed or lined with a plastic bag.
 - Coffee left in bags in the sun will begin to rot.

C. POSTHARVEST

1. Contain and kill CBB in wet mill

Processors can take the following precautions to avoid infesting surrounding coffee.

- Screen the entire wet mill or portions of it, such as the flotation and fermentation tanks, to keep CBB from escaping.
- Maintain traps in the wet mill.
 - Traps seem to be more effective in enclosed areas.
- Cover skin, pulp, and mucilage piles with a tarp and secure the edges.
- Disinfest empty burlap bags:
 - Heat to 122°F (50°C) for at least 25 minutes [5], or
 - Boil in water for 5 minutes, or
 - Soak overnight in soapy water.

2. Transportation of CBB to other fields

To prevent CBB from escaping, hitchhiking, and being released back to farms on trucks, tightly tie shut plastic-lined burlap bags, and clean coffee cherry-delivery trucks and equipment with soapy water following deliveries and before re-entering the farm.

3. Contain and kill CBB at the dry mill

- Enclose the drying deck with plastic or screen.
- Dry parchment to at most 10.7% moisture level.

- CBB may still be alive, but they do not reproduce nor infest adjacent uninfested beans.
- Rapid mechanical drying may kill CBB.
- Low humidity (50–60%) helps mitigate CBB by encouraging beetles to evacuate the bean.
- Since very little CBB activity is observed in green beans, the mechanical hulling process may kill CBB, perhaps with physical crushing.
- GrainPro® bags are good for storage, but CBB can chew through the bags.

SECTION V: SHIPPING

As of December 2016, CBB has been found on three Hawaiian Islands—Hawai'i, O'ahu, and Maui. Currently, an intra-island (on-island) quarantine for Hawai'i Island and O'ahu is NOT in effect. However, the Hawai'i Department of Agriculture has placed a quarantine on ALL regulated coffee items, including but not limited to unroasted coffee, coffee plants and plant parts, used coffee bags, and coffee-harvesting equipment shipped from Hawai'i Island and O'ahu to all other islands.

- Inspection by HDOA Plant Quarantine Inspectors and certain treatments such as fumigation, freezing, or heating and bagging are required prior to shipping. **ALL** regulated items (plants, parts, green beans, and used equipment, etc.) must have a valid permit issued by the Plant Quarantine Branch before transport is allowed.
 - Refer to Hawai'i Department of Agriculture rule 4-72, coffee shipping
 - <https://hdoa.hawaii.gov/wp-content/uploads/2012/12/4-72-HAR-2012.pdf>
- Transporting coffee plants and plant parts for propagation from Hawai'i Island to a non-infested island requires treatment with an approved pesticide and quarantine and monitoring in a State facility for a period of not less than one year.
- Failure to comply with quarantine regulations may result in civil penalties and/or fines, and the shipment may be confiscated and destroyed.

APPENDIX A

Farm Record Log for CBB-Control Activities

Year:

Farm Name:

The following Farm Record Logs are examples of the types of information farmers would collect and forms that might be used to better understand CBB activity throughout the year. Other options for keeping records include calendars and notebooks or journals.

RAINFALL (Inches/month)

Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec

FLOWERING

Date of first flowering:

Date of main flowering:

TRAPS

Date traps were set:

Date Checked	CBB in Trap	Notes
	High / Med / Low	
	High / Med / Low	
	High / Med / Low	
	High / Med / Low	
	High / Med / Low	

Notes _____

FERTILIZER APPLICATION

Date of Application	Type of Fertilizer	Quantity	Notes

Notes _____

SAMPLING

Date	% Infestation	% A/B	% C/D	Notes

Notes _____

PESTICIDE APPLICATION

Date	Material & Quarts per Acre	Gals of H ₂ O	Notes

Date	Price/Unit of Pesticide	# of Units Purchased	Total Cost	Receipt Saved for Subsidy
				Yes / No
				Yes / No
				Yes / No
				Yes / No
				Yes / No
				Yes / No

Notes _____

HARVEST

Date	Bags or Lbs. Harvested	Price	Sales	% Infestation	Notes

Notes _____

SANITATION

Date of Pre-Harvest Strip-Pick: Weight: Cost:

Date of Post-Harvest Strip-Pick: Weight: Cost:

Notes _____

PRUNING

Date of Stump-Pruning:.....

Notes _____

FLAT BARK BEETLE RELEASE

Date: Date: Date:

Notes _____

APPENDIX B

Thirty Trees Sampling Method for CBB Monitoring – 2016

Based on a Presentation by Luis F. Aristizábal

Revised: October 2016 by A.M. Kawabata, S.T. Nakamoto, R.T. Curtiss, S. Shriner, and L.F. Aristizábal

It is not enough to know that your coffee trees are infested with the coffee berry borer; it is also important to understand what the beetle population is doing on your farm. In addition, it is important to understand that cherry infestation is not equal to bean damage. This simple sampling method will show you cherry-infestation and bean-damage levels, but more importantly, it will show whether the beetle is vulnerable to being killed by spray or not. Sampling may reveal hot spots on your farm and allow you to minimize costs by identifying the most effective times to spray *Beauveria*.

Begin monitoring and sampling about 30 days after your initial flowering, or sooner if there is an increase in CBB activity, as indicated by trap catch or visual observations. Continue monitoring through peak harvest, sampling green berries only. Sample your farm every 2 weeks at the beginning of the season to catch early-season infestations and then at least monthly thereafter. Sample at least 30 trees per 2.5-acre plot, but for smaller plots, sample a minimum of 12 trees per acre to determine infestation level. Sampling more trees may provide a more accurate representation of the farm.

Individual farmers may need to adapt these protocols based on their particular situation and needs. For example, if your farm is situated on relatively even terrain or within a single microclimate and your trees are of similar age, under similar management practices, etc., a single sample size of 30 trees might be sufficient for a 3-acre plot. Conversely, you may need to subdivide your farm into smaller plots to address different varieties, tree ages, topographies, areas with shade vs. sun, etc.

Materials

- Farm map
- Knife
- Clipboard
- Attached “Thirty Trees Sampling Worksheet”
- Pencil/pen
- Permanent marker
- Container with lid or resealable Ziploc® bag
- Flagging tape or ribbon
- Hand lens, magnifying glass, reading glasses, or other vision aids
- Calculator
- Optional: counter or tally counter

Step 1: Monitoring the CBB Infestation

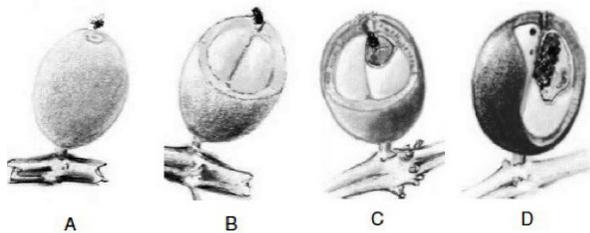
1. Begin monitoring and sampling about 30 days after your initial flowering.
2. Get or draw a map of the coffee plot* to be sampled.

*Plot can be determined by these factors:

- Location, topography, physical features such as roads or gullies
 - Orchard age or pruning stage
 - Variety
 - Kīpuka or microclimate
 - Management practices (e.g., mechanization, organic vs. conventional, pruning, availability of irrigation)
3. Mark a zigzag pattern on the map to follow as you sample. Choose at least 12 trees per acre or 30 trees per 2.5-acre plot to sample along the zigzag.

4. Begin sampling at tree #1 close to a corner of the coffee plot.
 5. Randomly select a lateral branch in the middle of the tree with 30–120 berries.
 6. Record the total number of green berries (up to 120 berries) on the branch in column A.
 7. Record the number of green berries infested by CBB (berries with a hole) on the branch in column B.
 8. Pick 3–4 CBB-infested green berries (not those with fungus) from the branch (or nearby branches if you cannot find enough on that branch) and place them in the container or bag.
 9. Flag any trees observed with high numbers of berries with holes.
 10. Record anything noteworthy in column C.
 11. Move to the next tree and repeat steps #5–10 until all trees have been sampled.
 12. If you sample 30 trees, there should be about 100 infested green berries collected in your container.
 13. Proceed to Step 2.
1. Dissect your collected green berries; determine and tally A/B and C/D positions of CBB on the attached “Thirty Trees Sampling Worksheet.” Be careful not to kill the beetle while opening the berry, as determining whether the beetle is alive or dead is very important.
 2. Complete all calculations on the worksheet.
 - % infestation
 - % A/B
 - % C/D
 3. Based on your calculations, proceed to make a decision to spray or not to spray.

Step 2: Positions of CBB in Berries Used to Determine Whether to Spray



In A/B position, the CBB is entering or boring into the fruit, but the endosperm (coffee seed) has not been damaged. In this position, CBB may be controlled by applications of *B. bassiana* and other pesticides or repellants.

In C/D position (inside the endosperm or coffee seed), CBB females and progeny (larvae) have already damaged the bean. Neither *B. bassiana* nor chemical insecticides can effectively control CBB in the C/D position; CBB may only be controlled by field-sanitation methods like manual collection of infested green, ripe, and over-ripe berries.

Step 3: Decision-Making

The timing of *Beauveria* sprays may vary greatly from farm to farm. It is better to control CBB early in the season than fight a larger population later.

Table 1 on page 16 is an example provided to aid in pesticide application decision-making. This sample table demonstrates how a farmer would decide which CBB infestation level of the entire field would trigger pesticide applications.

In this example, when % A/B and % infestation intersect to exceed 1, then the farmer would consider spraying. When the intersection exceeds 20, the farmer may have lost the opportunity to control CBB. If % C/D is high, the farmer may need to review spray techniques and program and to alter them for greater effectiveness.

Farmers should establish their own spray thresholds based on their individual situations.

Thirty Trees Sampling Worksheet: Percent Infestation by CBB

Date: Farm:

Plot # or ID: Evaluator:

Branch	Column A: # of Green Berries	Column B: # of Infested Berries	Column C: Notes
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			
29			
30			
Total	Column A Total:	Column B Total:	

Tally of CBB from Dissected Berries

A/B Alive:	A/B Absent:
A/B Dead:	C/D:
Total # of Dissected Berries =	

Calculations Used to Determine When to Spray

$$\% \text{ infestation} = \frac{\text{Column B Total:}}{\text{Column A Total:}} \times 100 = \boxed{}$$

$$\% \text{ A/B alive} = \frac{\text{A/B Alive Tally:}}{\text{Dissected Berry Total:}} \times 100 = \boxed{}$$

$$\% \text{ C/D} = \frac{\text{C/D Tally:}}{\text{Dissected Berry Total:}} \times 100 = \boxed{}$$

Table 1. Example of Percent Live CBB in the A/B Position for Spray Determination

		% A/B Alive																			
		0	1%	2%	3%	4%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%
% infestation	1%	0.01	0.02	0.03	0.04	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6	0.65	0.7	0.75	
	2%	0.02	0.04	0.06	0.08	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1	1.1	1.2	1.3	1.4	1.5	
	3%	0.03	0.06	0.09	0.12	0.15	0.3	0.45	0.6	0.75	0.9	1.05	1.2	1.35	1.5	1.65	1.8	1.95	2.1	2.25	
	4%	0.04	0.08	0.12	0.16	0.2	0.4	0.6	0.8	1	1.2	1.4	1.6	1.8	2	2.2	2.4	2.6	2.8	3	
	5%	0.05	0.1	0.15	0.2	0.25	0.5	0.75	1	1.25	1.5	1.75	2	2.25	2.5	2.75	3	3.25	3.5	3.75	
	10%	0.1	0.2	0.3	0.4	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	
	15%	0.15	0.3	0.45	0.6	0.75	1.5	2.25	3	3.75	4.5	5.25	6	6.75	7.5	8.25	9	9.75	10.5	11.25	
	20%	0.2	0.4	0.6	0.8	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
	25%	0.25	0.5	0.75	1	1.25	2.5	3.75	5	6.25	7.5	8.75	10	11.25	12.5	13.75	15	16.25	17.5	18.75	
	30%	0.3	0.6	0.9	1.2	1.5	3	4.5	6	7.5	9	10.5	12	13.5	15	16.5	18	19.5	21	22.5	
	35%	0.35	0.7	1.05	1.4	1.75	3.5	5.25	7	8.75	10.5	12.25	14	15.75	17.5	19.25	21	22.75	24.5	26.25	
40%	0.4	0.8	1.2	1.6	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30		
45%	0.45	0.9	1.35	1.8	2.25	4.5	6.75	9	11.25	13.5	15.75	18	20.25	22.5	24.75	27	29.25	31.5	33.75		
50%	0.5	1	1.5	2	2.5	5	7.5	10	12.5	15	17.5	20	22.5	25	27.5	30	32.5	35	37.5		
		=0-0.99 – Spraying not recommended; will cost more than the expected value of coffee saved from CBB																			
		=1-1.99-Consider spraying, especially early in the season																			
		=2-4.99 – Especially early in the season, this is a critical level to start spraying to avoid economic loss.																			
		=5-9.99 – You are starting to lose money due to CBB damage. Losses will be greater if you don't spray.																			
		=10-19.99 – You are losing money due to CBB damage, but you may still want to spray.																			
		=>20 – Processors may reject your harvest. The value of your harvest may not cover picking cost, so consider focusing on your next crop (i.e. strip pick, stump prune)																			

APPENDIX C

Traps

Traps will not control or eradicate CBB, but they can be used as an optional monitoring tool to determine when CBB populations may be increasing and to help indicate when to start sampling. Visual inspection or sampling (e.g., the “Revised Thirty Trees Sampling Method – 2016”) is better than trapping for detection, determining infestation estimates, and finding “hot spots” because traps may not catch CBB until populations are high. Dozens of virtually identical beetles (e.g., tropical nut borer from macadamia nut trees) may be attracted to the traps and may skew numbers. If used, trapping should be part of a program that includes visual inspection and sampling of coffee cherry on your trees to verify catch.

1. How do I best use traps for monitoring?

- At a minimum, start trapping immediately after the harvest season to detect mass movement of CBB.
- Verify observed trap catch increases by sampling cherry or by visual survey before spraying *Beauveria*.

2. Which trap should I use?

- Homemade traps with inward-facing flaps and commercial broca traps are equally effective.
- Cleaning at least yearly and painting traps may help to extend life.
- Visible trap colors aid in locating traps in the field; red traps appear to be favored by CBB over white ones [3,10].
- While deployed, traps should be supplied with an attractant lure and kill solution at all times.

3. How many traps per acre do I use?

As few as five traps per acre can help as a tool for monitoring CBB activity; more may increase effectiveness in the monitoring program. Use as many traps as you can service without having to sacrifice activities like strip-picking, spraying *Beauveria*, and harvesting.

4. Where should I put my traps?

- Hang traps on coffee trees, stakes, or poles in the field to monitor CBB activity.
- Hang traps along the farm border to aid in early detection of CBB in previously non-infested fields.
- Once a farm is infested with CBB, distribute traps throughout the farm.
- Hang traps between 2 and 5 feet from the ground; most CBB are trapped at this height.

5. What should I use to kill CBB in my traps?

Soapy water is recommended, but traps must be serviced regularly.

- Use a few drops of unscented dish soap per cup of water to break surface tension so CBB cannot crawl out of the cup.
- Insecticidal or pest strips (ex: Hercon® Vapor-tape™ II) are also allowed in traps.
 - Drainage holes in collection cups keep pest strips from becoming saturated.
 - Toxicants are effective for up to 12 weeks; cutting them in half reduces their effectiveness to 4 weeks.

6. Which attractant should I use in my traps?

A mixture of methanol and ethanol is the best available CBB attractant [12].

- Use a 1:1 or 3:1 methanol to ethanol solution in a vial with a 2 mm hole, or
- 3:1 methanol to ethanol solution in a disposable pouch.

7. How often should I be monitoring and servicing my traps?

Service traps as often as local conditions dictate.

- Monitor traps for CBB activity at least every 2 weeks.
- Research indicates that trap catch is highly influenced by rainfall events [11].
- Change lures every 4–6 weeks.

- Inspect vials for holes which may allow attractants to leak out or evaporate too quickly.

8. When do I stop trapping?

Once young cherry develop on the trees, the “Revised Thirty Trees Sampling Method for CBB Monitoring – 2016” is more effective for monitoring than trapping, and trapping can cease.

9. Instructions for building home-made traps:

- <http://www.ctahr.hawaii.edu/Site/CBBTrap.aspx>
- <https://gms.ctahr.hawaii.edu/gs/handler/getmedia.ashx?moid=2626&dt=3&g=12>

APPENDIX D

Summary of Tested Insecticides and Repellents for CBB Control in Coffee – 2016

Below are research summaries of coffee-approved insecticides and repellents tested by the University of Hawai'i College of Tropical Agriculture and Human Resources (UH CTAHR) for control of coffee berry borer (CBB). All products listed are registered for use on coffee in Hawai'i. Do not use or attempt to use pesticide products on coffee that are not registered for use on coffee and in Hawai'i.

As new research information is forthcoming, there may be new products tested and added to the lists below for CBB control.

PESTICIDE PRECAUTIONS

- All chemicals and products should be used in accordance with directions on the manufacturer's label.
- Use pesticides safely.
- Read and follow directions on the manufacturer's label.

If you have questions about pesticides or repellents, please contact your local Hawai'i Department of Agriculture (HDOA) Pesticides Branch or UH CTAHR Cooperative Extension Service. Contact information can be found at

- HDOA Pesticides Branch: <http://hdoa.hawaii.gov/pi/pest/pesticide-branch-contacts/>
- UH CTAHR Cooperative Extension Service: <http://www.ctahr.hawaii.edu/Site/Locations.aspx>

In case of an emergency, contact your physician or call 911.

TABLE OF CONTENTS

1. INSECTICIDES TESTED IN LABORATORY BIOASSAYS FOR CBB CONTROL IN COFFEE, VARIOUS.....	20
2. PRODUCTS TESTED IN-FIELD FOR REPELLENCY AND CBB CONTROL IN COFFEE: GARLIC BARRIER®, BOTANIGARD ES®.....	21
3. PRODUCTS TESTED IN-FIELD FOR REPELLENCY AND CBB CONTROL IN COFFEE: SURROUND® WP, MYCOTROL® O	22

1. Insecticides Tested in Laboratory Bioassays for CBB Control in Coffee, Various

Mike Kawate,¹ Julie Coughlin,¹ James Kam,¹ and Andrea Kawabata²

¹UH-Mānoa/CTAHR/Plant & Environmental Protection Sciences, ²Tropical Plant & Soil Sciences

All products were tested using maximum labeled rates, assuming a spray volume of 100 gallons per acre. Widespread[®] Max was added to all spray solutions at the rate of 8 fl. oz. per 100 gallons of spray volume.

Product Name	Active Ingredient	EPA Reg. No.	Direct-Contact CBB Control ¹	Indirect-Contact CBB Control ²
Admire Pro[®] Systemic Protectant	Imidacloprid	264-827	No	No
Applaud[®] Insecticide	Buprofenin	71711-21	No	No
EverGreen[®] Crop Protection EC 60-6	Pyrethrins + PBO	1021-1770	Yes	No
Movento[®]	Spirotetramat	264-1050	No	No
M-Pede[®]	Potassium salts of fatty acids	10163-324	No	No
Neemix[®] 4.5	Azadirachtin	70051-9	No	No
Prev-Am Ultra	Sodium tetraborohydrate decahydrate	72662-3	No	No
Provado[®]	Imidacloprid	264-763	No	Moderate
PyGanic[®] Crop Protection EC 5.0³	Pyrethrins	1021-1772	No	No
Trilogy[®]	Clarified hydrophobic extract of neem oil	70051-2	No	No

¹ **Direct Contact: Spray applied directly to CBB female adults.**

² **Indirect Contact: Coffee berries dipped in spray solution and allowed to dry; CBB female adults then immediately exposed to treated coffee berries.**

³ **Preliminary Results: Repeat bioassay to be conducted.**

2. Products Tested In-Field for Repellency and CBB Control in Coffee

Elsie Greco

Formerly with UH-Mānoa/CTAHR/Plant & Environmental Protection Sciences

In 2012, Garlic Barrier® AG+ was tested at a rate of 5 fl. oz. per gallon of water plus ¼ teaspoon Silwet®. This spray was applied for 2 days in a row and retained repellency for about 1 week.

In 2013, two products and a combination thereof were tested for CBB repellency and control on coffee. 1) Garlic Barrier® AG+ was tested at a rate of 3 fl. oz. per gallon of water plus 0.08 fl. oz. of Widespread® Max. 2) BotaniGard® ES was tested at a rate of 32 fl. oz. plus 8 fl. oz. of Widespread® Max per acre. Testing was also done on 3) a combination of Garlic Barrier® AG+ (3 fl. oz. per gallon of water plus 0.08 fl. oz. of Widespread® Max) and BotaniGard® ES (32 fl. oz. plus 8 fl. oz. of Widespread® Max per acre). Sprays were applied 3 days in a row and then anywhere from 10 to 44 days after the initial 3 sprays.

Repellency was determined by counting newly infested cherry.

Product Name	Active Ingredient	EPA Reg. No.	Repellency*
Garlic Barrier® AG+ (insect repellent)	Garlic juice	Exempt	Yes
BotaniGard® ES	<i>Beauveria bassiana</i> strain GHA	82074-1	No
Garlic Barrier® AG+ and BotaniGard® ES	Garlic juice, <i>Beauveria bassiana</i> strain GHA	Exempt; 82074-1	Yes

* As compared to control (untreated berries)

Results showed that Garlic Barrier® has potential as a repellent to reduce CBB attack if used frequently, and it can be used as a component of an integrated program to control CBB. Garlic Barrier®, used alone, did not have an effect on the mortality of CBB. Good coverage and frequent spraying of Garlic Barrier® and other treatments examined are necessary to reduce CBB attack, especially during the rainy season.

Further research is recommended.

3. Products Tested In-Field for Repellency and CBB Control in Coffee

Elsie Greco¹ and Shawn Steiman²

¹Formerly with UH-Mānoa/CTAHR/Plant & Environmental Protection Sciences, ²Coffea Consulting

Surround[®] WP was sprayed at a rate of 50 g of Surround[®] WP + 3 ml of Nu Film per 1 liter water every 2 weeks.

- Year 1 (2011) results (kaolin vs. no kaolin) were inconclusive due to the lack of treatment or improper treatment applications.
- Year 2 (2012) results showed promising repellency with Surround[®] WP (kaolin) treatments; however, CBB infestation rates ranged from 5.8% to 53%.
- Only one farm sprayed a combination of Mycotrol[®] O and Surround[®] WP. Compared to the other farms, this farm had the lowest CBB infestation for both years. This combination was most effective at keeping the CBB infestation below 2%. This treatment has the highest cost per application. Mycotrol[®] O was sprayed at a rate of 8 fl. oz. Mycotrol + 4 fl. oz. spreader per 100 gallons water per acre.

CBB mortality was observed and was the result of *Beauveria* infection only.

Product Name	Active Ingredient	EPA Reg. No.	Reduction in CBB Infestation
Surround [®] WP (crop protectant)	Kaolin clay	70060-14	Yes
Mycotrol [®] O	<i>Beauveria bassiana</i> strain GHA	82074-1	Yes
Surround [®] WP and Mycotrol [®] O	Kaolin clay; <i>Beauveria bassiana</i> strain GHA	Exempt; 82074-1	Yes

Results showed that Surround[®] WP has potential as a repellent to reduce CBB attack if used properly and frequently and can be used as a component of an integrated program to control CBB. Good coverage and frequent spraying of Surround[®] WP and other treatments examined are necessary to reduce CBB attack, especially during the rainy season.

Further research is recommended.

APPENDIX E

Further Reading

1. Aristizábal, L.F., A.E. Bustillo, and S.P. Arthurs. 2016. Integrated pest management of coffee berry borer: strategies from Latin America that could be useful for coffee farmers in Hawaii. *Insects*. 7(1): 1–24. DOI:10.3390/insects7010006
2. Beaumont, J.H., and E.T. Fukunaga. 1958. Factors affecting the growth and yield of coffee in Kona, Hawaii. Hawaii Agricultural Experiment Station Bulletin 113. <http://www.ctahr.hawaii.edu/oc/freepubs/pdf/B-113.pdf>.
3. Dufour, B.P., and B. Frérot. 2008. Optimization of coffee berry borer, *Hypothenemus hampei* Ferrari (Col., Scolytidae), mass trapping with an attractant mixture. *Journal of Applied Entomology*. 132(7): 591–600.
4. Follett, P.A., A. Kawabata, R. Nelson, G. Asmus, J. Burt, K. Goschke, C. Ewing, J. Gaertner, E. Brill, and S. Geib. 2016. Predation by flat bark beetles (Coleoptera: Silvanidae and Laemophloeidae) on coffee berry borer (Coleoptera: Curculionidae) in Hawaii coffee. *Biological Control*. 101: 152–158. <http://doi.org/10.1016/j.biocontrol.2016.07.002>.
5. Gautz, L.D., and A.J. Bowles. 2012. Determining effects of time, temperature, and humidity on mortality of coffee berry borer (*Hypothenemus hampei*). Presented at the 24th International Conference on Coffee Science, San Jose, Costa Rica. 11-16 November 2012.
6. Hollingsworth, R.C., E.B. Jang, and P.A. Follett. 2013. Freezing as a treatment to prevent the spread of *Hypothenemus hampei* (Coleoptera: Curculionidae), in coffee. *J. Econ. Entomol.* 106(2): 653–660. <http://doi.org/10.1603/EC12373>
7. Jaramillo, J., A. Chabi-Olaye, and C. Borgemeister. 2009. Temperature-dependent development and emergence pattern of *Hypothenemus hampei* (Coleoptera: Curculionidae: Scolytinae) from coffee berries. *J. Econ. Entomol.* 103(4): 1159–1165. <http://doi.org/10.1603/EC09408>.
8. Jaronski, S.T. 2011. *Beauveria* and other fungi: tools to help manage coffee berry borer, not magic bullets. Presented at the Symposium: “Invaded! Implications of Coffee Berry Borer in Hawaii and Prospects for its Management” held during the 95th Annual Meeting of the Pacific Branch of the Entomological Society of America, Waikoloa, HI. 29 March 2011. http://www.ctahr.hawaii.edu/site/downloads/CBB/Sym11/Jaronski_PBESA_March2011.pdf.
9. Jaronski, S.T. 1997. New paradigms in formulating mycoinsecticides. In G.R. Goss, M.J. Hopkinson, and H.M. Collins (Eds.), *Pesticide Formulations and Application Systems: 17th Volume (99–114)*. West Conshohocken, PA, American Society for Testing and Materials.
10. Mathieu, F., L.O. Brun, C. Marchillaud, and B. Frérot. 1997. Trapping of the coffee berry borer *Hypothenemus hampei* Ferr. (Col. Scolytidae) within a mesh-enclosed environment: interaction of olfactory and visual stimuli. *Journal of Applied Entomology*. 121(1-5): 181–186.
11. Mathieu, F., L.O. Brun, B. Frérot, D.M. Suckling, and C. Frampton. 1999. Progression of field infestation is linked with trapping of coffee berry borer, *Hypothenemus hampei* (Col., Scolytidae). *Journal of Applied Entomology*. 123(9): 535–540.
12. Messing, R.H. 2012. The coffee berry borer (*Hypothenemus hampei*) invades Hawaii: preliminary investigations on trap response and alternate hosts. *Insects*, 3(3): 640–652. <http://doi.org/10.3390/insects3030640>.
13. Sim, S.B., N.M. Yoneishi, E. Brill, S.M. Geib, and P.A. Follett. 2016. Molecular markers detect cryptic predation on coffee berry borer (Coleoptera: Curculionidae) by Silvanid and Laemophloeid flat bark beetles (Coleoptera: Silvanidae, Laemophloeidae) in coffee beans. *J. Econ. Entomol.* 109(1):100–105. <http://doi.org/10.1093/jee/tov284>.

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