



Recommendations for Coffee Berry Borer Integrated Pest Management in Hawai'i 2020

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The following document is a collaborative effort between the University of Hawai'i at Mānoa's College of Tropical Agriculture and Human Resources (UH CTAHR), Hawai'i Department of Agriculture, and the United States Department of Agriculture Agricultural Research Service-Daniel K Inouye-Pacific Basin Agricultural Research Center.

Coffee berry borer (CBB, *Hypothenemus hampei*) integrated pest management (IPM) recommendations were previously issued in 2013, 2015, and 2016. This edition represents current, field-tested information available for controlling CBB as of the date of publication. Highlights of this version include updated information on the impact of feral and unmanaged coffee and the importance of starting the season with as low an infestation as is feasible, then maintaining that with spraying and efficient harvesting. 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. [13]¹ and Aristizábal et al. [1]. These publications can help you understand the importance of following recommendations.

Research in foreign coffee-producing regions has shown that no single approach will control CBB. Not

all recommendations will apply to all farmers, but for maximum effect we recommend following an integrated pest management approach, using as many of these suggestions as possible and in the order listed. Starting the season with low population levels is key to effective CBB management. This document does not include an economic analysis of the recommendations, since conditions vary widely from farm to farm and from year to year. Producers should decide the most cost-effective methods for their farm with according to the available information and their business/financial records.

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

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

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CBB infestation is influenced by how effectively CBB were managed in the previous session. The most efficient CBB-management strategy is to begin the current season with the lowest infestation possible, then use IPM practices to maintain the low level. If CBB populations are allowed to build up to high levels in mid-season, it is extremely difficult and costly to reduce infestations even if all the practices are followed. CBB reproduce quickly, and once they have bored into the coffee bean, they are too well-protected to control. It is important to take advantage of the coffee crop cycle and CBB behavior to effectively manage them. The IPM strategy employs strip-picking at the end of harvest, before pruning, and again at the beginning of the next season to remove CBB breeding sites. Other components of the CBB IPM strategy include timely spraying of pesticides, efficient harvesting, and stump pruning by blocks to create a protracted period when CBB have no food.

SECTION I: FIELD SANITATION

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

A. STRIP-PICKING

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

- Strip-pick all green, ripe, over-ripe, and raisin coffee 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 these options:
 - » Strip-pick after the peak harvest season, or
 - » Harvest every two to three weeks and remove all raisin, ripe, and over-ripe cherry at each harvest.
- Additional pre-harvest-season strip-picking of berries that were missed or that grow between seasons is effective at further reducing CBB

populations in the field. However, this cannot replace the end-of-season strip-pick. See the Harvesting section.

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

- Completely enclose CBB-infested coffee in containers or bags to prevent re-infestation of your coffee farm:
 - » 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 and reused to contain and kill CBB. 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 [11].
- 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

CBB management starts with several strip-picking rounds, including after harvest and before pruning. Strip-pick ALL (green, ripe, over-ripe, and raisin) coffee PRIOR to pruning to remove berries that otherwise would be dislodged and left in the field during the pruning process.

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

- Stump-prune trees AFTER strip-picking all green, ripe, over-ripe, and raisin coffee. Stump-pruning in blocks may control CBB infestations within an orchard during the first year of production.
- Stump pruning by rows, i.e., Beaumont-Fukunaga style of pruning, will not control CBB.
- 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.

C. FERAL AND UNMANAGED COFFEE TREES

Feral and unmanaged coffee trees provide habitat that produce persistent CBB populations which continually infest managed farms. A review by Damon [4] suggests female CBB can live for an average of 157 days and lay between 31 and 119 eggs within an individual coffee berry. Although CBB can move up to 213 feet (65m) unassisted by wind, most beetles remain within 49 feet (15m) of their origin [9]. Research [16,17] in Hawai'i shows that unmanaged trees on farms have greater populations of CBB than wild, feral coffee trees. These discoveries emphasize the importance of removal or management of feral and unmanaged coffee to reduce CBB and their ability to disperse into and infest managed plots.

1. What do I do about feral and/or unmanaged coffee trees neighboring my farm?

- If, and only if, you are able to obtain consent from the property owner and/or manager of neighboring properties, consider doing the following. (Note, however, that if permission is denied or you cannot reach the owner/manager, do not enter the property).
 - » Strip-pick berries and then destroy all seedling, feral, and unmanaged trees, or
 - » Strip-pick and then stump trees to eliminate

coffee production for an extended period.

- » If berry and raisin removal is not possible, placing CBB traps along the border nearest to the feral and unmanaged trees may help to reduce overflow beetle movement by capturing and killing CBB during dispersal flights. Service these traps regularly, as detailed in Appendix C. Note that trapping is NOT otherwise a recommended practice for CBB control, other than monitoring adult numbers.

SECTION II: FIELD MONITORING

Use the “Thirty Trees Sampling Method for CBB Monitoring – 2020,” traps, visual monitoring, or a combination of these methods on your farm to help determine the most effective times to manage CBB. Beetle numbers and activity may fluctuate greatly during the course of a season, so sporadic sampling may miss significant CBB movement. Year-round monitoring will lead to a better understanding of your operation and will help you assess beetle activity and make informed decisions on appropriate management actions.

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 crop and the distinct dynamics of your farm, your farm-management needs, and the relationship between events on your farm and CBB behavior. It is also recommended that you save the records of each sampling (pages 16 and 17 of Appendix B) for future reference.

B. MONITORING

CBB-monitoring methods were created by Cenicafé [3] and then revised and validated in two studies [21, 22] to more adequately 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 pesticide sprays will help to reduce infestations before populations explode. Sampling is vital to determining when to start spraying, spray intervals, and locations of “hot spots,” but remember field sanitation is by far the most important CBB-control method.

- Follow the “Thirty Trees Sampling Method for CBB Monitoring - 2020” 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 Sampling Method,” nor as a control² 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 *B. bassiana* products approved for use to spray and kill CBB on coffee grown in Hawai'i (see list of licensed pesticides at <https://hdoa.hawaii.gov/pi/pest/licensed-pesticides/>):

- BotaniGard[®] ES (EPA Reg. No. 82074-1) – conventional
- Mycotrol[®] ESO (EPA Reg. No. 82074-1) – organic

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

For tree applications:

- Spray coffee trees with 32 ounces (1 quart) of BotaniGard[®] ES or Mycotrol[®] ESO per acre; **plus**

² CBB traps are best utilized and deployed after the harvest season and before bean maturity.

- At least 30 gallons of water per acre.
 - » Use as much water as needed per acre, but use ALL 32 oz. of BotaniGard[®] ES or Mycotrol[®] ESO.
 - » Optional: Surfactant, sticker, and/or deposition aid (Silwet L-77[®] Surfactant, Wide-spread[®] 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.
- Spray the entire tree, including the trunk, base of tree, and underside of leaves and berries.
- Spray to wet but avoid excess runoff.
- Calculations of water rates per acre and the amount of *Beauveria* product per gallon must be tailored to each farm, taking into account the type of sprayer, tree size and density, plant spacing, etc. UH CTAHR publications [25, 26] provide spray calibration information.

2. When should I spray Beauveria?

- Spray BotaniGard[®] or Mycotrol[®] when percent of CBB infestation and percent of A/B alive levels are over your thresholds as determined by the “Thirty Trees Sampling Method for CBB Monitoring – 2020.”
- 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 [10, 12, 23].
 - » Beetle activity is most often observed in the afternoon, and beetle mortality may be higher if sprays contact the beetles directly [27] and spraying is done during this time of day.
 - » *Beauveria* is reasonably safe to bees; however, avoid spraying all pesticides during bloom and while bees are actively foraging.

3. How often should I spray?

Spray as often as justified by thresholds, sampling, and monitoring, or at least once a month. When sprayed, *Beauveria* 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. Optimal *Beauveria* growth occurs under conditions of above-74°F (23°C) temperature with constant high (96–100%) relative humidity for 2–3 days, but it declines quickly as temperature increases above 82°F (28°C) [14,15].

- Spray BotaniGard® or Mycotrol® when CBB % infestation and % A/B alive levels exceed thresholds (example in Appendix B).
- Spray BotaniGard® or Mycotrol® 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 or the application of other approved insecticides due to, for example, dry, hot weather, effectiveness of product, unpredictable patterns of CBB flight, etc.

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 [16], so spraying *Beauveria* on the ground may help to kill CBB when they emerge and are contacted by live spores. Field sanitation is still extremely important to reducing CBB populations on the farm and should be practiced. Follow the pesticide 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 <https://www.bioworksinc.com/wp-content/uploads/products/shared/botaniGard-es-tank-mix-compatibility.pdf>, or visit <http://www.bioworksinc.com> for additional product information. Also, test any unique mixed solutions on a small scale for physical compatibility and phytotoxic effects.

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), make sure that all materials that had 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,” germinate, modify, or otherwise adulterate *Beauveria* prior to application, as this will minimize effectiveness of sprays.
- Avoid spraying during or directly before heavy or persistent 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 – 2020. 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 using insect natural enemies, are limited to generalist predators, namely flat bark beetles (*Cathartus quadricollis* and *Leptophloeus* sp.).

- Flat bark beetles are the only biological natural enemy 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 raisins 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 [6, 24].

- Learn more about these predators and how to rear and release them at <https://www.hawaiicoffeeed.com/predators-of-cbb.html>

SECTION IV: HARVESTING

Start the season with as low an infestation as is feasible and then to use “efficient harvesting” and spraying. An efficient harvest includes harvesting to avoid over-ripe cherries and raisins on the tree, removing all ripe/over-ripe/raisin coffee at each harvest, and minimizing dropped coffee. The latter is essential to ensure that CBB carryover to the next season is as low as possible.

A. PRE-HARVEST, EARLY SEASON STRIP-PICK

The strip-pick at the end of the previous season will invariably miss some berries, and with stray blossoms and small flowerings before the main flowering event, any residual mature coffee berries on the farm will provide refuge for CBB between the seasons.

An early season strip-pick, timed somewhere between the main bloom and when the main crop is still very immature, is an opportunity to remove infested berries before CBB are able to emerge and infest the new crop. This should occur before the first harvest of the main crop.

Although the first round of coffee harvested will typically yield very little marketable coffee compared to main round-harvested coffee, growers should avoid leaving this first-round cherry and raisin on the trees. Similar to the berries that were carried over between seasons, this crop 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.
- Since CBB will sit in the AB position until the coffee berry is mature enough, having only immature berries on the tree also might help the efficiency of sprays by leaving CBB in a vulnerable position for a longer time.
- Process and/or destroy all fruit from this first-round harvest. An option is to float the harvest by dumping it into a container of water and removing

the raisins and badly damaged berries which rise to the surface.

B. MAIN HARVEST

1. Picker training

Coffee cherry and raisin left in the trees and on the ground could harbor CBB [16] and become reservoirs for the remainder of the current season and 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 should avoid harvest intervals of more than a month to prevent the escape of CBB from berries as well as to keep infested over-ripe cherry from falling to the ground.

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

3. Harvest bags

When infested cherry are placed in burlap bags, CBB will escape and can reinfest developing fruit in 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.
 - » Coffee left in bags in the sun will begin to rot.
- Avoid transporting cherry in bags through clean areas, and do not move cherry in bags to clean areas within the farm, especially if bags are not closed or lined with a plastic bag.

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 CBB 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 [8], 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.

If the farm is not yet infested, provide picking supplies and do not allow pickers and guests to enter the farm with vehicles, shoes, hats, clothing, and other materials that are potentially infested with CBB from other farms. Do not accept cherry and unroasted coffee from other farmers without a disinfestation protocol prior to delivery.

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 infest

adjacent uninfested green beans [7].

- » Rapid mechanical drying may kill CBB.
- » Low humidity (50–60%) helps mitigate CBB by encouraging beetles to evacuate the bean.
- GrainPro® bags are good for storage, but CBB can chew through the bags.

SECTION V: SHIPPING

As of December 2019, 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, Maui, 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 beans, coffee plants and plant parts, used coffee bags, and coffee-harvesting equipment shipped from Hawai'i Island, Maui, and O'ahu to all other islands.

- Inspection by HDOA Plant Quarantine Inspectors is required, including treatment requirements such as fumigation, freezing, or heating and bagging. **ALL** regulated items (plants, parts, green beans, and used equipment, etc.) must be inspected and 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, Maui, and O'ahu to a non-infested island will require an inspection by HDOA prior to export to the non-infested island. Coffee plants that have completed the one-year quarantine period in the HDOA quarantine facility will be inspected and shipped directly from the quarantine facility to the respective island.
- Failure to comply with quarantine regulations may result in civil penalties and/or fines, and the shipment may be confiscated and destroyed.
- For questions and additional information, contact HDOA's Plant Quarantine Department: <https://hdoa.hawaii.gov/pi/pq/pqcontacts/>

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	Gallons of Water	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 Pruning:.....

Notes _____

FLAT BARK BEETLE RELEASE OR BREEDING STATION DEPLOYMENT

Date: Date: Date:

Notes _____

APPENDIX B

Thirty Trees Sampling Method for CBB Monitoring – 2020

Based on Cenicafé sampling methods [3]

Revised: December 2019 by A.M. Kawabata, S.T. Nakamoto, M. Miyahira, and J. Burt

To make management decisions, it is not adequate to simply 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 terms of population growth and proportion of berries infested. In addition, it is important to understand that berry infestation is not equal to bean damage. This simple sampling method will show you berry-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. For smaller plots, you may sample a minimum of 12 trees per acre to determine infestation level; however, 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.

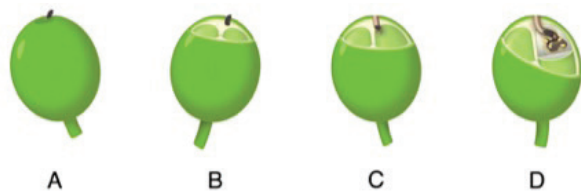
*Plot can be determined by these factors:

- 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. Randomly pick 3–4 CBB-infested green berries 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 #3–8 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.

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



Created by J. Burt (2019).

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, over-ripe, and raisin berries.

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.

Complete all calculations on the worksheet:

- % infestation
- % A/B
- % C/D

Based on your calculations, proceed to make a decision to spray or not to spray.

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 17 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 alive 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 their spray techniques and program and 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 “Thirty Trees Sampling Method – 2020”) 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, which may cause you to reach unreliable conclusions about CBB activity. If used, trapping should be part of a program that includes visual inspection and sampling of coffee berries 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. Do not substitute trapping for the end-of-season strip-pick. 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.
- Clearly detectable trap colors aid in locating traps in the field; red traps appear to be favored by CBB over white ones [5,18].
- While deployed, traps should always be supplied with an attractant lure and a kill solution.

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 stakes or poles in the field to monitor CBB activity.
- While some growers hang traps on coffee trees, this may attract CBB to berries on the tree.
- Hang traps along the farm border to aid in early detection of CBB in 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, as 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 (e.g., Hercon® Vapor-tape™ II) are also allowed in traps.
- Drainage holes in collection cups keep pest strips from becoming saturated.
- Toxicant strips 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 [20].
- 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 semi-permeable 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 [19].
- 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 berries develop on the trees, the “Thirty Trees Sampling Method for CBB Monitoring – 2020” is more effective for monitoring than trapping, and trapping can cease.

9. Instructions for building homemade 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 – 2020

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 here:

- 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.

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3. **PRODUCTS TESTED IN-FIELD FOR REPELLENCY AND CBB CONTROL IN COFFEE: SURROUND® WP, MYCOTROL® O23**

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 ³	No
Applaud[®] Insecticide WG	Buprofezin	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[®] (discontinued)	Imidacloprid	264-763	No	Moderate ⁴
PyGanic[®] Crop Protection EC 5.0	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 “No” means that the product did not result in significant mortality of CBB female adults.

⁴ “Moderate” for Provado indicates that control was variable, whereas in the other treatments, the results were consistent, with very little variability.

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

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