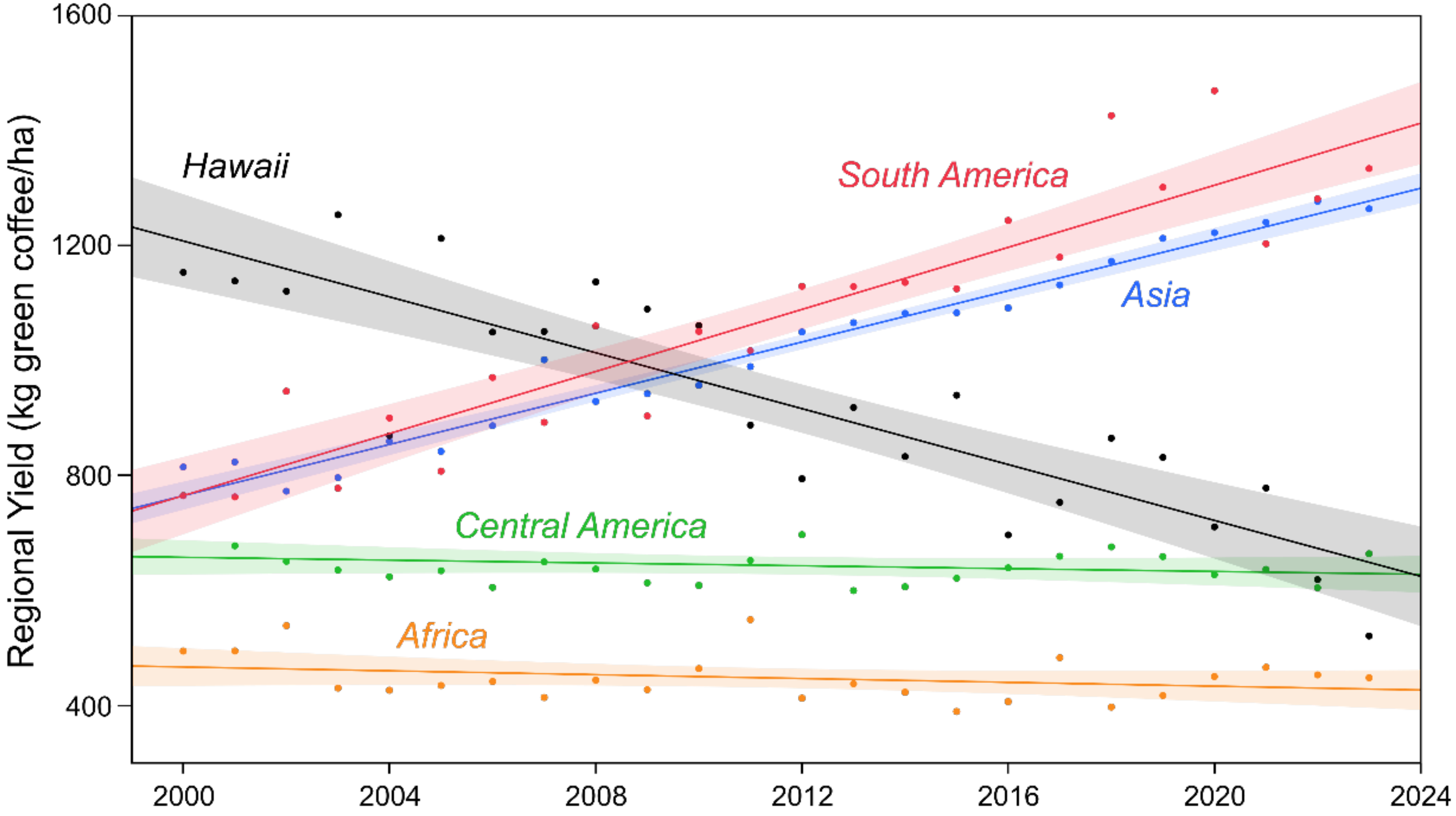
Hawaiian Coffee Plant Nutrition and Soil Fertility




Franklin Linam[1], Suzanne Shriner[2], Melissa A. Johnson[1]
[1]USDA-ARS Pacific Basin Agricultural Research Center
[2]Synergistic Hawaii Agricultural Center

Why are coffee yields declining?

- Statewide coffee yields have dropped ~50% in past two decades
  - 1200 kg/ha down to 650 kg/ha
- Stark contrast to other coffee producing regions, which have increasing or stable yields
- Causes: pests, diseases, aging orchards, drought

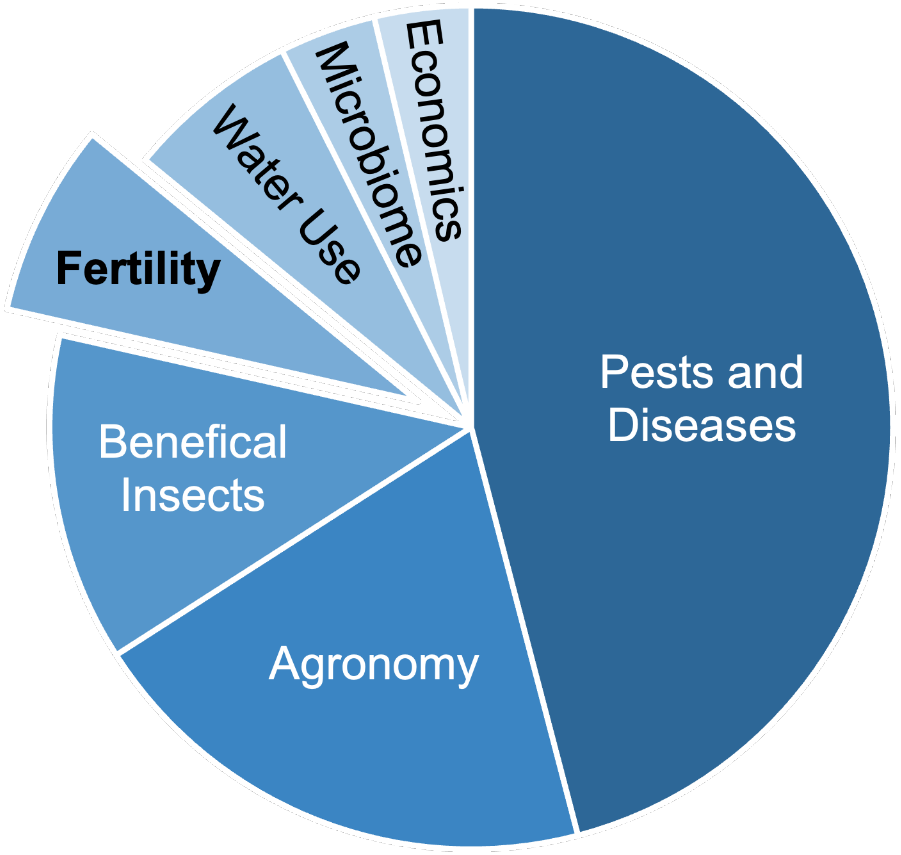


FAO STAT 2015, USDA-NASS 2025

We study pests – but rarely nutrition

- Most Hawaii coffee research has focused on pests and diseases
- Very little research on coffee nutrition
- Questions:

1. Are poor plant nutrition and low soil fertility limiting Hawaii's coffee yields?
2. Are we fertilizing Hawaiian coffee correctly?

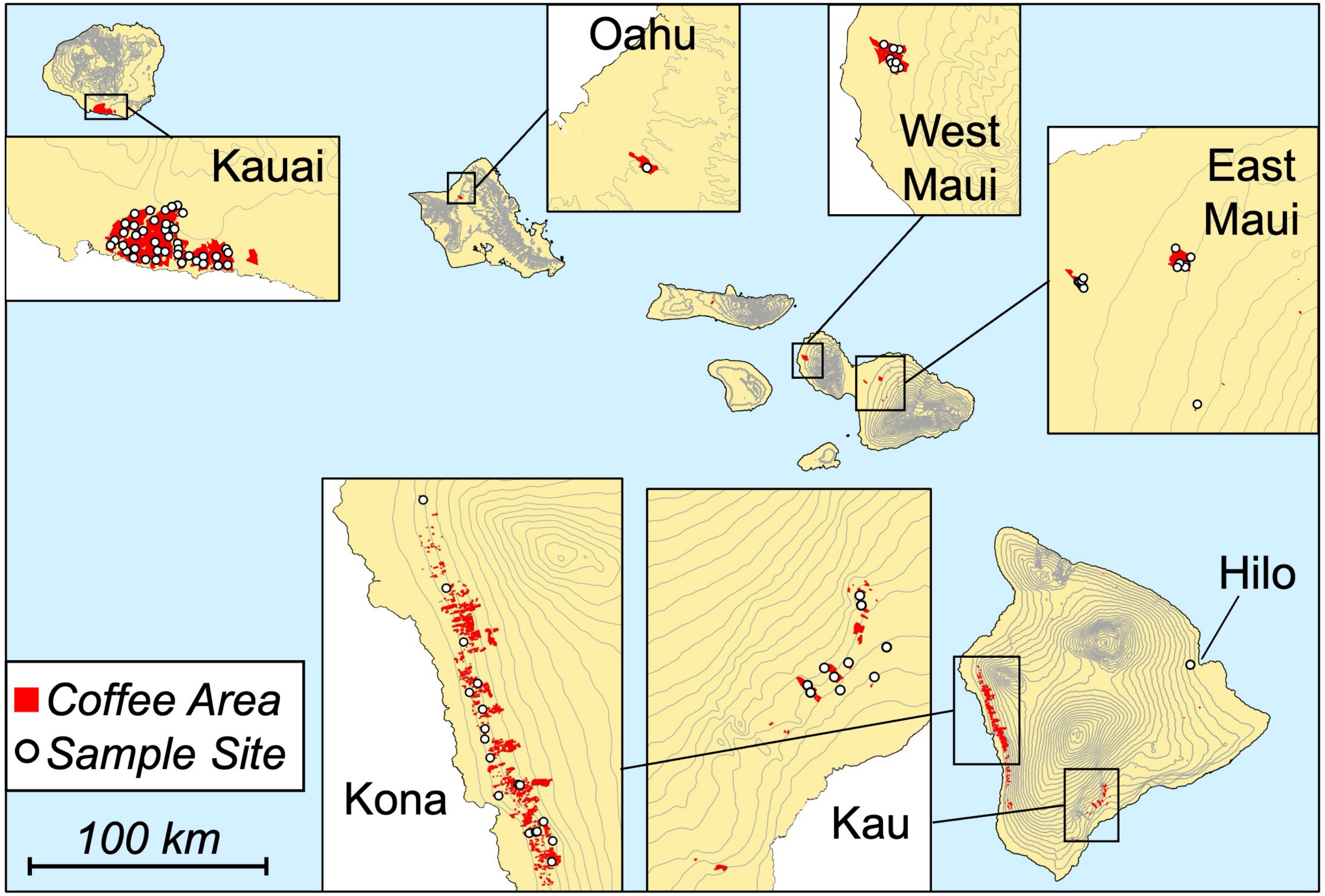


121 studies on Hawaiian coffee

What we did

- First Statewide baseline of coffee nutrition in Hawaii
  - 7 growing regions
  - One-time sampling
  - 236 soil samples
  - 139 leaf samples

- Hawaii Island
  - 21 farms
  - Multi-year sampling (2021-2024)
  - leaf + soil samples
  - fertilizer inputs
  - yields



How we measured coffee nutrition & soil fertility

- Used CTAHR recommended sampling methods
- When: Dec-Mar (post-harvest)
- 3rd pair of fully-emerged leaves on mid-level branches
- Soil sample from halfway between trunk and drip line down to 6” deep
- Composite from 10-15 trees

Not all Hawaiian soils behave the same

- Old soils on Kauai
  - Clay-rich
  - Better water holding capacity
  - Enriched in Fe, Al
  - Low organic matter

- Young soils on Hawaii Island
  - Rocky, sandy loam
  - Fast drainage
  - Nutrients leach easily
  - Low P, High N

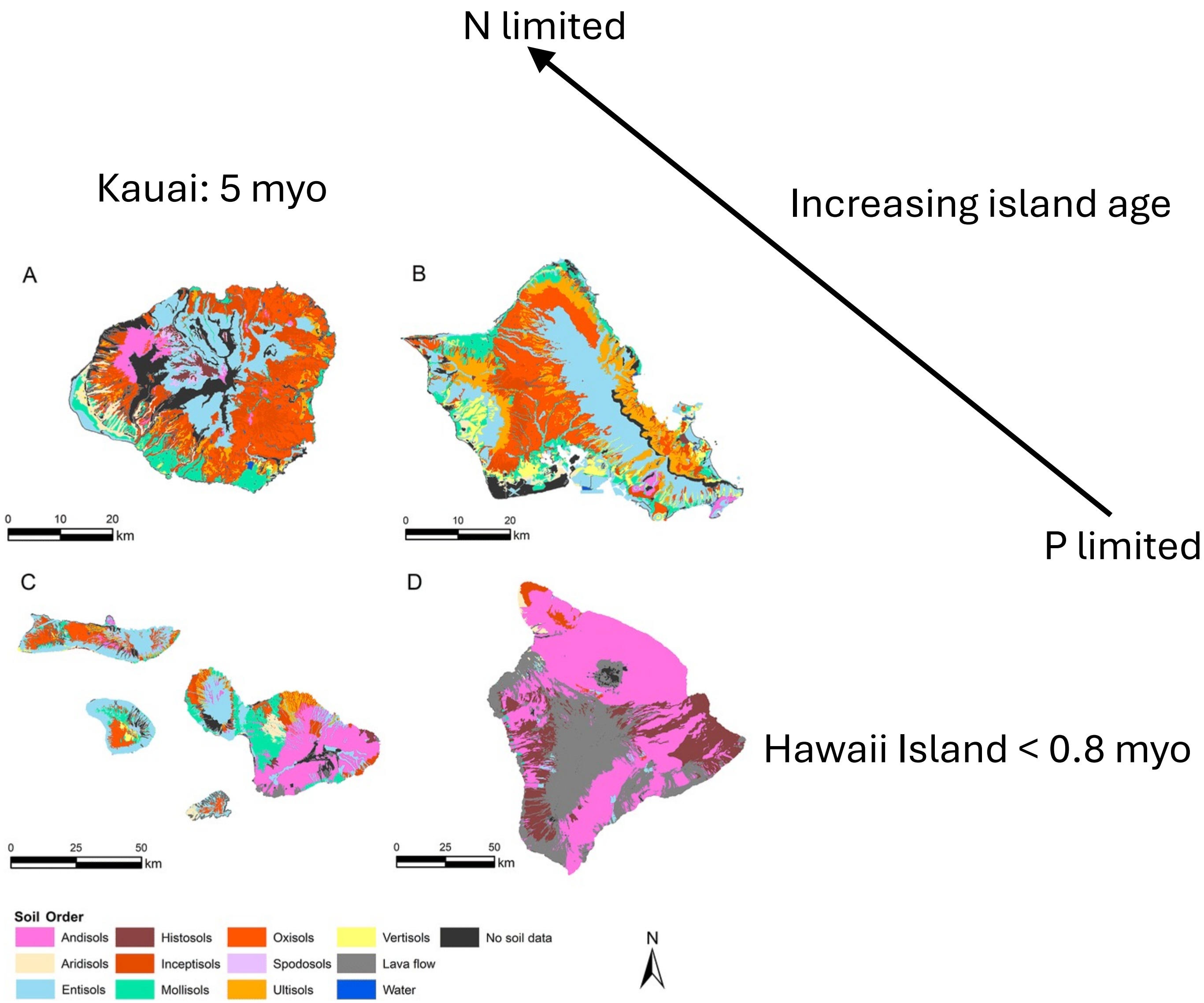
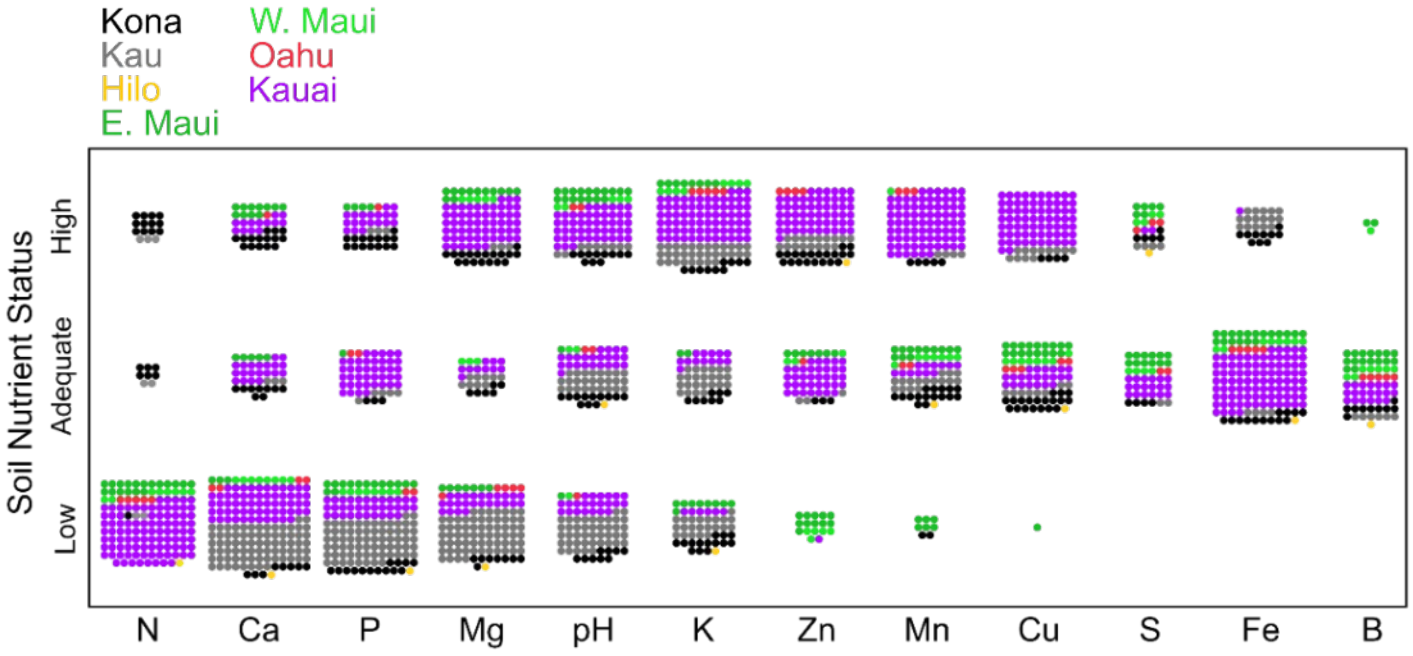


Figure: USDA 2015

Soil nutrient deficiencies

- What nutrients are most deficient in Hawaii coffee soils?
  - N: 85%
  - Ca: 67%
  - P: 61%
  - Mg: 48%
  - K: 22%

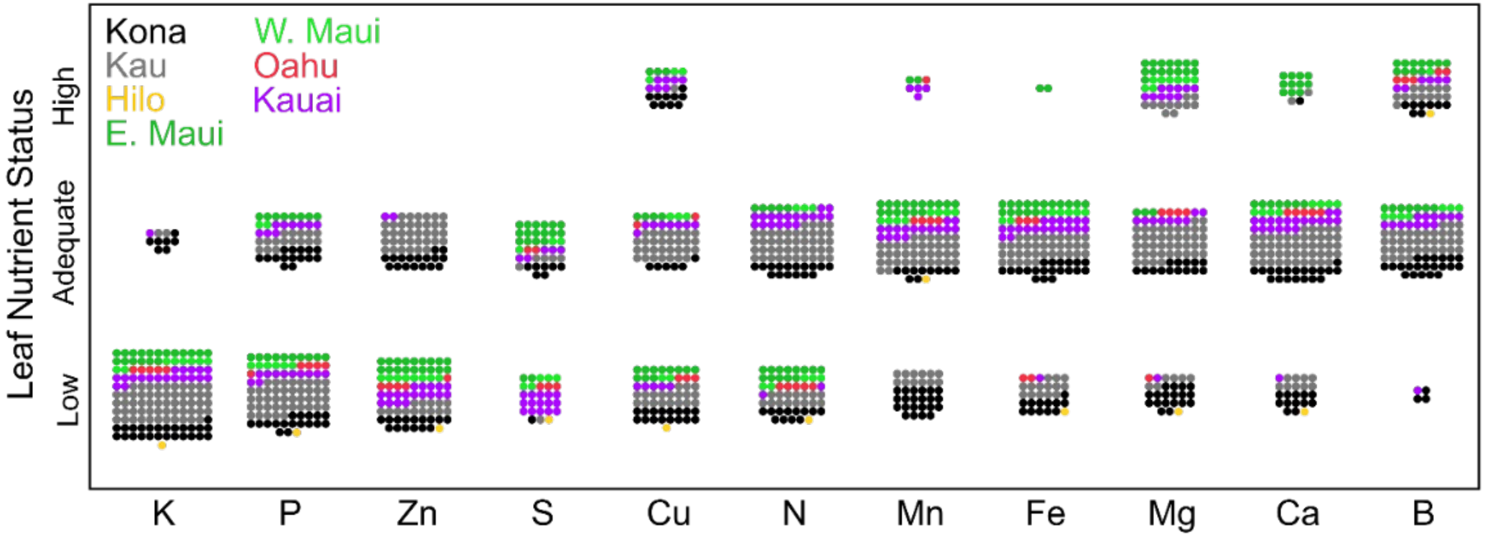


- Kauai, Oahu, Maui: N limited

- Hawaii Island: P, Ca, Mg, K limited

Leaf nutrient deficiencies

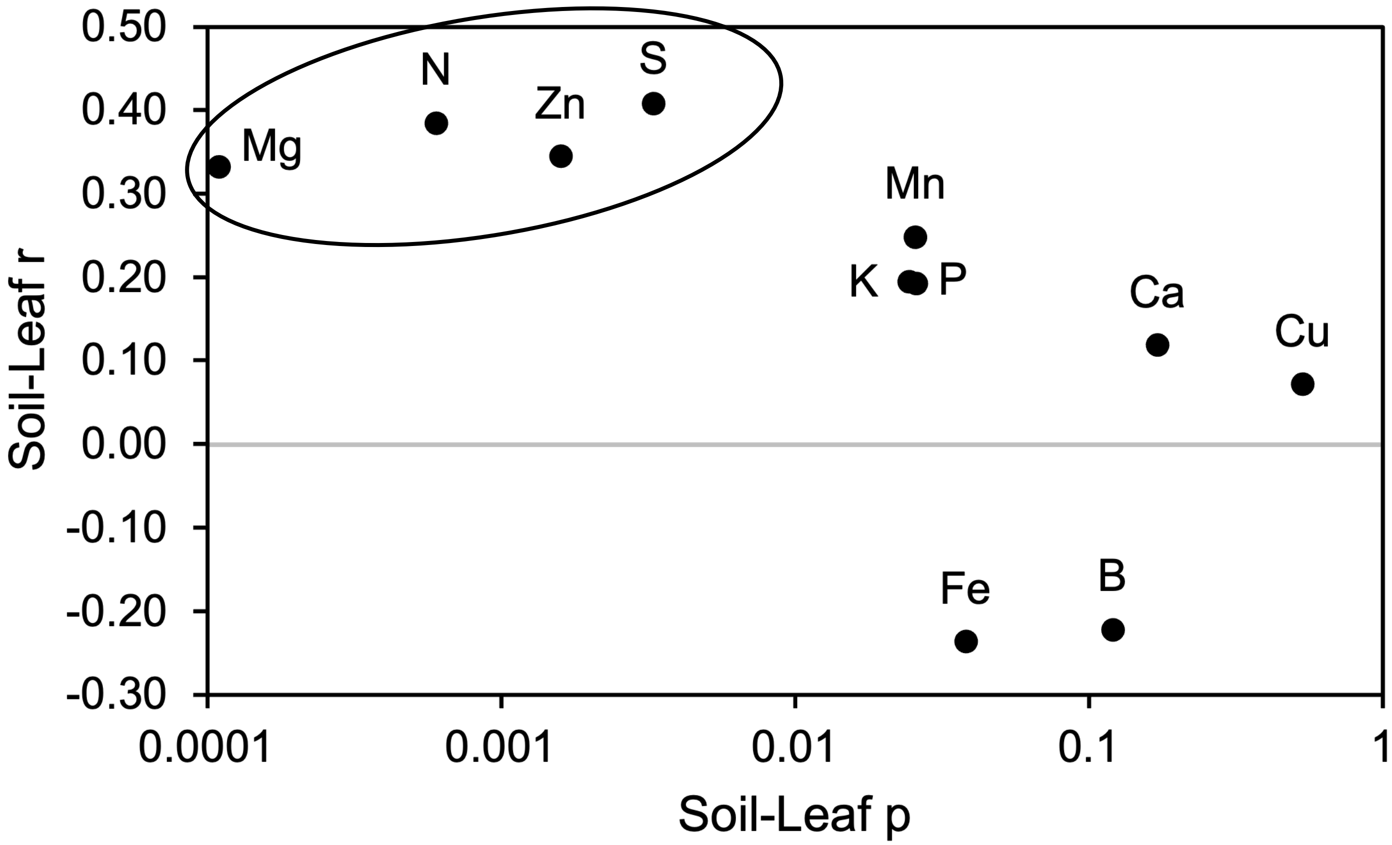
- What nutrients are most deficient in Hawaii coffee plants?
  - K: 93%
  - P: 65%
  - Zn: 59%
  - Cu: 42%
  - N: 38%



- Potassium is single most widespread deficiency in Hawaii coffee

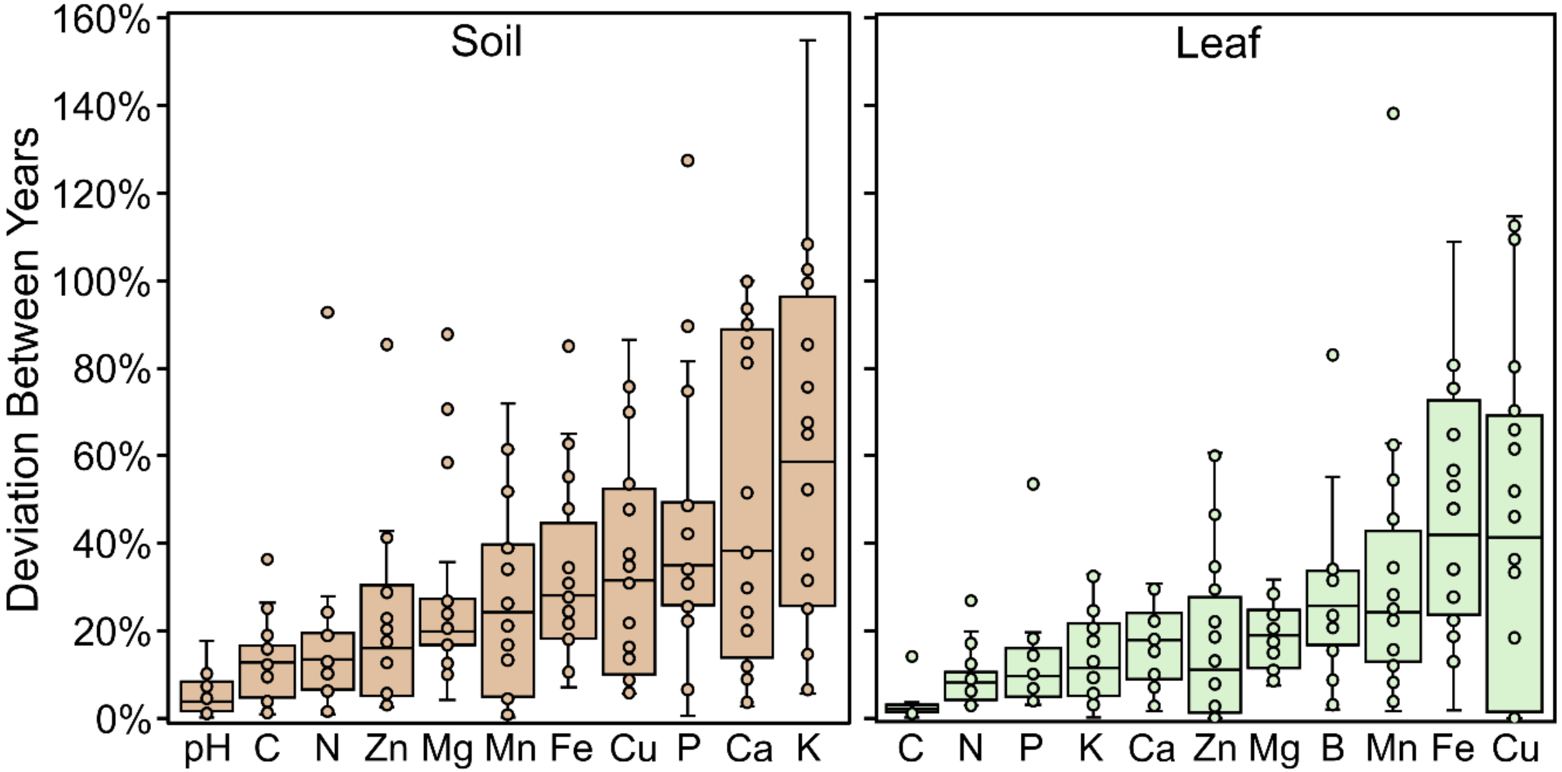
Do soil nutrients predict plant nutrition?

- Soil testing worked well for:
  - N, Mg, Zn, S
- Soil testing poor predictor for:
  - K, P, Ca, Fe, Cu, Mn, B
- If you're relying on soil tests alone, you may be misdiagnosing deficiencies



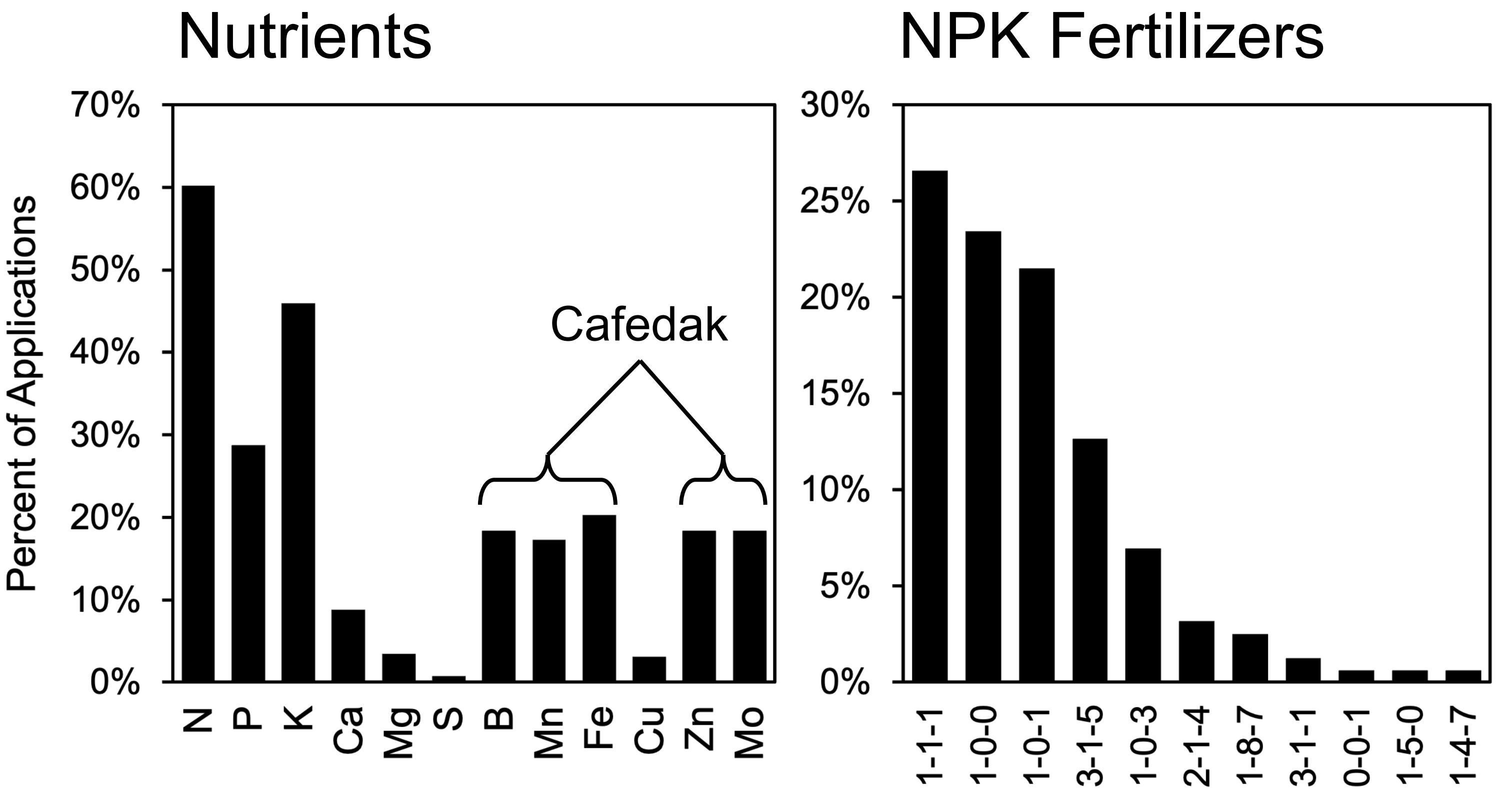
Inter-annual variation in nutrients

- Soil K, Ca, and P fluctuated a lot year to year
- Leaf micronutrients also fluctuated a lot
- Leaf macronutrients like N, P, and K were more stable
- One-time soil tests are unreliable for P and K
  - Leaf testing gives more stable signal



What are growers applying?

- Most applications were NPK:
  - 1-1-1, 1-0-0, 1-0-1
- Few applications included:
  - Ca, Mg, S, Cu
- Micronutrients applied through one foliar blend (Cafedak)



Fertilizer programs don’t match deficiencies

- No correlation between leaf nutrient levels and fertilizer frequency
- Nitrogen most frequently applied, but Potassium is most common deficiency
- More fertilizer does not automatically mean better nutrition
- It’s not about how much you apply, it’s about what you apply

Commonly Deficient	Commonly Applied
K	N
P	K
Zn	P
Cu	Micronutrient blends
N	Ca
Mn	Mg

What should growers do?

1. Leaf & soil testing should be routine – at least once per year

2. Prioritize potassium, as it's the most widespread plant deficiency

3. Smaller, more frequent applications reduce nutrient loss through leaching and runoff– especially on young rocky soils

4. Don't apply nutrients blindly, use targeted strategy guided by test results

5. Adjust fertilizer strategy to your soil type and rainfall
   - Young soils: expect leaching, focus on smaller splits of NPK, monitor Ca:Mg
   - Old soils: watch for N limitation, add organic matter

Acknowledgements

- Funding: USDA NIFA Specialty Crop Research Initiative (SCRI) grant
- Field support: Taya Brown, Karma Kissinger, Jared Nishimoto, Jessica George, Colby Maeda
- Data support: Luis Aristizábal


USDA Agricultural Research Service
U.S. DEPARTMENT OF AGRICULTURE

Synergistic Hawaii Agriculture Council

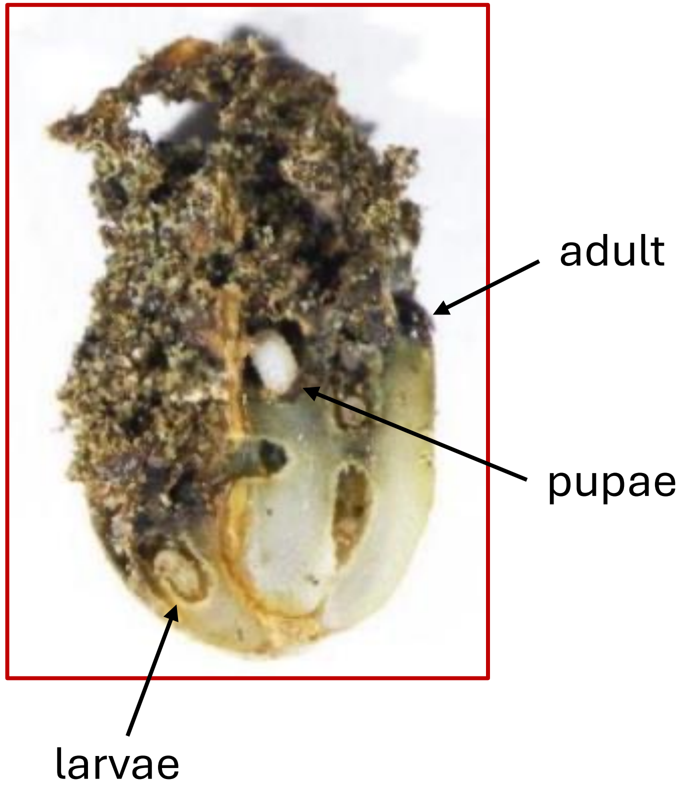


Biological Control of Coffee Berry Borer in Hawaii

Melissa A. Johnson[1], Peter A. Follett[1], Colby T. Maeda[1], Luis F. Aristizábal[2], Mark G. Wright[2]
[1]USDA-ARS Pacific Basin Agricultural Research Center
[2]University of Hawaii at Manoa

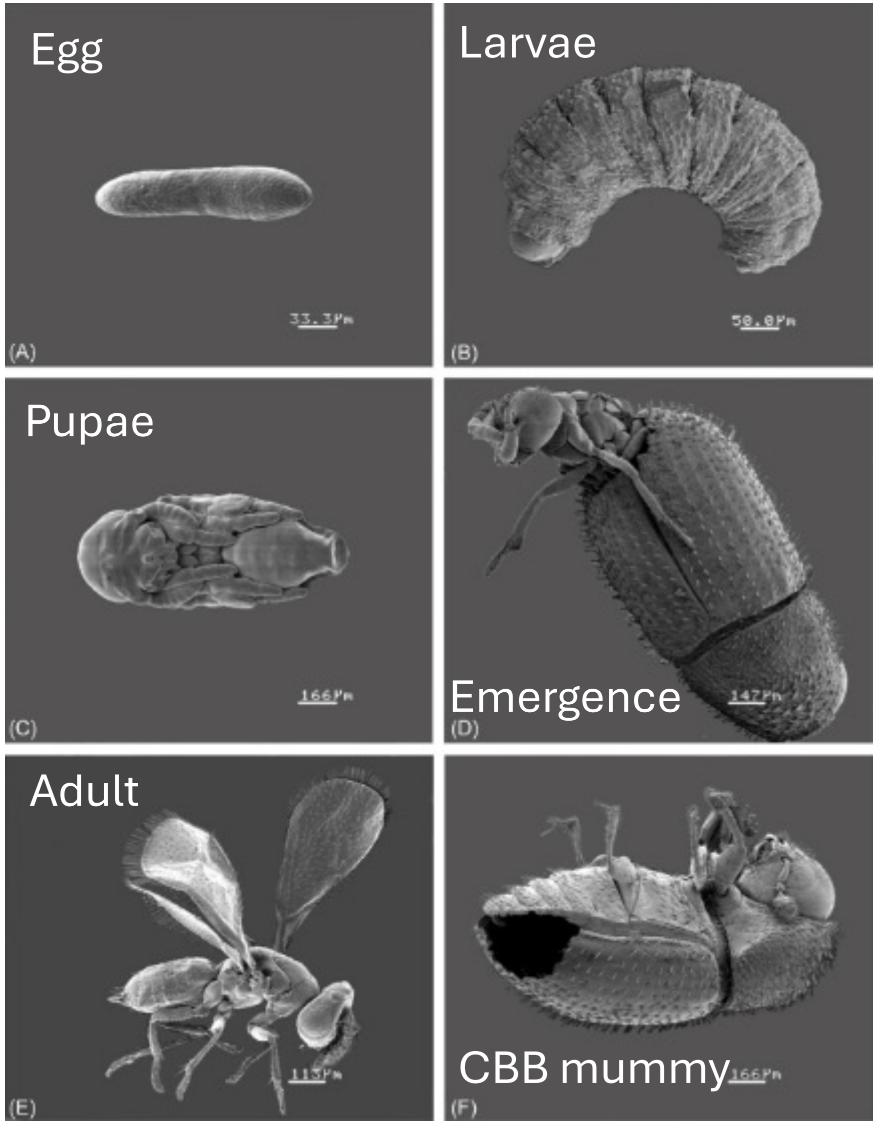
CBB management in Hawaii

- CBB is the most damaging pest in Hawaii coffee
- IPM strategy
  - Pruning (particularly block-stumping)
  - Monitoring
  - *Beauveria bassiana* sprays
  - Frequent & efficient harvesting
  - Sanitation and strip-picking
- Current IPM works but labor intensive and costly
- Lower cost, lower labor solutions are needed



Phymastichus coffea as a potential biocontrol

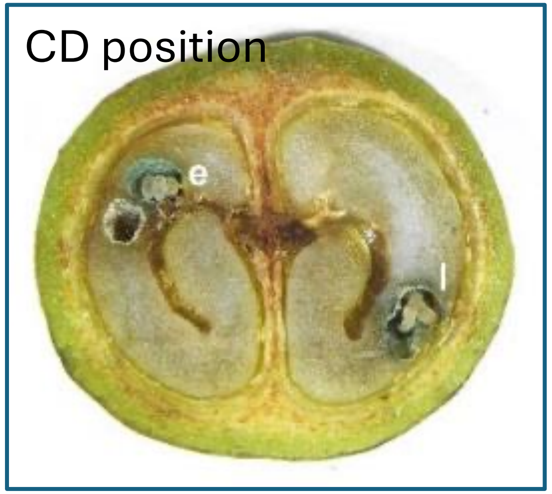
- Tiny wasp ~1 mm in length
- Only known parasitoid of **adult** CBB
- Lays two eggs inside the female CBB during berry entry
- Host dies before reproducing



Vega et al. 2015

P. coffea attacks at the most important stage

- CBB damage begins when female enters berry
- Most other natural enemies attack later
- *P. coffea* attacks during entry – before reproduction
- Prevents damage of the bean



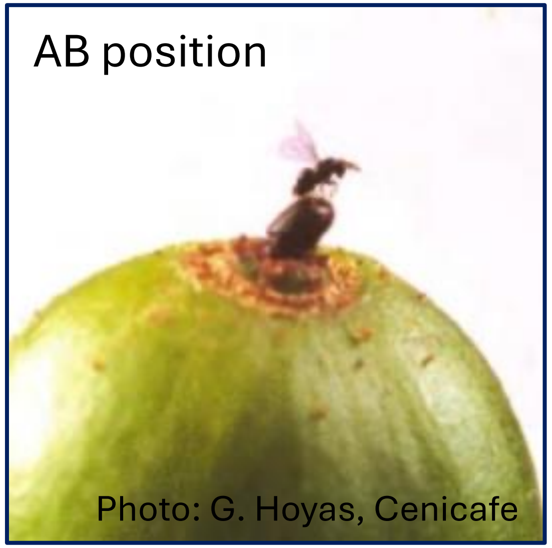


Photo: G. Hoyas, Cenicafe

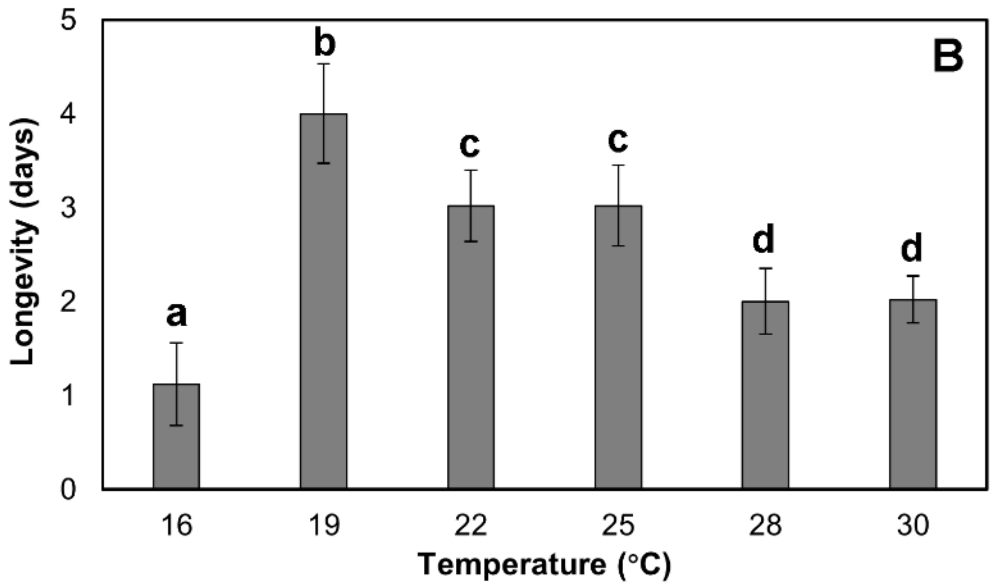
What has been observed elsewhere?

- Parasitism rates: highly variable 10-80%
- Works best when timed with peak CBB flight
- Short-term impact is strong
  - Reduced berry infestation
  - Improved yields & quality
- Long-term establishment inconsistent
  - Environmental conditions
  - Host population, release timing

Photo: D. Honsberger

Limitation #1: Very short adult lifespan

- Only lives for 1-4 days
- Must find host quickly
- Little time to feed
- Most vigorous in first 4-8 hrs
- If CBB flight is low, wasps may die without parasitizing beetles



Giraldo-Jaramillo et al. 2026

Limitation #2: Needs synchrony with CBB flight

- Parasitoids attack adult female CBB as they are boring into the berry
- If CBB are already deep inside berries, it’s too late
- Success depends on release timing
- Requires strong monitoring program
- Timing errors = wasted releases

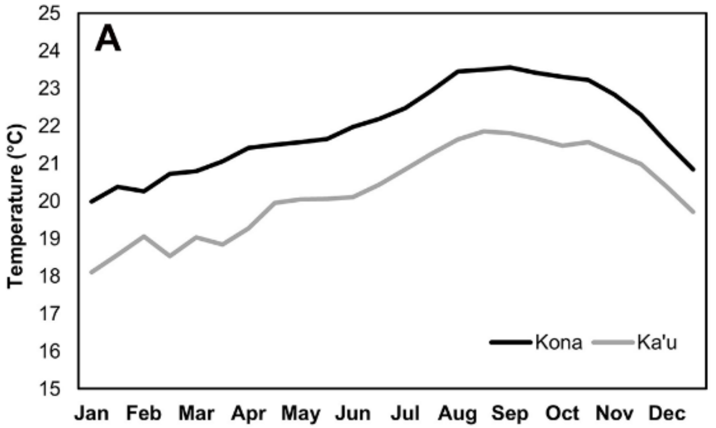
Benavides et al. 2023

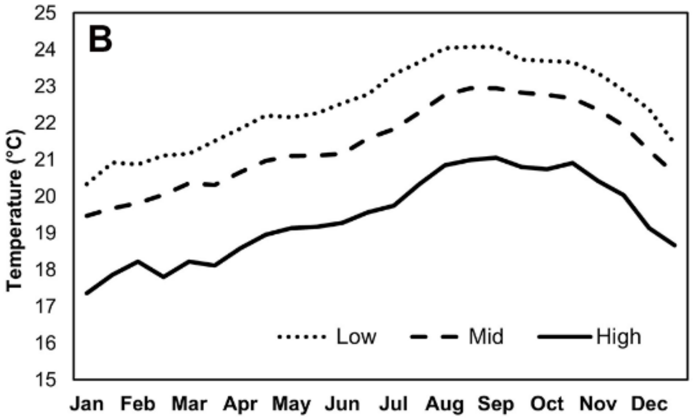
Limitation #3: Seasonal host gaps

- If no CBB, no hosts
  - impact of post-harvest sanitation
- Wasps cannot persist without adult CBB
- Not a self-sustaining "forever" solution
- Likely requires repeat augmentative releases

Limitation #4: Climate constraints

- *P. coffea* optimal temperature range: 22-28 °C
- Hawaii temperatures are generally favorable
- Microclimate differences may affect parasitoid
- Could perform better in some districts/ elevations than others





Limitation #5: Cost & production logistics

- Requires rearing on live CBB hosts
- Production scale affects costs
- Genetic diversity of reared colonies must be maintained
- Economic viability depends on:
  - Cost per acre
  - Reduction in sprays
  - Yield/quality improvement

Field collections in Kenya

Lab colony on diet

Parasitizing CBB on parchment coffee

What a Hawaii strategy might look like

1. Monitor CBB flight
2. Release *P. coffea* just before or at peak flight
3. Follow with *Beauveria* sprays
4. Continue sanitation to reduce breeding sites

Combined effects > individual tactics

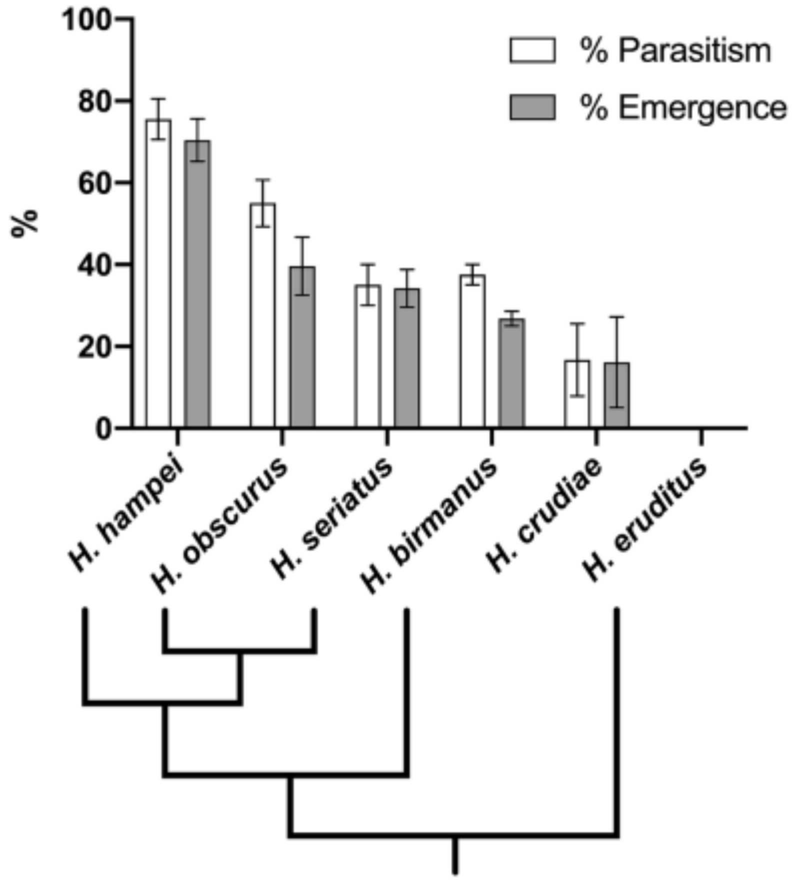
Release of *P. coffea* in the field using mesh pouches

CBB mummies in parchment

P. coffea pupa

Progress here in Hawaii: Host testing

- Host-range testing in Hawaii shows minimal non-target risk
- Highly host-specific to CBB
- 43 beetle species tested, only parasitized 5
- All parasitized beetles were non-native pests



Yousuf et al. 2021

Progress here in Hawaii: CBB colony development

CBB raised on artificial diet to control consistency, reproducibility, and cost when rearing on a large scale


Artificial diet key ingredients:

1. Protein (wheat germ, casein)
2. Carbs (sugar)
3. Nutrient cue (green coffee bean powder)
4. Preservatives (control mold, bacteria)
5. Vitamins (micronutrients)
6. Antibiotic (reduces bacteria)


Progress here in Hawaii: Parasitoid rearing

Ten shipments of *P. coffea* from Cenicafe, Colombia

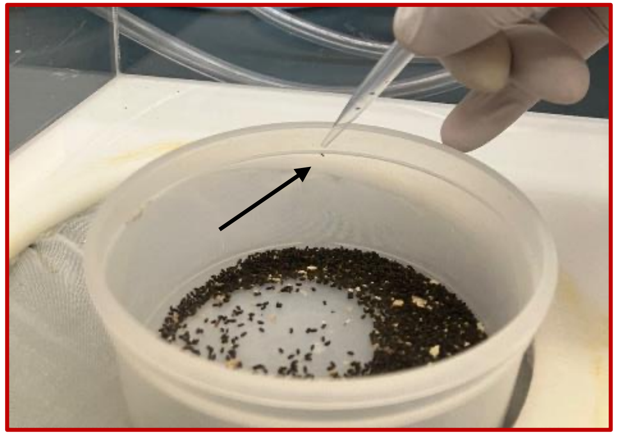
- Shipping considerations (temperature, emergence timing)
- Received in Hawaii ~7-14 days later
- Emergence highly variable: 7-50%

Must be reared in Volcano quarantine facility for 2 generations

Rearing conditions must be perfect

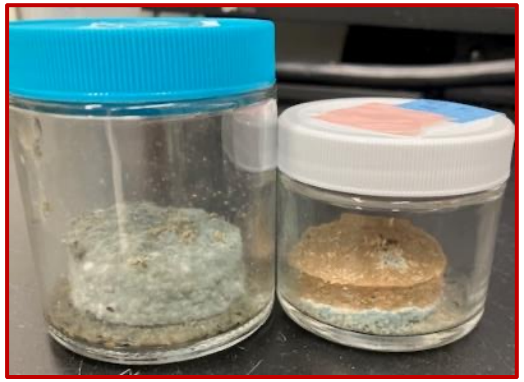
- Light/dark, temperature, humidity
- Access to food and hosts on emergence
- Host density, feeding
- Post-parasitism development
- No contamination (fungus, mites)

parasitoid emerging



parasitoid collection from mummies

Contaminated diet



Potential benefits

- Reduced early infestation pressure
- Fewer berries colonized
- Potential reduction in spray frequency
- Improved quality premiums
- Reduced chemical dependence

What it is NOT: Important clarifications

- Not a silver bullet
- Not a replacement for existing IPM practices
- Not guaranteed to establish permanently
- Works best in coordinated, area-wide programs

What we still need to figure out

- How to optimize parasitoid rearing on mass scale
- Optimal release timing for each district/ elevation
- Cost and logistics of mass rearing locally
- Best integration with *Beauveria*
- Landscape-level coordination

Acknowledgements

- Funding: USDA-APHIS Farm Bill grant, USDA-ARS PBARC base funds

- Technical support: Jessica George, Jared Nishimoto, Karma Kissinger

- Collaborators:

  Pablo Benavides, Zulma Gil, Luis Escobar (Cenicafe)

  Ivan Rwomushana, Duncan Chacha, Dickson Munyasia (CABI Kenya)

  Hilda Diaz-Soltero (USDA-APHIS)

USDA Animal and Plant Health Inspection Service
U.S. DEPARTMENT OF AGRICULTURE

USDA Agricultural Research Service
U.S. DEPARTMENT OF AGRICULTURE