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Evaluation of Coffee Leaf Rust-Resistant Trees Grown at the Kona Research Station

At a Glance: This publication shares our work to identify Coffee Leaf Rust-resistant trees for release to growers. Research was conducted on coffee brought to Hawai'i by Dr. Philip Ito of UH-CTAHR and planted at the UH-CTAHR Kona Research Station. Evaluations of yield and coffee quality spanned the 2021–2022 and 2022–2023 harvest seasons, and two suitable accessions were selected.

Figure 1. Severe defoliation of coffee trees, at left, caused by Coffee Leaf Rust (*Hemileia vastatrix*), at right. (Photos by Andrea Kawabata)

Background

In the mid-1980s, under research supported by a project of the U.S. Agency for International Development (USAID), Dr. Philip J. Ito imported Catimor and Sarchimor hybrid and other coffee seeds from South America to explore coffee's potential as a viable replacement crop for opium growers in Southeast Asia. Following the evaluation of cup quality by Ms. Cathy Cavaletto, two to six seedlings from each of 11 different trees (54 trees or accessions total) were established at the Kona Research Station around 1987. These trees were maintained by station staff for over 30 years, but no further research was conducted until 2021.

Coffee Leaf Rust (CLR) and CLR Resistance in Hawai'i

Coffee Leaf Rust (*Hemileia vastatrix*), or CLR, is found throughout the world on coffee farms. Its arrival to new locations triggers significant changes to the way farmers produce coffee. For over a century, Hawai'i was free of CLR, but in late 2020 this fungal pathogen was discovered on Maui and quickly spread throughout the state (HDOA 2020; Keith et al. 2022). CLR attacks coffee leaves of susceptible varieties and causes lesions, thereby reducing photosynthesis. When CLR is not controlled properly, defoliation occurs (Figure 1). Severe CLR infection can cause yield losses to the farm's current and future crops, tree losses, and high overall economic damage.

Nearly all coffee produced in Hawai'i is from *Coffea arabica.* Among the more common varieties grown in the state are 'Kona Typica', 'Bourbon', 'Mundo Novo', 'Catuai', and 'Caturra', all of which are susceptible to CLR. While there

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are selections of *C. liberica* and *C. canephora* (also known as Robusta), these are typically reserved for rootstock seed to combat the Kona Coffee Root-knot Nematode (*Meloidogyne konaensis*), or CRKN, with grafting (Myers et al. 2020).

After the arrival of CLR to Hawai'i Island, it was observed that 20 of the remaining trees from Dr. Ito's project (Figure 2) showed resistance to rust even though CLR was clearly present on surrounding feral and managed coffee. Leaf bioassay tests, conducted by plant pathologist Dr. Lisa Keith at the U.S. Department of Agriculture, Agricultural Research Service, U.S. Pacific Basin Agricultural Research Center (USDA-ARS-PBARC) in Hilo, confirmed resistance of the trees to CLR Race XXIV (Keith et al. 2023), the only race currently found in Hawai'i. Leaf samples from these trees were collected and submitted by Dr. Tracie Matsumoto of USDA-ARS-PBARC to research geneticist Dr. Dapeng Zhang at the USDA-ARS in Beltsville, Maryland. Dr. Zhang used single nucleotide polymorphisms, or SNPs (Zhang et al. 2021), to identify 15 of the trees as Catimor hybrids, two as Sarchimor hybrids, and three as T8667 hybrids.

Catimor (Diniz et al 2012; World Coffee Research n.d.) is a hybrid created by Portuguese scientists in the late 1950s by crossbreeding 'Caturra' and Hibrido de Timor coffee. 'Caturra' is a natural mutation of 'Bourbon'. Hibrido de Timor or Timor hybrid coffee is the only known natural crossing of *C. canephora* (Robusta) and *C. arabica* that occurred on the island of Timor in Southeast Asia in the early 1900s. Catimor hybrids receive their resistance to CLR from their *C. canephora* heritage. Sarchimor hybrids are a cross between the Timor hybrid and 'Villa Sarchi', a natural mutation of a 'Bourbon' population. T8667 is a cross between a specific Timor hybrid and 'Caturra'. In Central America, T8667 is an important plant for their Coffee Leaf Rust plant breeding program. The T stands for the Turrialba district of Costa Rica, where the Tropical Agricultural Research and Higher Education Center (CATIE) is located, and the numbers represent the accession or tree number.

Assessing for Quality

In 2021, a project was initiated by the authors to determine coffee production, quality, and suitability of these trees for Hawai'i's coffee industry. Data and observations were collected for two seasons. Trees had been stump pruned in early 2021. Subsequently, all except one vertical had been removed in order to manage CLR. During the 2021–2022 season, the harvest was collected from the single, first-year fruiting lateral and in 2022–2023 the harvest was collected from one second-year and two first-year fruiting laterals. Several trees lacked enough fruit for a comparison during those years. Ripe cherries were hand-harvested every two weeks and separated for individual trees. Annual yield and the average weight of at least 250 ripe cherries per season were determined for each tree. Once picked, the ripe fruit were immediately pulped, and the parchment was fermented in water overnight, sun-dried to 10.0–12.0% moisture content, and then vacuum-sealed and stored. Harvests were kept separated by tree throughout the processing.

Following the harvest in 2022, trees with both high yield and large cherry were considered for further quality assessment and cupping. For each accession, parchment coffee from the main harvests were combined,

Figure 2. Important germplasm, including Coffee Leaf Rust-resistant coffee trees, has been housed at the Kona Research Station for more than 30 years. (Photo by Andrea Kawabata)

Figure 3. Beans from 'Kona Typica' and Trees #1, #2, #3, #4, #6, and #15 were assessed during an event held at Greenwell Farms in Kealakekua, Hawai'i in 2023. Coffee Quality Institute-certified Arabica Q-graders conducted standard Specialty Coffee Association cupping for Arabica coffee assessment of fragrance/aroma, flavor, aftertaste, acidity, body, balance, uniformity, clean cup, sweetness, defects, and overall preference. Clockwise from left: Darsen Aoki, Brittany Horn, Dr. Tracie Matsumoto, MaryAnn Villalun, Madeleine Longoria-Garcia, Alex Brooks, and Chai Neo (not pictured). (Photo by Andrea Kawabata)

hulled, sorted on a size-16 screen, and hand-sorted for defects. The larger sorted green beans were roasted by Greenwell Farms, Inc. at a medium roast the day prior to cupping, ground, and then cupped. Using Specialty Coffee Association (SCA) cupping standards, cup quality of five coffees on March 14, 2022 and six coffees on April 4, 2023 was assessed by a panel of Coffee Quality Institute-certified, Arabica Q-grade cuppers (Figure 3). 'Kona Typica' coffee from the Kona Research Station was similarly grown, harvested, processed, and cupped for comparison.

Results and Observations

All 20 trees exhibiting CLR resistance are dwarf in stature (Figure 4) and have either light bronze (Trees #13 and #14), dark bronze (Trees #11, #12, #15, #16, and #17), or green tips (all remaining). The cherries ripen to a red or dark merlot color and are borne in moderately dense clusters (Fig. 5).

Figure 4. Comparative sizes of 'Kona Typica' (left: 12 feet) and Catimor hybrid (right: 8 feet) trees with 3-year-old verticals grown in adjacent fields at the Kona Research Station. (Photos by Andrea Kawabata)

Annual yield and average cherry weight varied greatly among the accessions or individual trees and at times,

Figure 5. Fruiting laterals with immature to ripe cherries on 2- and 3-year-old verticals. This tree produced 23.4 lbs. of coffee in the 2022–2023 season on one vertical in its second year of harvest and two verticals in their first year of harvest. Bamboo props support the vertical to prevent the branch from breaking under the heavy weight. (Photo by Andrea Kawabata)

even among seedling trees from the same mother plant. 'Kona Typica' is the historical standard of Kona Coffee. As such, the goal for any selection from this project was to meet or exceed the production and quality of 'Kona Typica'.

Table 1 provides a summary of data collected from the Catimor, Sarchimor, and T8667 hybrid trees along with the 'Kona Typica'. Selected high-yielding trees that were cupped in the first and/or second years are shaded in green. The two-year total yield and fruit weights of these trees were similar to or greater than that of 'Kona Typica'.

Total yields for the two seasons ranged from 0.3 lbs. to 47.1 lbs. Overall, Tree #15 produced the highest total yield for two seasons at 47.1 lbs, followed by Tree #2 at 42.5 lbs. If adjusted to an annual basis, seven trees had yields higher than or similar to the Hawai'i standard of 15 lbs. per tree needed to produce 100 bags or 10,000 lbs. of cherry per acre.

Average cherry weights for the second season ranged between 2.02 and 2.80 grams per cherry, compared to 2.15 grams for 'Kona Typica'. Average weights were consistently lower for the first harvest, perhaps reflecting increased management, including fertilization, as trees were returned to active cultivation. Tree #4 produced the largest ripe cherry at 2.80 grams per fruit followed by Tree #9 with 2.55 grams. The implication of larger fruit is that processed coffee will have a high percentage of beans in the higher grades, e.g., Extra Fancy and Fancy.

Cupping scores validated the assessments made by Cathy Cavaletto when the accessions were originally selected in the 1980s. Tree #4 produced coffee that cupped highest in both years with average scores of 84.00 and 83.79 followed by Tree #2 with average scores of 82.25 and 82.29. These rate as "specialty coffee" and are higher than the respective scores for 'Kona Typica' of 81.92 and 81.86 for the two harvests. Of note, all of the trees that were cupped had scores that qualify as specialty coffee.

One characteristic of dwarf trees is that the wood of verticals can be brittle. By the second year of production, some of the verticals could not be bent and harvested without potentially breaking the branch. So, benches were employed to reach cherries on the upper branches.

Some trees were observed to have production or processing problems during one or both seasons. Trees #5, #9, and #12 had broken vertical branches, which reduced total yield. These branches were damaged either during harvest or following heavy rain. During both seasons, Trees #11 and #12 produced coffee with a high percentage (>26%) of floaters, or hollow seeds. Additionally, Trees #13 and #14 were accidentally uprooted on August 1, 2022, so yield was lost during that season. These trees were preserved by field grafting (Figure 6) vertical scions onto *C. liberica* rootstock.

Fruit-laden branches were observed to break under the extreme weight of the crop and during heavy rain. Unless noted above, with branch propping and careful picking, the majority of fruits were retained on the laterals and harvested when ripe. Proper methods and timing of pruning, desuckering, and fertilization may help to avoid this issue in future crops.

Releases to Industry

After careful consideration of each individual tree's attributes and contributions to the quality of Hawai'i coffee, Trees #2 and #4 were selected for release to growers. Both had yields higher than or comparable to 'Kona Typica', larger average cherry sizes than 'Kona Typica', and the highest cupping scores among the accessions tested. Seeds from Trees #2 and #4 were germinated, potted, and prepared

Figure 6. After the original trees were uprooted, scion materials from verticals of Trees #13 and #14 were successfully splice grafted onto C. liberica rootstock suckers arising from a grafted coffee tree stump more than 30 years old. This preserved the germplasm for future use while also conferring protection from the Kona coffee root-knot nematode. (Photo by Andrea Kawabata)

Table 1. Yield and quality characteristics from the 2021–2022 and 2022–2023 seasons of ‘Kona Typica’ and top five vs. all other CLR-resistant accessions. Coffees in each group are ranked by total yield (right column).

Tree No.	Tree Accession	2021–2022			2022–2023			Total Yield (lbs)
		Yield (lbs)	Average Cherry Weight (g)	Average Cupping Score*	Yield (lbs)	Average Cherry Weight (g)	Average Cupping Score*	
Accessions selected for quality assessment and cupping								
15	T8667/Costa Rica 95 Hybrid - 67(2-2) No. 12	6.6	2.16	81.92	40.5	2.35	81.54	47.1
2	**Catimor Hybrid - 64(2-4) No. 8 AH**	**4.0**	**2.04**	**82.25**	**38.5**	**2.23**	**82.29**	**42.5**
3	Catimor Hybrid - 64(2-4) No. 8 AH	5.2	1.89		31.7	2.41	81.86	36.9
	‘Kona Typica’**	1.25	1.85	81.92	30.2	2.15	81.86	31.45
4	**Catimor Hybrid - 64(4-1) No. 5 AH**	**5.5**	**1.96**	**84.00**	**24.9**	**2.55**	**83.79**	**30.4**
6	Catimor Hybrid - Catimor 8664 PT1	4.5	2.36	83.33	21.4	2.45	80.79	25.9
All other accessions								
1	Catimor Hybrid - 64(2-4) No. 8 AH	2.0	1.98		32.2	2.19		34.2
7	Catimor Hybrid - 67(2-2) No. 12	2.1	1.88		29.1	2.23		31.2
11	Catimor Hybrid - Catimor Unidentified ***floaters	2.6	1.93		26.5	2.53		29.1
8	Catimor Hybrid - Catimor 8664 PT1	1.1	1.86		26.8	2.04		27.9
10	Catimor Hybrid - 62(2-2) No. 9	3.8	1.55		23.4	2.38		27.2
20	Catimor Hybrid - 62(2-2) No. 12 AH	4.5	1.62		22.6	2.02		27.1
16	T8667/Costa Rica 95 Hybrid - 67(2-2) No. 12	1.9	2.08		21.9	2.24		23.8
19	Catimor Hybrid - 62(2-2) No. 12 AH	1.4	1.69		19.7	2.09		21.1
17	T8667/Costa Rica 95 Hybrid - 67(2-2) No. 5	0.2	2.67		20.1	2.48		20.3
9	Catimor Hybrid - Catimor Excell AH	N/A	N/A		19.9	2.80		19.9
18	Catimor Hybrid - 62(2-2) No. 12 AH	0.5	1.89		17.1	2.26		17.6
5	Catimor Hybrid - 64(2-4) No. 8 AH	2.4	1.67		9.6	2.19		12.0
12	Catimor Hybrid - Catimor Unidentified ***floaters	2.6	2.20		2.0	2.25		4.6
14	Sarchimor Hybrid - Catimor de Columbia T11670	4.2	1.67		N/A	N/A		4.2
13	Sarchimor Hybrid - Catimor de Columbia T11670	0.3	1.63		N/A	N/A		0.3

Bold accessions selected for release to industry

* Size 16 and larger green beans were hand sorted for defects, roasted, cupped, and scored according to SCA protocols.

** ‘Kona Typica’ coffee harvested from grafted trees grown at the Kona Research Station. Yield and average cherry weight were determined from trees with verticals in their first or second year of production.

*** After pulping, more than 26% of parchment consisted of ‘floaters,’ a serious quality defect.

Figure 7. Seedlings and grafted trees from Trees #2 and #4 were propagated in a Kona Research Station greenhouse for release to industry for long-term management of Coffee Leaf Rust. (Photo by Andrea Kawabata)

for dissemination to growers as seedlings or grafted trees (Figure 7) on 'Fukunaga' or 'Meisner' rootstock. Further seed saving and replication is not recommended for these seedling and grafted trees distributed to industry. This is because cross pollination may have occurred, although pollinator exclusion bags were used to produce some of the seed. As of December 2024, growers had received more than 1,940 trees.

Current and Future Endeavors

Individual tree harvests and observations continue to be collected from the original 20 trees—particularly for those lacking a complete second year of data—to continue evaluating yields and quality. Thus far, all of the 20 original trees remain resistant to CLR Race XXIV. The trees will be maintained as potential sources of resistance in the event that other CLR races are introduced to Hawai'i.

Of the 54 trees planted in the 1980s, less than half survived to 2024. CRKN may be a contributing factor for the loss and if so, the surviving trees seem tolerant to that pest. Ongoing research is investigating the CRKN resistance of these accessions.

In 2022, five grafted clones for each of Trees #2 and #4 were established in another field at the Kona Research Station so that yield, cherry weight, and cupping data could be collected from young trees. Their first crop was produced during the 2024–2025 season, and data collection is ongoing. To date, these 10 trees show no susceptibility to CLR. We plan to also evaluate grafted trees from seedlings, grafted trees with tissue-cultured scions on *C. liberica* rootstock, and ungrafted tissue-cultured plants. We will also be establishing test plots to evaluate tree spacing and orchard layouts, and then to review and refine cultivation techniques adapted from 'Kona Typica' such as fertilization and pruning, for recommendation to growers of these new releases.

Important Reminder

The release of propagative materials from Catimor hybrid Trees #2 and #4 is vital for the long-term management of CLR in Hawai'i. Growers are reminded that rotational fungicide applications are still extremely important and necessary for CLR-resistant trees. New races of rust are known to generate from locations where CLR-resistant varieties are grown (Le et al. 2021). While Trees #2 and #4 are currently resistant to CLR Race XXIV, new races created or introduced to Hawai'i may break their resistance to rust and invalidate their role in combatting CLR.

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Disclaimer

Mention of a trademark or proprietary name does not constitute an endorsement, guarantee, or warranty and does not imply recommendation to the exclusion of other suitable products or businesses.

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