Strategic Plan to control Coffee Leaf Rust in Hawaii

December 23, 2020

Purpose of the plan:

- To **control/eradicate** Coffee leaf rust (CLR) in the Hawaii.
- To **assist growers in the immediate emergency** to deal with CLR.
- To **identify** the appropriate varieties of CLR resistant for HI islands; to **import**, **propagate** and **distribute** them to farmers; and to **evaluate** their establishment, **agronomical performance,** health and resistance to CLR on each Hawaiian island.
- To identify and educate farmers on farm management practices to mitigate CLR damage.
- To survey and monitor CLR distribution and response to control efforts.
- To evaluate the economic impacts of CLR in HI.

Strategic Plan

1. **Identify coffee varieties** (leads: Matsumoto, Nagai, Aristizabal (plant accessions) and Meza (cupping)
   Tasks:
   - Identify what potential cultivars in already in Hawaii genotype and determine how they currently perform (Matsumoto and Nagai)
   - Determine rust resistance on lines produced in Hawaii with international cooperators (Matsumoto and Nagai)
   - Determine resistance of cultivars already growing in Hawaii to rust race found in Hawaii. This can begin immediately. Lisa Keith will conduct preliminary disease screening with CLR in Hawaii. Tom Greenwell will collect and transmit leaf samples and has been in contact with PBARC on this topic. These varietals presumably may be cupped in the near term, if they have not already been.

   There are 3 status of CLR resistant varieties.

   A. Propagate and plant CLR resistant varieties already in HI
      - Obata: 100 seeds in Greenwell
      - Tupi: 600 seeds Greenwell (IAC Brazil) 30 trees in Greenwell; 1000 seeds.
      - Catimors: (8776 and 5174 from Promecafe)
      - Victoria: Farmers' Import (Kona Hills) has from Starbuck, Costa Rica
      - San Isidro: from Starbuck farm in Costa Rica
      - CTAHR has some Catimor and other varieties from old collection; rust resistance is not known

        Confirm genotypes by SNP assay before mass propagation?
      - New Coffee germplasm Collection in PBARC can help too. Will take several years. May get clones of varieties brought into HI. Marissa.
      - CR International Trial 36 clones at PBARC for trial at Kauai Coffee (most are resistant to CLR)
      - Varieties that have been imported by Farmers. One variety starts producing coffee in one year, per Chris Manfredi.
      - Cost of variety usage? Will be negotiated with each country and breeder. Cost may be per plant or one-time usage fee.
   - What are other cultivars that may be of interest to Hawaii growers?

     Selection of newly import varieties (Lead: Matsumoto and Nagai, Meza, Aristizabal)
      - Determine names of varieties to be imported
      - Chris: Starbucks is willing to help. Have CLR resistant varieties. Starbucks will prepare and share an ad-hoc catalogue of CLR resistant varieties

- Coffee Industry and Research Institute
  i.e. Promecafe, CENICAFE, WCR, India Coffee Council
  Nagai will contact her coffee breeders/scientists' colleagues:
  1. Alvaro Gaitan
     Director, CENICAFE, FEDERACION NACIONAL DE CAFETEROS DE COLOMBIA
     alvaro.gaitan@cafedecolombia.com

  2. N. Surya Prakash
     Head of Plant Breeding and Genetics, Central Coffee Research Institute, Karnataka, India
     (Gov. of India, Ministry of Commerce and Industry
     nayanirao@gmail.com, dhpb.coffeeboard@nic.in

  3. Bunoit Bertrand, CIRAD, France

  4. JC Herrera, CENIFAFE- Nestle, Tour, France

Contacts around the world, especially in Central America, inform these are CLR resistant varieties they are seeing good results with (information from Meza and Aristizabal).

- One variety that more than one specialty coffee exporter has highly recommended is Obata. Which we imported from IAC, Brazil and have in Hawaii already at HARC. I am told both yields (by BZ growers) and cup quality are superior to traditional cultivars - Typica/Caturra/Catuai Meza does not have much experience with tasting this particular Sarchimor strain, but there is another newer selection of this line called Parainema that is widely grown in Honduras now that I have tasted many times and I can attest that it can produce excellent cup quality.

- Parainema is part of the World Coffee Research variety trial collection so we should have this variety available to us. In addition to being rust resistant it is also nematode resistant. Different species of nematodes in Central America I believe than we have here, but another consideration in favor of this variety.

- **Tabi** is a coffee cultivar resistant to Coffee Left Rust (CLR) (*Hemilea vastratrix*) and Coffee Berry Disease (CBD) (*Colletotrichhum kahawae*). The fact that Tabi cultivar is resistant to CBD was found by a Colombian technician in Africa, since this cultivar was previous introduced to Africa. Tabi is the result of 25 years of research doing plant crosses between several cultivars including Hybrid of Timor, which is resistant to CLR (Race II) and other cultivars such as Tipica, Bourbon, Caturra, and Villa Sarchi. Since Tabi cultivar has a large seed mix from several coffee progenies, the large genetic diversity offers a complete resistance to CLR. Tabi has similar features to Tipica and Borbon related to the plant architecture, height, and bean size. The quality of Tabi coffee cup (cupping) is relatively similar to Tipica and Bourbon. This cultivar is adapted to low elevations (altitude) with partial shadow, high temperature, high sun radiation and long dry periods. It could be work well at low elevation in Kona.

There are some other varieties that are part of the World Coffee Research that Miguel Meza has some experience tasting that he would recommend we look to acquire.

- H1 Centroamericano F1 Hybrid. This one also came highly recommended from those I have talked with. Very good cup quality and excellent production. I have tasted examples from Costa Rica and Nicaragua. Very good acidity and citrusy flavor as washed. This variety makes excellent natural process coffee. Something to consider for the mechanical harvested farms.

- IPR107 from Brazil is also part of the WCR collection. I have tasted this from a higher elevation farm in Thailand where it was superior in the cup to almost all other varieties grown there. Typica, Bourbon, Caturra, Catimor lines. Very good acidity, sweet, citrusy and floral.

- Starmaya is another very recently released variety we should look to acquire. Only just now starting to come into commercial production, thus I have not had a chance to taste it yet. Since its parentage is from an advanced sarchimor line it is probably likely that cup is similar in quality to Obata and Parainema. From the literature, it is reported to be just slightly below the yields and cup quality of H1 Centroamericano, but it has the advantage of being able to be distributed by seed. It also produces a large bean size. A high amount of 19 screen, so potentially a good option for growers concerned with producing Extra Fancy grade. This variety is not Part of the WCR variety trial collection; however, I have a source for it in Nicaragua I have used to get seeds of for growers I work with in Asia in the past. $100/kg of seed. They also have another similar hybrid Called 'Mariana' which uses the same male sterile Ethiopian Parent, but a different Sarchimor parent - IAPAR59 instead of Marsellesa for the Starmaya.

- There are also the Colombian Hybrids. Castillo and many other lines. Castillo has very good cup quality and has been well accepted by the specialty coffee industry. Other Colombia Lines I have tasted like Catimor 129 in Africa produce very good cup quality as washed or natural processed coffees. Tends to have high acidity. Many of the Colombian hybrids also have the advantage of being resistant to coffee berry disease (Colletotrichum kahawae) the only remaining major coffee disease we have left to worry about after rust. The WCR collection has varieties from Colombia Simply called Colombia 1,2,3,4,5. Hopefully someone at WCR or at Cenicafe can provide more background into the differences between these varieties.

A Table with the following information (columns) will be prepared: Varietal, Source country, Yields, Bean size, Cup Quality/SCAA, Drought tolerance, Optimal altitude-elevation, CLR resistance, CBB (coffee berry borer) resistance, Root Knot Nematode resistance, First year of production, Breeder, Intellectual property rights, Priority Score. Below is a first draft of the table of cultivars by Aristizabal and Matsumoto.

Table 1: Cultivar Disease, Cupping, and IP Information

Variety Name	Provider	IP	in Hawaii	Cupping	Rust	CBD	Nematodes	Comments
Anacafe 14*	Guatemala	Public Domain	TBD	Good	Resistant	Susceptible	Susceptible	Drought tolerant,* not uniform and plants not stable from one generation to next
Batian	Kenya	UPOV	WCR IMLVT	Very Good	Tolerant	Resistant	Susceptible	
Castillo	Colombia	Cenicafe	TBD	Good	y	Y	N	
Castillo Zona Centro	Colombia	Cenicafe	TBD	High / 82	y	Y	N	
Castillo Zona Norte	Colombia	Cenicafe	TBD	High / 82	y	Y	N	
Castillo Zona Sur	Colombia	Cenicafe	TBD	High / 82	y	Y	N	
Catiga MG2	Brazil		WCR IMLVT		High	Unknown	Susceptible	"Catimor" from Catuai (not Caturra)

Catimor 129	Colombia	Public Domain	TBD	Good	Resistant	Resistant	Susceptible	
Cenicafe 1	Colombia	Cenicafe	TBD	High / 84	y	Y	N	
Centroamerica (F1)	Promecafe	PROMECAFE	WCR IMLVT	Very Good	Resistant	Tolerant	Susceptible	
Col1	Colombia		WCR IMLVT		High	Unknown	Unknown	
Col2	Colombia		WCR IMLVT		High	Unknown	Unknown	
Col3	Colombia		WCR IMLVT		High	Unknown	Unknown	
Col4	Colombia		WCR IMLVT		High	Unknown	Unknown	
Cuscatleco	PROMECAFE	Public Domain	TBD	Good	Resistant	Unknown	Resistant	Not resistant to Pratylenchus spp is resistant to Meloidogyne
EC15	CIRAD-ECOM		WCR IMLVT		Moderate	Moderate	Susceptible	
Fronton	Brazil	Public Domain	TBD	Good	Resistant	Unknown	Unknown	Early Production and high yielding. Primarily found in Puerto Rico.
Geisha	Panama	Public Domain	WCR IMLVT	Exceptional	Tolerant	Susceptible	Susceptible	
IAPAR 59	Brazil	Public Domain	TBD	Low	Resistant	Susceptible	Resistant	Not resistant to Pratylenchus spp is resistant to Meloidogyne
IPR103	Brazil	Public Domain	WCR IMLVT		Moderate	Unknown	Unknown	One parent is Icatu = originated from an interspecific cross between Arabica and Robusta
IPR107	Brazil	Public Domain	WCR IMLVT	High	High	Unknown	Unknown	
K7	Kenya	Public Domain	Growers	High	Tolerant	Tolerant	Susceptible	
Kartila 1	Indonesia		WCR IMLVT		Moderate	Unknown	Susceptible	
Marsellesa	CIRAD-ECOM	UPOV	WCR IMLVT	Good	Resistant	Tolerant	Susceptible	
Milenio	PROMECAFE	Request	TBD	Very Good	Resistant	Tolerant	Susceptible	F1 Hybrid
Mundo Maya	CIRAD-ECOM	UPOV	WCR IMLVT	Very Good	Resistant	Tolerant	Resistant	
Obata	Brazil		HARC	High	Resistant	Unknown	Unknown	
Oro Azteca	Mexico	UPOV	WCR IMLVT	Good	Resistant	Susceptible	Susceptible	
Parainema	Honduras	Public Domain	WCR IMLVT	Good	Resistant	Tolerant	Resistant	Not resistant to Pratylenchus spp is resistant to

								some Meloidogyne
Paraiso	Brazil		WCR IMLVT		High	Unknown	R Exigua	"Catimor" from Catuai (not Caturra)
Ruiru 11	Kenya	UPOV	WCR IMLVT	Good	Tolerant	Resistant	Susceptible	
S4808	India		WCR IMLVT		High	Unknown	Unknown	May segregate for few tall types
S795	India		WCR IMLVT		Moderate	Unknown	Unknown	S.288 (*C.liberica* introgressed line) x Kents
San Isirio	Costa Rica	Starbuck Costa Rica	TBD		Y			
Starmaya	CIRAD-ECOM	UPOV	TBD	Very Good	Resistant	Unknown	Unknown	
Tabi	Colombia	Cenicafe	TBD	Good	Y	Y	N	
Tupi			HARC		Resistant			
Victoria	Costa Rica	Starbuck Costa Rica	Kona Hills		Y			

Table 1 continued: Other Agronomic Traits

Variety Name	Habit	Genetic Group	Altitude	Yield	Bean Size	Prod Year	Drought Tol.	Reference
Anacafe 14*	Dwarf	Introgressed Catimor	>700m or >2,297 ft	High	Very Large	Year 2	Yes	1
Batian	Tall	Introgressed Catimor	>400m or >1,320 ft	High	Very Large	Year 2		1
Castillo								
Castillo Zona Centro								
Castillo Zona Norte								
Castillo Zona Sur								
Catiga MG2	Dwarf	Catimor						
Catimor 129	Dwarf	Introgressed Catimor	400–1000m or 1, 320-3,281 ft	Very High	Large	Year 2		1
Cenicafe 1								
Centroamerica (F1)	Dwarf	Hybrid	>400m or >1,320 ft	Very High	Large	Year 2		1
Col1	Dwarf	Catimor						
Col2	Dwarf	Catimor						
Col3	Dwarf	Catimor						
Col4	Dwarf	Catimor						
Cuscatleco	Dwarf	Introgressed Sarchimor	400–1000m or 1, 320-3,281 ft	Good	Large	Year 3		1
EC15	Dwarf	Hybrid						
Fronton	Dward	Introgressed Catimor	400–1000m or 1, 320-3,281 ft	Good	Average	Year 2		1
Geisha	Tall	Ethiopian landrace	>1000m or >3,281 ft	Medium	Average	Year 4		1

IAPAR 59	Dwarf	Introgressed Sarchimor	400–1000m or 1, 320-3,281 ft	Good	Average	Year 3		1
IPR103	Dwarf	Catucai						
IPR107	Dwarf	Sarchimor						
K7	Tall	Bourbon-Typica	400–1000m or 1, 320-3,281 ft	High	Large	Year 3		1
Kartila 1	Dwarf	Catimor						
Marsellesa	Dwarf	Introgressed Sarchimor	400–1000m or 1, 320-3,281 ft	High	Average	Year 3		1
Milenio	Dwarf	F1 Hybrid	>700m or >2,297 ft	Very High	Large	Year 2		1
Mundo Maya	Dwarf	F1 Hybrid	>700m or >2,297 ft	High	Large	Year 2		1
Obata	Dwarf	Introgressed Sarchimor	400–1000m or 1, 320-3,281 ft	High	Large	Year 3		1
Oro Azteca	Dwarf	Catimor	400–1000m or 1, 320-3,281 ft	High	Average	Year 3		1
Parainema	Dwarf	Introgressed Sarchimor	400–1000m or 1, 320-3,281 ft	Good	Large	Year 3		1
Paraiso	Dwarf	Catimor						
Ruiru 11	Dwarf	Multiple hybrid	>400m or >1,320 ft	Very High	Large	Year 2		1
S4808	Dwarf	Catuai						
S795	Tall	Introgressed Liberica						
San Isirio								
Starmaya	Dwarf	F1 Hybrid Introgressed	700-1000m or 2,297-3,281 ft	High	Large	Year 2		1
Tabi			Low elevations					
Tupi		Introgressed Sarchimor						
Victoria								

Budget Task 1: Identify coffee varieties	Year 1	Year 2	Year 3	Year 4	Year 5 to 10
Point A: Propagate & plant CLR resistant varieties in HI	1000K	1000K	1000K	1000K	TBD
Point B: Selection newly imported Varieties Nagai and Matsumoto	30K	30K	30K	30K	TBD

Subtotal	130K	130K	130K	130K	TBD

2. **<u>Coffee varieties in testing in HI as of December 2020 recommended for propagation</u>** (leads: Tracie Matsumoto)
    A. Varieties in testing in HI
    Obata and Tupi
    -In 2017-2018, Cupping quality of Tupi and Obata (HARC Kunia Field) was evaluated. No difference from SL28
    -About 100 seedlings of 2 varieties were at Tom Greenwell Farms. Some trees are producing seeds.
    -DNA fingerprinting was conducted by USDA-ARS Beltsville , Dapeng Zhang's team
- In October 2021, 1000 seeds from each variety are available at HARC for planting

A table with the following information (columns) will be prepared: Varietal, Source country, Yields, Bean size, Cup Quality/SCAA, Drought tolerance, Optimal altitude-elevation, CLR resistance, CBB (coffee berry borer) resistance, Root Knot Nematode resistance, First year of production, Breeder, Intellectual property rights, Priority Score. Below is a first draft of the table by Chifumi Nagai.

Collection of rust resistant cultivars imported to Hawaii (Chifumi Nagai)

Cultivar	***Breeding Line***	***Source***	***Year***	***Rust***	***Progeny***	***Importer***
Icatu	?	Brazil	1992	R	Yes	Pioneer Mill Co
Catimor	T-5175	Promecafe, Dr. Osorto, Guatemala	1991	R	Yes	HARC
Catimor	T-8667	Promecafe, Dr. Osorto, Guatemala	1991	R	Yes	HARC
Icatu vermelho	2941	Dr. H. Medina, IAC, Campinas,Brazil	1997	R, horizontal	No	Dan Kuhn CTHAR
Icatu vermelho	LMC4782	Dr. H. Medina, IAC, Campinas,Brazil	1997	R, horizontal	No	Dan Kuhn CTHAR
Catimor	5175	Dr. H. Medina, IAC, Campinas,Brazil	1997	R	No	Dan Kuhn CTHAR
Obata	LMC1669-20	Dr. H. Medina, IAC, Campinas,Brazil	1997	R	2016crosses	Dan Kuhn CTHAR
TUPI	LMC1669-33	Dr. H. Medina,IAC, Campinas, Brazil	1997	R	2016 crosses	Dan Kuhn CTHAR

B. Additional Research needs for this task

- What race(s) of CLR is in HI? Lead: Tracie Matsumoto, Lisa Keith working with Vitor Varzea from Portugal.

- What race(s) are more virulent in other countries? Do this research. The ARS unit in Ft. Detrick, MD has historical collections of rust isolates in a repository. Currently, they are collaborating with Cathy Aimee, Purdue Univ., to sequence some of these isolates. Potentially more work could be done with this collection. Contact is Tim Widmer, ARS.

- Look for varieties that are resistant to nematodes, which nematodes are affecting them?
  Many coffee varieties have nematode resistance (Pratylenchus spp or *Meloidogyne* spp), but the resistance to *Meloidogyne konaensis*, the root knot nematode prevalent in Hawaii, is unknown for many of the CLR resistant varieties. In Kona nematodes create 60% reductions in coffee. Greenwell wants all the varieties possible to be brought into HI. Roxana Myers at PBARC is working on nematodes resistance.

- There is Modeling for coffees in other countries to predict disease severity; ask for those models.

- Coffee production loss.
  The losses in Kona have not been directly measured outside CTAHR research. More accurately, current statewide statistics show a 60-70% drop in yield. Since not all the state -- only the Big Island and Maui is known to be infested, the implication is that losses in affected areas are much higher. Greenwell wants all the varieties possible to be brought into HI. PBARC is working on nematode resistance in collaboration with CTAHR.
- Grafting techniques - If cloned/tissue cultured plantlets of non-resistant/tolerant varieties will be used, there is a need to investigate grafting techniques onto coffee root-knot nematode resistant/tolerant rootstock.

  A. Greenhouse comparisons (LEAD: Roxana Myers)
     a. New CLR resistant varieties will be inoculated in potted assays to determine the resistance to *Meloidogyne konaensis*
     b. Will determine if new CLR resistant plants will need to be grafted or can be planted directly into potentially infested soil.

  B. Grafting compatibilities (Myers and Matsumoto)
     a. Determine if cultivars susceptible to *Meloidogyne konaensis* are compatible with different resistant rootstock
     b. How does the grafted material perform in the field?

  C. **Field comparisons** for productivity and general acceptability of selected CLR resistant varieties, as ungrafted and grafted (for *Meloidogyne konaensis* nematode management) plants. (Kawabata, Nakamoto)

     a. **Field comparisons** of selected CLR resistant varieties, as ungrafted and grafted (for *Meloidogyne konaensis* nematode management) plants. Lead: Kawabata, Nakamoto.

     b. Side by side comparisons, in typical field conditions, to assess characteristics including yields and quality, general plant characteristics, plant health including susceptibility to nematodes and CLR

  D. **Outreach & Communication** (Kawabata, Nakamoto)**:** CTAHR will work with PBARC to incorporate grafting with rootstock into CLR integrated pest management recommendations for Hawaii producers. This information will be shared with researchers, farmers, industry professionals and interested agencies through a variety of materials including scientific publications, short outreach reports, newsletters, website, printed materials, mailings, presentations, workshops, field days, one-on-one and small group consultations, and farm doctor visits.

Budget Task 2: Coffee varieties in testing recommended for propagation	Year 1	Year 2	Year 3	Year 4	Year 5 to 10
Point A: Coffee varieties in testing	50K	50k	50K	50K	TBD
Point B: Research needs	80K	80K	80K	80K	TBD
Point C: Field comparisons	$100K	$30K	$30K	$30K	TBD
Point D: Outreach & communication	$30K	$20K	$20K	$20K	TBD
Subtotal:	$260K	$180K	$180K	$180K	TBD

3. **<u>Obtain permits to import CLR resistant coffee varieties</u>** into Hawaii (lead: Tracie Matsumoto/Chifumi Nagai (plant accessions)

- **<u>Negotiate use rights and HI State permits of the CLR resistant varieties already in HI</u>** (Chifumi Nagai, Tyler Jones, Tracie Matsumoto)
  Negotiate a faster HDOA regulatory permitting process. Need to remove barriers to permits, importation and propagation during quarantine. Shorten quarantine period (currently one year). Privatize/license quarantine facilities to grow capacity.

- **<u>Negotiate use rights and federal permits of the CLR resistant varieties outside of HI from other USA states or countries</u>** (Chifumi Nagai, Tyler Jones, Chris Manfredi, Vernon Harrington, Tracie Matsumoto)

- Secure APHIS and HDOA permits to bring in material
- Negotiate permits to propagate coffee lines from other US states
- Negotiate permits to propagate coffee lines from other countries
  Colombia (negotiate with Cenicafe)
  Nicaragua
  Other countries?
- 100 varieties: how many are open source? Chris will find out from Starbucks. Tracie and Chifumi Nagai will make a table with the information; and rank them. This is a two months task.

- Include trials in different climatic regions (ie. Kau, Kauai, Kona, Maui and Oahu).Lead: Matsumoto
  - <u>Expand WCR and other varieties to fields trials in different locations.</u>
  - Compare agronomic trait growth, yield, flowering and fruiting seasonality.
  - Resistance to pest and diseases - including resistance to CLR and *Meloidogyne konaensis*. Determine best management practices for CLR susceptible cultivars. Determine susceptibility to new pest and diseases currently in Hawaii.

- Cupping quality – including bean yield, size and cupping quality.

Budget Task 3: Obtain permits to import CLR resistant varieties to HI	Year 1	Year 2	Year 3	Year 4	Year 5 to 10
Point A: Use rights for varieties in HI	30K	30K	0	0	0

Point B: Use rights for varieties in states or other countries	30K	30K	0	0	0
Compare agronomic traits & resistance to pests; trials in different islands	120K	120K	120K	120K	TBD
Subtotals	$180K	$180K	$120K	$120K	TBD

4. **Propagation of CLR resistant varieties, both imported from states or countries and those already in HI** (lead: Chifumi Nagai-HARC and Tyler Jones)
   Propagate while in quarantine, as well as after quarantine. Planting Material for field evaluation:
   - F1 hybrids: Clonal propagation by tissue culture (somatic embryogenesis)
   - Self-seeds: At flowering self-pollinated by using pollination bag
   - Coffee plants imported from states or other countries

A. **Micropropagation of CLR Resistant Varieties at HARC** (Lead Tyler Jones)

Hawaii has limited capacity to produce planting material of putative CLR resistant varieties at commercial scale. Micropropagation through somatic embryogenesis (SE) is a powerful tool to rapidly produce large quantities of plants from a limited initial supply. The methods for SE are well developed for coffee and have been performed in Hawaii.

Production of plantlets has three primary stages

- Stage 1: Establishing embryo culture in preparation for large scale micropropagation
- Stage 2: Setup of Bioreactor Facility
- Stage 3: Plantlet production and acclimatization

Plantlets produced through the SE process could be sent to nurseries/farmers to incorporate into their existing nursery operations, grafted immediately onto nematode resistant root stock or used for scion production for field grafting. Plantlets would also be made available to CLR resistant variety trials.

Stage 1: Establishing coffee embryo culture in preparation for large scale micropropagation

HARC has previous experience in establishing coffee embryos from leaf tissue and existing staff and facilities without any need for significant investment to complete stage 1. The embryos created during this process would be suitable for further multiplication in bioreactors. Varietal differences in adaptability to propagation is common in almost all crops, and coffee is likely no different. The success rate of varieties will not be known until the process begins. The costs are based on the varieties responding reasonably well to embryo establishment, but with some buffer to further multiply if some of the varieties are more difficult.

Annual Costs Estimate: $35,000

Timeframe: 6-9 months after receiving the leaves depending on the varietal effects.

Stage 2: Setup of Bioreactor Facility at HARC

HARC's existing tissue culture facility has space for approximately 1600 additional bioreactors. HARC has no additional capacity in our existing bioreactors, so setup costs would be relatively significant. Costs are based an initial setup of 400 bioreactors in first year. Additional bioreactors to be setup in year 2-3 based on demand. HARC to provide methods and consultation to private sector in setting up additional capacity as requested.

Timeframe: 1 month

Year 1 Cost Estimate: $51,000: $120 per bioreactor, (400 x $120 = $48,000) plus $3,000 for miscellaneous supplies and labor to setup.

Stage 3: Plantlet Production in Bioreactors at HARC

The exact number of plants to fit in each bioreactor and the time needed to go from embryo to rooted plantlet is unknown (variety specific), so a range is presented:

- 100 plants per bioreactor = 40,000 plants
- 200 plants per bioreactor = 80,000 plants

After production in bioreactor, plantlets to be transferred into high humidity greenhouse for acclimatization prior to shipment. Plantlets will be transferred to soil in HARC's acclimation Room and will be sent to nurseries in 1 to 2 inches size.

Timeframe: 4-7 months after embryos produced

Costs: $85,000

Total time needed: 10 - 15 months

Total Plants: 40,000-80,000 plantlets

Year 1 Costs: $170,000

- $35,000 for embryo production is relatively fixed, annual costs
- $51,000 in capital costs for bioreactors. Bioreactors have lifespan of 7+ years to be reused
- $85,000 for labor and supplies and to growing plants in bioreactors and acclimatization in greenhouse are variable costs ($1.07 - $2.13 per plantlet)

Future Production and Costs: $155,000 per year for years 2-5

- 40,000-80,000 plants every 6-8 months; 60,000 – 160,000 per year
- $155,000 per year: $35,000 for embryo generation + $120,000 for plantlet production
- Ability to add 1,200 additional bioreactors to meet demand

B. Field Grafting / Orchard Rehabilitation

The ability to field grafting CLR resistant scion onto trees stumped as part of farmers CBB management practices would allow farmers to test CLR resistant varieties without needing to replant existing orchards and with minimal loss of production. This type of on-farm testing would work in parallel with the more centralized, scientifically rigorous variety trials planned. The book, *Coffee: Growing, Processing, Sustainable Production*, edited by Jean Nicolas (2004), provides an extensive review of coffee orchard rehabilitation through grafting onto stumped trees in an existing orchard (pages 107 – 115). Multiple techniques are available and detailed in the book. As grafting success is dependent on genetic and climate factors, R&D is needed to develop optimal methods for Hawaii and the different climate regions within Hawaii. The steps required to develop the optimal methods are relatively straightforward and should progress rapidly. Once developed, methods would be taught to farmers. In addition to determining grafting methods, R&D is needed to determine efficient production methods of CLR resistant scion at scale.

Timeline:

- Year 1: Optimization of field grafting for the various growing regions in Hawaii and R&D to develop prototype scion production nurseries
- Year 2: Training with Hawaii coffee farmers and establishment of commercial scale scion production nursery and transfer nursery production to private sector; monitoring of grafted orchard performance and continued optimization
- Year 3: Continued R&D on scion production and addition of new CLR varieties; transfer of nursery production to private sector;
- Year 4: Continued addition of new varieties, monitoring, optimization and tech transfer
- Year 5: Continued addition of new varieties, monitoring, optimization and tech transfer

Budget:

- Year 1: $80,000
- Year 2: $80,000
- Years 3 - 5: $65,000; years 6 to 10 TBD

C. Identify the coffee plant characteristics when they are ready for transplant in farms. (Matsumoto). Identify the different coffee varieties best suited to each HI island (Matsumoto)

Budget Task 4: Propagation	Year 1	Year 2	Year 3	Year 4	Year 5 to 10
Point A: Micro propagate CLR Resistant varieties Tyler	170K	155K	155K	155K	TBD
Point A: Acclimation & Distribution Tyler	80K	80K	80K	80K	TBD
Point B: Field Grafting R&D and Tech transfer Tyler	80K	80K	65K	65K	TBD
Point C: Monitor plant characteristics at transplanting & best coffee for each island Matsumoto	-	80K	80K	80K	TBD
Subtotals	$250K	$395K	$380K	$380K	TBD

5. **<u>Distribution of CLR resistant varieties to farmers</u>** (Lead Coffee Industry Manfredi? and Andrea Kawabata)

   A. Subsidize materials, equipment, pesticides, other chemicals, soil, fertilizer needed by farmer. Cost estimates per tree propagated; give as cash to the farmer with the tree.
   B. Train farmers (give certification) of coffee variety transfer.
   C. Quarantine station delivers trees to each farm (minimizes contamination at quarantine)
   C. <u>Outreach & Communication (Kawabata, Nakamoto)</u>**:** CTAHR will work with PBARC, HARC, and the coffee associations to incorporate CLR resistant variety results into CLR integrated pest management recommendations for Hawaii producers. This information will be shared with farmers, industry professionals and other interested parties through a variety of materials including extension publications, short outreach reports, newsletters, website, printed materials, mailings, presentations, workshops, field days, one-on-one and small group consultations, and farm doctor visits.

Budget Task 5: Distribution CLR resistant varieties to farmers	Year 1	Year 2	Year 3	Year 4	Year 5 to 10
Point A: Subsidies to farmer per Tree Manfredi	TBD	TBD	TBD	TBD	TBD
Point B: Train farmers Manfredi	TBD	TBD	TBD	TBD	TBD
Point C: Delivery from Quarantine Stations Manfredi	TBD	TBD	TBD	TBD	TBD

Point D: Outreach & Communication	30K	20K	20K	20K	TBD
Subtotals:	$30K	$20K	$20K	$20K	TBD

6. **CLR Survey and monitoring program** (leads: Lisa Keith, Melissa Johnson)
   Objectives:
   A. Germplasm screening using leaf bioassays (Lisa).

   B. Survey coffee farms for CLR % incidence and severity (Lisa).

   C. Collect data on plant performance/health (coffee yield and quality) (Melissa).

   D. Expand existing network of weather stations to monitor microclimate factors that may promote/limit CLR in different coffee-growing areas (Melissa).

   E. Outreach and Communication of research findings (Andrea/Stuart).

   Study Sites: The study will be carried out at farms varying in elevation and microclimates on Hawaii Island, Kauai, Maui and Oahu. For the coffee variety trials, farms will employ conventional management practices without attempting to control CLR. For overall CLR monitoring on Hawaii Island. On Hawaii Island, 6 farms will be monitored in Kona, 4 in Ka'u, and 2 in Hilo. On neighboring islands, the number of farms surveyed will need to be determined by availability of labor. Individual teams on each island will monitor study sites every two weeks. PBARC can monitor farms on Hawaii Island. Similar efforts will need to be expanded to other islands, and PBARC can assist with training field workers in monitoring methods.

   Experimental Design**:** Potential CLR resistant varieties already present or imported into Hawaii will be used in this field study. The experimental plots will be laid out in a Randomized Complete Block Design with four replications per farm. CLR susceptible Typica will serve as the positive control for comparison purposes. Each cultivar will be represented by 20 trees consisting of five trees per replication (or adjusted accordingly depending on how much germplasm is available for testing). Cultivars will be pre-screened using leaf bioassays and a collection of CLR isolates collected from Hawaii Island and Maui.

   Disease assessment**:** The incidence and severity of CLR and the area under the disease progression curve (AUDPC) will be evaluated. CLR incidence (percentage of trees affected per farm) will be assessed at 20-day intervals from randomly selected leaves from the lower and middle thirds of the canopy (Silva-Acuña et. al., 1999). Disease severity will be scored using a 0-9 scale developed by Eskes and Toma-Braghini (1981). The severity of CLR will be measured in the upper, middle and lower sections of the coffee trees and scoring will be done when defoliation starts and more than 50% of the leaves of the most susceptible genotypes have sporulating lesions.

   Environmental variables**:** Rainfall, air temperatures, relative humidity, solar radiation, wind speed and direction, and leaf wetness will be monitored using RX3000 remote weather stations. Soil classification and pH range will also be determined.

   Yield & Quality**:** Crop yield will be assessed by collecting and weighing all mature fruit from experimental trees bi-weekly throughout the harvest season to get an average yield per tree. Coffee fruit will then be processed, dried and roasted according to standardized protocols developed and used at PBARC. Quality assessments will be made based on cupping scores averaged across a panel of certified Q graders.

Data analysis**:** Generalized Linear Mixed Models (GLMM) will be used to compare rust resistance in existing varieties (e.g. typica) with newly planted varieties (TBD). Fixed factors will include % incidence, severity, yield, and quality. Random factors will include year, farm, and elevation. Correlations will be done to estimate the relationship between incidence and severity with individual weather factors

Outreach & Communication (lead--Kawabata, Nakamoto)**:** PBARC will work with CTAHR to incorporate results into CLR integrated pest management recommendations for Hawaii producers. This information will be shared with researchers, farmers, industry professionals and interested agencies through a variety of materials including scientific and extension publications, short outreach reports, newsletters, website, printed materials, mailings, presentations, workshops, field days, one-on-one and small group consultations, and farm doctor visits.

Budget Task 6: CLR Survey and Monitoring	Year 1	Year 2	Year 3	Year 4	Year 5 to 10
Point A: Germplasm screening (Lisa)	$15K	$10K	$10K	$10K	TBD
Point B: Incidence & severity monitoring (Lisa)	$95K	$85K	$85K	$85K	TBD
Point C: Yield & quality monitoring (Melissa)	$55K	$55K	$55K	$55K	TBD
Point D: Weather station network (Melissa)	$25K	$5K	$5K	$5K	TBD
Point E: Outreach & Communication (A&S)	$30K	$20K	$20K	$20K	TBD
Subtotals:	$220K	$175K	$175K	$175K	TBD

7. **CLR field management research program**.

The development and availability of rust resistant varieties will encompass a multi-year timeline for the industry to transition to new cultivars. However, some coffee growers will not want to replace the Typica variety known for superior coffee quality. In either scenario, fungicides will be an important management tool for coffee leaf rust, but copper fungicides must be present on the leaf prior to infection and copper soil accumulation is a major environmental concern. Currative treatments include the use of systemic fungicides (triazoles and strobilurins). Other fungicides, such as dithiocarbamates, are effective but their residues do not adhere well to the waxy leaves and are susceptible to heavy rain wash-off. The effectiveness of fungicides as control measures is significantly affected by the timing and rates of applications. As a further challenge, most systemic fungicides are not registered for use on coffee in Hawaii. In addition to fungicides, several cultural practices are important in preventing/managing coffee leaf rust. Major coffee growing regions of the world use an integrated approach to control CLR. Protocols include environmental monitoring to predict optimum CLR conditions, fungicide sprays, optimizing fertilization for tree health, pruning, and sanitation practices. Many of the techniques used in other countries could be employed in Hawaii. However, due to the high degree of variability in environmental and cultural practices in Hawaii, these practices should be customized into CLR management programs that are specific to each location within the landscape context. The critical challenge for Hawaii will be to implement "custom" IPM at the landscape level. To reach this goal, we will need to define, test and implement suites of control strategies in a location-specific system to optimally control CLR across the variable coffee-growing microclimates in Hawaii. Completion of the following tasks will lead to an integrated, yet custom, system for Hawaii's coffee growers to control CLR.

A. Produce initial CLR IPM recommendations for coffee farmers. Use APHIS CLR Guidelines 17 Nov. 2020. Hold CLR summit to organize CLR IPM recommendations.

B. Determine timing, scheduling and application rates of available registered fungicides and conduct efficacy trials. Determine fungicide rotations and conduct trials with new systemic fungicides.

C. Determine the role and timing of stumping, pruning and disposal methods for CLR management. Determine optimum field sanitation methods.

D. Determine the role of feral, abandoned, and poorly managed coffee on the spread of CLR to managed coffee orchards.

E. Implement environmental monitoring and CLR incidence data into predictive models for preventative sprays. Integrate into mobile app to disseminate real-time data to growers.

Budget Task 7: Field Management	Year 1	Year 2	Year 3	Year 4	Year 5 to 10
Point A: Intial CLR IPM recomm.	$5K	0	$5K	0	TBD
Point B: Fungicide trials	$80K	$50K	$80K	$50K	TBD
Point C: Pruning & sanitation	$80K	$50K	$80K	$50K	TBD
Point D: Feral coffee CLR spread	$40K	$40K	$40K	$40K	TBD
Point E: Integrate data to mobile app	$50K	$50K	$50K	$50K	TBD
Subtotals:	$255K	$190K	$130K	$190K	TBD

8.Economic Analysis and Impacts (lead Marisa Wall with APHIS support Zavala)

A. Potential loss if widespread CLR. For a quick estimate: use 2019's $53 million farmgate value x whatever loss percentage is desired. Multiply by 2 to include a crude estimate of effect on the rest of the economy ("multiplier effect").
B. Cost to switch to CLR resistant varieties.
C. Short term costs for treatment (data for# 8 above)

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Budget Task 8: Economic Analysis	Year 1	Year 2	Year 3	Year 4	Year 5 to 10
Point A: Potential loss if widespread CLR Marisa	$40K	$40K	-	-	TBD
Point B: Cost to switch to CLR varieties Marisa	$30K	$60K	-	-	TBD
Point C: Short term cost of treatments Marisa	$30K	$40K	-	-	TBD
Subtotals:	$100K	$140K	-	-	TBD

9. **Coordinator for the Implementation of the CLR Strategic Plan**
   A. Salary and benefits $200,000 per year (APHIS permanent position, stationed in HI)

Budget Task 9: Coordinator for Implementation of Strategic Plan	Year 1	Year 2	Year 3	Year 4	Year 5 to 10
Point A: Salary & benefits	200K	200K	210K	210K	TBD
Point B: Travel	50K	50K	50K	50K	TBD
Point C: Office costs	34K	24K	24K	24K	TBD

Subtotals:	$284K	$274K	$274K	$274K	TBD

BUDGET SUMMARY

Budget to Implement Strategic Plan	Year 1	Year 2	Year 3	Year 4	Year 5 to 10
Task 1: Identify Coffee Varieties	130K	130K	130K	130K	TBD
Task 2: Varieties in HI for propagation	260K	180K	180K	180K	TBD
Task 3: Permits from HI and APHIS	180K	180K	120K	120K	TBD
Task 4: Propagation of imported varieties	250K	395K	380K	380K	TBD
Task 5: Distribution to farmers	30K	30K	20K	20K	TBD
Task 6: Survey and Monitoring	220K	175K	175K	175K	TBD
Task 7: Field Management	255K	190K	130K	190K	TBD
Task 8: Economic Analysis and impacts	100K	140K	0	0	TBD
Task 9: Coordinator CLR In APHIS	284K	274K	274K	274K	TBD
Subtotal per year:	**$1,679K**	**$1,694K**	**$1,409K**	**$1,469K**	**TBD**
Total for first 4 years				**$6,251K**	

POTENTIAL FUNDING SOURCES:
Any connection to NRCS? Can they help fund practices (cost)? Do they have a block grant to deal with this?
Any connection to NIFA? Can they help fund some of the tasks above? Do they have a block grant or combined grants to deal with some of these tasks?
Congressional allocation?
Other APHIS funds?
Coffee leaf rust (CLR) Resistant Coffee Varieties Team
Members of the Team, in alphabetical order:

Luis F. Aristizabal

Interest in this Team: Support research and extension by addressing the integrated pest management of CLR in Hawaii
Organization: Independent Consultant for Synergistic HI Agriculture Council, SHAC
Mailing Address: P. O. Box 5579, Kailua-kona, HI 96745
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Cell: 808-498-3657

Dave Chun

Interest in this Team: Looking for funding opportunities
Position: Legislative Director, Office Congresswoman Tulsi Gabbard
US Congress House of Representatives
Mailing Address: 1433 Longworth House Office Building,
Washington, DC 20515
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Cell: (202) 306-4887

Fred Cowell, Coffee Grower

Interest in this Team: Kauai Coffee has hosted plant variety trials for nearly 30 years.
General Manager, Kauai Coffee Company, LLC
Proposed host for WCR IMLVT to begin in 2021
Organization: Kauai Coffee Company, LLC
Mailing Address: P.O. Box 530, Kalaheo, HI 96741
E mail: fcowell@kauaicoffee.com
Cell: (808) 936-3032

Hilda Diaz-Soltero

Interests in this Team: prepare Strategic Plan to control or eradicate CLR in HI
Position: Caribbean Advisor to the APHIS Administrator and CBB Coordinator
Organization: USDA/APHIS Office of the Administrator
Mailing address: 1201 Ceiba Street, Jardín Botánico Sur,
San Juan, Puerto Rico USA 00926
Cell (202) 412-0478
E mail: hilda.diaz-soltero@usda.gov

Tommy Greenwell, coffee grower

Interest in this Team: _CLR Resistant variety trials
Organization: Greenwell Farms Inc.
Mailing Address: PO box 248 Kealakekua Hawaii 96750
E mail: tom@greenwellfarms.com
Cell: 808 960 4435

Darwin Inman, coffee grower

Interest in this Team: Experience bringing CLR resistant varieties to the islands for over three years, and legally imported and quarantined plants to HI.
Organization: Kona Hills LLC
Mailing Address: 81-964 Haleki'i Street, Bldg. 3, Suite A, Kealakekua HI 96750
E mail: darwin@konahillsllc.com
Cell: 209-988-5659

Dr. Melissa Johnson

Interests in this Team: Survey and Monitoring

Position: Research Biologist
Organization: DKI US Pacific Basin Agricultural Research Center
USDA - Agricultural Research Service
Address: Address: 64 Nowelo St. Hilo HI 96720
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Cell: (808) 937-0022

Tyler Jones

Interest in this Team: CLR resistant varieties selection; propagation methods to rapidly multiply and distribute new varieties; Tech transfer to private sector; disease screening.
Position: Assistant Research Director
Organization: Hawaii Agriculture Research Center (HARC)
Mailing Address: PO Box 100, Kunia HI 96759
E mail: tjones@harc-hspa.com
Cell (808) 927-7508

Roger Kaiwi

Interest in this Team: provide information to Kona coffee growers
Position: General Manager
Organization: Hawaii Coffee Roasters
Mailing Address:
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Dr. Lisa Keith

Interests in this Team: survey and monitoring using a pathology approach (screening and monitoring resistance with % incidence and severity; plant disease triangle and role of environment, aspects of early detection, etc.).
Position: Research Plant Pathologist
Organization: USDA/ARS, DKI-PBARC
Mailing address: 64 Nowelo St., Hilo, HI 96720
Cell: 808-896-0487
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Andrea Kawabata

Interest in this Team: Outreach, coffee root knot nematode tolerance-resistance, assistance with grafting onto coffee root-knot nematode tolerant rootstock, applied research, and possible field trial site at the Kona Research Station
Position: CTAHR, Associate Extension Agent for Coffee and Orchard Crops
Organization: University of Hawaii at Manoa College of Tropical Agriculture and Human Resources
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Chris Manfredi

Interests in this Team: Organization and coordination among local, state, federal and private sector resources. Communication among various industry stakeholders. Collaborate to develop short and long-term strategies and assist in implementation.
Position: President

Organization: Hawaii Coffee Association
Mailing Address: PO Box 168, Kealakekua HI 96750
Cell: 516-526-5010
Office phone: 808-929-9550
E mail: president@hawaiicoffeeassoc.org

Dr. Tracie Matsumoto

Interests in this Team: Selection, importation, and evaluation of coffee leaf rust resistance lines for the Hawaii specialty crop market.
Position: Tropical Plant Genetic Resources & Disease Research Unit, Research Leader
Organization: USDA ARS Daniel K. Inouye U.S. Pacific Basin Agricultural Research Center
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ARS phone: (808)959-4358 temp office 959-4349
FAX: (808) 959-5470

Miguel Meza:

Interest in this Team: coffee cupper, roaster, green coffee exporter, CLF resistant coffee varieties for HI
Organization: Synergistic Hawaii Agricultural Council
Mailing Address: 250 Keawe Street, Hilo Hawaii 96720
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Tel office: 808-365-9041

Dr. Chifumi Nagai

Interest in this Team: Selection of CLR resistant varieties based on performance data at other regions and communication with coffee breeder and scientist network. Strategic planning for new variety trial and evaluation.
Organization: Hawaii Agriculture Research Center (HARC)
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Stuart T. Nakamoto

Interest in this Team: Outreach, coffee root knot nematode tolerance-resistance, assistance with grafting onto coffee root-knot nematode tolerant rootstock, applied research, and possible field trial site at the Kona Research Station.
Position: CTAHR, Extension Specialist: Ag Economics, Marketing and Adding Value
Organization: University of Hawaii at Manoa College of Tropical Agriculture and Human Resources
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Office: 808-956-8125

Dr. Marisa Wall

Interest in this Team: Coordinate research at USDA-ARS to support CLR plan. Lead cupping quality research of CLR resistant varieties.
Position: Center Director, U.S. Pacific Basin Agricultural Research Center
Organization: USDA-ARS
Mailing address: 64 Nowelo Street, Hilo, HI 96720

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Dr. Timothy L. Widmer
Interest in this Team: Strategic planning of ARS research activities
Position: National Program Leader – Plant Health
Organization: USDA/ARS
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