

Surveying, Sampling, and Monitoring of Coffee Leaf Rust (*Hemileia vastatrix*) for Early Disease Control in Hawai'i

Coffee Leaf Rust (CLR), *Hemileia vastatrix*, the world's most devastating coffee disease, was identified in Hawai'i in October 2020. Approved contact and translaminar fungicides can be used to control CLR, but these have little-to-no effect on advanced stages of CLR leaf infection. Therefore, the timing of the applications and coverage are extremely important. If CLR is allowed to continue uncontrolled (Fig. 1) or is improperly addressed, an increase in spore population in the farm is expected, and leaves will be lost. Yields in the first season with CLR infection are frequently not affected. However, due to diminished tree health and vegetative growth, coffee production in subsequent years will be severely reduced [9] and tree death can occur. Hence, active surveying, sampling, and monitoring for presence of this disease on farms is critical for early detection, maximizing fungicide applications, and reducing CLR impact on farm productivity and profitability.

Review the [Spraying to Suppress Coffee Leaf Rust \(*Hemileia vastatrix*\) in Hawai'i](#) publication [2,3,4,5] to understand proper spray methods and approved fungicide products for CLR management. Rotating between the different FRAC groups listed on Table 1 of the spraying publication mentioned above is highly recommended to reduce the chances of CLR and other diseases developing pesticide resistance. Follow all pesticide label directions.

To reduce transport of CLR spores and the spread of infection, follow [sanitation recommendations](#) [10] prior to entering and upon exiting a farm, as well as when moving from potentially infected to uninfected areas within the farm. Additional CLR information can be found at www.HawaiiCoffeeEd.com/CLR or by contacting your local UH-CTAHR Extension agent.

CLR Scouting and Sample Submissions

Growers should actively scout their entire farm(s) for the first symptoms of CLR on coffee leaves. Early detection of CLR presence on a farm is crucial for management and mitigation of this plant pathogen.

Early in the disease cycle, the greatest concentration of



Figure 1. In Hawai'i, early disease detection is crucial for coffee leaf rust management. Without it, CLR becomes unmanageable, even with available fungicides.

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Andrea M. Kawabata

Department of Tropical Plant and Soil Sciences
andreak@hawaii.edu, (808) 322-4892

Lisa Keith

USDA-ARS Daniel K. Inouye Pacific Basin
Agricultural Research Center

Darcy Oishi

Hawai'i Department of Agriculture

Stuart T. Nakamoto

Department of Human Nutrition, Food,
and Animal Sciences

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Brackets, e.g. [2], correspond to literature citations found in the Literature Cited section. This publication is expected to evolve as more is learned about coffee leaf rust in Hawai'i.

spores is usually found within four feet of the ground [6] (Fig. 2) and all stages of leaf development are susceptible to CLR. The first CLR symptoms (Fig. 3A, C, D) are small, irregular, pale yellow spots (2-4 mm) on the upper and lower surface of the leaf and can be found anywhere on the leaf where there are stomates (microscopic pores on



Figure 2. A recent CLR infection on leaves within the bottom third of the coffee canopy (left). The excerpt close-up (right) shows leaves with pale yellow, irregular spots and blotches (circled) with no browning or necrosis - early signs of coffee leaf rust.

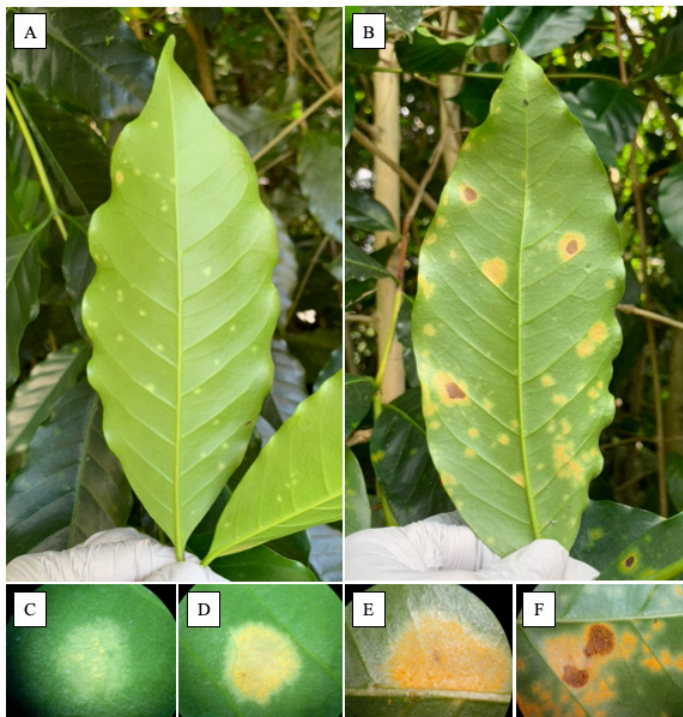


Figure 3. The underside of a coffee leaf showing (A) early and (B) advanced symptoms of coffee leaf rust (CLR). Early symptoms may or may not have obvious spores within the spot. (C-F) Close-ups of CLR spots in various stages of disease development, including (C) early with minimal spores visible and (F) late with brown, necrotic (dead or dying) leaf tissue. Photo credit: Dr. Lisa Keith of USDA ARS DKI PBARC (3C-F).

the bottom of leaves). Often, these spots are concentrated near the leaf edge. Unlike cercospora leaf spot (*Cercospora coffeicola*), early CLR symptoms lack necrosis (cell death) and there is no browning in the middle of the yellow spot. Additionally, no raised pustules or sunken lesions develop as a symptom of CLR. As CLR continues to progress (Fig. 3B, E, F), yellow- to orange-colored powdery spores are noticeable within the blotches on the underside of the leaf approximately three weeks following initial infection [9]. With advanced symptom development, necrosis and browning can occur. See Appendices C through F for additional photos of CLR, cercospora leaf spot, and examples of leaf symptoms mistaken for CLR.

Submitting Coffee Leaf Photos and/or Samples for Identification of CLR

To reduce CLR spread, it is recommended to submit photographs of suspect CLR leaves first before submitting leaf samples.

Supplies for leaf sample submission:

- Clean, unused, sealable plastic bag
- Permanent marker
- Clean, unused paper towels
- Cooler or ice chest with a small bag of ice, an ice pack, and a small, light towel for keeping the samples cool during transport
- ≥70% alcohol in a spray bottle
- Optional – Gloves (need to be changed or sanitized between trees)

Procedures for disease identification and sample submission:

Step 1: Follow [sanitation protocols](#) prior to entering a farm, while scouting, and when leaving the farm.

Step 2: Look for CLR symptoms on the lower third of the tree canopy and scan the upper sections of the trees for advanced signs of CLR infection.

Step 3: Photograph the underside (in particular) and top-side of suspected leaves with CLR spots. Be sure that the photos are clear, sharp, and not blurry. If possible, hold the leaf being photographed against the light so size and shape of chlorotic (yellowing) spots become more visible.

Step 4: Complete an [HDOA submission form](#) (Appendix A) and submit this form with the photographs of suspected CLR-infected leaves to HDOA.PPC@hawaii.gov with the Subject: Suspect Coffee Leaf Rust.

- o Or, email or text your photographs and information to Andrea Kawabata (UH-CTAHR Cooperative Extension) at andreak@hawaii.edu or (415) 604-1511. Include your name, contact information, and location from where the photos were taken.

Step 5: If collecting leaf samples for submission to UH-CTAHR's Agricultural Diagnostic Service Center (ADSC), place suspect leaves between two sheets of dry paper towel and enclose the paper towels and leaves in a labeled, clean, sealable bag (Fig. 4).

- o Refrigerate or hold in a cooler and keep the sample chilled until the leaves can be submitted for ID.
- o Do not freeze samples.
- o Prevent decay and rot of leaves by submitting leaf samples as soon as possible.
- o Sanitize the outside of the bag with $\geq 70\%$ alcohol prior to submission.

Step 6: For expediency of transit (if necessary), samples are best submitted to a UH-CTAHR Cooperative Extension Office on Mondays or Tuesday mornings before 10:00 am. Offices are closed for State and Federal holidays.

- o Locate your nearest [Cooperative Extension Office](#) for submission assistance.
- o It is recommended to contact the Extension Office and make an appointment to ensure that staff are available to assist.
- o View all ADSC analytical service fee rates [here](#).

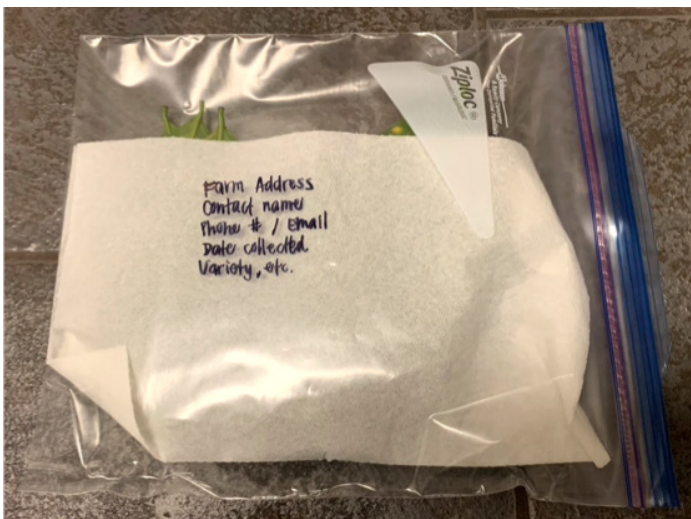


Figure 4. Samples contained in a clearly marked, enclosed bag, may be submitted for identification via the University of Hawai'i's Agricultural Diagnostic Service Center. Information such as those indicated on the bag – contact name, phone and/or email, farm address, collection date, coffee variety, area or plot ID from where sample was collected, etc. – should be provided with the sample. This will assist staff with the sample submission, completion of forms, and payment.

Monitoring for CLR Incidence Rate

CLR incidence (the percentage of diseased leaves per plot or acre) can be used for monitoring [8] and as an indicator for spraying. CLR incidence is estimated by randomly sampling leaves, and while there are various methods for sampling, the following is a combination of three methods identified by coffee scientists [11]. At minimum, researchers elsewhere have recommend monitoring for CLR symptoms at the beginning of the rainy season and then again at the start of harvest. However, due to the novelty of this disease and Hawai'i's microclimates and wide-ranging weather patterns, at least monthly monitoring may be necessary to detect CLR at incidences under 5%. This 5% level is critical for sprays to be effective in managing CLR in Hawai'i.

Supplies for CLR monitoring:

- Picture guide of CLR signs and symptoms (this publication and/or the [HDOA field guide](#))
- Sampling worksheet (Appendix B)
- Pen/pencil
- Clean, unused, sealable plastic bag
- Permanent marker to label bags
- $\geq 70\%$ alcohol in a spray bottle
- Optional - visual aids including glasses, magnifying hand lens, loop, dissecting or compound microscope, etc.
- Optional – Gloves (need to be changed or sanitized between trees)

Procedures for CLR monitoring:

Step 1: Follow sanitation protocols prior to entering a farm, while monitoring for CLR, and when leaving the farm.

Step 2: Randomly select 10 trees per plot or per acre.

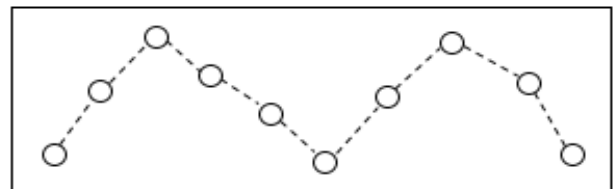


Figure 5. For good field representation, start at one end of the plot and collect samples by walking the plot in a zig-zag pattern.

Step 3: Randomly collect 10 leaves per tree from laterals (horizontal branch) in the lower third of the canopy. Sanitize your hands and supplies after sampling each tree to reduce the risk of moving spores from one tree to another.

- Step 4: Collect these leaves from the middle of the lateral or horizontal branch and from the third or fourth pair of leaves from the branch tip.
- Step 5: Collect a total of 100 leaves per plot or per acre.
- Step 6: Count the number of leaves with symptoms of CLR and then dispose of leaves as instructed below.
- Step 7: Calculate the percentage of CLR incidence with the following equation:

$$\text{CLR incidence (\%)} = \frac{\text{No. of leaves with CLR symptoms} \times 100}{\text{Total no. of leaves collected}}$$

Using the Monitoring Results and % Incidence for Decision-making

| Incidence Level | Recommendation |
|-----------------|---|
| 0% | Continue to monitor for CLR and determine percent incidence. Optional: Apply approved fungicides for prophylactic or preventative treatment. |
| <5% | Spray an approved fungicide immediately. Multiple applications, while following all label directions, may be necessary to maintain an incidence level under 5%. |
| >5% | Contact fungicides will not effectively control live CLR within the leaves. Leaf removal, pruning, and spraying may be necessary to reduce the CLR incidence level to under 5%. Without the use of systemic fungicides for control, expect defoliation and yield losses in the following season(s). |

At least monthly monitoring for CLR incidence is necessary unless spraying on a schedule. In optimal weather, rust spores complete their life cycle in about 30 days. The first signs of pale-yellow spots can appear about 24 days after initial infection and, without systemic fungicides, CLR can remain alive in the leaves on trees for several months [11].

In Hawai'i, systemic fungicides are not approved for use on coffee, and resistant varieties are not yet available. Field sanitation, pruning, and preventative fungicides are the only tools currently available for growers to combat CLR. When applied properly, and at a CLR incidence rate under 5%, contact fungicides can be helpful in protecting coffee trees from initial and increased disease severity [12]. At incidence rates of 5% and greater, there is limited-to-no control with preventative fungicide applications, and growers should expect defoliation and yield losses in the following season(s) [1]. Current fungicides in Hawai'i will slow the disease but will not cure CLR. Thus, catching the disease early is critical.

In-depth knowledge of your farm, its management prac-

tices, and business aspects is important for operation profitability. Maintaining and improving tree health and vigor is also important for reducing CLR susceptibility. Since contact fungicides are only effective at a low CLR incidence rate, farm scouting for early symptoms of CLR infection is essential for effective control and reduction of CLR impact on the trees and farm.

Methods of Destruction of CLR-Infected Leaves and Branches

CLR favors moderately warm weather for survival and is an obligate plant pathogen, which means it requires a living host to remain alive [9]. In addition, a CLR spore can live for approximately six weeks [7] outside of a living host. As such, some of the methods of destruction revolve around non-living leaves, heat, and drying.



Figure 6. At higher CLR incidence levels, spraying followed by removal and disposal is currently the only option for regaining control of this disease in Hawai'i.

To minimize the spread of live CLR spores, at least one application of an approved fungicide is recommended prior to leaf removal, pruning, and movement of infected coffee plant materials. Be sure to follow re-entry interval (REI) periods and other pesticide label requirements. Minimize the transport of infected materials through uninfected areas of the farm and avoid moving CLR-infected coffee materials off-site. Further, sanitize any tools and equipment as necessary and always follow pesticide product label directions.

Methods of disposal of plant material infected by CLR include:

Burning

- o Apply for and abide by the regulations of your approved agricultural burning permit from the [Hawai'i Department of Health's \(DOH\) Clean Air Branch](#).
- o Contact the DOH's Clean Air Branch at (808) 586-4359 or cab@doh.hawaii.gov.



Composting

- o Pile infected leaves and branches and securely cover the pile to prevent live spores from being transferred back into the field.
- o Manual cutting or using a flail mower will help to reduce the size of branches and increase the rate of decomposition. A chipper might be used, but chipping will blow material into the air and could disperse CLR spores.
- o Since branches may poke holes in the covering, use a thick, non-porous material without holes or openings.
- o Keep the pile covered for at least 6 weeks.

Solar Heating

- o Collect infected leaves and enclose them in a non-porous bag, bucket or bin with a secured lid.
- o If adding branches, use a thick, non-porous material to prevent branches from poking holes in the bag.
- o Leave the bag or container in direct sun for at least 6 weeks.

Once devoid of live CLR spores, all materials can be returned to the farm as mulch or compost.

If you have questions, contact your [local Cooperative Extension](#) or statewide coffee agent, Andrea Kawabata, at andreak@hawaii.edu or (808) 322-4892. Texts and photos can be sent to (415) 604-1511.

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Literature Cited

1. Brown, J.S., J.H. Whan, M.K. Kenny, and P.R. Merriman. (1995). The effect of coffee leaf rust on foliation and yield of coffee in Papua New Guinea. *Crop Protection*, 14(7): 589-592. [https://doi.org/10.1016/0261-2194\(95\)00040-2](https://doi.org/10.1016/0261-2194(95)00040-2).
2. Kawabata, A.M. and S.T. Nakamoto. (2021). Spraying to suppress coffee leaf rust (*Hemileia vastatrix*) in Hawai'i. Honolulu (HI): University of Hawai'i. p. 6. (Plant Disease; PD-118). <https://www.ctahr.hawaii.edu/oc/freepubs/pdf/PD-118.pdf>.
3. Kawabata, A.M. and S.T. Nakamoto. 2021. Pambobomba Upang Sugpuin ang Kalawang ng Kape (*Hemileia vastatrix*) Dito sa Hawaii. Honolulu (HI): University of Hawaii. p. 6. (Plant Disease; PD-122 in Tagalog). <https://www.ctahr.hawaii.edu/oc/freepubs/pdf/PD-122.pdf>.
4. Kawabata, A.M. and S.T. Nakamoto. 2021. Panagpaysuyot Tapnon Malappedan ti Lati ti Bulong ti Kape (*Hemileia vastatrix*) dito y Hawaii. Honolulu (HI): University of Hawaii. p. 6. (Plant Disease; PD-121 in Ilocano). <https://www.ctahr.hawaii.edu/oc/freepubs/pdf/PD-121.pdf>.
5. Kawabata, A.M., R. Gutierrez-Coarite and S.T. Nakamoto. (2021). Pulverización para suprimir la roya del café (*Hemileia vastatrix*) en Hawai. Honolulu (HI): University of Hawai'i. p. 6. (Plant Disease; PD-120). <https://www.ctahr.hawaii.edu/oc/freepubs/pdf/PD-120.pdf>.
6. Kushalappa, A.C. and A.B. Eskes. (1989). Advances in coffee rust research. *Annual Review of Phytopathology*, 27(1):503-531.
7. Schieber, E. and G.A. Zentmyer. (1984). Coffee rust in the Western Hemisphere. *Plant Disease*, 68(2):89-93. https://www.apsnet.org/publications/PlantDisease/BackIssues/Documents/1984Articles/PlantDisease68n02_89.PDF.
8. Silva-Acuña, R., L.A. Maffia, L. Zambolim, and R.D. Berger. (1999). Incidence-Severity Relationships in the Pathosystem *Coffea arabica*-*Hemileia vastatrix*. *Plant Disease*, 83:2, 186-188. <https://apsjournals.apsnet.org/doi/pdf/10.1094/PDIS.1999.83.2.186>.
9. Talhinas, P., D. Batista, I. Diniz, A. Vieira, D.N. Silva, A. Loureiro, S. Tavares, A.P. Pereira, H.G. Azinheira, L. Guerra Guimarães, V. Várzea, and M.d.C. Silva. (2017), The coffee leaf rust pathogen *Hemileia vastatrix*: one and a half centuries around the tropics. *Molecular Plant Pathology*, 18: 1039-1051. <https://doi.org/10.1111/mpp.12512>.
10. USDA ARS DKI PBARC. (2020). CLR sanitation protocol. <https://www.hawaiicoffeeed.com/clrsanitation.html>.
11. Virginio Filho, E.d.M., and C. Astorga Domian. (2019). Prevention and control of coffee leaf rust: Handbook of best practices for extension agents and facilitators. 1st ed. Turrialba, Costa Rica. Tropical Agricultural Research and Higher Education Center (CATIE), 96 p.

Appendix A: Coffee Leaf Rust (CLR) Submission Form

Complete and send this form and photos of CLR-suspect leaves to the Hawai'i Department of Agriculture for identification.

DO NOT COLLECT SAMPLES OF INFECTED PLANTS TO PREVENT POTENTIAL SPREAD.

If you suspect coffee leaf rust

1. **First, do not touch or collect diseased plants.**
2. Do take clear photos.
How to photograph coffee leaf rust:
 - Take photographs of whole plant (refer to Field Guide to Coffee leaf rust pages 3 and 4).
 - Take photographs of upper and lower surface of suspect leaves (refer to Field Guide to Coffee leaf rust pages 5-7).
3. Do not touch or collect diseased plants and flag or visibly mark the area where CLR was found. Let everyone (land owner, manager, workers, visitors, etc.) know to stay away. Do not move soil, plant materials, or supplies from the location.
4. Submit photos and Coffee Leaf Sampling Form to HDOA.PPC@HAWAII.GOV through e-mail with the Subject: **Suspect Coffee Leaf Rust**
 - We will be in contact on how to proceed.
 - Your information is confidential and will not be shared outside of Hawai'i Department of Agriculture.
5. Decontaminate at site if possible! If you have touched or contaminated your clothing, footwear, hat, etc. with the fungal pathogen or think you may have, shower immediately with soap and water and wash your clothing, footwear, hat, etc. in laundry detergent and hot water and dry with high heat. Once decontaminated, then it is safe to travel from your farm or location.

DO NOT COLLECT SAMPLES OF INFECTED PLANTS TO PREVENT POTENTIAL SPREAD.

Coffee leaf rust Sampling Form

Please complete this form as it applies and to the best of your ability. Include it with corresponding image(s). Submit only 1 form per farm/location/residence. Your information is confidential and will not be shared outside of the Hawai'i Department of Agriculture.

| | |
|--|--|
| Contact Name: _____ | Disease symptoms or signs (check all that apply): |
| Contact E-mail: _____ | Dropping of green leaves |
| Contact Phone: _____ | Bare to nearly bare branches |
| Date collected: _____ | Yellowish circular spots or lesions on leaves, which may or may not have brown centers |
| Farm name: _____ | Clusters of orange to yellow-orange powder-like substance on the lower leaf surface below leaf spots on upper leaf surface |
| Address: _____ | Number of plants affected: _____ |
| GPS Coordinates: _____ | Farm Nursery Residence Wild growing |
| Location Type (Indicate or describe in Other): | Other: _____ |

This will be filled out by lab.

| | |
|------------------------|---------------------|
| Received by: _____ | Action taken: _____ |
| Date received: _____ | Notes: _____ |
| Final ID: _____ | |
| Identifier: _____ | |
| Date identified: _____ | |

DO NOT COLLECT SAMPLES OF INFECTED PLANTS TO PREVENT POTENTIAL SPREAD.



Appendix B: Coffee Leaf Rust (CLR) Percent Incidence Sampling Worksheet

To use, fill in the blue and yellow sections and file for record keeping purposes. Use your percent incidence (yellow section) and Table 1 to help guide your CLR management decisions.

Date: Farm:
 Plot # or ID: Evaluator:

| Tree # | Column A: # of Leaves | Column B: # of CLR- Infected Leaves | Column C: Notes |
|--------------|--------------------------|--|--------------------|
| 1 | 10 | | |
| 2 | 10 | | |
| 3 | 10 | | |
| 4 | 10 | | |
| 5 | 10 | | |
| 6 | 10 | | |
| 7 | 10 | | |
| 8 | 10 | | |
| 9 | 10 | | |
| 10 | 10 | | |
| Total | 100 | | |

| | |
|--|------------------------|
| Percent (%) Incidence = $\frac{\text{Total of Column B}}{\text{Total of Column A}} \times 100$ | <input type="text"/> % |
|--|------------------------|

Table 1. Example of Percent CLR-incidence for Spray Determination

| Incidence Level | Recommendation |
|-----------------|---|
| 0% | Continue to monitor for CLR and determine percent incidence. Optional: Apply approved fungicides for prophylactic or preventative treatment. |
| <5% | Spray an approved fungicide immediately. Multiple applications, while following all label directions, may be necessary to maintain an incidence level under 5%. |
| >5% | Contact fungicides will not effectively control live CLR within the leaves. Leaf removal, pruning, and spraying may be necessary to reduce the CLR incidence level to under 5%. Without the use of systemic fungicides for control, expect defoliation and yield losses in the following season(s). |

Read and follow all pesticide product label directions. The label is the law.

Appendix C: Examples of Coffee Leaf Rust (CLR) on Leaves with Various Stages of Development

Upper (top) and lower (bottom) leaf surfaces showing CLR symptom progression from early (left) to advanced (right) infection. Actual leaf size is not shown in these photos; however, the diameter of some spots is noted. For CLR spot size reference: $\frac{\text{10 mm}}{\text{10 mm}}$



Appendix D: Differences Between Coffee Leaf Rust (CLR) and Cercospora Leaf Spot Symptom

| | |
|--|---|
| <p>upper Coffee Leaf Rust lower</p> | <p>upper Cercospora Leaf Spot lower</p> |
| <ul style="list-style-type: none"> • Small, irregular, pale yellow to yellow-orange spots (2-4 mm) found anywhere on the upper leaf surface but may be concentrated on the leaf margin or edge. • Irregular, brown centers with advanced age of spots. • Powdery yellow to orange-colored spores on the lower leaf surface. | <ul style="list-style-type: none"> • Small, circular, brown spots (1-3 mm) surrounded by a light-yellow halo and found anywhere on the upper leaf surface including leaf veins. • Under magnification on the lower leaf surface, spots contain small depressions caused by tissue collapse. • No powdery spores on the lower leaf surface. |

Photos and slide credit: Dr. Lisa Keith of USDA ARS DKI PBARC

Appendix E: Examples of Coffee Leaf Rust (CLR) and Cercospora Leaf Spot Symptoms

| | |
|---|---|
| <p>upper Coffee Leaf Rust lower</p> | <p>upper Cercospora Leaf Spot lower</p> |
|---|---|

Photos and slide credit: Dr. Lisa Keith of USDA ARS DKI PBARC

Appendix F: Examples of What are NOT Coffee Leaf Rust

These photos of upper and lower leaf surfaces provide visual examples of other nutritional, pest, and disease symptoms but NOT coffee leaf rust. If unsure, submit your leaf/leaves for proper ID.

