Michael Schruckmayr
Nesbitt Discovery Academy
Asheville, NC USA
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Honduras: Sustainable Coffee to Reduce Food Insecurity

Sustainable agriculture and the reduction of food insecurity are crucial to the success of humanity over the following decades. In order to continue feeding Earth's growing population, it is paramount that sustainable agriculture is implemented on a large scale to reduce the stress of intensive agriculture. Sustainable solutions to pest reduction are crucial to successful agriculture in the long term. Crop diseases can cause a 20% to 40% reduction in yield for cash crops, which is detrimental to global food security (Richard et al., 2021). In the case of commodity crops grown by smallholder farmers, disease losses destabilize income and increase food insecurity for farmers. *Coffea arabica*, or coffee, is a crop with a supply that is heavily determined by the pest coffee leaf rust. From 2012 to 2017, three billion dollars in crops were lost to coffee leaf rust, additionally leading to two million farmers abandoning their farms (Torres Castillo et al., 2022). In addition to maintaining the coffee supply chain, sustainable solutions for coffee leaf rust are imperative to the stability of coffee farmers worldwide.

Honduras is a Central American country with coastlines on both the Pacific and Atlantic Oceans. The interior of the country is marked by vast mountain ranges and a temperate climate, while the coast contains narrow subtropical plains. It has a population of 9,529,188 people as of 2024, with 39.8% living in rural areas (Central Intelligence Agency, 2026). The capital, Tegucigalpa, has a population of 1.586 million people and the second largest city, San Pedro Sula, has a population of 982,000 people (Central Intelligence Agency, 2026). Nearly two million Hondurans face acute food insecurity, which is equivalent to 470,000 families lacking sufficient food (IPC, 2025). Furthermore, 32% of land in Honduras is currently used for agriculture (Central Intelligence Agency, 2026). Honduras has a real Gross Domestic Product (GDP) of 79.217 billion United States Dollars (USD) as of 2024, with 11.2% coming from agriculture (Central Intelligence Agency, 2026). The main agricultural products in Honduras are "sugarcane, oil palm fruit, maize, milk, bananas, [and] coffee" with coffee being the largest agricultural export (Central Intelligence Agency, 2026). In fact, coffee makes up five percent of the total GDP (Bueso Ucles, 2021). Furthermore, there are 120,000 total coffee farms, with 91,500 being family owned small and medium size farms (Bueso Ucles, 2021). A small coffee farm is considered to be less than 12 hectares, a medium coffee farm is between 12 and 50 hectares, and a large coffee farm is over 50 hectares (Starbucks, 2022). These small and medium size farms are equivalent to 87% of all Honduran coffee producers (Bueso Ucles, 2021). The average household size in Honduras is 3.35 people and families tend to be larger in rural regions than in urban regions (AFS-USA, 2016; UN, 2019). This means that there are almost half a million Hondurans who are dependent on the cultivation of coffee as their primary source of income (UN, 2019). The average age of Honduran coffee growers dropped from 56 to 46 from 2005 to 2015 (Mercanta, 2015). This signifies that young people are involved in coffee cultivation and it remains a family industry.

Typical Honduran foods are corn, beans, cassava, rice, tortillas, fruit, and seafood (Together Women Rise, 2023). Even though 32% of land in Honduras is devoted to agriculture, much of the food consumed by Honduras is imported (Inestroza, 2024). Wheat, rice, and pork are imported to supplement the demand of the Honduran population (Inestroza, 2024). According to the World Bank, 64.1% of the population lives below the upper middle poverty line of 6.85 USD per day (Berman et al., 2025). Most rural Honduran families earn less than two dollars a day and rely heavily on agriculture for this income (Savage, 2025). How will sustainable agriculture solutions for coffee cultivation affect food security in Honduras?

Coffee cultivation, which significantly contributes to the GDP of Honduras and the livelihoods of roughly half a million Honduran farmers, faces significant challenges in order to maintain high yields. *Coffea arabica* is the primary species of coffee grown in Honduras, however, it is heavily affected by extreme weather events and disease (Fiallos, 2025). In fact, coffee exports from Honduras change significantly year to year, as shown in the 12% decrease of coffee production from 2020 to 2021 as recorded in the United States Department of Agriculture (USDA) Coffee Annual Report (2021). This 12% decrease in production is attributed to weather conditions which increased coffee leaf rust outbreaks (Bueso Ucles, 2021).

Hemeleia vastarix, the pathogen responsible for coffee leaf rust, is the most significant parasitic pest affecting coffee production. *H. vastarix* manifests on coffee as a mass of orange sori, or fungal reproductive structures, on the bottom of the host's leaves (Torres Castillo et al., 2022). These characteristic orange sori appear on the leaves three weeks after the initial infection. The spores of *H. vastarix* inhibit the function of the leaves, especially the stomata, and eventually cause severe defoliation (Talhinhas et al., 2017). The adverse effects to coffee harvesting occur when the coffee tree has been defoliated to the point where coffee cherry production is severely reduced. Coffee cherries, which are then processed, shipped to market, and roasted, are used to produce coffee beverages. In the case of a visible infection, it is common protocol for the infected trees to be cut down and burned (Santiago-Santiago et al., 2023). In addition to decreased coffee cherry production, it also reduces the number of coffee trees per farm, which can take years to grow back.

It is the vegetative loss from the coffee leaf rust that eventually reduces the trees' capacity to produce coffee cherries, not just the infection itself (Talhinhas et al., 2017). Since germination of *H. vastarix* urediniospores increases with high humidity and temperatures, coffee leaf rust has steadily risen alongside climate change. As noted in her study, Mendes discovered the latent period, or time it takes for the urediniospore to completely infect the host plant, is inversely related to CO2 in the atmosphere (2009). If CO2 concentrations continue to rise, the latent period could decrease from 36.4 days to 21.2 in the following decades (Mendes, 2009). With a shorter latent period, *H. vastarix* can germinate many more times in one wet season, leading to an increased rate of infection. Increases in temperature will also increase the amount of time that *H. vastarix* has to germinate, moving the first infection date of the year forward (Ghini et al., 2011).

During the Central American coffee leaf rust epidemic of 2008 to 2013, coffee production decreased by up to 54% in some parts of the region (Avelino et al., 20153). These extreme fluctuations in coffee production greatly affected the income of coffee farmers and laborers and their ability to purchase food. Many farmers and their families faced food insecurity during this time as much of the Honduran diet consists of imported food. Nearly half a million Hondurans were at risk of going hungry during the coffee leaf rust epidemic.

The two most common solutions to coffee leaf rust are resistant cultivars and chemical fungicides. Most resistant cultivars are derived from breeding *C. arabica* with *C. canephora*, a coffee species native to Kenya (Torres Castillo et al., 2022). As of now, there are many resistant cultivars distributed throughout the world, however, the development of these resistant cultivars can take 25 to 30 years (García-Pérez et al., 2021). Furthermore, many of these hybrid coffee plants lose the desired flavor and quality of *C. arabica* (Torres Castillo et al., 2022). Due to the steady rise of annual temperatures and humidity, there are over 40 variants of *H. vastarix*, some of which infect previously resistant cultivars (Torres Castillo et al., 2022). Coffee monoculture, which has poor long term performance and decreases biodiversity, often involves the cultivation of large swaths of resistant coffee varieties (Jackson et al., 2012).

The application of chemical fungicides has also become widespread over the past decades to reduce coffee leaf rust. Most fungicides contain copper, which eventually builds up in soils and becomes toxic to

coffee plants (Torres Castillo et al., 2022). Fungicides also have to be rigorously applied before the coffee plants become infested, increasing costs for farmers (Torres Castillo et al., 2022). For this reason, chemical fungicides are not an environmentally nor economically sustainable solution to coffee leaf rust, as they will only maintain a net benefit for the next five to ten years (Torres Castillo et al., 2022).

Biofungicides may be a solution with increased efficacy. Biofungicides are naturally derived essential oil solutions of secondary metabolites which can inhibit the germination of fungal pests. Secondary metabolites are compounds with low molecular weights derived from plants (Santiago-Santiago et al., 2023). These secondary metabolites can act as a defense system against pathogens (Torres Castillo et al., 2022). Terpenes, polyphenols, and glycosides are common secondary metabolites which damage pathogens. Specifically, secondary metabolites disrupt the cell membrane of the uredospores, killing the fungus (García-Pérez et al., 2021). These biofungicides are an attractive solution to coffee leaf rust because of their biodegradable nature, meaning they would not have long term environmental effects (Santiago-Santiago et al., 2023).

Research conducted by García-Pérez et al. investigated the inhibition of *H. vastarix* germination in vitro from secondary metabolite solutions derived from plants common in the state of Veracruz, Mexico (2021). These plants include *Eriobotrya japonica, Ardisia compressa,* and *Ocimum basilicum* (García-Pérez et al., 2021). These solutions were created by collecting leaves from each plant, drying for 24 hours, grinding to 0.5 mm particles, boiling for 70 seconds, putting the resulting liquid through a centrifuge, and then passing the liquid through a two nanometer filter (García-Pérez et al., 2021). The researchers then added 1.75 milliliters of the biofungicide to 0.04 grams of *H. vastarix* urediniospores (García-Pérez et al., 2021). The *E. japonica* solution led to a germination rate of 0.12%, *A. compressa* at 0.34%, and *O. basilicum* at 0.38% (García-Pérez et al., 2021). This experiment shows the efficacy of using readily available plants to create a simple biofungicide solution that greatly inhibits *H. vastarix* germination.

Biofungicides are the most pertinent solution to reducing coffee leaf rust in Honduras. Biofungicides derived from plants commonly found in Honduras will have the largest positive impact for Hondurans. In cooperation with the Honduran Institute of Coffee (IHCAFE), significant research must first be conducted on the use of common plants in the inhibition of *H. vastarix* germination. First, similar investigations to that of García-Pérez et al. will take place with a variety of plants commonly found in Honduras, with a priority on plants considered abundant weeds, including *Pilea microphila, Eryngium foetidum, Portulaca oleracea*, etc. (PictureThis, 2026). Once the most common weeds in Honduras have been categorized based on their inhibition rates of germination in vitro, research will be conducted on the efficacy of these biofungicides in the field, specifically focusing on the success rates of the aqueous solution mode of dispersant, times of dispersal, and the concentration of biofungicides for substantial germination inhibition. It will be assumed that the aqueous solution remains the most successful mode of dispersion. Once the most potent weeds are identified and the respective minimum concentrations for significant inhibition are identified as well, research will then be conducted on the scaling of biofungicide production to accommodate the countless coffee farmers in Honduras. Further research will also be required to discern the variability of biofungicide efficacy across differing microclimates as according to Talhinhas, humidity and temperature are very influential in coffee leaf rust germination (2017). Due to the relatively simple biofungicide creation method identified by García-Pérez et al., most steps, including the grinding, boiling, and filtration, can be easily scaled to accommodate larger batches (2021). However, the use of a centrifuge for solid phase removal will be a limiting factor to the scaling of the process. The most promising alternative to the centrifuge is settling the biofungicide solution for a long period of time and extracting the pure liquid phase. There will also need to be testing on the human health effects of these biofungicides.

The following part of the recommended solution relies on heavy cooperation with the IHCAFE. As the IHCAFE has 42 local offices across Honduran coffee growing regions, the IHCAFE will use these offices as biofungicide production stations (Peligros-Espada et al., 2018). The IHCAFE will release an advertisement to coffee growers across Honduras for free, sustainable, and biodegradable fungicide that they will aid in making. The advertisement will encourage the farmers to collect approved weeds from their farms and surrounding lands and bring them to their local IHCAFE office. The IHCAFE will then process these weeds into a biofungicide using the prior research. This biofungicide will then be distributed to coffee growers along with instructions and free community classes across different districts for application derived from the previous research. This sustainable solution is also a strong treatment because of low costs, as all of the plant material is free, with the only costs coming from the production equipment and water. It is also important to mention that the biofungicide success rate will most likely be variable in different farm sizes. As the biofungicide is produced on a small scale, it may be difficult for farmers with large coffee farms to successfully implement the biofungicide across the entire farm. As it is not an expensive solution, the IHCAFE would not incur substantial costs that are outside of its budget. Furthermore, there have been significant past investments into Honduran coffee cultivation from the Honduran government, such as the 10 million dollar investment in 2024 (Prensa Latina, 2024). This proves that a smaller investment into the production of biofungicides would be possible. After the biofungicide is established as a viable solution to coffee leaf rust within the Honduran coffee growing community, the production of the biofungicide will be replicated by individual farmers, with the IHCAFE aiding farmers in procuring the needed production equipment.

The initial categorization of effective biofungicidal weeds should take two years. The testing of these biofungicides on live coffee trees will also take two years. The IHCAFE led production of biofungicide will last five to ten years. Finally, the transition to farmer-made biofungicide can act as a permanent solution until commercial biofungicides become a more affordable solution.

As there are half a million individuals whose primary income source is coffee cultivation in Honduras, the reduction of coffee leaf rust is crucial for stabilizing the income of coffee farmers and reducing food insecurity. The use of biofungicides derived from secondary metabolites from common Honduran weeds is a viable solution for coffee leaf rust inhibition. Using the system of local IHCAFE offices throughout Honduras to produce the biofungicide will be a strong solution to reducing coffee leaf rust in Honduras. Through the use of biofungicides, the coffee crop will stabilize and food insecurity will decrease for half a million Hondurans.

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