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Rates of Fungus Infection in Coffee Plantations at Varying Distances from the Forest Edge

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Abstract

Coffee (*Coffea arabica*, Rubiaceae) is an important economic crop for many small farmers in Monteverde, Costa Rica. The humid, cool and dark conditions near the forest as compared to the middle of a plantation provide an optimal habitat for fungal growth. In each of three different farms in Cañitas, three transects were set from the forest edge into the plantations. The amount of fungus on the coffee leaves was measured at varying distances away from the forests. A significant increase in the percent of fungus on the leaves between zero meters and five meters into the plantations was found (3-way ANOVA; $p < 0.0001$). These results suggest that farmers may find it more economically efficient to create a 10m buffer zone of non-host crops to reduce the impact of the forest microclimate in that area.

Resumen

El café es un cultivo muy importante para la economía de muchos pequeños caficultores en Monteverde. Las condiciones húmedas, frescas y protección contra el sol cerca del bosque, en comparación con el cafetal, proveen un hábitat óptimo para los hongos. Se hicieron tres transectos de 40 metros en tres fincas en Cañitas. Se midió la cantidad de hongos en las hojas a cinco distancias del bosque. Había un aumento significativo en el porcentaje de hongos sobre las hojas entre solamente 0m y 5m en el cafetal. Los caficultores, tal vez, deberían crear una zona de 10m de un cultivo que no es un huesped para el hongo para reducir el impacto del clima del bosque, en esta area. Esto va a proteger los bosques también, pues son tapavientos beneficiosos.

Introduction

Coffee is a major economic crop in Costa Rica. In Monteverde, many small farmers can at least supplement their incomes by producing coffee. The majority of farmers who grow coffee in the Monteverde area are primarily dairy farmers, with small plots for coffee (Griffith et al. 2000).The coffee fruits ripen throughout the rainy season and are then harvested in December and January. Both the Caturra and Catuai sun varieties of coffee have higher rates of production than the Arabigo variety and are considered “improved” in this area (Griffith et al 20000). Many farmers have switched from the traditional shade coffee system to planting in full sun. The main reason for the switch was to avoid the fungal infection that is facilitated when shade trees hold moisture on coffee leaves (Perfecto et al. 1996).

Pests and pathogens attack coffee plants and decrease production rates, and fungi can cause serious damage to crops (National Research Council 1993). Introduction of *Hemileia* *vastatrix* to Brazil in 1970 quickly allowed the rust to radiate throughout the Americas (Smith et al 1992; Gilbert and Hubbell 1996). On coffee, many common fungi infect the leaves and look like round, 2 cm or less, spots of discolored tissue. Many farmers use fungicides to control or prevent invasions (Altieri 1995). In fact, even organic farmers use fungicides to control or prevent invasions (Altieri 1995). In fact, even organic farmers use some fungicides, because infection is so prevalent (Griffith et al. 2000). However, some fungicides decrease the associated biodiversity in plantations, increasing harmful chemicals that cause a litany of environmental problems (Begon 1990; Perfecto et al 1996). In countries where chemicals are to costly, knowledge of fungal diseases and alternate ways to control them will prove beneficial (National Research Council 1993). In general, the concept of integrated pest management calls for creative methods to control diseases by changing agricultural practices (National Research Council 1993). It is known that Katimor, an older variety, is more resistant to *H. vastatrix*, the rust-colored fungus (Griffith et al 2000). Also, avoiding high intensity and low biodiversity agricultural systems, which are notorious for low stability, will also increase resistance to disease (National Research Council 1993).

Agricultural systems nearby forests enjoy many benefits. The forests provide services to agricultural areas in close proximity, such as renewing soil, providing pollinators and beneficial insects, controlling other pests, and dispersing seeds and fruits (Daily 1997). The abiotic conditions caused by an adjacent forest are different than those of an open area. The canopy of the forest blocks out direct light, decreases the temperature, and holds moisture for the plants underneath (Altieri 1995; Nepstad et al. 1996; Perfecto et al. 1996). These factors provide a shaded, cool, and humid microclimate. However, many fungi thrive in these conditions, and higher rates of fungal infection are expected to be found close to the forest that provides optimal growth conditions.

Materials and Methods

This study was conducted from October 19 to November 15, 2000. This particular year was abnormal compared to a typical year. Usually, there is much more rain, which increases the amount of fungus, but this season was noticeably dry (Torres pers. comm. 2000; Pounds pers. comm. 2000).

This study was conducted at three farms belonging to Miguel Delgado, Victor Torres, and Caesar Santamaria. All of the farms were in Cañitas, outside of Santa Elena, on the Pacific Slope of Costa Rica. Two plots were sampled at each farm, with all the plots using the Caturra variety of coffee plant. Fungicides were last applied either one or two months prior to sampling.

The sizes of the plots ranged from 3,000 to 15,000m². The adjacent forest patches were at least 50 meters wide. The heights of the forests were between 6.7 m and 11.4 meters (Table 1).

At each of the six plots, three transects were set and three plants were sampled at each distance of 0 meters, 5m, 10m, 20m, and 40m away from the forest. From each plant 12 leaves were systematically sampled. From 12 branches, one leaf was measured at the third node in from the tip. If both leaves were missing, the next available leaf was selected. To estimate the area of the fungus on the leaf, a transparent grid with quarter-inch squares was used. To determine the area of the leaf, the lengths, widths, and areas of 53 leaves were measured. Then, a regression line was made to decide whether area was better correlated with length or width. The widths of the leaves were a better determinant of the area ($R^2 = 0.952$; $Y = 2.366 + 0.028X$). When a leaf was sampled in the field, the width was measured, and then the area was determined. Using the area of the fungus divided by the area of the leaf, the percent of fungus affecting the leaf was found for the statistical tests.

A 3-way ANOVA test and subsequent post-hoc tests were used to determine differences in the amount of fungus at varying distances away from the forest.

Results

The 3-way ANOVA test showed significant differences in the amount of fungus at varying distances away from the forest ($P < 0.0001$). The area of fungus on the leaves decreased at increasing distances away from the forest (Figure 1). Significant differences in the amounts of fungi were found when comparing the plants at 0 meters to all other distances (Fisher's PLSD; $P < 0.0001$). Comparing the amount of fungus at 5m away from the forest to 10m, there was no significant difference (Fisher's PLSD; $P = 0.1281$), but between 5m and 20m (Fisher's PLSD; $P = 0.0084$) and 5m and 40m (Fisher's PLSD; $P = 0.0173$) there were significant differences in the amount of fungus. Differences in percent fungi between 10m, 20m, and 40m were not significant (Fisher's PLSD; all $P < 0.2661$).

There were no significant differences between the three plants at each distance (3-way ANOVA; $P = 0.7803$), or between the transects within a given farm (3-way ANOVA; $P = 0.6903$). However, there were significant differences between the three farms. While all three farms showed similar patterns of decreasing fungus area at increasing distances from the forest (3-way ANOVA; $P = 0.0619$), the Delgado farm had a higher rate of infection at 0m (Figure 2), which made it statistically different from both the Santamaria and Torres farms (Fisher's PLSD; $P < 0.0001$). The Santamaria and Torres farms were not significantly different (Fisher's PLSD; $P = 0.0560$).

At all three farms, the leaf area also decreased away from the forest (Figure 3). Despite this, the amount of fungus present was not affected by the various leaf sizes ($R^2 = 1.433E\text{-}4$). There was no relation between the area of the leaf and the area of fungus covering the leaf (simple regression analysis; $P = 0.0594$) (Figure 4).

Discussion

There were higher rates of fungus infection close to the forest edge. Only 5m away, rates of infection dropped significantly. This suggests that the shade, cooler temperatures, and moisture near the forest provide optimal conditions for the fungus. Therefore, planting coffee close to a forest is not ideal. It would probably be more economically efficient for farmers to diversify their crops. Bananas, various citrus fruits, and avocados can all be grown in tandem with coffee plants (Perfecto et al. 1996). Many families with "home gardens" use these crops as a personal supplement (Van Dusen 2000). Also, polycultures are generally less prone to diseases than monocultures (Griffith et al. 2000). Raising a different non-host crop, in that strip, would supply an effective and viable "buffer zone" between the coffee and the forest (Altieri 1995). It would also protect the forest that suffers a notable amount of infection from the same fungus. Actinidiaceae, Poaceae, and Euphorbiaceae samples from the forest were all noted with the rust on their leaves. Glodoski (1998) found that forest samples of *Myrcianthes fragrans* (Myrtaceae) had higher rates of infection close to infected coffee plantations. The plantations provide a large and dense source area for the fungus to spread. Trees that were isolated from a disease source (either a conspecific or coffee plant) had decreased rates of infection (Glodoski 1998). The presence of interspersed non-host species can delay the establishment of the fungus, reduce the spore dispersal, or modify microenvironmental conditions (humidity, light, temperature, and air movement)(Altieri 1995). This type of density-dependent pathogen infection can reduce unnatural monocultures in the species rich forests (Janzen 1970; Gilbert and Hubbell 1996). Fragmentation and other human disturbances will also cause a rise in plant disease epidemics (Gilbert and Hubbell 1996). Since the source of the fungus is the coffee – both were introduced to the neotropics – protecting these primary forests from invasion of a pathogen is environmentally important (Gilbert and Hubbell 1996).

At some farms, the decreases in fungus occurred into the 5m to 10m range. This may be due to the varying ranges in forest height. The higher rates of fungus infection at the Delgado farm may also have been caused by the increase in optimal conditions for the fungus provided by the taller forests (Table 1). Another effect of the forest shade is changing the leaf morphology of the coffee plants. At the forest edge, the leaves are larger in order to increase the area available to capture light. This is a typical low-light, understory leaf adaptation (Richards 1996; Rundel and Gibson 1996). These leaf adaptations support the idea that forest-like conditions continue a short distance into the plantation.

Forests act as natural windbreaks by creating a barrier against large open agricultural areas. Windbreaks are still necessary to reduce damage to the plants, because damaged plants are more vulnerable to fungus invasion (Griffith et al 2000). This benefit, in addition to other larger benefits and ecosystem services from the forests to the entire agricultural area, outweigh the problem of increased fungus in the small 5-10m strip.

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Table 1. Height of the forest in meters adjacent to the study sites.

Farm	Plot 1	Plot 2
Delgado	11.4 m	10.2 m
Torres	8.2 m	6.7 m
Santamaria	9.8 m	7 m

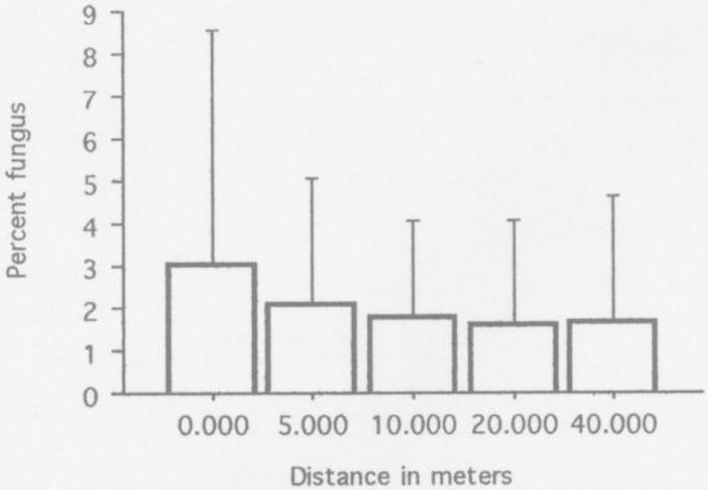

Figure 1. At increasing distances away from the forest, the percent of fungus affecting the coffee leaves decreases as an average of all the farms. 1-way ANOVA.

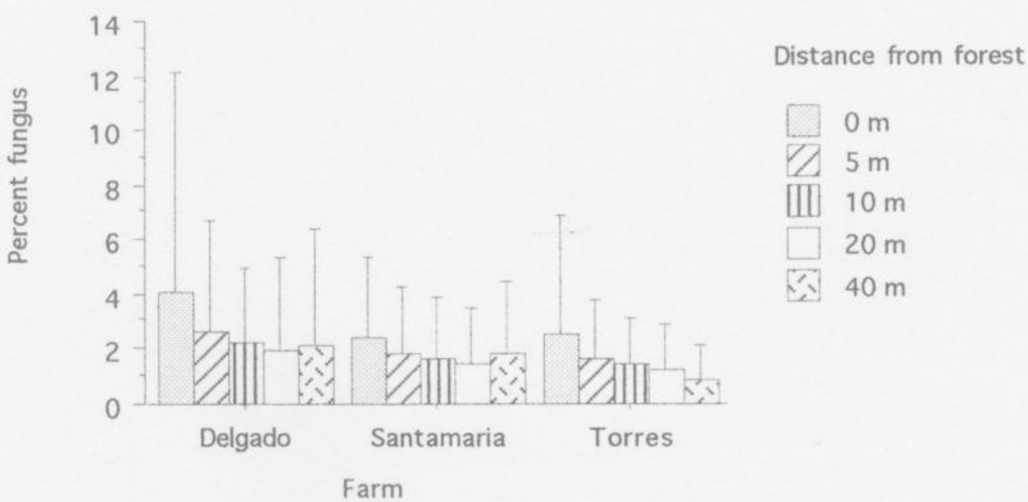

Figure 2. In each farm, there was an increase in the percent fungus affecting the leaves close to the forest. 2-way ANOVA.

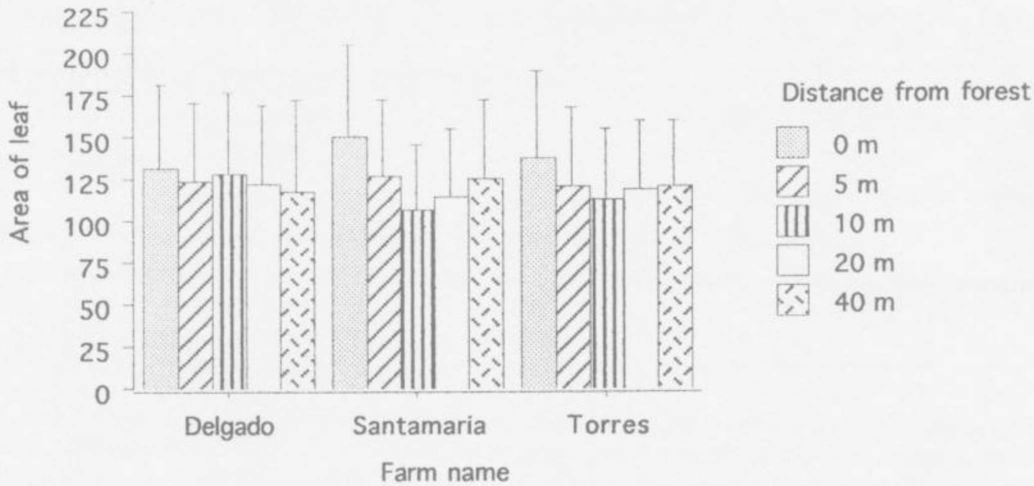

Figure 3. Leaf area is the largest close to the forest at 0 m, and it decreases at increasing distances at all three farms. This pattern is similar to the pattern of decreasing percent fungus at increasing distances away from the forest. 2-way ANOVA.

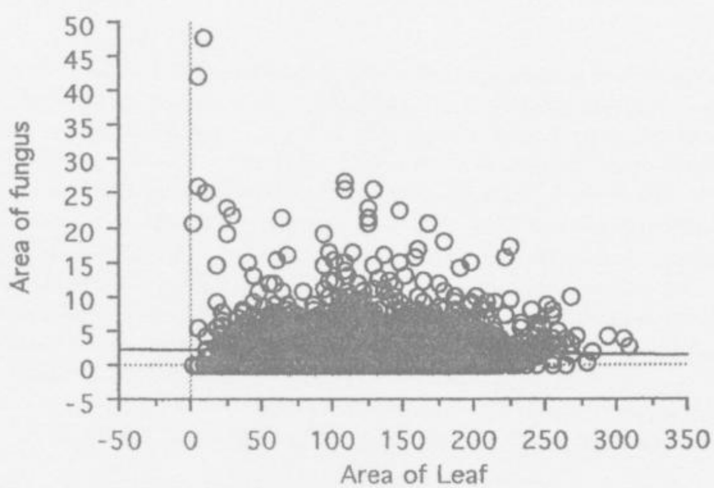

Figure 4. The amount of fungus present on the leaves is not related to the size of leaves. Simple regression analysis; $P = 0.0594$; $Y = 2.3 - 0.002x$; $R^2 = 0.001$