Interplay between harvesting, planting density and ripening time affects coffee leaf rust dispersal and infection

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ABSTRACT

Coffee leaf rust (*CLR; Hemileia vastatrix*) is one of the principal coffee diseases and has caused devastating loss of production around the globe. This fungus disperses between plants or regions through direct contact, water splash, or local turbulent wind conditions. Some studies have proposed that coffee harvesters can also bear CLR during harvesting. Their different trajectories depend on management and coffee plant characteristics, like the planting density or the ripening synchronicity, but also on the social organization of the plantation. However, it is not clear how relevant these movements are for CLR dispersal and plot-level infection in plots with other modes of CLR dispersal and different planting densities. Here we present a qualitative computational model to explore the role of coffee ripening synchronicity and the number of workers per plot in reproducing the different movement trajectories observed in the field. We then evaluate how these trajectories modify rust dispersal and change CLR infection in plots with increasing planting densities. We found that interplant asynchronous ripening and tree scarcity generate trajectories with long steps. In our model, the number of workers does not modify the trajectories. The harvest dispersal significantly increases coffee plot infection (up to 15%) compared to scenarios where only local mechanisms for CLR dispersal (contact-mediated or splash) are present. This effect is maximal for trajectories with long steps and in plantations with medium planting densities. At larger planting densities, plants are all already infected due to the local CLR dispersal. Our results aim to spur discussion on practices that could reduce the impact of harvesting and specific trajectories, in scenarios where one can benefit from asynchronous maturation of berries and shaded plantations. Some examples of practices include reducing the long-distance movements during the same day, for instance, by avoiding harvesting at the end of the harvest season when trees ripening asynchronicity and CLR levels are higher.

KEYWORDS

Coffee leaf rust dispersal; harvesting movement; coffee ripening; dynamical modelling; planting density

1. INTRODUCTION

The life cycle of pathogens in plants can be divided broadly into two stages: the infection stage where the organism invades the host and reproduces, and the dispersal stage where new replicates of the pathogen move from one host to the other (Avelino et al., 2004; Pangga et al., 2011). The rate and extent at which both stages are completed largely determine the magnitude of the epidemic and the crop loss (Avelino et al., 2004). Contrary to epidemics in non-sessile organisms, the host's density and spatial arrangement play a central role in plants, as they can modify the range and dynamics of the pathogen's dispersal (Keeling, 1999; Vandermeer et al., 2018; Papaïx et al.; 2015). In agriculture, this spatial structure depends on management factors (Beasley et al., 2022), plant-to-plant interactions (Li et al., 2020), and also on the topography of the field, among others (Soto-Pinto et al., 2000). Additionally, the interaction of the arrangement of the hosts and the disease depends on the characteristic transmission's distance of dispersal (Park et al., 2001; Hajian-Forooshani and Vandermeer, 2021). Studying these spatial relationships is crucial for an ecological approach to pest management that does not rely on synthetic pesticides, or solely on resistant plant varieties that focus on the infection stage (Avelino et al; 2004).

Coffee leaf rust (CLR), caused by *Hemileia vastatrix* Berk. & Br is one of the principal coffee diseases and has caused devastating loss of production in different coffee sites around the globe (McCook and Vandermeer, 2015; Talhinhas et al., 2017). Its mechanisms for dispersal have been amply studied (Becker and Kranz, 1977; Kushalappa and Eskes, 1989; Li et al., 2023; Vandermeer et al., 2018) and thus provide a great model to explore the disease's spatially explicit dynamics and its relations with the host’s spatial arrangement and density (Beasley et al., 2022; Gagliardi et al., 2020; Hajian-Forooshani and Vandermeer, 2021; Mora Van Cauwelaert et al., 2023). CLR forms urediniospores that can travel to neighboring coffee

plants through direct contact, water splash, or local turbulent wind conditions (Kushalappa and Eskes, 1989). The urediniospores may also ascend to the atmosphere and travel to other plantations (Becker and Kranz, 1977; Vandermeer and Rohani, 2014). For each of these ways of dispersal, there are agroecological management proposals to reduce the spread, like reducing the density or clustering of the plantations (Beasley et al., 2022; Ehrenbergerová et al., 2018), avoiding regular patterns that can make the epidemic thrive through contact or splash-mediated dispersal (Hajian-Forooshani and Vandermeer, 2021; Mora Van Cauwelaert et al., 2023; Li et al., 2023), but also planting different trees within the plots and in the borders to reduce local and regional wind dispersal (Avelino et al., 2022; Boudrot et al., 2016; Gagliardi et al., 2020)

It has been observed that workers can also disperse CLR within the plot and between regions (Becker and Kranz, 1977; Ramírez-Camejo et al., 2022; Schieber and Zentmyer, 1984). At the plot scale, this relates to the fact that some foci of infection occur close to harvesting paths and human settlements (Waller, 1982, 1972) and that the build-up of the epidemic correlates with the harvesting season (Avelino et al., 1993, 1991; Mora Van Cauwelaert et al., 2023). However, it is unclear how relevant the dispersal by harvesters is for the whole epidemic in contrast to other modes of dispersal, and what agroecological measures could be implemented to reduce its impact.

Besides, the dynamics of harvesting in coffee plantations depend on the scale, land tenure regimes, goal of production, and specific ecological practices; or on what has been called "the syndrome of production" (Andow and Hidaka, 1989; Perfecto et al., 2019). In large-scale and landlord-owned plantations, the trajectory of paid workers during harvest depends on the interaction of management decisions with biological factors (Masarirambi et al., 2009; Mora Van Cauwelaert et al., in press). In particular, we show in previous studies that the daily movement of harvesters in large-scale plantations has two states: short steps between coffee plants or long steps across the plot or between the plots (Mora Van

Cauwelaert et al., in press). The difference in the proportion of each state during the daily harvest presumably relies on the maturation synchronization of the berries or the number of workers in the plot (Mora Van Cauwelaert et al., in press). These different trajectories could play an important role in CLR dispersal and its impact on plantations with distinct managements or planting density characteristics.

Here we present a mathematical model to study the workers' spatial movement during coffee harvesting and its contribution to CLR dispersal and infection at a plot level. We first explore if the different spatial trajectories drawn by the workers in large-scale plantations (with or without long steps; Mora Van Cauwelaert et al., in press) can be reproduced in simulated coffee plots with different berries maturation synchronicity and number of workers in the plot. We then evaluate how these trajectories modify rust dispersal and change the final average CLR infection in plots with increasing planting densities. Finally, we discuss the implications of our results in a broader context of different syndromes of coffee production.

2. METHODS

The objective of implementing a model was twofold: i) characterize some of the sufficient factors (ripening asynchronicity and number of workers) to reproduce the reported trajectories of the workers during the harvest and ii) explore the effect of these trajectories for dispersal and average rust infection in coffee plots with different planting densities. We first describe the procedure illustrated in Figure 1 and the different simulated scenarios. Then, we explain the analyses for each of the objectives.

2.1 Model Description

Coffee infection and dispersal process. We simulated coffee plants in a plot as N randomly placed points in a 100 x 100 m square with non-periodic boundaries. As we fixed the area, N represents the average planting density per ha of coffee plantations. Each plant had one of two states of infection: ***susceptible*** or ***infected*** (with rust spores present) (Fig. 1A). An infected plant can disperse and infect neighboring plants by two mechanisms. Through ***contact-mediated dispersal***, infected plants infect all 1.5 m apart or less susceptible neighbors. This mimics the local dispersion of rust either by contact between two nearby plants or by splash (as proposed by Vandermeer et al., 2018). The process creates networks of infected nearby plants where each pair of plants are 1.5 m apart or less (gray and black circles in Fig. 1A). The ***worker-mediated dispersal*** occurs when a worker harvests an infected plant and reaches a susceptible plant in the following step (yellow circle in Fig.1A). When an infected plant infects susceptible neighbors at time step t, these become infected at *t+1*. Each unit represents roughly 30 days, this is, the time needed for rust to complete a cycle of infection (Leguizamon et al., 1998).

Coffee ripening and harvesting motion. Additionally, each plant can have berries (***present***) or no (***absent***) (Fig.1B). We defined two coffee interplant ripening scenarios. In the Synchronous scenario (S), all the plants have ripe berries at the date of harvest. In the Asynchronous scenario (A), only 50% randomly selected plants have ripe berries at harvest (Fig. 1B). The presence of berries defines the harvesting motion: at the date of harvest each worker starts harvesting in a plant with berries, collects it (changing the status of berries of that plant to ***absent***), and moves to the closest plant with berries (Fig.1A). This cycle repeats until half of the plants in the plots are visited (Fig.1A). Depending on the number of plants harvested and number of workers, the process represents one or multiple working days (one worker collects around 30 plants per hour; Mora Van Cauwelaert et al., *in press*).

Whole model dynamic. We start the simulations with a small percentage of infected plants (T0 in Fig.1A) and run five cycles of contact-mediated dispersal and infection (these five cycles mimic the five months from the beginning of CLR buildup to the peak of harvesting; Mora Van Cauwelaert et al., 2023). At the time of harvest (TH = 5 time steps) almost all the plants in the same contact-mediated networks with one or more initially infected plants are infected (gray circles in Fig. 1A). These infected networks define the extent to which the pathogen spreads with contact mediated dispersal but without any harvesting. In the non-control scenarios, the harvesting takes place at TH. During the harvest, new infections emerge (yellow circles in Fig. 1A). After this harvesting event, we generate seven new cycles of contact-mediated dispersal and infection in which the newly infected plants spread the rust across their contact-mediated networks (black circles in Fig.1B). The whole simulation represents the maximum rust spread during one year, without acknowledging for leaf loss or other mechanisms or climate factors that in practice reduce the general infection (Kushalappa and Eskes, 1989). This is useful to compare the expansion of rust in our

different scenarios. In the control scenarios, no harvesting process takes place and the simulations run an equivalent time than the non-control scenarios.

2.2. Scenarios and measurements

We first characterized the trajectories and the distribution of steps simulated under two scenarios of coffee ripening (A and S), five planting densities (500, 1000, 2000, 3000, and 5000 plants per ha), and two quantities of simulated workers (1 and 5) (totalling 20 scenarios). We then took the last 160 steps of trajectories drawn in planting density of 3000 plants/ha to compare them with data that presented a similar average of harvested trees in plantations with different levels of ripening synchronicity (Mora Van Cauwelaert et al., in press). In particular, we took two examples from a large-scale organic plantation with an asynchronous ripening at the date of harvest ("organic plantation", henceforth) and two from a slightly shaded, large-scale non-organic plantation with synchronous ripening at the date of harvest (conventional plantation). Both plantations had a planting density between 3000 to 4000 plants/ha.

Secondly, we used our model to explore the effect of these simulated trajectories (20 scenarios) on the plot average rust infection, compared to control non-harvesting scenarios (5 additional scenarios, one for each planting density). We replicated each scenario 30 times to account for the random initial arrangement of plants. Each simulation started with 20% of infected plants (We show results for other initial infections in the supplementary material). To further explore the mechanisms behind our results, we registered the newly infected plants during harvest (yellow circle in Fig.1A) and the newly infected network after harvest and their size (black circles in Fig. 1A).

The model and simulations were implemented in the *Python* 3.10.6 programming language, using the modules *NumPy, SciPy, Pandas, and Seaborn*, and ran on the LANCIS facilities, at the Ecology Institute of UNAM. The data analyses and figures were done in

Rstudio 2023.03.1+446 using *plyr, dplyr, tidyverse, ggplot2, patchwork* libraries, and *Inkscape 1.0.* All code and data required to reproduce results in the work can be accessed at https://github.com/tenayuco/toyModel_harvest.

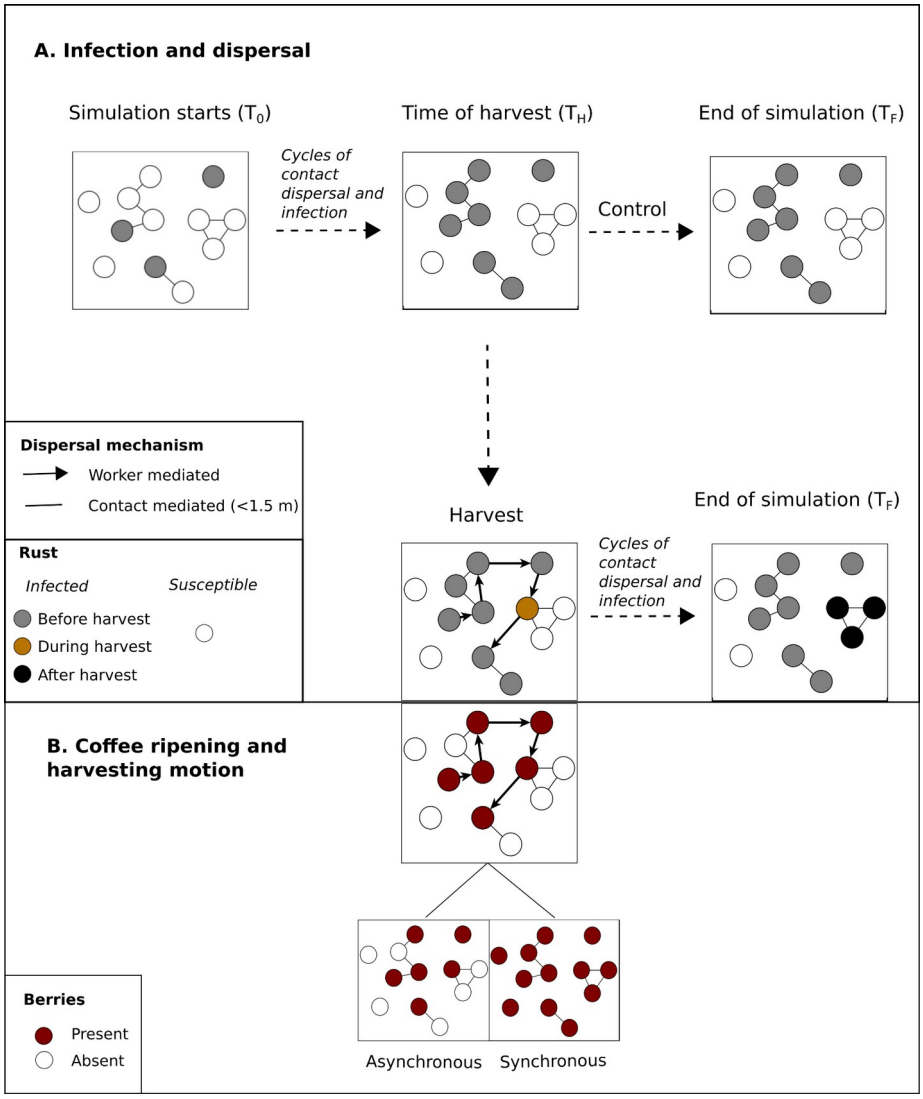

Fig. 1. Model structure and dynamics. ***(A) Infection and dispersal***. Plants can have two states of infection: infected or susceptible (white circles). Infected plants can be infected before the harvest (gray circles), during the harvest (yellow circles) or after the harvest (black circles). Black edges represent pairs of plants that are 1.5 m apart or less and can be infected through contact-mediated dispersal. Black arrows represent the movement of the harvester. We depict the start of the simulation (T_0), the five cycles of contact dispersal and infection until the time of harvest (T_H) and the two possible scenarios afterwards: the control scenario where no harvesting takes place, and the harvest scenario where harvesters can create new infections (yellow circle) that might disperse to the neighbors after new seven cycles of contact-mediated dispersal and infection. ***(B). Coffee ripening and harvest motion***. Plants can have two states of berries: with berries (red circles) or without (white circles). We illustrate the two coffee ripening scenarios explained in the text. In the synchronous scenario all the plants have berries at the time of harvest and in the asynchronous scenario, half have berries and the other half do not.. The presence of berries determines the trajectory of the worker (black arrows) during harvest.

3. RESULTS

3.1. Coffee ripening synchronization produces two qualitatively different harvesting trajectories that are equivalent to the trajectories of the workers in large-scale plantations

The deterministic movement of the simulated workers across randomly distributed plants generates random trajectories. (Fig.2 and Fig.S1.1). For both synchronization scenarios, the distribution of step length is positively skewed and can be approximated with continuous lognormal and exponential distributions (Fig.S1.3). Within each planting density, the mode is equivalent (Table S1.1). Under the asynchronous ripening scenario, the trajectory exhibits medium to large steps (30 to 100 m) and produces a heavy-tailed distribution (Fig.2). In the synchronous scenario, the steps are smaller than 30 m, creating a short-tailed distribution (Fig.2). In the asynchronous scenario the workers also explore a larger area of the plot.

Interestingly, the presence of large steps (>30 m) is not directly related to the initial low density of plants with berries in the asynchronous scenario. In fact they are not present in any of the equivalent and sometimes lower planting densities in the synchronous scenarios (Fig. S1.1 and Fig. S1.2). Large steps are concentrated near the end of the harvesting process (Fig. S1.2) for all planting densities, suggesting they are related to an increasing scarcity of trees with berries during the harvesting in the asynchronous scenario. Finally, we note that the number of simulated workers does not generate significantly different trajectories (Fig.S1.1). Hence we model only one worker in the plot in the following analysis.

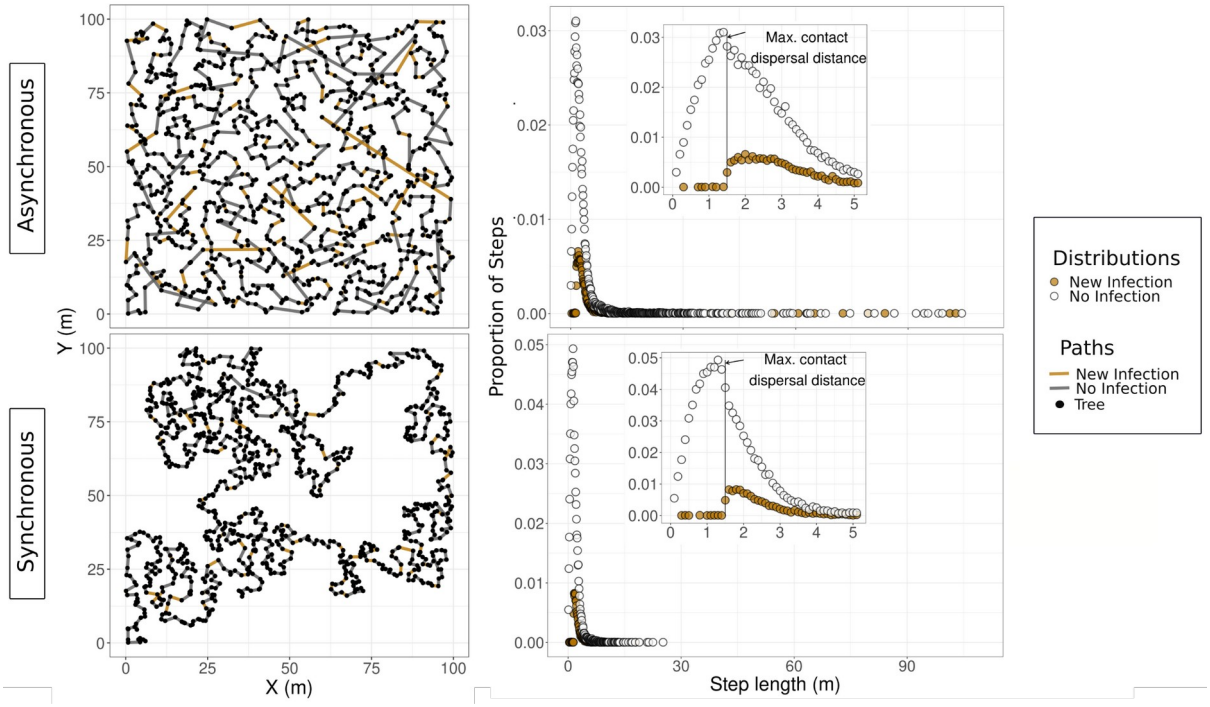

Figure 2. Simulated trajectories (left column) under two scenarios of coffee ripening and their respective step distribution (right column). The trajectories show one of the repetitions but the distributions are calculated over 30 repetitions. The color depicts if the harvesting step generated a new infection (this is, if the worker travels from one infected plant to one susceptible one) (yellow lines and dots) or no (gray lines and white dots). The line in the inset represents the maximum contact-mediated dispersal distance between plants. In the distribution we can distinguish two qualitative distributions of steps: with and without large steps. The modes of the skewed distributions are 1.7 and 1.3 for the asynchronous and synchronous scenarios, respectively. For the presented data, N= 2000, w= 1. The trajectories for other planting densities and number of workers are presented in Fig. S1.1.

The generated trajectories for the last 160 trees at a planting density of 3000 plants/ha are qualitatively similar to in-field trajectories drawn by workers in two large-scale coffee plantations with equivalent planting density (3000 to 4000 plants/ha) but that differed in their ecological management and their ripening synchronicity at the date of harvest (Fig. 3). This implies that the coffee ripening differences and the scarcity of trees with berries at the end of harvesting in our model might be sufficient to reproduce the short and large steps observed in the field. This behavior corresponds to observed jumps by the workers between coffee plots when a zone is depleted during the same day (to maximize daily harvest). Contrarily, synchronous ripening or a short harvesting process (before reaching the scarcity of trees; Fig. S1.2) would enable workers to stay in the same area during the day (Fig.3).

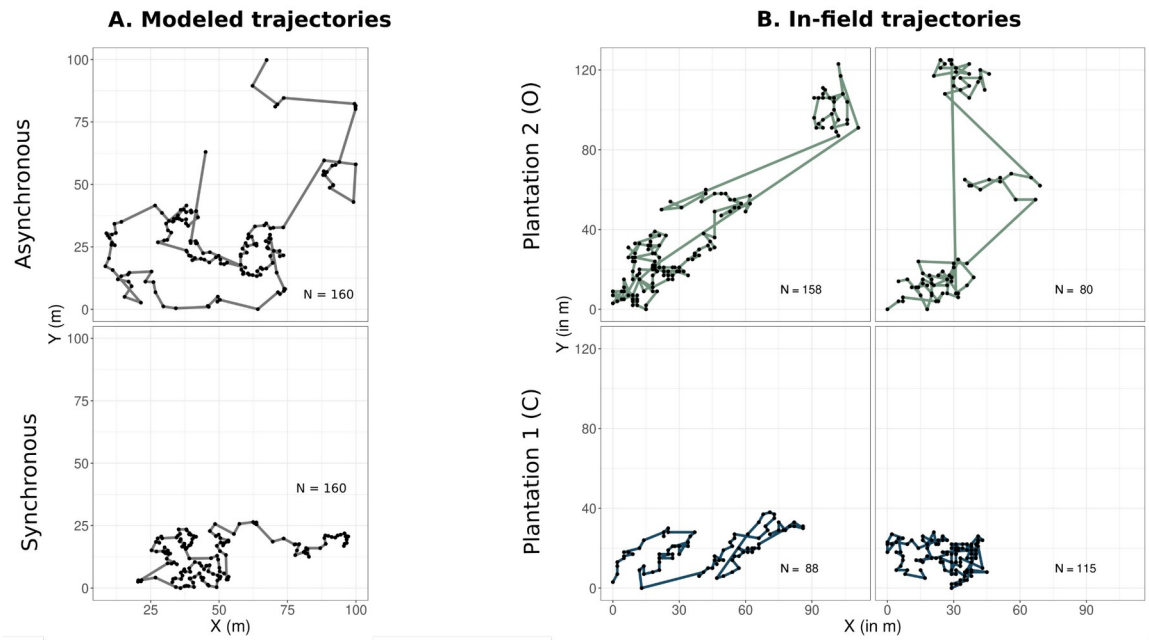

Fig. 3. Comparison of the model with in-field trajectories. A. Two examples of the modeled trajectories for the last 160 plants, drawn under the asynchronous and the synchronous scenarios, with N= 3000 plants/ha and w=1. **B.** Examples of in-field registered trajectories from Mora Van Cauwelaert et al. (in press). Organic plantation (green line) is a large-scale shaded and organic plantation with an asynchronous ripening at the date of harvest. Conventional plantation (blue line) is a slightly shaded, non-organic large-scale plantation with synchronous ripening at the date of harvest). For both plantations 160 plants were visited on average (see Mora Van Cauwelaert et al., in press for more details). Both plantations are around 300 ha, with a planting density between 3000 to 4000 plants per ha.

3.2. Dispersal during harvesting increases final rust infection specially for trajectories with large steps.

In this section we analyze the effect of the different generated simulated trajectories (with large steps from the asynchronous ripening scenario, and without large steps from the synchronous scenario) on the average rust in the plot. Higher planting density increases the plot-average infection in scenarios where only contact-mediated dispersal is present (control; gray line in Fig. 4A). Nonetheless, for each planting density, adding the harvesting event increases the final infection compared to the control (orange and blue lines in Fig. 4A).

The difference between the average rust with harvesting and without harvesting follows a non-linear curve for both kinds of trajectories with increasing planting density (orange and blue boxes in Fig. 4B). The maximum effect of harvesting with large steps lies at 2000 plants/ha (~15% average rust increase), and between 1000 and 2000 plants/ha for trajectories without these steps (~ 8% increase) (Fig. 4. B). At 5000 plants/ha, the impact of harvesting drops for both scenarios as almost all the plants are already infected by contact (Fig4. A and B). Harvesting with large steps increases rust infection more than without these steps, especially at medium densities (2000 plants/ha; more than 6% of rust infection difference (Fig. 4B). Only at very low densities (500 plants/ha) the difference between both scenarios is not distinct from zero.

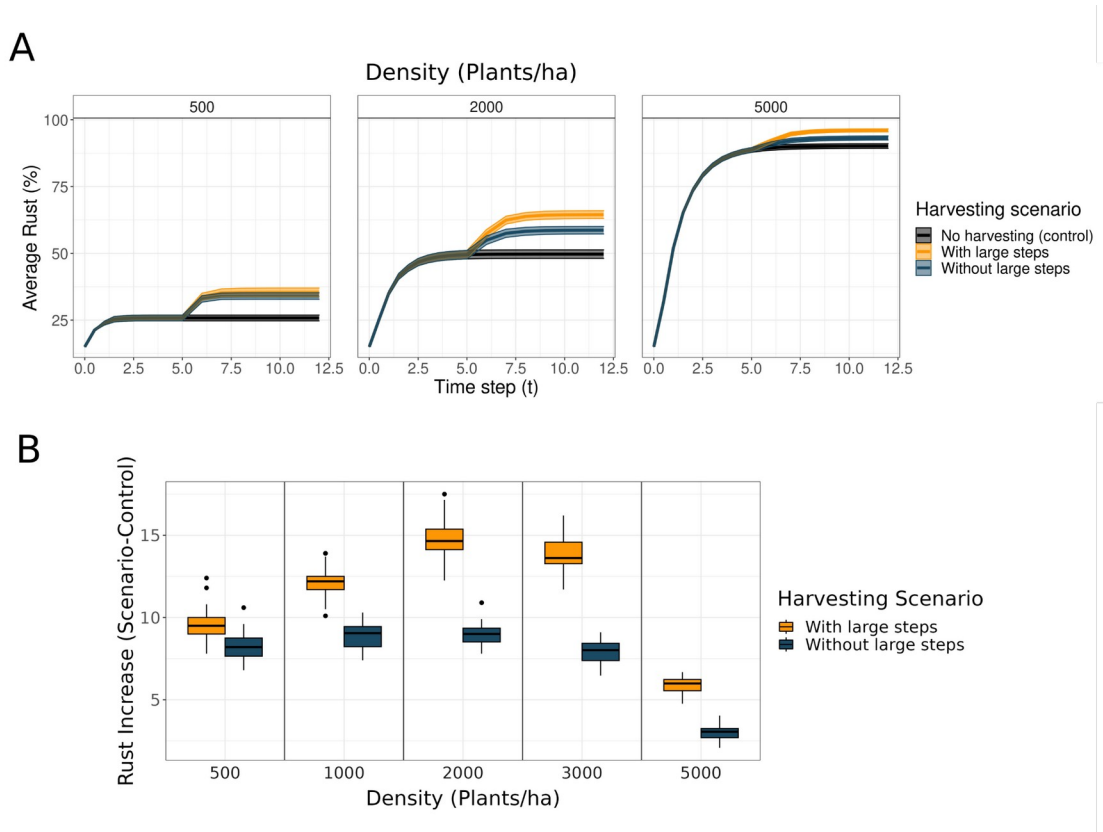

Figure 4. Effect of different harvesting trajectories on the average plot rust infection. ***A.*** Full time series of the average rust for three planting densities, for the control and the two harvesting trajectories generated under the coffee ripening scenarios (**A**; gray: control, orange: trajectories with large steps, blue: trajectories without large steps). The time series for 1000 and 3000 plants/ha were equivalent. **B.** Rust's increase due to the harvesting for each of the trajectories (harvesting scenario - control) for the five different planting densities (orange box: with large steps, blue: without large steps). In all simulations, we started with 20% of infected plants at T_0. We fixed 1 worker per plot.

3.3. The interaction between the number of new infected networks of plants and their size underlies the effect of harvesting on plot average infection

In Fig.2, we differentiate the steps that carried infection (yellow dots) from those that didn't (white dots). We observe that before 1.5 meters, the frequency of worker-mediated dispersal events (steps during harvest that promotes new infections) is almost zero. This distance corresponds to the contact-mediated infection reach: almost all the plants within this reach should be already infected at T_H (Fig.1). When we explore the proportion of worker-mediated dispersal events larger than 1.5 m, we observe that the values drop as we increase the density and that there is no difference between coffee ripening scenarios (Fig.S1.4). In this sense, the maximum rust's increase at medium densities (Fig. 4B) is not directly related to the proportion of new infections created during harvest.

In Fig.5 we show the proportion of infected networks of plants after the harvest event and the new cycles of contact-mediated infections (AH) (black circles in Fig.1 and the subplot in Fig.5) and their mean size. We include the product of both magnitudes as a proxy for the number of infected plants after the harvest event and the new rounds of infection (plants that would not be infected otherwise). For both trajectories with and without large steps, the proportion of new infected networks of plants decreases as planting density increases (black lines with circles dots in Fig. 5). This makes sense since the connectivity between plants increases with density, making almost all the plants already infected before harvest (gray dots in the subplot in Fig.5). On the contrary, the average size of new infected networks after harvest increases with planting density (black lines with triangle dots in Fig. 5). The estimated number of newly infected plants after the harvest (as an interaction of the number of networks and their mean size) follows a non-linear behavior in both scenarios that peaks between 2000 and 3000 plants (red dashed line with square points, Fig.5). This

curve is equivalent to the observed increase of infection in Fig. 4 and might be the mechanism underlying its nonlinear behavior.

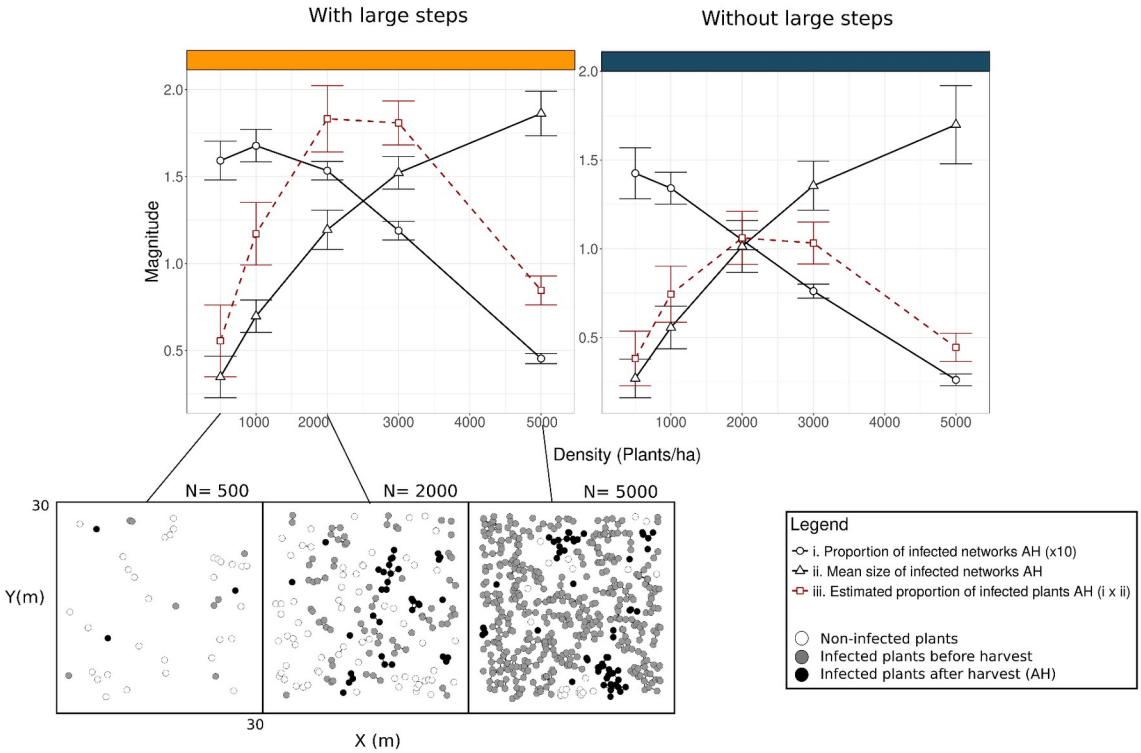

Fig. 5. Relationship between the trajectories of harvesting and the infected networks during the infection dynamic. We have one plot for the scenario with large steps (orange) and one for the scenarios without large steps (blue). In each plot, we present the proportion of new infected networks of plants after harvest/total plant visited; black lines with circles dots), the mean size of these network (black lines with triangle dots) and the multiplication of these factors as a proxy of the proportion of new infected plants (red dashed line with square points). In the below figure, we show three examples (at 500, 2000 and 5000 plants/ha) of the spatial disposition of susceptible plants (white circle), plants infected before the harvest (gray circle) and plants infected after harvest and the new cycles of contact-mediated infection (black circles). For visualization purposes we multiplied the proportion of infected networks by 10.

4. DISCUSSION AND CONCLUSIONS

Understanding the relationship between the spatial arrangement of the hosts and the different modes of dispersal of CLR is central to developing preventive strategies to reduce the impact of the pathogen on crop production (Hajian-Forooshani and Vandermeer, 2021). Here we present a model to study the determinants of the movement of the workers in the field during harvesting and its relevance in CLR dispersal and infection at the plot level. Our results suggest that we can reproduce random walks or large relocalizations by regulating the coffee ripening synchronicity and the scarcity of trees with berries at the end of harvest. Relocalizations in deterministic walks on a random set of points have been documented for other systems (Brown et al., 2007) and simulated in rectangle domains (Boyer, 2008; Santos et al., 2007) or varying the size of the targets (Boyer et al., 2006). These studies present specific widths or target size uniformity ranges where the modeled workers fail to find closer unvisited points and "jump" to another zone of the area (Boyer, 2008; Boyer et al., 2006). Concerning the CLR impact, we found that increasing the planting density where only contact-mediated dispersal was present increases the final CLR at the plot level. This is in line with other studies (Hajian-Forooshani and Vandermeer, 2021; Zambolim, 2016; Mora Van Cauwelaert, et al. 2023) and emphasizes planting at lower densities to avoid big bursts of the pathogen (Ehrenbergerová et al., 2018). The harvest event magnifies the final CLR infection for all scenarios and densities. Its effect is more important for medium densities (2000 to 3000 plants/ha), which is a common density of coffee plots owned by small-scale farmers (Soto-Pinto et al., 2000). If densities are too high, harvesting becomes irrelevant as the plot is already infected. Other modes of dispersal, such as wind-mediated relocalizations from neighbor plantations, were not included (as in (Hajian-Forooshani and Vandermeer, 2021; Vandermeer and Rohani, 2014). This assumption stands for the rainy seasons where

local contact is more relevant to build the initial epidemic (Boudrot et al., 2016). The different types of trajectories generated under the two coffee ripening scenarios changed the plot average CLR and varied nonlinearly with increasing planting density. Movements with medium and large steps promote new foci of infection (Zadoks and Van Den Bosch, 1994) that eventually become newly infected networks with optimum size and number at planting densities between 2000 to 3000 plants/ha. It is important to note that we modeled a random arrangement of the plants in the lattice. This assumption is likely valid for old plantations and shaded coffee managements (Moguel and Toledo, 1999) but should be revisited for aggregated or uniform patterns.

While we observe an increase in CLR in the asynchronous scenario, our results do not imply that asynchronous ripening conducts *per se* to higher rust. On the one hand, the medium to large steps are not generated due to the asynchronous ripening alone, but mainly due to the scarcity of closer trees at the end of harvest in that scenario. This would also be the case for large-scale landlord owned plantations where the workers are paid by the daily harvest (Jiménez-Soto, 2021); even if the following plant is hundreds of meters distant, it becomes necessary for them to reach it within the same day (Mora Van Cauwelaert et al., in press). In these plantations it is also common to force the workers to harvest at the end of the season when only few scattered trees still have berries (Mora Van Cauwelaert et al., in press). On the other hand, the simulated trajectories in the two coffee ripening scenarios suppose otherwise similar conditions on the plot. But in the field, asynchronous ripening is associated with characteristics that change these conditions and that can reduce the general rust impact. For example, the susceptibility of coffee plants to rust increases with fruit charge (Salgado et al., 2008). Hence, the asynchrony in the maturation of berries due to erratic rainfalls, or simply due to different coffee varieties (DaMatta et al., 2007), generates a mixed spatial pattern of resistant and susceptible plants that could reduce rust dispersal. On the other hand, shade trees in the plot form different patches of maturation (and the

potential for large steps during harvest) but also create barriers to wind-mediated rust dispersal (Gagliardi et al., 2020).

Our study aims to spur discussion on practices that can reduce the impact of harvesting and specific trajectories, in scenarios where one can benefit from asynchronous maturation of berries and shaded plantations (Ehrenbergerová et al., 2018; Liebig et al., 2019; Soto-Pinto et al., 2000). This is crucial as almost all the plantations have or will have this kind of ripening (DaMatta et al., 2007; Masarirambi et al., 2009), especially in the predicted climate scenarios of increasingly erratic rainfalls (Avelino et al., 2015; Huang et al., 2012; Rana et al., 2014). Along with planting different genetic varieties (Silva et al., 2006) or having other species of trees inside the plot and between them (Avelino et al., 2022), our results show the importance of reducing long-distance movements during the same day by avoiding harvesting at the end of the harvest season when trees ripening asynchronicity and CLR levels are higher (Avelino et al., 1991; Mora Van Cauwelaert in press); or simply skipping rust-infected trees and working fewer hours a day, even if this represents a short term decrease in harvested berries. These practices presuppose the right to decide how and when to harvest the coffee plantations.

We hope this mechanistic model will contribute to educating our intuition on the relationships between host spatial disposition and dispersal. With this approach, we try to build working hypotheses for an agroecological approach to pest management that does not rely solely on the control of the infection stage of the pathogen, but also on preventive measures that focus on the dispersal of the fungus.

5. ACKNOWLEDGMENTS

EMVC is a doctoral student from the Programa de Doctorado en Ciencias Biomédicas, Universidad Nacional Autónoma de México, and has received CONACyT scholarship 686776 and support from the Programa de Apoyo a los Estudios del Posgrado (PAEP) for his research stay at the University of Michigan (USA). MB acknowledges financial support from UNAM-DGAPA-PAPIIT (IN207819). JV acknowledges financial support from the US National Science Foundation, grant number DEB-1853261. EMVC thanks the people from La Parcela and Perfectomeer lab for their great ideas and friendship, and specially the GEO organization for their continuing strike for a living wage. EMVC and MBK are also thankful to Gustavo Bautista, Gabriel Domínguez, Elisa Lotero and Cecilia González for the discussions and help during the fieldwork. The authors thank Denis Boyer and Alfonso Valiente for the valuable feedback on the results and Rodrigo García Herrera for his technical support.

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