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Shade has Antagonistic Effects on Coffee Berry Borer

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SUMMARY

This work was addressed to clarify shade effects on the coffee berry borer, *Hypothenemus hampei* (Coleoptera: Curculionidae). The research was carried out in 2010, in Turrialba, Costa Rica, at 600 m of elevation, in a trial established by CATIE where different shade trees and coffee managements are compared. We studied several combinations of three levels of exposure to light (full sun, medium shade of *Erythrina poeppigiana*, dense shade of *E. poeppigiana* and *Chloroleucon eurycyclum*) and three coffee managements (organic with applications of the entomopathogen fungus *Beauveria bassiana*, conventional with insecticide sprays, and conventional insecticide-free). The response variables were: (i) populations of *H. hampei* in green, ripe and dry berries, and (ii) number of bored berries. We also monitored the microclimate in full sun exposure and dense shade conditions. Shade tended to increase *H. hampei* populations into coffee berries. With the conventional management, with insecticide or with no pest control, the number of CBB females, into the ripe and dry berries from the branch, was 70 % higher on average under shade than at full sun exposure. When analyzing the percentage of bored berries, we observed almost the same trend. With the conventional management, with insecticide, shade significantly increased the proportion of berries bored by the insect: 6.4 % and 2.4 % of bored green and ripening berries at the beginning of the harvest under dense shade and at full sun exposure respectively. However, shade effect was reversed when *B. bassiana* was applied. The proportion of bored berries was significantly higher under the moderate shade (4.9 %) as compared with the dense shade (4.0 %). Shade has therefore antagonistic effects on *H. hampei*. In one side, shade increases CBB populations when no *B. bassiana* is applied, but in the other side, it decreases the number of bored berries when the entomopathogen fungus is sprayed. This can be explained by the microclimatic conditions which were more favorable to the insect and to the entomopathogen fungus under shade. Under dense shade, temperatures were buffered (particularly high temperatures) and relative humidity and plant organs wetness were higher as compared to full sun exposure.

INTRODUCTION

Shade tree effects on coffee berry borer (CBB) are poorly understood. Different effects are mentioned in the literature. Shade has often been reported to favour CBB infestations [1-3]. However, different shade effects have been described according to the shade cover that trees provide. For instance, abundant CBB populations were observed under dense shade (60-70 % of shade cover), whereas similar low infestations were observed at full sun exposure and under moderate shade (40-50 %) [3]. In other circumstances, no shade effect was detected [4]. Shade has even been recommended for fighting CBB within the framework of an increase of temperatures related to climate change [5].

Shade effects on coffee pests and diseases are usually not clear, because shade may stimulate several pathways at the same time with opposed effects, some favouring the pest and others hampering it. The balance of these effects is therefore unsure. The case of CBB seems to support that view. For instance, shade trees can provide propitious conditions for some species that are directly involved in CBB biocontrol, as birds, ants, and the entomopathogen fungus *Beauveria bassiana* [6-8]. However, full sun exposure seems favourable to other natural enemies. According to Hargreaves [9], *Prorops nasuta* Waterston and *Heterospilus coffeicola* Schmiedkenecht, natural CBB parasitoids in Uganda, seem more active on CBB populations colonizing berries exposed to sun than on those under shade. In addition, shade may directly affect CBB survival. Some shade trees are alternative hosts for CBB [10, 11]. Microclimatic conditions under shade may also have an effect on CBB. It is frequently admitted that CBB survives for longer and reproduces better in humid and shady conditions [10]. Moreover, shade tends to buffer temperatures [12-15] and may affect CBB through that way. The direction of the effect would depend on if these buffered temperatures are closer or not to CBB temperature optima. Shade may also influence CBB populations through its effect on the coffee plant, on its phenology, particularly on its flowering pattern [16], which is a key factor explaining the growth of CBB populations [17].

This work was addressed to clarify shade effects on the coffee berry borer.

MATERIALS AND METHODS

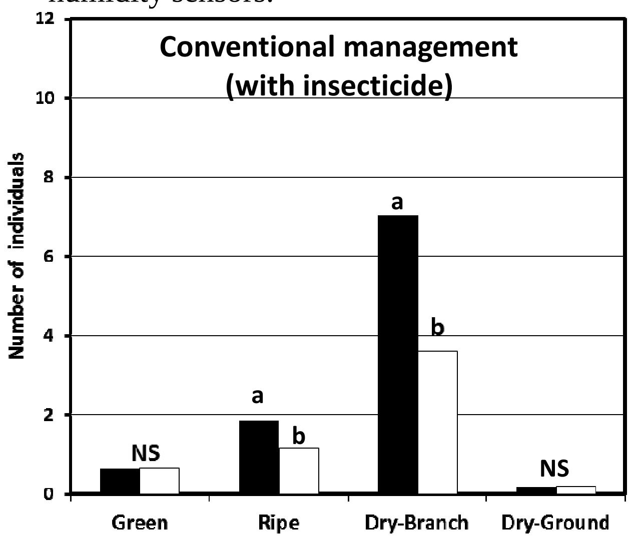
A field experiment was carried out from February to August 2010 at the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE) experimental station (Turrialba, Costa Rica; 9° 53’ N, 83° 38’ W). This location has climatic characteristics conducive to CBB development. Rainfall is almost evenly distributed throughout the year and abundant, 2700 mm 69-year average annual rainfall. The CATIE experimental station is located at 600 m above sea level, close to the lowest altitude at which coffee is cultivated in Costa Rica. The mean annual temperature is 22 °C (53-year average) with very little variation. The absence of marked dry season has consequences on the coffee flowering pattern. Flowerings are multiple, spreading normally from December to May, and of low intensity, resulting in multiple fruit cohorts and harvest rounds from July to December.

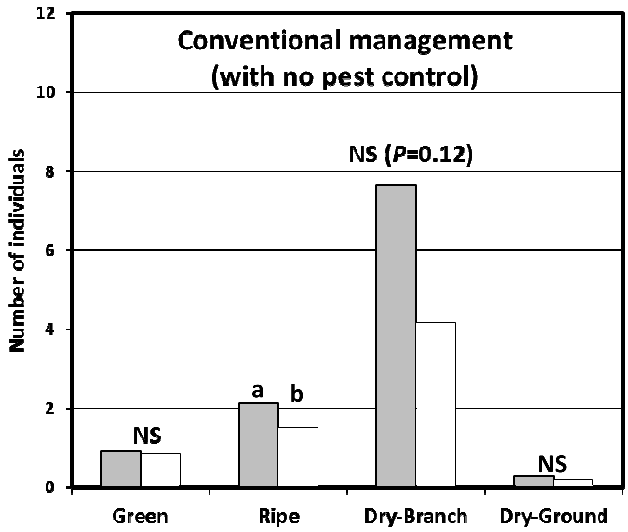
The study was performed on a 6 ha long term trial established in 2000 by CATIE where several coffee production systems are compared [18]. Coffee production systems differ with respect to shade trees and input regimes for nutrient, pest and weed management. Main plots are different shade trees used alone or in combination two by two. A full sun treatment was also included in the trial. Main plots are subdivided in four subplots, as a maximum, corresponding to two crop management strategies, conventional and organic, with two intensity levels of input application each. In our study, we only used four of the 20 combinations of shade conditions and input regimes present in the trial: (i) full sun and (ii) shade provided by *Erythrina poeppigiana* and *Chloroleucon eurycyclum*, both in combination with the least intensive conventional input regime, including insecticide applications against CBB, (iii) shade provided by *E. poeppigiana* only and (iv) shade with *E. poeppigiana* and *C. eurycyclum*, both in combination with the most intensive organic input regime, including applications of the entomopathogen fungus *B. bassiana* to control CBB. We incorporated in the study two additional combinations, by using plots contiguous to the trial and established at the same time. These plots were managed under the same least intensive conventional input regime as in the trial, but with no use of any CBB control method. One of these treatments was at full sun exposure, and the second one with shade provided by *E. poeppigiana*. Each combination is replicated three times in a randomized block design.

The shade percentage was checked twice in March and May 2010 in four places of each plot. We did this using a spherical densiometer employed to measure forest overstory density [19]. We obtained an average shade cover ranging from 23 to 41% in the *E. poeppigiana* plots, and from 48 to 69 % in the *E. Poeppigiana* with *C. eurycyclum* plots.

Two main CBB population assessments were performed: (i) the number of individuals at different development stages (particularly live females) and times, found in bored coffee berries (dry, green, ripe) coming from the ground and from the tree (ii) the progress over time of the number of bored berries on the coffee tree.

Air temperature, wetness (free water) and relative humidity were also monitored. Two Hobo H21-001 weather stations were positioned at the center of two close plots with contrasted light exposure conditions: (i) full sun exposure with low intensive conventional management and no insecticide applications and (ii) dense shade provided by *E. poeppigiana* and *C. eurycyclum* with high intensive organic management. Each weather station had nine sensors: four rigid wetness sensors, two air temperature sensors and three air temperature relative humidity sensors.





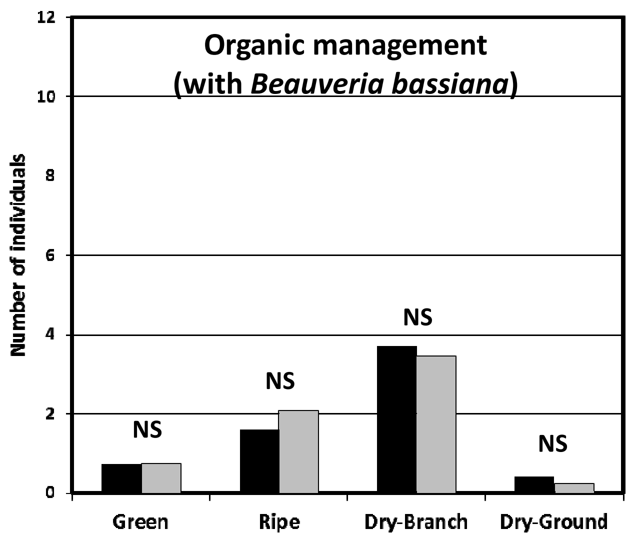


Figure 1. Shade effects on the number of live females into different kinds of berries (green, ripe, dry from the branch and from the ground). Average of five assessments from February to June 2010.
Black: dense shade provided by *Erythrina poeppigiana* and *Chloroleucon eurycylum*. Gray: regular shade provided by *E. poeppigiana*. White: full sun exposure.
Data with different letters are significantly different according to the contrast analysis (P<0.05). NS: not significant (P>0.05)

We used a general linear mixed model to analyse the data, where the combinations of shade and input regimes were considered as fixed factor and the assessment dates as random factor. When significant differences were highlighted, contrast analyses were performed to compare different shade conditions under the same input regimes.

Microclimate data were analysed by comparing intra-day variations for the two plot conditions. We plotted (i) the means of five sensors for air temperature (ii) the means of three sensors for relative humidity, and (iii) wetness frequency, which was deduced from the four wetness sensors. Data were processed separately according to the daily rainfall amount: no rain, 0-5 mm, >5 mm.

RESULTS AND DISCUSSION

With the conventional management, with insecticide and with no pest control, shade tended to increase the number of CBB females into the ripe and dry berries from the branch (Figure 1). The number of females was almost the double in each kind of berry. However, no differences were found into the green berries and dry berries from the ground, possibly because the

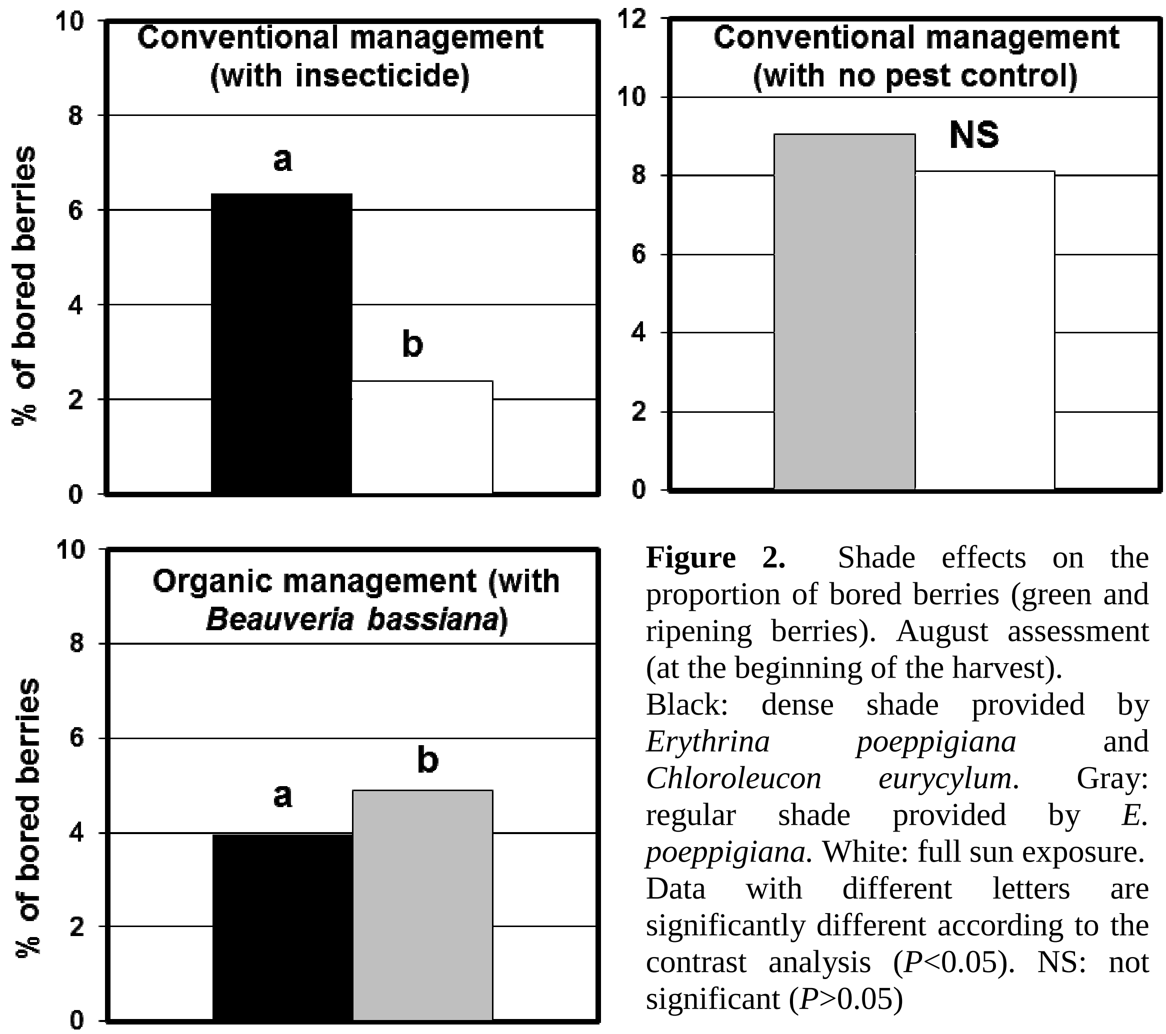
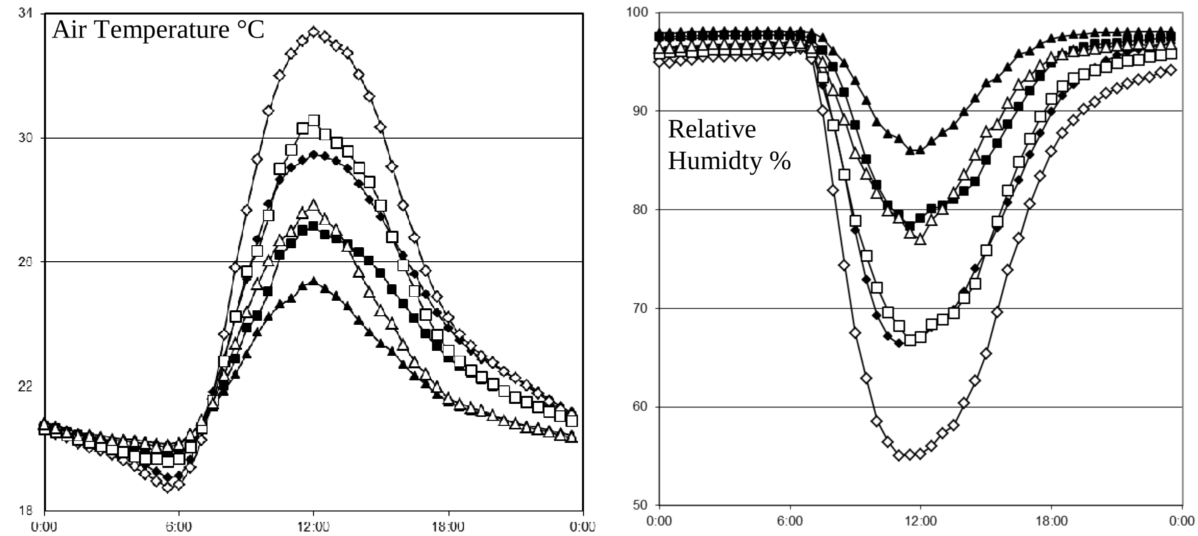


Figure 2. Shade effects on the proportion of bored berries (green and ripening berries). August assessment (at the beginning of the harvest). Black: dense shade provided by *Erythrina poeppigiana* and *Chloroleucon eurycylum*. Gray: regular shade provided by *E. poeppigiana*. White: full sun exposure. Data with different letters are significantly different according to the contrast analysis (P<0.05). NS: not significant (P>0.05)

number of females was very reduced. The green berries were recently colonized and the dry berries from the ground were mostly abandoned. With the organic management, we did not see any difference between the two studied conditions of shade. The number of females was low in both conditions, suggesting a favourable effect of shade on CBB control under the organic management (Figure 1).

When analyzing the percentage of bored berries, we observed almost the same trend (Figure 2). With the conventional management, with insecticide, shade increased the proportion of berries bored by the insect. This effect was not found with the conventional management with no pest control, possibly because the shade cover was lower. Shade effect was completely reversed when *B. bassiana* was applied. The proportion of bored berries was higher under the moderate shade as compared with the dense shade (Figure 2).

This behavior can be probably explained by the microclimatic conditions which were more favorable to the insect and to the entomopathogen fungus under shade. Under dense shade, light was reduced, temperatures were buffered (particularly high temperatures) and relative humidity and plant organs wetness were higher as compared to full sun exposure (Figure 3). It



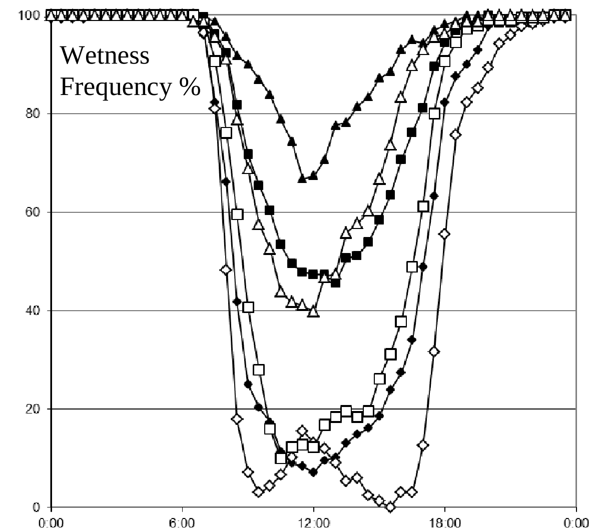


Figure 3. Intra-day variations in air temperature, wetness, relative humidity, under different daily rainfall conditions (no rainfall: rhombus, 0-5 mm: square, >5 mm: triangle) with full sun exposure (white) and under dense shade (*Erythrina poeppigiana* + *Chloroleucon eurycylum*, black)

is noticeable that in dry days, microclimate in the plantation under shade is equivalent to microclimate at full sun exposure on low rainfall days. Similarly, microclimate under shade on low rainfall days is equivalent to microclimate at full sun exposure on high rainfall days. On dry days and on low rainfall days, average temperatures exceeded 30°C at full sun exposure around noon , whereas under shade this temperature was not reached. In general, the proportion of surviving *H. hampei* colonizing females decreases considerably above 30°C. The development is also strongly restricted [20]. Concerning humidity, Baker [21] mentioned that the borer development and survival were improved between 90-95% of relative humidity. Under shade, the relative humidity was always at least 10 % higher than at full sun exposure, with a minimum of 65 % on average in dry days around noon.

Our results indicate that shade has antagonistic effects on *H. hampei*. In one side, shade increases CBB populations when no *B. bassiana* is applied, but in the other side, it decreases the number of bored berries when the entomopathogen fungus is sprayed. It can be concluded that with no applications of *B. bassiana*, it is better to reduce shade cover to control CBB. On the contrary, when *B. bassiana* is applied, it is better to provide higher shade cover to enhance the entomogenous fungus activity. However, there is probably not a single response for shade effects on CBB, and variations can be expected in diverse environments. A site-specific shade management is necessary.

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