Effects of Light on Cacao Productivity and Pathogen Presence/Severity

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Abstract

For the past few decades, cacao has grown to be a highly valuable export for Latin American countries. Used to make chocolate, offer medicinal properties, and allow economic security for both local communities and countries, cacao has developed an impressive reputation worldwide. In the Madre de Dios region, Southeastern Peru, cacao plantations have an incredible potential to become an internationally competitive crop and it is being implemented just yet for agroforestry, bringing sustainable agriculture to local communities as a better example to use their land. Every year, a fair portion of cacao yields are inedible due to two main fungi: *Crinipellis perniciosa* (witches' broom) and *Phytophthora sp.* (black pod). This study is built to examine the effects of light on the severity of fungal attacks on cacao pods between farmed cacao plants and wild ones in an agroforestry experimental plot at Finca las Piedras, Madre de Dios. It is important to investigate these factors to prevent major fungal issues and mitigate large scale effects. Additionally, understanding plant-pathogen interactions in an experimental plot can improve our farming technique and lead the example of sustainable agriculture in the region.

Introduction

Food, medicinal properties, economic prosperity, and literally meaning "Food of the Gods", it is with no doubt that *Theobroma cacao* is highly revered in the Peruvian Amazon. Cacao exports alone boosted from 6% to over 60%, grossing more than $230 million USD in 2014 (1. Scott et al., 2015). Unfortunately, its opulence cannot withstand the pernicious effects of nature. A multitude of factors including light gaps, animal attacks, fungi and pathogens, etc. can all play a role in the discontinuous productivity levels. A previous study done within the Native Food Forest constructed a light gradient to track the effects of different levels of sunlight on the growth of cacao trees. Their findings concluded a trend of proportionate growth to increased levels of sunlight, which could serve as a viable reason for low productivity.

Additionally, two of the most common and destructive pathogens in Latin America are witches' broom *(Crinipellis perniciosa)* and black pod disease *(Phytophthora sp.)* It is expected that pathogens will be less likely to occur in an agroforestry system in comparison to conventional agriculture, where they are intensively contained with chemicals. In addition, forest edges represent a different set of environmental variables compared to the forest's interior (i.e., wind, light availability), such factors could improve plant growth by eradicating the pathogens or animal attacks. Hence, our objective is to explore the presence, prevalence, and severity of pathogens in *Theobroma cacao* planted in light and shaded areas. To this aim, field observations were conducted within the Native Food Forest, an experimental agroforestry plot at Finca las Piedras, a biological station Southeastern Peru. Understanding these different factors in an experimental plot can improve our farming technique and lead the example of sustainable agriculture in the region.

Methods

Study Site

The site used for this investigation is the Native Food Forest (NFF) within the Finca Las Piedras (FLP) Research Station. Though FLP has a history of selective logging within the past 30 years, it is currently under protection of Alliance for a Sustainable Amazon (ASA) where various reforestation and research projects are continually practiced. The area of interest within NFF is located relatively close to the forest edge and thus exhibits a multitude of light gaps and gradients.

Study Species

The species of interest for this study is *Theobroma cacao*, a popular plant commonly found throughout the region of Madre de Dios. Commonly exported to other countries for chocolate production and medicinal properties, the cacao tree has served a huge economic benefit to the people of Madre de Dios region. Not to be confused with its counterpart, *Copoazu*, distinct differences can be identified to distinguish the two (Figure 1).

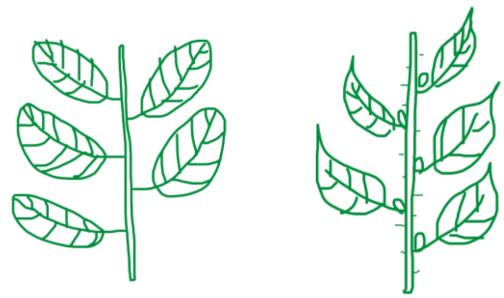

Figure 1. *Theobroma cacao* and *T. grandiflora* representations with their characteristic botanical features.

Data collection

Field observations took place over the course of a week in August–the driest month of the year. Two groups, Light and Shade, were established with a sample of 10 trees in each. Data collection involved going into the Native Food Forest to mark 10 trees in the full sun (75%-100% sun exposure from approximately 11am-3pm) and 10 trees in shade (>50% in shade from approximately 11am-3pm). From here, data categories regarding number of pods, size of pods, number of infected pods, and severity of pods were collected. Disease observations will involve identifying trees that appear to be infected based on present symptoms (large black spots on pods).

Note: Severity measurements will consider the size of the pods based on proportion of infection in fruit.

To measure size of pods, we used a 1-3 scale:

1=small
2=medium
3=large

To measure severity of pods, we used a 1-3 scale:

1=mild [1 small circle (>10% of plant)]
2=moderate (1-2 large black circles 25%-50% of plant)
3=extreme [almost entire pod is black (>50% of plant)]

Data Analysis

After inputting the data into an Excel spreadsheet, we ran three t-tests between Light and Shade treatments using R Studio: number of pods, number of infected pods, and severity of infection.

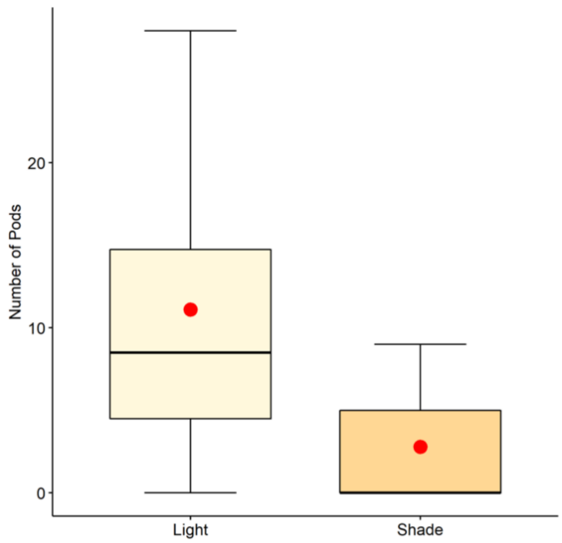

Figure 2: Box plot demonstrating the number of pods found in the Light treatment and Shade treatment. Red dots indicate the mean.

To perform the three t-tests, we used the software Excel. For the number of pods, we made a t-test with two-sample assuming equal variances.

Table 1: T-test with Equal Variances summary statistics for number of pods found between Light treatment and Shade treatment.

	7	*0*
Mean	11.555556	3.1111111
Variance	99.527778	15.611111
Observations	9	9
Pooled Variance	57.569444	
Hypothesized Mean Difference	0	
df	16	
t Stat	2.3609203	
P(T<=t) one-tail	0.0156264	
t Critical one-tail	1.7458837	
P(T<=t) two-tail	0.0312527	
t Critical two-tail	2.1199053	

For the proportion of infected pods and severity of infection, we used a two sample assuming unequal variances given that many of the shaded plants expressed lower productivity. Additionally, to create the box plots, we used R Studio with slight modifications in the code using *ggpubr* for finding the mean.

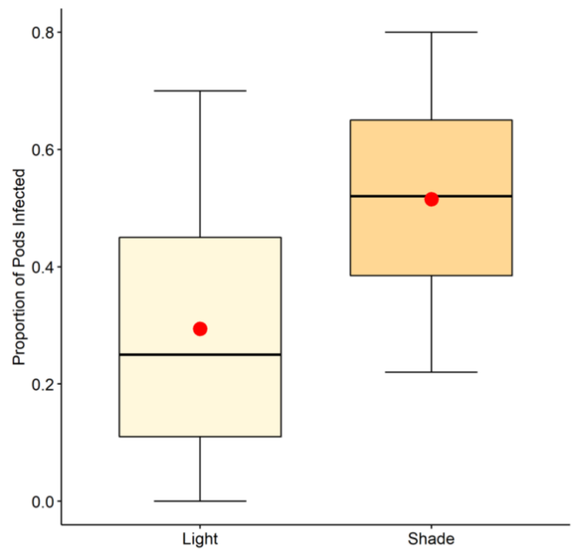

Figure 3: Box plot demonstrating the proportion of infected pods out of the total number of pods for both Light treatment and Shade treatment.

Results

Cacao trees exposed to light exhibit significantly higher productivity than their shaded counterparts (Fig. 2) with a mean of ~11.6 pods in the light treatment versus the ~3.1 pods in the shaded treatment (Table 1) (t=2.3, df=16, p=0.03).

Table 2: T-test with Unequal Variances summary statistics for proportion of infected pods out of total number of pods between Light and Shade treatments.

	Variable 1	*Variable 2*
Mean	0.2944916	0.5166667
Variance	0.0617751	0.0597119
Observations	9	4
Hypothesized Mean Difference	0	
df	6	
t Stat	-1.5050393	
P(T<=t) one-tail	0.0915097	
t Critical one-tail	1.9431803	
P(T<=t) two-tail	0.1830194	
t Critical two-tail	2.4469119	

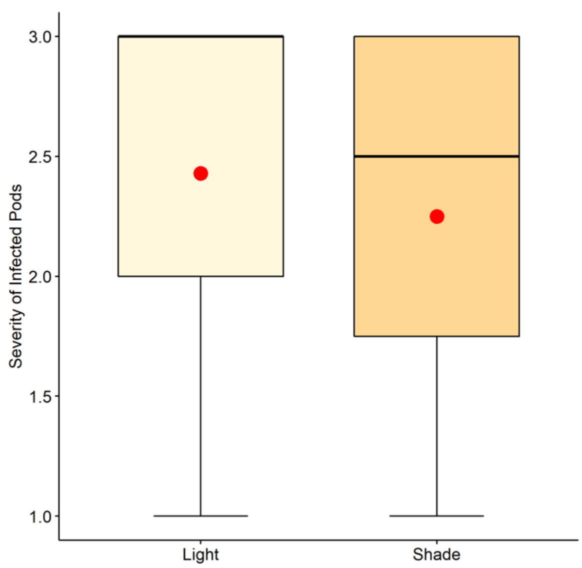

Figure 4: Box plot demonstrating severity of infected pods for Light treatment and Shade treatment using the 1-3 scale.

The proportion of cacao pods infected out of the total pods found per tree was greater in the shade treatment despite having less productive trees (Fig. 3). The mean of the proportion in the light treatment is 29% (n=9), meanwhile the mean for the shade treatment is 52% (n=4). The difference between both proportions is not statistically significant (Table 2) (t = -1.5, df=6, p=0.76, n.s.)

Table 3: T-test with Unequal Variances summary statistics for severity of infected pods between Light and Shade treatments.

	Variable 1	*Variable 2*
Mean	2.4285714	2.25
Variance	0.6190476	0.916666667
Observations	7	4
Hypothesized Mean Difference	0	
df	5	
t Stat	0.3168621	
P(T<=t) one-tail	0.3820755	
t Critical one-tail	2.0150484	
P(T<=t) two-tail	0.764151	
t Critical two-tail	2.5705818	

Discussion:

Initially, we expected the cacao trees to grow primarily in full sun with minimal proximity to animal habitats and water pools will demonstrate higher productivity. We predicted a lower susceptibility to witches' broom and black pod will likely be present due to the lower humidity levels and higher exposure to sunlight. Thus, Cacao trees present further from the forest edge would demonstrate a higher likelihood of attack due to increased humidity and lower exposure to sunlight.

While my initial hypothesis regarding higher infection rates was confirmed, seeing how the severity of shaded plants is higher compared to the light treatment raised more questions and interests for future projects.

Our findings from this study allowed us to conclude the importance of sunlight for high cacao productivity along with testing for trends and significance in pathogen presence and severity in cacao trees based on light and shade treatments.

Literature Cited:

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