Cataloging Pests of the Theobroma cacao in Madre de Dios, Peru for the Development of Integrated Pest Management Strategies

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Abstract

Theobroma cacao (cacao) is a species of tree growing in various tropical regions of South America, including that of Peru. For many families in these regions, the cacao fruit has become a keystone to their economy. It provides the families who grow, harvest, and sell their crops with most, if not all, their annual income. Regions where the cacao tree can thrive can also express unparalleled biodiversity if the land is looked after. As the modernization of agriculture has boomed, farmer and crop reliance on pesticides has posed yet another environmental threat to the land and to the farmer's independence. The consistent use of pesticides can severely impact the health of the land, weakening the strength of the crops to fight diseases and other environmental factors (droughts, low temperatures, etc.). Both the crop yield and even more importantly, the biodiversity are major factors to the smallholder farmers' success. If done well, the land can grow trees with the potential to support families over many generations to come. For this reason, a scientific basis on which pests plague the cacao tree can become a tool. For scientists, this can be the beginning of creating an Integrated Pest Management practice (IPM), allowing farmers to fight against the most detrimental of pests without sacrificing the health of the land. For farmers, it promises economic stability and the well-being of their families.

Introduction

Modern agriculture has seen a tremendous rise in the use of pesticides to increase crop yields for farmers worldwide (Kalia & Gosal, 2010). While they may deliver promising results in the short term, reliance on external outputs such as these decreases farmer sovereignty and has a negative impact on soil quality (Vig et al., 2008). Over long-term use, pesticides have the potential to cost the farmer in both yields and pesticide expenses, making it an unsustainable solution to pests

Madre De Dios is a region in Southeastern Peru's Amazon basin, which is considered the country's biodiversity capital (Sanchez-Cuervo, 2020). While there are many fruits and vegetation native to the forest, cacao has become one of the most prominent and important cash crops for smallholder farmers in Peru (Franzen & Mulder, 2007). There are various benefits for biodiversity in the growing of cacao trees, but they are mostly linked to cacao grown in the shade, and even more in the shade of other native forest species. However, the most common type of cacao production is now the full sun, high-yielding species type (Tscharntke et al., 2022). Understandably, this type of growth may have the most immediate economic turnout for farmers, but it puts the crop at a higher risk to pests than other methods of growing and in turn threatens the long-term economic safety of the farmer (Tscharntke et al., 2022). The financial well-being of smallholder farmers is imperative as they produce approximately

70% of the cacao exported around the world, and many of them rely completely on crop production as their only source of income (Tscharntke et al., 2022). Furthermore, the use of pesticides over long periods degrades the soil, and biodiversity, negatively impacting plant resistance (Vig et al., 2008). Over time, larger amounts of pesticides will be needed, until resilience is so low that even higher amounts of pesticide will no longer create the higher yields promised (Kilien & Glotzbach, 2021).

IPM involves the regulation of pests through methods that eliminate or lessen the need for external inputs (Dara, 2019). It also involves doing this in a way that is the least harmful to the biodiversity of the system (Dara, 2019). With the knowledge of which species of insect pests are most found in cacao trees, we can begin to study not only what plagues the cacao, but if these species have natural enemies. If the natural enemies can be successfully introduced into the same ecosystem, a form of pest management that excludes the excessive use of pesticides is created (Castillo, 2013). In a similar study conducted in a different region of Peru, Los Valles de Tumbes y Zarumilla, they found that the most common pests plaguing the cacao were: *Selenothrips rubrocinctus, Frankliniella parvula, Monalonion dissimulatum, Antiteuchus sp., Bolbonota sp.,* and *Toxoptera aurantia* among others (Castillo, 2013). The effect of these species varies from fruit discoloration to leaf consumption (Castillo, 2013).

Recording the pests most common to the cacao plant is the aim of this experiment, as it is an essential step in the development of a more sustainable future in the world of agriculture. This study can be the beginning of research that looks toward creating an integrated pest management strategy. In this way, cacao trees can be grown in methods that support biodiversity, sustain the resilience and health of the soil, and ensure the economic safety of smallholder farmers.

Methods

Study site

The study was conducted at Finca Las Piedras, a biological research station in Madre de Dios, Peru (-12.226348°, -69.112599°). It was conducted in July, the dry season and the period when friajes occur most often. Friajes are cold fronts that move into the Amazon Basin from the southern part of the continent, significantly lowering temperatures in the region for an average of four to five days (Benedix, 2008).

The site consists of both primary and secondary terra firma forests. Sampling was carried out in the Native Fruit Forest (NFF), a section of secondary forest that is surrounded by primary forest (-12.22792, -69.11284). The NFF was established in 2017 on 8,400m of abandoned land previously cleared for agriculture. More than 800 hundred fruit trees of 26 different species were planted, such as guava, copoazu, and cacao.

Study group

A group of 10 mature cacao trees planted in the NFF were studied. Cacao is a small tree (5 to 8 m) (De Souza, 2018) that grows in tropical regions of South and Central America (Callisaya, 2017).

Data collection

Ten points were chosen using a random number generator to select the cacao trees. The maximum and minimum longitude and latitude values of the NFF were input into the generator and 10 values for each were produced. The coordinates were formed by pairing the longitude and latitude values together in the same order that they were output. The closest mature cacao trees were labeled and pinned onto a GPS map. When choosing trees, it was ensured that there were at least a few meters of land separating the trees to avoid the overlap of insect populations.

Monitoring occurred six times over the course of two weeks (three days starting at 8:30 a.m. and three days starting at 2:30 p.m.). Rainfall and temperature data from the station and nearby primary forest floor, respectively for these dates were obtained. Researchers at Finca las Piedras have records from the last six years.

Observations of the trees (leaves, branches, trunks, and fruits) were made from the base of the trunk up to 1.5m off the ground. This was to ensure specimens were within a visible range and were easily accessible. At Tree 1, two observers started at the same point (the branch with a ribbon that specified the tree number) and made observations of each leaf on every branch throughout the circumference. Leaves and branches closest to the ground were looked at first until all lower branches had been studied closely, then the higher branches would be studied. The observers moved in opposite directions around the tree until they reached the same point. Observations were made from the outermost point of the branches, inspecting the leaves and fruits first, and then moving inwards towards leaves closer to the trunk. Each leaf was examined individually, looking at the top side first then carefully flipping over part of the branch and viewing the underside. The span of the tree's trunk was then inspected. Care was taken throughout the process to minimize disturbances in the branches before the data was recorded.

Findings including the name and abundance of any insects observed, as well as the activity (feeding, walking, etc.) were communicated. Observers recorded the latter in their field journal, by tallying the findings in categories by activity. If the name was unknown, a specimen name based on physical characteristics (for example, a small round iridescent beetle) was assigned. To make sure that specimens were named consistently, visual confirmation by the two observers was obtained prior to naming. Both observers also took photographs of any insect observations using a macro lens. Where possible, multiple photographs from different angles were taken to maximize the likelihood of identification. This process was repeated for the remaining nine trees. The order of observation remained consistent across all six days. The same trees were monitored six times so that potential increases in proficiency in finding insects across the trial period did not influence the results.

Data analysis

The organisms were categorized into their respective taxonomic orders and the total number of individuals within orders (across all days) was calculated for each tree. This information was transformed into a bar graph with the frequency of organisms on the Y axis and the tree identification numbers (1 through 10) on the X axis. The data for each tree were separated by using bars of different colors which represent each of the orders. Then, a similar bar graph was created which compared the sum of all individuals found per day instead of by tree number. In order to determine if the time of day impacts the abundance of insects found on the cacao trees, another bar graph was developed showing the total number of organisms found during the morning and afternoon sessions. The frequency of pests for each day was also graphed against the temperature data by creating a combined bar and line graph. The comparison was made to allow the impact of weather conditions to be seen and compared, potentially explaining any variation in frequency results. A catalog of common species found on the trees was created which includes the identification of the organisms, photographs of the specimen, their interactions with the cacao, and basic information about their taxonomic order.

Results

The resulting data collected throughout the experimental period serves as a jumping start for future researchers looking to develop an IPM method for Theobroma cacao. Results and figures were organized and created to serve as a database in which future researchers can pick apart and analyze according to tree number, day, time of day, and weather conditions.

Observers found that the Green lacewing larvae (Neuroptera) were very common. The larvae were eventually found on every tree throughout the 6-day experimental period. Organisms were distributed across nine orders (Arachnida, Bladontia, Blattodea, Coleoptera, Diptera, Hemiptera, Hymenoptera, Lepidoptera, and Mantodea).

Figure 1 separates the data by tree number, showing the total number of specimens on each tree across all six days. The graph shows variations in the abundance and proportion of orders between the trees. For example, Tree 1 has the lowest number of organisms, 11, while the highest was Tree 9 with 98 individuals. Tree 5 had a much higher proportion of orthoptera than any of the other trees.

Figure 2 compares the frequency of organisms in each order between each of the six days. Day 1 had the lowest number of organisms recorded with a total of 62. In comparison, there were 84 individuals recorded on the highest day, Day 5. The graph also shows that the orders most commonly found overall were Coleoptera, Orthoptera, and Lepidoptera.

As shown by Figure 3, which compares the abundance of organisms between the morning and afternoon sessions, there were slightly more organisms during the afternoon. Specifically, in the morning 198 individuals were recorded while in the afternoon there were 225.

Figure 4 shows the total number of organisms for each of the days plotted against the weather data recorded in the nearby primary forest. For the first five days, the temperature remained fairly consistent (within 1*C). On the sixth day, there was a decrease in temperature of

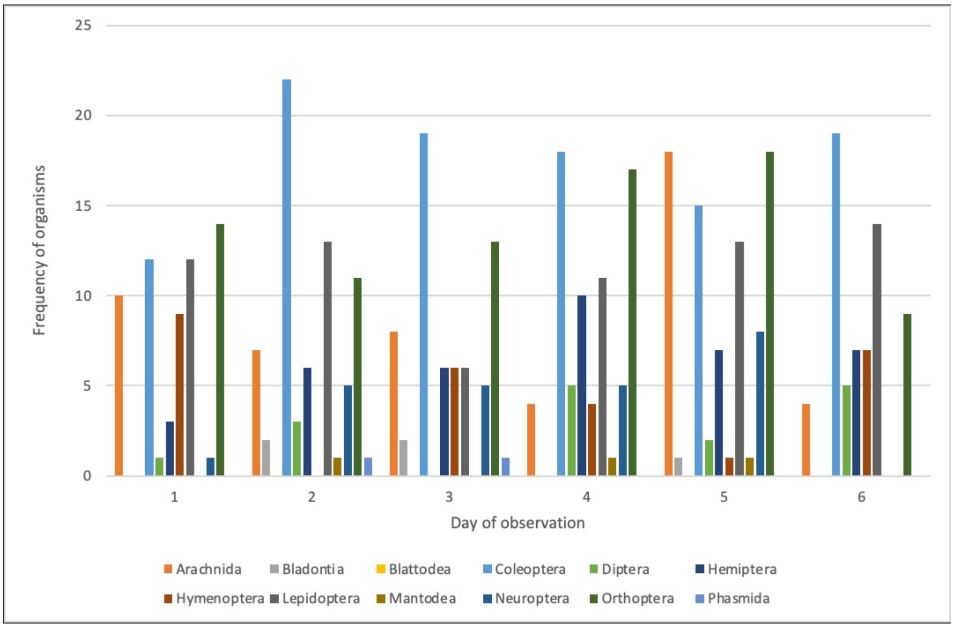

Figure 1. Frequency of organisms organized by order and separated by tree number.

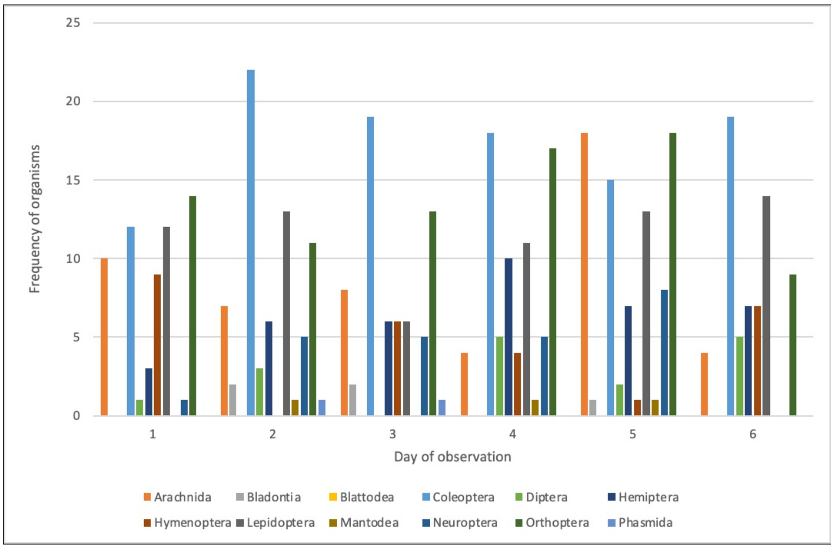

Figure 2. Frequency of organisms organized by order and separated by day of observation.

5.5*C.and the number of insects was also lower compared to the previous day. However, it is not the lowest value recorded overall.

Discussion

The data led to the conclusion that there was a notably large population of Chrysopidae, or Green lacewing larvae (Order Neuroptera) in the NFF. Raw data collected at the site from a notebook and transformed into an Excel sheet showed the total number of Neuroptera found on each tree and how many of them overall were Chrysopidae. The Green Lacewing Larvae made up a large part of the total individuals of Neuroptera recorded. This is significant, as the Green lacewing larvae have already been experimented with as a type of IPM in other parts of the world (Hanumantharaya et al., 2008). Green lacewing larvae are known as relentless predators of many aphids and soft-bodied arthropods (Koutsoula et al., 2022). This is an exciting find, as this could indicate a potential use of the Green Lacewing larvae as an IPM strategy.

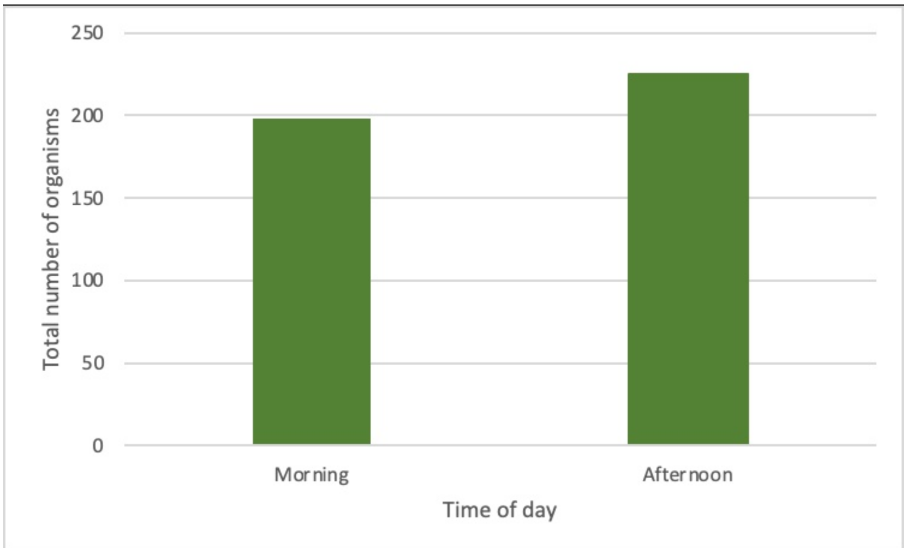

Figure 3. Comparison of frequency of organisms observed during the morning (starting 8:30 a.m.) and afternoon sessions (starting 2:30 p.m.). Values were calculated by adding the number of individuals for the tree

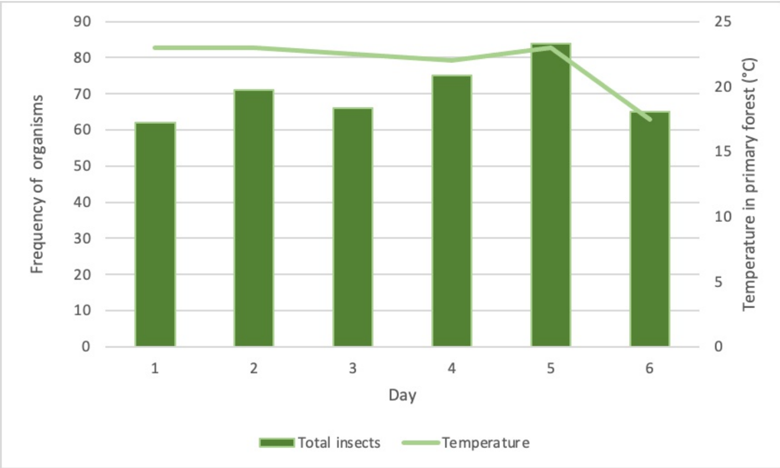

Figure 4. Frequency of organisms over the six sessions compared to the daily temperature. Temperaturedata were obtained from the nearby primary forest floor.

The organisms living on the cacao trees were primarily small insects as found in a similar study, by Castillo (2013) and Ocampo (2023). While there were individuals from nine orders, the majority of the specimens were from three main orders: Coleoptera, Orthoptera, and Lepidoptera. This is also consistent with findings from similar studies on cacao tree pests. Based on the study by Castillo (2013), pests were identified in the orders/families of Hemiptera (Membracidae), Coleoptera (Chrysomelidae), and Lepidoptera (Geometridae), and species in the two latter families were identified.

The lowest number of individuals recorded was on the first day of the experimental period and continued to increase across the remaining five days. This may suggest that a lack of experience and proficiency in insect observation at the beginning of the experimental period affected the first recorded findings. However, this was the reason why the observers chose to study a sample set of trees over the course of six days, as opposed to studying a different set of trees every day.

The decrease in organisms found on day six may be due to the friaje - however, more samples would be needed to determine if this result is significant or as a result of chance/other factors.

This study was just the beginning of research in Madre de Dios, Peru for the potential use of IPM on the Theobroma cacao. The nature of this study and the researcher's circumstances posed potential challenges that could be addressed by future researchers. The limited sampling capacity (observations were restricted to the bottom 1.5m of trees) and the high level of foliage may influence the results as it is likely that not all organisms present on the trees will be found. Flying and other highly mobile insects sometimes moved away from the tree before an identification could be made or photographs were taken. Furthermore, it will only be possible to detect specimens that are visible to the human eye without magnification so any microscopic pests will not be discovered.

Conclusion

Finding a sustainable way of agriculture is crucial to the future success and health of genrations to come. If the use of pesticides does not slow down or come to an end, farmers will continue to struggle with low-quality soil, and in turn, financial instability. IPM represents a potential solution to the pests that plague the Theobroma cacao, a highly important cash crop in Peru. The findings of this study are optimistic, as they show that species such as the Green lacewing larvae could be used as a form of IPM. This study will hopefully become a part of the research needed to find the right solution for both farmers and the biodiverse land of Madre de Dios Peru.

Works Cited

Alliance for a Sustainable Amazon (2021). Finca Las Piedras—Species List.

Bendix, J., Rollenbeck, R., Fabian, P., Emck, P., Richter, M. and Beck, E. (2008). Climate Variability: Temporal Heterogeneities. Gradients in a tropical mountain ecosystem of Ecuador, pp.281-290.

Bottrell, D.G. and Council (1979). Integrated Pest Management.

Callisaya, H. H., Fuentes, C. M. & Delgado, F. M. (2017). Control Del Chinche Del Cacao (Monaloniondis Simulatum Dist.) Con Aplicación De Bioinsecticidas En La Región De Los Yungas De Bolivia. Revista de Investigación e Innovación Agropecuaria y de Recursos Naturales [online]. 4 (1). pp.31-39. doi: https://doi.org/10.1002/eap.2886

Castillo, P. 2013. Pest insects and natural enemies of Theobroma cacao L. (cocoa) in the valleys of Tumbes and Zarumilla, Peru. Manglar, 10, 3-16. doi:10.17268/manglar.2013.002

Dara, S., (2019). The New Integrated Pest Management Paradigm for the Modern Age, Journal of Integrated Pest Management, 10 (1), pp. 12. doi: https://doi.org/10.1093/jipm/pmz010

De Souza, P. A., Moreira, L. F., Sarmento, D. H. A. & Da Costa, F. B. (2018). Cacao—Theobroma Cacao. In: Rodrigues, S., De Oliveira Silva, E. & De Brito, E. S. (Eds.) Exotic Fruits. Academic Press. pp 69-76. doi:https://doi.org/10.1016/B978-0-12-803138-4.00010-1.

Franzen, M. and Borgerhoff Mulder, M. (2007). Ecological, economic and social perspectives on cocoa production worldwide. Biodiversity and Conservation, 16(13), pp.3835–3849. doi:https://doi.org/10.1007/s10531-007-9183-5.

Kalia, A. and Gosal, S.K. (2011). Effect of pesticide application on soil microorganisms. Archives of Agronomy and Soil Science, 57(6), pp.569–596. doi:https://doi.org/10.1080/03650341003787582.

Kliem, L. & Sievers-Glotzbach, S. (2022). Seeds of resilience: the contribution of commons-based plant breeding and seed production to the social-ecological resilience of the agricultural sector. International Journal of Agricultural Sustainability, 20, 595-614. doi: https://doi.org/10.1080/14735903.2021.1963598.

Ocampo Ariza, C., Vansynghel, J., Bertleff, D., Maas, B., Schumacher, N., Ulloque-Samatelo, C., Yovera, F., Thomas, E., Steffan-Dewenter, I. & Tscharntke, T. (2023). Birds And Bats Enhance Cacao Yield Despite Suppressing Arthropod Mesopredation. Ecological Applications, 33(5). doi: 10.1002/eap.2886.

Sánchez-Cuervo, A.M., de Lima, L.S., Dallmeier, F., Garate, P., Bravo, A. and Vanthomme, H. (2020). Twenty years of land cover change in the southeastern Peruvian Amazon: implications for biodiversity conservation. Regional Environmental Change, 20(1). doi:https://doi.org/10.1007/s10113-020-01603-y.

Teja Tscharntke, Ocampo-Ariza, C., Vansynghel, J., Ivañez-Ballesteros, B., Aycart, P., Rodriguez, L., Ramirez, M., Ingolf Steffan-Dewenter, Maas, B. and Thomas, E. (2022). Socio-ecological benefits of fine-flavor cacao in its center of origin. Conservation Letters, 16(1). doi:https://doi.org/10.1111/conl.12936.

Vig, K., Singh, D.K., Agarwal, H.C., Dhawan, A.K. and Dureja, P. (2008). Soil microorganisms in cotton fields sequentially treated with insecticides. Ecotoxicology and Environmental Safety, [online] 69(2), pp.263–276. doi:https://doi.org/10.1016/j.ecoenv.2006.12.008.