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A Proposed Framework for the Use of Biological Control Agents for a Cacao Pest

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Abstract

An industry study on cacao considers the Philippines as a minor player in the global cacao trade and is not properly positioned to take advantage of the surge in demand. Domestic production dived in the 1990s despite pump-priming initiatives. It should also be noted that farmer awareness of the economic potential of cacao is very low, with very few engaged in cultivation due to various difficulties, among these problems mainly considered are the high costs of insecticides and pesticides and the prevalence of pests. This paper provides a framework by which a biological control agent for the cacao pest could be designed so that farmers may eventually lessen their dependence on expensive and chemically based pesticides and insecticides and rely on the natural relationships of predator and prey available in nature. Although many studies suggest that the Asian Weaver Ant *Oecophylla smaragdina* Fabricius is a predator of arthropods, among them the mirid bug and cacao pest *Helopeltis bakeri* Poppius, this assertion needs to be further supported by substantial evidence that clearly shows that such ant has available predatory properties against this specific prey. This procedure is very important especially if the farmer's welfare is hinged on the idea of using biological control. It should then be proposed that a systematic and logical implementation of the demonstration of *O. smaragdina's* properties as a possible biological control agent for the cacao pest *H. bakeri* be established.

Keywords: ants; biological control; Helopeltis bakeri Poppius; Oecophylla smaragdina Fabricius; research framework; Theobroma cacao L.

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1. Introduction

Mirids of the genus *Helopeltis* (Figure 1) are serious pests of various cultivated plants in the world, among them is the cacao plant [1]. It was reported that in South-East Asia, the *Helopeltis spp.* is responsible for the damage related occurrences and if left unattended for three years, can reduce yields by as much as 75% [2] (Figure 2). The report went on to surmise that the spread of this pest along with the decline in the price of cocoa led to decreases in production in many Asian countries, particularly, here on the Philippines' Luzon Island.

The majority (87%) of insects on cocoa are ants [3], and ant distribution and relationships in cocoa have received considerable attention mostly in parts of Africa where it is a high-income generator [4], but from elsewhere in this region and other parts of the world, particularly in the Philippines, relatively few studies have been made mainly because competition for dominance and other community relationship is very difficult to demonstrate in a natural setup and experimental manipulations of ant assemblages are difficult to perform, particularly in the field [5,6]. It is therefore the aim of this paper to provide a basic conceptional structure to eventually demonstrate if indeed ants, specifically the Asian Weaver ant *O. smaragdina* could be a potential biological control agent for the cacao pest *H. bakeri*.

Initially, cacao farms reported to be infested with *H. bakeri* should be surveyed for the diversity of ants found in the area. The result of this survey is needed to determine if ants are known to have predatory properties on *H. bakeri*. As it has been recognized that ants that act as a predator of pests are the ones with dominant attributes [7], a dominance test should be in place. Dominance, in ant ecology, is interpreted within the context of manifestations of ants in competition: that is behavioral dominance and numerical dominance [8]. This dominance in competition could be considered an ideal property of a biological control agent. For the preparation of this ant behavior dominance demonstration, stratified parts of the cacao trees should be surveyed for ant diversity using baits, as many myrmecological studies have focused on the results of ant resource use by observing interactions at baits [9]. Once the numerically and behaviorally dominant ants in the cacao trees have been established, these ants may now be subjected to tests to display predatory or aggressive behavior towards the cacao pest *H. bakeri*. Before proceeding to the assays for gut or diet analyses, additional inference for patterns of co-occurrences could be extracted using exploratory data analysis as co-occurrence analyses have been previously used to explore patterns in such ant mosaics of dominant ants [10]. Just like most insects, ants tend to be small and exhibit unstructured gut content, therefore making gut analysis an efficient means to acquire data on predatory capabilities [11].

Figure 1: The cacao mirid pest *Helopeltis bakeri*.

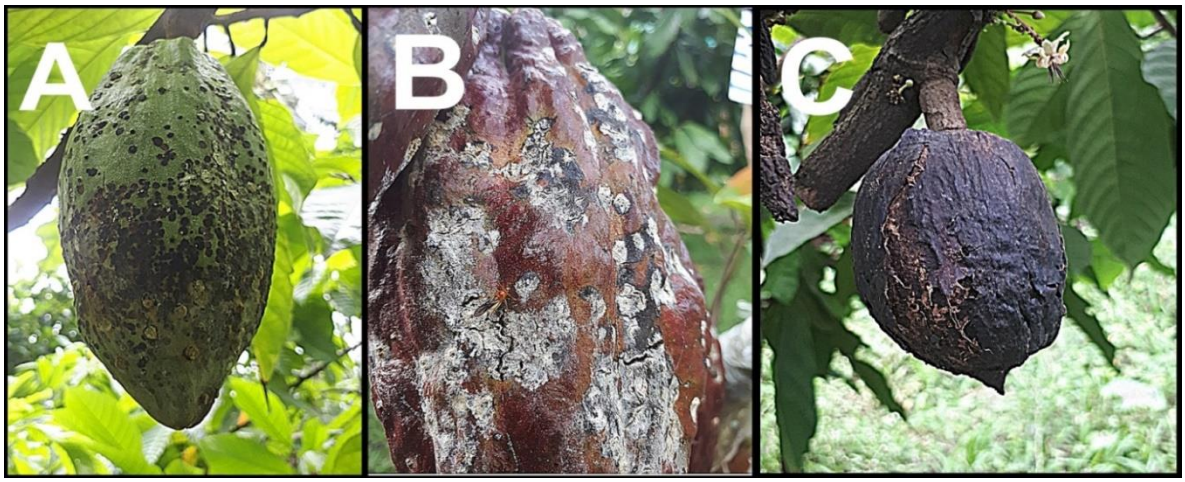

Figure 2: Images showing the lesions created by the cacao mirid pest *H. bakeri* from injecting their stylets into the husk of the pod (A) which mediates pathogenic fungi infections (B) causing the pod to die and turn black, a case called 'black pod disease' (C).

The top three dominant and aggressive ants to be observed for *H. bakeri* remnants by gut analysis assay would be the main part of the study. Both the experiments for the predatory and aggressive behavior towards *H. bakeri* and the gut analysis would demonstrate that there is indeed predation.

Demonstration of prey reduction in the field could also be an option that could augment the diet analysis experiments. The application and innovation assays would be the rearing and conservation of *O. smaragdina* for possible release to cacao farms to either augment or replace the dependence on chemical pesticides and insecticides. Figure 3 shows a conceptual diagram for this framework.

2. On the survey of reported cacao farms with *H. bakeri* for ant diversity

As no *H. bakeri* has been reported yet in the Visayas and Mindanao region, a survey for ant diversity of cacao areas would concentrate on Luzon Island. The objective of this study is to establish if the ants available in the geographic area of interest are also the ants cited in previous papers that have the potential to be used as biological control agents. The importance of this initial study is of great relevance, as this will demonstrate the particular taxon that is available for further assessment as a biological control agent. The Ant of the Leaf Litter (ALL) protocol [12], which is the standard collection technique for ants will be modified as it is projected that few to no leaf litter would be available from mostly private cacao farms in the area.

3. On the survey of stratified parts of the cacao tree for ant diversity

Once the result of the survey of ant diversity from cacao farms with *H. bakeri* has been recorded, it may be used as a reference for the results coming from the survey of stratified parts of the cacao tree or vice-versa. As the ant collection protocol allows leaf litter and microhabitats such as dead rotten trees and proximal intercropped trees to be handpicked for ants in the cacao farm survey, this survey from the stratified parts of the cacao tree does not merely duplicate what was done in the initial study. Moreover, it further verifies the result of the initial investigation and prepares the collected ant diversity for further tests to show if they could be used as potential biological control agents. The setting up for the collection of ant diversity in stratified parts of the cacao tree simultaneously sets it up also for the testing of competitively dominant ant species. The modification of the ALL protocol for this survey would be following the techniques of [13, 14]. The collection would be on the foliage, trunk, and soil.

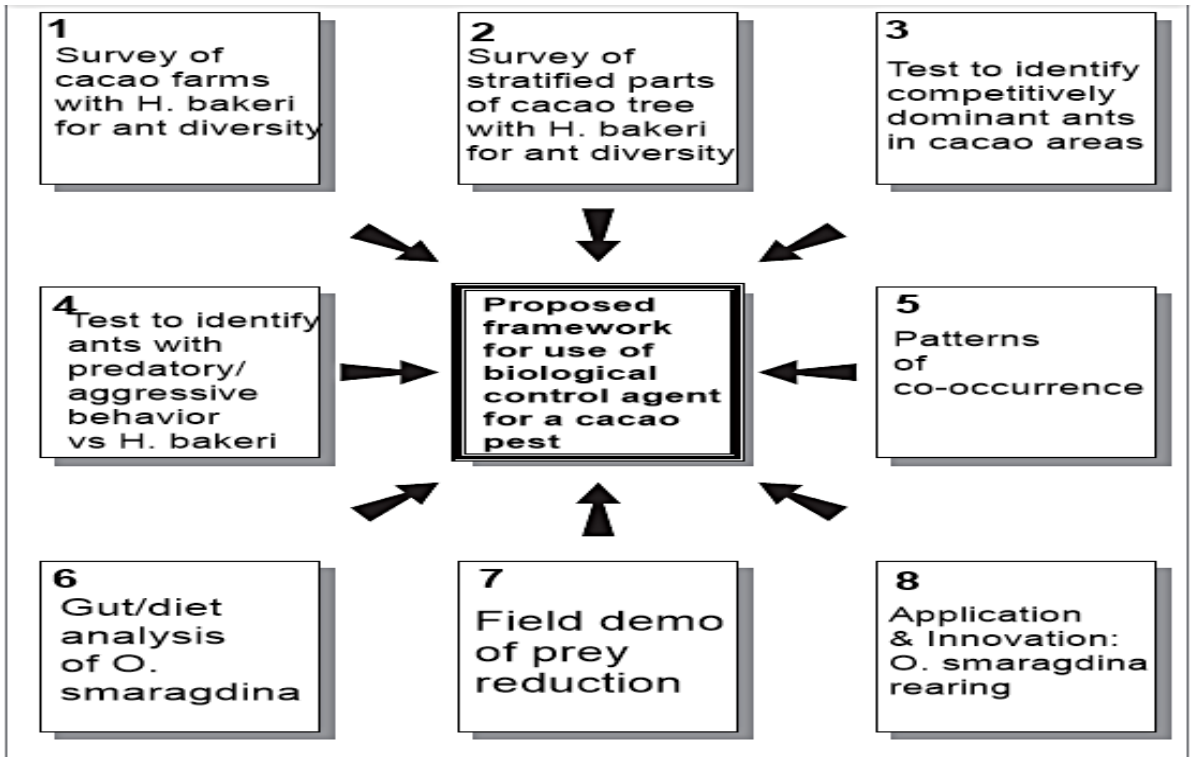

Figure 3: Conceptual diagram of the proposed framework for use of biological control agent for a cacao pest.

4. On the patterns of co-occurrence

Co-occurrence analyses have been done to examine patterns in myrmecological studies [15,10,16]. These studies mentioned delved into different topics such as ant mosaics, between different habitat types and different scales, as well as investigations on invasive species in community assemblies. The point here being raised is that data coming from the diversity and abundance studies could be checked using available soft wares for patterns, specifically possible patterns of co-occurrence. Data on co-occurrence patterns could give additional inference for the community relationship (mutualism, competition, etc.) manifested by the taxa of interest in this study.

5. On the test to identify competitively dominant (numerically and behaviorally dominant) ant species in cacao areas

The term dominance in ecology happens when a single species makes up quite a large percentage of community volume (biomass and individual numbers) [8]. In ant ecology, dominance is within the realms of predatory ant's behavior in competition, which is behavioral dominance and numerical dominance. The identified ant population in the stratified parts of the cacao trees is also the same ants that would undergo the test for numerical and behavioral dominance. This assay is meant to observe dominant ants through competition happening between different species through baits, as studies on ant ecology have focused on the outcomes of ant resource use and competition by observing interactions during baiting [9]. Competition here is broadly defined as a negative interaction between individuals on a shared, limited resource, and the outcome of such competition between species is an increase in fitness of one species over another due to superior ability to access a resource [8]. A novel but simple scoring system will be implemented to identify the dominant ant that comes out to exploit the baits planted within the cacao tree and its proximal area. It is stated that baits are commonly used to estimate the composition and richness of the active ground-foraging ant fauna and to examine ant activity and behavior patterns, these authors also suggested that different baits should be used to attract ants with different types of diets [13].

6. On the test to identify ants with predatory and/or aggressive behavior towards cacao pest *H. bakeri*

Once again, the identified ant population coming from the survey of the stratified parts of the cacao trees will immediately be brought to the laboratory for feeding experiments (choice and no-choice tests). Live collected ants from the field will immediately be brought to the laboratory and sorted out into different genera. Whenever available, fifteen replicates for each genus will be given three *H. bakeri* individual castes: first instar brood, male adult, and female adult for the choice test, and a combination of the different *H. bakeri* individual castes for the choice test. The ants that will show predatory and/or aggressive behavior towards *H. bakeri* will be subjected to the next assay which is gut analysis.

7. On the demonstration of remnants of *H. bakeri* in the gut of *O. smaragdina*

Among the experiments mentioned above, this test could prove to be the most significant one, as finding remnants of the specific prey within the gut of the predator is considered as the most efficient mean of acquiring data on predation [11]. The only question remaining here is if the remnant found came from another predator of

the prey concerned, so additional assays such as barcoding and additional control/s in protein analyses may circumvent the problem at hand. The top three dominant ant species coming from the dominance experiments will be used as control groups for the diet analysis. SDS PAGE, ELISA, may be used as the assay of choice.

8. On the demonstration of prey reduction

Actual field experiments of cacao trees with and without (control) *O. smaragdina* and checking for cacao pod infestation of *H. bakeri* could further enhance the possibility of using *O. smaragdina* as a biological control agent. The positive result here also would augment the outcomes from previous experiments.

9. On the rearing, release and conservation of O. smaragdina

As this study was mainly designed to help the welfare of the farmers by lessening their dependence on expensive chemical insecticides and pesticides, *O. smaragdina* ant would be used as a biological control agent for the cacao pest *H. bakeri* if the results of the experiments previously mentioned would satisfy the objectives at hand. Therefore, the hallmark procedures of a biological control system such as rearing, release, and conservation of *O. smaragdina* would be the needed application and innovation of this research framework at hand.

10. Summary

This paper proposed a framework by which a biological control agent for the cacao pest will be designed so that farmers may lessen their dependence on pesticides and insecticides. It would start with cacao farms with *H. bakeri* infestations being surveyed for their ant diversity. Results of this survey will then determine if ants known to have predatory properties on *H. bakeri* claimed in previous studies also exist in the said cacao farms. As predatory behavior is reflected through dominance, a test for the behaviorally and numerically dominant ant would also be in order. Stratified parts of the cacao trees, aside from the cacao farm should be surveyed for ant diversity using baits, as it has been recognized that many myrmecological studies have focused on the results of ant resource use and community relationships by discerning interactions using such baits. Now, with available data on ant diversity, and numerical and behavioral dominance, patterns of co-occurrence could be extracted using exploratory data analysis for additional inference. After which the established numerically and behaviorally dominant ants have been identified, these ants may now be subjected to tests to display predatory or aggressive behavior towards the cacao pest *H. bakeri*. As gut analysis is considered the main process to observe and acquire data on predation, this assay would be considered the most important process of the proposed research framework. As a way to augment the mentioned laboratory experiments, actual field tests to demonstrate prey reduction on cacao trees with *O. smaragdina* can be implemented. If it is indeed the weaver ant, *O smaragdina* that shows promise as the biological control agent for *H. bakeri*, the application and innovation assays would be to rear and conserve these weaver ants for possible release to cacao farms and eventually lessen their dependence on chemical pesticides and insecticides.

To demonstrate that a specific taxon has the potential to be used as a biological control agent both in the field and in the laboratory is difficult to perform and will surely be quite challenging for the ecologist. But to provide

a valid framework that could be used to design experiments that would give pertinent data for us to either accept or reject our speculations and hypotheses is a step toward providing relevant, important, and useful information.

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