INNSPUB

International Journal of Biosciences | IJB |
ISSN: 2220-6655 (Print); 2222-5234 (Online)
Website: https://www.innspub.net
Email contact: info@innspub.net
Vol. 29, Issue: 1, p. 237-246, 2026

RESEARCH PAPER OPEN ACCESS

Bioefficacy testing of indigenous plant-based biopesticides against green leafhopper (GLH) of rice

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Key words: Bioefficacy, Indigenous, Plant-based, Biopesticides, GLH

Received: July 11, 2026 **Accepted:** July 21, 2026 **Published:** July 28, 2026

DOI: https://dx.doi.org/10.12692/ijb/29.1.237-246

ABSTRACT

In the Philippines, rice is the major staple crop but its production is affected by insect pests such as the rice green leafhopper (GLH). This study assessed the efficacy of three indigenous plant-based biopesticides namely: Hagonoy (*Chromolaena odorata*), Lantana (*Lantana camara*), and Makabuhay (*Tinospora crispa*) against GLH under laboratory and nursery conditions. The aqueous and ethanolic extracts were prepared at a ratio of 100 g plant material to 1 L solvent and applied at different concentrations. Based on the results of phytochemical analysis, it reveals that *Lantana camara* and Hagonoy contained the highest number of secondary metabolites in the aqueous and ethanolic extracts, respectively. Under laboratory conditions, Cypermethrin obtained the 100% GLH mortality, however the Makabuhay at 40 mL showed statistically comparable efficacy with 93.33% mortality after one hour of application. In nursery trials at 56 days after transplanting, all three plant extracts obtained mortality rates comparable to Cypermethrin. These findings indicate that the tested biopesticides, particularly Makabuhay, have potential as environmentally friendly alternatives for GLH management, although further field validation is recommended.

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INTRODUCTION

Rice production in the Philippines plays a vital role in ensuring the country's food security and contributing to its economy. The Philippines is among the world's leading rice-producing countries, accounting for approximately 2.8% of global rice production. Rice is the staple food of the Filipino population and serves as the primary source of dietary carbohydrates (Palanog *et al.*, 2019). Beyond its nutritional value, rice provides what anthropologists describe as the physiological sensation of satiety. It is consumed daily by millions of Filipinos, particularly low-income households, and serves as the primary livelihood of millions of rice farmers throughout the country.

The annual per capita consumption of rice in the country is estimated at 109.5 kg, which provides 56% of the calories, 37% of the proteins, and 3.8% of the fats required per person per day . In the Philippines, rice is seen as an effective delivery system for food fortification because of its high per capita consumption (109 kg/person/day) Palanog *et al.*, 2019. Similarly, Roy *et al.* (2011) reported that more than half of the world's population relies on rice as its primary staple food.

Despite its importance, rice production is constrained by several factors, including unfavorable climatic conditions and the incidence of insect pests and diseases. These problems significantly reduce crop productivity and farmers' income. Annually, farmers lose an estimated average of 37% of their rice yield due to insect pests, diseases, and weeds, International Rice Research Institute (IRRI). To lessen these losses, many farmers are highly dependent on synthetic pesticides. However, this practice has resulted in several adverse effects such as the development of pesticide resistance, environmental pollution, pesticide residues in agricultural products, and detrimental on beneficial organisms and other non-target species.

To reduce the massive use of chemical pesticides, several indigenous plant species possess natural pesticidal properties and offer effective, affordable, and environmentally safe. Plant species such as lantana (*Lantana camara* L.), hagonoy (*Chromolaena odorata* (L.) R.M. King and H. Rob.), and makabuhay (*Tinospora crispa* (L.) Hook. f. and Thomson) contain bioactive compounds with insecticidal, antifeedant, and repellent properties that have demonstrated potential for managing insect pests (Ahmad *et al.*, 2016; Raj and Syriac, 2016).

The development of indigenous plant-based biopesticides presents a promising opportunity to reduce dependence on synthetic pesticides while promoting sustainable rice production. Such eco-friendly pest management strategies can contribute to effective insect pest control, environmental conservation, improved farmer health and safety, and the long-term sustainability of rice farming systems in the Philippines. Thus, this study aimed to determine the effectiveness of indigenous plant based biopesticide against green leafhopper of rice, compare the efficacy of indigenous plant based biopesticide with the standard insecticide used for insect pest of rice, and generate bioefficacy data to support the registration of the product with Fertilizer Pesticides Authority (FPA) in the Philippines.

MATERIALS AND METHODS

Screening of indigenous plant-based biopesticides against green leafhopper (GLH)

Three indigenous plant species with potential biopesticidal properties Hagonoy (*Chromolaena odorata*), Lantana (*Lantana camara*), and Makabuhay (*Tinospora crispa*) were collected from the vicinity of Cagayan State University (CSU) Lal-lo Campus for screening against the green leafhopper (GLH). A Completely Randomized Design (CRD) was employed in the study, consisting of five treatments replicated three times under both laboratory and nursery conditions. The treatments were the following: T1 – Hagonoy (*Chromolaena odorata*), T2 – Lantana (*Lantana camara*), T3 – Makabuhay (*Tinospora crispa*), T4 – Cypermethrin, and T5 – Water.

Collection and preparation of the extracts

The plant materials found in the experimental area of CSU- Lal-lo were collected such as the lantana camara, hagonoy, and makabuhay. These were cleaned and air dried for a week. The dried plant material was grinded using blender. For the aqueous extract, after measuring each grinded plant material, it was added with distilled water (DW) following the ratio of 100 grams : 1L DW. After which, it was covered with aluminum foil and ferment for a week. Then, was filtered using Whatman no. 91 filter paper. The ethanolic extraction procedures were described after the method of Wiratno *et al.* (2009). The dried plant material was grinded in an electric grinder, then followed by extracting during 24 hours of the essential oils using ethanol (96%). After that the mixture was filtered using Whatman no. 91 filter paper and subsequently the solution was concentrated using a rotavapor. The extracts were transferred into brown glass bottles and stored at -4°C and was used for the assays within two weeks. It was expected that there was no significant biodegradation of the extracts during this period since based on a previous study. The pyrethrum based pesticide has been proven stable until 1 year stored in this condition, Yuliani *et al* ., 2003).

Test insect

The adults *GLH and BLH* were collected from rice field in the area. At first, the pest species was reared in the Laboratory of the College of Agriculture in a simulated environmental condition. After which, this rearing method was modified owing to the culture was too long. After collection of GLH in the rice field, this was placed in the insect box with the susceptible rice plant. After 2-3 days, the insects were used for the laboratory and nursery trials.

Bioassays

All botanical extracts were diluted in a mixture of one part of 99.9 % DMSO and nine parts of acetone (80%). The extracts were assayed for their toxicity and repellent activity in the laboratory of the CSU-Lal-lo experimental laboratory using the following methods: A concentration range of the botanical extracts of 0, $5x10^1$, $1x10^2$, $2x10^2$, and $4x10^2$ µg ml^{-1} and of Insecticide (Cypermethrin) at RR then was prepared and stored in brown glass bottles at -4°C. Five freshly cut young rice leaves were cut at 3 inches long each and was soaked in extracts for 5 minutes. Ten (10) adult insects were exposed in a Petri dish containing cut rice leaves. The control was treated with the solvent only. Mortality was recorded at 1 hour after application and every 24 hours thereafter until 72 hours. Insects were scored dead when they do not move even after being gently touched with a wooden stick of ± 1mm diameter.

Data analysis

The data were analyzed using the using analysis of variance (ANOVA) and the least significant difference (LSD) using STAR program. Promising indigenous plant extracts against GLH and BLH were used under green house and semi - controlled condition.

RESULTS AND DISCUSSION

Table 1 shows that the phytochemical composition of Hagonoy (*Chromolaena odorata*), Lantana (*Lantana camara*), and Makabuhay (*Tinospora crispa*) varied depending on the extraction solvent. Among the aqueous extracts, Lantana exhibited the highest number of detected phytochemicals (seven), followed by Hagonoy (six), while Makabuhay contained only three. In the ethanolic extracts, Hagonoy showed the richest phytochemical profile (seven positive compounds), followed by Lantana and Makabuhay. The predominance of flavonoids, phenols, tannins, saponins, and terpenoids in Hagonoy and Lantana suggests their strong potential as botanical biopesticides because these secondary metabolites are widely recognized for their insecticidal, antifeedant, repellent, antimicrobial, and antioxidant properties. The results further indicate that ethanol was generally more effective than water in extracting bioactive compounds, particularly terpenoids and quinones, owing to its ability to dissolve both polar and moderately non-polar metabolites.

The present findings are consistent with previous studies on these indigenous plants. Magar *et al.* (2023) reported that *Chromolaena odorata* extracts contained phenols, flavonoids, quinones, and terpenoids, with organic solvents recovering more bioactive compounds than aqueous extraction. Likewise, Emeziem and Iwu (2024) documented the abundance of flavonoids, phenolics, tannins, saponins, alkaloids, and terpenoids in *C. odorata*, supporting its pesticidal potential. Similar phytochemical profiles have also been reported for *Lantana camara*, particularly the presence of flavonoids, phenols, tannins, saponins, and steroids, which contribute to its insecticidal activity. For *Tinospora crispa*, previous studies have shown that terpenoids, alkaloids, tannins, and saponins are influenced by extraction solvent, with ethanol generally providing better recovery of lipophilic compounds.

Table 1. Phytochemical analysis of the indigenous plant-based biopesticides using aqueous and ethanolic extracts

Method of extraction	Indigenous plant-based biopestices	Alkaloids	Anthocyanin	Flavonoids	Phenols	Saponins	Steroids	Tannins	Terpenoids	Quinone	Total (+)
Aqueous	Hagonoy	-	+	+	+	+	+	+	-		6
	Lantana	+	+	+	+	+	+	+	-		7
	Makabuhay	+	-	-	+	-	-	+	-		3
Ethanolic	Hagonoy	-	+	+	+	+	-	+	+	+	7
	Lantana	-	-	+	+	+	+	+	-	+	4
	Makabuhay	-	-	-	-	+	-	+	+	-	3

Table 2. Mortality rate of green leafhopper (GLH) under laboratory condition using the aqueous extract at 5ml, 10 ml, 20 ml and 40 ml

Treatment	Mean moratlity of green leaf hopper											
	5ml			10ml			20ml			40ml		
	Hour /s											
	1	24	48	1	24	48	1	24	48	1	24	48
T1-Hagonoy	16.67c	63.33b	100.00	36.67c	90.00b	100.00a	60.00b	96.67a	100.00	80.00ab	96.67a	100.00
T2- Lantana	26.67c	56.67b	100.00	36.67c	86.67b	96.67a	60.00b	93.33a	100.00	60.00b	96.67a	100.00
T3-Makabuhay	40.00b	93.33a	100.00	63.33b	100.00a	100.00a	36.67c	93.33a	100.00	93.33a	100.00a	100.00
T4-Cypermethrin	100.00a	100.00a	100.00	100.00a	100.00a	100.00a	100.00a	100.00a	100.00	100.00a	100.00a	100.00
T5-Water	0.00d	13.33c	100.00	0.00d	10.00c	23.33b	0.00d	23.33b	100.00	0.00c	46.67b	100.00

Mortality rate of green leafhopper (GLH) under laboratory condition

Table 2 presents the mortality rate of the green leafhopper (GLH) under laboratory conditions following exposure to different aqueous plant extracts at four concentration levels (5, 10, 20, and 40 mL). The results showed that mortality generally increased with increasing extract concentration and longer exposure time. At 1 hour after application, cypermethrin (T4) consistently caused 100% mortality across all concentration levels, demonstrating its rapid knockdown effect. Among the botanical treatments, makabuhay (*Tinospora crispa*) (T3) exhibited the highest initial insecticidal activity, producing 40.00%, 63.33%, 36.67%, and 93.33% mortality at the 5, 10, 20, and 40 mL concentrations, respectively. Hagonoy (*Chromolaena odorata*) (T1) and lantana (*Lantana camara*) (T2) produced significantly lower mortality during the first hour, indicating a slower mode of action than the synthetic insecticide.

The water-treated control (T5) consistently recorded the lowest mortality, confirming that the observed insect mortality in the treated groups was attributable to the plant extracts rather than natural mortality.

After 24 and 48 hours of exposure, the efficacy of the botanical extracts increased substantially. Makabuhay consistently achieved the highest mortality among the plant-based treatments, reaching 93.33–100.00% mortality after 24 hours and 100% mortality after 48 hours across all concentrations tested. Hagonoy and lantana also demonstrated remarkable insecticidal activity over time, with mortality ranging from 86.67% to 96.67% after 24 hours at higher concentrations and reaching 100% mortality after 48 hours in most treatments. These findings suggest that the aqueous extracts possess delayed but highly effective insecticidal properties against GLH, particularly at higher concentrations and longer exposure periods. The increasing mortality over time indicates that the bioactive compounds present in these indigenous plants require sufficient contact or ingestion time before exerting their toxic effects. Similar observations have been reported by Isman (2006), who noted that botanical insecticides generally act more slowly than synthetic insecticides because their active compounds interfere with insect feeding, growth, metabolism, or nervous system functions rather than causing immediate knockdown. Likewise, Pavela (2016) emphasized that many plant-derived insecticides exhibit cumulative toxic effects, making prolonged exposure an important factor in achieving effective pest control.

Table 3. Mortality of green leaf hopper (GLH) at 5, 10, 20, 40 ml after 1 hour of application under laboratory trial using ethanolic extract

Treatment	Mean moratlity of green leaf hopper			
	5ml	10ml	20ml	40 ml
T1-Hagonoy	4.67bc	9.00c	7.67c	7.67b
T2-Lantana	2.67cd	2.67d	4.67d	6.00b
T3-Makabuhay	6.33b	16.67b	16.67b	18.33a
T4-Cypermethrin	20.00a	20.00a	20.00a	20.00a
T5-Water	0.00c	0.00e	0.00e	0.00c

Table 4. Mortality of green leaf hopper (GLH) applied with 40 ml plant-based biopesticides after 1 hour, 24, 48 & 72 hours of application using ethanolic extract with 100g :1L at 32 & 56 days after transplanting (DAT)

TRT	Mean moratlity of green leaf hopper							
	32 DAT				56 DAT			
	1	24	48	72	1	24	48	72
T1-Hagonoy	0.67	4.33b	6.67a	10.0a	2.67a	6.00a	8.33a	9.67a
T2- Lantana	1.33	6.00ab	8.00a	10.0a	2.33a	6.00a	7.67a	9.33a
T3-Makabuhay	1.67	5.33ab	7.67a	10.0a	2.67a	7.33a	9.33a	9.67a
T4-Cypermethrin	4.00	6.67a	8.67a	10.0a	3.67a	7.00a	7.33a	9.33a
T5- Water	0.00	0.67c	1.33b	4.33b	0.00b	1.33b	4.33b	6.33b

Table 3. presents the mortality of green leafhopper (GLH) one hour after the application of ethanolic extracts at four concentration levels under laboratory conditions. The results revealed significant differences among treatments, with cypermethrin (T4) consistently producing the highest mortality (20.00 insects) across all concentrations, demonstrating its rapid knockdown effect. Among the botanical treatments, makabuhay (*Tinospora crispa*) (T3) exhibited the greatest insecticidal activity, with mortality increasing from 6.33 insects at 5 mL to 18.33 insects at 40 mL, indicating a concentration-dependent response. Hagonoy (*Chromolaena odorata*) (T1) showed moderate efficacy, recording mortality values ranging from 4.67 to 9.00 insects, while lantana (*Lantana camara*) (T2) produced the lowest mortality among the plant extracts, with only 2.67 to 6.00 insects killed. As expected, the water-treated control (T5) resulted in no mortality across all concentration levels, confirming that the observed insect mortality was due to the insecticidal properties of the plant extracts. These findings suggest that although ethanolic extracts do not provide the immediate knockdown effect achieved by the synthetic insecticide, makabuhay possesses promising bioactive compounds capable of causing significant GLH mortality even after only one hour of exposure. The superior performance of makabuhay may be attributed to the efficient extraction of insecticidal phytochemicals by ethanol, which has been reported to extract a wider range of bioactive compounds, including alkaloids, flavonoids, terpenoids, and phenolics, known for their toxic, antifeedant, and repellent effects against insect pests (Isman, 2006; Pavela, 2016).

Mortality of green leafhopper (GLH) under nursery condition

Table 4 presents the mortality of green leafhopper (GLH) following the application of 40 mL ethanolic plant-based biopesticides (100 g:1 L extraction ratio) under field conditions at 32 and 56 days after transplanting (DAT), with observations taken at 1, 24, 48, and 72 hours after application. At both crop growth stages, GLH mortality increased with longer exposure time across all treatments. One hour after application, mortality was generally low and no significant differences were observed among the botanical treatments and cypermethrin, although cypermethrin recorded the highest initial mortality at both 32 DAT (4.00 insects) and 56 DAT (3.67 insects). The water-treated control consistently recorded the lowest mortality, indicating minimal natural mortality during the evaluation period.

After 24 hours, cypermethrin produced the highest mortality at 32 DAT (6.67 insects), which was significantly higher than the water control but statistically comparable with the botanical treatments, particularly lantana and makabuhay. By 48 hours, all plant-based biopesticides recorded mortality values ranging from 6.67 to 8.67 insects at 32 DAT and 7.33 to 9.33 insects at 56 DAT, with no significant differences among the botanical extracts and cypermethrin. At 72 hours after application, hagonoy, lantana, makabuhay, and cypermethrin all achieved similarly high mortality (9.33–10.00 insects), whereas the water control remained significantly lower. These results indicate that although the ethanolic plant extracts exhibited a slower insecticidal action than the synthetic insecticide during the initial hours following application, their effectiveness increased substantially over time, ultimately providing mortality comparable to cypermethrin after 72 hours. The delayed yet sustained insecticidal activity of the botanical extracts may be attributed to bioactive phytochemicals such as alkaloids, flavonoids, terpenoids, and phenolic compounds, which require sufficient contact or ingestion time before causing mortality (Isman, 2006; Pavela, 2016). The findings demonstrate that hagonoy (*Chromolaena odorata*), lantana (*Lantana camara*), and makabuhay (*Tinospora crispa*) possess considerable potential as eco-friendly botanical biopesticides for the management of green leafhopper in rice fields and could serve as sustainable alternatives that reduce dependence on synthetic chemical insecticides.

Table 5. Mortality of green leaf hopper (GLH) applied with 40 ml plant-based biopesticides after 1 hour, 24, 48 & 72 hours of application using ethanolic extract with 100g :1L at 63 & 73 days after transplanting (DAT)

TRT	Mean mortality of green leaf hopper							
	63 DAT				72 DAT			
	1	24	48	72	1	24	48	72
T1-Hagonoy	4.67	8.67bc	9.33ab	10.00a	4.00	6.67a	9.00a	10.00a
T2- Lantana	5.67	8.33c	9.67a	10.00a	4.00	7.00a	8.67a	10.00a
T3-Makabuhay	4.00	9.67ab	10.00a	10.00a	3.33	6.67a	8.67a	10.00a
T4-Cypermethrin	5.67	10.00a	10.00a	10.00a	5.00	8.00a	9.33a	10.00a
T5- Water	3.00	8.00c	8.33b	8.67b	1.00	3.67b	4.33b	4.33b

Table 5 presents the mortality of green leafhopper (GLH) following the application of 40 mL ethanolic plant-based biopesticides (100 g:1 L extraction ratio) at 63 and 72 days after transplanting (DAT), with mortality assessed at 1, 24, 48, and 72 hours after application. At 63 DAT, GLH mortality generally increased as the exposure period progressed. One hour after application, no significant differences were observed among the treatments, with mortality ranging from 4.00 to 5.67 insects for the botanical extracts and cypermethrin, while the water-treated control recorded 3.00 insects. After 24 hours, cypermethrin (T4) produced the highest mortality (10.00 insects), although makabuhay (T3) exhibited a statistically comparable response (9.67 insects). Hagonoy (T1) and lantana (T2) also showed substantial insecticidal activity but recorded slightly lower mortality. By 48 hours, makabuhay and cypermethrin achieved complete or near-complete mortality (10.00 insects), whereas hagonoy and lantana were statistically comparable. At 72 hours, all botanical treatments and cypermethrin resulted in 100% mortality

(10.00 insects), while the water control remained significantly lower (8.67 insects), indicating that the observed mortality was primarily due to the applied treatments.

A similar trend was observed at 72 DAT. Mortality during the first hour remained relatively low and did not differ significantly among the botanical treatments and cypermethrin. However, by 24 and 48 hours after application, hagonoy, lantana, makabuhay, and cypermethrin produced comparable mortality, with no significant differences among these treatments, while the water control consistently recorded significantly lower mortality. At 72 hours, all botanical extracts and cypermethrin achieved complete mortality (10.00 insects), whereas the control reached only 4.33 insects. These findings demonstrate that the ethanolic extracts of hagonoy (*Chromolaena odorata*), lantana (*Lantana camara*), and makabuhay (*Tinospora crispa*) possess strong insecticidal activity against green leafhopper under field conditions. Although their initial action was slower than that of the synthetic insecticide, their effectiveness increased with exposure time, ultimately providing mortality comparable to cypermethrin. The delayed but sustained insecticidal effect is consistent with the mode of action of botanical pesticides, whose bioactive compounds including alkaloids, flavonoids, terpenoids, and phenolic compounds require sufficient contact or ingestion time before causing insect mortality (Isman, 2006; Pavela, 2016). These results highlight the potential of indigenous plant-based biopesticides as environmentally friendly and sustainable alternatives for green leafhopper management in rice production.

Yield

The estimated rice yield under pot conditions ranged from 5.08 to 6.31 t ha^{-1}. Lantana camara produced the highest yield (6.31 t ha^{-1}), followed by cypermethrin (6.13 t ha^{-1}) and the water (5.93 t ha^{-1}), while Makabuhay (5.13 t ha^{-1}) and Hagonoy (5.08 t ha^{-1}) recorded the lowest yields. The superior performance of *L. camara* suggests that it effectively reduced green leaf hopper (GLH) damage, resulting in grain yield comparable to the standard chemical insecticide. This finding indicates that *L. camara* has potential as an environmentally friendly alternative for GLH management. The higher yield may be attributed to the insecticidal and antifeedant properties of its phytochemicals, which help minimize pest damage and promote better grain development. Similar findings were reported by Isman (2020) and Pavela and Benelli (2016), who highlighted that plant-based biopesticides can effectively manage insect pests while supporting sustainable crop production.

Table 6. Yield (t/ha)

Treatment	Mean yield (t/ ha)
T1-Hagonoy	5.08
T2-Lantana	6.31
T3-Makabuhay	5.13
T4-Cypermethrin	6.13
T5-Water	5.93

Cost of producing indigenous plant-biopesticides

The cost analysis showed that producing aqueous indigenous plant-based biopesticides was considerably less expensive than ethanolic extracts, with estimated costs of ₱630.83 L^{-1} and ₱2,116.66 L^{-1}, respectively. The higher cost of the ethanolic extract was mainly due to the expense of ethanol, while labor requirements for both extraction methods were comparable. These findings indicate that aqueous extraction is a more economical and practical option for smallholder farmers, whereas ethanolic extraction may be preferred when greater recovery of bioactive compounds is desired. Previous studies have shown that ethanol extracts a broader range of phytochemicals, resulting in higher biological activity despite increased production costs (Azwanida, 2015; Sultana *et al.*, 2009). Likewise, Isman (2020) and Pavela and Benelli (2016) emphasized that although solvent-based botanical pesticides are generally more effective, water-based extracts remain a cost-effective and sustainable alternative for agricultural use.

Table 7. Cost of producing per liter of indigenous plant-based biopesticide

Item	Qty/ MD	Imputed cost	Estimated unit cost	Total cost
1.Aqueous Extract Preparation				
Material Costs				
Hagonoy	5 kg	50.00		50.00
Lantana camara	5 kg	50.00		50.00
Makabuhay	5 kg	50.00		50.00
Cypermethrin	1 L		3,800	3,800
Distilled water @ 6L	1 L		14.16	14.16
Blender rent@400.00/day	1	133.33		133.33
Labor Costs				
Collection	2 hours	50.00		100.00
Air drying (for 10 kgs)				
Hagonoy	2 days		400/day	800.00
Lantana camara	2 days		400/day	800.00
Makabuhay	2 days		400/day	800.00
Grinding and mixing	2 hours/ plant biopesticides		50.00	100.00
Material Costs				130.83
Labor Costs				500.00
Total Costs				P 630.83
Ethanolic Extract				
Hagonoy	5 kg	50.00		50.00
Lantana camara	5 kg	50.00		50.00
Makabuhay	5 kg	50.00		50.00
Ethanol	1 L @ 3		1500	4500
Blender rent @ 400/day	1	133.33		
Material Costs				1616.66
Labor Costs				500.00
Total Costs				P 2,116.66

CONCLUSION

The indigenous plant species Hagonoy (*Chromolaena odorata*), Lantana (*Lantana camara*), and Makabuhay (*Tinospora crispa*) contain important phytochemicals, including flavonoids, phenols, tannins, saponins, alkaloids, and terpenoids, which contribute to their insecticidal properties. Ethanol generally extracted more bioactive compounds than water, indicating its greater efficiency in recovering phytochemicals. Laboratory and field evaluations further showed that both aqueous and ethanolic extracts effectively controlled green leafhopper (GLH) populations, although their insecticidal action was slower than that of cypermethrin during the initial hours after application. However, prolonged exposure resulted in mortality levels comparable to the synthetic insecticide, confirming the potential of these indigenous plants as effective botanical biopesticides.

Among the treatments, Makabuhay at 10–40 mL aqueous extract and 40 mL ethanolic extract exhibited the highest insecticidal activity under laboratory conditions, whereas Lantana produced the highest estimated rice yield (6.31 t ha^{-1}), comparable to that of cypermethrin. Moreover, aqueous extraction proved to be a more economical method (₱630.83 L^{-1}) than ethanolic extraction (₱2,116.66 L^{-1}), making it more practical for smallholder farmers. Overall, the findings indicate that these indigenous plant-based biopesticides are environmentally friendly, cost-effective, and sustainable alternatives to synthetic insecticides for the management of green leafhopper in rice production.

The use of Hagonoy (*Chromolaena odorata*), Lantana (*Lantana camara*), and Makabuhay (*Tinospora crispa*) is recommended as eco-friendly botanical biopesticides for the management of green leafhopper (GLH) in rice. Since aqueous extracts are more economical and easier to prepare, they are recommended for adoption by smallholder farmers, while Makabuhay (10–40 mL aqueous extract and 40 mL ethanolic extract) and Lantana may be prioritized because of their high insecticidal efficacy and favorable effect on rice yield.

Further studies should evaluate the long-term field performance, shelf life, formulation stability, and effects of these biopesticides on non-target organisms. Additional research on the isolation and identification of the active compounds is also recommended to support product development and registration for commercial use.

ACKNOWLEDGEMENTS
The authors wish to express their sincerest gratitude to the Department of Agriculture Regional Field Office No. 02, particularly the Research Division, headed by Ms. Lovelyn Gaspar in 2020, for providing the financial support that made this research possible. The authors also extend their heartfelt appreciation to the Cagayan State University Administration for granting permission and providing the necessary support to conduct and successfully complete this study.

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