



Synergistic Molluscicidal Efficacy of *Averrhoa Bilimbi* and *Cardiospermum Halicacabum* against *Pomacea Canaliculata*

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ABSTRACT

The golden apple snail (*Pomacea canaliculata*) remains one of the most damaging pests of rice in the Philippines, feeding on young seedlings and cutting yields. This study examined whether ethanolic leaf extracts of *Averrhoa bilimbi* (kamias) and *Cardiospermum halicacabum* (balloon vine), applied alone and in combination, could kill this snail under laboratory conditions. An experimental design, laid out as a Completely Randomized Design, was used. Snails were exposed to 25%, 50%, and 75% concentrations of the individual and combined extracts, with distilled water (0%) serving as the negative control; each treatment had three replicates of ten snails, and mortality was recorded at 24, 48, and 72 hours. Qualitative phytochemical screening of the combined extract confirmed the presence of tannins, saponins, flavonoids, coumarins, steroids, cardiac glycosides, alkaloids, and carbohydrates. Mortality climbed with both concentration and exposure time. The combined extract killed every snail within 24 hours at the 75% and 50% concentrations, and the 25% treatment reached complete mortality by 48 hours, while the negative control recorded no deaths at all. Taken together, the results point to the combined ethanolic extracts as a strong botanical molluscicide and a promising, environmentally friendlier option for managing golden apple snails in rice fields.

Keywords: botanical pesticide; pest management; crop protection; invasive gastropods; sustainable agriculture; secondary metabolites

1. Introduction

The Philippines is an agricultural country, and rice sits at the center of daily life in it. Most families depend on rice both as their staple food and as a source of income, which makes protecting rice crops and improving farming practice a matter of livelihood, not just preference. Farming sustains many rural households and keeps the economy moving, yet it still faces problems that pull yields and income down. These problems are not unique to the Philippines, but they weigh more heavily here precisely because the country leans so heavily on rice. In 2023 the country produced about 20.06 million metric tons of rice, a figure that shows how central the crop remains [1]. Central Luzon alone turned out roughly 3.6 million metric tons that year, close to one-fifth of the national total [1]. Bulacan ranks among the top rice-producing provinces, harvesting more than 260,000 hectares of palay and producing over 1.1 million metric tons [2]. San Miguel, a municipality in Bulacan, is known for its wide rice fields and high production, and thousands of local families live off rice farming.

One of the biggest threats to rice in the region is the golden apple snail (*Pomacea canaliculata*). This invasive snail feeds mainly on young rice seedlings during the first two to three weeks after transplanting, and the damage can be severe. Even a small number of snails is enough to reduce tiller counts, and a large population can wipe out nearly every seedling in an affected field [2]. Across the country, an estimated 1.2 to 1.6 million hectares are infested, with losses put at around USD 32.71 million [3].

Farmers usually reach for synthetic molluscicides to control the snails, but these products can harm other organisms, pollute water and soil, and strain the budget of small farmers. Plant-based pest control offers a way around this. Botanical extracts break down naturally, often cost less than synthetic chemicals, and can be sourced from plants already growing in local communities. Many plants produce phytochemicals, natural substances that can discourage pest feeding, slow growth, or lower survival. Leaning on local plants also supports sustainable farming by cutting costs, reducing environmental harm, and using materials farmers can find on their own.

Two local plants that look promising are *Averrhoa bilimbi* (kamias) and *Cardiospermum halicacabum* (balloon vine). Both grow widely in the Philippines and both have shown activity against some pests in recent studies [4]. Even so, published research specifically testing kamias leaf extract or balloon vine leaf extract against the golden apple snail remains scarce, so their direct effects on this snail under field-like conditions are still unclear. Testing these plants helps fill that gap with practical options farmers might actually use.

Snails respond to things that damage their soft bodies, interfere with feeding, or upset their water balance. Some plant compounds irritate snails, stop them from feeding, block digestion, or poison them outright, which cuts down their movement, feeding, or survival. Physical factors such as drying agents, rough particles, or substances that strip away mucus can also reduce snail activity. Control methods generally work best when reduced feeding is

paired with lower survival or reproduction. Studies of kamias leaf extracts show they can reduce feeding, slow growth, and increase death in certain insect and mollusk pests under laboratory conditions [5]. Balloon vine leaf extracts have shown deterrent effects, reduced feeding, and toxic effects against certain insect pests and aquatic snails in experiments [6].

These properties, reduced feeding, lower survival, and deterrence, suggest the two leaves may work in different ways: discouraging snails from feeding, making feeding less effective, and lowering survival or reproduction. Because mixing extracts can sometimes produce a synergistic effect, where the combination outperforms each extract on its own, this study tested kamias and balloon vine together to see whether their combination reduces snail feeding, decreases survival, or lowers reproduction, while also watching for effects on non-target organisms and seedlings.

The value of this work lies in giving rice farmers in San Miguel, Bulacan a practical, affordable, and environmentally friendly way to control snail infestations. By using locally available plants, the study supports sustainable practices that reduce dependence on synthetic chemicals. Beyond helping farmers directly, the results may feed into agricultural research, environmental protection, and pest-management policy. Specifically, this study answered the following questions:

What phytochemical constituents are present in *Averrhoa bilimbi* and *Cardiospermum halicacabum* leaf extract?

What is the mortality rate of *Pomacea canaliculata* when exposed to different exposure times at varying concentrations: 25% leaf extract, 50% leaf extract, and 75% leaf extract?

Which concentration and exposure time yield the highest molluscicidal activity based on the test analysis?

2. Literature review

The golden apple snail (*Pomacea canaliculata*) is a major agricultural pest that threatens rice production, chiefly by feeding on young rice plants. Synthetic molluscicides have long been the go-to control measure, but growing concern over their environmental effects has pushed researchers to look at plant-based alternatives. Work on eco-friendly substances for controlling the golden apple snail supports the continued search for botanical approaches to pest management [7]. How well a plant-derived molluscicide performs, however, tends to vary with the plant species, the concentration used, and the length of exposure.

Averrhoa bilimbi (kamias) has potential as a botanical pest-control material because its leaves carry a range of bioactive secondary metabolites. Phytochemical work has reported flavonoids, alkaloids, saponins, tannins, and other biologically active constituents in *A. bilimbi*, and further study of its leaves has turned up additional biologically active compounds, supporting the plant's promise for biological applications [8]. These compounds have been linked to activities that may interfere with the physiological processes of pest organisms. Despite this potential, studies that directly evaluate *A. bilimbi* as a molluscicide against *P. canaliculata* remain limited.

Cardiospermum halicacabum (balloon vine) also contains a variety of phytochemicals with documented biological activities. Reported constituents include flavonoids, alkaloids, saponins, tannins, terpenoids, steroids, and other secondary metabolites, a profile that suggests promise for agricultural pest management. Existing research, however, has focused mostly on the plant's medicinal and biological properties rather than its molluscicidal action against *P. canaliculata*, leaving thin evidence on how well it works as a botanical molluscicide.

Combining plant extracts has also been drawing attention in botanical pest management. Different extracts bring different groups of bioactive compounds, so a mixture can act on several physiological processes in the target pest at once [9]. Even so, the effectiveness of combining two particular locally available plants cannot be assumed from the biological activity of their individual constituents alone.

Although earlier studies back the biological potential of *A. bilimbi* and *C. halicacabum* and the broader use of plant-based materials for pest management, little is known about applying the two together against *P. canaliculata*. In particular, how the two extracts perform as molluscicides at different concentrations and exposure periods has not been adequately documented. That gap is what the present study addresses: it evaluates the individual and combined effects of *A. bilimbi* and *C. halicacabum* leaf extracts against *P. canaliculata* and contributes experimental evidence on whether their combined application can work as a botanical approach to golden apple snail management.

3. Methodology

3.1 Materials

The following materials were used in preparing the plant extracts and running the molluscicidal bioassay:

70% ethanol solution (technical grade, VWR Chemicals), used as the extraction solvent

Whatman No. 1 filter paper (11 µm pore size), used to filter the extracts

Food-grade aluminum foil, used to cover containers during extraction to limit evaporation and contamination

Distilled water, produced in-house with a water distillation apparatus

Amber glass containers (borosilicate glass, 250 mL capacity), used to store the crude extracts

Dechlorinated water, prepared by letting tap water stand for 24 hours, used for snail acclimation and the bioassay

Fresh young papaya leaves, bought from a local source in San Miguel, Bulacan, used as feed during acclimation

Rotary evaporator (Buchi R-300, Switzerland) with vacuum pump and temperature-controlled water bath, used to remove the solvent

Analytical balance (0.01 g precision), used to weigh plant materials and snails

Vernier caliper (0.01 mm precision), used to measure snail size

Glass stirring rod (borosilicate glass), used to mix the combined extracts

Sterile polypropylene containers of various capacities, used to combine and store the extracts

3.2 Experimental procedures

3.2.1 Preparation of plant extracts

Collection of plant materials. A total of three kilograms of fresh kamias (*Averrhoa bilimbi*) leaves and three kilograms of fresh balloon vine (*Cardiospermum halicacabum*) leaves and fruits were gathered from healthy, mature plants in Sta. Ines, San Miguel, Bulacan. Only undamaged, disease-free, fully developed leaves were selected to keep the plant material consistent in quality.

Authentication. The collected kamias leaves and balloon vine leaves and fruits were submitted to Central Luzon State University (CLSU) for authentication, where qualified personnel with expertise in plant identification verified their identity and taxonomic classification.

Washing. The plant materials were washed thoroughly twice in clean tap water to remove loose particles and visible impurities, then rinsed with distilled water to strip out any remaining contaminants that could affect extract quality.

Drying. The washed materials were dried under a sun shield: they were left in sunlight but covered with a transparent plastic sheet. This removes moisture while softening direct exposure to intense sun, which helps preserve heat- and light-sensitive phytochemicals and other bioactive compounds. The materials stayed under these conditions until completely dry [5].

Pulverization. After drying, the materials were pulverized separately in a clean, dry blender until a fine, uniform powder formed. Pulverizing increases the surface area, letting the extraction solvent penetrate more easily and release more of the bioactive compounds. The blender was cleaned carefully between samples to prevent contamination, and the powders were kept in clean, airtight containers in a dry place until extraction [6].

Ethanol extraction. The pulverized materials were soaked separately in 70% ethanol by maceration at a plant-to-solvent ratio of 1:10. For kamias, 50 g of powdered leaves were soaked in 500 mL of 70% ethanol; for balloon vine, 50 g of powdered leaves and fruits were soaked in 500 mL of the same solvent. The plant material was kept fully submerged to maximize contact with the solvent, and the containers were covered with aluminum foil during extraction to limit evaporation and contamination. The extracts were then filtered to obtain clear solutions [6].

Rotary evaporation. Each ethanolic extract was concentrated separately on the rotary evaporator under reduced pressure and controlled temperature, allowing the ethanol to come off at a lower boiling point while protecting heat-sensitive phytochemicals. The liquid crude extracts were transferred to sterile amber glass containers and refrigerated until further use.

3.2.2 Preparation of golden apple snails

Collection. A total of 400 golden apple snails (*Pomacea canaliculata*) were collected by hand from irrigated rice fields and nearby freshwater bodies in San Miguel, Bulacan. Snails clinging to rice plants, aquatic vegetation, submerged objects, or the muddy substrate were gathered carefully to avoid injury and to keep only healthy, active individuals, which were placed in clean containers for transport.

Authentication. The collected snails were submitted to Central Luzon State University (CLSU), where qualified personnel verified their identity and taxonomic classification.

Size selection. Snails measuring 20 to 40 mm in height and weighing more than 5 g were chosen so that size and developmental stage stayed uniform, minimizing variation that could skew the results.

Acclimation. The snails were acclimatized for 24 hours before the bioassay so they could recover from the stress of handling and transport. They were held in 8.1 L of dechlorinated water with 300 g of fresh young papaya leaves at ambient temperature. The snails were divided into 36 containers, each holding 10 snails in 225 mL of dechlorinated water with 8 g of papaya leaves, with 9 containers allotted per extract and 9 to the control group [7].

3.2.3 Preparation of the combined extract

Combination. The filtered extracts were first allowed to come to room temperature for 15 to 20 minutes. A physical compatibility check was then done by visual observation, looking for precipitation, phase separation, discoloration, or sediment. Once compatibility was confirmed, the extracts were combined at a 1:1 ratio (50% kamias leaf extract and 50% balloon vine leaf and fruit extract) in a clean, sterile container and mixed thoroughly with a glass stirring rod. The mixture was inspected for uniformity before being transferred into properly labeled containers. Equal-ratio combinations of plant extracts have been used in studies evaluating synergistic effects against mollusks [4].

Rotary evaporation. The combined extract was then concentrated on the rotary evaporator under reduced pressure and controlled temperature, gently removing the solvent while minimizing degradation of heat-sensitive bioactive compounds. The resulting liquid crude extract was transferred into clean, airtight containers and stored appropriately until use.

3.2.4 Molluscicidal bioassay

The liquid crude extracts were tested against golden apple snails to gauge their effectiveness. Snails were exposed to 0%, 25%, 50%, and 75% concentrations of each extract, with three replicates per treatment, under controlled laboratory conditions. Mortality and observable behavioral changes, such as reduced mobility, withdrawal into the shell, and loss of responsiveness, were monitored and recorded at 24, 48, and 72 hours. The data were used to quantify molluscicidal activity and to assess the extracts' potential as environmentally friendly, plant-based molluscicides [7].

3.3 Data analysis

The effects of the plant extracts were evaluated from the mortality observed after each exposure period. Mortality data for each treatment concentration were analyzed by probit analysis to estimate the median lethal concentration (LC50), the concentration needed to kill 50% of the test snails; the estimated LC50 values served to compare toxicity and overall molluscicidal effectiveness. Mortality was computed as:

$$\text{Mortality (\%)} = (Nd / Nt) \times 100 \quad (1)$$

where *Nd* is the number of dead snails and *Nt* is the total number of snails per treatment.

The LC50 values, together with their 95% confidence limits, were calculated using the probit method described by Finney (1971). All statistical analyses were run in SPSS v26.0 (IBM Corp., Armonk, NY, USA). Analysis of variance (ANOVA) was used to test for significant differences among treatment means, and Tukey's Honestly Significant Difference (HSD) test was applied for post-hoc comparison of means when significant differences were detected. All quantities are reported in SI units (g, mL, °C, %, h).

4. Results and discussion

This section presents and discusses the results of the study in line with the statement of the problem. It covers the phytochemical constituents present in *Averrhoa bilimbi* (kamias) and *Cardiospermum halicacabum* (balloon vine) extracts, the mortality of *Pomacea canaliculata* at different concentrations, and how concentration and exposure time shaped mortality.

Table 1 - Qualitative phytochemical analysis of the combined *Averrhoa bilimbi* and *Cardiospermum halicacabum* leaf extracts.

Test conducted	Name of test	Result (+/-)
Test for tannins	Ferric chloride test	+
Test for saponins	Froth test	+
Test for flavonoids	Ammonia test	+
Test for coumarins	Sodium hydroxide test	+
Test for steroids	Salkowski test	+
Test for cardiac glycosides	Keller-Killiani test	+
Test for alkaloids	Mayer's test	+
Test for carbohydrates	Molisch's test	+

Detecting all eight classes of compounds suggests that combining the two plant extracts delivers a wider variety of phytochemicals than either plant on its own. These compounds have been associated with biological activities that could contribute to the control of the golden apple snail (*Pomacea canaliculata*), including disruption of cell membranes, interference with feeding and physiological functions, and toxic effects on invertebrates [10].

Table 2 - Qualitative phytochemical analysis of Averrhoa bilimbi leaf extract.

No.	Phytochemical	Ethanol extract
1	Alkaloid	+
2	Saponin	+
3	Tannin	+
4	Flavonoid	+
5	Steroid	+
6	Carbohydrate	+
7	Glycoside	+

The kamias extract was found to contain alkaloids, saponins, tannins, flavonoids, steroids, carbohydrates, and glycosides, showing that the leaves are rich in biologically active compounds [11]. Substances of this kind have been tied to a wide range of biological activities, which makes *A. bilimbi* a credible source of plant-derived compounds for pest management. The table serves as supporting evidence for the bioactive components the plant may contribute.

Table 3 - Qualitative phytochemical analysis of Cardiospermum halicacabum leaf extract.

Phytochemical	Ethanol extract
Alkaloids	+
Flavonoids	-
Phenols	+
Saponins	+
Tannins	+
Terpenoids	+
Quinone	-
Steroids	+

The balloon vine extract was found to contain alkaloids, phenols, saponins, tannins, terpenoids, and steroids, while flavonoids and quinones were absent [12]. The phytochemical profile indicates that *C. halicacabum* is rich in biologically active compounds that may contribute to its pesticidal and molluscicidal properties. These compounds have been reported to possess antioxidant, antimicrobial, insecticidal, and molluscicidal activities, making the plant a potential source of natural pest control agents. Taken together, the two profiles support the potential effectiveness of *C. halicacabum* leaf extract against *Pomacea canaliculata* and back its use as a plant-based alternative to synthetic molluscicides.

The next tables present the results of the bioassays, whose main goal was to determine and compare the molluscicidal effects of *Averrhoa bilimbi*, *Cardiospermum halicacabum*, and their combined extracts on *Pomacea canaliculata* at 25%, 50%, and 75% concentrations over 24, 48, and 72 hours.

Table 4 - Mortality rate of Pomacea canaliculata exposed to different concentrations of Averrhoa bilimbi extract.

Concentration	Exposure time	Replicate (dead/total)	1 Replicate (dead/total)	2 Replicate (dead/total)	3 Replicate (dead/total)	Mean mortality rate (%)
75%	24 h	10/10	9/10	10/10		96.67
75%	48 h	10/10	10/10	10/10		100.00
75%	72 h	10/10	10/10	10/10		100.00
50%	24 h	8/10	9/10	9/10		86.67
50%	48 h	9/10	9/10	9/10		90.00
50%	72 h	9/10	9/10	10/10		93.33

Concentration	Exposure time	Replicate (dead/total)	1	Replicate (dead/total)	2	Replicate (dead/total)	3	Mean mortality rate (%)
25%	24 h	7/10		8/10		9/10		80.00
25%	48 h	7/10		8/10		9/10		80.00
25%	72 h	7/10		8/10		10/10		83.33
0%	24 h	0/10		0/10		0/10		0.00
0%	48 h	0/10		0/10		0/10		0.00
0%	72 h	0/10		0/10		0/10		0.00

Mortality rose as extract concentration and exposure time increased. The 75% concentration produced the highest mean mortality rate, reaching 96.67% after 24 hours and complete mortality (100.00%) after 48 and 72 hours. The 50% concentration gave mean mortality rates of 86.67%, 90.00%, and 93.33% after 24, 48, and 72 hours, respectively, so mortality climbed with exposure but never reached 100%. The 25% concentration posted the lowest rates, 80.00% at both 24 and 48 hours and 83.33% after 72 hours, a clearly weaker effect than the higher concentrations. The 0% (control) treatment recorded no mortality at any observation point, which shows that no natural deaths occurred under the experimental conditions and confirms that the deaths in the treated groups were due to the *Averrhoa bilimbi* leaf extract.

Table 5 - Mean mortality rate of *Pomacea canaliculata* exposed to different concentrations of *Averrhoa bilimbi* extract.

Concentration	24 hours (%)	48 hours (%)	72 hours (%)
75%	96.67	100.00	100.00
50%	86.67	90.00	93.33
25%	80.00	80.00	83.33
0%	0.00	0.00	0.00

The pattern repeats in the summary table: the 75% concentration consistently recorded the highest mean mortality, 96.67% after 24 hours and 100.00% after 48 and 72 hours, making it the most effective treatment under the conditions of the study. The 50% concentration produced 86.67%, 90.00%, and 93.33% across the three observation times, rising gradually but staying below the 75% treatment. The 25% concentration was lowest overall, at 80.00% for both 24 and 48 hours and 83.33% after 72 hours. The 0% control stayed at 0.00% throughout, confirming that the observed deaths trace back to the molluscicidal effect of *Averrhoa bilimbi* leaf extract.

Table 6 - Mortality rate of *Pomacea canaliculata* exposed to different concentrations of *Cardiospermum halicacabum* extract.

Concentration	Exposure time	Replicate (dead/total)	1	Replicate (dead/total)	2	Replicate (dead/total)	3	Mean mortality rate (%)
75%	24 h	10/10		10/10		10/10		100.00
75%	48 h	10/10		10/10		10/10		100.00
75%	72 h	10/10		10/10		10/10		100.00
50%	24 h	9/10		10/10		10/10		96.67
50%	48 h	10/10		10/10		10/10		100.00
50%	72 h	10/10		10/10		10/10		100.00
25%	24 h	8/10		8/10		10/10		86.67
25%	48 h	10/10		10/10		10/10		100.00
25%	72 h	10/10		10/10		10/10		100.00
0%	24 h	0/10		0/10		0/10		0.00
0%	48 h	0/10		0/10		0/10		0.00

Concentration	Exposure time	Replicate (dead/total)	1	Replicate (dead/total)	2	Replicate (dead/total)	3	Mean mortality rate (%)
0%	72 h	0/10		0/10		0/10		0.00

The same concentration and time trend holds for balloon vine, though with faster action. The 75% concentration produced complete mortality throughout the observation period, holding at a mean of 100.00% from 24 hours onward. The 50% concentration recorded 96.67% after 24 hours and then complete mortality (100.00%) after 48 and 72 hours, meaning a longer exposure was needed to eliminate all test organisms. The 25% concentration posted the lowest 24-hour mean at 86.67% but also reached complete mortality after 48 and 72 hours, showing it became fully effective with extended exposure. The 0% control again recorded no deaths at 24, 48, or 72 hours, so no natural mortality occurred under the experimental conditions and the observed deaths can be attributed to the *Cardiospermum halicacabum* extract.

Table 7 - Mean mortality rate of *Pomacea canaliculata* exposed to different concentrations of *Cardiospermum halicacabum* extract.

Concentration	24 hours (%)	48 hours (%)	72 hours (%)
75%	100.00	100.00	100.00
50%	96.67	100.00	100.00
25%	86.67	100.00	100.00
0%	0.00	0.00	0.00

At 24 hours, the 75% concentration had already killed all snails, while the 50% and 25% concentrations produced 96.67% and 86.67% mortality, respectively. By 48 hours, every concentration had reached 100% mortality, and that level held at 72 hours. The 0% control consistently recorded 0.00% mortality across the whole observation period, confirming that no snail died in the absence of the extract.

Table 8 - Mortality rate of *Pomacea canaliculata* exposed to combined extracts of *Averrhoa bilimbi* and *Cardiospermum halicacabum*.

Concentration	Exposure time	Replicate (dead/total)	1	Replicate (dead/total)	2	Replicate (dead/total)	3	Mean mortality rate (%)
75%	24 h	10/10		10/10		10/10		100.00
75%	48 h	10/10		10/10		10/10		100.00
75%	72 h	10/10		10/10		10/10		100.00
50%	24 h	10/10		10/10		10/10		100.00
50%	48 h	10/10		10/10		10/10		100.00
50%	72 h	10/10		10/10		10/10		100.00
25%	24 h	10/10		8/10		10/10		93.33
25%	48 h	10/10		10/10		10/10		100.00
25%	72 h	10/10		10/10		10/10		100.00
0%	24 h	0/10		0/10		0/10		0.00
0%	48 h	0/10		0/10		0/10		0.00
0%	72 h	0/10		0/10		0/10		0.00

At both the 75% and 50% concentrations, all three replicates recorded complete mortality (10/10 dead snails) after 24, 48, and 72 hours, a 100% mean mortality rate. At 25%, one replicate recorded only 8 out of 10 dead snails after 24 hours, giving a mean of 93.33%; by 48 and 72 hours, all replicates had reached 10/10, or 100% mortality. The 0% control recorded no deaths in any replicate at any time point, so no natural mortality occurred during the experiment and the observed deaths were due to the combined extracts.

Table 9 - Mean mortality rate of *Pomacea canaliculata* exposed to combined extracts of *Averrhoa bilimbi* and *Cardiospermum halicacabum*.

Concentration	24 hours (%)	48 hours (%)	72 hours (%)
75%	100.00	100.00	100.00
50%	100.00	100.00	100.00
25%	93.33	100.00	100.00
0%	0.00	0.00	0.00

Table 9 shows that the combined extracts produced complete mortality at 75% and 50% within 24 hours, maintained through 48 and 72 hours. At the lowest concentration, 25%, mortality stood at 93.33% after 24 hours and reached 100% by 48 hours, holding there at 72 hours. The 0% control stayed at 0.00% at 24, 48, and 72 hours, confirming that no snail died in the absence of the combined extracts during the laboratory observation period.

Table 10 - Concentration that yielded the highest mortality rate per sample.

Extract treatment	Concentration
* <i>Averrhoa bilimbi</i> *	75%
* <i>Cardiospermum halicacabum</i> *	75%
Combined extract of * <i>Averrhoa bilimbi</i> * and * <i>Cardiospermum halicacabum</i> *	75%

Based on the observed mortality rates, the combined *Averrhoa bilimbi* and *Cardiospermum halicacabum* extracts showed the highest molluscicidal activity. Both the 50% and 75% combined concentrations produced 100.00% mortality after 24 hours, which held at 100.00% after 48 and 72 hours. The 25% combined concentration also performed strongly, at 93.33% after 24 hours and 100.00% after 48 hours. For comparison, the 75% *Averrhoa bilimbi* extract needed 48 hours to reach complete mortality, while the 75% *Cardiospermum halicacabum* extract got there within 24 hours.

This study set out to determine whether *Averrhoa bilimbi*, *Cardiospermum halicacabum*, and their combination can reduce *Pomacea canaliculata* populations, and the results make clear that plant concentration and exposure time directly determine effectiveness: stronger doses and longer contact consistently killed more snails. These findings answer the research questions by confirming that all three setups produced measurable mortality at 25%, 50%, and 75% across 24, 48, and 72 hours, and by identifying the 75% balloon vine concentration as the most effective treatment overall. In practical terms, local farmers can develop affordable, plant-based snail control that protects crops without relying on expensive or harmful chemicals (Cho et al., 2023) [7].

5. Conclusion

This study concludes that the combined extracts of *Averrhoa bilimbi* (kamias) and *Cardiospermum halicacabum* (balloon vine) show potential as an effective plant-based molluscicide against *Pomacea canaliculata*, the golden apple snail. Phytochemical screening revealed the presence of flavonoids, saponins, tannins, and alkaloids, compounds known for their molluscicidal properties. The bioassay showed that the combined extract causes high mortality among golden apple snails, with higher concentrations and longer exposure periods leading to greater mortality. Notably, the combined extract outperformed the individual plant extracts, suggesting that blending the two plants enhances their effectiveness. These findings indicate that the combined extracts of kamias and balloon vine can serve as a safer, more environmentally friendly alternative to synthetic molluscicides.

Since both plants are locally available, they offer a practical and affordable option for rice farmers managing golden apple snail infestations while reducing reliance on chemical pesticides. Although the work was conducted under laboratory conditions, it provides useful groundwork for developing natural pest control methods and contributes to sustainable, eco-friendly pest management practices that protect rice production and support farmers' livelihoods.

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