Effectiveness of Natural Insecticide from Leaf Extracts as a Control for Leaf Caterpillar Pests *(Doleschallia bisaltide)* on Handeuleum Plants *(Graptophyllum pictum L. Griff)*

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ABSTRACT

Leaf caterpillar pests pose a serious threat to plant growth and agricultural productivity by damaging leaf tissues and reducing photosynthesis. Although synthetic insecticides are widely used for their rapid action, excessive application has caused environmental pollution, pest resistance, and ecosystem imbalance, creating an urgent need for sustainable, climate-adaptive pest control alternatives. This study aims to analyze the effectiveness of natural insecticides derived from betel leaf, papaya leaf, lemongrass leaf, and soursop leaf as a bioscience-based solution for controlling leaf caterpillar pests on handeuleum plants. A quantitative experimental method was employed, using caterpillar mortality time as the leading indicator of effectiveness. The results revealed significant differences among the tested extracts. Betel leaf extract showed the highest effectiveness with an average mortality time of 1.45 minutes, followed by soursop leaf (5 minutes), papaya leaf (8 minutes), and lemongrass leaf (15 minutes). These findings indicate that betel leaf extract has strong potential as an environmentally friendly and sustainable pest control method. The use of locally sourced plant-based insecticides can reduce dependence on synthetic pesticides, support ecosystem balance, and contribute to food security, reinforcing the role of bioscience innovation in achieving sustainable agriculture and the Sustainable Development Goals (SDGs).

Keywords: *Doleschallia bisaltide*, Leaf extract, *Graptophyllum pictum L. Griff*, Natural insecticide.

1. INTRODUCTION

Indonesia occupies a strategic position as one of the countries with the highest biodiversity in the world, particularly for its wealth of native medicinal plants, ranking second only to the Amazon Rainforest (Azmi et al., 2022). The tropical agroclimatic conditions with high rainfall in the West Java region, including Cicurug, Sukabumi, are very conducive to the cultivation of medicinal plants, one of which is handeuleum *(Graptophyllum pictum L. Griff)*. This plant is widely known in traditional medicine for its phytochemical content, such as saponins, tannins, alkaloids, and triterpenoids, which are effective in treating various chronic and degenerative diseases (Manalu & Mariana, 2023). The presence of medicinal plants in the home environment is crucial, especially for communities with limited access to formal health facilities (Sari & Andjasmara, 2023), underscoring the need for their sustainable cultivation in the context of public health and local resource resilience.

However, efforts to preserve and utilize handeuleum plants at the household level face serious challenges in the form of leaf caterpillar pests, particularly Doleschallia bisaltide, which are commonly found in the West Java region. This pest attacks plants from the egg to the larval stage, causing significant leaf damage, reaching 300.28–745.86 mm² per individual, which can kill plants if not controlled effectively (Sartiami et al., 2019). In practice, pest control is still dominated by chemical insecticides due to their immediate effectiveness. However, excessive reliance on synthetic insecticides has caused serious problems, including environmental pollution, the death of non-target organisms, biodiversity decline, harmful residues on plants, and pest resistance (Sanjaya & Santori, 2022; Sinambela, 2024; Suryani et al., 2020).

This situation highlights the gap between the need for effective pest control and the demand for safe, environmentally friendly, and sustainable agricultural practices. Various studies have indicated the potential of natural insecticides based on plant extracts as a safer alternative, utilizing bioactive compounds that are toxic or repellent to insects. Papaya leaves *(Carica papaya)* are known to contain papain, flavonoids, alkaloids, and saponins that can disrupt the digestive system of pests (Akmalina et al., 2023), while lemongrass leaves *(Cymbopogon citratus)* contain geraniol and citronellal, which act as repellents and insecticides (Obenu et al., 2021). In addition, betel leaves *(Piper betle)* and soursop leaves *(Annona muricata)* contain eugenol, flavonoids, and acetogenins, which have been proven effective in inhibiting the growth and causing the death of insect larvae (Kurniawan et al., 2022; Tristiyanti et al., 2023).

However, existing empirical studies are generally limited to testing the effectiveness of a single type of leaf extract, thereby failing to provide a comparative picture of the relative efficacy of natural ingredients in controlling pests on specific plants. This limitation raises the research question: *which leaf extract is most effective as a natural insecticide for controlling leaf-caterpillar pests on handeuleum plants?* Therefore, this study aims to explicitly analyze and compare the effectiveness of natural insecticides derived from papaya, betel, lemongrass, and soursop leaf extracts in controlling leaf caterpillar pests on handeuleum plants.

This study argues that the use of local biological resources as raw materials for natural insecticides is an approach that is not only biologically effective, but also in line with the principles of sustainable agriculture and the achievement of the Sustainable Development Goals (SDGs), particularly goals 3 (good health and well-being), 12 (responsible consumption and production), and 15 (life on land). The research focused on testing the effectiveness of natural insecticides in terms of time to pest death under controlled experimental conditions on one plant and one pest type. The novelty of this research lies in its systematic comparative approach to several local leaf extracts applied to handeuleum plants, as a first step in developing efficient, applicable, and sustainable natural insecticides, while also opening up opportunities for further research based on active compound analysis and long-term field trials.

2. LITERATURE REVIEW

Pest control in sustainable agriculture is based on the theory of plant pest management, which emphasizes ecosystem balance, control efficiency, and minimization of environmental impact (Mabitsela et al., 2025). In this context, natural insecticides are considered part of a biological control approach that uses bioactive plant compounds to suppress pest populations without harming non-target organisms (Raj & Kar, 2025). The basic concept of natural insecticides is based on the mechanisms of action of phytochemical compounds, such as alkaloids, flavonoids, saponins, terpenoids, and acetogenins, which act as contact poisons, stomach poisons, growth inhibitors, or repellents against insects (Saldaña-Mendoza et al., 2025). The effectiveness of natural insecticides is determined not only by the type of active compound but also by the concentration, application method, and biological characteristics of the target pest (Henkhaus et al., 2020).

Previous studies have proven the potential of plant extracts as environmentally friendly insecticides. Akmalina et al. (2023) reported that papaya leaf extract effectively reduces insect larval survival rates by disrupting the digestive system via papain enzyme activity. Obenu et al. (2021) showed that lemongrass leaf extract has significant repellent and toxic effects on insect pests, mainly through its citronellal and geraniol content. Furthermore, Kurniawan et al. (2022) emphasized the role of eugenol and flavonoids in betel leaves in inhibiting insect growth and development, while Tristiyanti et al. (2023) found that acetogenins in soursop leaves can cause larval mortality in various pest species. Although these results are consistent in demonstrating the effectiveness of natural insecticides, most studies are still conducted separately on different plant or pest types, focusing on a single type of leaf extract without a systematic comparative analysis.

These conditions identify a knowledge gap regarding the comparative effectiveness of various leaf extracts in controlling specific pests on the same plant type. In particular, there is still limited research on the efficacy of natural insecticides against handeuleum *(Graptophyllum pictum)*, even though this plant has significant medicinal value and is susceptible to leaf caterpillar infestation. In addition, few studies have used pest mortality time as a quantitative parameter to assess the speed and efficiency of natural insecticides, especially in the context of household-scale applications.

This study was conducted within a theoretical framework in which leaf extract types were independent variables and pest control effectiveness was the dependent variable, measured as the time to death of leaf caterpillars. This framework assumes that differences in the content and mechanisms of action of bioactive compounds across leaf extracts will result in variations in insecticide effectiveness. Thus, a comparative analysis of leaf extracts is expected to provide a scientific basis for selecting the most efficient, applicable, and sustainable natural insecticide ingredients, while strengthening the integration of bioscience innovation into agricultural practices aligned with the principles of sustainable development and the Sustainable Development Goals (SDGs).

3. METHODS

This study used a quantitative method with a simple experimental approach to determine the effectiveness of natural insecticides from several types of leaf extracts, namely betel leaf, papaya leaf, lemongrass leaf, and soursop leaf, in killing leaf caterpillar pests *(Doleschallia bisaltide)* on handeuleum plants *(Graptophyllum pictum L. Griff)*. The subject of this study is leaf caterpillars used as targets for natural insecticide spraying, while the object of the study is the effectiveness of natural insecticides from leaf extracts in killing these leaf caterpillars. The research variables included: 1) independent variables, namely the types of leaf extracts (betel leaf, papaya leaf, lemongrass leaf, and soursop leaf); 2) dependent variables, namely the time of caterpillar death after spraying the leaf extracts; and 3) control variables, namely the number of sprays, caterpillar size, and container conditions.

3.1. Research Procedures

3.1.1. Preparation of Tools and Materials

The equipment used includes a basin, blender, plastic bottles, spray bottles, funnels, plastic cups, knives, sieves, stopwatches, cutting boards, pestles, and transparent containers. The materials used include water as the solvent, fresh leaves (betel, papaya, lemongrass, and soursop), and leaf caterpillars as the target.

3.1.2. Leaf Extract Preparation

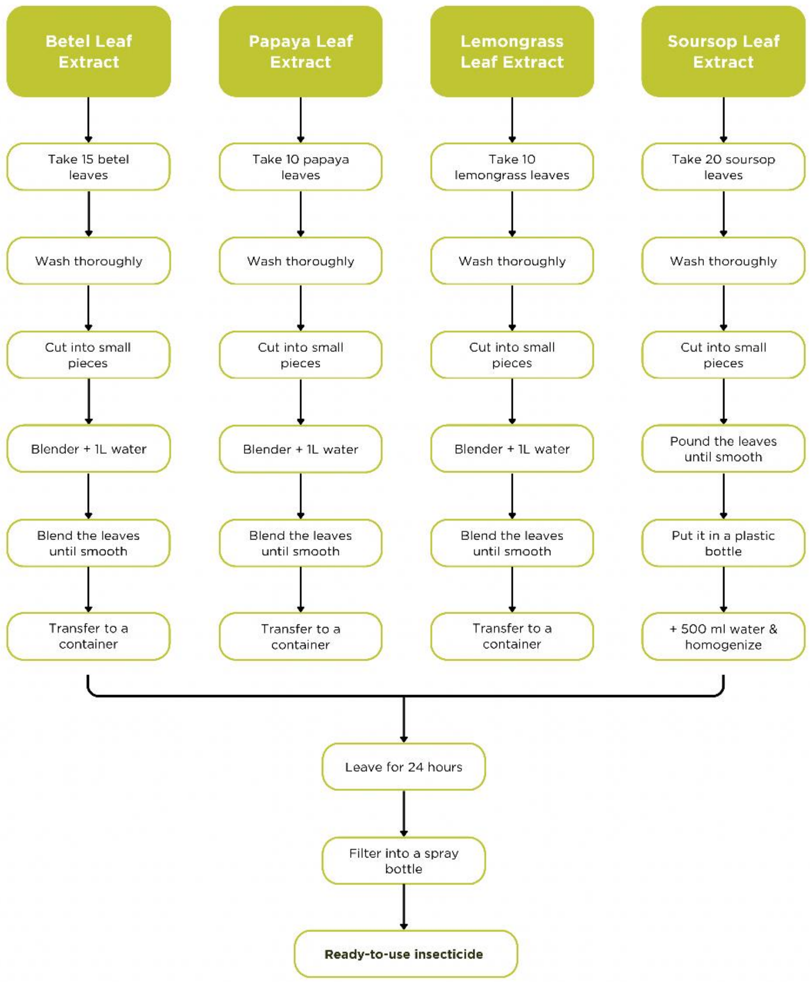

Figure 1. Flowchart for Making Natural Insecticide from Leaf Extracts

3.1.3. Application of Treatment and Observation

Application of treatment, as follows: prepare four transparent containers, each containing one leaf caterpillar, spray betel leaf extract on container one and observe how long it takes for the leaf caterpillar to die after 60 sprays, then record the results of the observation, spray papaya leaf extract on container two and observe how long it takes for the leaf caterpillar to die after 60 sprays, then record the results of the observation. Spray lemongrass leaf extract into container three and observe how long it takes for the leaf caterpillars to die after 60 sprayings, then record the results of the observation. Spray soursop leaf extract into container four and observe how long it takes for the leaf caterpillars to die after 60 sprayings, then record the results of the observation.

Data were collected through direct observation of caterpillars after spraying. The data collected were the time of caterpillar death for each type of leaf extract. The data obtained were analyzed descriptively and quantitatively, namely by comparing the time of caterpillar death after spraying with each leaf extract. The analysis was carried out by sorting the time of death from fastest to slowest to determine which extract was most effective at killing leaf caterpillars. The results of the analysis were presented in tables and bar graphs to compare the effectiveness of each type of extract.

4. FINDINGS

The study aimed to determine the effectiveness of natural insecticides derived from leaf extracts, including betel leaf, papaya leaf, lemongrass leaf, and soursop leaf, to identify the most effective leaf extract for controlling leaf caterpillar pests on handeuleum plants. The treatment was carried out by spraying each leaf extract 60 times into a container containing one leaf caterpillar. After that, observations were made on the time of death of the caterpillar since the spraying. The results are shown in Table 1.

Table 1. Observation Results of Caterpillar Death Time

No.	Types of Leaf Extracts	Number of Sprays	Time of Caterpillar Death (Minutes)	Description
1.	Betel Leaf	60 times	1.45	The caterpillar became restless, weak, stopped moving at the 30-second mark, showed no response, and died.
2.	Soursop Leaf	60 times	5	The caterpillar moves slowly, writhes weakly, shows no response, and slowly dies.
3.	Papaya Leaf	60 times	8	The caterpillar curled up, its movements weakened, it writhed, and slowly died.
4.	Lemongrass Leaf	60 times	15	The caterpillar secretes green fluid at the 29th second, its body weakens, and it dies slowly.

Based on Table 1, all leaf extract types tested showed differences in the time to caterpillar death and the symptoms of death. Betel leaf extract was the fastest to cause caterpillar death, with a death time of approximately 1.45 minutes. In this treatment, the caterpillars appeared restless and weak, then stopped moving at 30 seconds, showed no response, and eventually died. Soursop leaf extract caused the caterpillars to die within 5 minutes, with symptoms including slowed movement, weak, writhing movements, no response, and slow death. Furthermore, papaya leaf extract caused death in around 8 minutes, marked by caterpillars curling up, weakening, writhing, and gradually dying. Meanwhile, lemongrass leaf extract had the longest death time, around 15 minutes, characterized by the caterpillars secreting green fluid at the 29th second, their bodies weakening, and finally dying slowly. These results indicate that each leaf extract type has a different level of effectiveness in causing caterpillar death.

5. DISCUSSION

5.1. Effectiveness of Betel Leaf Extract

Betel leaf extract *(Piper betle)* showed the fastest time of death, which was 1.45 minutes, indicating that betel leaves have a powerful toxic effect on leaf caterpillars. Betel leaves contain eugenol, chavicol, and flavonoid compounds that are antimicrobial and insecticidal, and are capable of inhibiting the growth and development of insects (Kurniawan et al., 2022). Eugenol is a phenylpropanoid compound that has neurotoxic effects on insects. This compound disrupts the function of neurotransmitters, which play an essential role in the transmission of nerve impulses in insects. When exposed to eugenol, caterpillars experience muscle spasms, nerve disorientation, paralysis, and eventually rapid death (Annasya et al., 2025).

Chavicol compounds irritate the insect nervous system and can disrupt the integrity of cell membranes and the activity of insect metabolic enzymes. Chavicol compounds also have repellent and feeding deterrent properties, so leaf caterpillars are not attracted to plants containing these compounds (Mistaji et al., 2022; Sadiah et al., 2022). Lastly, flavonoid compounds exhibit antioxidant, antimicrobial, and insecticidal activities. These compounds can inhibit insect digestive enzymes, such as amylase and protease, disrupt energy metabolism, and reduce appetite and larval growth. Flavonoid compounds can increase the effectiveness of eugenol and chavicol by accelerating the destruction of internal caterpillar tissue and slowing down the detoxification of toxic compounds (Bahrina et al., 2024; Ramadhan et al., 2019).

These three compounds work synergistically: eugenol attacks the nervous system, chavicol damages the metabolic and digestive systems, and flavonoids reinforce systemic physiological damage. This combined effect disrupts the caterpillar's vital functions, such as loss of nerve coordination, eating disorders, internal organ damage, and ultimately death within a short period of time. This potential makes betel leaves an effective, environmentally friendly, and highly competitive alternative natural insecticide for pest control.

5.2. Effectiveness of Soursop Leaf Extract

Soursop leaf extract *(Annona muricata)* kills caterpillars within 5 minutes. Soursop leaves contain acetogenins, saponins, and tannins that have proven insecticidal activity and can kill larvae of several insect species (Tristiyanti et al., 2023). Acetogenins have several main compounds, namely annonacin, sabadelin, and rolliniastatin, which are lipophilic and easily enter insect cells. Annonacin and other acetogenin compounds also disrupt neuronal function, thereby affecting motor coordination and the central nervous system in insect larvae (Rahmadi et al., 2022; Rohaniah et al., 2023; Zega & Fau, 2021). Saponins are glycoside compounds with both lipophilic and hydrophilic parts, which enable them to disrupt the membranes of caterpillars. Saponin compounds can damage cell membranes, inhibit appetite, and disrupt digestion and nutrient absorption in insects, thereby slowing larval growth. Larvae will experience internal dehydration, metabolic disorders, and decreased activity, followed by cell and tissue death (Asfahani et al., 2022).

Lastly, tannin compounds can bind proteins and precipitate them, thereby interfering with caterpillar digestive enzymes such as amylase and protease, causing irritation of the digestive tract, accelerating food emptying, and reducing the conversion of feed into energy (Purnamasari, 2021; Siswaatmadja et al., 2022). Asetogenin acts as a neurotoxin and a cell respiration inhibitor; saponin damages membrane structure and the digestive system, while tannin interferes with the nutritional function of larvae. The combination of the three creates a multisystem toxic effect that causes rapid insect death. Although not as fast as betel leaf, death within 5 minutes demonstrates the significant potential of asetogenin as a natural insecticide.

5.3. Effectiveness of Papaya Leaf Extract

Papaya leaf extract *(Carica papaya)* takes 8 minutes to kill leaf caterpillars. Papaya leaves contain papain, flavonoids, alkaloids, and saponins, which act as contact poisons against insects and disrupt the digestive system of pests (Akmalina et al., 2023). Papain and alkaloids are protein-degrading compounds that can damage insect proteins and disrupt the digestive and metabolic systems of caterpillars. Papain can disturb the internal tissue structure of caterpillars, especially in the digestive tract and muscles, and damage the epithelial cells of the larval intestine, preventing proper nutrient absorption. Papain not only acts directly, but also causes rapid internal damage when ingested by insects (Kulu, 2021; Tambun et al., 2025).

The alkaloid compounds inhibit enzyme activity and neurotransmitter receptors, disrupting nerve communication and ion balance, and altering nerve impulses, which can trigger seizures, paralysis, and death. They also disrupt the larval metabolic system, causing the body to run out of energy and leading to cell death. The caterpillars become weak, stop eating, and show signs of paralysis before dying (Serdani et al., 2022; Wahyuni & Yuliani, 2023). Papain acts as a proteolytic enzyme that destroys insect body tissue, flavonoids and saponins interfere with digestive function and appetite, while alkaloids are neurotoxic and inhibit the caterpillar's nervous system. The combination of these compounds produces a strong insecticidal effect, although it takes slightly longer to work.

5.4. Effectiveness of Lemongrass Leaf Extract

Lemongrass leaf extract *(Cymbopogon citratus)* showed the lowest effectiveness, with the longest time to death (15 minutes). This slow effect is related to the mechanism of action of the compounds in lemongrass, which tend to be non-systemic, dose-dependent, and contact-active. Lemongrass leaves contain the compounds geraniol, citronellal, and citronellol, which have repellent and toxic effects on various types of insect pests (Obenu et al., 2021). Geraniol is a compound that acts as a strong repellent against multiple insects and has mild neurotoxic effects, particularly by disrupting nerve cell function and cell membranes. Geraniol can disturb the integrity of insect cell membranes and the normal function of the peripheral nervous system, as well as reduce the insect's ability to detect food or threats. Geraniol is not immediately lethal, but it works by slowing bodily functions, inhibiting feeding activity, and causing gradual death due to nervous system failure (Widyatama et al., 2025). Citronellal is the main component that gives lemongrass its distinctive aroma and has insecticidal, repellent, and strong irritant effects. Citronellal can irritate insects' sensory systems, disrupting their olfactory and contact receptors, preventing caterpillars from properly recognizing their environment. At high concentrations, it can potentially inhibit respiration and cause cell death. Citronellal causes caterpillars to become restless, stop eating, and gradually become paralyzed by disrupting their sensory and respiratory systems (Nazia et al., 2024; Sari et al., 2024).

Lastly, citronellol has repellent and antimicrobial properties and acts as a mild neurotoxin for insects. Citronellol compounds can disrupt the nervous system, particularly the receptors in insects' legs and antennae, and weaken muscles, slowing caterpillars (Yulianti et al., 2025). Citronellol causes slow reactions, reduced responsiveness to stimuli, and ultimately death due to damage to the body's coordination system. After 15 minutes, insecticidal activity is still evident, but attention must be paid to the concentration and extraction method for optimal results (Af'idah et al., 2023). The following table compares the effectiveness of lemongrass leaf extract with other leaf extracts and explains why it is less effective.

Table 2. Factors Causing Low Effectiveness of Lemongrass Leaf Extract

No.	Factor	Lemongrass Leaf	Betel / Soursop / Papaya Leaf
1.	Primary mechanism	Repellent & contact irritant	Systemic & metabolic toxins
2.	Body system targets	Sensory system & peripheral nerves	Central nervous system, digestion, metabolism
3.	Toxicity strength	Mild to moderate (depending on dose)	Moderate to strong (at low doses)
4.	Speed of work	Slow (15 minutes)	Fast (1.45–8 minutes)
5.	Properties of compounds	Volatile, evaporates quickly	Stable, easily absorbed by insect bodies

Lemongrass leaf extract acts as a repellent and slow paralytic, not as a direct poison like betel leaf or soursop leaf extract. Another factor contributing to the low effectiveness of lemongrass leaf extract as a leaf-caterpillar pest control agent is the larger size of the caterpillars compared to those in other caterpillar samples. Figure 2 shows the difference in size of the leaf caterpillars used as test samples.

Figure 2. Differences in Caterpillar Size. Description:
(A: Papaya Leaf, B: Betel Leaf, C: Soursop Leaf, D: Lemongrass Leaf)

Large caterpillars have stronger resistance than small caterpillars, resulting in a slower and weaker response to toxic compounds. Larger caterpillars also require higher insecticide doses to work optimally. Therefore, the effectiveness of lemongrass leaves can be increased by using higher concentrations and appropriate application methods, depending on the size of the leaf caterpillars. This study was conducted under controlled conditions, limited to one pest species and plant, and did not analyze the active compounds or long-term effects in the field.

6. CONCLUSION

This study concluded that all leaf extracts tested have the potential to be used as natural insecticides to control leaf caterpillar pests on handeuleum plants, with varying degrees of effectiveness. Betel leaf extract showed the highest effectiveness with the fastest kill time (average of 1.45 minutes), followed by soursop leaves (5 minutes), papaya leaves (8 minutes), and lemongrass leaves (15 minutes). These differences are related to variations in the content and mechanism of action of the bioactive compounds in each extract. These findings confirm that betel leaf is the most efficient natural insecticide alternative for controlling leaf caterpillar pests on handeuleum plants.

In practical terms, the results of this study support the use of natural insecticides derived from local resources to reduce dependence on chemical insecticides and encourage environmentally friendly, sustainable agricultural practices, in line with achieving the SDGs. Further research is recommended to examine variations in concentration, analyze active compounds, and conduct long-term field trials to obtain more comprehensive results.

Author Contributions: The first author contributed to formulating the study's main ideas, directing the conceptual framework and methodology, and providing overall academic supervision of the research process and article writing. The second author contributed to data collection, conducting experiments, and drafting the initial version of the article, particularly the introduction and research methodology sections. The third author was involved in the literature review, the development of the theoretical framework, and the analysis and interpretation of the research results. The fourth author contributed to data processing and visualization, the writing of the results and discussion sections, and the editing of the article's language and format in accordance with the guidelines.

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Data Availability Statement: The data supporting the findings of this study were obtained from experiments conducted by the authors and are available upon reasonable request to the corresponding author. The data are not archived in a public repository due to the study's limited scope and the absence of institutional requirements for open data uploads. There is no sensitive data restricted by privacy or ethical considerations. During the preparation of this manuscript, the authors used ChatGPT (OpenAI) to assist with academic language composition and editing. The use of this tool did not influence the research design, data collection, data analysis, or interpretation of research results. The authors are solely responsible for all scientific content and conclusions.

Conflicts of Interest: The author declares that there is no conflict of interest.

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