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Papaya Leaves as a Plant-Based Pesticide to Control Pests and Plant Diseases

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A B S T R A C T

The purpose of writing this article is to explore information regarding the effectiveness of papaya leaf extract in controlling plant pests and diseases. The writing method uses library research by collecting data through searches on Web of Science, Google Scholar, ScienceDirect, and Citation Index. Based on phytochemical tests of papaya leaf extract, there are several chemical compounds in the form of flavonoids, alkaloids, tannins, saponins, and terpenoids which have potential as natural ingredients for vegetable pesticides because they can affect plant pest insects. Papaya leaf extract can kill pests such as aphids, whiteflies, and caterpillars. Papaya leaf extract can also control diseases such as anthracnose and late blight. Using papaya leaf extract can help farmers increase crop yields and reduce dependence on chemical pesticides

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INTRODUCTION

Pest attacks and plant diseases cause a decrease in agricultural productivity and often cause plant deaths (Javandira et al., 2023) To increase the productivity of agricultural products, the government promotes the green revolution through the use of synthetic fertilizers and pesticides to meet the need for food. The use of pesticides and chemical fertilizers reaps various problems due to mismanagement in agricultural land, namely pollution by chemical pesticides and synthetic fertilizers due to excessive use of these materials and has an impact on decreasing environmental quality and human health (Irfan, 2016) The uncontrolled use of synthetic pesticides has caused concern among researchers and practitioners, so that the idea of finding safer alternatives to pest and plant disease control has emerged (de Jesus Oliveira et al., 2024) Saravanan (2022) stated various negative impacts caused by synthetic pesticides, including: causing environmental damage, causing poisoning, killing natural enemies of pests and plant diseases, causing resistance to pesticides, causing diseases for humans, and polluting water and soil.

Eco-friendly agriculture is a sustainable agricultural system that aims to increase productivity by paying attention to environmental health by minimizing the use of harmful chemicals (Manson et al., 2022) Another definition is an agricultural production system that relies on natural ingredients and avoids or minimizes the use of inorganic fertilizers, pesticides, herbicides, fungicides and other chemicals. Organic farming systems apply natural practices to improve soil fertility, control pests and diseases and produce healthy and nutritious crops (Wihardjaka, 2018).

The application of an environmentally friendly agricultural system can increase the productivity of food crops followed by environmental conservation is a principle of environmentally friendly and sustainable agriculture. The manufacture of plant-based pesticides is one of the environmentally friendly and sustainable solutions in facing the challenges of modern agriculture. Agricultural sustainability is the main key to increasing crop yields and environmental sustainability (Kamarubayana *et al*., 2022; Sutriadi *et al*., 2020; Wihardjaka, 2018).

LITERATURE REVIEW

Insects and plant diseases are known as a terrifying scourge for farmers because it is not uncommon to cause crop failure. Pest attacks and plant diseases threaten the stability of agricultural production due to yield loss and decreased crop productivity (Sutriadi *et al*., 2020). Pests and plant diseases also have more serious long-term impacts. Declining crop quality, stunted crop growth and even crop failure are terrible consequences that farmers must bear. The use of plant-based pesticides can be part of an integrated approach to sustainable pest and disease management, taking into account their benefits and limitations as well as maintaining a balance between the environment and human health (Siregar, 2023). Plant-based pesticides function to inhibit and kill pests and pathogens found in plants. This is because plants contain many bioactive compounds such as *alkaloids, terpenoids, phenolic* and other compounds (Vandalisna *et al*., 2021).

The use of plant-based pesticides has several important influences in controlling pests and plant diseases, including: a) reducing pest populations, the active compounds contained in plant-based pesticides can disrupt the nervous system, cause death and inhibit their development, b) control plant diseases, some plant-based compounds have antimicrobial properties that are effective in fighting pathogens that cause plant diseases, such as bacteria or fungi, c) reduction of chemical residues on crop yields, plant-based pesticides have a short half-life and are easily degraded by microorganisms or other natural processes, d) human and environmental safety, plant-based pesticides generally have lower toxicity and are easily degradable naturally, reducing negative impacts on non-target organisms and the environment, e) agricultural sustainability, the use of plant-based pesticides helps maintain the balance of agricultural and health ecosystems environment and humans.

According to (Hasfita *et al*., 2013) the use of plant-based pesticides is needed as an alternative to pest and disease control that is safer and more environmentally friendly. The chemical compounds contained in plant insecticides can inhibit or kill pests by: (1) damaging the development of eggs, larvae, and pupae from insect pests; (2) interfere with insect pest communication; (3) causing insect pests to refuse to eat; (4) inhibiting the reproduction of female insect pests; (5) reduce the appetite of insect pests; (6) block the ability of insect pests to eat; and (7) repelling insect pests (Kusumawati & Istiqomah, 2022).

Potential natural ingredients as plant-based pesticides that can replace chemical pesticides are available in abundance and are easily available around the environment of agricultural activities. One potential alternative is the use of plant-based pesticides from papaya leaves (*Carica papaya.,* L.). Papaya leaves contain various bioactive compounds that have pesticide effects, such as alkaloids, flavonoids and saponins. These compounds can kill pests and control plant diseases. Papaya leaves are one of the alternative plant-based insecticides, this is because papaya leaves contain secondary metabolites such as saponins, alkaloids, carpine, papain, flavonoids (Khairunnisa *et al*., 2023) which act as plant pest poisons, besides that papaya plants are widely cultivated and easy to find in the community (Piri *et al*., 2022).

The use of plant-based pesticides from papaya leaves has several advantages, including: safe for human health and the environment, relatively cheap and easy to make, environmentally friendly and effective in controlling pests and diseases. This study aims to evaluate the effectiveness of papaya leaf extract in controlling pests and plant diseases. The papain compound contained in papaya leaf extract is a contact poison that enters the body of pests through the pores of the insect body. Papain compounds also work as a stomach poison that enters through the mouth to the digestive tract of insects resulting in disruption of the digestive system (Vandalisna et al., 2021) The papaya leaves used are widely cultivated by the community around the yard of the house and the leaves used should be old. This research is expected to provide useful information for farmers in controlling pests and diseases of their crops in a safer and more environmentally friendly way.

METHODOLOGY

The writing of this article uses a literature review, namely analyzing existing research. The steps taken are to collect scientific literature relevant to the topic, analyze and present the findings. A comprehensive electronic literature search that includes databases such as Web of Science, Google Scholar, ScienceDirect and Citation Index.

Based on research conducted by Rainer & Wohlin (2024) it is stated that literature studies include various types of secondary studies, such as Systematic Literature Review (SLR) and systematic mapping studies (SMS). Both literature studies should label the correct primary studies because otherwise the data would be considered invalid. According to Resnawita & Hendrik (2023) the literature study method used is the *Systematic Literature Review* (SLR) method which includes research questions, searching literature, inclusion and exclusion criteria, quality assessment, data collection, data analysis. This method focuses on conducting a systematic review of the analysis of previous research results by using the parameters of the influence of the use of papaya leaf extract as a vegetable pesticide on various plants. In literature studies, transparency is expected so that it is useful for readers in understanding what has been done, for reviewers and editors in evaluating work and finally for other researchers who want to conduct similar research in the future (Massaro et al., 2019)

Literature studies involve intelligence in finding quality literature, expertise in analyzing data and the ability to present findings. The ability to think critically and use literature studies is carried out only based on written works such as books, journals and scientific articles, both published and unpublished. The ability to think critically provides many benefits for life and is used for the benefit of humanity so it needs to be honed and developed in daily life (Syafitri et al., 2021)

The advantages of literature studies include: a) efficient and cost-effective, literature studies can be carried out with less cost and time than other research methods such as field research or experimental research. Researchers do not need to collect data directly, but only need to search and analyze various existing sources, b) wide accessibility, literature sources such as books, journals, and scientific articles can be easily accessed through the internet. This allows researchers to obtain relevant information from different parts of the world, c) the ability to synthesize information, literature studies allow researchers to synthesize information from various sources and produce a more comprehensive understanding of a topic, d) strengthen the credibility of the research, the use of credible literary sources can strengthen the credibility of the research and make it more convincing.

According to Kennedy (2007) the disadvantages of literature studies include; a) dependence on existing sources, literature studies depend on existing sources, researchers have no control over the quality or accuracy of the information contained in the sources, b) potential for bias, researchers unconsciously include their own biases in their interpretation of literature sources, c) lack of primary data, Literature studies do not produce primary data, so researchers cannot directly observe or measure the phenomena they are

studying, d) require good literacy skills, literature studies require good literacy skills, such as the ability to find, evaluate, and analyze information sources.

Literature study is an important step in research, both for qualitative and quantitative research. Literature studies can help researchers to: 1) build a theoretical framework, literature studies can help researchers build a strong theoretical framework for their research. The theoretical framework is a theoretical foundation used to guide research and interpret the results, 2) Identify research gaps, literature studies can help researchers to identify research gaps, namely areas that have not been researched or that still need further research, 3) develop research questions, literature studies can help researchers to develop clear and focused research questions, 4) strengthen arguments, Literature studies can help researchers to strengthen their arguments by using evidence from credible sources, 5) study research methodologies, literature studies can help researchers to study research methodologies used by other researchers (Kennedy, 2007)

RESULT & DISCUSSION

1. Results of Phytochemical Tests of Papaya Leaf Extract

The active ingredients contained in papaya leaves and other plant materials contain flavonoids, alkaloids, tannins, saponins and triterpenoids have the potential as natural ingredients for vegetable pesticides because they can affect insect pests of plants.

Table 1. Results of Phytochemical Tests of Papaya Leaf Extract (*Carica Papaya*)

Types of Secondary Metabolite Compound Groups	Test Results
Alkaloid	+
Polyphenol	+
Kuinon	+
Flavonoid	+
Terpenoid	+

Source: Julaily & Setyawati, 2013

Papaya leaf vegetable peptides contain active substances from the secondary group of metabolites, such as alkaloids, flavonoids, quinones, terpenoids and other chemical substances. This active ingredient can affect Plant Disrupting Organisms (OPT) in various ways, such as repellents, antifeedants, growth regulators, attractants, and as deadly toxins (Kusumawati & Istiqomah, 2022) The papain enzyme contained in papaya leaf extract is effective in controlling plant-sucking pests. According to Yudiawati & Hapis (2016) papain works actively as a stomach poison that enters the body and responds to pests so that it decreases eating activity. The working system of papain as a stomach poison in the body of insects is absorbed by the walls of the digestive organs of insects and then sent to the

nerve center so that it exerts pressure and lowers the metabolic process of internal organs and inhibits eating activities and causes the death of insects (Siahaya & Rumthe, 2018).

Alkaloid

Alkaloids are chemical compounds produced by plants and can be used as vegetable pesticides to control armyworm pests on plants (Rizki, 2022) Alkaloid compounds contained in papaya leaves such as karpain, karpaina and carpaiini. These compounds have a varied effect on insects, therefore they can act as effective plant-based pesticides. Alkaloids are bitter and toxic compounds that can cause dizziness and unwillingness to eat in insect pests due to their bitter taste and eventually death (Sonja V.T. Lumowa, 2018)

Alkaloid compounds are toxic to insects because they act as stomach *poisoning*, so if these alkaloid compounds enter the insect's body, it will interfere with their digestive tract and can interfere with taste receptors in the insect's oral area (Javandira, Widnyana, & Suryadarmawan, 2016). Alcolloid compounds can also inhibit insect growth, this is because alkaloids are in the form of salts so that they can cause degradation of cell membranes, and can inhibit the action of the acetyl cholinesterase enzyme which causes disruption of the larval nervous system (Koneri & Pontororing, 2016).

The mechanism of action of papaya leaf alkaloid compounds in insects is as follows:

1. **Nervous System Disorders**
   Alkaloids can interfere with the insect nervous system by binding to nerve receptors and interfering with the transmission of nerve signals. This can lead to paralysis, disorientation and death in pests.
   Karpain, one of the main alkaloids in papaya leaves, is known to contain neurotoxicity in various insect pests such as caterpillars, aphids, and leafhoppers.
2. **Digestive Breakdown**
   Alkaloids work to damage the digestive system of insect pests by disrupting digestive enzymes and food absorption, this results in starvation, weakness and death in insects.
3. **Growth Inhibition**
   Alkaloids can inhibit the growth of insect pests by interfering with insect growth hormones and metabolism. This causes the growth of insects to slow down, becoming smaller and less reproductive.
   Karpain and karpaina are two alkaloids in papaya leaves that work to inhibit the growth of insects. Alkaloid compounds are able to inhibit the process of metamorphosis from larvae to pupa (Siahaya & Rumthe, 2018)
4. **Repellent Effect**
   Alkaloids act as repellents that repel insect pests from plants, this is due to the bitter taste and smell of alkaloids that insects do not like.
5. **Increases Plant Resistance**
   Alakaloids can increase plant resistance to pest attacks by strengthening plant cell walls and activating plants' natural defense mechanisms.

Polypenol

Tannins are one of the phenolic compounds that are included in the group of polyphenols found in papaya plants. Tannins can be defined as polyphenol compounds with a very large molecular weight of more than 1000 g/mol and can form complex compounds with proteins. Tannins have a large biological role because of their function as protein precipitators and metal carriers. Therefore, tannins can play a role as biological antioxidants (Noer et al., 2018) Tannins produced by plants function as protective substances inside and outside the tissues. Tannins have properties that are resistant to overhaul or fermentation (Indrawijaya et al., 2019)

The mechanism of action of tannin compounds is to activate the cell lysis system due to the activity of proteolytic enzymes in the body cells of insects exposed to tannins. Complex compounds resulting from the interaction of tannins with proteins are toxic which play a role in inhibiting growth and reducing insect appetite through inhibiting digestive enzyme activity. Tannins have a bitter taste as a fungi repellent to herbivores and as a self-defense in plants.

Tannins can react with proteins to form copolymers that are insoluble in water. This reaction makes proteins more difficult to reach by the digestive juices of insects, one of the main functions of tannins in plants is as insect repellents. Tannins have a function as a plant's defense against insects. Tannin compounds can affect the ability of larvae to digest food, by inhibiting the work of digestive enzymes (Koneri & Pontororing, Hesky, 2016) Tannins are also antimicrobial. Tannin mechanisms work in controlling insect pests including:

1. **Protein and Enzyme Binding**
   Tannins have the ability to bind proteins and enzymes to insects. This can interfere with the digestion, metabolism and reproduction processes of pests. This binding mechanism mainly occurs in highly hydroxylated tannins such as galic acid and tannic acid which are abundant in papaya leaves.
2. **Cell Membrane Damage**
   Tannin compounds can damage pest cell membranes by disrupting their structure and function. This can cause cell leakage that leads to the death of insects. This cell membrane damage mainly occurs in low-hydroxylized tannins, such as catechins and epigallocatechin gallate found in papaya leaves.
3. **Antioxidant Effects**
   Tannins have powerful antioxidant properties that can help protect plants from damage from free radiation produced by insect pests.
4. **Repellent Effect**
   Tannins have a bitter and astringent taste that insect pests do not like. This makes insect pests not interested in plants
5. **Increases Plant Resistance**
   Tannins can increase plant resistance to pest attacks by activating plants' natural defense mechanisms. Tannins can induce the

production of plant defense enzymes and proteins and strengthen plant cell walls.

Kuinon

Quinine is an organic compound that contains an aromatic ring with two carbonyl groups. This compound is found in several types of plants, one of which is found in papaya leaves and acts as a vegetable pesticide. Based on research by Fatan *et al* (2021) it was stated that in the results of activity tests of five types of plants, one of which is papaya leaves contain quinone and produce isolates with different activities. The results of the activity test include antioxidants, antibacterial, anticancer, intiinflammatory, analgesic, antipyretic and antitumor.

Quinone is one of the derivatives of phenolic compounds that show biological and pharmacological activity and is also a derivative compound of aromatic compounds that have color as its characteristic properties and have unique carbonyl with chromophores consisting of 2 carbonyl groups that conjugate with 2 double bonds (Klaritya Anisya Kurnia, Shafa Qotrunnada Widyatamaka, Shipa Paujiah *et al*., 2021) . Quinons are divided into 4 groups, namely benzoquinones (chromophores consisting of 2 carbonyl groups conjugated with 2 carbon double bonds), naphthoquinones, interquinones, and isoprenoid quinones. To release free quinones in the benzoquinone, naphthokuinone, and anthraquinone groups, acid hydrolysis is required, while in the isoprenoid quinone groups involved in photosynthesis and cell respiration, a special way is needed to separate them from other lipid materials (Fatan et al., 2021)

Kuinon has several working mechanisms that can control and kill plant pests, including:

1. **Respiratory System Disorders**
   Quinine can disrupt the respiratory system by inhibiting enzymes involved in the cellular respiration process. This causes a lack of oxygen and leads to the death of insect pests.
2. **DNA Damage**
   Quinon can damage the DNA of insect pests by producing free radicals that can attack and break DNA strands. This can lead to gene mutations, chromosomal damage and cell death.
3. **Stunting Growth**
   Quinine can inhibit the growth of insect pests by interfering with growth hormone and metabolism. This causes insects to grow slower, become smaller and less reproductive.
4. **Repellent Effect**
   Quinine has an odor that pests don't like, this makes the plant less attractive to insect pests.
5. **Increases Plant Resistance**
   Quinine can increase plant resistance to pest attacks by activating the plant's natural defense mechanisms.

Flavonoid

It is one of the chemical compounds found in papaya leaves and plays an important role as a vegetable pesticide. The distinctive properties of flavonoids are that they have a sharp odor, bitter taste, are soluble in water and easily decompose at high temperatures. Flavonoids work to inhibit insect appetite also have a role as regulators of antimicrobial and antiviral action. Flavonoids function as respiratory inhibitors that can inhibit respiration and result in insect death (Gangga Dewanti Gita Maharani et al., 2022)

Flavonoid compounds also have toxic power as a stomach poison (Javandira et al., 2016), can inhibit larval growth, and affect three main hormones in insects, namely brain hormones, exdicone hormones and growth hormones (juvenile hormones), so that they can prevent larval movement and inhibit the metamorphosis process. Flavonoids also work to weaken nerves and damage the spiracles, causing pests to be unable to breathe and eventually die.

The mechanism of action of flavonoids that can control and kill insect pests includes:

1. **Digestive System Disorders**
   Flavonoids interfere with the digestive system of insect pests by binding to digestive enzymes and inhibiting the absorption of nutrients so that they cause blindness, weakness and even death in pests.
2. **Cell Damage**
   Flavonoid compounds damage pest insect cells by inducing oxidative stress and apoptosis (programmed cell death). This causes damage to DNA, proteins and cell membranes which ultimately leads to the death of insects.
3. **Stunting Growth**
   Flavonoids can inhibit the growth of insect pests by interfering with growth hormones and insect metabolism. This causes insects to shrink and reproduce less.
4. **Repellent Effect**
   Flavonoids have a bitter taste and smell that pests do not like so plants are not attracted to insects and repel them.
5. **Increases Plant Resistance**
   Flavonoids can increase plant resistance to pest attacks by activating the plant's natural defense mechanisms.

Terpenoid

This compound is a terpenoid compound that has the activity of binding free sterols in the digestive system so that the decrease in the number of free sterols will affect the skin turnover process in insects. Based on the research of Teheni *et al*.(2023) states that papaya leaves contain saponin compounds that have the ability to be plant-based pesticides. Saponins are found in all parts of the papaya plant such as roots, leaves, stems and flowers. The active compounds in saponins are able to form foam if shaken with water and produce a bitter taste that can reduce surface tension so that it can damage the membrane of insect cells.

Saponins are secondary metabolites that act as chemical barriers or shields in the plant's defense system against pathogens and herbivores. Terpenoid compounds have great potential as plant-based pesticides because they are able to inhibit feeding and are toxic that cause insects to die (Siahaya & Rumthe, 2018)

According to Indrawijaya *et al*. (2019) The characteristics of saponins are in the form of foam or foam, so that when shaken and reacted with water, foam will form that can last for a long time. Saponins are easily soluble in water, have a bitter taste that pierces and causes sneezing and irritation of the mucous membranes and is insoluble in ether. Saponins are toxins that can destroy blood granules or hemolysis in the blood. It is toxic to cold-blooded animals. Saponins that are hard or toxic are commonly referred to as sapotoxins. Saponins are glycosides, which are a mixture of simple carbohydrates and aglycones found in various plants. Saponins are differentiated based on the results of their hydrolysis into carbohydrates and sapogenins, while sapogenins consist of two groups, namely steroid saponins and triterpenoid saponins.

Saponins are compounds that have a sharp bitter taste and can cause stomach irritation when eaten, besides that saponins are also able to bind sterols, sterols are hormone precursors, so if the number of free sterols decreases, it will interfere with the skin turnover process. These saponin and flavonoid compounds are also able to inhibit larval growth, namely brain hormones, edixon hormones and growth hormones (Sadewo, 2015).

The administration of saponins can show insecticide activity, which is causing growth inhibition and death in insects. Saponins are one of the steroids that are also anti-feeding and repellent for insects. Insects refuse to eat plants that contain saponins. In addition, if insects eat leaves that have been treated with saponins, saponins can cause lysis of intestinal mucosal cells in insects because saponins can increase the permeability of cell membranes.

Saponins can cause decreased activity of digestive enzymes and food absorption. This is due to the interaction between saponins and mucosal cell membranes, these interactions can result in changes in permeability caused by the loss of enzyme-binding activity on the membrane (Kurniawan et al., 2013). Saponins also bind to free sterols that function as precursors of the hormone exdison in food digestion, and can cause irritation of the mucous membrane in the esophagus (Kurniawan et al., 2013).

Terpenoid compounds can function as repellants because they have a strong odor, causing the larvae to not want to eat (Nuraeni & Darwiati, 2021). In addition, triterpenoid compounds can also affect nerves by inhibiting the enzyme cholinesterase, so that it can result in decreased muscle coordination, convulsion, and death in larvae in the development phase into adult insects.

Effect of Toxicity of Papaya Leaf Extract on Pests

According to research conducted by Vandalisna *et al* (2021), the chemical content of papaya leaves, namely papain, works actively as a stomach poison that enters the body or responds to aphids, thereby reducing the feeding activity of aphids. The working system of papain as a stomach poison in the body of aphids, namely absorbed by the walls of the aphid's digestive organs, will then be transmitted to the nerve center of aphids so that it will have the potential to exert pressure and reduce the metabolic process of internal organs and inhibit the eating activity of aphids, causing aphids to die. Pesticide residues of papaya leaf extract cause the eating activity of insects to decrease or may stop which leads to a decrease in movement activity.

Papaya leaves also contain flavonoids that act as nerve toxins that are thought to cause aphids to experience a decrease in motor activity. Flavonoid compounds also cause wilting of nerves and damage to the spiracles so that insects cannot breathe and eventually die. The presence of papain enzyme in papaya leaves so that it is effective to control caterpillars and sucking pests is because the papain enzyme in the sap naturally causes insects to become weak through toxicity and toxicity. The papain compound is a contact poison that enters the body of the caterpillar causing disruption in the eating activity of the caterpillar which can decrease the eating activity of the caterpillar and slowly the caterpillar will die.

Based on research conducted by Lolodatu *et al*.(2019) that papaya leaf extract can control *Plutella xylostella* Linnaeus pests on cabbage plants. The combination of the entomopathogenic fungus *Beauveria bassiana* (Balsamo) *vuillemin* with papaya leaf extract effectively controlled *Plutella xylostella* L. The administration of papaya leaf extract was inversely proportional to the growth of *B. bassiana* fungus. The addition of papaya leaf extract at a concentration of 10,000 to 40,000 ppm has a compatibility category that is non-toxic or compatible. The result of the synergism ratio obtained was 1.87. This shows that the combination of *B. bassiana* with papaya leaf extract is able to increase efficacy by 1.87 times compared to the application *of B. bassiana* alone (Laksana *et al*., 2022). Papaya leaf extract can be used to control caterpillars on mustard plants. papaya sap that produces alkaloid Compounds, terpenoids, flavonoids and non-protein amino acids are highly toxic to plant-eating pests.

Effects of Toxicity of Papaya Leaf Extract on Fungal Diseases

Papaya leaf extract as a plant-based pesticide is effective in controlling various fungal diseases in plants. The content of chemical compounds such as flavonoids, tannins and alkaloids in papaya leaves plays an important role in antifungal activity. Woasiedem *et al*.(2024) stated that papaya leaf extract is effective in controlling black spot disease in cocoa fruits caused by *Phytophthora* spp attack. Papaya leaf extract is effective in controlling late blight in chili plants caused by the fungus *Colletotrichum gloeosporioides* (Ariani, 2016). Papaya leaf extracts with concentrations of 5% and 10% provide the most effective results in inhibiting fungal growth and improving the health of chili plants.

According to Faujiah *et al*. research. (2023) that papaya leaves have antibacterial activity against *Staphylococcus aureus*. Papaya leaf extract also has the effectiveness of inhibiting the growth or controlling the wilt disease of Fusarium *oxysporum f.sp.lycopersici* in tomato plants. The combination of the use of tembelekan leaf extract and papaya leaf can control the armyworm pest (Spodoptera litura) on red chili plants (Lolodatu *et al*., 2019).

Herlina *et al*., (2020) stated that papaya leaf extract using a 96% ethanol solvent is able to inhibit the growth of *Staphylococcus aureus* bacteria by the Kirby Bauer agar diffusion method. Papaya leaf extract is diluted with aquades to facilitate the application process in the field. The application should be done in the morning because at that time the leaf pores open perfectly which makes it easier for vegetable pesticides to enter the plant tissues.

Mechanism of Action of Plant-Based Pesticides

Papaya leaf plant-based insecticides have several compounds that are antifungal so that they are able to inhibit the growth and infectivity of fungi (Laksana *et al*., 2022). The effectiveness of papaya leaf extract in controlling fungal diseases through several mechanisms, including: preventing fungal phenation into plants, where chemical compounds in papaya leaves can form a protective layer on the surface of the plant that inhibits the penetration of fungal spores, interfering with fungal growth, where chemical compounds in papaya leaves can interfere with the metabolism and growth of fungi, thereby inhibiting the development of diseases, stimulates plant resistance so that plants are stronger in fighting fungal infections.

Based on the research of Herlina *et al*.(Tuntun, 2020) states that the mechanism of action of the active substances contained in papaya leaves as an antibacterial by poisoning protoplasm, damaging and penetrating bacterial cell walls, in addition to precipitating bacterial cell proteins. Phenolic compounds are able to inactivate essential enzymes in bacterial cells, even at low concentrations. Phenolic compounds are able to break peptidoglycan bonds on the cell wall, namely by damaging the hydrophobic bonds of cell membrane components (such as proteins and phospholipids) and the dissolution of hydrophobically bonded components which will result in increased membrane permeability, this causes leakage so that the cell contents come out. Damage to the cell membrane results in inhibition of the activity and biosynthesis of specific enzymes required in metabolic reactions.

Karpaine alkaloids have base groups that can react with bacterial DNA. This reaction will damage the DNA of the bacteria causing damage to the nucleus of the bacterial cell. Cell damage makes bacteria unable to metabolize so that they undergo lysis, thus bacteria become inactive and destroyed. Alkaloid compounds are the largest group of active plant compounds. The role of alkaloids can interfere with the formation of peptidoglycan components in bacterial cells, so that the cell wall layer is not formed completely and causes death in bacteria.

Based on the research of Gangga Dewanti Gita Maharani *et al*. (Gangga Dewanti Gita Maharani et al., 2022) flavonoids work as inhibitors that will inhibit bacterial DNA replication and transcription. Flavonoids can bind to

extracellular bacterial proteins and can dissolve bacterial cell walls. Flavonoids are metabolite compounds that are often found in plants. One of the roles of flavonoids for plants is as an antimicrobial and antiviral, so plants containing flavonoids are widely used in traditional medicine. This compound is an antimicrobial due to its ability to form complexes with dissolved extracellular proteins as well as microbial cell walls. Flavonoids that are lipophilic will damage microbial membranes. Flavonoids work as type II Topoisomerase inhibitors that will inhibit the replication and transcription of bacterial DNA and can bind to bacterial proteins, namely extracellular and soluble proteins and the bacterial cell wall of papaya leaves also contains organic acids such as lauric acid, caffeine acid, gentisic acid and ascorbic acid, which can lower the intracellular pH of bacteria so that bacterial cells cannot multiply.

Some Research Results on the Utilization of Papaya Leaf Extract as a Plant-Based Pesticide

1. The results of the study showed that the administration of 80 g papaya leaf extract had a real effect on the number of trapped rice field snails (Astuti, 2013).
2. The best treatment to kill armyworms is the combination of tembelekan leaves (25) : papaya leaves (75) with a mortality rate of 96.7% (Lolodatu et al., 2019).
3. According to the results of the study (Piri *et al*., 2022), the most effective concentration of papaya leaf extract to kill 100% of house flies is a concentration of 60% after 6 hours of treatment.
4. The results of the research by Indrawijaya et al (Indrawijaya et al., 2019) were obtained from caterpillars that died on the 14th day with a concentration of 55% Japanese papaya leaf extract, from the results of observation of 6 dead armyworms (mortality rate of 60%), at a concentration of 65% Japanese papaya leaf extract, the results of observation of 6 dead armyworms (mortality rate of 60%), at a concentration of 75% Japanese papaya leaf extract, The results of observation of 7 dead armyworms (mortality rate of 70%) and in the treatment of 85% concentration of Japanese papaya leaf extract, the results of observation of 8 dead armyworms (mortality rate reached 80%).
5. The results of the study showed that papaya leaf extract could inhibit the growth of *Escherichia coli* bacteria at concentrations of 20% to 100% with an average zone diameter of 6.5 mm to 9.1 mm. Against Staphylococcus aureus bacteria types, it can inhibit the growth of bacteria at concentrations of 30% to 100% with an average zone diameter of 7.9 mm to 13.2 mm (Tuntun, 2020).
6. In a study conducted by Rumende *et al.* (2021) using solution concentrations of 100 grams/L, 300 grams/L, 500 grams/L, and 700 grams/L with four repetitions. The results of the observation of the mortality of armyworms (S. fru giperda) from 24 hours to 96 hours after the treatment of a solution concentration of 700 grams/L is the solution

that has the largest mortality of 100% and from the LC50 calculation obtained a value of 35.457%.

7. The results of Nur Fadilah *et al*'s (2017) research show that papaya leaf extract lotion is effective in repelling Aedes aegypti mosquitoes at a concentration of 30% with a repellentness of more than 90%.
8. Plant-based insecticides of basil and papaya leaves P2D3 treatment are most effective against fruit fly mortality with a mortality percentage of 100%, and a dose of 18% is most optimal against fruit fly mortality (Pratiwi & Asngad, 2018).
9. The results of the study by Dhenge *et al* (2021) showed that papaya leaf extract was effective as a larvicide for Aedes aegypti (p=0.001). In the analysis of probit, the LC50 from the extract against Aedes aegypti was 23% while the LC 99 was 55%. The conclusion of this study is that papaya leaf extract is effective as a vegetable larvicide for the larvae Aedes aegypti instar III/IV.
10. The research conducted by Rizki (Rizki, 2022) uses a type of papaya leaf extract, soursop and a combination of both with concentrations of 0%, 5%, 10%, 20% and 40%. The parameters observed, larval mortality, percentage of larvae to pupa, percentage of pupae to imago. The analysis using Two Way ANAVA was followed by the Tukey test with the SPSS program. The percentage of larvae becoming pupa was the highest at 80% in the control treatment, the lowest was 0% in the combination extract at a concentration of 40%. The percentage of pupa to imago was the highest at 60% in the control treatment, the lowest was 0% in the combined extract of 20% and 40% concentrations.
11. The results of this study showed that concentrations of 0ppm (control), 125ppm, 250ppm, 500ppm, and 1000ppm, papaya leaf extract (*Carica Papaya L*) respectively caused larval death, namely 0%, 8%, 16%, 40%, and 56%, for 24 hours of treatment, and 0%, 16%, 28%, 68%, and 96%, for 36 hours of treatment. Based on the probit test, the LC50 and LC90 values at the 24th hour were 657.278 ppm, and 1209.82 ppm and at the 36th hour were 424.086 ppm and 837.754 ppm. The results of the *Kruskall-Wallis test* showed that the value of $p<0.05$ so that it can be concluded that there is a significant difference in the number of dead larvae between the groups compared. The conclusion in this study is that papaya leaf extract is effective as a larvicide against the larvae of the An mosquito. *Aconitus* (Enis Wilda Ningsi, Nani Yuniar, 2016).
12. The results of the study show that papaya leaf extract can kill fruit flies. This proves that papaya leaf extract has the potential as a toxic agent to fruit fly mortality. The exact concentration of papaya leaf extract on the mortality of fruit flies from the tests that have been carried out is at a concentration of 1.86%. The lowest range is at 0.017 % and the highest range is at 3.121 % (Raymond Wibisana et al., 2016).
13. The results of the study showed that the higher the concentration of extracts, the higher the mortality rate of *P. xylostella larvae.* From the observation results, it was shown that the administration of soursop leaf

extract and papaya leaf was effective in killing the larvae *of P. xylostella* pest with the highest mortality rate of 100% in each treatment with an extract concentration of 20% (Mawuntu, 2016).

14. The conclusion of the study is that the administration of papaya leaf extract (Carica papaya) has an effect on the activity of cockroaches (Periplaneta americana) (Rohma & Wikanta, 2021).
15. The results obtained showed that ethanol extract was the most effective extract in causing toxicity in test larvae with the highest percentage of 96.6%. Meanwhile, n-hexane extract was more effective in inhibiting larval feeding capacity with the lowest feeding percentage of 0.72%. The most effective concentration against toxicity and inhibition of larval feeding is a concentration of 3%. The LC50 value of ethanol extract was 0.0207% and n-hexane extract was 0.0459%. Both extracts are known to contain a group of compounds, namely tannins, terpenoids, flavonoids and alkaloids (SARI, 2021).
16. The highest average mortality of *Ae. aegypti mosquito larvae* was at a concentration of 10%, which was 5.12 (SD=3.44 heads), while the lowest was at a concentration of 1.5%, as many as 1.25 (SD=1.753 heads). Based on contact time, the highest average death was at 24-hour contact time, as many as 6.4 heads (SD=2,366 heads), the lowest at 4-hour contact time, as many as 0.50 heads (SD=0.707 heads). It was proven that there was an effect of papaya leaf extract concentration (p-value=0.043) and contact time (p-value=0.000) on the death of *Aedes aegypti* mosquito larvae. It can be considered to evaluate the death of non-target biota in future studies (Putri, 2021).
17. The results of the study by Arianto *et al* (2023) showed that the dose of papaya leaf extract with the average number of dead flies from the 35% dose was 6.75 and the 15% dose was only 2.9 flies. There was a significant effect on the average number of dead flies with variations in the dose of peapaya leaf extract with a value of P = 0.000.
18. The results showed that the highest mortality in the treatment of stomach poison and contact poison was at a concentration of 40 g/100 ml of water of 100%, respectively, while the lowest mortality was at a concentration of 10 g/100 ml of water, respectively of 35% and 20% (Siahaya & Rumthe, 2018).
19. The results showed that 100% papaya leaf extract was the best treatment to suppress the growth of *Echerichia coli* and *Staphylococcus epidermidis* bacteria with an average inhibitory capacity of 14,110 mm and 14,707 mm, respectively (Lumbantobing et al., 2022).
20. The results showed that papaya leaf extract as a vegetable pesticide had a real effect on the intensity of attack (%), plant height (cm), number of leaves (strands) and number of fruits per plant (fruit). K3 treatment with a dose of papaya leaf extract of 30 ml/liter of water is the best treatment against the intensity of Aphid attack (Homoptera: Aphididae) on red chili plants (Capsicum annum).

21. Vegetable insecticide of fresh sheet papaya leaves (M3) is able to control the number of rice aphid populations. Vegetable insecticide of fresh sheet papaya leaves (M3) produces 84.88% whole rice, 15.12% broken rice, 38.17% water content, 0.92% fat content, 15.22% protein content and 91.64% carbohydrate content (Wenda, 2016).
22. Papaya leaf extract with a concentration of 40 g/100 mL of water is the best concentration because it is able to kill all Plutella xylostella larvae ten days after treatment, either given through feed as a stomach or given through drops on the body of insects as a contact poison. (Siahaya & Rumthe, 2018).

CONCLUSIONS AND RECOMMENDATIONS

Chemical compounds found in papaya leaves such as alkaloids, polyphenols, quinones, flavonoids, terpenoids are able to kill pests and control diseases in various types of plants. The toxic effect caused by pests is that it affects eating activities which leads to the death of pests. Meanwhile, in diseases, the chemical compounds contained in papaya leaf extract are able to prevent fungal phenation into plants, form a protective layer on plants, interfere with fungal growth because metabolic processes are disrupted and inhibit disease development. Pest and disease responses to plant-based pesticides differ depending on the target pest. The mechanism of action of plant-based pesticides is not only disabling but also as an anti-feedant and repelant. Field application must be adjusted to the right formulation and should be done in the morning when the pores or leaf stomata open perfectly.

The obstacles faced in the application of plant-based pesticides include: (1) plant-based pesticides are easier to decompose in nature so that their application must be repeated, (2) plant-based pesticides are very sensitive to the influence of environmental parameters such as sunlight, temperature, etc., (3) the use of plant-based pesticides requires a large amount so their availability is limited, and (4) the ability of botanical pesticides to control plant-disturbing organisms is not directly lethal or, in other words, their killing power is low so public interest is lacking.

Efforts to socialize the use of papaya leaves as a vegetable pesticide must be carried out massively and continuously among farmers to realize environmentally friendly agriculture. Further research regarding the types of plants that can be combined with papaya leaves as a plant-based pesticide needs to be carried out, this is to obtain a plant-based pesticide with better control capabilities.

FURTHER STUDY

This article is still limited to a literature review, so field research and trials are needed to obtain more accurate data. The article also only looks at one type of material and does not yet attempt to combine several types of plants to get a better botanical pesticide.

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