Utilization of *Papaya* Waste (*Carica papaya* L.) as Biopesticide to Manage the Aphid Population in Chili (*Capsicum annuum* L.)

Dian Indratmi[1*], *Dyah* Roeswitawati[1], *Iswandy* Iswandy[1] *and Hidayat* Widi Saputra[2]

[1]Department of Agrotechnology, Faculty of Agriculture and Animal Science. University of Muhammadiyah Malang, 65144 East Java, Indonesia
[2]Department of Information Technology, State Polytechnic of Malang, 65144 East Java, Indonesia

Abstract. Chili cultivation (*Capsicum annuum* L.) is a farming activity that promises attractive profits due to high market demand. The low production of horticultural crops, among others, can be caused by plant disrupting organisms in the form of pests, diseases and weeds. The use of chemicals is an alternative for farmers to inhibit pest and disease attacks. Aphid attack causes plants to grow abnormally, with leaves turning yellow, crinkling, and dying. The importance of developing long-term pesticides for environmental health is crucial, so that the use of natural pesticides derived from papaya leaves and seeds can be considered. The purpose of the study was to determine the right concentration and effectiveness of papaya leaf and seed waste in suppressing aphid pests. The study used an experimental method with various concentrations arranged in a Randomized Group Design. The results of the evaluation of the application leaves+ papaya seeds showed a better concentration treatment for the variables of pest population, intensity of attack, percentage of infested leaves, and yield of chili 90-120 g/l. With the application of leaves, papaya seeds can increase chili production 2.5 times.

1 Introduction

The majority of Indonesian people are farmers. The main products are horticultural crops, including fruits and vegetables. Chili is needed by almost all circles of society at various levels [1, 2]. Farming activities of chili plants (*Capsicum annuum* L.) are very promising and provide benefits, especially for farmers in Indonesia. Pest attacks first occur in the vegetative phase. The impact can be detrimental to chili plants [3, 4].

Aphids belong to the Homoptera group, and Aphididae are small insects that attack various plants by absorbing plant fluids. These pests have a piercing-sucking mouthpart that enables them to extract nutrients from flowers, stems, leaves, and even roots [5]. At present, the control of aphids still relies heavily on chemical pesticides, as they are considered fast and effective in reducing pest populations. However, continuous use of chemical pesticides poses risks such as environmental pollution, pesticide residues on crops, pest resistance, and negative impacts on beneficial organisms. Therefore, attention has shifted toward the

* Corresponding author: dian@umm.ac.id

development of natural alternatives in the form of biopesticides. Plant-based pesticides derived from neem leaf extracts, tobacco, soursop, bandotan, cloves, amethyst leaves, pepper, garlic, and other sources show strong potential to suppress aphid infestations. These natural pesticides are more environmentally friendly, leave no harmful residues, and are easily accessible to farmers. Compared to chemical pesticides, which may cause long-term ecological damage, biopesticides provide a safer and more sustainable approach to managing aphid populations while reducing the economic losses caused by these pests [6, 7].

Since the emergence and high application of various chemical pesticide products, the degree of environmental damage has increased rapidly [8, 9]. It is important to switch to environmentally friendly pesticides. Papaya waste in the form of leaves and seeds has important active compounds such as carpain (flavonoids), inhibiting the performance of microorganisms and pests. Flavonoids are polyphenolic compounds that bind to proteins in the cell membrane. As a result, the cell membrane becomes lysed and polyphenols can penetrate into the cell nucleus, resulting in changes in permeability that can cause cell death, so that the protein structure will be damaged [10, 11].

Papaya (*Carica papaya* L.) is a tropical fruit widely cultivated for its nutritional and economic value, but its agricultural processing often generates large amounts of unused biomass such as peels, seeds, and leaves. These by-products, commonly considered waste, contain bioactive compounds including alkaloids, phenolics, flavonoids, and proteolytic enzymes like papain, which possess antimicrobial and insecticidal properties. Instead of being discarded, papaya waste holds significant potential as a sustainable resource in integrated pest management. By converting these residues into biopesticides, farmers can reduce dependency on synthetic chemicals, minimize production costs, and contribute to environmentally friendly agriculture. This potential makes papaya waste a promising alternative for controlling insect pests such as aphids in chili cultivation [12].

2 Research Methods

The research was conducted in the Agrotechnology laboratory of Muhammadiyah University of Malang and in the Tegalgondo area, Gondang Hamlet, Karangploso District, Malang, at an altitude of 550 m above sea level. The plants used were chili variety Perwira, compost, polybag 35 x 35 cm, water, scouring ash, papaya leaves and seeds in powder formula for botanical pesticide ingredients.

2.1 Research design

The method used was a simple randomized block design, with papaya leaf and seed extract, with seven treatments. Each treatment was repeated 4 times, each treatment using five chili plants. Each concentration includes: without application of papaya leaves and seeds + without aphids (Control -), without application of papaya leaves and seeds + investment in aphids (Control +), leaves + papaya seeds 30 g/L, leaves + papaya seeds 60 g/L, leaves + papaya seeds 90 g/L, leaves + papaya seeds 120 g/L, leaves + papaya seeds 150 g/L.

2.2 Activity stages

2.2.1 Preparation of natural pesticides from papaya leaves and seed powder formula

Waste leaves and seeds from ripe papaya were collected in amounts of 1 kg each. Seeds were cleaned using scouring ash by squeezing the seeds to remove the attached seed sarcotesta. Washing the leaves and seeds with running water. Oven at 50 °C for 4 hours. Separately, papaya leaves and seeds were pulverized using a grinder until they became powder. Powdered papaya leaves (40%) and seeds (60%) are weighed according to the concentration treatment of 30 g, 60 g, 90 g, 120 g and 150 g. 1 Liter of water is added to each concentration, allowed to stand for 24 hours, filtered, the results of the filtering are used for application to chili plants to allow for complete dissolution or reaction [13].

2.2.2 Rearing aphids

Maintenance of aphids is obtained by preparing 18 chili plants that are used as traps and propagation of target pests. Investment target pests is done by inoculating chili plants with aphid imago as many as 4-6 imago/plant at the age of 20 DAP (days after planting). Imago is left for 10 days to adapt, breed and lay eggs on the leaves of chili plants. Aphids are *parthenogenetic,* and their eggs hatch in the body (*ovoviviparous and viviparous*) [14].

2.2.3 Application of botanical pesticides

The application of pesticides is mixed with Agrister surfactant so that the pesticides are attached to all parts of the plant. The application of pesticides is carried out at 07.00 WIB by spraying all parts of the plant. The application of pesticides was carried out 7 times when the plants were 30 - 79 DAP with an interval of 7 days. The application used a *handsprayer* with a cone *nozzle* shape, at a pressure of 1 bar and an intensity of 0.5.

2.2.4 Fertilization

Manure was applied at the time of planting media preparation. Supplementary fertilizer is given at 14 days after planting (DAP), 35 DAP, and 60-65 DAP. Supplementary fertilization uses 250 kg/ha pearl NPK, 500 kg/ha TSP, and 400 kg/ha KCL. At the age of 60-65 DAP, 150 kg/ha white KNO 3 fertilizer was given.

2.2.5 Control other than target pests and diseases.

Control of pests such as fruit flies (Bactrocera spp) using sticky traps by applying Glumon trap liquid on the sticky trap that has been provided. This control is carried out when the plants enter the generative phase with an interval time of 10 days. Control of diseases such as fungi using Dithane M-45 fungicide with Agrister adhesive. Fungicide was applied only when disease attack was encountered.

2.2.6 Observation variables

Observations included: plant height (cm), infestation intensity (%), percentage of infested leaves (%), infested leaf area (cm^2), pest population, number of fruits per plant, and fruit weight per plant (g). The level of pest attack intensity can be calculated using the formula:

$$I = \Sigma \frac{n\, x\, V}{N\, x\, Z}\, x\ 100\% \qquad (1)$$

I = Intensity of attack
n = Number of infested samples
V = Sample scale value (1= 1-25% low category; 2= >25-50 moderate category; 3= >50-75 heavy category; 4= >75 very heavy category) N = Number of samples observed
Z = Scale value of the highest category

2.2.7 Percentage of infested leaves

$$P = \frac{a}{b}\, x\ 100\% \qquad (2)$$

P = Percentage of infested leaves
a = number of infested leaves
b = number of leaves per plant

2.2.8 Data analysis

Observation data were calculated using analysis of variance to determine whether there was an effect of the treatment given. To determine the best treatment, *Duncan's Multiple Range Test* DMRT 5%.

3 Results and Discussion

3.1 Chili plant height

The treatment of leaf and papaya seeds concentration showed no significant effect on the height of chili plants at all observation ages (Table 1).

Table 1. Average chili plant height.

Concentration treatment of leaf+seed of papaya	Plant Height (cm)					
	12 DAI	24 DAI	36 DAI	48 DAI	60 DAI	72 DAI
Control -	11,7	15,6	18,4	20,1	21,5	21,7
Control +	11,2	15,2	17,6	19,5	20,7	22,5
30 g/L	12,3	16,5	18,6	20,6	22,6	23,2
60 g/L	12,3	16,4	19,1	21,7	22,3	23,2
90 g/L	12,3	16,1	18,9	20,5	21,8	23,8
120 g/L	11,2	15,2	18,0	20,0	22,0	23,7
150 g/L	11,6	14,0	18,2	19,7	21,7	22,7

Notes: DAI=days after inoculation.

The application of papaya leaves and seeds at various concentration levels did not affect the growth of chili plant height from day 12 until day 72. The application of papaya leaves and seeds is targeted to reduce the population of aphids. Aphids attack mainly on the leaves, not the growing point.

3.2 Aphids attack intensity (%)

Based on the analysis of variance on the variable intensity of attack showed a significant effect at the age of 13-60 Days After Inoculation (DAI). The average intensity of attack is presented in Table 2.

Table 2. Average attack intensity of aphids on chili plants.

Concentration treatment of leaf+seed of papaya	Attack Intensity (%)				
	13 DAI	26 DAI	39 DAI	52 DAI	60 DAI
Control -	25,0 c	22.9 cd	25,0 d	25,3 b	25,9 c
Control +	25,0 c	25,0 d	25,0 d	26,0 b	27,0 c
30 g/L	25,0 c	16,6 b	18,7 b	22,9 b	22,9 b
60 g/L	25,0 c	22.9 cd	25,0 d	22,9 b	20,8 b
90 g/L	18,7 a	12,5 a	14,6 a	16,6 a	14,6 a
120 g/L	22.9 bc	20,8 c	22.9 cd	22,9 b	22,9 b
150 g/L	20.8 ab	25,0 d	20.8 bc	25,0 b	21,2 b

Notes: Numbers followed by the same letter and column show no significant difference based on 5% DMRT test. DAI=days after inoculation.

Based on table 2, the concentration of 90 g/L gives the lowest aphid attack intensity in every DAI compared to all other treatments. It means a concentration of 90 g/L is better for controlling aphid intensity that generally attack the young shoots of plants, causing inhibition of the photosynthesis process during the vegetative phase, so giving the concentration indirectly helps for new shoot growth that is vulnerable to aphids. The decrease in the intensity of aphid attack is related to the increase in plant age caused by the number of plant leaves that have emerged [15]. Plant resistance to pest attack is actually already present in the plant itself, and appears naturally which rejects, prevents and tolerates pest attacks. Factors that affect the intensity of attack are age, plant conditions and environment [16,17].

3.3 Percentage of infested leaves (%)

Spraying papaya leaves and seeds had a significant effect on the percentage of infested leaves at all observation ages. The averages are presented in Table 3.

Table 3. Average percentage of aphids infested leaves on chili plants.

Concentration treatment of leaf+seed of papaya	Percentage of infested leaves (%)				
	13 DAI	**26 DAI**	**39 DAI**	**52 DAI**	**60 DAI**
Control -	10 b	8 b	16 c	12 c	18 b
Control +	14 c	13 c	22 d	15 d	22 c
30 g/L	9 b	7 ab	7 a	9 ab	7 a
60 g/L	9 ab	7 ab	10 b	8 ab	5 a
90 g/L	7 ab	5 a	6 a	7 a	4 a
120 g/L	9 ab	6 ab	12 b	10 bc	6 a
150 g/L	8 a	6 ab	13 bc	8 ab	6 a

Notes: Numbers followed by the same letter and column show no significant difference based on 5% DMRT test. DAI=days after inoculation.

Overall, the application of papaya leaf waste+seeds is able to protect chili peppers from aphid attack. This can be seen from the leaves that are attacked by aphids in the low category. The concentration of 90 g/L gives the lowest number of infested leaves to aphids in every DAI compared to all other treatments. It means a concentration of 90 g/L is the best amount for reducing the percentage of leaves attacked by aphids compared to other treatments. This is caused by aphids, where the attack generally begins by sucking the liquid in the leaves, flower stalk tops or other plant parts, so that the leaves become chlorosis. Symptoms of attack vary such as wilting, dwarfing, curling leaf tops, abnormal leaf growth, curling and damage to plant tips that damage plant growth [15].

Symptoms that often appear due to pest attacks are the presence of leaf malformation or leaf deformities, where the leaves will roll up, curl, there are yellow rickets, wrinkle and circle, so that it can cause plant growth to be stunted, wilt and tissue death. This pest also secretes a sweet, honey-like liquid to attract ants and other pests [18].

3.4 Pest population

The treatment of papaya leaves+ seeds concentration has a significant effect on the population of aphids at all observation ages. The average is presented in Table 4.

Table 4. Average population of aphid pests on chili plants.

Concentration treatment of leaf+seed of papaya	Pest Population					
	10 DAI	**20 DAI**	**30 DAI**	**40 DAI**	**50 DAI**	**60 DAI**
Control -	19,5 b	17,6 d	17,9 b	22,5 c	24,1 b	25,3 c
Control +	33,2 c	26,3 a	33,5 c	39,8 d	41,6 c	47,3 d
30 g/L	15,0 b	11.8 cd	13.9 ab	14.2 ab	12,1 a	10,0 b
60 g/L	13.3 ab	11,9 a	14.8 ab	15,3 b	13,1 a	8,9 b
90 g/L	7,8 a	9.1 bc	9,8 a	9.6ab	9,6 a	3,0 a
120 g/L	8,4 a	10.3 bc	13.6 ab	15,2 b	11,1 a	7.1 ab
150 g/L	8,0 a	5.6 ab	13.3 ab	8,1 a	8,7 a	5.2 ab

Notes: Numbers followed by the same letter and column show no significant difference based on 5% DMRT test. DAI=days after inoculation.

On days 10, 30, and 60 concentrations of 90 g/L gives the lowest aphid population. But, on days 20, 40, and 50, concentration 150 g/L gives the lowest aphid population. It means concentration of 90 g/L and 120 g/L overall showed better potential in suppressing the population of aphids compared to other treatments.

The decrease in the population of aphids is caused by the application of leaf extract+ papaya seeds according to their respective concentrations in each treatment, namely papaya seeds contain carpain substances that are contact poisons for aphids that enter the body through natural holes. Papain compounds from the leaves also work as a stomach poison that enters through the mouth apparatus in insects then the liquid enters through the esophagus and then enters the digestive tract which will cause disruption of eating activities, therefore the decline in pest populations decreases with suppression in eating activities [12, 13].

3.5 Area of infested leaves, number of fruits, and fruit weight/plant/harvest

The treatment of leaf+ papaya seeds concentration had a significant effect on the area of infested leaves, the number of fruits, and the weight of chili fruits. The averages are presented in Table 5.

Table 5. Average number and weight of chili fruits per plant per harvest.

Concentration treatment of leaf+seed of papaya	Leaf Area Affected (%) 64 DAI	Number of Fruit 65 DAI	Fruit Weight/harvest (g) 65 DAI
Control -	4,3 a	3,8 a	30,8 a
Control +	4,4 a	6,0 b	32,1 a
30 g/L	4.7 ab	7.2 bc	49,5 b
60 g/L	5,1 b	6,7 b	47,7 b
90 g/L	5,2 b	7.1 bc	63.5 bc
120 g/L	5,2 b	11,0 d	78,2 c
150 g/L	6,4 c	9,7 c	71,2 c

Notes: Numbers followed by the same letter and column show no significant difference based on 5% DMRT test. DAI=days after inoculation.

In terms of leaf area affected, concentrations of 90 g/L and 120 g/L showed better results compared to other treatments. But, in terms of number of fruit and weight/harvest, a concentration of 120 g/L showed the better result compared to other treatments.

Controlling aphids with papaya waste proved to be able to provide higher chili production. Based on gas chromatography-mass spectrometry (GC-MS) analysis, papaya seeds contain many valuable functional chemical compounds. Among them are Hexasiloxane ($C_{12}H_{38}O_5Si_6$), Octasiloxane ($C_{16}H_{50}O_7Si_8$) and Heptasiloxane ($C_{14}H_{44}O_6Si_7$) (Figure 1) which are pesticidal in nature.

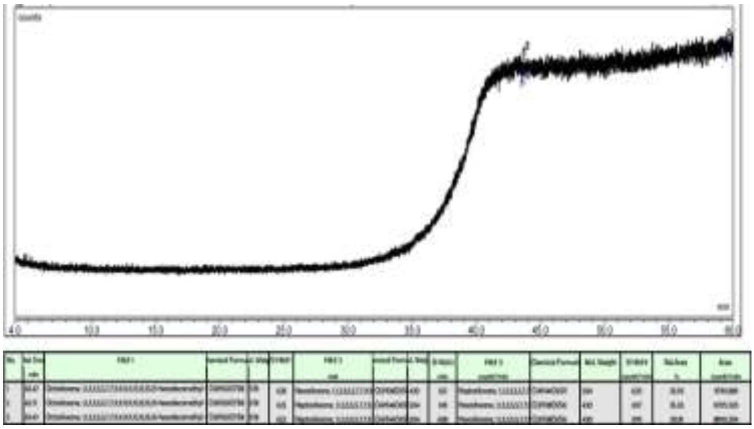

Fig. 1. Chromatogram of active compound content of papaya seeds

The main substance that plays a role in controlling aphids is Heptasiloxane as it’s an insecticide [13]. Moreover, Papaya leaf extract contains secondary metabolites of alkaloids, flavonoids, saponins, terpenoids, and phenolic compounds that are insecticidal and antimicrobial as well to support the main insecticide substance [12, 19, 20]. According to Rahayu [21-24] papaya leaves and seeds contain various active compounds with bioinsecticidal activities that are able and effective in inhibiting the growth of polyphagous pests Spodoptera litura. The application of papaya waste (leaves and seeds) is able to reduce the population, intensity of attack, and the percentage of infested leaves in the low category, so that chilies can grow and produce better.

4 Conclusion

The concentration of papaya seed leaves that is quite effective in controlling aphids attack is 90 g/l, which is indicated by lower attack intensity, aphid population, and percentage of infested leaves. But on chili production parameters, papaya seed leaf concentration of 120 g/l showed a better treatment. The application of biopesticides made from papaya seed leaves can increase the yield of chili peppers 2.5 times higher.

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