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Aphis gossypii (Hemiptera: Aphididae) Resistance to Synthetic Insecticides in Curug and Kasemen, Serang City

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Abstract

Aphis gossypii is one of the main pests on vegetable plants in Serang City, especially in Curug and Kasemen Districts. The intensive use of synthetic insecticides to control this pest has the potential to cause resistance, thereby reducing the effectiveness of the control measures. This study aims to analyze the effect of various types of synthetic insecticide active ingredients, namely carbamates, organophosphates, pyrethroids, neonicotinoids, and flupyradifuron, on Aphis gossypii mortality and to assess the level of pest resistance based on LC_{50} and LT_{50} values. The study was conducted using a completely randomized design (CRD) with two factors: the type of insecticide active ingredient and concentration (0%, 5%, 50%, 95%, and 100%). The experiment was replicated three times, and probit analysis was used for data analysis. The results showed that insecticides containing organophosphate and pyrethroid active ingredients had higher effectiveness than neonicotinoids, with lower LC_{50} and LT_{50} values. Aphis gossypii resistance began to appear at 50% concentration, marked by a longer LT_{50} value compared to higher concentrations. In addition, morphological analysis revealed changes in the color and texture of the pest's body after exposure to insecticides, which are attributed to the melanization process and physiological disorders.

Keywords: Aphid Pests, Aphis gossypii, Resistance, Serang City, Synthetic Insecticides

INTRODUCTION

Indonesia is an agricultural country that plays a crucial role in fulfilling the food needs of its population and supporting the export of agricultural products. Its agricultural sector is largely dominated by food crops and vegetables. However, agricultural production is frequently disrupted by pest attacks, one of which is the aphid (*Aphis gossypii*). Aphids are small insects that live in colonies on the underside of leaves. They feed on plant nutrients by sucking from young plant parts such as leaf tips, flowers, young stems, and fruits. As a result, plant growth is impaired, along with a decline in both the quality and quantity of harvests, according to Sari et al. Sari et al. (2020). This pest can infest various types of crops, including vegetables, and has a rapid spreading capability if not promptly controlled. Currently, synthetic insecticides are widely used to manage aphid populations; however, in certain areas, resistance of the pest to these chemical agents has emerged as a growing concern.

In Serang City, Banten, particularly in the districts of Curug and Kasemen, the aphid (*Aphis gossypii*) has become one of the primary pests attacking vegetable crops such as chili peppers, mustard greens, cucumber, and lettuce. Uncontrolled infestation by this pest can cause severe damage to crops and a significant decline in harvest yields. According to data from the Central Bureau of Statistics (BPS) of Serang City, the district of Curug experienced a decrease in chili pepper production, with yields of 36 quintals in 2022 declining to 25 quintals in 2023, representing a reduction of 30.56%. Meanwhile, in the district of Kasemen, chili pepper production decreased from 145 quintals in 2022 to 77 quintals in 2023, resulting in a yield reduction of approximately 46.9%. This decline in agricultural production may be influenced by various factors, including climate change, land use efficiency, and the increasing resistance of pests to synthetic insecticides.

Farmers commonly use synthetic insecticides to control pest populations. However, excessive and uncontrolled use can lead to pest resistance against these insecticides. Insecticide resistance occurs when pest populations become tolerant to the active ingredients of pesticides, resulting in reduced effectiveness of pest control and posing significant challenges in agricultural management. This resistance develops due to repeated exposure to insecticides at improper dosages, leading to a decrease in susceptible individuals and an increase in the dominance of resistant individuals within the population (Directorate General of Disease Prevention and Control, 2018).

IRAC (*Insecticide Resistance Action Committee*) has classified several types of insecticides commonly used to control aphid pests. However, IRAC's studies have identified resistance in *A. gossypii*. This study employs active ingredients such as carbamates, organophosphates, pyrethroids, neonicotinoids, and flupyradifurone to determine the resistance level of the aphid pest to synthetic insecticides still categorized under IRAC classifications. Therefore, it is necessary to examine the effect of various concentrations of carbamate, organophosphate, pyrethroid, neonicotinoid, and flupyradifurone insecticides on the resistance of *Aphis gossypii* in Curug and Kasemen Subdistricts, Serang City, where resistance has been detected at a treatment concentration of 50%.

RESEARCH METHODOLOGY

This research was conducted in September–November 2024. Aphid (*Aphis gossypii*) samples were collected from two subdistricts: Curug and Kasemen, in Serang City. The aphid testing was carried out at the Basic and Plant Protection Laboratory, Faculty of Agriculture, Sultan Ageng Tirtayasa University, Serang, Banten. The tools and materials used included scissors, *plastic cups* with a diameter of 6.4 cm, a 1-liter beaker glass, a micropipette with a capacity of 0.01 liters, an insect rearing room, labels for sample identification, insect sample containers, a *binocular* microscope, forceps, a *hotplate*, a camera, a *magnetic stirrer*, a brush, a balance, stationery, distilled water, adult *Aphis gossypii* specimens, pakcoy plants as host plants, agar-agar, insecticides containing active ingredients of carbamate, organophosphate, pyrethroid, *neonicotinoid*, *flupyradifurone*, and tissue paper. This research uses a Completely Randomized Design (CRD) consisting of two factors. The first factor is the type of active insecticide ingredient, which includes six levels: control treatment (I0), carbamate (I1), organophosphate (I2), pyrethroid (I3), *neonicotinoid* (I4), and *Flupyradifurone* (I5). The second factor consists of five concentration levels: 0% (K0), 5% (K1), 50% (K2), 95% (K3), and 100% (K4). The response variables in this study were LT_{50}, LT_{99}, LC_{50}, and morphological observations. The research was conducted following the method outlined by the *Insecticide Resistance Action Committee* (IRAC), which involves sample collection from Curug and Kasemen Subdistricts by selecting aphids that are colonized or grouped on the leaves and stems of host plants (S. P. Sari et al., 2020). The collected samples were immediately transported to the laboratory for further analysis.

A. Testing of Aphid Pests (*Aphis gossypii*)

Testing of the aphid pest (*Aphis gossypii*) was conducted using two methods: the agar method and the paper method. In the agar method, agar was mixed with clean water, heated until boiling, and then cooled slightly while continuously being stirred. After cooling for approximately 10 minutes, the warm agar solution was poured into *plastic cups* to a minimum depth of 5 cm. In the paper method, the paper was cut to fit the size of the *plastic cups* and then moistened with distilled water. After preparing the testing media, insecticide solutions were prepared. Insecticides containing active ingredients of organophosphate, pyrethroid, neonicotinoid, and *flupyradifurone* were dissolved in water at different concentrations for each insecticide according to the test percentages. For the carbamate-based insecticide, which is in powder form, a specific amount was weighed and dissolved in water until fully diluted. The test procedure began by cutting chili and pakcoy leaves to fit the shape of the plastic cups, serving as a food source. Each leaf was dipped individually into the test solutions for 10 seconds with gentle stirring, then dried on tissue paper. Care was taken to ensure even coverage of the solution across the leaf surface, and wilting of the leaves was avoided. Observations were conducted starting 24 hours after treatment up to 72 hours post-treatment, with observations made every 12 hours (at 24, 36, 48, 60, and 72 hours). Data were analyzed using IBM SPSS *Statistics* 21 *software*.

B. Data Analysis

The data obtained from observations were processed using *Microsoft Excel for Windows*. A two-factor Completely Randomized Design (CRD) analysis of variance (ANOVA) was conducted at a 5% significance level. Further post-hoc analysis was carried out using *Duncan's Multiple Range Test* (DMRT) with the additional *software* DSAASTAT ver. 1.514.

RESULTS AND DISCUSSION

The results of this study indicate variations in the resistance levels of the aphid *Aphis gossypii* to synthetic insecticides in Curug and Kasemen Subdistricts. Based on the data obtained, the mortality rate of aphids differed across subdistricts and observation times, suggesting the presence of potential resistance to the insecticides used. This is presented in **Table 1.**

Table 1. Summary of Variance Analysis (ANOVA) on the Resistance of the Pest *Aphis gossypii* (Hemiptera: Aphididae) to Synthetic Insecticides: A Case Study in Curug and Kasemen Subdistricts, Serang City

No	Observed Parameters	Treatment				
		Observation Time (HSA)	Synthetic Insecticide Active Ingredients	Synthetic Insecticide Concentrations	Interaction	Error
1.	Total Mortality (%) Curug Subdistrict	24	**	**	ns	11,43
		48	**	**	ns	5,42
		72	ns	ns	ns	3,70
2.	Total Mortality (%) Kasemen Subdistrict	24	**	**	**	8,43
		48	**	**	ns	4,25
		72	ns	**	ns	3,12

Note: * Significant Effect
** Highly Significant Effect
Ns Not Significant

Summary of the variance analysis (ANOVA) results for the treatments of synthetic insecticide active ingredients and concentrations in Curug Subdistrict showed that mortality at 24 and 48 hours after application (HAA) was highly significant, while mortality at 72 HAA was not significant. The interaction between factors at 24, 48, and 72 HAA was also found to be not significant. Meanwhile, the summary of the variance analysis results for the treatments of synthetic insecticide active ingredients and concentrations in Kasemen Subdistrict indicated that mortality at 24 and 48 HAA was significant, while at 72 HAA, the effect of synthetic insecticide active ingredients was not significant. However, the effect of synthetic insecticide concentration treatment at 72 HAA was highly significant. Furthermore, the interaction between the two factors was highly significant on mortality at 24 hours after application (HAA), but not significant at 48 to 72 HAA.

Lethal Time 50 and Lethal Time 99 (LT_{50} dan LT_{99})

Lethal Time 50 (LT_{50}) and *Lethal Time 99* (LT_{99}) were determined to assess the time required for 50% and 99% of the *Aphis gossypii* aphid population to die after exposure to various types of insecticides.

Curug Subdistrict

Based on probit analysis conducted using IBM SPSS *Statistics* 21 *software* to determine the *Lethal Time 50* (LT_{50}) and *Lethal Time 99* (LT_{99}) in Curug Subdistrict, the results are presented in **Table 2**.

Based on **Table 2**, the probit analysis results using SPSS for Curug Subdistrict showed that the organophosphate insecticide active ingredient had the fastest LT_{50} and LT_{99} values among the tested synthetic insecticides and concentrations, with estimated mortality times ranging from approximately 23 to 46 hours after application (HAA). This organophosphate active ingredient is commonly used by farmers in Curug Subdistrict under the commercial name Curacron 500 EC, which contains profenofos as its active compound. This finding aligns with the journal by (Surya et al., 2017) , which states that the chemical structure and mode of action of organophosphates are closely related to nerve agents. These compounds are capable of rapidly suppressing insect populations and exhibit moderate persistence in the environment, making them a potential alternative to organochlorines over time.

Tabel 2. Probit Results of *Lethal Time* in Curug Subdistrict

Concentration	Lethal Time	Carbamate (Marshal)	Organophosphate (Curacron)	Sidamethrin (Piretroid)	Confidor (Neonicotinoid)	Sivanto (Flupyradifuron)
5%	LT_{50}	39,893	26,818	28,659	37,849	30,341
	LT_{99}	59,224	46,240	46,473	67,095	59,035
50%	LT_{50}	34,682	25,748	27,782	35,781	26,295
	LT_{99}	60,094	42,752	45,571	63,648	56,431
95%	LT_{50}	29,147	23,466	26,996	33,087	24,564
	LT_{99}	55,826	40,705	43,601	59,674	56,134
100%	LT_{50}	23,563	23,396	24,990	29,273	23,409
	LT_{99}	51,026	41,180	41,988	57,160	54,097

Based on Table 3, which presents the percentage mortality of the aphid pest *A. gossypii* in Curug Subdistrict, Serang City, it was found that synthetic insecticides with different active ingredients showed varying levels of effectiveness at each observation period. The control treatment (I0) did not show a significant difference in effectiveness compared to other insecticides at 24, 48, and 72 hours after application (HAA). This indicates that, without the presence of synthetic insecticide active ingredients, pest control is suboptimal in Curug Subdistrict, as *A. gossypii* is capable of producing offspring weekly as long as sufficient food sources are available on its host plants (chili pepper). In the view of Nurani *et al*. (2022), the population of *Aphis* *gossypii* increases daily, even exceeding tenfold from the initial count on the first day. This suggests that in the absence of insecticide application, *Aphis gossypii* infesting chili plants continues to reproduce normally.

At 24 hours after application (HAA), the treatment with synthetic insecticide active ingredients showing the highest average mortality rate, as presented in the percentage mortality table, was the pyrethroid (I3) treatment. To determine the most effective treatment for controlling *Aphis gossypii*, the evaluation was based on the level of insect mortality percentage following insecticide application. The higher the mortality rate produced by a treatment, the more effective the insecticide is in suppressing pest populations (Safirah et al., 2016). The pyrethroid treatment (I3) showed the highest average mortality percentage of *A. gossypii*, which was 6.08%. Meanwhile, the best performance among the synthetic insecticide concentration treatments was observed at the 100% concentration (K4), with a mortality rate of 6.87%. Thus, increasing the concentration of synthetic insecticides contributes to improved efficacy in controlling *A. gossypii*. However, this efficacy also strongly depends on the type of active ingredient used. As reported by Sari *et al*., (2022)Pyrethroid-based insecticides act as axonic toxins that target nerve fibers. These compounds work by binding to proteins in the nervous system, thereby inhibiting nerve signal transmission and causing paralysis in insects. One of the main characteristics of pyrethroids is their rapid action against insects, resulting in significant *knockdown* and *flushing* effects.

Table 3. Percentage of Mortality of *Aphis gossypii* in Response to Active Ingredient and Concentration Treatments of Synthetic Insecticides in Curug Subdistrict

Observation Time (HAA)	Type of Synthetic Insecticide Active Ingredient	Synthetic Insecticide Concentration				Mean
		K1	K2	K3	K4	
		...%...				
24	I0	0	0	0	0	0^{a}
	I1	3,33	4,00	5,33	6,67	4,83^{b}
	I2	4,67	5,33	6,67	7,00	5,92^{d}
	I3	5,00	5,33	6,67	7,33	6,08^{d}
	I4	3,33	5,00	5,67	6,67	5,17^{bc}
	I5	4,33	5,67	6,00	6,67	5,67^{cd}
	Mean	4,13^{a}	5,07^{b}	6,07^{c}	6,87^{d}	
48	I0	0	0	0	0	0^{a}
	I1	8,67	9,00	9,67	10,00	9,33^{bc}
	I2	9,67	9,67	10,00	10,00	9,83^{d}
	I3	9,67	9,67	10,00	10,00	9,83^{d}
	I4	8,33	8,67	9,33	9,67	9,00^{b}
	I5	9,33	9,67	9,67	10,00	9,67^{cd}
	Mean	9,13^{b}	9,33^{b}	9,73^{c}	9,93^{c}	
72	I0	0	0	0	0	0^{a}
	I1	9,67	10,00	10,00	10,00	9,92^{b}
	I2	9,67	9,67	10,00	10,00	9,83^{b}
	I3	9,67	10,00	10,00	10,00	9,92^{b}
	I4	9,67	9,67	9,67	10,00	9,75^{b}
	I5	9,67	10,00	10,00	10,00	9,92^{b}
	Mean	9,67^{a}	9,87^{ab}	9,93^{ab}	10,00^{b}	

Note: Numbers followed by the same letter within the same column indicate no significant difference based on Duncan's Multiple Range Test (DMRT) at 5% significance level.

At 48 hours after application (HAA), the effectiveness of various synthetic insecticide active ingredients against *Aphis gossypii* mortality can be observed in the percentage mortality table, where organophosphate (I2) and pyrethroid (I3) showed the highest average mortality rate of 6.83%. Meanwhile, the most effective synthetic insecticide concentration was found at 100% (K4), with an average mortality rate of 6.87%. At 72 HAA, the treatment with synthetic insecticide active ingredients that showed the highest average mortality percentage was observed in carbamate (I1), pyrethroid (I3), and flupyradifurone (I5), all showing the same mortality value of 9.92%. This result indicates that these three active ingredients had similar efficacy in controlling *Aphis gossypii* at this observation stage. As noted by (Liang et al., 2019) Flupyradifurone is the first member of the butenolide insecticide class, classified by the *Insecticide Resistance Action Committee* (IRAC) under Group 4D. This insecticide acts by mimicking acetylcholine in the insect nervous system, reversibly binding to nicotinic acetylcholine receptors (nAChRs), thereby causing uncontrolled nerve stimulation. In addition, flupyradifurone also has sublethal effects that can slow development and reduce the reproductive rate of subsequent generations, thus suppressing the population growth of *A. Gossypii*. Meanwhile, the treatment with the highest average mortality rate among the insecticide concentration levels was recorded at the 100% concentration (K4), with a value of 10.00%. This indicates that increasing the concentration of the insecticide can enhance its effectiveness in pest control.

Kasemen Subdistrict

Based on the probit analysis conducted using IBM SPSS *Statistics* 21 software, the Lethal Time 50 (LT_{50}) and (LT_{99}) values for Kasemen Subdistrict are presented in **Table 4**.

Table 4. Probit Results of *Lethal Time* in Kasemen Subdistrict

Concentration	Lethal Time	Carbamate (Marshal)	Organophosphate (Curacron)	Sidamethrin (Piretroid)	Confidor (Neonicotinoid)	Sivanto (Flupyradifuron)
5%	LT_{50}	28,385	23,460	29,222	41,229	27,879
	LT_{99}	43,459	48,009	54,115	67,647	55,862
50%	LT_{50}	23,662	21,980	27,560	37,058	25,312
	LT_{99}	43,388	44,167	48,786	63,237	54,647
95%	LT_{50}	20,835	15,834	26,751	35,203	21,766
	LT_{99}	41,163	42,029	47,665	60,466	44,785
100%	LT_{50}	14,437	14,090	24,441	32,819	21,622
	LT_{99}	39,634	38,452	44,003	55,846	41,380

Based on the probit analysis results using SPSS in Kasemen Subdistrict presented in Table 4, it was found that at concentrations of 5%, 50%, and 95%, the fastest LT_{50} values were achieved by the organophosphate insecticide, while the fastest LT_{99} values were obtained from the carbamate insecticide. However, at the 100% concentration, both the fastest LT_{50} and LT_{99} were consistently achieved by the organophosphate. These differences are closely related to the mode of action and chemical properties of each insecticide. Organophosphates act by inhibiting the acetylcholinesterase enzyme in the insect nervous system, leading to the accumulation of acetylcholine, which causes rapid paralysis and death, especially at high doses. In this study, the organophosphate used was Curacron 500 EC, containing profenofos as the active ingredient. According to Puspitasari et al. (2022), this is a non-systemic insecticide and acaricide that effectively inhibits cholinesterase enzymes through various toxic pathways, including contact, inhalation, and oral exposure. In contrast, although carbamates also inhibit acetylcholinesterase, their binding is more reversible, requiring more time to achieve maximum effectiveness at low concentrations. However, at certain concentrations, carbamates can reach LT_{99} faster than organophosphates. Carbamates are N-methyl derivatives of carbamic acid that act through carbamylation at neuronal and neuromuscular synapses. Their mechanism is similar to that of organophosphates but is reversible when compared to the phosphorylation caused by organophosphates (Silberman & Taylor, 2025), resulting in slower efficacy at higher concentrations.

Based on Table 5, which presents the analysis results of the mortality percentage of *Aphis gossypii*, it was found that with the first factor, the control treatment (I0) did not show a significant effect on aphid mortality across all observation times (24, 48, and 72 hours after application, HAA). This confirms that without the use of active insecticidal ingredients, the aphid population did not experience a significant decline. Furthermore, at the 24-hour observation time (HAA), differences among the tested synthetic insecticide treatments could be observed based on the distinct notations for each treatment. The most effective synthetic insecticide treatment at 24 HAA was Curacron (I2). This organophosphate-based treatment showed the highest average mortality percentage of *A. gossypii*, reaching 7.42%. In addition, based on the mortality percentage table, the synthetic insecticide concentration treatments showed significant differences in their effects. The best-performing concentration treatment was the 100% concentration (K4), which is also the highest concentration tested. It resulted in the highest average mortality rate of *A. gossypii*, reaching 7.2%.

Table 5. Percentage of Mortality of *Aphis gossypii* in Response to Active Ingredients and Concentrations of Synthetic Insecticides in Kasemen Subdistrict

Observation Time (HAA)	**Type of Synthetic Insecticide Active Ingredient**	**Synthetic Insecticide Concentration**				**Mean**
		K1	K2	K3	K4	
		...%...				
24	I0	0	0	0	0	0[a]
	I1	4,00	6,00	7,33	8,33	6,42[d]
	I2	6,00	6,67	8,33	8,67	7,42[e]
	I3	4,33	5,33	5,67	6,33	5,42[c]
	I4	3,00	3,67	4,33	5,33	4,08[b]
	I5	5,33	5,67	7,00	7,33	6,33[d]
	Mean	4,53[a]	5,47[b]	6,53[c]	7,2[d]	
48	I0	0	0	0	0	0[a]
	I1	9,67	9,67	10,00	10,00	9,83[c]
	I2	9,33	10,00	10,00	10,00	9,83[c]
	I3	9,67	9,67	10,00	10,00	9,83[c]
	I4	7,67	8,33	9,00	9,67	8,67[b]
	I5	9,67	9,67	10,00	10,00	9,83[c]
	Mean	9,2[a]	9,47[a]	9,80[b]	9,93[b]	
72	I0	0	0	0	0	0[a]
	I1	9,67	10,00	10,00	10,00	9,92[b]
	I2	9,67	10,00	10,00	10,00	9,92[b]
	I3	9,67	10,00	10,00	10,00	9,92[b]
	I4	9,33	9,67	10,00	10,00	9,75[b]
	I5	9,67	10,00	10,00	10,00	9,92[b]
	Mean	9,6[a]	9,93[b]	10,00[b]	10,00[b]	

At 48 hours after application (HAA), the effectiveness of several active insecticide ingredients began to show a more significant increase. Insecticides containing carbamate (I1), organophosphate (I2), pyrethroid (I3), and flupyradifurone (I5) as active ingredients showed highly significant effects on the mortality of *Aphis gossypii*, with all achieving the same average mortality percentage of 9.83%. This indicates that insecticides with different modes of action can exhibit high efficacy over a longer period. Meanwhile, among the synthetic insecticide concentration treatments, the highest average mortality percentage was observed in the 100% concentration treatment (K4), which reached 9,93%.

At 72 hours after application (HAA), the synthetic insecticide treatments that showed the highest average mortality percentage were those containing carbamate (I1), organophosphate (I2), pyrethroid (I3), and flupyradifurone (I5) as active ingredients. All four treatments exhibited the same mortality percentage of 9.92%. This indicates that these four active ingredients had similar efficacy in controlling Aphis gossypii populations over this observation period. Meanwhile, the concentration-based treatments revealed that the 95% (K3) and 100% (K4) concentrations resulted in the highest average mortality rates, both reaching 10.00%. These results suggest that increasing insecticide concentration contributes to higher pest mortality.

Lethal Concentration 50 (LC_{50})

Lethal Concentration 50 is the concentration required to cause mortality in 50% of the *Aphis gossypii* population. The LC values are presented in Table 6.

Table 6. Probit Analysis Results of *Lethal Concentration* in Curug and Kasemen Subdistricts

Active Ingredient	Lethal Consenteration	Subdistrict	
		Curug	Kasemen
Control	LC_{50}	0	0
Carbamate (Marshal)	LC_{50}	54,132	59,842
Organophospate (Curacron)	LC_{50}	48,861	52,546
Piretroid (Sidamethrin)	LC_{50}	41,763	58,363
Neonicotinoid (Confidor)	LC_{50}	71,288	72,806
Flupyradifuron (Sivanto)	LC_{50}	69,168	65,918

Based on **Table 6**, the probit analysis results of LC_{50} in Curug Subdistrict indicate that the insecticide active ingredient requiring the lowest concentration to achieve 50% mortality of the pest population is the pyrethroid-based insecticide (I3). This indicates that pyrethroids exhibit higher efficacy against the pest, due to their rapid mode of action in disrupting the insect's nervous system. This is also supported by a study conducted in China, as reported in (Qiu & Chen, 2024) , which states that synthetic pyrethroid insecticides at LC_{50} concentrations can inhibit the reproduction of parental *A. gossypii* generations while increasing the reproductive potential of subsequent generations (F1 and F2). In contrast, the insecticide that requires the highest concentration to achieve the same effect, as indicated by its LC_{50} value, is the neonicotinoid (I4). The higher LC_{50} value for neonicotinoids suggests that pests in Curug Subdistrict have a greater tolerance or resistance to this active ingredient compared to other tested insecticides.

In Kasemen Subdistrict, different results were observed. The insecticide with the lowest LC_{50} value, indicating the highest efficacy in killing pests at minimal concentrations, was the organophosphate (I2). Meanwhile, the insecticide with the highest LC_{50} value in Kasemen Subdistrict remained the same as in Curug Subdistrict, which is the neonicotinoid (I4). The high concentration required to achieve 50% mortality indicates that pests in Kasemen Subdistrict have a higher tolerance toward neonicotinoid-based insecticides. As reported by Kaleem Ullah *et al*. (2023) the mode of action of organophosphates, which inhibit the enzyme *acetylcholinesterase* (AChE), is highly effective against *Aphis gossypii*, particularly because the AChE enzyme in aphids is highly sensitive to inhibition by organophosphates. In contrast, carbamate, pyrethroid, and neonicotinoid insecticides exhibited higher LC_{50} values, requiring greater concentrations to achieve the same level of mortality. Furthermore, some populations of *Aphis gossypii* have developed resistance to carbamates, pyrethroids, and neonicotinoids, which may reduce their overall effectiveness.

Morphological Observation of Aphid (*Aphis gossypii*)

The aphid (*Aphis gossypii*) belongs to the order Hemiptera and family Aphididae. It is known as a sap-sucking organism that damages crops and has the potential to reduce harvest yields. This insect has a small body size, ranging from 1–2 mm, with color variations including yellow, reddish, to dark green or black. One of the distinctive characteristics of *A. gossypii* is its ability to live in colonies, which allows for rapid reproduction and infestation of plants in large numbers (Putri & Yunus, 2023). The adult stage (imago) of the aphid is typically green in color with an elongated body.

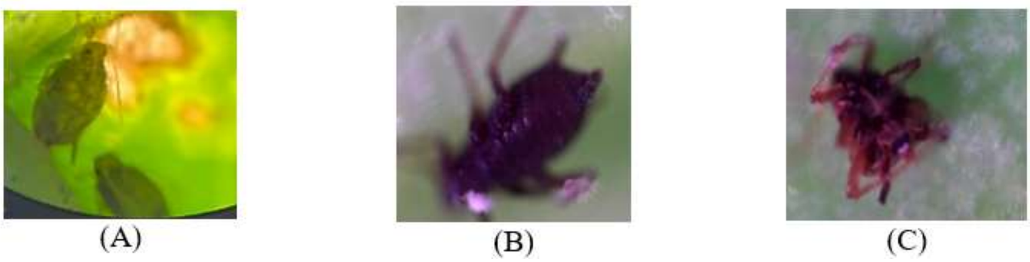

Figure 1. Morphological observations of *A. gossypii* were conducted under treatments of synthetic insecticide active ingredients and synthetic insecticide concentrations in Curug and Kasemen Subdistricts. (A) *A. gossypii* still alive, exhibiting a greenish-yellow color. (B) Dead *A. gossypii* specimens from Curug Subdistrict. (C) Dead *A. gossypii* specimens from Kasemen Subdistrict. (Research Documentation, 2024).

Morphological observation in *Figure 1* of *A. gossypii* shows differences in morphology, including structure, shape, color, and body texture before and after synthetic insecticide treatments. As shown in Figure 1 (A), live *A. gossypii* specimens that had not yet been exposed to any synthetic insecticide active ingredients or concentrations exhibited a complete body structure, with an intact form. The body color was predominantly greenish-yellow, and the texture of the body was soft. This indicates that the *A. gossypii* individuals were in a normal and healthy condition.

After the application of insecticides, morphological changes were visible in *A. gossypii* specimens from Curug Subdistrict, as shown in Figure 1 (B). The aphids from Curug that had been treated with synthetic insecticide active ingredients and concentrations exhibited a rigid body structure and shape, along with a hardened texture. Meanwhile, in Figure 1 (C), *A. gossypii* specimens from Kasemen Subdistrict that had undergone similar treatments showed a shrunken body structure and hardened texture. This change is attributed to the synthetic insecticides targeting the abdomen of the pest, which caused a physiological stress response. Before treatment, the aphids exhibited active movement; however, their activity became significantly reduced after exposure to the insecticides. As reported by Nursal *et* *al*., in Ramadhona *et al*. 2018, the toxic compounds present in the insecticides, such as carbamate, organophosphate, pyrethroid, neonicotinoid, and flupyradifurone, are capable of causing the body structure of *A. gossypii* to become stiff. This rigidity disrupts normal physiological activities, leading to impaired metabolic and digestive functions in the aphid.

A noticeable color change was also observed in the aphids after insecticide treatment. In Curug Subdistrict, the treated *A. gossypii* individuals exhibited a dark black coloration (Figure 1B), whereas those from Kasemen Subdistrict showed a dark brownish-black coloration (Figure 1C). This color change is attributed to the process of melanization occurring in the bodies of *A. gossypii*. Melanization always involves the enzyme polyphenol oxidase and is characterized by the appearance of brown or black pigmentation (Nappi *et al*., 1992; Dono *et al*., 2012).Fauzana & Harahap, 2021). The type of active ingredient and concentration of synthetic insecticides can interfere with hormone production, leading to physiological imbalances in *Aphis gossypii*. As a result, the molting process is disrupted, preventing *A. gossypii* from completing its life cycle.

CONCLUSION AND RECOMMENDATIONS

Based on the research results, various insecticide active ingredients (carbamate, organophosphate, pyrethroid, neonicotinoid, and flupyradifurone) showed highly significant effects on the mortality of *Aphis gossypii* at 24 and 48 hours after application in both Curug and Kasemen Subdistricts. Insecticide concentration also significantly influenced pest mortality, with an interaction between active ingredient and concentration detected in the Kasemen Subdistrict at 24 hours. The LC_{50} values of 72.806% (neonicotinoid, Kasemen) and 71.288% (neonicotinoid, Curug) indicate potential resistance. This is further supported by avoidance behavior observed in the aphids, which reflects behavioral resistance as classified by IRAC. Therefore, it is recommended to implement insecticide rotation using compounds with different modes of action, such as Spirotetramat (Group 23), Sulfoxaflor (Group 4C), and Azadirachtin, along with regular monitoring of resistance development, to support adaptive pest management strategies.

REFERENCES

BPS [Badan Pusat Statistik] Provinsi Banten. (2020). https://serangkota.bps.go.id/id/statistics table/2/MjA2IzI=/produksi-tanaman-sayuran-menurut-kecamatan-dan-jenis-tanaman-di kota-serang.html. Produksi Tanaman Sayuran Menurut Kecamatan dan Jenis Tanaman di Kota Serang (kuintal), 2022-2023. Diakses pada Tanggal 21 Juni 2024. Serang.

Fauzana, H., & Harahap, R. A. (2021). Uji Beberapa Konsentrasi Ekstrak Tepung Daun Srikaya (*Annona squamosa* L.) Untuk Mengendalikan Hama *Aphis gossypii* Glover Pada Tanaman Cabai. *Jurnal Agroteknologi*, *12*(1), 9. https://doi.org/10.24014/ja.v12i1.11722

Kaleem Ullah, R. M., Gao, F., Sikandar, A., & Wu, H. (2023). *Insights into the Effects of Insecticides on Aphids* (Hemiptera: Aphididae): *Resistance Mechanisms and Molecular Basis*. *International Journal of Molecular Sciences*, *24*(7), 6750. https://doi.org/10.3390/ijms24076750

Liang, P. Z., Ma, K. S., Chen, X. W., Tang, C. Y., Xia, J., Chi, H., & Gao, X. W. (2019). T*oxicity and Sublethal Effects of Flupyradifurone, a Novel Butenolide Insecticide, on the Development and Fecundity of Aphis* *gossypii* (Hemiptera: Aphididae). *Journal of Economic Entomology*, *112*(2), 852–858. https://doi.org/10.1093/jee/toy381

Nurani, S., Sularno, & Azwar, E. (2022). Efektivitas Ekstrak Buah *Morinda citrifolia* Terhadap Pengendalian Kutu Daun *Aphis gossypii* Pada Tanaman *Capssicum frutescens* Linn. Untuk Panduan Praktikum Fisiologi Tumbuhan. *Journal BEST: Journal of Biology Education, Science and Technology*, *5*(1), 155–161.

Puspitasari, L., Maissy, A. A., & Adani, K. (2022). Kajian Residu Profenofos dan Cypermethrin pada Cabai Merah Keriting yang Beredar di Provinsi Jawa Tengah. Dinas Ketahanan Pangan Provinsi Jawa Tengah. 42 hal.

Putri, A., & Yunus, M. (2023). Preferensi Kutu Daun *Aphis gossypii* Glover (Hemiptera:Aphididae) Pada Beberapa Jenis Tanaman Inang. *J. Agrotekbis*, *11*(6), 1472–1478. https://doi.org/10.22487/agrotekbis.v11i6.2004

Qiu, Y., & Chen, Z. (2024). *Intergenerational Effects of Sublethal Lambda-Cyhalothrin Exposure on Aphis gossypii Glover* (Hemiptera: Aphididae) *Reproduction and Development*. *Insects*, *15*(3), 173. https://doi.org/10.3390/insects15030173

Ramadhona, R., Djamilah, D., & Mukhtasar, M. (2018). Efektivitas Ekstrak Daun Pepaya Dalam Pengendalian Kutu Daun Pada Fase Vegetatif Tanaman Terung. *Jurnal Ilmu-Ilmu Pertanian Indonesia*, *20*(1), 1–6. https://doi.org/10.31186/jipi.20.1.1-6

Safirah, R., Nur, W., & Budiyanto, M. A. K. (2016). Uji Efektifitas Insektisida Nabati Buah *Crescentia cujete* dan Bunga *Syzygium aromaticum* Terhadap Mortalitas *Spodoptera litura* Secara In Vitro Sebagai Sumber Belajar Biologi. *Jurnal Pendidikan Biologi Indonesia*, *2*(3), 265–276.

Sari, A. H., Hestiningsih, R., Yuliawati, S., & Martini, M. (2022). Pengaruh Ekstrak Daun Bintaro (*Cerbera Odollam* Gaertn) Terhadap Mortalitas Lalat Rumah (*Musca Domestica* Linnaeus). *Jurnal Kesehatan Masyarakat*, *10*(2), 178–183. https://doi.org/10.14710/jkm.v10i2.32589

Sari, S. P., Suliansyah, I., Nelly, N., & Hamid, H. (2020). Identifikasi Hama Kutudaun (Hemiptera: Aphididae) Pada Tanaman Jagung Hibrida (Zea mays L.) di Kabupaten Solok Sumatera Barat. *Jurnal Sains Agro*, *5*(2). https://doi.org/10.36355/jsa.v5i2.466

Silberman, J., & Taylor, A. (2025). *Carbamate Toxicity*. *National Center for Biotechnology Information.*

Surya Utami Dewi, I. G. A., Mahardika, I. G., & Antara, M. (2017). Residu Pestisida Golongan Organofosfat Komoditas Buah Cabai Merah (*Capsicum annuum* L.) Pada Berbagai Lama Penyimpanan. *ECOTROPHIC : Jurnal Ilmu Lingkungan (Journal of Environmental Science)*, *11*(1), 34. https://doi.org/10.24843/EJES.2017.v11.i01.p06.