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Resistance of Aphids (*Aphis gossypii*) to Different Types and Concentrations of Synthetic Insecticides

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Abstract

Aphids (*Aphis gossypii*) are the primary pests that attack agricultural land in Indonesia. In addition to being pests, aphids can act as plant disease vectors. Controlling this pest is essential to increase crop productivity and maintain economic value. Farmers typically use synthetic insecticides for pest control. However, the continuous use of synthetic insecticides can lead to aphids developing resistance. This study aims to assess the resistance levels of aphids in Serang City to various synthetic insecticides. The study utilized five synthetic insecticide active ingredients: carbamates, organophosphates, pyrethroids, neonicotinoids, and flupyradifurone, at concentrations of 5%, 50%, 95%, and 100%. The study measured LT50, LT99, and LC50 values for each synthetic insecticide and observed morphological changes in aphids. The results indicated that aphids in agricultural areas of Serang sub-district, Serang City, showed resistance to organophosphate insecticides. Additionally, aphids in Cipocok sub-district, Serang City, were suspected of developing resistance to pyrethroid insecticides. Higher concentrations of insecticides resulted in faster pest mortality. Based on the LC50 values, carbamate and neonicotinoid insecticides are recommended for controlling aphid pests (*Aphis gossypii*). The study also observed changes in behavior and morphology of aphid pests following insecticide application.

Keywords: Aphids (*Aphis gossypii*), LC, LT, Synthetic Insecticides, Resistance

1. Introduction

Horticultural crops are a rapidly growing sector in Indonesian agriculture. The obstacles commonly faced by farmers are pests and diseases that affect the growth and yield of the plants (Tanaya et al., 2022). The production of horticultural crops in the city of Serang, such as chilies, has decreased from 196 tons to 2 tons (BPS 2020). Most farmers complain about the quality of their harvests, which are sometimes not good. This is not only caused by environmental and weather conditions but can also be caused by their plants being attacked by aphids (Rebecca, 2020). Several types of aphids usually interfere with agricultural land, including *Aphis gossypii* (cotton aphids), Pseudococcidae (whiteflies), and Myzus persicae (peach aphids). In addition to being pests, aphids can act as vectors of viruses in plant diseases (Maharani et al., 2020).

Aphids (*Aphis gossypii*) live in groups and are found under the surface of leaves, reproducing through parthenogenesis. These insects are 1-2 mm in size and have green, brown, and yellow colors. They attack plants by inserting their stylets and sucking plant cell fluids from the leaves and leaf stalks, resulting in the leaves of the plant becoming curly and unable to develop normally (Ramadhona et al., 2018). Losses due to attacks by aphids can reach 10-30% outside the dry season, while losses can increase to 40% in the dry season. If this pest is a vector, the losses experienced by the plant can reach 80% (Sari et al., 2020)

In order to increase crop production and suppress the aphid pest population, pest control is carried out to produce good crops and avoid economic losses. Farmers typically use chemical insecticides to eliminate pests and diseases. The use of chemical insecticides continues to rise yearly due to their ease of use and quick results. However, the continuous use of chemical insecticides can lead to resistance in these pests (Bande et al., 2020). The Insecticide Resistance Action Committee (IRAC) has classified several types of insecticides commonly used to eradicate aphids, including MoA groups 1-2, 7, 9, 12, 23, 28, 29, and 32. Based on data on the types of insecticides

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effective against aphids, some insecticides are believed to be resistant to aphids. Research by Shang et al. (2014) indicated that organophosphates and carbamates, insecticides from groups 1B and 1A, are resistant to aphids, but their functional validation is still needed to demonstrate and quantify their role in resistance.

Therefore, information on the resistance of aphids to synthetic insecticides needs to be known in order to determine which insecticides can be used to eradicate aphids. In this study, insecticides were tested with active ingredients that IRAC has classified as insecticides that are resistant to aphids, namely carbamates, organophosphates, neonicotinoids, pyrethroids and flupyradifurone which will be tested on aphids in Serang City, Banten.

2. Material and Methods

The research was conducted in September-November 2024. The research was conducted on the 3rd floor of the Basic Laboratory of Plant Science and Protection, Faculty of Agriculture, Sultan Ageng Tirtayasa University. The location used has an altitude of 120 meters above sea level with longitude coordinates 106.1246054 and latitude coordinates -6.1159551. The tools used in this study are scissors, petridish size 90 x 18 mm, 1 liter glass cup, 0.01-liter micropipette, insect rearing room, labels as sample markers, insect sample testing containers, binocular microscopes, tweezers, hotplate, camera, magnetic stirrer, brushes and stationery. While the materials used in this study are distilled water, adult aphids, chili plants as host plants, agar, insecticides with active ingredients carbamate, organophosphate, pyrethroid, neonicotinoid, flupyradifurone and tissue.

The implementation of this research includes taking pest samples, propagating aphids (*Aphis gossypii*), making test media, making insecticide media, testing, and observation.

Propagation of aphids (*Aphis gossypii*) was carried out by taking aphids samples on each agricultural land in Serang and Cipocok Jaya sub-districts, Serang City, which were then reared to obtain the 3rd generation for 1 month in the laboratory by moving aphids samples to new host plants. Then, testing was carried out by making insecticides that were tested with different concentrations. Testing was carried out by moving 10 aphids samples to each insecticide sample to be tested.

The design used in this study was a Completely Randomized Design (CRD) consisting of 2 factors, namely the first factor of insecticides with active ingredients of carbamate, organophosphate, pyrethroid, neonicotinoid, and flupyradifurone, and control (without treatment) and the second factor was insecticide concentrations of 5%, 50%, 95%, and 100%. There were 24 combinations of treatments from the two factors, each combination was repeated 3 times so that 72 experimental units were obtained. The data obtained from the observation results were analyzed using analysis of variance (F test) at the 5% level, if the analysis of variance showed a significant or very significant effect, then further testing was carried out in this study with the Duncam Multiple Range Test (DMRT). The effect of the toxicity of each synthetic insecticide tested on aphid pests (*Aphis gossypii*) was calculated by determining the LT50, LT99, and LC50 values measured at 24 hours, 48 hours, and 72 hours after application, which were analyzed using probit analysis on SPSS software version 29. In addition, morphological observations were made on aphids.

The research stages can be seen in the following flow diagram:

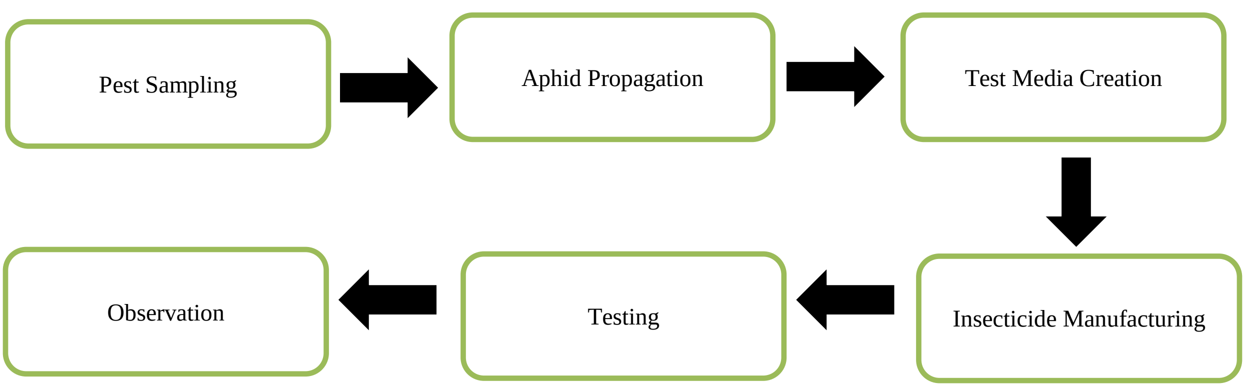

Figure 1. Research flow diagram

3. Results and Discussion

Based on tables 1 and 2. The results of mortality analysis carried out on aphids in Serang sub-district and Cipcok Jaya sub-district showed very significant results in the observation of 24 hours to 72 hours.

3.1. LT50 and LT99 Serang Subdistrict

The toxicity level of several synthetic insecticides against aphids is carried out by looking at the LT50, LT99, and LC50 values. The LT50 value is a time parameter needed to kill 50% of pests from test insects while the LT99 value is a time parameter needed to kill 99% of pests from test insects (Santi et al., 2022). The LC50 value is a parameter to measure what concentration can kill 50% of pests from test insects (Priyanto, 2010).

Table 1. Percentage mortality of aphid pests (*Aphis gossypii*) Serang subdistrict.

Treatment	Observation		
	Hours		
	24	48	72
	…%..		
Carbamate			
Control (k0)	0±0b	0±0d	0±0d
Concentration 5% (k1)	0,5±0a	0,96±0,05ac	0,96±0,05ac
Concentration 50% (k2)	0,53±0,05a	1±0ab	1±0ab
Concentration 95% (k3)	0,5±0a	1±0a	1±0a
Concentration 100% (k4)	0,63±0,15a	1±0a	1±0a
Average	0,432±0,01	0,792±0,002	0,792±0,002
Organophosphates			
Control (k0)	0±0b	0±0b	0±0b
Concentration 5% (k1)	0,26±0,11a	0,73±0,15a	0,96±0,05a
Concentration 50% (k2)	0,3±0,1a	0,76±0,11a	1±0a
Concentration 95% (k3)	0,36±0,05a	0,8±0,17a	1±0a
Concentration 100% (k4)	0,4±0,17a	0,83±0,15a	1±0a
Average	1,32±0,003	3,12±0,02	0,792±0,002
Pyrethroids			
Control (k0)	0±0b	0±0b	0±0b
Concentration 5% (k1)	0,33±0,05a	0,9±0,17a	0,96±0,05a
Concentration 50% (k2)	0,4±0,1a	0,93±0,11a	1±0a
Concentration 95% (k3)	0,33±0,05a	1±0a	1±0a
Concentration 100% (k4)	0,4±0,17a	1±0a	1±0a
Average	1,46±0,001	3,83±0,003	3,96±0,002
Neonicotinoids			
Control (k0)	0±0b	0±0b	0±0b
Concentration 5% (k1)	0,4±0,1a	0,96±0,05a	0,96±0,05a
Concentration 50% (k2)	0,46±0,25a	1±0a	1±0a
Concentration 95% (k3)	0,53±0,11a	1±0a	1±0a
Concentration 100% (k4)	0,6±0,1a	1±0a	1±0a
Average	1,99±0,01	3,96±0,002	3,96±0,002
Flupyradifurone			
Control (k0)	0±0c	0±0c	0±0b
Concentration 5% (k1)	0,2±3,39b	0,73±0,11b	0,96±0,05a
Concentration 50% (k2)	0,53±0,05a	1±0a	1±0a
Concentration 95% (k3)	0,56±0,11a	1±0a	1±0a
Concentration 100% (k4)	0,6±0,17a	1±0a	1±0a
Average	0,378±0,25	0746±0,001	3,96±0,002

Based on the test results of several types of insecticides with different active ingredients, namely carbamates, organophosphates, neonicotinoids, pyrethroids, and flupyradifurone with concentrations of 5%, 50%, 95%, and 100% in the treatment of 24 hours, 48 hours, and 72 hours after application based on the LT50 and LT99 values can be seen in Table 3. The results of the probit analysis carried out on samples of aphid pests (*Aphis gossypii*) in Serang District showed that the lowest LT50 value was obtained from neonicotinoid insecticides with a time span of (26.867; 25.976; 24.364; 24.781 hours), while the highest LT50 value was obtained from organophosphate insecticides (40.767; 40.636; 40.514; 40.205 hours). For the lowest LT99 value obtained from neonicotinoid insecticides with a time span (35.270; 34.616; 34.419; 33.848 hours), while the highest LT99 value was obtained from organophosphate insecticides (67.664; 66.754; 66.203; 65.235 hours). When associated with the type of insecticide with the concentration used, the higher the concentration of insecticide, the faster the time needed to kill pests. The length of time needed for insecticides with organophosphate active ingredients to be able to kill 50% and 99% of aphids from the number of test insects allows insecticides with organophosphate active ingredients to experience resistance in agricultural land in Serang District, Serang City. The results obtained can be said to be the same as the research conducted by Ullah et.al., 2023, namely that aphid species such as *Aphis gossypii*, Myzus persicae, Aphis fabae, and Rhopalosiphum padi have been reported to have resistance to organophosphates ranging from low to quite high levels.

Table 2. Percentage mortality of aphids (*Aphis gossypii*) Kec. Cipocok

Treatment	Observation		
	Hours		
	24	48	72
	…%...		
Carbamate			
Control (k_0)	0±0[d]	0±0[b]	0±0[b]
Concentration 5% (k_1)	0,5±0[c]	1±0[a]	1±0[a]
Concentration 50% (k_2)	0,53±0,15[bc]	0,96±0,05[a]	0,96±0,05[a]
Concentration 95% (k_3)	0,73±0,05[ab]	1±0[a]	1±0[a]
Concentration 100% (k_4)	0,76±0,20[a]	1±0[a]	1±0[a]
Average	2,52±0,16	3,96±0,002	3,96±0,002
Organophosphates			
Control (k_0)	0±0[c]	0±0[b]	0±0[b]
Concentration 5% (k_1)	0,36±0,20[b]	1±0[a]	1±0[a]
Concentration 50% (k_2)	0,5±0[ab]	1±0[a]	1±0[a]
Concentration 95% (k_3)	0,53±0,05[ab]	0,96±0,05[a]	0,96±0,05[a]
Concentration 100% (k_4)	0,6±0,1[a]	1±0[a]	1±0[a]
Average	1,99±0,007	3,96±0,002	3,96±0,002
Pyrethroids			
Control (k_0)	0±0[c]	0±0[c]	0±0[b]
Concentration 5% (k_1)	0,13±0,05[bc]	0,6±0,1[b]	1±0[a]
Concentration 50% (k_2)	0,2±3,39[ab]	0,66±0,15[b]	0,96±0,05[a]
Concentration 95% (k_3)	0,26±0,11[ab]	0,66±0,05[b]	1±0[a]
Concentration 100% (k_4)	0,33±0,11[a]	0,9±0,17[a]	1±0[a]
Average	0,184±0,001	0,564±0,01	3,96±0,002
Neonicotinoids			
Control (k_0)	0±0[b]	0±0[b]	0±0[b]
Concentration 5% (k_1)	0,3±0,1[a]	0,76±0,05[a]	1±0[a]
Concentration 50% (k_2)	0,36±0,05[a]	0,8±0,2[a]	0,96±0,05[a]
Concentration 95% (k_3)	0,4±0,1[a]	0,83±0,15[a]	1±0[a]
Concentration 100% (k_4)	0,5±0,17[a]	0,9±0,1[a]	1±0[a]
Average	0,312±0,01	0,658±0,01	3,96±0,002
Flupyradifurone			
Control (k_0)	0±0[d]	0±0[c]	0±0[b]
Concentration 5% (k_1)	0,2±3,39[c]	0,73±0,15[b]	0,96±0,05[a]
Concentration 50% (k_2)	0,3±01[b]	0,93±0,11[a]	1±0[a]
Concentration 95% (k_3)	0,46±0,05[a]	1±0[a]	1±0[a]
Concentration 100% (k_4)	0,5±0[a]	1±0[a]	1±0[a]
Average	0,292±0,003	0,938±0,006	3,96±0,002

The Table 4 shows the highest LC50 values obtained from testing various insecticides and concentrations on agricultural land in Serang District, Serang City. The insecticide with the highest LC50 value contained carbamate as the active ingredient, with a value of 59.844% and a range of 27.541% to 74.075%. On the other hand, the insecticide with the lowest LC50 value contained neonicotinoid as the active ingredient, with a value of 48.962% and a range of 21.739% to 82.869%. A lower LC50 value indicates higher toxicity of the active ingredients in the synthetic insecticide. According to Ak'yunin's (2008) study, neonicotinoid-based insecticides are recommended for their ability to quickly kill aphids due to their unique working mechanism on insect receptor proteins, which differs from conventional insecticides and can effectively control pests that were previously resistant to traditional insecticides.

Table 3. LT50 and LT99 Serang Subdistrict value

K	Lethal Time	Estimation	Time (hour)	
			Lower Limit	Upper Limit
Carbamate				
5%	LT_{50}	28,572	6,218	36,37
	LT_{99}	56,870	43,13	688,49
Std. Error		1.87		
50%	LT_{50}	28,249	19,84	32,72
	LT_{99}	49,807	41,84	82,98
Std. Error		2,74		
95%	LT_{50}	26,785	21,93	30,67
	LT_{99}	39,373	33,53	65,20
Std. Error		4,17		
100%	LT_{50}	26,448	12,98	35,31
	LT_{99}	35,176	29,08	426,5
Std. Error		8,71		
Neonicotinoids				
5%	LT_{50}	26,867	22,21	31,74
	LT_{99}	35,270	30,35	63,07
Std. Error		6,77		
50%	LT_{50}	25,976	22,73	31,57
	LT_{99}	34,616	29,59	88,03
Std. Error		7,08		
95%	LT_{50}	25,364	21,92	31,24
	LT_{99}	34,419	29,23	142,34
Std. Error		7,28		
100%	LT_{50}	24,781	18,38	38,54
	LT_{99}	33,848	28,50	1059,0
Std. Error		8,43		
Organophosphate				
5%	LT_{50}	40,767	10,79	48,10
	LT_{99}	67,664	54,99	1073,59
Std. Error		2,75		
50%	LT_{50}	40,636	23,29	46,82
	LT_{99}	66,754	55,45	204,10
Std. Error		2,85		
95%	LT_{50}	40,514	32,23	44,90
	LT_{99}	66,203	57,21	102,12
Std. Error		3,02		
100%	LT_{50}	40,205	31,99	44,58
	LT_{99}	65,235	56,29	101,99
Std. Error		3,11		
Pyrethroids				
5%	LT_{50}	34,726	19,32	40,00
	LT_{99}	63,630	53,89	134,04
Std. Error		3,05		
50%	LT_{50}	33,407	16,37	39,06
	LT_{99}	62,571	52,70	142,57
Std. Error		3,05		
95%	LT_{50}	30,043	22,63	33,72
	LT_{99}	47,872	41,64	72,44
Std. Error		3,32		
100%	LT_{50}	28,917	22,59	32,62
	LT_{99}	47,398	40,84	69,90
Std. Error		2,87		

Table 3. LT50 and LT99 Serang Subdistrict value (*continued*)

K	Lethal Time	Estimation	Time (hour)	
			Lower Limit	Upper Limit
		Flupyradifurone		
5%	LT_{50}	39,391	11,10	46,55
	LT_{99}	68,550	55,09	945,33
Std. Error		2,14		
50%	LT_{50}	28,619	264	37,38
	LT_{99}	57,584	42,91	7175,55
Std. Error		1,95		
95%	LT_{50}	28,177	19,02	33,01
	LT_{99}	52,820	43,88	90,68
Std. Error		2,45		
100%	LT_{50}	25,588	18,30	29,86
	LT_{99}	51,502	42,38	86,03
Std. Error		2		

Table 4. LC50 Serang Subdistrict value

LC	Estimation	Lower Limit	Upper Limit
	Carbamate		
LC_{50}	59,844	27,54	74,07
	Organophosphate		
LC_{50}	57,771	9,37	77,51
	Neonicotinoids		
LC_{50}	48,962	21,73	82,86
	Pyrethroids		
LC_{50}	50,553	5,76	68,87
	Flupyradifurone		
LC_{50}	52,349	000	74,24

Based on the LT50 and LT90 values obtained from testing with aphid pest samples in agricultural land in Cipocok District, Serang City in table 5. the results of the probit analysis showed that the lowest LT50 value was obtained from organophosphate insecticides with an estimated time of (26.867; 25.843; 25.134; 24.781), while the highest LT50 value was obtained from pyrethroid insecticides with an estimated time of (43.802; 43.234; 42.858; 34.726). For the lowest LT99 value obtained from insecticides with organophosphate active ingredients with estimated time (35.270; 34.885; 33.904; 33.848), while the highest LT99 value was obtained from insecticides with pyrethroid active ingredients (72.721; 71.389; 70.639; 63.630). In the population of aphids in agricultural land in Cipocok District, Serang City, it is suspected that there is resistance to insecticides with pyrethroid active ingredients. This occurs because the time required for insecticides with pyrethroid active ingredients is longer than other insecticides tested. The results obtained can be said to be the same as the research conducted by Field et al., 2017, namely that pyrethroids are one of the insecticides that are widely used on agricultural land to control pest attacks, one of which is aphids and disease vectors in plants, but this type of insecticide has experienced resistance because it works through interaction with sodium channels.

The highest LC50 value in testing several types of insecticides and concentrations on agricultural land in Cipocok District, Serang City, can be seen in Table 6. The highest LC50 value was obtained from insecticides with neonicotinoid active ingredients, namely 58.163% with a lower limit of 38.515 and an upper limit of 70.263. While the lowest LC50 value was obtained from insecticides with carbamate active ingredients, namely 49.079% with a lower limit of 000 and an upper limit of 71.384. The smaller the LC50 value of the synthetic insecticide, the more toxic the insecticide is. The results of the study stated that insecticides with carbamate active ingredients can be recommended to control borer pests and sucking pests such as aphids (*Aphis gossypii*) because this insecticide works systemically. Carbamate insecticides have also been consistently widely used on agricultural land.

In Figure 2, there are the results of observations made on the morphological changes that occur in aphid pests (*Aphis gossypii*) after synthetic insecticides are applied namely the initial sign of death in aphids is that their bodies stiffen, after which there is a change in the color of the previously green aphids after the application of the aphid insecticide changes to reddish brown.

Table 5. LT50 and LT99 Cipocok Subdistrict Value

K	Lethal Time	Estimation	Time (hour)	
			Lower Limit	Lower Limit
Carbamate				
5%	LT_{50}	28,527	6,21	36,37
	LT_{99}	56,870	43,13	688,49
Std. Error		1,87		
50%	LT_{50}	28,211	20,11	32,73
	LT_{99}	52,088	43,55	85,03
Std. Error		2,39		
95%	LT_{50}	23,146	13,56	27,17
	LT_{99}	40,983	33,10	128,02
Std. Error		3,48		
100%	LT_{50}	22,213	10,38	266,26
	LT_{99}	40,395	32,47	167,66
Std. Error		3,54		
Organophosphate				
5%	LT_{50}	26, 867	22,21	31,74
	LT_{99}	35,270	30,35	63,07
Std. Error		6,77		
50%	LT_{50}	25,843	22,34	30,93
	LT_{99}	34,885	29,77	85,82
Std. Error		6,7		
95%	LT_{50}	25,134	21,77	33,70
	LT_{99}	33,904	28,74	458,42
Std. Error		8,1		
100%	LT_{50}	24,781	18,38	38,54
	LT_{99}	33,848	28,50	1059
Std. Error		8,43		
Neonicotinoids				
5%	LT_{50}	40,636	23,29	46,82
	LT_{99}	66,754	55,45	204,10
Std. Error		2,85		
50%	LT_{50}	40,514	32,23	44,90
	LT_{99}	66,203	57,21	102,12
Std. Error		3,02		
95%	LT_{50}	40,205	31,99	44,58
	LT_{99}	65,235	56,29	101,99
Std. Error		3,11		
100%	LT_{50}	36,957	2,87	42,76
	LT_{99}	62,984	52,94	187,27
Std. Error		4,7		
Pyrethroids				
5%	LT_{50}	43,802	38,26	47,65
	LT_{99}	72,721	63,40	99,24
Std. Error		2,29		
50%	LT_{50}	43,234	37,75	47,09
	LT_{99}	71,389	62,21	97,64
Std. Error		2,33		
95%	LT_{50}	42,858	15,36	50,69
	LT_{99}	70,639	57,13	873,92
Std. Error		2,61		
100%	LT_{50}	34,726	19,32	40,00
	LT_{99}	63,630	53,89	134,04
Std. Error		3,05		

Table 5. LT50 and LT99 Cipocok Subdistrict Value

K	Lethal Time	Estimation	Time (hour)	
			Lower Limit	Lower Limit
Flupyradifurone				
5%	LT_{50}	38,595	5,28	46,36
	LT_{99}	69,613	55,06	3514
Std. Error		2,25		
50%	LT_{50}	33,213	24,88	37,63
	LT_{99}	60,095	51,46	90,84
Std. Error		2,36		
95%	LT_{50}	30,216	063	37,59
	LT_{99}	55,190	43,49	2010,5
Std. Error		2,68		
100%	LT_{50}	28,156	21,25	32,39
	LT_{99}	53,457	44,80	82,47
Std. Error		2,07		

Table 6. LC50 Cipocok Subdistrict value

LC	Estimation	Lower Limit	Upper Limit
Carbamate			
LC_{50}	49,079	000	71,38
Organophosphate			
LC_{50}	54,358	34,10	66,37
Neonicotinoids			
LC_{50}	58,163	38,51	70,26
Pyrethroids			
LC_{50}	57,043	31,35	71,06
Flupyradifurone			
LC_{50}	51,125	5,18	70,19

Figure 2. Aphids (*Aphis gossypii*) before insecticide application (A); Aphids (*Aphis gossypii*) after insecticide application (B, C).

Aphids that have been exposed to insecticides exhibit a harder texture compared to those that have not been exposed. Additionally, previously active aphids appear weaker and have difficulty moving after insecticide exposure. This indicates that synthetic insecticides impact aphids' behavior and activity levels (*Aphis gossypii*). Nindatu et al. (2016) suggested that the compounds present in the active ingredients of insecticides can easily stiffen the bodies of insects, including aphids, disrupting their activities and decreasing their metabolism.

4. Conclusion

Insecticide resistance levels against aphid pests in agricultural lands in Serang and Cipocok Jaya sub-districts, Serang City varied. In Serang sub-district, aphids are suspected to be resistant to insecticides containing organophosphate active ingredients, while in Cipocok Jaya sub-district, resistance to insecticides with pyrethroid active ingredients is suspected. The study found that insecticides with carbamate and neonicotinoid active ingredients had effective LC50 values for controlling aphid pests while minimizing resistance development. Additionally, morphological changes in leaves were observed before and after insecticide testing.

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