Screening of Effective Insecticides Against *Diaghania Pyloalis* in Mulberry Fields

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Abstract: In recent years, with the rapid development of the sericulture industry, the pests of mulberry trees are also increasing. *Diaghania pyloalis* Walker is one of the main pests of mulberry trees, has strong fecundity and very large food intake, especially in Sichuan and Chongqing areas. In order to find out the insecticides which can effectively control *D. pyloalis*, the screening test of high-efficiency control efficacy was carried out. In the summer of 2020, the 3rd instar larvae of *D. pyloalis* were selected as the test objects, and the indoor bioassay of 10 insecticides on *D. pyloalis* was carried out, and the results of the indoor bioassay were tested by field experiments in the autumn. The results show that 2000 times liquid of Dursban, Spinetoram, Chlorantraniliprole, and 1000 times liquid of Dichlorvos and Phoxim had the best control effect on *D. pyloalis*. Secondly, 2000 times liquid of Imidacloprid and Chlorfenapyr had the better control effect on *D. pyloalis*. Finally 2000 times liquid of Pymetrozine and Cyromazine had poor control effect, and 1000 times liquid of Azadirachtin had the worst control effect on *D. pyloalis*. To control *D. pyloalis*, 2000 dilution of Dursban and Spinetoram, and 1000 times liquid of Dichlorvos can be used in sericultural production. When using Chlorantraniliprole to control *D. pyloalis*, the leaves of mulberry should be picked with long interval to avoid affecting the quality of cocoons, and it is not recommended to use Cyromazine, Azadirachtin to control *D. pyloalis*.

1 INTRODUCTION

With the continuous development of silkworm industry, the planting area of mulberry trees also increases. According to the statistics of Chongqing Silk Net, the mulberry field area of Chongqing ranked fifth in China in 2019, Mulberry trees provide abundant food sources for insect pests such as *D. Pyloalis*, with the damage of pests, the quality and yield of mulberry leaves are greatly reduced, and the silkworm industry is also affected. (Cao, 2020) *D. Pyloalis*, is commonly known as mulberry caterpillar, oil worm, leaf roller, etc., belongs to Pyralidae in Lepidoptera, and is one of the main pests of mulberry trees. In addition to larvae eating mulberry leaves, Microsporidia infected by *D. Pyloalis* will also contaminate mulberry leaves through insect feces, Silkworms will get pebrine through eating mulberry leaves, pebrine influence seriously on the production of silkworm (Zhu, 2016). The mulberry moth has gradually become the primary pest in mulberry fields because of its wide spread, strong fecundity capacity, terrible diffusion ability (Yang, 2019). The pest occurred in sericultural areas except Xinjiang, especially in Jiangsu, Zhejiang, Guangdong, Anhui, Jiangxi, Sichuan, Hunan, Hubei, Guangxi and Chongqing (Zhao, 2013). For example, the damage rate of *D. Pyloalis* in Yizhou District of Guangxi was as high as 86% in 2019 (Wei, 2020), The study on the occurrence regularity and control method of *D. Pyloalis* has become an important subject in the mulberry protection field in China (Zhou, 2021). Therefore, this study is carried out screening of high-efficiency and low-toxicity insecticides for controlling *D. pyloalis*, providing reference for the future control and providing more scientific and reasonable measures for field prevention and control.

2 MATERIALS AND METHODS

2.1 Experiment Materials

The experiment was aried out at the Ganning Base of the Chongqing Three Gorges Academy of Agricultural Sciences. The experimental site is 325 m above sea level. Flat terrain, uniform fertility and consistent field management were chosen for experiments. The test soil was sandy loam soil, with thickness equal to or higher than 1.0 m.

The tested mulberry varieties were HuSang and Da Shi. Insecticides were selected for testing listed in table 1.

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Table 1. Insecticides information

Insecticides	Content/Formulation	Manufacurer
Imidacloprid	10% WP	Shandong Jiacheng Crop Science Co.Ltd
Chlorfenapyr	8% ME	Guangxi Pastoral biochemical Co. Ltd
Cyromazine	80% WDG	Guangdong Zhongxun Agricultural Science Co. Ltd
Bifenthrin	2.5% EW	Chengdu Kelilong biochemical Co.Ltd
Thiamethoxam	25% WDG	Jiangsu Changqing Agrochemical Co.Ltd
Azadirachtin	0.3% Oil	Chengdu Green Gold biotechnology Co.Ltd
Spinetoram	60 g/L SA	Dow Enong Co.USA
Dursban	40% Oil	Anhui Huaxing Chemical Co. Ltd
Pymetrozine	25% SA	Shanxi Huangpai Crop technology Co.Ltd
Chlorantraniliprole	5% SA	American Fumei Real Company
Dichlorvos	77.50% Oil	Shandong Dacheng Bio-Chemical Co.Ltd
Phoxim	40% Oil	Lianyungang Liben Crop Technology Co. Ltd

2.2 Experiment Methods

2.2.1.Laboratory virulence test of Diaghania pyloalis

In the summer of 2020, the larvae of *D. Pyloalis* were reared with fresh mulberry leaves after hatching and collectively reared before the third instar. The third instar larvae were selected as the experimental objects to conduct the laboratory virulence test of 10 insecticides (see the top 10 insecticides in table 1) against *D. Pyloalis*. Five gradients were set for each insecticide, and water treatment was the blank control. The ripe mulberry leaves were soaked in the corresponding agent for 1 min, dried naturally, and placed in the crisper box. 30 mulberry moth larvae were fed with mulberry leaves in each treatmentarea, and fed continuously for 7 days. Each treatment was repeated 3 times. The number of poisoning deaths of *D. Pyloalis* was investigated daily.

2.2.2.Field control experiment of Diaghania pyloalis

In the autumn of 2020, 10 insecticides (see table 1) were selected to conduct field control experiments on *D. Pyloalis*, but Bifenthrin and Thiamethoxam were not selected for the experiment because of their high toxicity to silkworm (Ren, 2020). The dilution times of Azadirachtin, Dichlorvos and Phoxim were 1000 times, and the dilution times of other insecticides were 2000 times. Water treatment was blank control, and each treatment was repeated 3 times and randomly arranged. Before the experimental control, 10 mulberry trees were randomly selected in each plot, and the number of larvae on the labeled mulberry branches was investigated. The number of remaining insects was investigated at 1, 2, 5 and 7 days after the treatment. The rate of pest decline in each pesticide treatment area was calculated and the control effect was corrected.

2.2.3.Data analysis

Data were processed and statistically analysed using IBM SPSS 16.0, and the method of analysis of variance for survey data was One-Way ANOVO, denoted as x, n=3.

The following is the calculation formula: Mortality rate (%) = the number of dead insects / total number of insects before application×100; Insects population decline rate (%) = (total number of insects before application - the number of live insects after application) / total number of insects before application×100; Field control effect (%) = (insects decline rate in treatment area - control area insects decline rate) / (100 - insects decline rate in control area) ×100.

3 RESULTS AND ANALYSIS

3.1 Indoor toxicity of different insecticides against *Diaghania pyloalis*

The virulence test was carried out on *D. pyloalis*, the results showed that eight insecticides had the best control effect against *D. pyloalis* (shown in table 2). First of all, Bifenthrin, Thiamethoxam, and Dursban had the best control effect against *D. pyloalis*, and all the mulberry moth larvaedied after continuous feeding mulberry leaves for 24 hours. There was no significant difference in the control effect of the three treatments at different concentrations, which was significantly higher than that of other treatments. Secondly, Spinetoram, Chlorfenapyr, Imidacloprid, Chlorantraniliprole and Cyromazine had better control effect against *D. pyloalis*, and there were significant differences in the control effects at different concentrations. All the larvae of Chlorfenapyr and Spinetoram treatments died after continuous feeding mulberry leaves for 48 hours. All the larvae of Imidacloprid treatments at 1000~1500 times liquid died after continuous feeding mulberry leaves for48 hours, and all the larvae of Imidacloprid treatments at 2000~2500 times liquid died after continuous feeding mulberry leaves for 72 hours. All the larvae of Chlorantraniliprole treatments died after continuous

feeding mulberry leaves for 72. All the larvae of Cyromazine at 1500~3000 times liquid died after feeding mulberry leaves for 96 hours. Finally, Pymetrozine and Azadirachtin had poor control effect against *D. pyloalis*, and Azadirachtin had the worst control effect, the larvae survived in the high concentration area which were continuously fed for 7 days.

Table 2. Indoor toxicity of different insecticides against *Diaghania pyloalis*

Insecticides	Dilution times	Feeding for 24 h		Feeding for 48 h		Feeding for 72 h		Feeding for 96 h		Feeding for 7 d	
		Death number	Decline rate/%	Death number	Decline rate/%	Death number	Decline rate/%	Death number	Decline rate/%	Death number	Decline rate/%
Imidacloprid	1000	29.67	98.89 a	30.00	100.00 a	-	-	-	-	-	-
	1500	25.67	85.56 cd	30.00	100.00 a	-	-	-	-	-	-
	2000	24.33	81.11 de	28.33	94.44abc	30.00	100.00 a	-	-	-	-
	2500	24.33	81.11 de	29.00	96.67 ab	30.00	100.00 a	-	-	-	-
	3000	17.33	57.78 hi	26.33	87.78 c	28.67	95.56 a	30.00	100.00 a	-	-
Chlorfenapyr	1000	29.33	97.78 a	30.00	100.00 a	-	-	-	-	-	-
	1500	26.67	88.89 bc	30.00	100.00 a	-	-	-	-	-	-
	2000	18.67	62.22 h	30.00	100.00 a	-	-	-	-	-	-
	2500	26.33	87.78 c	30.00	100.00 a	-	-	-	-	-	-
	3000	22.33	74.44 fg	30.00	100.00 a	-	-	-	-	-	-
Cyromazine	1000	26.00	86.67 cd	26.67	88.89 bc	26.67	88.89 bc	26.67	88.89 b	26.67	88.89 a
	1500	21.00	70.00 g	27.00	90.00 bc	30.00	100.00 a	30.00	100.00 a	-	-
	2000	10.67	35.56 j	16.33	54.44 e	26.00	86.67 c	30.00	100.00 a	-	-
	2500	8.33	27.78 k	12.00	40.00 gh	25.67	85.56 c	30.00	100.00 a	-	-
	3000	6.00	20.00 l	8.67	28.89 i	26.67	88.89 bc	30.00	100.00 a	-	-
Bifenthrin	1000	30.00	100.00 a	-	-	-	-	-	-	-	-
	1500	30.00	100.00 a	-	-	-	-	-	-	-	-
	2000	30.00	100.00 a	-	-	-	-	-	-	-	-
	2500	30.00	100.00 a	-	-	-	-	-	-	-	-
	3000	30.00	100.00 a	-	-	-	-	-	-	-	-
Thiamethoxam	1000	30.00	100.00 a	-	-	-	-	-	-	-	-
	1500	30.00	100.00 a	-	-	-	-	-	-	-	-
	2000	30.00	100.00 a	-	-	-	-	-	-	-	-
	2500	30.00	100.00 a	-	-	-	-	-	-	-	-
	3000	30.00	100.00 a	-	-	-	-	-	-	-	-
Azadirachtin	500	2.00	6.67 mn	6.00	20.00 j	8.67	28.89 f	13.00	43.33 d	20.67	68.89 b
	1000	1.67	5.56 mno	6.00	20.00 j	10.67	35.56 f	13.67	45.56 d	23.00	76.67 b
	1500	1.00	3.33 no	2.00	6.67 kl	3.33	11.11 g	5.67	18.89 e	16.00	53.33 c
	2000	0.67	2.22 no	2.33	7.78 k	3.33	11.11 g	5.67	22.22 e	13.67	45.56 c
	2500	1.67	5.56 mno	2.67	8.89 k	4.33	14.44 g	7.00	23.33 e	13.67	45.56 c
Spinetoram	1000	30.00	100.00 a	-	-	-	-	-	-	-	-
	1500	30.00	100.00 a	-	-	-	-	-	-	-	-
	2000	28.33	94.44 ab	30.00	100.00 a	-	-	-	-	-	-
	2500	26.33	87.78 c	30.00	100.00 a	-	-	-	-	-	-
	3000	23.00	76.67 ef	30.00	100.00 a	-	-	-	-	-	-
Dursban	1000	30.00	100.00 a	-	-	-	-	-	-	-	-
	1500	30.00	100.00 a	-	-	-	-	-	-	-	-
	2000	30.00	100.00 a	-	-	-	-	-	-	-	-
	2500	30.00	100.00 a	-	-	-	-	-	-	-	-
	3000	30.00	100.00 a	-	-	-	-	-	-	-	-
Pymetrozine	1000	11.00	36.67 j	22.67	75.56 d	24.33	81.11 c	26.67	88.89 b	30.00	100.00 a
	1500	11.00	36.67 j	15.00	50.00 ef	20.33	67.78 d	25.00	83.33 bc	30.00	100.00 a
	2000	9.67	32.22 jk	14.67	48.89 ef	20.00	66.67 d	24.33	81.11 bc	30.00	100.00 a
	2500	5.33	17.78 l	13.67	45.56 fg	20.67	68.89 d	24.33	81.11 bc	30.00	100.00 a
	3000	3.33	11.11 m	10.67	35.56 hi	17.33	57.78 e	22.67	75.56 c	30.00	100.00 a
Chlorantraniliprole	1000	16.33	54.44 i	28.67	95.56abc	30.00	100.00 a	-	-	-	-
	1500	18.67	62.22 h	26.33	87.78 c	30.00	100.00 a	-	-	-	-
	2000	21.67	72.22 fg	26.67	88.89 bc	30.00	100.00 a	-	-	-	-
	2500	18.33	61.11 h	28.33	94.44abc	30.00	100.00 a	-	-	-	-
	3000	18.00	60.00 hi	28.00	93.33abc	30.00	100.00 a	-	-	-	-
CK		0.00	0.00 o	0.00	0.00 l	0.00	0.00 h	0.00	0.00 f	3.67	12.22 d

3.2 Field protection effects of different insecticides against *Diaghania pyloalis*

In the autumn of 2020, Bifenthrin and Thiamethoxam were not selected because of their highly toxic to silkworms, 10 pesticides (shown in table 1) were selected for field control effect experiments against *D. pyloalis*. The results (shown in table 3) showed that the control efficacy of each treatment increased continuously within 7 days. Firstly, after 7 days of spraying, 2000 times solution of 40% Dursban Oil, 60g/L Spinetoram SA, 5% Chlorantraniliprole SA, and 1000 times solution of 77.50% Dichlorvos Oil, 40% Phoxim Oil had the best control effect against *D. pyloalis*, there was no significant difference in the control effect among different treatments, the control effects were higher than 98.79% and significantly higher than that of other treatments. Secondly, 2000 times solution of 10% Imidacloprid WP and 8% Chlorfenapyr MEhad better control effect, the control effects were 82.32% and 83.95%, respectively. Finally, the control effects of 2000 times solution of 25% Pymetrozine SA, 80% Cyromazine WDG, and 1000 times solution of 0.3% Azadirachtin Oil which were less than 60% were poor. The control effect of 0.3% Azadirachtin Oil which was less than 20% was the worst. After 20 days of spraying, 2000 times solution of 5% Chlorantraniliprole SA, 40% Dursban Oil, 60g/L Spinetoram SA had the best control effects against *D. pyloalis*, the control effects were 99.13%, 98.15%, and 93.65%, respectively. 1000 times solution of 77.50% Dichlorvos Oil and 40% Phoxim Oil had the better control effects which were 87.27% and 77.07%. The control effects of Imidacloprid and Chlorfenapyr at 2000 times liquid were poor, these were 64.61% and 63.85%. 80% Cyromazine WDG at 2000 times liquid and 0.3% Azadirachtin Oil at 1000 times liquid had the worst control effects, which were 42.98% and 24.95%, especially, the control effect of 0.3% Azadirachtin Oil was lower than 30%.

Table 3. Control effect of different insecticides against *Diaghania pyloalis* in mulberry field

Insecticides	Dilution times	Total number before application	Spraying for 1d		Spraying for 2d		Spraying for 5 d		Spraying for 7d		Spraying for 20d	
			Decline rate/%	Control effect/%	Decline rate/%	Control effect/%	Decline rate/%	Control effect/%	Decline rate/%	Control effect/%	Decline rate/%	Control effect/%
Imidacloprid	2000	19.30 n	31.23 e	30.70 e	57.43 c	56.97 c	72.93 b	72.08 b	83.13 b	82.32 b	79.60 b	64.61 cd
Chlorfenapyr	2000	19.00 n	43.24 d	42.81 d	64.38 c	63.99 c	70.82 b	69.91 b	84.68 b	83.95 b	79.16 bc	63.85 cd
Cyromazine	2000	17.90 n	8.64 fg	7.95 fg	15.60 e	14.67 e	28.30 c	26.06 c	41.06 d	38.25 d	67.13 cd	42.98 ef
Azadirachtin	1000	19.10 n	0.83 g	0.08 fg	3.40 f	2.34 f	13.44 d	10.73 d	21.89 e	18.16 e	56.74 d	24.95 f
Spinetoram	2000	22.90 n	73.43 b	73.23 b	89.24 b	89.12 b	97.20 a	97.11 a	99.52 a	99.50 a	96.34 a	93.65 ab
Dursban	2000	19.00 n	84.80 a	84.69 a	99.41 a	99.41 a	100.00 a	100.00 a	100.00 a	100.00 a	98.94 a	98.15 a
Pymetrozine	2000	18.60 n	14.45 f	13.80 f	27.96 d	27.18 d	29.02 c	26.80 c	55.12 c	52.97 c	75.12 bc	56.84 de
Chlorantraniliprole	2000	19.70 n	48.06 d	47.66 d	86.95 b	86.81 b	99.05 a	99.02 a	100.00 a	100.00 a	99.50 a	99.13 a
Dichlorvos	1000	18.80 n	81.14 ab	80.99 ab	93.68 ab	93.61 ab	98.18 a	98.13 a	98.85 a	98.79 a	92.66 a	87.27 ab
Phoxim	1000	18.90 n	61.69 c	61.40 c	93.01 ab	92.93ab	98.60 a	98.56 a	99.57 a	99.54 a	86.78 ab	77.07 bc
CK		18.90 n	0.76 g	0.00 g	1.08 f	0.00 f	3.03 e	0.00 e	4.56 f	0.00 f	42.35 e	0.00 g

4 DISCUSSION AND CONCLUSIONS

4.1 Discussion

Effective insecticides were evaluated to control *D. pyloalis* by indoor toxicity and field trials in this article, the results showed that 2000 times solution of 40% Dursban Oil, 60g/L Spinetoram SA, 5% Chlorantraniliprole SA, and 1000 times solution of 77.50% Dichlorvos Oil, 40% Phoxim Oil had the best control effect against *D. pyloalis*. According to the research reports (Chen, 2010), the insecticide residue in mulberry leaves for a long time when Chlorantraniliprole was sprayed on mulberry trees, and mulberry leaves used for rearing silkworms will do great harm to silkworms. Dursban is a commonly used insecticide in mulberry fields for pest control with low insecticide residue (Lan, 2021). The control effects of 2000 times solution of 25%Pymetrozine SA, 80% Cyromazine WDG, and 1000 times solution of 0.3% Azadirachtin Oil were poor, in particular, the control effect of 0.3% Azadirachtin Oil was the worst, because larvae still survived after feeding for 7 days in the high concentration area.

4.2 Conclusion

The 3rd instar larvae of *D. pyloalis* were selected as the experiment objects, and the indoor bioassay of 10 insecticides on *D. pyloalis* was carried out, and the results of the indoor bioassay were tested by field experiments. The results show that 2000 dilution of Dursban and Spinetoram, and 1000 times liquid of Dichlorvos can be used for *D. pyloalis* control in sericultural production. When using Chlorantraniliprole to control *D. pyloalis*, the leaves of mulberry should be picked with long interval to avoid affecting the quality of cocoons, and it is not recommended to use Cyromazine, Azadirachtin to control *D. pyloalis*. In addition, the integrated control technology such as agricultural control, biological control and physical control can be used in production to against *D. pyloalis*.

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REFERENCES

1. Cao Hongmei, Du Xianming, Hu Guiping, Wang Junwen, Wen Xinyue, Hu Lichun, Deng Zhenhua, Wang Feng, Huang Meizhen, Xia Feng. Controlling experiments of biological food attractants on *Diaghania pyloalis* [J]. Newsletter of Sericulture and Tea, 2020(06): 1-2+5.
2. Chen Weiguo, Dong Ruihua, Sun Haiyan, Dai Jianzhong, Zhu Haolong, Wu Fu'an. An In vestigation on Toxicity of the Agricultural Pesticide Chloran-traniliprole to the Silkworm,Bombyxmori [J]. Sericulture Science, 2010, 36(01): 84-90. DOI:10.13441/j.cnki.cykx.2010.01.005.
3. Lan Yiquan. Combined toxicity of chlorpyrifos and four Insecticides on Bombyxmori[J]. Agricultural Disaster Research, 2021, 11(04): 180-182.
4. Ren Jiequn, Zhang Minghai, Chen Li, Tan Lixin, Yi Yang. Screening of chemical insecticides against *Diaghania pyloalis* [J]. IOP Conference Series: Earth and Environmental Science,2020,615(1).
5. Wei Rijian. Study on control effects of 60% DDVP-Malathion emulsifiable on *Diaghania pyloalis* and residual toxic period in silkworms[J]. South China Agriculture, 2020, 14(02): 22-24 + 26. DOI: 10.19415 /j.cnki.1673- 890x. 2020.02.012.
6. Yang Songjie, Tian Hui, Pu Po, Xu Xiang, Ma Li, Wang Li. Occurrence regularity and control techniques of *Diaghania pyloalis*[J]. Plant Doctor, 2019, 32 (05): 73-75. The DOI: 10.13718 / j.carol carroll nki zwys. 2019.05.016.
7. Zhao Xuhua, Bai Xichuan, Shi Guofang. Research progress on occurrence regularity of *Diaghania pyloalis* and control techniques [J]. Sericulture Bulletin, 2013, 44(03):5-10.
8. Zhou Yuting, She Longyu. Occurrence trend and prevention measures of *Diaghania pyloalis* in Ningnan County [J]. Sichuan Canye, 2021, 49 (03): 55-56 + 59. DOI: 10.13886 / j.cnki. sccy. 2021.03.024.
9. Zhu Zhidong, Yang Bin, Zhou Jianqun, Hang Zhongbao. Occurrence and control strategies of *Diaghania pyloalis* in dongtai city [J]. Jiangsu Sericulture, 2016, 38(03): 12-15.