Philippine Journal of Science
153 (5): 1879-1885, October 2024
ISSN 0031 - 7683
Date Received: 27 Mar 2024

Efficacy of Select Insecticides against Corn Planthopper *Peregrinus maidis* Ashmead (Hemiptera: Delphacidae)

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One of the most significant insect pests of maize in the Philippines is the maize planthopper – scientifically known as *Peregrinus maidis* Ashmead (Hemiptera: Delphacidae) – which can inflict direct damage and spread the two main viral diseases to corn, the Maize mosaic virus, and Maize stripe virus. This study assessed the efficacy of three insecticides against *P. maidis* – namely azadirachtin, deltamethrin, and triflumezopyrim. Three different solutions were prepared and used, including the recommended rate. The evaluation focused on sublethal effects and mortality at 6, 12, 24, and 36 h intervals. The mortality rate of the *P. maidis* was significantly affected by the three insecticides, with *p*-values ranging from 0.000–0.008, indicating it is against the null hypothesis ($p < 0.05$). Only the 12-h data fit well, according to probit analysis, with a Pearson correlation of more than 0.80 (0.863–0.994). The findings showed that the LC_{50} values for azadirachtin, deltamethrin, and triflumezopyrim were 121.89, 12.05, and 8.84 mg/L. respectively. In terms of the treated group's sublethal effects, there was no statistically significant difference between treatments ($p > 0.05$). Thus, the assessed pesticides' effectiveness in controlling the *P. maidis* population and preventing its reproduction is notable.

Keywords: biopesticide, corn planthopper, insect vector, insecticide, *Peregrinus maidis*

INTRODUCTION

Maize (*Zea mays* L.) – following rice, wheat, and soybeans – is one of the most important crops in Asia and around the world. In the Philippines, it is utilized as food and animal feed. As reported by the Philippine Statistics Authority (PSA 2022), the total maize production is 915,592 mt, with white corn accounting for 22.24% and yellow corn for 77.76%. However, production dropped to 681,100 mt in the first quarter of the year.

Given its economic importance, maize is more vulnerable than many other crops to damage from various species of insects and diseases, from seedlings to storage. Unfortunately, harmful insect pest infestations – more specifically *Peregrinus maidis*, commonly known as maize planthoppers – compromised corn production. Various delphacid planthoppers pose a threat to corn plants, with *P. maidis* being one of them. This insect pest infests corn across many tropical and subtropical maize-growing countries worldwide (Hasibuan *et al*. 2021). *P. maidis* develops into three main phases – eggs, nymphs in Stages 1–5, and adults. It has been reported as a serious pest in Hawaii, transmitting corn mosaic virus and causing hopperburn. Furthermore, it attacks corn fields in neighboring countries such as Indonesia, India, Taiwan, and China (Nelly *et al*. 2017), becoming a limiting factor in maize production in the tropics.

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The common control used for *P. maidis* includes chemical treatments such as carbaryl and endosulfan. While chemical-based control of *P. maidis* has proven to be a practical and efficient solution, overuse has led to resistance, which has allowed insects to continue to rampage corn production and has seriously contaminated the environment (Yao *et al.* 2013). Although *P. maidis* does not have a specific program, experiments using several insecticides in the laboratory have revealed that the efficacy and residual effects of the chemicals vary. Imidacloprid has been found to effectively control *P. maidis* with significant mortality observed up to 7 d post-application (Zhang *et al.* 2016). Spinosa also demonstrated high efficacy in laboratory tests, and mortality rates for up to 10 d after treatment (Cisneros *et al.* 2002). In this paper, three insecticides against *P. maidis* were evaluated. Deltamethrin has been known to be effective against several insect pests – specifically the mosquito, *Aedes aegypti.* Moreover, according to Zhou *et al.* (2018), it successfully controls adult rice stem borers but not rice planthoppers. This paper would be the first study to assess its impact on maize planthoppers, notably *P. maidis*, as it has not yet been undertaken. Triflumezopyrim as its active ingredient, is a new product from DuPont Crop Protection. It is a new mesoionic chemical that effectively controls hoppers, particularly the brown planthopper *Nilaparvata lugens,* by interfering with the nicotinic acetylcholine receptor (n*AChR*), specifically blocking the orthosteric binding site. This disrupts normal neurotransmission, leading to the insect's death. According to Cordova *et al.* (2016), this mechanism of action is what makes this mesoionic chemical effective in controlling these pests. Azadirachtin is a biopesticide that is used against *N. lugens* (Raut 2000), this biopesticide functions as a growth regulator, antifeedant, and repellent for insects (Chaudhary *et al*. 2017). The goal of this study is to determine the most effective commercial insecticides at various concentrations, to determine their LC_{50} and LT_{50} values, and to evaluate the sub-lethal effects, specifically fecundity.

MATERIALS AND METHODS

The study was carried out in the Physiology Laboratory at the Institute of Weed Science, Entomology, and Plant Pathology (IWEP) within the College of Agriculture and Food Science (CAFS) of the University of the Philippines Los Baños (UPLB). The Laboratory is situated at approximately 14.1674° N latitude and 121.2433° E longitude in College, Laguna, the Philippines, with environmental conditions at temperatures of 20–30 °C, with relative humidity of 70–80%, and with natural light supplemented by artificial sources suitable for experimental needs.

Susceptible corn (UPLB Lagkitan) was obtained from the Institute of Plant Breeding of the UPLB. Corn seeds were planted in pots and placed in a greenhouse prior to the experiment. Some plants were covered in nets, whereas others were caged. Thirty (30) pots, each containing three seeds, were used. Thinning occurred 14 d after planting, and fertilizers were applied at that time as well. The plants were grown according to the cultural practices for corn to ensure optimal growth and development.

Populations of *P. maidis* were collected from a cornfield located at Pili Drive in UPLB using an insect net and aspirator. Adult *P. maidis* are characterized by their brown or white coloration and feed at the base of corn plants. *P. maidis* was placed in a container containing corn leaves. Masking tape was used to secure all the containers and were labeled accordingly.

P. maidis was grown in potted corn plants at the IWEP-CAFS-UPLB experimental nursery. Rearing of the test insect (*P. maidis*) underwent five instar nymphal development under laboratory conditions, feeding on maize plants under controlled conditions (25–30 °C, 70–80% humidity). After completing the fifth instar, nymphs molt into adults with fully developed wings. The adult females lay eggs on maize leaves. No pesticides were applied, and the F1 adult egg generation was separated and nurtured in new corn pots. The bioassay study used the nymph (4th instar) and adult F1 generations.

Table 1. Concentrations of three insecticides were used in the experiments.

Percentage concentration	Concentration (mg/L)		
	Triflumezopyrim	Deltamethrin	Azadirachtin
0	0	0	0
10%	12.25	3.00	12
25%	31.25	7.50	30
50%	62.50	15.00	60
75%	93.75	22.50	90
100% (RC)	125.0	30	120

Different insecticide concentrations were prepared (Table 1). The highest concentration, as recommended on the label, was used as the stock solution for preparing the other concentrations. Distilled water was used as the diluent to prepare the following concentrations from the stock solution: 10, 25, 50, and 75%. To prevent pesticide degradation, the stock solution was stored and kept in the refrigerator at 4 °C.

For each of the three insecticides (triflumezopyrim, deltamethrin, and azadirachtin), a bioassay was performed using the leaf dip method. The corn leaves measuring 8 cm by 5 cm were dipped in the respective insecticide solutions, the excess solution was thoroughly drained from the leaves, and they were allowed to air dry for 1 h. Dried leaves were placed in bioassay cups with a volume of 70 cm^3. Twenty (20) *P. maidis* individuals were released into each bioassay cup, which was then covered with a mesh net.

Mortality counts were taken at 6, 12, 24, and 36 h. Three replications of each pesticide concentration were tested. The control was a blank solution (distilled water) without any pesticide. Abbott's formula was used to adjust the death rates if natural mortality occurred in the control group (Abbott 1925).

$$Mortality\ (\%) = \frac{Percent\ survival_{Control} - Percent\ survival_{Treatment}}{Percent\ survival_{Treatment}}\ x\ 100$$

Sub-lethal effect (Fecundity)

To assess the pesticides' sub-lethal effects, 50 cm (L) x 50 cm (W) x 50 cm (H) cages were constructed, and the frame material used was stainless. This provides space for insects to exhibit their natural movements. The use of fine mesh gauze with a mesh size of 2 mm ensures proper ventilation and prevents insects from escaping while allowing for easy observation during experiments. These cages were constructed to keep the surviving 10 male and female pairs of *P. maidis* from the mortality test, along with corn plants inside the cages. The insecticides were applied to the corn plants using a spray bottle. The control group was maintained, where the insects were exposed to the same conditions but without any insecticide application. Female insects were allowed to oviposit for 7 d. Adults were removed after the oviposition period. After 10 days, nymphs were observed with the use of a magnifying device. Fecundity was measured by averaging the number of nymphs counted for each treatment.

Statistical Analysis

The log-dose probit model was utilized to estimate the lethal concentration (LC_{50}) needed to kill 50% of the test insect population, along with the calculation of 95% confidence intervals to assess the precision of the estimates. The LC_{50} was determined using the Minitab 19 application. Sublethal effects were analyzed using the STAR (Statistical Tools for Agriculture Research) software, applying significance levels of 5 and 1%. The treatment comparison was based on the least significant difference at 5% (LSD 0.05). Mortality data were standardized using Abbott's formula (Abbott 1925).

RESULT AND DISCUSSION

Lethal Concentration Estimation of the Three Insecticides (LC_{50})

The three pesticides were tested to determine *P. maidis* mortality. Tables 2–4. demonstrates the effect of triflumezopyrim on % mortality of *P. maidis*. The recommended dose of triflumezopyrim (62.5 mg/L) resulted in 100% mortality after 24 h.

For deltamethrin treatment, the recommended 100% mortality was obtained at a concentration of 15 mg/L after 24 h (Table 3), whereas the same was true for azadirachtin at a concentration of 12 mg/L after 36 h (Table 4).

Probit analysis was carried out to determine each

Table 2. Percent mortality of *P. maidis* treated with different concentrations of triflumezopyrim (N = 20, replicates = 3).

Triflumezopyrim concentration (mg/L)	Number of hours			
	6	12	24	36
0	0	0	0	0
15.625	13.33	50.00	96.67	100
31.25	13.33	63.33	96.67	100
62.50	16.67	80.00	100	–
93.75	26.67	83.33	100	–
125.0	20.00	93.33	100	–

Table 3. Percent mortality of *P. maidis* treated with different concentrations of deltamethrin (N = 20, replicates = 3).

Deltamethrin concentration (mg/L)	Number of hours			
	6	12	24	36
0	0	0	0	0
3.00	16.67	46.67	90.00	100.00
7.50	13.33	53.33	93.33	100.00
15.00	23.33	60.00	100.00	–
22.50	23.33	63.33	100.00	–
30	23.33	66.67	100.00	–

Table 4. Percent mortality of *P. maidis* treated with different concentrations of azadirachtin (N = 20, replicates = 3).

Azadirachtin concentration (mg/L)	Number of hours			
	6	12	24	36
0	0	0	0	0
12	3.33	13.33	40.00	100.00
30	3.33	20.00	60.00	100.00
60	6.67	26.67	63.33	100.00
90	13.33	36.67	76.67	100.00
120	20.00	50.00	76.67	100.00

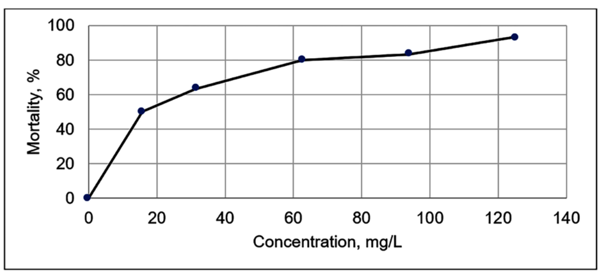

Figure 1. Percent mortality of *P. maidis* treated with different concentrations of triflumezopyrim.

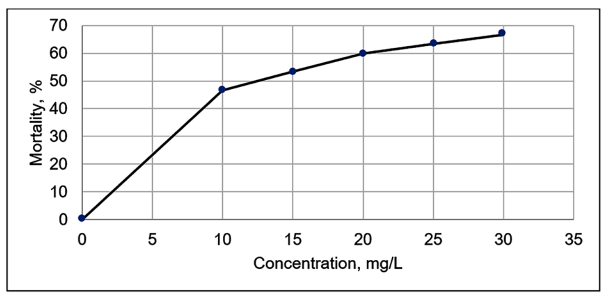

Figure 2. Percent mortality of P. maidis treated with different concentrations of deltamethrin.

insecticide's LC_{50}. Pearson's good fit was evaluated using Pearson correlation across different times at 6, 12, 24, and 36-h intervals. The findings revealed that only 12-h intervals provided a good fit, with Pearson correlation values greater than 0.80 for all insecticides. On the other hand, the other time intervals (6, 24, and 36 h) showed lower correlation values, indicating a weaker fit to the probit model.

Figure 1 shows that triflumezopyrim had a significant effect on death rates, with a *p*-value of 0.000 at the 95% confidence level. A Pearson goodness-of-fit value of 0.863 was obtained using probit analysis, indicating accurately assessed mortality and concentration.

Among pesticides used, triflumezopyrim proved to be the most harmful. In a similar study, Zhu *et al.* (2018) found that the LC_{50} for Pexalon varied between 0.88 to 1.31 mg a.i./L across various brown planthopper populations in Chinese rice fields, indicating widespread susceptibility. Guruprasad *et al.* (2016) found that triflumezopyrim was effective in managing *P. maidis* when used at application rates of 25 and 35 g a.i./ha at the Agricultural Research Station in Gangavathi, Karnataka, India. This demonstrates the insecticide's efficacy in managing pest populations in field conditions. However, a previous work by Caasi-Lit and Marmeto (2022) indicated that triflumezopyrim was also toxic to the predators of *P. maidis*, which led to a resurgence resurgence of the *P. maidis* population. This observation drives the potential development of resistance in *the P. maidis* population to triflumezopyrim. Several studies have shown resistance in various insect species to pyrazole insecticides, including triflumezopyrim. Clark *et al.* (2019) reported resistance mechanisms such as metabolic detoxification enzymes,

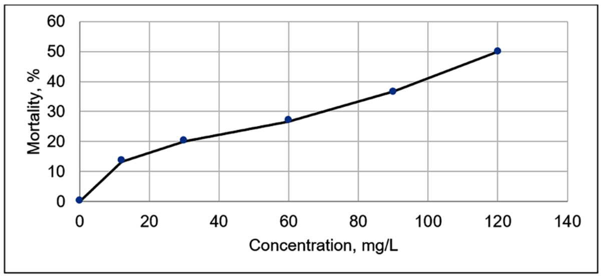

Figure 3. Percent mortality of *P. maidis* treated with different concentrations of azadirachtin.

this resistance develops under selection pressure from repeated insecticide application.

Similarly, deltamethrin (Figure 2) showed a significant effect on mortality rates, with a *p*-value of 0.008 at the 95% confidence level and an LC_{50} of 12.05 mg/L. A strong correlation between the probit model and the observed mortality rates was indicated by the Pearson goodness-of-fit value of 0.994, confirming the accuracy of the model in assessing deltamethrin's concentration-effect relationship. Deltamethrin has been known to be effective against several insect pests – specifically the mosquito (*Aedes aegypti*). However, its impact on non-target organisms has raised widespread concern. Deltamethrin adversely affects pollinators (*e.g.* bees) and predators such as ladybugs and lacewings. Studies show that long exposure to deltamethrin can lead to acute toxicity, behavioral changes, and reduced reproductive capacity. For instance, the sublethal effects of deltamethrin can impair the foraging behavior and learning abilities of *Apis mellifera*, which are crucial for pollination (Thompson and Maus 2007).

Azadirachtin (Figure 3) showed a significant effect on mortality rates, with a *p*-value of 0.000 at the 95% confidence level. An LC_{50} of 121.89 mg/L was obtained from the probit analysis, and a Pearson goodness-of-fit value of 0.993, indicating a strong correlation between the model and the mortality data. These results align with findings from Preetha *et al*. (2010), who observed that azadirachtin caused 90% mortality of *P. maidis* within 12 h of application at a concentration of 121.86 mg a.i./L, supporting the consistency of the current study. Azadirachtin, derived from the neem tree (*Azadirachta indica*), is a biopesticide that disrupts the growth and development of insects (Mordue and Nisbet 2000). Compared to deltamethrin and triflumezopyrim, neemactin offers several advantages azadirachtin is considered safe for humans and other mammals, with low acute toxicity and minimal side effects, making it suitable for integrated pest management. Moreover, due to its multiple modes of action, neemactin can be an effective tool in managing insecticide resistance. However, given its low toxicity, neemactin acts more slowly than deltamethrin and triflumezopyrim, leading to delayed mortality of insect pests. Hence, this slower action can be a disadvantage where immediate pest control is needed (Isman 2006).

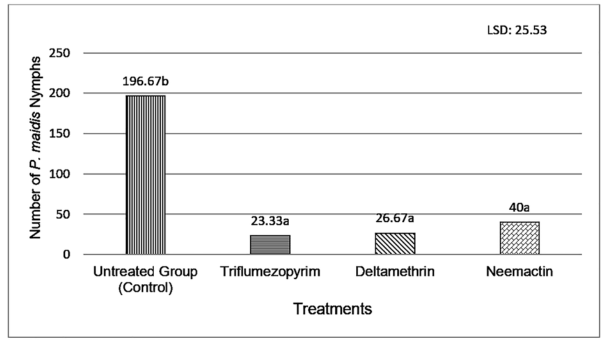

Figure 4. Fecundity of *P. maidis* in several pesticides' treatments and control.

As shown in Figure 4, the results indicate that the three tested insecticides – deltamethrin, triflumezopyrim, and azadirachtin – showed no significant differences in their effects on the fecundity of *P. maidis*. However, all three insecticides significantly differed from the control, implying that each insecticide effectively reduced fecundity compared to the untreated group.

Deltamethrin is known for its neurotoxic effects on insects, primarily targeting the sodium channels in nerve cells, leading to paralysis and death (Soderlund 2012). Studies have shown that sublethal doses of deltamethrin can affect insect reproduction. For example, research on *Aedes aegypti* showed that exposure to deltamethrin led to reduced oviposition and egg viability due to sublethal physiological effects (Dusfour *et al.* 2011). This coincides with our results, where deltamethrin significantly reduced fecundity compared to the untreated group.

Triflumezopyrim is a new pesticide that targets n*AChR*s in insect nervous systems, resulting in paralysis and death (Sparks *et al.* 2013). Various studies on insect pests, including planthoppers, have shown that triflumezopyrim effectively reduces insect populations by impairing feeding behavior and survival (Gorman *et al.* 2017). Although there are limited studies specifically focused on the effects of triflumezopyrim on fecundity (the ability of an organism to reproduce), our results indicate that this insecticide may interfere with reproductive processes. In this paper, insects exposed to triflumezopyrim showed a marked reduction in the number of offspring they produced compared to the untreated group. This suggests that triflumezopyrim could be impacting the reproductive system or behavior of the insects, leading to a lower reproduction rate. Azadirachtin disrupts insect growth and development by interfering with hormone regulation (Isman 2006). Azadirachtin has been shown to reduce fecundity in the diamondback moth (*Plutella xylostella*) and cotton bollworm (*Spodoptera armigera*), with significant reductions in egg production and hatchability reported after azadirachtin treatment (Martinez and van Emden 2014; Mordue and Nisbet 2010). This coincides with our results, where neemactin significantly reduced fecundity compared to the untreated group.

CONCLUSION

The evaluation of the three insecticides – triflumezopyrim, deltamethrin, and azadirachtin – showed strong effectiveness in both killing and reducing the reproduction of *P. maidis*. Triflumezopyrim at 62.5 mg/L and deltamethrin at 22.50 mg/L concentrations both achieved complete mortality of 100% within 24 h. Azadirachtin at 30 mg/L reached the same level of effectiveness within 36 h. The LC_{50} values at 12 h were effectively analyzed using probit analysis, with Pearson correlation coefficients ranging from 0.863–0.994. All three insecticides had a significant effect on mortality rates, with *p*-values ranging from 0.000–0.008 at a 95% confidence level. While deltamethrin, triflumezopyrim, and neemactin do not differ significantly from each other in their effects on *P. maidis* fecundity, they all significantly reduce fecundity compared to the untreated group. This indicates that each of these selected insecticides is effective in reducing the reproductive capacity of *P. maidis*.

ACKNOWLEDGMENTS

We are gratefully acknowledging the endless support received from the D110 Insect Physiology Laboratory of IWEP-CAFS-UPLB.

STATEMENT ON CONFLICT OF INTEREST

The author declares that they have no competing interests.

DECLARATION

For language and readability enhancement such as grammar and style, the authors utilized AI tools accessible at https://chatgpt.com/c/7ba8a29b-6f6a-42d6-93fe-b2dea89f80b3

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