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Comparative and combined toxicity of some microbial, chemical, and botanical pesticides on *Haplothrips tritici* K. (Thysanoptera: Phlaeothripidae) in laboratory conditions

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Introduction

Wheat (*Triticum aestivum* L.), with the highest production in the world, provides a large part of human nutritional needs. Wheat thrips, *Haplothrips tritici* (Kurdjumov) (Thysanoptera: Phlaeothripidae), is an important pest in wheat fields, which reduces the yield and the bakery value of wheat. Integrated pest management seeks to develop selective pesticides to exploit the interaction between biological and chemical control agents. Therefore, the use of low durability and unstable pesticides that are highly specialized for the target pest is important. It is also more cost-effective to use bio-pesticides in combination with chemical insecticides. Botanical and microbial insecticides are used as a substitute for chemical insecticides due to their less harmful effects on non-target organisms, human safety, easy biodegradability, and prevention of environmental pollution. The combination of biological and chemical insecticides to increase pest control efficiency may be synergistic, consuming lower concentrations of toxins and preserving natural enemies, while it can reduce environmental pollution due to chemical insecticides as well as insect resistance to insecticides. Also, it is very important to control wheat thrips and reduce the dose of chemical insecticides. Therefore, in this study, the insecticidal activity of botanical (Tondexir and Palizin) and microbial pesticides (*Bacillus thuringiensis* (B.t)) in combination with chemical (Thiacloprid and Thiacloprid+Deltamethrin) insecticides on wheat thrips was investigated.

Material & methods

This research was conducted in laboratory conditions. Wheat thrips (2nd instar nymph) were used for the experiment. Chemical insecticides (Thiacloprid and Thiacloprid+Deltamethrin) and bioinsecticides (Tondexir, Palizin, and *Bacillus thuringiensis* var. kurstaki (B.t)) were used in this study. The first experiment was performed to obtain the minimum and maximum concentrations (25% and 75% mortalities) of each insecticide on this pest by dilution method. Wheat leaves were soaked in insecticides for 10 s and 15 2nd instar nymphs were placed on leaves. Mortality was calculated after 12 hours. After identifying the concentrations that caused 25% and 75% mortality, three concentrations were determined using logarithmic distance. The final experiment was performed with five concentrations for each insecticide with control treatment. Distilled water was used as the control treatment. Thiacloprid and Thiacloprid+Deltamethrin contained five concentrations of 100, 250, 500, 750, and 1000 ppm. The five concentrations were 1300, 3200, 6500, 9800, and 13000 ppm for Palizin, 1700, 4250, 8500, 12500, and 17000 ppm for Tondexir, and 0.00025, 0.016, 0.9, 53, and 320 ppm for B.t. Wheat leaves were immersed in the concentrations prepared from insecticides for 10 s and then placed at room temperature for 10 min to dry. Leaves were then placed on the petri dish and 15 2nd instar nymphs were transferred to it. To examine the mixing of microbial insecticide with botanical and chemical insecticides, a chemical insecticide and a botanical insecticide with the lowest lethal concentration of 50% (LC_{50}) on the 2nd instar nymphs of thrips were selected, and then, two sub-lethal concentrations of 15% and 30% (LC_{15} and LC_{30}) were determined from them. Afterward, wheat leaves were immersed in LC_{15} and LC_{30} concentrations for 10 s. The 2nd instar nymphs were placed on leaves. Then, 12, 24, and 48 h later, the LC_{50} concentration of B.t was applied. Treatments were: LC_{15} insecticide, LC_{30} insecticide, LC_{50} B.t, LC_{15} insecticide+LC_{50} B.t, LC_{30} insecticide+LC_{50} B.t, and control (distilled water). The mortality was calculated 48 h later. The ~~amount~~ number of LCs was calculated by probit analysis with SPSS 16. Statistical analysis was done by ANOVA-One-Way. Mean comparison was performed by Duncan's multiple range test ($P \leq 0.05$) using SPSS 16.

Results & discussion

Probit diagrams of concentration logarithm-mortalities showed that with increasing the concentration of chemical and botanical insecticides, the rate of mortality increased in the 2nd instar nymphs of wheat thrips. With increasing duration after application of chemical and botanical insecticides, LC_{50}, LC_{30}, and LC_{15} decreased and thrips mortalities increased so that the lowest values of LC_{50}, LC_{30}, and LC_{15} were observed 48 h after application of Thiacloprid, Thiacloprid+Deltamethrin, Palizin, and Tondexir. After 12, 24, and 48, the lowest LC50 values among the chemical insecticides Thiacloprid and Thiacloprid+Deltamethrin were related to Thiacloprid+Deltamethrin and among the botanical insecticides, Palizin and Tondexir belonged to the Palizin. As a result, the chemical insecticide Thiacloprid+Deltamethrin and the botanical insecticide Palizin were used in the experiment related to the combined application with B.t insecticide. The LC_{50} value of B.t insecticide decreased with increasing time after its application and the mortality rate increased so that the lowest value of LC_{50} with a concentration of 2.34 ppm was obtained in 48 h after its application. The highest percentage of mortality (84.44%) was obtained at 1000 ppm Thiacloprid and after 48 h of application. The highest mortality percentage (88.89%) by Thiacloprid+Deltamethrin was related to the 1000 ppm after 48 h. The maximum percentage of mortality (82.22%) was observed in 13000 ppm Palizin after 48 h of application. The highest mortality percentage (62.22%) by Tondexir was related to the 17000 ppm after 48 h. The maximum mortality percentage (88.89%) by B.t was observed in the 320 ppm after 48 h. In the insecticide combination examination, the concentrations of 7 and 20 ppm of Thiacloprid+Deltamethrin, the concentrations of 26 and 72 ppm of Palizin, and the concentration of 221 ppm of B.t were evaluated on the 2nd instar nymphs of wheat thrips. The results of the analysis of variance showed that the effect of combined insecticides on the mortality of 2nd instar nymphs of wheat thrips at 12, 24, and 48 h was significant ($P < 0.01$). The highest percentage of mortality (76.67%) was observed in the combined application of B.t+LC_{15} Thiacloprid+Deltamethrin, especially after 48 h. The negative effects of B.t, Thiacloprid+Deltamethrin, and Thiacloprid insecticides on pests have been reported by other researchers, which was in line with the results of this study. Although Tondexir and Palizin do not have lethal effects similar to chemical insecticides, they, especially Palizin, had a relatively favorable effect on wheat thrips. The insecticide Thiacloprid is a neonicotinoid and therefore affects insect acetylcholine receptors, while Deltamethrin interferes by modulating the entry of sodium into the nervous system of insects. The effect of B.t on wheat thrips reduced the initial leaf consumption, indicating the effect of bacterial poisoning and anti-nutrition on this pest by infecting the insect's midgut.

Conclusion: The bioinsecticides Palizin, Tondexir, and B.t in a single application can be useful in controlling wheat thrips and can be used as an alternative to chemical insecticides. The combined application of insecticides can improve the control of wheat thrips and reduce the risk of thrips' resistance to insecticides as well as environmental pollution. The combined application of Thiacloprid+Deltamethrin LC_{15} with the B.t was highly toxic to wheat thrips and significantly controlled (76.67% mortality) the 2nd instar nymphs. It can be recommended after field studies as an alternative to chemical insecticides to protect wheat against thrips.

Keywords: *Botanical pesticide, Entomopathogenic bacteria, Biscaya, Proteus, Integrated control, Biological control*

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Conflict of interest declaration: The authors declare that they have no conflict of interest.