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Differential degradation dynamics of λ-cyhalothrin in mineral and peat soils: a comparative study under laboratory condition

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Received: 27 October 2023 / Accepted: 5 February 2024
Published online: 19 February 2024

Abstract
Dissipation kinetics of λ-cyhalothrin in mineral and peat soils of Semongok (mineral soil) and Sibu (peat soil) farms was investigated in a laboratory incubation experiment under different temperature and moisture conditions at normal and double application dosages. The soil was spiked with λ-cyhalothrin at 5 and 25 µg/g soil, respectively. The soil moisture content was adjusted to 20, 40, and 60% of field capacity and then incubated in three climatic chambers at 15, 25, and 35 °C. Samples were collected at 0, 7, 21, 42, 70, and 105 days and analysed by Gas Chromatography-Electron Capture Detector (GC-ECD). Pesticides from the soil were extracted via a facile-modified QuEChERS method. Recovery studies of λ-cyhalothrin in mineral and peat soils were carried out at 0.05, 0.1, 0.5 and 1.0 µg/g fortification levels. The percentage of recovered amount was in the range of 81.4–95.0% and 81.3–86.5% for mineral and peat soils, respectively which falls within the acceptable recovery range of 70.0–120.0%. Factors i.e., soil carbon content, moisture, temperature, and applied dosage that render the degradation of λ-cyhalothrin in mineral and peat soils were evaluated. Findings showed that faster λ-cyhalothrin degradation took place in soil that contained low organic carbon content (< 12%), low soil moisture (≤ 20%) and incubated under higher temperatures (≤ 35 °C). Degradation of λ-cyhalothrin was described by first-order kinetics in both mineral and peat soils at various conditions. Half-lives of λ-cyhalothrin in mineral soil were shorter compared to peat soil. This is due to its lower carbon content and lower soil organic matter availability. This study provides significant information to the agriculture industry and farmers on the important factors such as soil properties, environmental conditions and application dosage that will influence the fate of pesticides in soil.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s42452-024-05712-9.

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dosages showed that the larger pesticide treatment dosage (5 times) did not significantly impact the degradation rate of λ-cyhalothrin in soils. The possibility of soil matrix existing in the soils could also influence microbial degradation. Soil matrix promotes high sensitivity to chemical substances such as λ-cyhalothrin and rapid mineralization by soil microbes [39]. Similar studies also reported on the degradation of chlorpyrifos with only a slight increase of half-lives (1–2 times) [14]. While no significant differences of acephate's half-lives in humid tropical soils applied at similar application rates [13]. However, the half-life of λ-cyhalothrin under laboratory conditions would likely have a significant difference compared to field studies. Photodegradation is limited under laboratory conditions. Photodegradation of pesticides on soil surfaces in field studies is a key factor for faster dissipation and degradation due to the formation of by-products to reduce the toxic effects of pesticides. In field studies, the shorter half-life reported for λ-cyhalothrin degradation in tropical soils without crops was 5 days [35, 44]. For the other Py, the half-life of cypermethrin in soil was 5.6–7.6 days.

4 Conclusion

Factors such as soil carbon content, soil moisture level, surrounding temperature and application dosage that render the degradation of λ-cyhalothrin in mineral and peat soils were evaluated. From this study, soils having a lower percentage of organic carbon content (< 12%), low moisture level (≤ 20%) and kept under higher temperatures (≤ 35 °C) led to rapid degradation of λ-cyhalothrin. Degradation of λ-cyhalothrin was described by first-order kinetics in both mineral and peat soils for all factors tested. Half-lives of λ-cyhalothrin in mineral soil were shorter compared to peat soil. Soil with higher organic carbon content such as peat soil led to longer half-lives of λ-cyhalothrin. This was inferred that strong adsorption of λ-cyhalothrin onto soil organic matter hindered λ-cyhalothrin microbial degradation by limiting its bioavailability to soil microbes. λ-Cyhalothrin degradation in soils was accelerated at higher temperatures as the increasing temperature promotes higher microbial activity in the soils as well as other degradation processes. Higher soil moisture content decreased the degradation rate of λ-cyhalothrin in mineral and peat soils. The findings obtained from this laboratory incubation study are significant in providing knowledge and information to the farmers and the pesticide user on factors that may impact the degradation rate of a pesticide, especially λ-cyhalothrin in mineral and peat soils under humid tropical and temperate countries. Thus, the issue of λ-cyhalothrin contamination in the environment can be avoided. These findings can also be used as input for GAP programs to lessen the risks to the environment and health caused by the excessive usage of λ-cyhalothrin. Although the degradation of pesticides studies have been done worldwide by many researchers, much work is still needed to fully understand the degradation pattern of specific pesticides and surrounding factors and conditions that could inhibit their degradation following their application to soils. The application dosage of pesticides needs to be carefully considered, considering the specific pesticide type and soil characteristics, to minimize risks to the environment and human health.

Acknowledgements The authors would like to thank Universiti Malaysia Sarawak and the Ministry of Education for the research fund. The authors also wish to acknowledge Philip Gudom, Winnie Rosime and Tay Guan Tong from the Pesticides Residue Laboratory for technical assistance.

Author contributions Experimental work was performed by C.R., and M.C.H. The Manuscript was written and edited by Z.N., S.F., M.C.H and A.C. All authors read and approved the final manuscript.

Funding This work was supported by the Ministry of Higher Education Malaysia, fundamental research grant scheme, FRGS/1/2019/STG01/UNIMAS/01/1.

Data availability All experimental data generated in this study are available on request to the corresponding author if required.

Declarations

Ethics approval and consent to participate This article does not contain any of the authors' research on human participants or animals.

Consent for publication The authors agree to publish this article.

Competing interests The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Generative AI in scientific writing The application dosage of pesticides needs to be carefully assessed by considering the specific pesticide type andsoil characteristics to minimize risks to the environment and human health.