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Research Article
Dissipation of Lambda-cyhalothrin under Organic Amendment in Vegetable Soils in Burkina Faso under Laboratory Conditions

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Abstract
Background and Objective: Pyrethroids are a group of pesticides widely used currently. Lambda-cyhalothrin is a pyrethroids insecticide used in Burkina Faso for crop protection. This insecticide efficacy is well known by vegetable farmers. However, no information is available on the persistence of lambda-cyhalothrin in soil under Burkina Faso climate conditions. The objective of this study was to determine the persistence of lambda-cyhalothrin in vegetable soil in Burkina Faso. **Materials and Methods:** The first experiment to determine the persistence of lambda-cyhalothrin was carried out under laboratory conditions in sterile and non-sterile soil to evaluate the microbial contribution to degradation. The second experiment has been done in soil with and without manure to evaluate the contribution of manure to lambda-cyhalothrin degradation. **Results:** During the incubation, 73.2% of lambda-cyhalothrin degraded in 7 days in non-sterile soil as opposed to 12.0% in sterile soil during the same period. During all the incubation period (20 days), lambda-cyhalothrin degradation was still slow in sterile soils (64%) compare to the degradation in non-sterile soil (83.7%). The half-life of lambda-cyhalothrin in sterile and non-sterile soil was 27.36 and 14.33 days, respectively. The results of the contribution of manure to lambda-cyhalothrin degradation have showed that the dissipation in soil in the presence of manure is higher (26.25%) than the dissipation without manure (21.5%) during the first 7 days and from 8-20 days after incubation. **Conclusion:** Microorganisms, abiotic factors and soil organic manure contribute to the dissipation of lambda-cyhalothrin in the soil.

Key words: Micro-organisms, soil, lambda-cyhalothrin, dissipation

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Pyrethroids are synthetic analogs, structural derivatives of the naturally occurring pyrethrins, which have known efficacy against a wide range of insect pests and their non-persistency in the environment[1]. Most of the earlier synthetic pyrethroids were successfully commercialized mainly for the control of household insects as well as agriculture. In agriculture, pyrethroids are used for protection of many crops like rice[2] and vegetables[3]. However, because of their high toxicity to aquatic organisms pyrethroids are banned in some countries like China[4].

Among pyrethroids, lambda-cyhalothrin is the most used insecticides in vegetable garden in Burkina Faso[3]. Lambda-cyhalothrin is a 1:1 mixture of two stereoisomers, (S)-α-cyano-3-phenoxybenzyl- (Z)-(1R,3R)-3-(2-chloro-3,3,3-trifluoroprop-1-enyl)-2,2-dimethyl cyclopro-panecarboxylate and (R)-α-cyano-3-phenoxybenzyl-(Z)-(1S, 3S)-3-(2-chloro-3, 3, 3-trifluoroprop-1-enyl)-2,2-dimethyl-cyclopropanecarbo-xylate. It allows controlling pests in tomato, onion and cabbage garden. Lambda-cyhalothrin has been widely used to control insect pests, including aphids and coleopterous and lepidopterous pests, in cotton, cereals, hops, ornamentals, potatoes, vegetables and flowers in agriculture, gardens and homes[2]. In addition, the pesticide has been applied to control cockroaches, mosquitoes, ticks and flies in public health management[1].

Lambda-cyhalothrin is widely used by vegetable farmers in the three biggest cities of vegetables production in Burkina Faso (Ouagadougou, Bobo Dioulasso and Ouahigouya). Between 24 and 31% of farmers use lambda-cyhalothrin for crop protection in Burkina Faso.

A wide range of insecticides used for crop protection contaminated soils and affects their fertility. The residues of lambda-cyhalothrin have been detected in many environmental matrices. For example, lambda-cyhalothrin concentration has been reported to be 7-10 μg kg^{-1} in sediment and soil in Burkina Faso[5]. The behavior of lambda-cyhalothrin in the soil is controlled by some factors such as pH[6], adsorption[7] and photo-Fenton reaction[8]. The degradation of lambda-cyhalothrin by micro-organisms is also important for the elimination of lambda-cyhalothrin residue in farm soil[9].

The behavior of lambda-cyhalothrin in soils used for vegetable garden need to be investigated in Burkina Faso. The objective of this study is to determine the persistence of lambda-cyhalothrin in vegetable soil in Burkina Faso. It hypothesized that soil micro-organisms contribute to degrade a great part of lambda-cyhalothrin and organic amendment at the rate used by farmers in Burkina Faso increase the dissipation of pesticide residues in soils.

MATERIALS AND METHODS

The experiment was conducted at the laboratory of the Division of Agricultural Chemicals, Indian Agricultural Research Institute, New Delhi during 4 months from January-April, 2014.

Lambda-cyhalothrin: Lambda-cyhalothrin is an insecticide with the chemical formula $C_{23}H_{19}ClF_3NO_3$ from the pyrethroid family. It is used to control sucking insects such as; caterpillar, tomato worm, aphids, leafhoppers and cucurbit flies, particularly on the vegetables and fruits. Lambda-cyhalothrin is considered as an endocrine disruptor (E.C., 2004)[10]. Prior to the previous investigations, lambda-cyhalothrin is used by vegetable farmers in Burkina Faso, especially in the areas of Ouagadougou, Bobo-Dioulasso and Ouahigouya[3].

The physical and chemical properties of the lambda-cyhalothrin are summarized in Table 1.

Chemicals and reagents: A reference standard of lambda-cyhalothrin (purity 98%, Chem service) was supplied from India. All the solvents (acetone and dichloromethane) were analytical grade and purchased locally. Anhydrous sodium sulfate (AR grade) was used as a drying agent for different samples.

Instrument and operating conditions: The lambda-cyhalothrin residues were analyzed on Varian CP 3800 Gas Liquide Chromatograph (GLC) equipped with electron capture detector (ECD) and CP-Sil 5 CB (25 m×0.25 mm×0.25 μm) column. Helium (purity $\geq$99.999%) was used as the carrier gas at a flow rate of 1 mL/min. One microliter of extract was injected in split less mode. The injection temperature was 280°C. The oven temperature was initially 200°C, ramped to 260°C at a rate of 10°C/min, held at 260°C for 1 min, climbed to 270°C at 30°C/min and held there for 12 min. Total run

Table 1: Physical and chemical properties of the lambda-cyhalothrin

Parameters	Lambda-cyhalothrin
CAS no.	91465-08-6
Molecular weight	449.9
Number of isomers	2
Solubility in water (mg L^{-1})	0.0008 (25°C)[a,b,c]
Kow (L kg^{-1})	10^{7}[a,d,e] (20°C)
Predicted Kow[f]	$10^{6.85}$

[a]SRC physical properties database. [b]Meylan *et al.*[11], [c]Worthing and Walker[12], [d]Wauchop *et al.*[13], [e]Tomlin[14] and [f]Biobyte[15]

Table 2: Physical and chemical properties of the soil and manure sampled in the experiment of Ouahigouya's vegetable farms in Burkina Faso

Properties	Soil	Manure
Clay (%)	14.29	-
Silt (%)	25.56	-
Sand (%)	60.15	-
Ct (g kg^{-1})	308.00	411.20
Nt (g kg^{-1})	24.07	24.85
C/N (g kg^{-1})	12.79	16.54
Pt (mg kg^{-1})	720.00	8210.00
Kt (mg kg^{-1})	1216.00	10250.00
pH	6.80	7.96

time was 10.33 min. The MS was operated in selected ion monitoring (SIM) mode and characteristic fragment ions (m/z = 181, 197 and 208) were used for the lambda-cyhalothrin analysis. Under these GC conditions lambda-cyhalothrin retention time (RT) was at 8.55 min.

Soil and organic amendment: The soil samples were collected from the vegetable garden located in the city of Ouahigouya, Burkina Faso (3°35 00" N, 2°25 00" W).

Sampling sites were in vegetable production areas and determined by use of multilocation random sampling.

The samples were sieved through 2 mm mesh. For the experiment, the manure was added at the rate of 5% that is around the recommended rate of 20 t ha^{-1}. Manure was obtained locally in Ouahigouya, Burkina Faso. Soil and manure were air dried and characterized as described earlier by Nare *et al.*[3] (Table 2).

Field capacity determination: The amount of water required to bring the air dry soil to field capacity moisture level was determined by placing 100 g of dry soil in a 100 mL capacity measuring cylinder.

The cylinder was gently tapped to give proper packing. Water (10 mL) was then added carefully without disturbing the soil layer. The cylinder was capped with aluminum foil and kept undisturbed. The level of wet soil (volume) was recorded after 24 h in a room temperature. From the volume of wetted soil, the amount of water required to wet 100 g of dry soil (the field capacity) was calculated. The field capacity of the test soil[16] was found to be 19.60%.

Effects of manure on the dissipation of lambda-cyhalothrin in soil: A quantity 10 g of soil with or without manure (5%) was moistened at the field capacity moisture, then 1 mL of lambda-cyhalothrin (100 µg mL^{-1}) was added to obtain a concentration of 10 µg g^{-1} of soil. The samples were incubated at room temperature and moisture was maintained by adding water at regular intervals. Samples were taken 0, 1, 3, 7, 13 and 20 days after incubation to determine the amount of pesticide remaining in the soil. The difference between the amount of pesticide added and that remaining in the soil is the amount dissipated.

Microbial degradation of lambda-cyhalothrin in soil: Microbial degradation of lambda-cyhalothrin was studied in sterile soil (SS) and non-sterile soil (S). Soil (10 g) was sterilized by auto-claving twice at 120°C for 30 min. Soil sterilization was performed immediately before commencement of the degradation study and the SS was subsequently handled under aseptic condition. Both actions were taken in order to maintain soil sterility throughout the experiment time. Three replicate of SS samples were prepared. The lambda-cyhalothrin was applied at the rate of 10 µg g^{-1} de sol. All treated samples were incubated in the dark at 25°C and moisture was maintained by adding water regularly. Sub-samples were taken at 0, 3, 7, 13 and 20 days after incubation. From each sub-sample lambda-cyhalothrin was extracted and analyzed to monitor the half-life of the compound, for the half-life was calculated by means of the equation:

$$T1/2 = \frac{In\ 2}{k}$$

where, T1/2 is the half-life and k is the apparent elimination constant. The first-order equation provided a satisfactory fit for the data (r>0.9) providing the basis for the half-life calculation.

Lambda-cyhalothrin extraction and clean-up: For each sample, 20 mL of acetone was added to flasks containing soil and shaken on a horizontal shaker for 30 min and the supernatant phase was filtered in a flask through a funnel by using a water pump. The extraction was repeated twice with the same solvent and filtered in the same flask. About 50 mL of 10% $NaCl_2$ was added and then extracted with dichloromethane three times. They were then evaporated followed by diluting in hexane for Gas Liquid Chromatograph (GLC) analysis[16].

Statistical analysis: Data is the mean of three repetitions of each treatment and the bars represent the standard error of the mean. Regression equation and means have been determined by using excel software version 2013.

RESULTS AND DISCUSSION

Microbial degradation of lambda-cyhalothrin in the soil: Sterile and non-sterile soils were used to test the microbial degradation of lambda-cyhalothrin. Results showed that degradation was faster in non-sterile soil than in sterile soil, indicated the role of microbes in lambda-cyhalothrin degradation (Fig. 1). During the incubation, 73.2% of lambda-cyhalothrin degraded in 7 days in non-sterile soil as opposed to 12.0% in sterile soil during the same period (Fig. 2). During all the incubation period (20 days), lambda-cyhalothrin degradation is still slow in sterile soils (64%) compare to the degradation in non-sterile soil (83.7%). The half-life of lambda-cyhalothrin in sterile and non-sterile soil was 27.36 and 14.33 days, respectively (Table 3). The rate of disappearance of lambda-cyhalothrin in sterile and non-sterile soil followed first-order kinetics. The data fitted well the regression equations with R^2 values of 0.96 and 0.94, respectively in sterile and non-sterile soil. Apparently, the degradation of lambda-cyhalothrin was mainly caused by soil microbial activity.

Several studies have found that a rapid loss of lambda-cyhalothrin was observed in non-sterile soil, while only slight dissipation occurred in sterile soil[6,17,18]. Lambda-cyhalothrin has been degraded in sterile soil without microbial activity, this suggested that lambda-cyhalothrin was unstable in soil and could be degraded partially by an abiotic process. Indeed, Wang *et al.*[6] reported that lambda-cyhalothrin was hydrolysed to cyanohydrin in a alkaline soil conditions. This showed that soil pH play an important role in the degradation of lambda-cyhalothrin. In addition to hydrolysis, other abiotic processes like adsorption[7,19] and transformation[9,20] photo-Fenton reaction[8] promoted up to 100% of lambda-cyhalothrin degradation in soil.

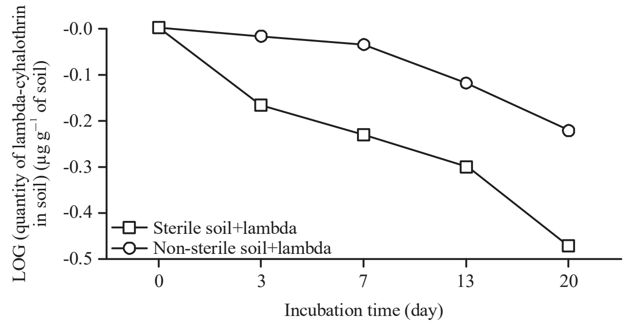

Fig. 1: Linear plots for dissipation of lambda-cyhalothrin in sterile and non-sterile soil

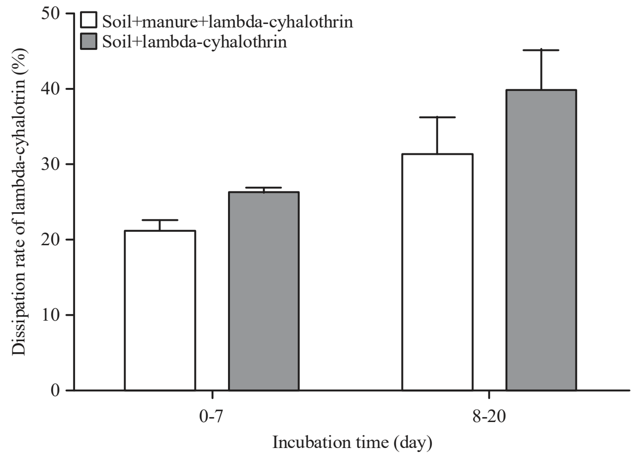

Fig. 2: Dissipation of lambda-cyhalothrin in the soil with manure and without manure

Table 3: Half-life, correlation coefficient and regression equation in sterile soil and non-sterile soil

Type of soil	Half-life (days)	Correlation coefficient r^2	Regression equation
Sterile soil	27.36	0.9636	Y= -0.0113x+0.0178
Non-sterile soil	14.33	0.9414	Y= -0.021x+0.0537

Effect of manure on the dissipation of lambda-cyhalothrin in soil: The results have showed that the lambda-cyhalothrin dissipation in the presence of manure is higher (26.25%) than the dissipation without manure (21.5%) during the first 7 days and from 8-20 days after incubation (Fig. 1). This can be explained by the phenomenon of cometabolism, where manure is degraded primarily by soil micro-organisms. The enzymes secreted during this degradation and transform the pesticides present in the soil. Indeed, studies carried out on the impact of organic amendments on the degradation of pesticides have showed a stimulation of the degradation. Nare *et al.*[21] have observed that endosulfan degradation was 1.5 and 1.3 time more in the soil with manure at the rate of 6.67 and 3.33 g kg^{-1} of soil, respectively. This indicated that the degradation rate is proportional to the amount of manure in the soil. Under a field conditions, Das and Mukherjee[16] showed an increase of flubendiamide degradation after manure application. The half-life passed from 151.1-130.8 days after manure application. The interaction between pesticides and organic amendment lead to pesticide adsorption[21]. This showed that application of organic manure increases the organic carbon content of the soil, hence, increases soil microbial activity. According to Kookana[22], there was a significant decrease of the rate of microbial degradation of pesticides in soil after adsorption by organic matter. This can be explained by the unviability of pesticides in the soil solution. However, Schnurer[23] showed a stimulation of the pesticides degradation after adsorption by organic matter in the soil. This could be explained by the possibility of the pesticides availability through desorption process after their adsorption by organic matter in soil.

Further research is necessary, both on the level of semifield and field conditions to take into account environment conditions like volatilization and rains.

CONCLUSION

The present study clearly demonstrated that the micro-organisms in soil from Ouahigouya's vegetables garden in Burkina Faso contribute to the degradation of lambda-cyhalothrin in the soil. However, the dissipation of lambda-cyhalothrin in sterile soil shows that some abiotic factors lead to its degradation. The rate of manure used in vegetable garden to maintain soil fertility stimulates the degradation of lambda-cyhalothrin in the soil. It will be interesting to determine the rate of lambda-cyhalothrin degradation under different types of soils and organic amendments used by farmers in Burkina Faso.

SIGNIFICANCE STATEMENT

This study discovered that the rate of manure used by farmers in Burkina Faso can be beneficial to reduce the effects of lambda-cyhalothrin on soil organisms and be used for soil depollution. The results can be beneficial for farmers and all the population in term of using this rate of manure for soil depollution to reduce the pesticides impacts on human health.

This study will help the researchers to uncover the critical areas of soil pollution that many researchers did not explore.

REFERENCES

1. Gu, B.G., H.M. Wang, W.L. Chen, D.J. Cai and Z.J. Shan, 2007. Risk assessment of λ-cyhalothrin on aquatic organisms in paddy field in China. Regulat. Toxicol. Pharmacol., 48: 69-74.
2. Zalom, F.G., N. Toscanoand F.J. Byrne, 2005. Managing resistance is critical to future use of pyrethroids and neonicotinoids. California Agric., 595: 11-15.
3. Nare, R.W.A., P.W. Savadogo, Z. Gnankambary, H.B. Nacro and M.P. Sedogo, 2014. Analyzing risks related to the use of pesticides in vegetable gardens in Burkina Faso. Agric. For. Fish., 4: 165-172.
4. Weston, D.P., J. You and M.J. Lydy, 2004. Distribution and toxicity of sediment-associated pesticides in agriculture-dominated water bodies of California's central valley. Environ. Sci. Technol., 38: 2752-2759.
5. Lehmann, R.E.G., 2017. Impact assessment of pesticides applied in vegetable-producing areas in the Saharan zone the case of Burkina Faso. EPFL: Infoscience. https://infoscience.epfl.ch/record/233605
6. Wang, S., S.W. Kimber and I.R. Kennedy, 1997. The dissipation of lambda cyhalothrin from cotton production systems. J. Environ. Sci. Health Part B, 32: 335-352.
7. Jiang, W., J. Gan and D. Haver, 2010. Sorption and desorption of pyrethroid insecticide permethrin on concrete. Environ. Sci. Technol., 45: 602-607.
8. Colombo, R., T.C. Ferreira, S.A. Alves, R.L. Carneiro and M.R. Lanza, 2013. Application of the response surface and desirability design to the Lambda-cyhalothrin degradation using photo-Fenton reaction. J. Environ. Manage., 118: 32-39.
9. Zheng, B., X. Zhao, L. Liu, Z. Li and K. Lei *et al*., 2011. Effects of hydrodynamics on the distribution of trace persistent organic pollutants and macrobenthic communities in Bohai Bay. Chemosphere, 84: 336-341.
10. EC., 2004. Commission staff working document SEC (2004) 1372 on implementation of the community strategy for endocrine disrupters-A range of substances suspected of interfering with the hormone systems of humans and wildlife (COM (1999) 706). Europaische Kommission, Brusse.
11. Meylan, W.M., P.H. Howard and R.S. Boethling, 1996. Improved method for estimating water solubility from octanol/water partition coefficient. Environ. Toxicol. Chem.: Int. J., 15: 100-106.
12. Worthing, C.R. and S.B. Walker, 1987. The Pesticide Manual. A World Compend. 8th Edn., British Crop Protection Council, UK.
13. Wauchop, R.D., T.M. Buttler, P.W.M. Hornsby, B. Augustijn and J.P. Burt, 1992. The SCS/ARS/CES pesticide properties database for environmental decision-making. Rev. Environ. Contain. Toxicol., 123: 1-155.
14. Tomlin, C.D.S., 1997. The Pesticide Manual. 11th Edn., The British Crop Protection Council, Surrey, UK.
15. Biobyte, 1999. CLOGP for Windows Ver. 4.0. Biobyte Corpration, Claremont, USA.
16. Das, S.K. and I. Mukherjee, 2012. Effect of moisture and organic manure on persistence of flubendiamide in soil. Bull. Environ. Contamin. Toxicol., 88: 515-520.
17. Laabs, V., W. Amelung, A. Pinto, A. Altstaedt and W. Zech, 2000. Leaching and degradation of corn and soybean pesticides in an oxisol of the Brazilian cerrados. Chemosphere, 41: 1441-1449.
18. Tariq, M.I., S. Afzal and I. Hussain, 2006. Degradation and persistence of cotton pesticides in sandy loam soils from Punjab, Pakistan.. Environ. Res., 100: 184-196.
19. Ali, M.A. and P.J. Baugh, 2003. Sorption-desorption studies of six pyrethroids and mirex on soils using GC/MS-NICI. Int. J. Environ. Anal. Chem., 83: 923-933.

20. Zheng, L.L., H.J. Mou and J. Li, 2012. Determination and microbial degradation of lambda-cyhalothrin. Adv. Mater. Res., 343: 430-437.
21. Nare, R.W.A., P.W. Savadogo, V.T. Gajbhiye, S. Gupta, N. Singh, H.B. Nacro and M.P. Sedogo, 2017. The role of manure on adsorption-desorption of profenofos and acetamiprid in the agricultural soils of Burkina Faso. Int. J. Innov. Trends Eng. Res., 2: 55-63.
22. Kookana, R.S., 2010. The role of biochar in modifying the environmental fate, bioavailability and efficacy of pesticides in soils: A review. Soil Res., 48: 627-637.
23. Schnurer, Y., 2006. Influence of soil properties and organic pesticides on soil microbial metabolism. Ph.D. Thesis, Acta Universitatis Agriculturae Sueciae, Department of Forest Ecology and Management, Umea, Sweden.