Simulating the Environmental Fate of Cypermethrin Using the PeFT Rice Model

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Abstract –*Simulation of the environmental fate of an insecticide in a paddy field is very important to come up with an effective cultural management practice that would minimize its adverse effect on the environment and the society. Furthermore, due to complexity and high cost of laboratory analysis, the use of a model is indispensable. The study is aimed at simulating the residue concentration of cypermethrin insecticide in the ponded water of a paddy field using the PeFT Rice Model. Four (4) identical paddy plots uniformly planted with the same rice variety were setup for this experiment. Each paddy plot was uniformly sprayed at the same rate with cypermethrin insecticide. Water samples were collected from each plot during Days 0 (before pesticide application), 1, 2, 3, 5, 7 and 14 following standard protocols and were analyzed using the liquid chromatography method at a third party laboratory.*

Result of the study revealed that cypermethrin insecticide could last in the paddy water up to five (5) days after its application. Hence, in order to prevent or minimize insecticide contamination of proximate bodies of water that serves as drainage basins, lowland rice farmers should ensure containment of paddy water and should not be drained from the field up to five days after the application of the insecticide. Moreover, the PeFT Rice Model can correctly simulate the environmental fate of cypermethrin insecticide in the paddy field as proven by its very low root mean square error (RMSE) value of 5.78%.

Keywords –*Environmental fate of pesticide, PeFT Rice Model, pesticide concentration simulation*

INTRODUCTION

With the objective of increasing rice production in order to supply the increasing food demand of the increasing population and become rice sufficient in spite of decreasing land and water resources, rice farmers are prompted to utilize high yielding varieties that are heavily dependent on agrochemicals like synthetic fertilizers and pesticides. And due to decreasing soil fertility coupled with increasing severity of pest and diseases, farmers are becoming more reliant on agrochemicals just to ensure high yield and income.

Numerous studies however, revealed that frequent use of pesticides has adverse impacts both in the environment and the society. Rice production is considered as a major contributor to pesticide contamination of the environment [1] and it is conveyed to the environment through the water that flows from the application points [2]. In irrigated rice irrigation system, all runoff from rice fields is collected in the main drainage system and this ultimately discharges the effluent into water bodies such as river, lake, or the sea[1]. In the Philippines, many of the river and canal systems received inputs of potentially contaminated wastewaters either from point sources and/or diffuse run-off from agricultural land [3]. Moreover, 37% of total water pollution originates from agricultural practices, which include animal wastes and fertilizer and pesticide runoffs[4].

Evidences also reveal that serious health consequences are significantly associated with indiscriminate use and long term exposure to pesticide[5]. In addition to this, some pesticides are suspected to be, or are recognized as mutagenic, carcinogenic, teratogenic, endocrine disruptors, or immunosuppressive in humans [6].

Cypermethrin belongs to a group of chemicals called pyrethroids. It is a synthetic chemical similar to the pyrethrins in pyrethrum extract (which comes from the chrysanthemum plant). Pyrethroids insecticides, including cypermethrin are developed to have properties better than those of the pyrethrins [7]. The product is available as an emulsifiable concentrate or wettable powder. It is one of the most commonly used insecticides in lowland rice production and is categorized in the Philippines as Category II, yellow labelled insecticide. Insecticidal products containing pyrethroids have been widely used to control insect pests in agriculture, public health, and homes and gardens [8]. In agriculture, target crops include cotton, rice, cereals, ornamentals, potatoes, and vegetables, with applications made to control aphid, coleopterous, and lepidopterous pests [9]. Pyrethroids are also important tools used in public health management where applications are made to control cockroaches, mosquitoes, ticks, and flies, which may act as disease vectors. Pyrethroids like cypermethrin works by disrupting the normal functioning of the nervous system when ingested or contacted by an organism [7]. By disrupting the nervous system of an insect it may cause paralysis or death [10].

Considering the harmful effects of the heavy and frequent application of pesticides that could be inflicted to humans and the environment and since paddy fields is one of the major source of pesticide contaminated water that could contaminate nearby bodies of surface water such as ponds, creek, rivers and lakes where it discharges into, there is a need to strictly monitor and quantify concentrations of pesticide residue in the paddy water in order to prevent or minimize its harmful effect. Furthermore, since daily water sampling is a very burdensome task for a farmer to do combined with a very complex and costly laboratory analysis, the utilization of a model that could simplify and facilitate the monitoring and assessment is indispensable.

OBJECTIVES OF THE STUDY

Generally, the study is aimed at simulating the environmental fate of cypermethrin in a lowland paddy field. Specifically, it aims to simulate the daily cypermethrin residue concentration in the ponded water of a paddy field.

MATERIALS AND METHODS

Four (4) identical paddy plots with dimensions of 8m x 8m were setup for this experiment. The plots were planted with the same rice variety and the paddy dikes were constructed such that water entry and exit were completely controlled. To ensure that no other insecticide will be loaded in the area, the paddy fields were irrigated by pumping water from adeep well. Each paddy plot was uniformly sprayed at the same rate with cypermethrininsecticide at Day 0. Water samples were collected from each plot during Days 0 (before pesticide application), 1, 2, 3, 5, 7 and 14 following standard protocols. However, due to financial limitations water samples were not collected from the drainage channel. Three (3) liters of water samples were collected and were placed in three 1-liter amber bottles. The bottles were covered with cork and aluminium foil and properly sealed with packing tape to avoid spillage during transport. Immediately after sampling, water samples were placed in an insulated box with ice in order to preserve the samples during transport to the laboratory for analysis. The water samples were analyzed using the Liquid Chromatography method at a third party laboratory in Quezon City, Philippines.

The PeFT Rice Model

The PeFTRice Model was developed by the author to simulate the concentration of pesticide in the ponded and drainage water of a paddy system by tracking mathematically the total mass of chemical residue in the loading point to the drainage channel in terms of mass balance. Basic input data needed are the rate of pesticide application, physico-chemical properties of pesticide as well as characteristics of the paddy field and drainage channel. Output of the program is the daily pesticide concentration in the ponded water and at different lengths of the drainage channel. Fig. 1 shows the general concept and different processes taken into account by the model.

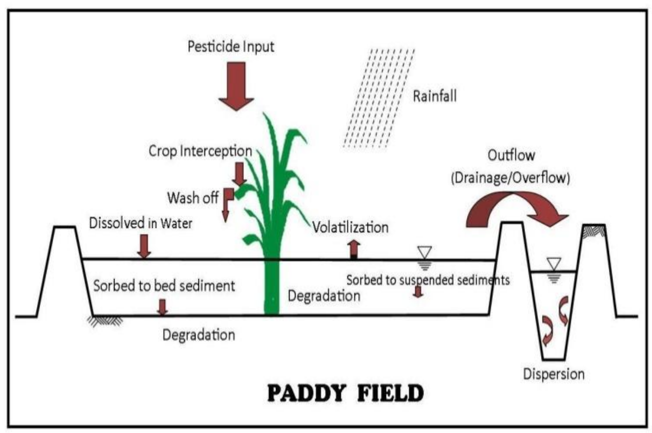

Fig. 1. The PeFTRice Model

With the assumption that there is no pesticide loss during application due to drifting, Fig. 1 shows that part of the pesticide applied through spraying into an irrigated rice area is intercepted by the plant foliage while the rest goes directly into the water if there is standing water in the field otherwise, it goes directly to the soil. Part of the pesticide that goes into the paddy water is dissolved and is suspended or absorbed by floating and bed sediments. Pesticide that is dissolved in the water and absorbed by the bed sediment is dissipated through degradation and volatilization. Furthermore, part of the insecticide adsorbed to suspended sediments likewise undergoes degradation while some of it goes with the floating sediments that eventually settle on the bed of the field.

Pesticide that remains in water and suspended sediments are transported in the drainage channel when this water is drained. Moreover, concentration of pesticide in the drainage channel decreases as it is affected by its dispersion rate in the drainage channel as well as length of channel where the drainage water is allowed to flow.

RESULTS AND DISCUSSION

Observed Insecticide Concentration

Results of the study revealed that there is a non-linear trend in the decrease of concentration of cypermethrin insecticide in the paddy water (Fig. 2). One (1) day after insecticide application, the level of concentration of cypermethrinin the paddy water was reduced by 62.65% from the initial concentration. Two and three days after the insecticide application, the concentration was reduced by 79.01% and 88.58%, respectively. On the fifth day, 96.60% of the pesticide was degraded in the paddy water and on the 7th and 14th day after pesticide application, cypermethrin concentration was already below limit of quantifiable level and was considered nil (Table 1).

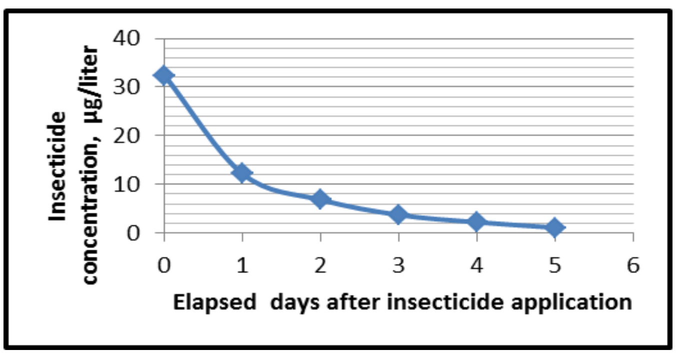

Fig. 2. Observed cypermethrin concentration in paddy water

Table 1. Observed pesticide residue concentration in paddy water.

Plot No.	Pesticide Residue Concentration (µg/litter)						
	Day 0	Day 1	Day 2	Day 3	Day 5	Day 7	Day 14
1	0.00	12.10	7.10	3.60	1.20	<LQL	<LQL
2	0.00	11.90	6.80	3.70	1.00	<LQL	<LQL
3	0.00	12.40	6.60	3.80	1.10	<LQL	<LQL
4	0.00	12.20	6.70	3.70	1.10	<LQL	<LQL
Mean	0.00	12.15	6.80	3.70	1.10	<LQL	<LQL
Rate of decrease in pesticide concentration (%)		62.65	79.01	88.58	96.60		

<LQL - less than the limit of quantifiable level

Simulated Insecticide Concentration

The PeFTRice model was developed to address the predominant dissipation pathways of pesticide while maintaining minimal input requirements for user comfort. It considers different transformation processes of the pesticide applied in the paddy field and simultaneously tracks the mass balance of the chemical in the water column and benthic sediments.

Simulation of the insecticide concentration using the PeFT Rice Model revealed a similar non-linear decrease in the cypermethrin residue concentration in the paddy water. As shown in Fig. 3, 68.82% of the insecticide was degraded one (1) day after application. During the 2nd and 3rd day after pinsecticide application, 82.70% and 89.50% was degraded, respectively. During the 5th day, almost all the insecticide was degraded as it is reduced to only 2.77% from its initial concentration. Six (6) days after the insecticide application, the cypermethrin residue concentration was considered nil.

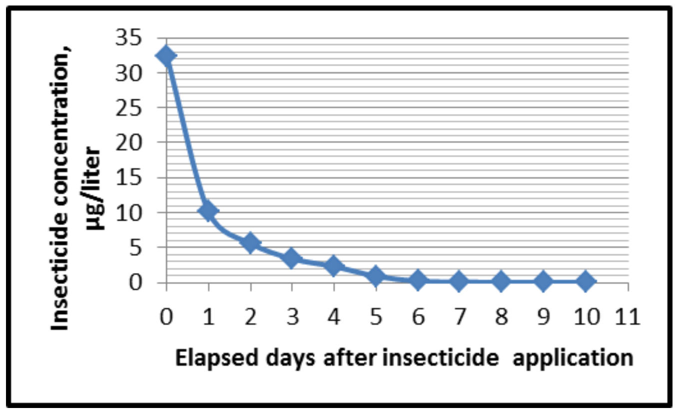

Fig.3. Simulated cypermethrin concentration in paddy water

Observed and Simulated Insecticide Concentration

Fig. 4 shows the plotted daily observed and simulated cypermethrin concentrations in the paddy water. As viewed from the figure, the observed and simulated insecticide concentration exhibits a similar and non-linear decreasing pattern. Statistical analysis of the data revealed that a very high positive degree of correlation (r=0.96) exists between the two sets of data. Moreover, test of significance (t-computed value of 0.2477) also revealed that there is no significant difference between the observed and simulated cypermethrin concentration. These findings imply that the PeFT Rice Model can correctly simulate the daily residual concentration of cypermethrinin the ponded water of a paddy field. Moreover, the root mean square error (RMSE) of 5.78%

further proves the accuracy of the model in predicting the cypermethrin concentration.

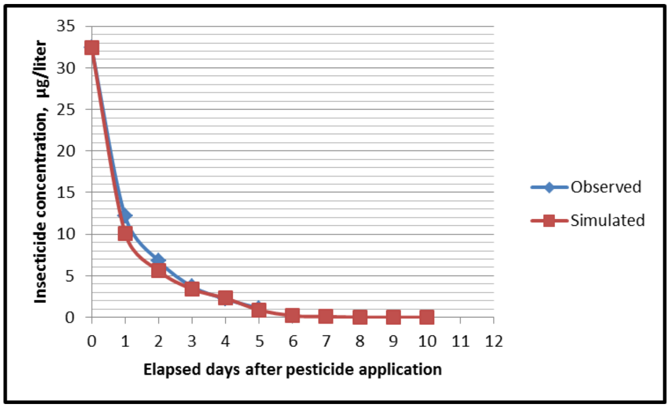

Fig. 4. Observed and simulated cypermethrin concentration

CONCLUSION AND RECOMMENDATION

The study revealed that cypermethrin insecticide, when applied in a paddy field could last in the paddy water up to five (5) days after its application. This means that it is almost completely degraded only after five days. Hence, in order to prevent or minimize insecticide contamination of bodies of water near paddy fields that serves as drainage basins, lowland rice farmers should ensure that the paddy water is properly contained and should not be drained from the field up to five (5) days after the application of the insecticide. Reusing or recycling of paddy water for washing, bathing, cleaning and for other purposes should be avoided five (5) days after the insecticide application to prevent being affected by the insecticide.Re-entry to the paddy field should not likewise be done during these times. Moreover, since the PeFT rice model can accurately simulate the residue concentration of cypermethrin in the ponded water in a paddy system, the use of the said model is recommended for regular monitoring of the pesticide concentration. Results of such monitoring could be used as a basis in formulating and implementing an effective cultural management practices inorder to minimize the negative effect of use of pesticide to humans and the environment.

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