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Adverse effects of cyfluthrin on *Cyphoderus javanus* Borner (Collembola) in soil

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ABSTRACT: Soil collembolans are key model organisms for ecotoxicological studies and play an inevitable role in litter degradation, nutrient cycling, energy flow and various ecosystem functioning. The detritivore collembolan, *Cyphoderus javanus*, was used to determine the toxicity of insecticide formulation cyfluthrin under laboratory conditions. The impacts of insecticide cyfluthrin on life history parameters of *C. javanus* revealed that mortality rates increased with increasing concentration. The fecundity rates, the number of eggs laid, the number of juveniles' emergence and longevity were found to be decreased drastically with insecticidal exposure. The high mortality of soil collembolans deducts the decomposition rate of organic matter and leaf litter, thereby reducing the fertility of soil.

KEYWORDS: Springtails, bioaccumulation, life history parameters

Soil is a complex living entity that breaths, assimilates organic and inorganic elements, breakdowns and mineralizes organic matters of biological origin, and stores reserves as organic matter (Sharma and Parwez, 2017). In most soils, 90 per cent of the soil micro arthropod population is composed of Collembola and Acarina (Wallwork,1976) and are of immense importance in major soil processes such as humification, recycling, mineralization of organic matter, mechanical decomposition of organic residues, stabilization of soil aggregates and pedogenesis (Emmerling *et al*., 2002). Collembola, commonly known as springtails, are small wingless, soft-bodied hexapods, usually found on or near soil surface, beneath rocks and the bark of trees (Paul *et al.,* 2011). These highly abundant groups of soil-dwelling micro arthropods can positively influence soil structure and functioning by modifying soil's biological, physical and chemical properties (Haque, 2018). Soil invertebrate communities, especially springtails, are crucial for monitoring the impacts of agricultural practices on environmental quality and soil functioning and are also regarded as valuable bio indicators to evaluate soil quality in human-altered systems (Velasquez *et al.,* 2007, Rousseau *et al*., 2013, Demetrio *et al.,* 2020). The most active detritivore collembolan, *Cyphoderus javanus* Borner, is considered an ideal potential biological marker of soil quality and ecosystem stability. The indiscriminate use of synthetic and organic pesticides, inorganic fertilizers and other agrochemicals resulted in the deterioration of crop yield, soil texture, disturbance of non-target

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organisms and ecological equilibrium of agricultural lands, mainly in tropical regions (Saha and Joy, 2014). A study by Thompson and Gore (1972) reported that springtails are highly susceptible to pesticides. Studies on the toxic impacts of pesticides and bioaccumulation of heavy metals in acarians, isopods and collembolans were reported earlier. Notable contributions among them are Mohammed *et al*., 1992; Park and Lees, 2005; Greenslade *et al.,* 2010; Vinod and Sanalkumar, 2017; Niemeyar *et al.,* 2018; Zhang and Filser, 2020. In India, limited data exist on toxicity works related to feeding, hatching and development of soil arthropods. Therefore, it is essential to carry out more research on eco-toxicological effects on various aspects of soil fauna, particularly for collembolans. Cyfluthrin a pyrethroid insecticide was chosen for the study. The adverse effects of cyfluthrin on mortality rate, and life history parameters (fecundity, juveniles' emergence and longevity) of *C. javanus* were investagated.

Experimental organisms, *C. javanus*, for the present investigation, were collected from three different sites in the Thiruvananthapuram district - Neyyar, Vithura and Agasthyavanam biological park. Sufficient soil samples of 5× 5 cm^2 from a depth of 0-10, 10-20 and 20-30 cm were randomly collected using a soil auger and taken to the laboratory in a labelled polythene cover. Extracted soil micro arthropods were carried out by Berlese Tullgren Funnel, and micro arthropods extracted overnight into a picric acid medium (Haarlov, 1947). Polythene rearing jars of 7×3 cm were used to maintain stock culture for experiments. Eggs of *C. javanus* from the culture were separated, and a group of five each were kept in separate replicate culture chambers.

Bioassay studies: Adult collembolans were collected in a separate culture chamber and fed with decayed jackfruit leaves for seven days for acclimatization. The culture chamber was moistened with a wet cotton plug and kept in one corner of the culture chamber. Cyfluthrin of 5, 12, 14, 18, 20 and 22 ppm concentrations were prepared by dissolving an appropriate amount of the chemical in one litre of distilled water (APHA, 2012). Adult collembolans were exposed to each concentration of cyfluthrin in different culture chambers. Decaying leaves washed in water and soaked in respective agrochemicals for 24 hours were given as food for the experimental group. A control was also maintained and mortality was recorded every 12, 24, 48, 72 and 96 h.

Fecundity studies: Five sub-adult females and five adult males were introduced to each culture chamber for fecundity studies. Its fecundity was recorded in each oviposition by carefully separating eggs from the culture chamber using a fine brush. The number of eggs in each oviposition was counted. Five replicates were maintained for the study, and individuals were fed with jack leaves soaked in the sublethal concentration of cyfluthrin.

Probit analysis (Finney, 1971) was used to calculate LC50 and LC100, the sub lethal and safe concentrations of each cyfluthrin. Two-way ANOVA was conducted to find any difference between the number of eggs in different replicates and between different oviposition.

The results of toxicity studies of the pyrethroid pesticide cyfluthrin on the mortality of *C. javanus* at 5, 12, 14, 18, 20 and 22 ppm tested for different groups of 50 individuals for 96 hours indicated high mortality. The mortality rate at 5, 12, 14, 18, 20 and 22 ppm were 8.2, 12.1, 19.2, 25.6, 45.2, 47.3 percentage at 12 h; 10.1, 16.4, 20.8, 39.4, 61.1, 67.5 at 24 h; 12.8, 22.4, 29.2, 39.3, 68.4, 76.1 at 48 h; 13.9, 27.8, 35.4, 46.2, 76.2, 88.1 at 72 h and 15.8, 37.2, 52.9, 58.7, 91.3,100 at 96 h (Table 1). The results revealed that the mortality of *C. javanus* increases with the concentration of the insecticide cyfluthrin.

LC100 value for cyfluthrin was found to be 22.75 ppm at 96 h, 25.62 at 72 h, 28.55 at 48 h, 30.3 at 24 h and 40.32 at 12 h respectively. The LC50 value was noticed as 13.43 ppm at 96 h, 15.58 at 72 h, 17.2 at 48 h, 18.5 at 24 h and 23.26 at 12 h. The safe level concentration of cyfluthrin was calculated as 3.30 ppm and its sub lethal concentration was observed as 0.83 ppm (Table 3).

The average number of eggs laid by

C. javanus after the treatment of sub lethal concentration of cyfluthrin showed a drastic decline in the number of eggs laid in each oviposition. The number of oviposition remains the same as in control. The number of eggs laid was between 50 to 56 in the first oviposition, 59-74 in the second, 42-50 in the third, 43-54 in the fourth, 34-40 in the fifth and 22 to 32 in the sixth. The mean number of eggs laid in each oviposition ranged from 41.83 to 48.66. Two-way ANOVA results indicated that there is significant variation in the number of eggs laid in each replicate during different oviposition (P 0.00179; P<0.05) and between the number of eggs laid during different oviposition (P 3.43X10-13; P<0.05).

Table 1. Mortality of cyfluthrin on *C. javanus*

ppm	Mortality (%)				
	12h	24h	48h	72h	96h
5	8.2	10.1	12.8	13.9	15.8
12	12.1	16.4	22.4	27.8	37.2
14	19.2	20.8	29.2	35.4	52.9
18	25.6	39.4	39.3	46.2	58.7
20	45.2	61.1	68.4	76.2	91.3
22	47.3	67.5	76.1	88.1	100

Sub-lethal adverse studies of cyfluthrin on *C. javanus* showed that the average number of juveniles in insecticide-treated sets was 34.43 from the 45.93 eggs, and the number of exuvia was found to be 1.75. The hatching success rate was observed to be decreased to 74.9 per cent in treated groups, and its longevity was recorded to be significantly less in treated specimens when compared to the untreated groups (Table 2). Most organisms persist for about 90-110 days in normal conditions, and in cyfluthrin-treated groups, longevity was obtained to be approximately 50 days.

Collembola is a very primitive tiny insect that undergoes growth and moulting frequently throughout its life cycle. Adult female collembolans lay eggs for a long time in fresh, uncontaminated pollution-free soils. Collembola is known to be vulnerable to insecticides (Frampton, 1994). Species assemblages in polluted soils may change due to quantitative and qualitative changes in food, increased bioavailability of metals, avoidance of contamination by migration, and species-specific detoxification abilities (Liu *et al.,*2018). Emigration of collembola out of the insecticide plots may have contributed to the observed decline in density after insecticide application (Endlweber *et al.,* 2006). Ghosal and Hati (2019) observed no noticeable change in the collembolan population after the insecticidal application. Chronic toxicity of cadmium was more significant on life history parameters of ten days old *C. javanus* observed that mortality decreased by 62 per cent, moulting declined by 69 per cent, and fecundity decreased by 97 per cent (Sahana *et al*., 2014).

In the present study, life history parameters such as fecundity, number of eggs laid, number of juvenile emergences etc., are reduced in cyfluthrin treatment sets. According to Fountain and Hopkin (2004), the number of juveniles produced was positively related to the number of adult *Folosomia candida* that survived in the soil. Eijsackers (2009) reported a smaller life span, decreased fecundity and increased frequency of moulting due to the impact of herbicides 2, 4, 5-T on collembola. Similar results were obtained in the present investigation; the longevity of *C. javanus* was reduced to 50 days after being treated with cyfluthrin. An increase in the oxygen consumption rates of animals exposed to pesticides provides a clear indication of changes in metabolic activity (Mohammed *et al*., 1992). According to Saha and Joy (2014), the rates of moulting and fecundity are regarded as potential indices of the impact of xenobiotics in soil. Intoxication and intrusion of toxicants into the reproductive system may lead to the disruption of vital functions, and total disturbance of the reproductive hormones, thereby reducing fecundity. This follows earlier findings of Cardoso *et al*. (2014), who noticed that enhanced egg production

Table 2. Sub lethal effects of cyfluthrin on *Cyphoderus javanus*

Eggs laid (nos.)	Juveniles (nos.)	Exuvia (nos.)	Hatching success (%)	Longevity (in days)
45.93	34.43	1.75	74.9	10

Table 3. LC50, LC 100, safe and sub lethal concentrations of cyfluthrin on *Cyphoderus javanus*

LC50					LC100					Safe Conc (ppm)	Sub lethal Conc (ppm)
12h	24h	48h	72h	96h	12h	24h	48h	72h	96h		
23.26	18.5	17.2	15.58	13.43	40.32	30.3	28.55	25.62	22.75	3.30	0.83

was observed at different concentra-tions of insecticide carbaryl. The ageing time is a critical determinant of toxicity because it is directly related to the actual concentration to which soil organisms are exposed (Wee *et al*., 2021). Pisa *et al*. (2015) reported that insecticides could significantly impact animal metabolism, affecting the detoxification, intermediary and energy metabolism pathways and reducing biomass gain. Dumestre *et al.* (1999) stated that elevated concentrations of copper in soils are toxic and may result in a range of effects, including reduced biological activity and subsequent loss of fertility.

From the experimental results, it is possible to conclude that the extensive utilization of the insecticide cyfluthrin negatively affects the fecundity, hatching, exuvium deposition and longevity of *C. javanus*. The greater rates of mortality in *C. javanus* due to cyfluthrin toxicity lead to the deterioration of the soil ecosystem and ecosystem balance.

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