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Acute Toxicity of Deltamethrin for Freshwater Mussel, *Unio elongatulus eucirrus* Bourguignat

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Abstract In this study, the acute toxicity of deltamethrin, contaminating aquatic ecosystems as a pollutant, on freshwater mussel, *Unio elongatulus eucirrus*, was examined. Deltamethrin was applied at concentrations of 1, 2, 3, 4, 5, 6, 7, 8, 16 and 32 mg L^{-1}. The 1, 24, 48, 72 and 96 h LC_{50} values of deltamethrin for freshwater mussels were determined as 10.07, 8.99, 8.09, 7.30 and 6.60 mg L^{-1}, respectively. There were significant differences in $LC_{10–90}$ values obtained for different times of exposure. The results show that deltamethrin is moderately toxic for freshwater mussel and it should be used with caution in agriculture to protect natural waters from contamination.

Keywords Freshwater mussel · *Unio elongatulus eucirrus* · Deltamethrin · Acute toxicity

Pesticides are toxic and designed to kill unwanted organisms, but applied to the land they may be washed into surface waters and kill or, at least adversely influence, the life of aquatic organisms. The synthetic pyrethroids are among the most potent and effective insecticides available, accounting for more than 30% of the world market in insecticides (Milam et al. 2000).

Pyrethroids have been shown to be neurotoxic and lethal to fish at concentrations 10–1,000 times lower than corresponding values for mammals and birds (Datta and Kaviraj 2003). The Environmental Protection Agency states deltamethrin's bioconcentration factor is 698 for whole fish (http://www.epa.gov/scripoly/sap/1999/february/pyreth.par). Pyrethroid toxicity is highly dependent on stereochemical structure (Milam et al. 2000). Synthetic pyrethroids have been found to be highly toxic to fish (Mestres and Mestres 1992; Mittal et al. 1994; Svobodova et al. 2003; Köprücü and Aydın 2004), zooplankton communities (Tidou et al. 1992) and some beneficial aquatic arthropods (Srivastav et al. 1997). The environmental fate and effects of synthetic pyrethroid insecticides have been summarized by Hill (1989). The World Health Organization published a report of acute toxicity data for deltamethrin in fish and classified it as highly toxic to fish; with the 96 h LC_{50} values ranging between 0.4–2.0 g L^{-1} (WHO 1990). Effects of deltamethrin on nervous, haematological and respiratory systems in fishes have been reported (Golow and Godzi 1994). Deltamethrin was shown to alter the filtration and pumping activity of mussels (Kontreczky et al. 1997).

In recent years, there has been considerable interest in the use of biochemical indices within bivalve molluscs. Mussels have a number of properties which make them useful sentinels for chemical pollution. By filtering large quantities water, mussels may be exposed to large quantities of pollutants even when their concentrations are quite small in water (Robillard et al. 2003). Mussels are used for several families of bivalve molluscs inhabiting lakes, rivers, and creeks, as well as intertidal areas along coastlines worldwide. The freshwater mussels (several allied families, the largest being the Unionidae) and saltwater mussels (Family: Mytilidae) are not closely related, and are grouped in different subclasses, despite some similarities in appearance. Although unionoids are diverse and conspicuous members of freshwater communities all over the world, they are often ignored or unknown to everyone except specially trained invertebrate zoologists (http://www.en.wikipedia.org/wiki/Mussel).

In Turkey, deltamethrin is a commonly used pesticide for pest control in the agricultural fields around freshwater reservoirs. Therefore, the present study was to determine

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the acute toxicity of deltamethrin on freshwater mussel, *Unio elongatulus eucirrus*. In addition, lethal concentrations of deltamethrin have been firstly determined on the *Unio elongatulus eucirrus* as a model species for Unionidae family.

Materials and Methods

In the present study, a semi-static acute toxicity bioassay was performed according to the standard method (APHA 1985) to determine the 1, 12, 24, 48, 72 and 96 h lethal concentration values ($LC_{10–90}$) of deltamethrin for freshwater mussel.

Deltamethrin, (S)-alpha-cyano-3-phenoxybenzyl (1R, 3R)-3-(2,2-dibromovinyl)-2,2-dimethylcyclopropancarboxylate, was obtained from Roussel Uclaf, in form of DECIS 2.5 EC (purity 2.5%, dissolved in 97.5% acetone).

Mussels, weighing 25–27 g and total length 5.9–6.3 cm, were obtained from the Pertek Region of Keban Dam Lake in Turkey. They were brought to the laboratory and acclimatized to laboratory conditions for 7 days. Water temperature in the aquaria was maintained at 12 ± 1°C using a heater and the mussels were subjected to a 12 h photoperiod using fluorescent lights. Mussels were fed with trout feed during adaptation, but they were not fed during the last 24 h of adaptation and throughout the duration of the test. Before starting the test, all experimental aquaria (280 L) were cleaned and filled with 270 L of dechlorinated tap water. The experimental water was kept in the tank for 24 h before deltamethrin was added.

Water quality characteristics in the control units were determined according to APHA (1985). Dissolved oxygen, pH and conductivity were determined by a digital oxygen meter and a pH meter. The mean quality parameters of water used for preparation of test solutions were as follows; dissolved oxygen 8.1 ± 0.3 mg L^{-1}, pH 7.2 ± 0.1, electrical

Table 1 Cumulative mortality of freshwater mussel

Concentrations (mg L^{-1})	Number of dead mussel				
	1 h	24 h	48 h	72 h	96 h
Control	0	0	0	0	0
1	0	0	0	0	0
2	0	0	0	0	5
3	0	0	0	6	8
4	0	0	8	13	19
5	0	12	16	22	30
6	14	19	23	31	50
7	18	25	34	52	72
8	27	37	54	ND	
16	87	92	ND		
32	100	ND			
Chi-square value	1.31	2.19	2.48	2.55	7.67
p	<0.05	<0.05	<0.05	<0.05	<0.05

ND no data because of 100% mortality

n = 100 in five replicates

Table 2 Lethal concentrations ($LC_{10–90}$) of deltamethrin depending on time (1–96 h) for freshwater mussel

Point	Lethal concentration values with 95% confidence limits (mg L^{-1})				
	1 h	24 h	48 h	72 h	96 h
LC_{10}	5.85 a (5.26–6.32)	5.10 ab (4.62–5.51)	4.43 b (3.86–4.83)	3.68 c (3.18–4.05)	3.06 d (2.66–3.39)
LC_{20}	7.04 a (6.51–7.51)	6.19 ab (5.76–6.58)	5.45 b (5.02–5.79)	4.66 c (4.27–4.99)	3. 99 d (3.64–4.29)
LC_{30}	8.06 a (7.55–8.57)	7.13 ab (6.71–7.54)	6.32 bc (5.96–6.73)	5.52 cd (5.16–5.95)	4.82 d (4.49–5.18)
LC_{40}	9.04 a (8.50–9.66)	8.03 ab (7.59–8.54)	7.18 bc (6.75–7.81)	6.38 cd (5.92–7.06)	5.67 d (5.28–6.18)
LC_{50}	10.07 a (9.44–10.86)	8.99 ab (8.46–9.64)	8.09 bc (7.50–9.08)	7.30 cd (6.66–8.38)	6.60 d (6.07–7.38)
LC_{60}	11.22 a (10.45–12.27)	10.05 ab (9.39–10.94)	9.12 bc (8.29–10.61)	8.36 cd (7.46–9.99)	7.68 d (6.94–8.86)
LC_{70}	12.60 a (11.60–14.03)	11.36 ab (10.47–12.56)	10.36 bc (9.20–12.57)	9.66 c (8.41–12.09)	9.04 c (7.98–10.81)
LC_{80}	14.42 a (13.08–16.44)	13.04 ab (11.86–14.80)	12.02 bc (10.38–15.34)	11.44 bc (9.64–15.15)	10.93 c (9.38–13.69)
LC_{90}	17.40 a (15.41–20.55)	15.85 ab (14.07–18.62)	14.79 b (12.26–20.26)	14.46 b (11.65–20.73)	14.23 b (11.72–19.01)

Lethal concentration values in rows with different letters significantly differ

Table 3 Toxicity studies for deltamethrin on various fish species

Scientific name	Fish size	Exposure time (h)	LC_{50} (μg L^{-1})	References
Cyprinodon macularius	4–5 cm	48	0.60	Mulla et al. (1978)
Ctenopharyngodon idella	17 g	24–96	155–91	Rao et al. (1983)
Esox lucius	65 mg	24–96	44–23	Rao et al. (1983)
Oncorhynchus mykiss	2.6 g	24–96	2.5–2.3	Lakota et al. (1989)
Cyprinus carpio	42 g	96	3.5	Lakota et al. (1989)
Cyprinus carpio	3–8 g	96	1.65	Calta and Ural (2004)
Cyprinus carpio	Embryo	48	0.21	Köprücü and Aydın (2004)
Cyprinus carpio	Larvae	48	0.07	Köprücü and Aydın (2004)
Poecilia reticulata	Adult	96	0.02	Mittal et al. (1994)
Oreochromis niloticus	1.6 g	24–96	16–14.5	Golow and Godzi (1994)
Clarias gariepinus	1.13 g	24–96	15–40	Datta and Kaviraj (2003)
Silurus glanis	15–18 g	24–96	1.45–0.7	Köprücü et al. (2006)

conductivity 218 ± 6.4 μS cm^{-1}, alkalinity 143 ± 19 mg L^{-1} and total hardness 198 ± 17 mg L^{-1} as $CaCO_3$.

Ten different concentrations of deltamethrin (1, 2, 3, 4, 5, 6, 7, 8, 16 and 32 mg L^{-1}) and a control with five replicates were used in the test series. Two control groups received acetone at a concentration used in the dilution of the maximum deltamethrin concentration. Exceeding aeration was applied to the aquarium for 2 h in order to obtain a homogeneous concentration of the toxic compound, and then ten mussels were transferred into each aquarium. Mortality was assessed at 1, 24, 48, 72 and 96 h after the start and dead mussels were removed immediately.

Statistical analyses were performed with the SPSS 10.1 computer program (SPSS Inc. Chicago, Illinois, USA). All replicates were used for calculation of mean values. Data obtained from the deltamethrin acute toxicity tests were evaluated using the probit analysis method. The lethal concentrations with 95% confidence limits were calculated. The Chi-square test was employed for comparing mean mortality values using a significance level of 0.05.

Results and Discussion

The results show that deltamethrin is moderately toxic (LC_{50} = 1–10 mg L^{-1}) (http://www.pesticideinfo.org/Docs/ref_ecotoxicity3.html# ExperimentType) to freshwater mussel, *Unio elongatulus eucirrus*. Its toxicity on freshwater mussel increased with increasing concentration and exposure time. For example, when mussels were exposed to 2 mg L^{-1} deltamethrin, only 5% died at 96 h whereas 87% died at 1 h when exposed to the 16 mg L^{-1} deltamethrin concentration ($p < 0.05$, Table 1).

In addition, the 1, 24, 48, 72 and 96 h LC_{50} values of water-soluble deltamethrin for freshwater mussels were determined as 10.07, 8.99, 8.09, 7.30 and 6.60 mg L^{-1}, respectively. There were significant differences in $LC_{10–90}$ values obtained for different times of exposure ($p < 0.05$, Table 2).

There are differences in the acute toxicity of deltamethrin for various fish species (Table 3). The 24–96 h LC_{50} values of deltamethrin for freshwater mussel, *Unio elongatulus eucirrus*, are higher than that of the fish. In general, this toxic effect changes with respect to species and size of fish and the duration of exposure. The results of the present study show that toxicity of deltamethrin for freshwater mussel under such conditions is also time-dependent. However, some other researchers have shown that exposure time is not significant in LC_{50} determinations for fish (Lakota et al. 1989).

Although the sensitivity of the freshwater mussel is less than that of the fish, the results showed that the insecticide deltamethrin has a harmful effect for mussels. Being a general toxicant for aquatic life, deltamethrin should be used with caution in agriculture to protect natural waters from contamination.

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