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Paraquat Toxicity to Louisiana Crayfish (*Procambarus clarkii*)

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Paraquat is one of several herbicides used in Louisiana. It is applied at the rate of 0.5 lb/A for controlling all annual grassy and broadleaf weeds (LSU EXTENSION SERVICE 1980). Since paraquat is highly soluble in water, toxic effects on aquatic organisms under field conditions may be expected if sufficient quantities of paraquat reach aquatic ecosystems.

There is a general paucity of knowledge concerning the toxicity of paraquat to freshwater crustaceans. The median immobilization concentration for Daphnia magna is 11 ppm (CROSBY & TUCKER 1966). When a small river in New Zealand was treated with paraquat, increasing deaths of amphipods, molluscans and hemipterans occurred with increase in time (BURNET 1972). The TL_m values for Lepomis macrochirus are 400 and 100 ppm at 24 and 48 h exposure, respectively (DAVIS & HUGHES 1963).

Louisiana red crayfish, Procambarus clarkii, has been selected as a bioassay organism due to its commercial importance as human food. Approximately 1.4 - 5.5 million kg is consumed in this state each year and this species makes up more than 90% total catch of all crayfish species (HUNER 1978).

MATERIALS AND METHODS

Adult crayfish and juvenile (6.0-10.5 and 2.0-4 cm, respectively) were collected from a bayou which receives backwater of Mississippi River. This bayou is located 2.5 miles south of Morganza Spillway at Maraquin, Louisiana. Animals were transported in well-aerated large plastic containers partially filled with bayou water from the collection site. The tap-water was dechlorinated by adding 1 mL saturated sodium thiosulfate solution to 20 gal of water which was used for all bioassays. Adult animals were separated from the juveniles to prevent cannibalism. Calcium chloride pellets (1/gal) were added to supplement salts necessary for shell growth. Crayfish were fed a chow during 96 h acclimatization period and not during testing.

One percent aqueous stock solution of paraquat was further diluted by dechlorinated tap-water to achieve desired concentrations. New stock solution was prepared

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for each test. One-gallon wide mouthed jars were used as test containers. Only one adult and 3-5 juveniles were exposed to paraquat in each jar.

Adult crayfish were exposed to 6 concentrations of paraquat (15-100 ppm) and the juveniles to 5 concentrations (0.5-8.0 ppm). These concentrations were chosen on the basis of range-finding tests. The dissolved oxygen of 10 randomly selected jars was measured by a self-stirring electrode type oxygen meter. The pH, dissolved oxygen, temperature and crayfish mortality were recorded at 24 h interval for 96 h. Those crayfishes failing to respond to a probe were considered dead and removed upon sight. The LC_{50} values were determined on an IBM computer using probit analysis program of DAUM (1970).

RESULTS

Dissolved oxygen, pH and temperature of the test solutions are given in Table 1. Little change in pH occurred during the testing period. The temperature ranged from 22 to 25 C.

TABLE 1. Water temperature, pH and Dissolved Oxygen Values for Adult Crayfish Bioassays.

TIME	0 h			24 h			48 h			72 h			96 h		
CONC. (ppm)	D.O	pH	T	D.O	pH	T	D.O	pH	T	D.O	pH	T	D.O	pH	T
0.0	5.0	6.5	25	3.8	7.0	23	3.0	6.9	21	3.0	7.0	22	3.0	7.0	21
0.5	5.4	7.8	22	3.8	7.0	20	3.1	6.9	23	3.1	6.9	24	2.9	6.8	23
3.0	5.8	7.1	23	3.7	6.8	24	2.8	6.8	21	2.8	6.8	23	2.0	6.8	23
15	6.4	6.9	22	3.1	7.1	23	2.1	6.9	25	2.1	6.9	23	1.5	6.6	22
100	6.0	7.1	24	3.0	7.1	23	2.0	6.0	23	2.1	6.9	23	1.5	6.6	22

The change in dissolved oxygen during 96 h testing period is summarized below:

CONC. (ppm)	OXYGEN CHANGE (ppm)	DIFFERENCE
0.0	(5.0 - 3.0)	2.0
0.5	(5.4 - 2.9)	2.5
3.0	(5.8 - 2.0)	3.8
15	(6.4 - 1.5)	4.9
100	(6.3 - 0.7)	5.6

Significantly greater amount of oxygen was consumed by treated crayfish, which was dosage dependent and directly proportional to increase in exposure time.

Much higher mortalities occurred in the control juvenile than adults, but they were within the acceptable range of 10% (Tables 2 and 3). None of the adult crayfish died upto 25 ppm (24 h) exposure, while approximately 50% juveniles

died in 8.0 ppm. The longer exposure resulted far greater deaths in juveniles, i.e., in 48 h 100% mortality in 8.0 ppm (juveniles) versus 16% adult mortality in 25 ppm.

TABLE 2. Percent Mortality of Adult Procambarus clarkii in Various Concentrations of Paraquat.

CONC. (ppm)	N	24 h	48 h	72 h	96 h
0	115	0.0	0.9	0.9	0.9
15	30	0.0	10	37	83
25	50	0.0	16	88	100
35	54	1.9	57	93	100
50	40	4.0	58	100	100
75	54	5.6	81	100	100
100	30	17	100	100	100

TABLE 3. Percent Mortality of Juvenile Procambarus clarkii in Various Concentrations of Paraquat.

CONC. (ppm)	N	24 h	48 h	72 h	96 h
0.0	134	3.7	6.7	8.9	9.7
0.5	64	1.6	9.3	25	33
2.0	62	8.1	26	45	46
4.0	62	19	40	61	77
7.0	32	38	91	97	100
8.0	60	47	100	100	100

In both juvenile and adult crayfish death rate consistently increased with time. The adults tolerated higher concentrations of paraquat which is also exhibited by the LC_{50} values (Table 4). The adult crayfish were 7.5 times more tolerant to paraquat in 48 h exposure and 6.9 times in 72 h, compared to juveniles. The LC_{50} for 24 h tests could not be computed due to fewer deaths of crayfishes. The difference in mortalities of adult and juvenile is further exemplified by their mortality curves (Fig 1 and 2). The greater susceptibility of juvenile is clearly visible by mortality curves as well as the tabular form of data.

TABLE 4. LC_{50} Values (Probit Analysis) and Upper and Lower Limits for Procambarus clarkii Exposed to Paraquat.

EXPOSURE TIME (h)	JUVENILE	ADULT	FOLD DIFF
24	**	**	
48	5.2 (2.7-20)	39 (29-51)	7.5
72	2.4 (0.2-8)	17 (14-19)	6.9
96	1.4 (0.5-3)	**	

** Non-significant regression

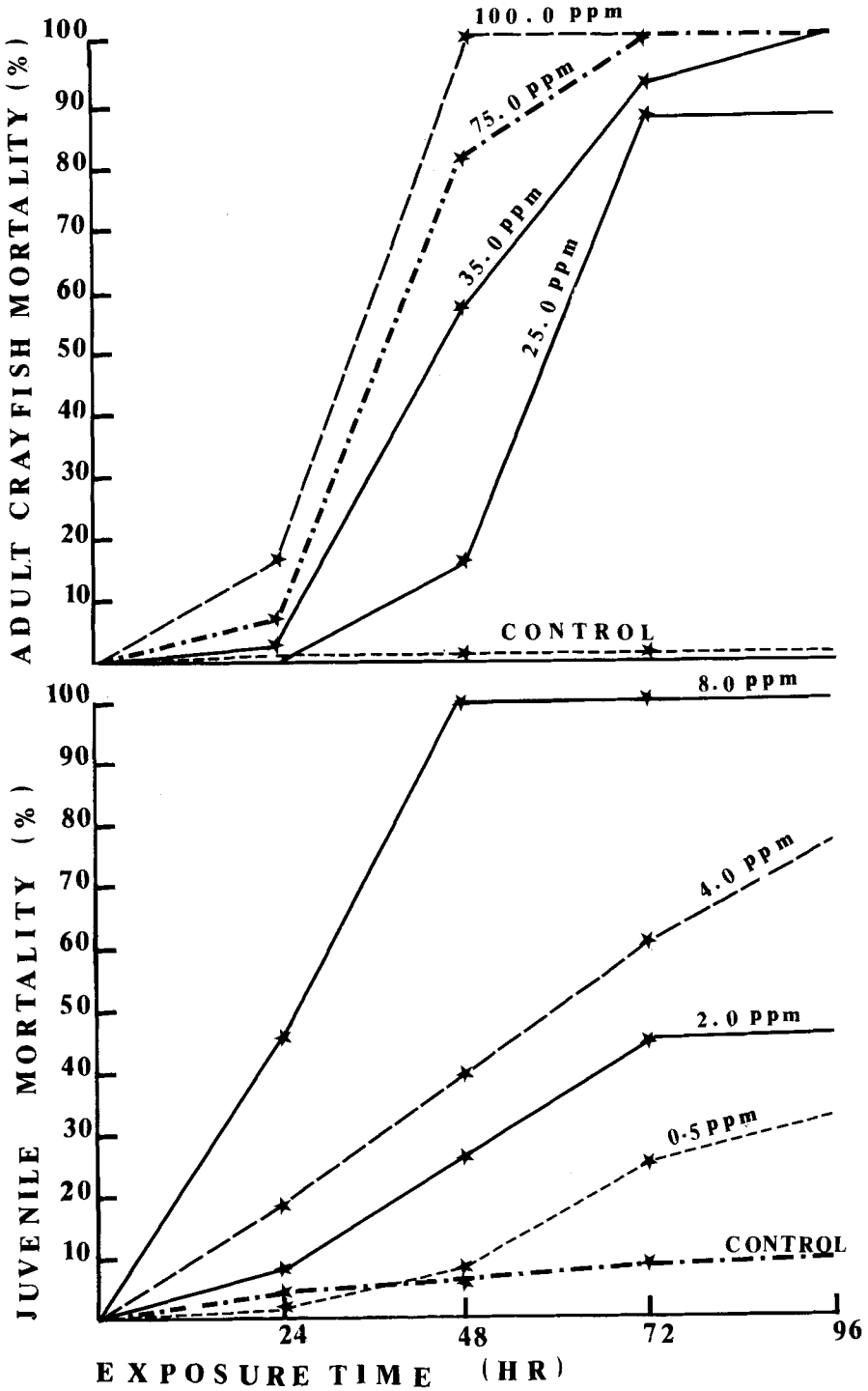

Fig. 1 and 2. Percent mortality of adult and juvenile crayfish, Procambarus clarkii exposed to various concentration of paraquat.

DISCUSSION

Mortality data clearly indicate that juvenile crayfish are far more susceptible than adults. Comparative LC_{50} for paraquat are unavailable. However, greater juvenile susceptibility for aldrin and mirex have been reported (HENDRICK & EVERETT 1965, LUDKE et al. 1971). This may also be explained as due to their similarity in mode of action. Paraquat is different from these compounds in chemical configuration as well as perhaps mode of action. The metabolism of paraquat in crustaceans is also unknown which may have caused the mortality difference. A comprehensive review of paraquat toxicity was done by HALEY (1979), but the majority of articles dealt with mammals.

Adult crayfish hyperactivity was dose dependent for which no valid reason can be given unless the mode of action is known. It may be presumed that hyperactivity could be in response of avoiding the toxicant. The fact that paraquat is rapidly inactivated by soil, absorbed by foliage and is resistant to removal by rain (HERBICIDE HANDBOOK 1979), it may not cause mortality of adult crayfish in the field. Nevertheless, the direct contamination of this herbicide may result in deaths of juvenile crayfish.

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