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Effects of Dietary Dieldrin on Behavior of White-footed Mice (*Peromyscus leucopus*) Towards an Avian Predator

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Chronic ingestion of sublethal quantities of dieldrin has resulted in behavioral effects in birds and mammals that could reduce their chances of survival in the wild. KREITZER and HEINZ (1974) reported suppression of group avoidance response of Coturnix quail (*Coturnix coturnix*) chicks to a moving silhouette during exposure to 5 ppm dietary dieldrin. Susceptibility to hand capture and choice of the deep side of a visual cliff were increased in offspring of penned pheasants (*Phasianus colchicus*) given capsules of dieldrin weekly during the breeding season (BAXTER et al. 1969, DAHLGREN et al. 1970, DAHLGREN and LINDER 1974). Both effects persisted through the third generation of offspring, suggesting the involvement of a genetic mechanism (DAHLGREN and LINDER 1974). SNYDER (1974) found that a single injection of 5 mg/kg dieldrin in deer mice (*Peromyscus maniculatus*) significantly impaired their ability to orient towards and return to their home area.

The effects of dieldrin on the ability of birds and mammals to react to environmental stimuli suggest that sublethal doses may alter their responses to natural predators. In addition to influencing survival of contaminated animals, this behavioral effect could facilitate transfer of residues to predators. JEFFERIES and PRESTT (1966) calculated that lethal levels of dieldrin found in some British falcons were unlikely to have resulted from long-term intake of the low background contamination present in populations of avian prey. They felt, rather, that raptors could be killed by ingestion of a few prey with high residue levels, and pointed out that peregrines select "... the weaker and probably more heavily contaminated birds ..." encountered in flocks. Thus, behavioral effects of sublethal body burdens of chemicals such as dieldrin in prey may result in predators selecting a diet more highly contaminated than the general population of prey.

Our study was designed to examine the effect of chronic dietary intake of dieldrin on the anti-predator response of the white-footed mouse (*Peromyscus leucopus*). The harrier (*Circus cyaneus*), a medium sized hawk, was chosen to provide the predator stimulus because it preys on *P. leucopus* (CRAIGHEAD and CRAIGHEAD 1956), and its hunting behavior (flying low over open country) can be readily elicited in the laboratory.

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MATERIALS AND METHODS

Adult mice that were the F_1 and F_2 cage-reared progeny of *P. leucopus* captured in Champaign County, Ohio, were assigned at random to a treatment group consisting of nine mice 3-4 months old and a control group composed of six mice that were 3-4 months old, two that were 5 and 7 mo, and three that were 18 mo. A separate chi-square analysis of the data from the control group showed that age did not influence behavior. Subjects were maintained in groups of two or three in cages 30 x 13 x 13 cm, and received pulverized laboratory chow *ad libitum* containing either 10 ppm dieldrin in corn oil, or in the case of control mice, corn oil only (10 g per kg of chow). The treated diet, prepared from technical dieldrin that contained 87% dieldrin, was administered for 3 mo prior to, and during the behavioral testing. Four days prior to testing, mice were placed individually in 30 x 20 x 15 cm hardware cloth observation cages equipped with removable nest chambers.

To test a mouse for reaction to the hawk, the observation cage was placed in the test arena, an open runway 3.3 x 1.0 m with walls 1.3 m high, and the mouse was ejected (if necessary) from its nest chamber. Mice were allowed 1 min before the hawk was induced to fly over the arena at a height of 1.5 m. If a mouse froze immediately upon leaving its nest and did not initiate movement within the first minute, the observation was not included in the reaction data. Otherwise, the subject was given an additional minute after initiating movement before exposure to the hawk. The maximum length of flight observable by a mouse was 7-8 m, depending on the flight path of the hawk. Subjects were observed from a blind at a distance of 1.5 m. A mouse was considered to respond to the hawk if it froze, dashed about the cage (ran), or watched the hawk fly over. Each mouse was tested once a day on 5 consecutive days, resulting in 45 observations for the experimental group and 41 for the controls (14 premature freeze responses). Responses of the experimental and control groups were tested for independence from treatment by the chi-square and Fisher exact tests.

RESULTS

Dietary intake of 10 ppm dieldrin during the 3 month period before behavioral testing did not influence adult mortality or result in the tremors or convulsions typical of acute dieldrin poisoning (HODGE et al. 1967). In previous studies, survival of adult laboratory rats and mice was not influenced by prolonged dietary intake of 10 ppm dieldrin but was markedly reduced in mice receiving 20 ppm (VIRGO and BELLWARD 1975) and in rats receiving 50 ppm (FITZHUGH et al. 1964). Experimental mice were hyperactive compared to controls in that they spent considerably

more time somersaulting in their cages and were more excitable during handling. Control mice appeared to be more cautious and apprehensive than experimental subjects when placed in the test arena for observation. Only one of 11 control mice failed to respond to the hawk on at least one occasion, significantly fewer ($P < 0.01$) than the seven of nine experimental mice that failed to respond at least once. The dieldrin-fed mice failed to respond to the hawk 9.3 times more often than did the controls (Fig. 1). The second difference between groups significantly ($P < 0.01$) related to treatment was in the freeze response which typically lasted from 3 to 270 sec, and was in all cases immediately followed by grooming. Seven control mice froze in response to hawk flyovers in seven (17%) of the trials, whereas dieldrin-fed mice never froze (Fig. 1).

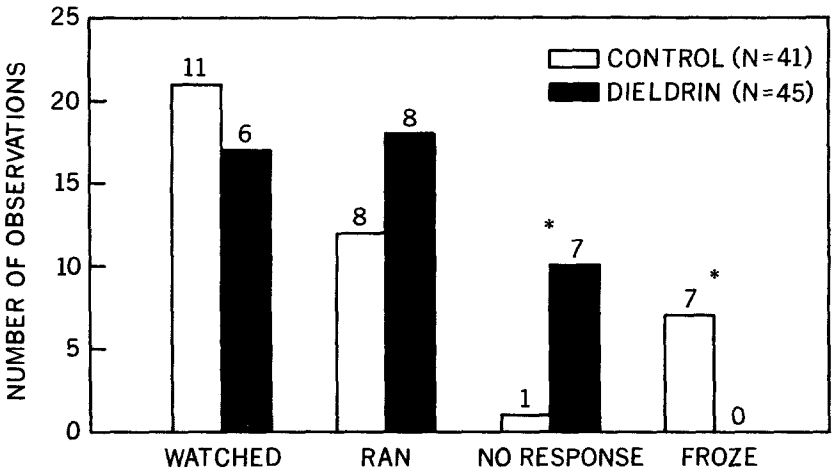

Fig. 1. Comparison of the frequencies of behavioral responses of 11 control and 9 dieldrin-fed white-footed mice to a harrier flying overhead. Asterisks indicate a significant ($P < 0.01$) relationship between response and treatment. The number above each bar shows how many mice exhibited that response.

Watching the hawk was the most common response in both groups (Fig. 1) and consisted of a mouse interrupting its activity to remain stationary while its head and eyes followed the movement of the hawk. This response was exhibited in 51% of the flyovers by all control subjects, compared to 38% by only six of the dieldrin-fed mice. Treated mice responded by running in 40% of the flyovers, compared to 29% among controls (Fig. 1). Neither running nor watching was significantly related to treatment.

DISCUSSION

Of the three reactions exhibited by *P. leucopus* to hawk flyovers, the two immobility responses (freezing and watching the hawk), would render the mouse less susceptible to avian predation than running. METZGAR (1967) reported that a screech owl (*Otus asio*) captured transient *P. leucopus* more frequently than resident mice familiar with the terrain. One factor contributing to the increased susceptibility of transient mice proposed by Metzgar was their higher activity level. Selection of more active prey has been demonstrated for barn owls (*Tyto alba*) and screech owls by KAUFMAN (1974), for a red-tailed hawk (*Buteo jamaicensis*) by SNYDER (1975), and for a ferruginous hawk (*Buteo regalis*) by SNYDER et al. (1976).

Absence of the freeze response among the dieldrin-fed mice may have been a result of hyperactivity induced by dietary dieldrin. In other studies involving dietary intake of 10 ppm dieldrin, female mallard ducks (WINN 1973) became hyperactive and less attentive in egg incubation, and rats (WALKER et al. 1969) showed signs of increased irritability (responsivity to stimulus). Thus, the "alertness" or "tenseness" typically ascribed to *P. leucopus* (SMITH and SPELLER 1970) may have been inhibited in treated mice by heightened responsiveness to environmental stimuli in general. Decreased alertness might also be the reason why dieldrin-fed mice failed to respond to the hawk significantly more often than did the controls.

Alternatively, the dieldrin-fed mice may have responded differently to hawk flyovers than control mice because of impaired visual acuity. The decreased avoidance response caused by dietary intake of dieldrin by quail (KREITZER and HEINZ 1974) and pheasants (BAXTER et al 1969, DAHLGREN et al. 1970, DAHLGREN and LINDER 1974) is suggestive of an effect on vision. Watching the hawk and running were, however, similar in frequency of occurrence between experimental and control groups (Fig. 1), indicating that dieldrin-fed mice saw the hawk more often than not. Differences in response between groups are therefore more readily explained by decreased alertness than by impaired vision.

It is also possible that responses were altered by dieldrin causing a depletion of neurohormones associated with behavior patterns. Changes in courtship and nesting behavior of mallards receiving 10 ppm dieldrin (SHARMA 1973, WINN 1973) were accompanied by decreased concentrations of three neurohormones (serotonin, norepinephrine, and dopamine) in the brain. Treated females, for example, flushed from their nests sooner at the approach of an intruder than did controls (WINN 1973). Hence, dieldrin may have interfered with the freeze response of treated mice through depletion of certain neurohormones.

The manner in which white-footed mice in this study responded to an avian predator suggests that, under field conditions, mice ingesting low levels of dieldrin may become more vulnerable to predation than uncontamined individuals. Evidence has been presented that elevated activity levels induced in tadpoles by DDT (COOKE 1971) and in carabid beetles by dieldrin (DAVIS 1966) resulted in increased susceptibility to predation. Consequently, predators may augment their dietary intake of pesticides by selecting prey that exhibit abnormal behavior induced by higher than average residue levels.

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