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Brain Cholinesterase Inhibition in Songbirds from Pecan Groves Sprayed with Phosalone and Disulfoton

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ABSTRACT: Brain cholinesterase (ChE) activities of songbirds collected in pecan groves 6 to 7 hr after separate applications of the organophosphorus pesticides, phosalone and disulfoton, were compared to mean ChE activities of controls (normals) as a measure of insecticide exposure. In general, reduction of brain ChE activity ≥2 standard deviations below the control mean indicates exposure to an anticholinesterase compound. Phosalone had little effect on brain ChE activity of birds from treated groves; only slight to moderate (21 to 38%) ChE inhibition was detected in blue jays (*Cyanocitta cristata*) and red-bellied woodpeckers (*Melanerpes carolinus*). However, 11 of 15 blue jays from disulfoton-treated groves had moderate to severe ChE depression, ranging from 32 to 72%. Inhibition ≥50% of normal may be diagnostic for cause of death. Direct mortality was not observed, but studies have shown that bird carcasses disappear rapidly from agricultural areas, many within 24 hr. We recommend additional field studies of the effects of disulfoton to wildlife, since large wheat-growing areas in the western United States are being considered for disulfoton treatment to control the Russian wheat aphid (*Diuraphis noxia*).

Key words: Cholinesterase inhibition, songbirds, disulfoton, phosalone, organophosphorus pesticides, insecticide, field study.

Pecan cultivation is a major industry in southern Georgia (USA). Thousands of acres of pecan groves are regularly sprayed during summer with large quantities of chemicals, mainly organophosphorus (OP) compounds. Many of the OP's are extremely toxic to wildlife, and reports of anticholinesterase poisoning in exposed avian populations have been well documented (Seabloom et al., 1973; Mendelssohn and Paz, 1977; Hill and Fleming, 1982; White et al., 1982). In general, reduction of brain cholinesterase (ChE) activity ≥2 standard deviations (SD) below the control mean is indicative of OP exposure, and inhibition ≥50% of normal may be sufficient for diagnosing cause of death (Ludke et al., 1975). Some investigators have measured brain ChE activity in wild birds collected in areas after OP applications as a means of monitoring exposure (Zinkl et al., 1980; DeWeese et al., 1983; Niethammer and Baskett, 1983; Grue and Hunter, 1984).

Many species of songbirds nest in pecan groves in southern Georgia. As part of a study to determine reproductive effects of pesticides on birds nesting in pecan groves, we collected specimens before and after phosalone (phosphorodithioic acid S-[(6-chloro-2-oxo-3(2H)-benzoxazolyl)methyl] 0,0-diethyl ester) and disulfoton (phosphorodithioic acid 0,0-diethyl S-[2-(ethylthio) ethyl] ester) applications to groves for brain ChE determinations. Here, we report the results of our brain ChE assays and discuss potential hazards to wildlife from the use of highly toxic OP's, such as disulfoton.

The study site was Wildmeade Plantation (31°30'N, 84°31'W) near Leary, Calhoun County, Georgia (USA); about 245 ha are in cultivated pecan groves. Blue jays (*Cyanocitta cristata*) and red-bellied woodpeckers (*Melanerpes carolinus*) were shot in pecan groves that were sprayed 6 to 7 hr earlier with phosalone on 8 July 1987 and with disulfoton on 26 August 1987. Both compounds (emulsifiable concentrates) were applied in separate groves by truck-mounted blower at the rate of 0.83 kg active ingredient/ha. Birds were tagged, placed in polyethylene bags on wet ice, and frozen (−20 C) at the end of the day. Control specimens for normal ChE determinations were collected in groves on 7 July 1987 before any pesticides were applied and handled in the same way. Partially thawed half-brains were excised and assayed for ChE activity following Ellman et al. (1961) as described by Hill and Flem-

TABLE 1. Brain cholinesterase (ChE) activities of controls collected in pecan groves before pesticide applications.

Species	n	ChE activity[a]		
		Mean	SD	Bounds[b]
Blue jay	5	34.5	3.7	27.1–41.9
Red-bellied woodpecker	5	35.9	2.1	31.7–40.1

[a] ChE activity expressed as micromoles acetylthiocholine hydrolyzed/min/g brain tissue, wet weight.
[b] Normal bounds = mean ± 2 SD.

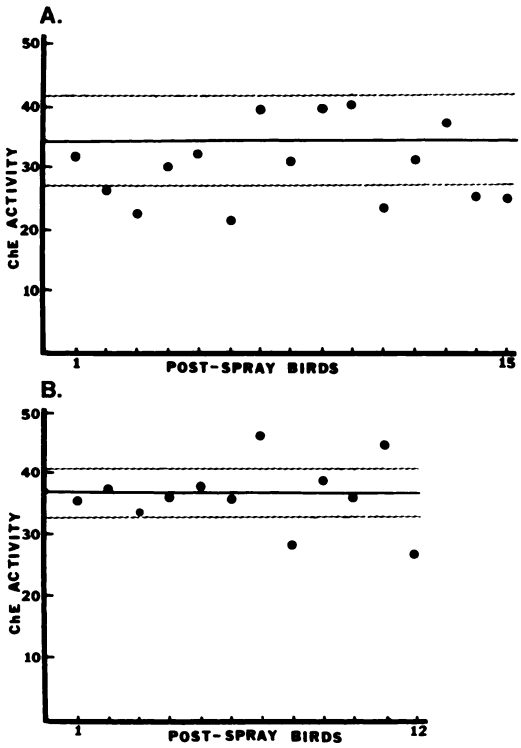

FIGURE 1. Brain cholinesterase (ChE) activities of 15 blue jays (A) and 12 red-bellied woodpeckers (B) from pecan groves 6 to 7 hr after a phosalone application. The black line in each graph is the control mean and wavy lines are normal bounds, defined as the control mean ± 2 SD.

ing (1982). Cholinesterase activities for controls and experimentals were determined concurrently on a Spectronic 401 spectrophotometer (Milton Roy Co., Rochester, New York 14625, USA) at about 25 C.

Brain ChE activities of controls collected in pecan groves before pesticide applications are summarized in Table 1. The mean ± standard error (SE) ChE activity (expressed as micromoles acetylthiocholine hydrolyzed/min/g brain tissue, wet weight) for blue jays was 34.5 ± 1.65 (range = 29.2 to 39.1) and that for red-bellied woodpeckers was 35.9 ± 0.94 (range = 32.9 to 38.4).

Cholinesterase activities of most birds collected from phosalone-treated groves 6 to 7 hr postspray were within the range of normal ChE activity (Fig. 1). Six blue jays had slight to moderate ChE inhibition when compared to the control mean, ranging up to 38%. Only two red-bellied woodpeckers showed slight ChE depression of 21 and 24%. Phosalone is a broad-spectrum nonsystemic OP insecticide and acaricide used primarily on fruit and nut trees; the major crop is pecans. Phosalone is considered only moderately toxic to laboratory animals, but its toxicity to most wildlife species has not been evaluated (Smith, 1987). Wildlife mortality or other adverse effects from phosalone applications have not been reported.

In contrast, blue jays collected from pecan groves 6 to 7 hr after disulfoton was applied had moderate to severe ChE depression. In 11 of 15 birds, ChE was inhibited by 32 to 72%; four birds had normal activity (Fig. 2). Only one red-bellied woodpecker was obtained, and its ChE activity was within normal bounds. Disulfoton is a systemic OP insecticide used as a side dressing, as a foliar spray or broadcast to control insects and mites. It is extremely toxic to mammals, birds, fish, aquatic organisms and bees (Thomson, 1982). In an eight to 10 county area where disulfoton was broadcast aerially, about 50 mammals and birds were reportedly killed (Environmental Protection Agency, 1981). Toxicity studies have documented very low acute oral LD_{50}'s for mammals and birds (Hudson et al., 1984), and acute dermal LD_{50}'s are also low, as disulfoton is rapidly absorbed through the skin (Hudson et al.,

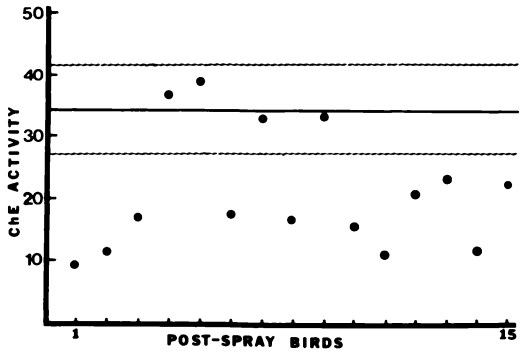

FIGURE 2. Brain cholinesterase (ChE) activities of 15 blue jays from pecan groves 6 to 7 hr after a disulfoton application. The black line is the control mean and wavy lines are normal bounds, defined as the control mean ± 2 SD.

1979; Gaines, 1969). Disulfoton residual insecticidal activity may last 6 to 8 wk after treatment (Chemagro Corporation, 1971).

The phosalone application probably had a minimal effect on blue jays and red-bellied woodpeckers using the groves, as indicated by normal ChE activity for most specimens 6 to 7 hr postspray (Fig. 1). However, eight of 15 blue jays collected 6 to 7 hr postspray (Fig. 2) had ChE depression (50 to 72%) within the range diagnostic for cause of death from OP toxicosis (Ludke et al., 1975). While average brain ChE depression of birds killed by OP's in the field usually is ≥80% (Hill, 1988), mortality may occur with as little as 39% ChE depression (White et al., 1989), dependent upon the chemical and the species affected. No dead birds were found during systematic searches along 200-m transects 24 hr after chemicals were applied, but mortality may have been undetected. Bird carcasses disappear rapidly from agricultural areas, many within 24 hr, presumably removed by predators or scavengers (Balcomb, 1986). In addition, sublethal exposure to an OP may alter nesting behavior (Grue et al., 1982; White et al., 1983) or render birds more susceptible to predation or food deprivation (White et al., 1979). Large numbers of songbirds nest in or adjacent to pecan groves in southern Georgia and studies are underway to evaluate the effects of OP's on reproduction in several species.

Presently, disulfoton is being considered for broad-scale use in wheat-growing areas of the western United States for control of the Russian wheat aphid (*Diuraphis noxia*). Few data exist of the environmental consequences of disulfoton use (Smith, 1987). Our limited results suggest that disulfoton may be hazardous to birds using treated areas; however, additional field studies incorporating a wider variety of species and collection regimens are warranted.

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