

DIELDRIN EFFECTS IN TWO GENERATIONS OF PENNED HEN PHEASANTS¹

WILLIAM L. BAXTER, South Dakota State University, Brookings²

RAYMOND L. LINDER, South Dakota Cooperative Wildlife Research Unit, Brookings

ROBERT B. DAHLGREN, South Dakota Cooperative Wildlife Research Unit, Brookings

Abstract: Effects of encapsulated dieldrin fed to penned hen pheasants (*Phasianus colchicus*) were studied through two generations. First-generation hens received 0, 2, 4 and 6 mg of dieldrin per week for 13 weeks. Hens which were offspring of these 0, 4 and 6 mg treated groups received 0 or 6 mg per week for 14 weeks. Effects of dieldrin were evaluated by measuring food consumption, weight, and egg production of hens, fertility and hatchability of eggs, and survival, weight gain, and behavior of chicks.

No mortality occurred in first-generation hens but among second-generation hens there was mortality in all groups receiving dieldrin. None occurred in controls. Food consumption was lower in the 6 mg group of first-generation hens and there was also lower egg production. The same effects were noted in groups of second-generation hens. Fertility and hatchability of eggs were significantly lower in groups where hens received dieldrin via the egg. No effect could be determined on chick survival or weight gain. A group of chicks hatched from eggs laid by hens receiving 8 mg dieldrin most commonly chose the deep side of a visual cliff while chicks hatched from control hens chose the shallow side ($P < 0.01$).

Eggs laid by first-generation penned birds had dieldrin residues averaging 15.7 ppm for the 4 mg group and 33.6 ppm for the 6 mg group. Up to 37 percent of the residue was eliminated from a hen's body when eggs were laid. Residues in fat of six penned hens which survived 2 and 4 mg levels ranged from 18.5 to 45.3 ppm. Dieldrin levels in brain tissue of treated hens which died during experimentation varied from 1.15 ppm to 26.7 ppm. Levels in wild birds were lower than levels found in penned birds.

A study on relationships of insecticides to pheasants was initiated at South Dakota State University in 1964. Objectives were to determine effects of dieldrin on first- and second-generation penned hen pheasants and to relate findings of pen studies to wild pheasant populations. Two phases of the study concerning first-generation hens have been reported (Lamb et al. 1967, Atkins and Linder 1967). This paper presents findings concerning effects of dieldrin on reproduction in second-generation hens and relates findings to wild populations.

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PROCEDURES

Experimental procedures for first-generation hens were reported by Atkins and Linder (1967). Second-generation hens were offspring of birds used in that experiment. Hens produced by first-generation control birds (0 mg) were randomly divided into four groups and received 0, 6, 8, or 12 mg of dieldrin (0-0, 0-6, 0-8, 0-12) per week for 14 weeks. Based on average food consumption, hens on 6 mg dieldrin per week received about 20 ppm in their diet. Hens produced by first-generation birds which received 4 mg of dieldrin were placed in two groups. One group received no dieldrin (4-0), the other 6 mg per week

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² Present address: Nebraska Game, Forestation, and Parks Commission, Lincoln.

Table 1. Mean food consumption and changes in weight and egg production by second-generation hen pheasants. Values for egg production are shown as transformed values $\sqrt{x + \frac{1}{2}}$ and were analyzed by least squares.

TREATMENT GROUP MG	NO. OF HENS		FOOD CONSUMPTION G/BIRD/DAY	HEN WT. CHANGE G/BIRD/WEEK	EGG PRODUCTION EGGS/BIRD/WEEK
	Started	Completed			
0-0	8	8	37.00	- 2.66	1.16
0-6	7	3	37.19	-18.84	1.34**
0-8	8	3	34.83	-24.36**	1.35**
0-12	8	1	26.61**	-37.52**	0.96**
4-0	7	7	38.94	- 1.22	1.36**
4-6	8	4	33.25**	-16.18	1.17
6-0	8	8	31.10**	- 4.04	0.76**
6-6	8	2	24.36**	-27.48**	0.76**

** Significantly different from control ($P < 0.01$).

(4-6). Hens produced by birds which received 6 mg in 1966 were treated in the same manner (6-0, 6-6). Cock pheasants used as breeders were produced by control birds of the previous year and were not given dieldrin. Initially, 8 hens were put in each group except 0-6 and 4-0 mg groups in which sample size was 7.

Hens were held in individual cages (12 × 18 × 12 inches) designed to facilitate handling of birds, identification of eggs, and measurement of food consumption. Pheasants were caged November 16 and artificial light was increased to 16 hours. Dieldrin first was administered March 6, at which time 52 of the 62 hens had laid one or more eggs. Technical-grade dieldrin (95 percent, Shell Chem. Co.) was ground, mixed with lactose, and given to hens in gelatin capsules via glass tube. Control birds were given capsules containing only lactose. Hens were bred and given a capsule at weekly intervals for 14 weeks. Eggs were collected, labeled, and set daily in a forced-draft incubator. Chicks were banded and held in commercial battery brooders until 4-5 weeks old.

Behavior was tested on a visual cliff, a modification of one used by Tallarico and Farrell (1964). It consisted of a sheet of glass, 22 × 28 inches, placed 12 inches above the base of a box 22 × 28 × 27 inches. The base of the box and half of the under-

side of the glass (22 × 14 inches) were covered with red and white ½-inch checked oilcloth. A runway 4 inches wide and 3 inches high divided the box into visually shallow and deep sides. Chicks hatched from eggs laid by control hens and those given 8 mg of dieldrin per week were tested on the cliff in the first 30 hours of life. They were allowed 10 minutes to make a choice between the visually shallow or deep surfaces.

RESULTS

Results of experiments with first generation penned birds as reported by Lamb et al. (1967) and Atkins and Linder (1967) will be summarized and findings on second-generation birds will be presented.

Mortality

First-generation hens incurred no mortality during a 13-week trial. Mortality occurred in all groups of second-generation hens receiving dieldrin (Table 1). Losses started 2 weeks after treatment and continued throughout the study. There was no mortality in 0-0, 4-0, or 6-0 mg groups.

Food Consumption and Hen Weight

In first-generation birds, dieldrin apparently reduced food consumption significantly ($P < 0.01$). This reduction brought

Table 2. Fertility and hatchability of eggs laid by second-generation hen pheasants. Percent fertility was calculated from number incubated and percent hatchability from the number fertile.

TREATMENT GROUP MG	NUMBER OF EGGS INCUBATED	FERTILE EGGS		CHICKS HATCHED		PERCENT SURVIVAL OF CHICKS	
		Number	Percent	Number	Percent	2 Weeks	4 Weeks
0-0	133	72	54.1	25	36.1	80.0	80.0
0-6	155	42	29.6	19	45.2	68.4	58.8
0-8	147	76	51.7	35	46.1	65.7	62.9
0-12	25	16	64.0				
4-0	159	52	32.7	10	19.2	80.0	70.0
4-6	114	24	21.1	8	33.3	50.0	50.0
6-0	13	5	38.5				
6-6	10	1	10.0				

about a corresponding decrease in body weight, most pronounced in the 6 mg group.

Analysis of variance also indicated a difference ($P < 0.01$) in food consumption among groups of second-generation hens (Table 1). Dunnett's (1955) procedure showed that the control (0-0 mg) group consumed significantly more food ($P < 0.01$) than the 0-12, 4-6, 6-0, and 6-6 mg groups. All groups lost weight during the study and analysis of variance indicated a significant difference ($P < 0.01$) between treatments (Table 1). Dunnett's procedure showed controls (0-0 mg) lost significantly less weight ($P < 0.01$) than the 0-8, 0-12, and 6-6 mg groups.

Egg Production

First-generation hens of the 6 mg group laid fewer eggs than control birds and rates of production varied with food consumption. Analysis of variance indicated a significant difference ($P < 0.01$) in egg production by second-generation hens in different treatment groups (Table 1). Dunnett's procedure showed that the controls laid fewer eggs per hen ($P < 0.01$) than the 0-6, 0-8, and 4-0 mg groups, and more eggs ($P < 0.01$) than the 0-12, 6-0, and 6-6 mg groups. Higher levels of dieldrin were related to reduced egg production and food consumption in both generations.

Fertility of Eggs

No differences in fertility were detected in first-generation birds. A significant difference in fertility ($P < 0.01$) between treatments of second generation birds (Table 2) was found. Fertility of eggs laid by controls was significantly higher ($P < 0.01$) than fertility of eggs in the 0-6, 4-0, 4-6, and 6-6 mg groups. An orthogonal set of comparisons showed fertility of eggs laid by hens in 0-6, 0-8, and 0-12 mg groups was significantly higher ($P < 0.01$) than eggs produced by hens receiving dieldrin via the egg (4-0, 4-6, 6-0, 6-6). There was no significant difference in fertility of eggs laid by offspring of first-generation hens that had received 4 or 6 mg of dieldrin.

Hatchability of Eggs

Dieldrin had no significant effect on hatchability of eggs from first-generation birds except one group receiving 2 mg. Increased hatchability in that group could not be explained unless the low level was stimulative. The 0-12, 6-0, and 6-6 mg groups were excluded from analysis because of small sample size. Significant differences in hatchability were detected ($P < 0.05$) between remaining groups (Table 2). Individual comparisons of each treatment level to controls and an orthogonal set of comparisons were computed. No significant differ-

Table 3. Visual cliff performance of pheasant chicks produced by hens receiving 0 and 8 mg of dieldrin per week. Chicks recorded as no choice were excluded from Chi-square analysis.

DECISION	0 MG	8 MG
Shallow	13	5**
Deep	2	10
No Choice	2	4
Total	17	19

** Significantly different from the control ($P < 0.01$).

ence was detected between controls and any treatment level. The orthogonal set indicated higher hatchability ($P < 0.01$) of eggs laid by 0-6 and 0-8 mg groups compared to 4-0 and 4-6 mg groups (Table 2).

Chick Survival

Survival rates of first-generation chicks were not significantly different between groups up to 2 or 8 weeks of age. Chick survival was analyzed for all second-generation groups except the 0-12, 6-0, and 6-6 mg groups, which were eliminated because of small sample size (Table 2). Chi-square analysis detected no differences between treatments for chick survival.

Chick Weight Gain

Differences in weight gain of chicks hatched from eggs laid by first-generation hens were small and did not reflect level of treatment. Weight gain in second generation offspring was analyzed by least-squares method and no significant differences were detected.

Behavior of Chicks

Chi-square analysis of chick performance on the visual cliff detected a difference ($P < 0.01$) between chicks produced by 0-0 mg and 0-8 mg hens (Table 3). Thirteen of 15 chicks hatched from control hens chose the visually-shallow side. However, 10 of

Table 4. Dieldrin residues in brain tissue of first- and second-generation hen pheasants.

TREATMENT LEVEL, MG	PPM		
	Hen 1	Hen 2	Hen 3
1966 (First Generation)			
2	0.07	0.16	0.75
4	0.85		
6	1.35	1.66	
1967 (Second Generation)			
0 ^a	0.00 ^c		
6 ^b	1.15	8.67	11.70
12 ^b	9.20	9.42	26.76
6-0 ^a	0.07		

^a Pooled sample of 3 birds.

^b All hens deceased.

^c Less than 0.05 ppm.

15 chicks hatched from 8-mg hens chose the visually-deep side. Dieldrin passed via the egg appeared to have changed the behavior pattern in pheasant chicks.

Analysis of Residues in Pinned Birds

Eggs were periodically collected from first-generation hens for chemical analysis (Lamb et al. 1967, Atkins and Linder 1967). Residues in eggs averaged 15.7 ppm for the 4-mg group and 33.6 ppm for the 6-mg group. Much of the chemical was eliminated from the hen's body when eggs were laid. There was a slow decline of residue deposition in eggs laid after termination of treatment. After 14 days, levels in body fat were still higher, with one exception, than in any one egg yolk during the experiment.

Brain tissue of 6 first-generation and 12 second-generation hen pheasants was chemically analyzed for dieldrin residues (Table 4). Although there was considerable variation among hens, residue levels were generally related to levels consumed.

Residue Analysis of Wild Pheasants

Birds and eggs were collected from an area in southeastern South Dakota having a history of highest insecticide usage in the state. During the past 5 years, chlorinated

Table 5. Chlorinated hydrocarbon residues (ppm) in juvenile and adult pheasants and eggs collected from southeastern South Dakota, 1967.

	DIELDRIN	ALDRIN	HEPTACHLOR EPOXIDE	DDD	DDE	DDT	LINDANE	TOTAL
Juveniles^a								
Brain								
Average	0.10	0	0.03	0.01	0.05	0.13	Trace	0.21
Range	0-0.49	0	0-0.10	0-0.04	0-0.08	0-0.60	0-0.02	0.07-1.21
Crop Contents								
Pooled	0.01	0	0	0.01	0	0.03	0	0.05
Adults^b								
Brain								
Average	0.03	0.04	0.05	Trace	0.01	Trace	Trace	0.13
Range	0.01-0.19	0-0.23	0-0.70	—	0-0.06	—	—	0.01-2.35
Fat								
Average	0.03	0.04	0.09	0	Trace	0	Trace	0.16
Range	0.03-0.15	0-0.48	0-1.81	—	—	—	—	0.01-1.90
Eggs^a								
Average	0.08	Trace	0.05	0.01	0.02	0.03	0.01	0.19
Range	0-1.45	—	0-0.24	0-0.04	0-0.08	0-0.28	0-0.06	0-1.95

^a Analyses by Experiment Station Biochemistry Department, South Dakota State University.

^b Analyses by Spectran Laboratory, Denver, Colorado.

hydrocarbons were used primarily on corn, the principal crop occupying 31 percent of farmland acres. Before 1964, aldrin was used routinely at about ½ lb per acre on about 80 percent of the cornland. Since 1964, an estimated 50 percent of cornland received aldrin or heptachlor at about 1 lb per acre every third year (Personal communication, B. Kantack).

Fourteen juveniles from 5-8 weeks of age were collected in July. Total residue load for brain tissue ranged from 0.07 ppm to 1.21 ppm and averaged 0.21 ppm. Residues in crop contents were 0.05 ppm (Table 5). Brain and fat tissues from 26 adult hen and 22 adult cock pheasants collected in February were analyzed and found to contain residues of seven chlorinated hydrocarbons (Table 5). Total residue load for fat tissues ranged from 0.01 to 1.90 ppm with a mean of 0.16 ppm, while brain tissues contained from 0.01 to 2.35 ppm with a mean of 0.13

ppm. There was little difference in levels of residue between sexes.

Seventy-two eggs were collected from 37 pheasant nests during early May and late June, 1967. One to three eggs were taken from each nest. Chemical analysis detected chlorinated hydrocarbons which ranged from 0 to 1.95 ppm with a mean of 0.19 ppm (Table 5). No apparent differences were noted among areas or between months of collection.

Table 6. Chlorinated hydrocarbon residues (ppm) in 12 birds of 100 collected from 24 counties in eastern South Dakota. (Analyses by D. J. Mitchell, State Chemist, University of South Dakota.) Remaining birds did not show levels greater than 0.05 ppm.

INSECTICIDE	NUMBER OF BIRDS	RANGE
BHC	1	8.00
Lindane	2	0.05
DDD	2	0.05
DDE	6	0.24-2.25
Dieldrin	2	0.05-0.10

South Dakota Game, Fish and Parks personnel also collected 100 pheasant hens from 24 counties in eastern South Dakota during three winters (1964–1967). Collections were made to sample rate and extent of insecticide contamination in the pheasant population. Chemical analysis showed that 12 of the 100 hens contained chlorinated hydrocarbon residues greater than 0.05 ppm (Table 6). Levels ranged from 0.05 ppm to 8.00 ppm in the 12 birds.

DISCUSSION

Sublethal quantities of chlorinated hydrocarbons may affect pheasant reproduction. Hunt and Keith (1963:10) reported a 46.6-percent loss of pheasant chicks hatched from eggs collected in an area of high insecticide use, and a 27.0-percent loss of chicks from an area with little or no direct insecticide exposure. De Witt (1956:866) reported reduced hatchability and survival of chicks when adult pheasants were fed a diet containing 10 ppm dieldrin. Genelly and Rudd (1956) found no significant effect on fertility and hatchability of eggs laid by birds receiving 25 and 50 ppm of dieldrin; however, egg production and chick survival were lowered.

Dieldrin reduced egg production in first- and second-generation hens and decreased fertility and hatchability of eggs laid by second-generation hens which had received dieldrin residues via the egg.

Dieldrin at the 6-mg level appeared to reduce food consumption and body weight of first-generation hens, and apparently lowered body condition and impaired egg-laying ability. It appeared that hens in the 6-0-mg group received enough dieldrin residues in eggs from which they hatched to lower food consumption and egg production. Dieldrin was deposited in eggs and amounts generally reflected level of treatment (Lamb et al. 1967:27). Presence

of up to 33.6 ppm of dieldrin in eggs laid by hens receiving 6 mg of dieldrin did not affect hatchability, but appeared to affect reproductive success of hens hatched from these eggs. Fertility and hatchability of eggs were significantly lower in groups where hens received dieldrin residues via the egg.

Chemical analysis showed that from 19 to 37 percent of the total dieldrin presented to hen pheasants in capsule form was deposited in the egg yolk (Lamb et al. 1967:27). Egg laying was important in eliminating dieldrin from the hen's body. Results of second-generation studies substantiated this conclusion in that mortality of hens appeared to be correlated with a reduction in egg production. Birds which received dieldrin and laid eggs throughout the study survived treatment, while most of the non-laying hens died. All hens which received no dieldrin lived, even though some did not lay eggs. No mortality occurred in first-generation hens receiving 6 mg of dieldrin, but most of these hens laid eggs. In the second generation, several hens died which were on the same treatment level, but not laying eggs.

Behavior was also affected by dieldrin in the diet. The quantity of dieldrin passed via the eggs laid by hens receiving 8 mg affected behavior in their progeny. Other studies have also demonstrated behavioral changes associated with exposure to sublethal concentrations of chlorinated hydrocarbons. James and Davis (1965) found control groups of bobwhite quail (*Colinus virginianus*) committed significantly fewer errors in a discrimination program than did groups receiving as little as 20 mg/kg of DDT in their diets. McEwen and Brown (1966) reported aberrant territorial breeding behavior among sharp-tailed grouse (*Pedioecetes phasianellus*) in a field study designed to determine response of grouse

to single oral doses of dieldrin and malathion.

Chemical analysis showed a high proportion of encapsulated dieldrin in lactose given to hens in this study was absorbed, and the chemical occurred in its original form for at least 14 days after termination of treatment. Total residue loads of chlorinated hydrocarbons in eggs and body tissues of wild pheasants were much lower than dieldrin levels which caused mortality or depressed reproductive success in our penned birds. However, levels in brain tissue of wild adult and juvenile pheasants did not differ greatly from dieldrin in brain tissue of 6-0 mg second-generation hens. These hens appeared to have received enough dieldrin via the egg to significantly lower egg production. Visual cliff studies also suggest that low-level contamination could affect pheasants by altering behavior. Altered behavior in wild birds could result in increased mortality.

In contrast to penned birds which received only dieldrin, wild birds contained residues of several chlorinated hydrocarbon pesticides. Chemicals in combination can be more toxic than one alone (Chemical and Engineering News 1966:19). It is not known how insecticides affect the reaction of wild birds to environmental pressures and physiological stresses.

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