EFFECTS OF DDT, TOXAPHENE, AND DIELDRIN ON PHEASANT REPRODUCTION

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AGRICULTURAL control chemicals of high toxicity are being applied in greater quantity every year. New chemicals are being developed and frequently appear on the market. Under these conditions, it is apparent that the potential hazard to wildlife species is increasing rapidly. Despite extensive studies carried on by the U. S. Fish and Wildlife Service and other agencies during the past decade, great gaps remain in our knowledge of chemical-wildlife relationships. One such gap is the effect of one or a series of chemicals on the reproductive capacity of an animal. Population declines may be brought about by an increase in the mortality rate or by a decline in the birth rate. A number of dead animals found in a treated area may indicate an increase in mortality, but the signs of a decrease in birth rate are far less obvious. Despite the lack of clear evidence for reproductive suppression under field conditions, experimental work with the fowl (Rubin et al., 1947) strongly suggests that these effects occur and warrant careful investigation.

It was the purpose of the present study to determine the relative impact of insecticide intake on four phases of pheasant reproduction—egg production, fertility, hatchability, and survival of young. Three chlorinated hydrocarbon insecticides commonly used in California—DDT, toxaphene, and dieldrin—were selected for study. Ring-necked Pheasants (*Phasianus colchicus*) raised on the State Game Farm at Yountville, California, were used as experimental animals.

EXPERIMENTAL CONDITIONS

Feeding tests were conducted with female pheasants in the fall and winter of 1953 to determine the chronic toxicity of each chemical (Genelly and Rudd, 1956). Two "sublethal" levels for each chemical based on the outcome of these trials were selected for the reproductive studies (Table 1). Previously untreated pheasants were segregated into 12 breeding subgroups, each consisting of one male and ten females. Two subgroups were fed at the higher sublethal level for each insecticide and a single subgroup at the lower level. Three subgroups were maintained as controls. Each subgroup of pheasants occupied a single breeding pen.

The principal food given to all birds was a high protein mash (commercial "Turkey grower") in pellet form. Fifty-pound lots of the mash were mixed with the appropriate quantity of insecticide. The

TABLE 1

EGG PRODUCTION, FERTILITY, AND HATCHABILITY

p.p.m. in mash	*Hen days*	*Eggs laid*	*Laying rate (eggs/ ♀/day)*	*Eggs incubated*	*Eggs fertile*	*Fertility (per cent)*	*Young hatched*	*Hatch-ability (per cent)*
DDT								
100	580	395	.681	282	256	90.8	189	73.8
400	1020	698	.684	525	472	89.9	310	65.7
Toxaphene								
100	459	333	.725	251	211	84.1	170	80.6
300	918	436	.475*	337	297	88.1	165	55.6*
Dieldrin								
25	490	326	.598*	215	208	96.7	145	69.7
50	1020	556	.545*	454	346	76.2*	269	77.7
Control								
0	1470	1047	.712	785	717	91.3	570	79.5

* Differs significantly from control at 5 per cent level.

TABLE 2

FOOD CONSUMPTION, INSECTICIDE INTAKE, AND WEIGHT CHANGES OF PHEASANTS DURING THE REPRODUCTIVE PERIOD

Concentration of chemical p.p.m. in mash	*in total diet*	*Mean daily consumption bird/day mash, gm.*	*chem., mg.*	*Mean live weight change of females (gm.)*
DDT				
100	90	57.2	5.72	+20
400	355	52.1	20.84	−20
Toxaphene				
100	89	47.4	4.74	+9
300	243	30.4	9.12	−62
Dieldrin				
25	22	44.6	1.12	−14
50	42	36.6	1.83	−36
Control				
0	0	51.6	0	+64

storage of the food within each pen made it possible to determine the amount of food consumed by each group and to equate this into the mean rate of consumption (Table 2). Stores of contaminated food were renewed midway through the test period. The amount fed daily was commensurate with the amount consumed. Uncontaminated scratch grain, in measured amounts, was substituted when rainy weather threatened pellet disintegration; hence the insecticide concentration of the "total diet" (Table 2) differs from that of the mash. Oyster shell was fed to all groups to aid in shell formation.

For convenience, the insecticide concentration of the mash has been used to denote the pheasant groups in the figures (Figures 1–4).

Egg-laying began two weeks after the inception of the tests and continued through the remainder of the period. The eggs were gathered twice daily, dated, identified as to group, and stored in a cool room until set. Storage of the eggs was from one to seven days with one exception: eggs laid during the first week were stored up to 14 days. Eggs with soft, chalky, or cracked shells were checked for fertility (Twining *et al.*, 1948) but were not incubated; hence the hatchability samples (Table 1) have relative rather than absolute value.

Artificial incubation of the first group of eggs began in the last week of April, 1954. The eggs from the controls and from each test group of females were separated within the incubator. Routine handling of eggs thereafter was in accordance with accepted game-farm practice. Candling of all eggs on the eighteenth day resulted in the elimination of those in which development was arrested. These eggs were opened later to determine fertility and the extent of development. All eggs possessing developing embryos were transferred from incubator to hatching compartments on the day before hatching.

Soon after hatching the chicks were toe-clipped for later identification, sexed by the pattern of the facial down (Latham, 1951), and transferred to a battery brooder. Feeding and care of the birds for the ensuing two weeks was identical to that normally accorded other pheasant young. Most of the young were destroyed at two weeks of age. However, all young from eggs last-incubated were maintained for two months.

EXPERIMENTAL RESULTS

Egg Production.—The mean rate of egg-laying was calculated for each group, since it was not feasible to determine the egg production of individual females. The "laying period" for each group was considered to begin with the appearance of the first egg and ended on May 13. The number of "hen-days" for each group is the product of the "laying period," in days, and the number of females present.

Weekly rates of egg production (Figure 1) reflect differences in egg-laying trends of the various test groups. DDT, fed at both levels, resulted in weekly rates very similar to and often in excess of those of the controls. Toxaphene fed at 100 p.p.m. markedly depressed laying from the fourth week. Dieldrin at 25 p.p.m. depressed egg laying slightly below that of the controls, but at 50 p.p.m. it, too, significantly lowered production during the last five weeks.

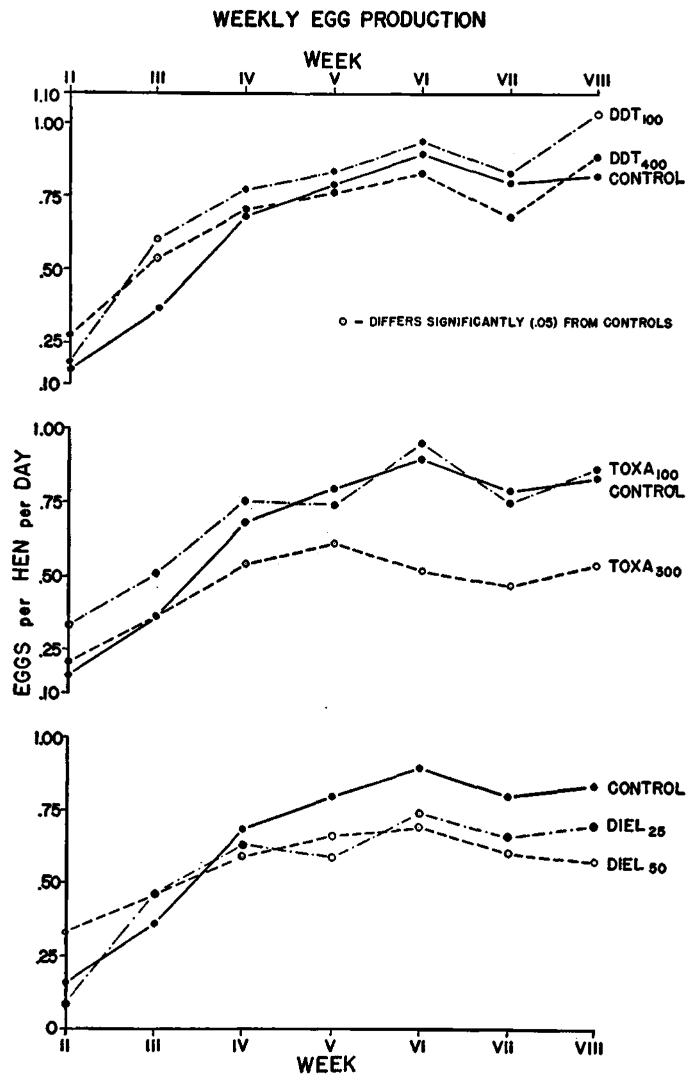

Figure 1. Weekly egg production.

With each chemical, the effect on egg-laying seemed to be proportional to the level of chemical intake.

The overall rate of egg production for each group (Table 1) reflects the weekly trends. Egg-laying was significantly depressed in the pheasants consuming 300 p.p.m. of toxaphene and either 25 p.p.m. or 50 p.p.m. of dieldrin.

The mode of action of the insecticides in reducing egg production is suggested by Figure 2. There appears to be a direct relationship between the amount of food consumed by the birds and the number of eggs laid. The aversion of Bobwhite Quail (*Colinus virginianus*) for food treated with insecticide has been noted by other investigators (Linduska and Springer, 1951). In acceptance tests, food treated with DDT was eaten almost as readily as untreated food, but food containing toxaphene usually was rejected. In similar tests lindane-treated food has been rejected by pheasants (Rudd and Genelly, 1954). It appears, therefore, that the reduced egg production of

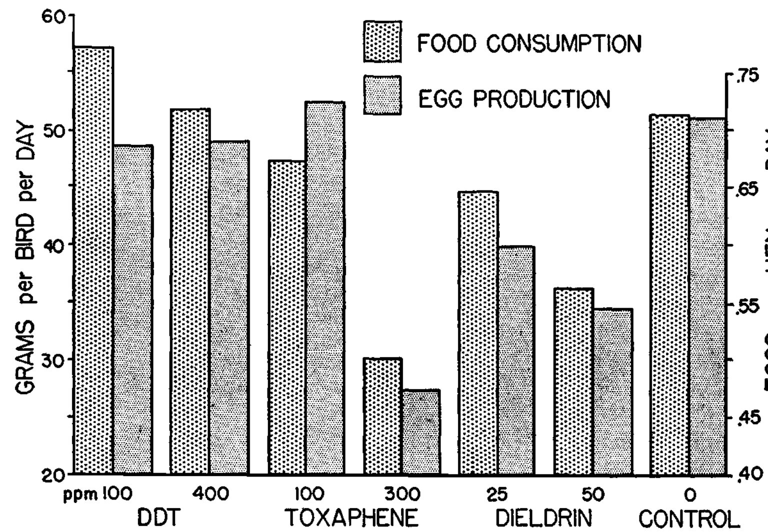

FIGURE 2. Relationship of egg production to food consumption.

the pheasants on dieldrin and 300 p.p.m. of toxaphene is due primarily to an aversion of the birds for the treated food.

Egg Fertility and Hatchability.—Fertility and hatchability varied with each chemical and concentration (Table 1). Moreover, the degree of effect was not related consistently to the level of chemical intake (Table 2). Only the effects of 50 p.p.m. of dieldrin on fertility and of 300 p.p.m. of toxaphene on hatchability are of statistical significance. Egg fertility might be lowered by physiological disturbance of the male, the female, or both. The male's role in lowering egg fertility, however, was suggested by the behavior and death of males consuming 50 p.p.m. of dieldrin.

The variability of the insecticide concentration in the eggs from each group (Table 3) suggests that the presence of the chemical within

TABLE 3

INSECTICIDE CONCENTRATION IN EGGS

p.p.m. of chemical — *in total diet*	*in eggs*	*Number of eggs tested**
DDT		
90	162	2
355	349	4
Toxaphene		
89	54	2
243	56	4
Dieldrin		
22	3	2
42	193	3
Control		
0	0	4

*All eggs analyzed were laid during the final week.

the egg is not solely responsible for the lowered hatchability. Judging from the weight loss and low food intake of the females consuming 300 p.p.m. of toxaphene (Table 2), it seems rather to reflect the poor condition of the birds.

Survival of young.—Survival curves for the young pheasants, from hatching to the thirteenth day, are presented in Figure 3. The total mortality of each test group is significantly greater than that of the controls for that period. Young birds from all test groups maintained until two months of age did not suffer undue mortality beyond the second week. The first two weeks following hatching, therefore, are apparently the most critical phase of pheasant reproduction with respect to insecticide contamination.

Reproductive Success.—The survival curves in Figure 4 were constructed to show the net effect on pheasant reproduction of each chemical concentration. The number of eggs produced by ten females in 30 days at the mean laying rate of each group (Table 1) is the basis for the hypothetical starting point. A decline in the laying rate of females, under field conditions, almost certainly would not reduce clutch size; rather it would delay completion of the clutch. For this reason, relative reproductive success (Figure 4) does not include the marked differences in egg production—young pheasants from 70 per cent of the control eggs were alive at the end of the test period.

As might be expected, the higher concentration of each chemical depressed reproductive success to the greater degree. DDT and toxaphene at comparable levels had similar effects. Dieldrin at considerably lower concentrations had slightly greater effects.

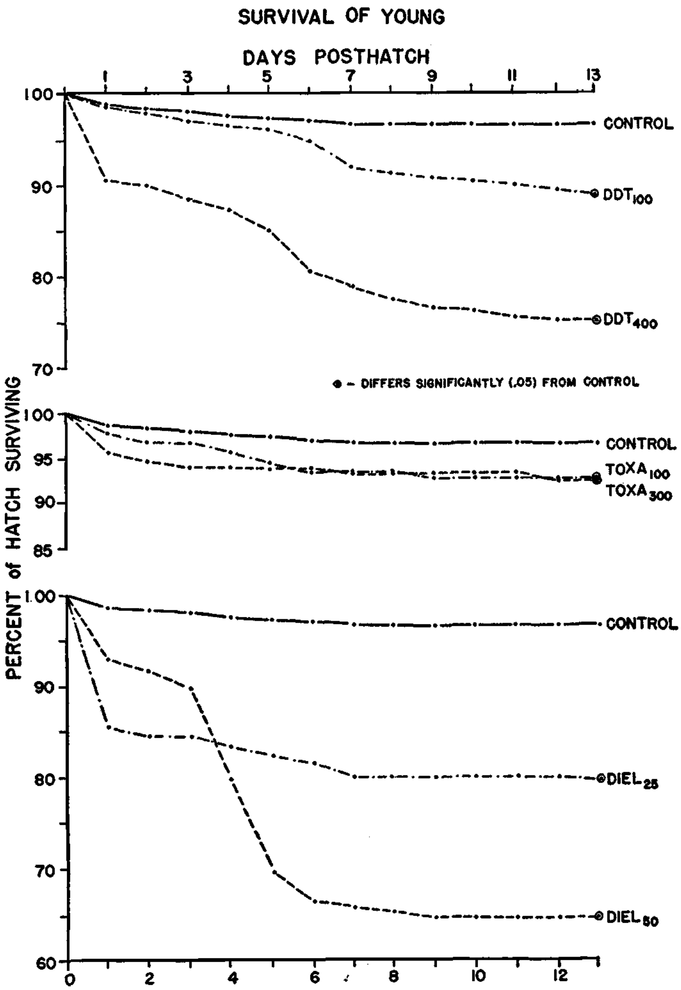

FIGURE 3. Survival of young.

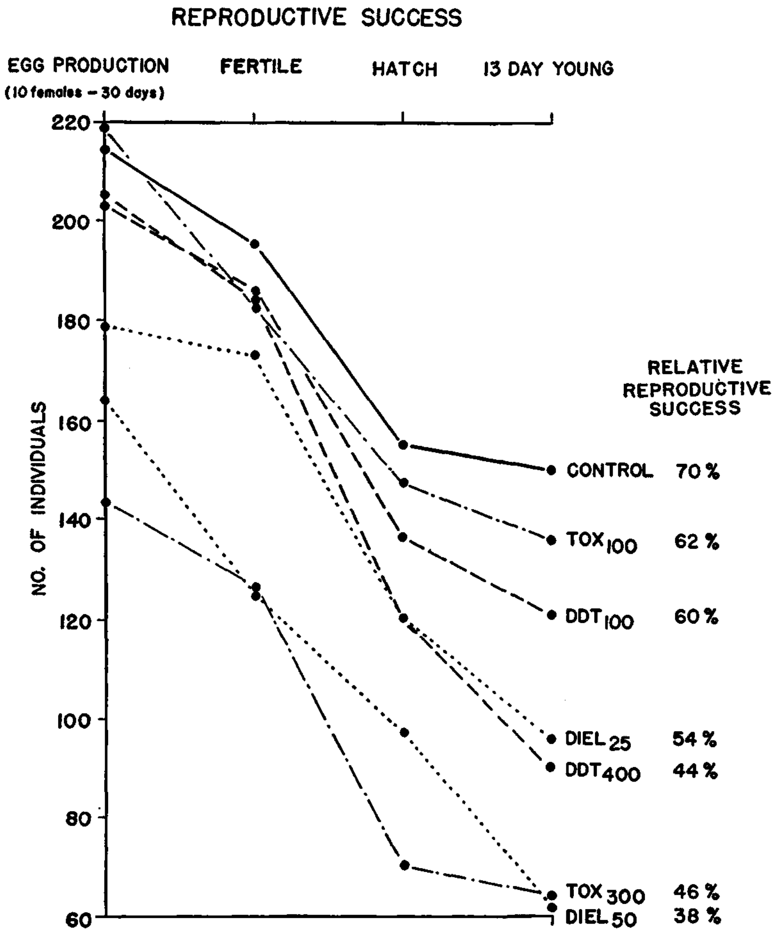

FIGURE 4. Reproductive success.

DISCUSSION

Evidence for the existence of similar reproductive effects under field conditions is largely lacking. However, the finding of dead birds in areas heavily treated with insecticide suggests the possibility of an effect upon the reproduction of birds that ingest sublethal quantities. In the orchards of Washington and British Columbia, DDT is applied at rates that may total 40 to 60 pounds per acre per year to control insect pests. Other insecticides, such as parathion and sulphenone, frequently are used on the same crops during the same season. Considerable mortality of ground-dwelling birds has been reported (Mohr et al., 1951; Barnett, 1950) in these treated areas, but apparently there has been no noticeable decline in the reproductive success of the species concerned. In the rice fields of California, the use of DDT-coated seed rice in 1953 was responsible for some mortality of breeding Ring-necked Pheasants (Rudd and Genelly, 1955), but overall reproductive success was higher that year than it had been in the previous year (C. M. Hart, 1954, pers. comm.).

Despite these reports the possibility remains that more susceptible species of restricted distribution might be seriously threatened by continued exposure to sublethal quantities of these chemicals. Single applications of insecticide frequently are of sufficient magnitude to deposit chemical residues (Laakso and Johnson, 1949; Barnett, 1950) equivalent to or in excess of the highest levels used in the tests. Although these residues decline in toxicity with weathering, several applications may be made in a single season. Wild birds would not be exposed to a constant level of contamination in their diets, as the pheasants were in the experiments, but rather to a series of sudden increases and gradual declines in the toxic content of their food supply. At first glance, this would seem to decrease the hazard; however, there is evidence that intermittent feeding of birds on contaminated diets may result in more severe effects than continuous feeding, at the same level (J. B. DeWitt, 1954, pers. comm.); moreover, wild birds at the time the chemical is applied might be contaminated by three routes of chemical entry: oral, by the ingestion of contaminated food; dermal, by absorption through the skin; and respiratory, by absorption through the lining of the lungs and air sacs. The penned birds were subjected to contamination by only one route—the oral. Although this portal is generally considered the most important in toxicological investigations, insufficient attention has been given to effects derived from multiple routes of entry such as might be expected under field conditions. Field studies to date have been concerned chiefly with acute mortality and immediate population declines. Population reduction in chemically-treated areas may result from direct mortality, movement from the area necessitated by a reduced food supply, and by impairment of reproduction. In most instances it is difficult to assess the relative importance of each factor in effecting a population decline. Although no one can state with finality that reproductive effects exist, on the basis of our experimental work we can state that chemicals at levels commonly used in agricultural practice can seriously affect reproductive behavior. Furthermore, similar chemicals may induce differential and often subtle responses of types frequently overlooked in field studies.

SUMMARY

Experiments were carried on at Yountville, California, in 1954, to determine the effects of insecticide-contaminated diets on reproduction of the Ring-necked Pheasant. Breeding groups of game-farm birds were fed varying levels of three insecticides—DDT, toxaphene, or dieldrin. Each group was compared with the control for egg production, fertility, hatchability, and survival of young.

Egg production was depressed significantly in the groups fed 300 p.p.m. of toxaphene and either 25 p.p.m. or 50 p.p.m. of dieldrin. There appeared to be a direct correlation between food consumption and egg production in all groups.

Egg fertility of the 50 p.p.m. dieldrin group and the hatchability of the eggs from the 300 p.p.m. toxaphene group were significantly lower than in the control. The lowered hatchability was associated with poor condition of the adult females rather than with the concentration of the insecticides within the eggs.

Mortality of young in each test group was significantly greater than that of controls for the first two weeks. From the second through the eighth week of age, survival of young did not differ appreciably between test and control groups.

Reproductive success ranged from 70 per cent in the control group to 38 per cent in the 50 p.p.m. dieldrin group. The higher concentration of each chemical had the greater net effect on reproduction.

Evidence of the relative importance of reproductive effects in reducing wild bird populations is lacking. However, insecticide levels similar to or in excess of those used in this study are of common occurrence in agricultural areas. Furthermore, wild birds are exposed to a greater contamination hazard, by aerial spraying, than the test birds.

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