p,p'-DDT and *p,p'*-DDE Effects on Egg Production, Eggshell Thickness, and Reproduction of Japanese Quail

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Stickel and Rhodes (1970) reported that DDT [1,1,1-trichloro-2,2-bis(p-chlorophenyl)ethane] at 40 ppm in the diet caused a 10-percent decrease in shell thickness of eggs of Japanese quail. Heath et al. (1969) had previously reported that both DDT and DDE [1,1-dichloro-2,2-bis(p-chlorophenyl)ethylene] caused thinning of eggshells of mallard ducks and that DDE was most likely the causative agent of the thinning when either DDT or DDE was fed. Davison and Sell (1972) observed that DDT fed at 200 ppm did not cause eggshell thinning in chickens maintained on controlled feeding regimens.

We were convinced that DDT and DDE caused eggshell thinning in ducks but not in chickens. We fed DDE to Japanese quail to determine whether DDE also caused eggshell thinning in quail as it did in the ducks studied by Heath et al. (1969). However, eggshell thinning was not detected in the quail. We then fed DDT to Japanese quail in experiments in which protocols from the report of Stickel and Rhodes (1970) were incorporated to determine whether DDT would cause eggshell thinning in our quail.

Methods

All quail were fed the same basic diet (Latshaw and Jensen, 1972) and were maintained on a light schedule of 14 hr. Chemically pure p,p'-DDT and p,p'-DDE were obtained from Aldrich Chemical Co., Inc., Milwaukee, WI. The chemicals were dissolved in corn oil and corn oil was added to the basic diet in amounts so that all diets contained 1 percent corn oil. Methods for measuring eggshell thickness and the statistical model used for analysis of variance have been described (Davison and Sell, 1972).

Experiment 1, DDE. Sixty 14-week-old female Japanese quail from the North Dakota State University colony, housed individually in battery cages measuring 17.5 X 24 X 18 cm, were assigned randomly and in equal numbers to diets containing 0, 2, 10, 40, or 200 ppm of DDE. Each bird was restricted to 14 g of food per day. All eggs were collected daily and weighed. The first egg laid by each quail during weeks 1, 3, 5, 7, 9, 11, and 13 were measured for shell weight and thickness. Eggs from clutches closest to and within 7 days of days 29, 57, and 85 were measured to determine possible effects of DDE on eggs in different positions within clutches. The experiment lasted 13 weeks.

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Experiment 2, DDT. Forty-eight 9-week-old female Japanese quail were housed in the cages described above, and 48 pairs of 9-week-old quail (male and female) were housed in cages measuring 22.5 X 38 X 17 cm. The quail (same source as in experiment 1) were randomly allotted to four treatment groups of 12 single quail and 12 pairs of quail each. Treatments consisted of diets fed *ad libitum*, which contained 0, 2.5, 10, and 40 ppm of DDT for 16 weeks. Eggs were collected daily and stored in a refrigerator. At biweekly intervals, the eggs were weighed, and one egg from each bird was randomly selected for shell thickness and weight measurements. The rest of the sound eggs from paired birds were incubated to examine fertility and hatchability.

Experiment 3, DDT. The strain of quail, the size of cages, and the duration in experiment 3 differed from those in experiment 2. Pharol D-1 quail, Marsh Farms, Garden Grove, CA, were used in experiment 3. Cages for single birds measured 15 X 17.5 X 17.5 cm, and cages for paired birds measured 30 X 17.5 X 17.5 cm. Duration was 12 weeks.

Results and Discussion

The parameters measured for egg production and eggshell characteristics in experiment 1 are summarized in Table 1. The statistical analyses of the data revealed no indication that the level of DDE in the diet affected any of the parameters studied. Statistical analyses based on clutches of eggs were not different from those based on individual eggs and provided no evidence of a within-clutch structure for the eggs laid by these quail.

Because Heath *et al.* (1969) had reported that both DDT and DDE caused eggshell thinning in ducks and Stickel and Rhodes (1970) and Bitman *et al.* (1969) had reported that DDT caused eggshell thinning in Japanese quail, we expected that DDE would also cause eggshell thinning in Japanese quail. However, data in Table 1 show that DDE did not cause such thinning. The degree of eggshell thinning in quail was greater in the experiment of Stickel and Rhodes (1970) than in the experiment of Bitman *et al.* (1969) in which a low-calcium diet was fed. Obvious differences in experimental protocols of Stickel and Rhodes (1970) from our experimental protocols were that Stickel and Rhodes (1970) fed their birds *ad libitum* and housed them in pairs (male and female), and we did not. Those who have worked with Japanese quail know that the male quail is very aggressive sexually. Possibly, stresses associated with sexual activity could affect the response of quail to DDT.

Results of experiment 2 are shown in Table 2. Paired quail laid fewer eggs ($P < 0.05$) with thinner and lighter ($P < 0.01$) shells than individually caged quail. Paired quail fed 40 ppm of DDT broke more eggs than any other group of quail. The interaction

TABLE I

Body Weight and Egg Production and Some Characteristics of Eggs of Japanese Quail Fed DDE

Parameter	Control	Level of DDE in Diet			
		2 ppm	10 ppm	40 ppm	200 ppm
Average initial weight of quail, g	121	116	118	123	120
Average final weight of quail, g	117	115	116	120	112
Total number of eggs laid/bird	43.5	39.2	48.2	37.9	40.8
Average egg weight, g	7.4	6.7	7.9	8.1	8.5
Number of clutches	12.1	12.6	14.1	11.9	10.9
Average length of clutch, eggs	2.2	1.8	2.4	1.9	2.2
Average eggshell weight, g X 10^2	59.0	61.2	60.4	62.1	62.5
Average eggshell thickness mm X 10^2	15.7	16.0	16.7	16.5	15.6
Average eggshell calcium, %	33.2	33.2	33.0	33.2	33.4

of caging X level of DDT fed was significant at $P < 0.05$. The magnitude of the values for number of eggs, eggshell thickness, and eggshell weight for paired quail fed 40 ppm of DDT was lower than the magnitude of the corresponding values for all other groups of quail. However, the interaction of caging X level of DDT fed for these three parameters was not significant at $P = 0.10$. From the data obtained, we <u>estimated</u> that a change of 0.138 eggs per bird per day, a change of 0.012 mm in shell thickness, and a change of 0.058 g in shell weight would have been significant at a probability level of $P = 0.05$ for main effects of dietary DDT. To further examine whether DDT might cause eggshell thinning in paired quail, we conducted a third experiment, similar in protocol to experiment 2, with another strain of quail.

Results of experiment 3 are shown in Table 3. Fewer eggs were laid by paired quail than by individually caged quail ($P < 0.01$); significant differences were not observed in any other parameter measured. Tremors were observed in two quail fed 40 ppm of DDT in the experiment.

TABLE II

Survival, Egg Production, Egg and Eggshell Characteristics, Fertility, and Hatchability of Japanese Quail Fed DDT and Housed Individually or in Pairs (Experiment 2)

Parameter	Individually caged quail					Paired quail				
	Control	DDT 2.5 ppm	DDT 10 ppm	DDT 40 ppm	Mean	Control	DDT 2.5 ppm	DDT 10 ppm	DDT 40 ppm	Mean
Number of deaths	1	0	1	1		0	1	2	2	
Avg. number eggs/ bird/day, $X\ 10^2$	73.8	76.0	76.6	85.8	78.1	73.1	61.8	77.3	59.7	68.2[a]
Avg. egg weight, g	9.6	9.6	9.7	10.0	9.7	9.8	9.2	9.3	9.5	9.5
Avg. eggshell thickness, mm $X\ 10^2$	19.0	19.2	18.7	18.9	19.0	18.3	17.8	18.0	17.0	17.8[b]
Avg. eggshell weight, g $X\ 10^2$	73.0	72.7	72.8	75.3	73.5	72.2	67.0	69.0	62.1	67.8[b]
Avg. eggshell calcium, %	34.0	33.8	34.0	34.2	34.0	34.4	33.8	33.7	33.1	33.8
Broken eggs, %	9.4	16.1	6.5	8.0	10.0	6.4	12.8	8.1	26.7[c]	13.0
Soft-shelled eggs, %	5.2	11.0	1.9	10.9	7.4	9.6	7.2	14.6	14.9	11.6
Fertility, %						56.9	58.6	71.8	67.5	63.7
Hatchability, %						50.6	54.2	60.0	42.9	51.9

[a]Significantly lower than mean for individually caged quail, $P < 0.05$.

[b]Significantly lower than mean for individually caged quail, $P < 0.01$.

[c]Interaction of caging X level of DDT fed was significant, $P < 0.05$.

TABLE III

Survival, Egg Production, Egg and Eggshell Characteristics, Fertility, and Hatchability of Japanese Quail Fed DDT and Housed Individually or in Pairs (Experiment 3)

Parameter	Individually caged quail					Paired quail				
	Control	DDT 2.5 ppm	DDT 10 ppm	DDT 40 ppm	Mean	Control	DDT 2.5 ppm	DDT 10 ppm	DDT 40 ppm	Mean
Number of deaths	1	0	0	0		0	0	1	1	
Avg. number eggs/bird/day, X 10^2	98.1	96.8	97.1	97.6	97.4	87.3	91.5	90.0	89.6	89.6[a]
Avg. egg weight, g	12.8	12.4	12.0	12.6	12.5	12.2	12.5	12.9	12.7	12.6
Avg. eggshell thickness, mm X 10^2	18.3	18.4	18.6	18.5	18.5	19.2	18.5	18.7	18.1	18.6
Avg. eggshell weight, g X 10^2	93.3	93.1	91.3	94.3	93.0	95.2	92.1	96.4	91.9	93.9
Avg. eggshell calcium, %	34.4	34.2	34.2	34.3	34.3	34.4	34.4	34.3	34.3	34.4
Broken eggs, %	0.7	3.7	0.6	1.9	1.7	2.7	2.9	3.1	3.0	2.9
Soft-shelled eggs, %	2.9	2.5	3.3	0.6	2.3	7.0	4.7	2.4	4.6	4.7
Fertility, %						80.0	88.9	86.7	89.7	86.3
Hatchability, %						68.7	74.3	66.1	63.3	68.0

[a]Significantly lower than mean for individually caged quail, $P < 0.01$.

Results of research reported here suggest that caged Japanese quail are resistant to eggshell thinning effects of DDT and DDE. If changes in shell thickness occurred, they were too small to be detected. However, sexual pairing of these caged quail provided sufficient "stress" to cause detectable reductions in egg production and eggshell thickness. DDT did not alter fertility and hatchability, and DDE was not tested for effects on these parameters of reproduction.

Summary

p,p'-DDT and p,p'-DDE were investigated for effects on egg production and eggshell thickness in Japanese quail. p,p'-DDT was examined for effects on hatchability and fertility. DDE was tested at 0, 2, 10, 40, and 200 ppm in the diet. No evidence suggested that DDE affected number of eggs laid, egg weight, or eggshell thickness at any level of DDE tested. DDT was tested at 1, 2.5, 10, and 40 ppm in the diet. In one experiment, quail fed DDT at 40 ppm and caged in male-female pairs broke more eggs than quail caged similarly but fed lower amounts of DDT or than quail fed an equal amount of DDT but caged alone. DDT did not detectably reduce eggshell thickness, number of eggs laid, fertility, or hatchability. However, paired quail laid fewer eggs than did single quail in two experiments and laid eggs with thinner shells in one experiment.

References

BITMAN, J., H. C. CECIL, S. J. HARRIS, and G. F. FRIES: Nature 224, 44 (1969).
DAVISON, K. L., and J. L. SELL: Bull. Environ. Contam. Toxicol. 5, 191 (1972).
DAVISON, K. L., and J. L. SELL: Arch. Environ. Contam. Toxicol. 2: 222 (1974).
HEATH, R. G., J. W. SPANN, and J. K. KREITZER: Nature 224, 47 (1969).
LATSHAW, J. D., and L. S. JENSEN: J. Nutr. 102, 749 (1972).
STICKEL, L. F., and L. I. RHODES: In J. W. Gillet (ed.): The biological impact of pesticides in the environment, pp. 31-35. Environmental Health Science Series, No. 1. Oregon State University, Corvallis: (1970).