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The comparison of commercially bred egg laying stocks with one advanced generation of the respective stocks

Robert James Mackin

To the Graduate Council:

I am submitting herewith a thesis written by Robert James Mackin entitled "The comparison of commercially bred egg laying stocks with one advanced generation of the respective stocks." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Animal Husbandry.

H. V. Shirley, Major Professor

We have read this thesis and recommend its acceptance:

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

November 27, 1967

To the Graduate Council:

I am submitting herewith a thesis written by Robert James Mackin, Jr. entitled "The Comparison of Commercially Bred Egg Laying Stocks With One Advanced Generation of the Respective Stocks". I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Poultry.

H. V. Shirley Jr.
Major Professor

We have read this thesis
and recommend its acceptance:

R. L. Tugwell

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Accepted for the Council:

Hilton A. Smith
Vice President for
Graduate Studies and Research

THE COMPARISON OF COMMERCIALLY BRED EGG LAYING STOCKS WITH ONE ADVANCED GENERATION OF THE RESPECTIVE STOCKS

A Thesis

Presented to

the Graduate Council of

The University of Tennessee

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Robert James Mackin, Jr.

December 1967

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INTRODUCTION

The increase in egg production in the last 20 to 30 years has been due to improved nutrition, management and the use of hybrid chickens; crossbreds, strain crosses, incrosses and incrossbreds. The commercial poultryman, as a rule, no longer produces his own **replacement** stock from his existing flock. He generally obtains new stock each year from the commercial breeders' outlets.

It is generally thought that if hybrids produced by these breeding systems were used to produce replacement pullets there would be a significant reduction in performance and an increase in variation. It is assumed that hybrid vigor expressed by these stocks would be reduced in the advanced generation as a result of the segregation and recombinations of the favorable genes or gene combinations.

Since the advent of chicken hybrids, it has been recommended to the poultryman that he purchase his replacement stock from the commercial breeder on a yearly basis. This recommendation is based in part on the many population experiments exemplifying the increased variability and decrease in the mean in a segregating generation. The recommendation is also based, to a great extent, on experiments with hybrid corn and a statement by Wright (1922) that, "a random-bred stock derived from inbred families will have $\frac{1}{n}$th less superiority over its inbred ancestry than the first cross or a random-bred stock from which the inbred families might have been derived without selection."

Also, Falconer, (1960) gives a good discussion by use of the Hardy-Weinberg formula of the reduced heterosis expressed in the F_2 generation. His conclusion is that heterosis in the F_2 generation can only be one half that shown in the F_1 generation.

The experiments with corn and Wright's work both deal with inbred lines used in the breeding system. However, not all commercial poultry breeders, today, employ inbred lines to produce their product.

This experiment is designed to ascertain if the reduction, if any, in the performance of an advanced generation produced from chicken hybrids is significant.

REVIEW OF LITERATURE

The expression of hybrid vigor by chickens has been the subject of many studies in the past 20 to 30 years. No attempt will be made to present a comprehensive review of literature concerning the expression of hybrid vigor as there are good reviews available by Warren (1958), Nordskog and Ghostley (1954), King and Bruckner (1952) and by Glazener *et al.* (1952) concerning the expression of this phenomenon in poultry.

Although there have been many reports concerning hybrid vigor in poultry, there is a lack of published work dealing with the effects of advanced generations from hybrids on the expression of hybrid vigor in chickens. Animal Breeding Abstracts reports on an experiment by Russian workers (Kopylovskaja, *et al.* 1961). Kopylovskaja is reported to have produced second, third and fourth generations by breeding *inter se* two lines of hybrid chickens imported from the United States. One of the lines being the product of the crossing of two inbred lines of Leghorns and the other line produced by crossing an inbred Leghorn male line on females produced by crossing Rhode Island Reds with New Hampshires. The performance of the advanced generations produced were compared with purebred Russian Whites. The advanced generations are reported to have declined in hatchability and in egg production as compared to the imported generation and the Russian Whites. The World Poultry Science Journal gives an abstract of work by two Romanian workers, Mauch and Paduraru, (1958). They found that breeding inter se crossbreds, produced from a cross of Leghorn and Rhode Island Red stock, produced progeny with lower production than the original crossbreds. Deacon (1956) reports a comparison of the first and second generation of a broiler stock. The first generation stock's average weight at nine weeks was 3.18 pounds and produced 38.4 pounds of live weight per 100 pounds of feed. The second generation stock's average weight being 2.95 pounds at nine weeks and producing 38.0 pounds of live weight per 100 pounds of feed.

The reduction in performance of advanced generation corn hybrids, produced by the crossing of inbred lines, has been demonstrated. Kiesselbach (1960) reports mean F_2 grain and fodder yields of single crosses declining to 73 percent and 78 percent of the F_1, respectively; for double crosses the were 85 percent and 87 percent of the F_1. Neal (1935) found F_2 and F_3 generations from single cross hybrids averaged 70.5 percent and 75.7 percent the grain yield of the F_1. The F_2 generation of double cross hybrids averaged 84.2 percent of the F_1 generation. He found from three-way hybrids the F_2 and F_3 generations averaged, respectively, 76.6 percent and 75.8 percent as much as the F_1 generation. Kiesselbach (1930) presents the comparative yields of the F_1, F_2 and F_3 generations of 21 single cross hybrids. The F_2 and F_3 generation hybrids averaged 68 percent and 66 percent, respectively, as much grain yield as the F_1 generation hybrids. Richey et al. (1934) compared the first and second generations of ten double cross hybrids. He found the second generations to yield from 95 percent to 76 percent of the yield of the F_1, with the average being 84.8 percent as much as the F_1 generation. Since the performance of an advanced generation hybrid depends, theoretically, on the amount of hybrid vigor expressed by the F_1 generation, some of the more recent reports dealing with poultry will be considered.

Many of the reports agree that crossbreeding results in a better growth rate, but the results concerning other traits are variable. King and Bruckner (1952) found highly significant hybrid vigor expressed for growth rate, age at first egg and egg production by the crossing of Barred Plymouth Rocks and Rhode Island Reds. They found the Sex-linked Cross, Rhode Island Red males x Barred Plymouth Rock females, produced 8.6 more eggs per bird than the best parent line and the reciprocal cross, the Barred Cross, produced 23.9 more eggs per bird than the best parent line. Warren (1942) found 21 out of 30 economic traits which he compared, to be better or equal in the crossbreds to that in the best parent stock. Glazener _et al._ (1952) compared crosses of White Leghorns, Rhode Island Reds, New Hampshires and Barred Plymouth Rocks in a two year study. He reports that 12 of the 15 crosses made were superior or equal to their respective purebreds for egg production. These were crosses made by selected males of one breed on females of another. Five different crosses were studied; Barred Plymouth Rocks male x White Leghorns, x New Hampshire and x Rhode Island Red females, New Hampshire males x Barred Plymouth Rock females and Rhode Island Red males x Barred

Plymouth Rock females. In four out of these five crosses the crossbreds laid more eggs, in a six month period, than did the best parent line. The data show that four crossbreds out of the five crosses reached sexual maturity at an earlier date than the best of the respective parental lines, but broodiness was higher in the crossbreds. It seems a subject for conjecture, that, if the crossbreds exhibited broodiness to a greater extent than the purebreds, what the effect on egg production would have been at the end of 360 days of production rather than just 180 days. Brunson and Godfrey (1951) reported that crossbreds were not always better than the parent lines for egg production. Dudley (1944) reports the crosses of Rhode Island Reds and White Leghorns resulted in lower mortality, earlier sexual maturity and greater egg production.

Nordskog and Ghostley (1954) report that crossbreds of New Hampshires, Rhode Island Reds, Barred Plymouth Rocks and Australorps were mated in all combinations in each of three years. Their results showed the crossbreds produced 12 percent more eggs than the pure breds.

The study of Nordskog and Ghostley (1952) also reported comparisons of strain crosses with pure strains. They found a ten percent increase in egg production as a result of crossing strains as compared to pure strains. Hutt and Cole (1962) compared an interstrain cross of White Leghorns. They found the strain cross was superior in hatchability, sexual maturity, rate of lay and body weight when compared to the parental strains.

Warren (1958) in reviewing some of the early work stated that the hybrids produced by the crossing of inbred lines resulted in hybrids superior to the inbred lines, but not any better than some pure strains available at the time. Nordskog <u>et al</u>. (1959) reported that progeny produced from four highly inbred Leghorn lines did not perform as well as progeny from four outbred male lines. Nordskog in his review of literature considering the use of inbred lines to produce hybrids found conflicting results.

Nordskog (1966) based on his own experiments concerning hybrid vigor and the literature makes the following statement, "I think that, more on the basis of experience than on real experimental demonstration, commercial breeders have turned to hybridization in its various forms in favor of pure lines."

MATERIALS AND METHODS

Experimental Animals

Three different tests were conducted over a 30 month period, employing 1568 mature pullets. This experiment was designed to produce progeny (referred to as the F_2 generation) from the mating of commercially available stocks, and compare these progeny with respective commercial stock (the F_1 generation). The commercial varieties used in these tests were produced by four different mating systems by breeders entering stock in the Tennessee Random Sample Laying Test. The mating systems as reported by the breeders for their respective stocks were: crossbred (BX), a cross of two or more breeds; incross (IN), a cross of two or more inbred lines of the same breed and variety; incrossbred (INX), a cross of two or more inbred lines from two or more breeds or varieties; and strain cross (SX), a cross of two or more pure strains or lines of the same breed or variety.

The F_2 birds were hatched from eggs produced by artificially inseminated hens of their respective commercial variety entered in the Tennessee Random Sample Test. The semen was collected from males of the respective stocks used in this experiment. The males used in Test 1 were obtained as the result of sexing errors, but those in Tests 2 and 3 were reared especially for this purpose. During the time fertile eggs were needed some 50 to 60 hens per stock were inseminated every third or fourth day. A small glass tube attached by plastic tubing to a 5 cc. syringe was used for insemination. The semen was collected, just prior to insemination, into a single small glass funnel with a paraffin plug in its stem. Semen from all males of one stock was contained in a single funnel. The semen was diluted with Avian Ringer's Solution (Bonnier and Trulsson, 1939) so as to provide a volume adequate for the insemination of .1 cc. of diluted semen per hen. All inseminations were performed after 3 p.m. In most varieties it was possible to use two to seven males, with the exception of the first test, only one male for one of the varieties was available. No selection was performed on either the males or females.

Hatching eggs of the commercial varieties used for comparison were obtained from commercial sources at the time the F_2 eggs were being collected. The eggs produced from the inseminated hens and those from the commercial sources were set simultaneously for each test in incubators located at the University of Tennessee Poultry Unit.

Care of Chickens

The birds were subjected to uniform management practices throughout all tests. At one day of age, the chicks were sexed and an appropriate number wing banded. All chickens, commercials and F_2's, were intermingled during the growing period. For the first ten weeks of age the chicks were housed in a brooder house employing infrared heat lamps as the heat source. At ten weeks of age the pullets were moved to a growing shelter. During the growing and rearing period each pullet had approximately 1.75 square feet of floor space. They were vaccinated for Newcastle disease and infectious bronchitis at one day, 70 days, and 140 days of age and for fowl pox when approximately 12 weeks of age. A coccidiostat was used from one day to ten weeks of age and, if needed, continued until housing at 20 weeks of age.

Cage laying houses were employed throughout these tests. The pullets were housed in single bird cages at 140 days of age, where they remained for 360 days of production. Test 1 consisted of three replicates of 17 birds per generation for each of four stocks, Test 2; four replicates of 15 birds per generation for each of five stocks, and Test 3; four replicates of ten birds per generation for each of seven stocks. Pullets were fed a 21.94 percent protein starter diet to ten weeks, a 17.18 percent protein grower diet from ten to twenty weeks, and a 16.75 percent protein laying diet throughout the laying period (Table I). These diets were calculated to meet or exceed all nutritive requirements for each class of pullets as given by the National Research Council.

Methods of Data Collection

Information was recorded on egg production, egg quality, feed consumption, mortality and body weights of birds on experiment. Production per pullet housed was calculated as the total number of eggs produced divided by the total number of birds housed. The

TABLE I

STARTER, GROWER AND LAYER DIETS

Feedstuff	Starter BR1*	Grower GR1*	Layer LR3*
	Lbs.	Lbs.	Lbs.
Yellow corn	636.00	718.75	669.75
Alfalfa meal, 17%	25.00	50.00	50.00
Fish meal	25.00	25.00	25.00
Vitamin mix*	6.00	6.00	5.00
Defluorinated Rock Phosphate	15.00	15.00	15.00
Ground limestone	6.00	10.00	60.00
Salt	4.80	5.00	5.00
Manganese Sulfate	0.20	0.25	0.25
Soybean Oil Meal, 50%	225.00	145.00	170.00
Coccidiostat Premix	25.00	25.00	-
	1000.00	1000.00	1000.00
Calculated to contain:			
Crude Protein	21.94	17.18	16.75
Productive energy, C/lb.	943	971	916
C/P (Calorie:protein ratio)	43.8	56.6	56.7
Metabolizable energy C/lb.	1333	1347	1271
Metabolizable energy C/P ratio	60.7	78.4	75.9
Methionine, %	0.408	0.336	0.327
Cystine, %	0.313	0.261	0.253
Calcium, %	0.960	1.126	3.026
Phosphorus, %	0.692	0.645	0.633
Available phosphorus, %	0.449	0.435	0.431
Manganese, mg./lb.	31.2	35.97	35.9
Vitamin A, I.U./lb.	5349	7970	7123
Vitamin D, I.C.U./lb.	340	340	1342
Riboflavin, mg./lb.	3.01	3.08	2.24
Niacin, mg./lb.	27.78	27.85	20.1
Pantothenic acid, mg./lb.	6.67	6.53	5.23
Choline, mg./lb.	718.0	601.0	607.5

*Mineral and vitamin content calculated to equal or exceed requirements as given by National Research Council.

average individual egg production for birds completing 360 days in the laying house and laying 100 eggs or over was determined and reported as production per survivor. Days to first egg is given as the average age to first egg. The age of the pullets calculated from hatching to the first day of the first two consecutive days that one half of the birds per pen produced and egg was considered as days to 50 percent production. Percent hen day egg production was determined by dividing the average number of eggs laid per hen by the average number of days each hen spent in the laying house, times 100.

Feed consumed was determined each month for each pen. Individual egg weights, in ounces per dozen, and the total weight of eggs, in grams, laid on one day each week were recorded for each pen, or replicate, enabling egg size distribution and the pounds of feed required to produce one pound of eggs and 24 oz. of eggs to be calculated. Individual body weights of pullets were obtained at housing and at the end of each test.

The following egg quality characteristics, shell thickness, albumen height, Haugh units, shell color, incidence and size of blood and meat spots, for all eggs laid by each pen one day each three months were measured. The specific gravity of the shell eggs was used as a measure of shell thickness. Ten salt solutions, ranging in specific gravity from 1.068 to 1.100, by increments of .004 were employed. The eggs determined as having a specific gravity of 1.068 or lower were given a score of zero. This score increased by 1 as the specific gravity of the solutions increased by .004, with eggs having a specific gravity higher than 1.100 being scored as a 9. The albumen heights of broken out eggs were measured with a tripod micrometer and at the same time the eggs were examined for the presence of meat and blood spots. The Haugh unit score was calculated using the average albumen height and average egg weight for each lot. To measure shell color, a color scale of nine graduations using actual egg shells was constructed, ranging from a chalky white shell, assigned a score of one, to a light brown shell color, given a score of nine. Eggs given a score of three or above were considered as tinted. The higher the score, the greater the tint of the shell color.

The income over chick and feed cost was calculated. The prices of feed, eggs, market hens and chicks used to calculated cost and income were identical for each stock in all three tests. The F_1 chick price was obtained from each breeder as the price per 1000 day-old pullet chicks. The price of the F_2 day-old chicks used was the same price quoted for the respective F_1 chicks. All hens were sold at the end of the 500 day test period at $0.07 per pound. Feed consumption during the growing period was calculated by determining the average weight of pullets at housing and multiplying this weight by six, the estimated pounds of feed required to produce one pound of egg type pullet to 140 days of age. The cost of the feed consumed during the laying period plus the value of feed consumed during the growing period and cost of the chicks at one day of age equaled the chick and feed cost for each of the three tests. The price of the starter-grower diet was calculated to be $3.84/cwt., and that of the laying mash was calculated to be $3.37/cwt.

The income from eggs laid was determined using the market price for small, medium and large size eggs quoted on the Chicago market, as secured from the Market News Report issued at Atlanta, Georgia. Prices quoted were those paid to first receiver, 80 percent Grade A. The total eggs, in dozens, of each size produced was multiplied by the average price per dozen for the year, giving the income from eggs. As the market reports gave no quotation for peewee size eggs, this price was determined by subtracting the average difference in price between small and medium sizes from the price paid for small size eggs. The prices used were: peewee $0.129, small $0.239, medium $0.349, large and over $0.404 per dozen. The income from eggs produced for each stock was determined as the gross income from eggs for that stock minus the percentage of the income lost due to all size meat and blood spots on a broken out basis for that stock.

Analysis of Data

Where pens or pen averages were the smallest unit of measurement, a Duncan's multiple range test for significant differences (Duncan, 1955) was used. A nested analysis of variance (Snedecor, 1956) was employed for analysis of eggs produced per bird, and body weights and days of age to first egg. A Chi-square test was used to determine significant differences between laying house mortality, and for the percent blood and meat spots for the respective F_1's and F_2's. The laying house mortality and the percent blood and meat spots for the F_1's were used as the expected for the respective F_2's.

RESULTS

Test 1

<u>Egg Production and Laying House Mortality</u>

Percent hen-day production, eggs per pullet housed and the days to 50 percent production are given in Table II. The F_2 generation of IN-1 is the only F_2 which exhibited no reduction in hen-day percent production. The F_2's of IN-2, INX-1 and BX-1 all show a significant[1] reduction in this performance characteristic.

The F_2 generation of BX-1 is the only F_2 of the four stocks tested showing a significant decrease in the number of eggs per pullet housed. The F_2 of IN-1 produced 21.3 more eggs per pullet housed than the F_1. The F_1 generation of IN-2, INX-1 and BX-1 produced, respectively, 18.8, 19.2 and 26.0 more eggs per pullet housed. The number of days to 50 percent production increased in all F_2 generations with the differences between all respective F_1's and F_2's being significant except IN-1.

The days to first egg, laying house mortality, and egg production per survivor are summarized in Table III. The days to first egg follows the same pattern as days to 50 percent production with all F_2's being significantly different from their respective F_1 except for the F_2 generation of IN-1. The F_2 generation in every case exhibited slightly more variation for this trait than

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[1]The term significant means statistical significance at the 5 percent level of probability throughout this paper.

TABLE II

EGG PRODUCTION AND DAYS TO 50 PERCENT PRODUCTION--TEST 1

Breeding system		Production		
		Hen-day	Hen-housed	Days to 50%
		percent	number	days
IN-1	F_1	64.7^{b}	213.7^{ab}	166.3^{b}
	F_2	66.8^{b}	235.0^{bcd}	168.3^{b}
IN-2	F_1	72.2^{c}	243.6^{cd}	169.6^{b}
	F_2	64.7^{b}	224.8^{abc}	177.0^{c}
INX-1	F_1	64.7^{b}	226.9^{abc}	168.7^{b}
	F_2	59.2^{a}	207.7^{a}	177.7^{c}
BX-1	F_1	72.0^{c}	255.7^{d}	150.0^{a}
	F_2	63.9^{b}	229.7^{bc}	166.0^{b}

Averages within each column not followed by the same letter are significantly different from each other ($P \leq 0.05$) as determined by Duncan's Multiple Range Test (1955).

IN - Incross   INX - Incrossbred   BX - Crossbred

TABLE III

DAYS TO FIRST EGG[1], EGG PRODUCTION PER SURVIVOR[1], AND LAYING HOUSE MORTALITY[2]--TEST 1

Breeding system		Days to first egg: Average		Days to first egg: Std. dev.	Average egg production of survivors[3]: Average		Average egg production of survivors[3]: Std. dev.		Percent laying house mortality[4]	
IN-1	F_1	161.2	NS	9.7	234.9	NS	42.06		13.72	NS
	F_2	161.0		12.7	246.3		31.58		5.87	
IN-2	F_1	164.0	*	9.5	258.8	*	25.86		10.22	NS
	F_2	173.2		10.0	233.1		49.13		5.87	
INX-1	F_1	161.2	*	8.6	234.1	NS	30.64		3.92	NS
	F_2	170.1		9.6	217.6		28.98		5.87	
BX-1	F_1	147.9	*	7.8	258.2	*	27.78	*	1.95	NS
	F_2	160.7		9.6	234.2		34.00		1.95	

[1]Significant differences between the respective F_1 and F_2 generations determined by a nested analysis of variance (Snedecor, 1956).

[2]Significant differences between the respective F_1 and F_2 generations determined by a Chi-Square test.

[3]Individual egg production for birds completing 360 days in the laying house and laying over 100 eggs.

[4]Based on hens housed.

[NS]Not significantly different from each other ($P \leq 0.05$).

[*]Significantly different from each other ($P \leq 0.05$).

IN - Incross INX - Incrossbred BX - Crossbred.

its respective F_1 generation.

The average egg production for birds completing 360 days in the laying house and laying over 100 eggs gave differences of 11.4 more eggs for the F_2 of IN-1; 25.7, 16.5 and 24.0 more eggs laid by the F_1's of IN-2, INX-1 and BX-1, respectively. The differences between the respective F_1's and F_2's of IN-2, 25.7, and BX-1, 24.0, are significant. The F_2 generations of IN-2 and BX-1 were more variable for this trait than their F_1's, with the reverse being true for IN-1 and INX-1. There were no significant differences in laying house mortality.

Egg Quality Characteristics

Presented in Table IV are the data for egg weight, specific gravity, Haugh units and meat and blood spots. The average egg weight difference between the F_1's and F_2's is significant for IN-1, IN-2 and BX-1, being 2.5, 3.0 and 3.0 grams, respectively, with the F_1 generation laying the heavier egg. The difference of 1.3 grams with the F_2 having the larger egg in the INX-1 comparison is not significant.

The eggs of the F_2 of INX-1 had a significantly lower specific gravity than its F_1. The specific gravity scores of the eggs of the F_1 and F_2 generations of IN-1, IN-2 and BX-1 are not significantly different. The F_2 generation of IN-2 had 5.50 percent fewer meat and blood spot eggs than F_1 generation, the difference is significant at the 5 percent level. The other three comparisons for differences in the percent meat and blood spots

TABLE IV

EGG QUALITY CHARACTERISTICS--TEST 1

Breeding system		Average egg weight (gms.)	Average specific gravity score[1]	Average Haugh units[2]	Meat and blood spots[3]	
					Percent	Chi-Square
IN-1	F_1	58.8^b	4.57^b	78.93^f	10.32	.55 NS
	F_2	56.3^a	4.50^b	78.67^f	8.33	
IN-2	F_1	61.1^c	3.94^{ab}	80.33^g	9.23	4.47 *
	F_2	58.1^b	4.40^b	69.43^a	3.73	
INX-1	F_1	60.7^c	4.31^b	75.33^d	7.46	1.12 NS
	F_2	62.0^c	3.45^a	77.22^e	10.00	
BX-1	F_1	61.4^c	3.45^a	73.00^b	2.96	2.44 NS
	F_2	57.9^b	3.46^a	74.17^c	5.30	

Averages within each column not followed by the same letter are significantly different from each other ($P \leq 0.05$) as determined by Duncan's Multiple Range Test (1955).

[1,2,3] Calculated from quarterly breakouts during the 360 day test period.

[NS] Not significantly different from each other ($P \leq 0.05$).

*Significantly different from each other ($P \leq 0.05$).

IN - Incross   INX - Incrossbred   BX - Crossbred.

show no statistical significance at the 5 percent level.

Egg shell color data are summarized in Table V. There are no significant differences between the two generations for shell color score. The percentage of eggs which received a score of one or two are not significantly different within any of the stocks tested. The F_1 generation of IN-1 and BX-1 show significantly more eggs than their respective F_2 generation, receiving of score of three or over. There were significant differences found between the F_1 and F_2 generations of the remaining two stocks for the percentage of eggs with a score of three or over.

Egg Size Distribution

The percentages of eggs within each egg size class; peewee, small, medium, large and extra large, and the percentages of large and over are given in Table VI. There are no significant differences for percent peewee and small size eggs within any of the stocks tested. The differences in the percent of medium and extra large size eggs are significantly different for IN-1, IN-2 and BX-1 with the F_2 generation producing a higher percentage than its respective F_1. INX-1 shows no significant difference for percent medium or extra large size eggs. The F_1's and F_2's of IN-2 and BX-1 are significantly different from each other for the percentage of large eggs produced, the F_2's producing more in each case. The remaining two stocks show no significant differences for large egg size. The respective F_1 and F_2 generation of IN-1, IN-2 and BX-1 produced significantly different percentages of eggs in the class large and

TABLE V

SHELL COLOR SCORE AND DISTRIBUTION--TEST 1

Breeding system		Average shell color score	Distribution by shell color scores		
			Score 1[1]	Score 2	Score 3 or over
				percent	
IN-1	F_1	1.35[a]	76.77[a]	12.65[a]	10.58[d]
	F_2	1.20[a]	86.46[a]	11.38[a]	2.16[a]
IN-2	F_1	1.31[a]	75.75[a]	17.86[a]	6.39[bc]
	F_2	1.22[a]	82.41[a]	14.54[a]	3.06[ab]
INX-1	F_1	1.09[a]	90.65[a]	9.35[a]	0.00[a]
	F_2	1.12[a]	90.60[a]	8.01[a]	1.39[a]
BX-1	F_1	1.48[a]	66.33[a]	26.38[a]	7.29[cd]
	F_2	1.21[a]	84.51[a]	12.10[a]	3.39[ab]

Averages within each column not followed by the same letter are significantly different from each other ($P \leq 0.05$) as determined by Duncan's Multiple Range Test (1955).

[1] Score 1 - chalk white   Score 9 - light brown

IN - Incross   INX - Incrossbred   BX - Crossbred.

TABLE VI

EGG SIZE DISTRIBUTION--TEST 1

Breeding system		Egg size					
		Peewee	Small	Medium	Large	Extra large	Large & over
		Percent					
IN-1	F_1	$.47^{a}$	3.82^{a}	19.78^{b}	37.33^{bcd}	38.60^{b}	68.94^{a}
	F_2	$.82^{a}$	4.93^{a}	25.31^{c}	43.85^{d}	25.09^{a}	75.93^{b}
IN-2	F_1	$.44^{a}$	2.22^{a}	13.80^{a}	32.06^{abc}	51.48^{c}	83.21^{c}
	F_2	$.31^{a}$	3.11^{a}	19.41^{b}	43.84^{d}	33.33^{b}	77.17^{b}
INX-1	F_1	$.12^{a}$	1.74^{a}	12.33^{a}	28.65^{ab}	57.16^{c}	85.80^{c}
	F_2	$.13^{a}$	0.88^{a}	12.73^{a}	28.87^{ab}	57.39^{c}	88.26^{c}
BX-1	F_1	$.20^{a}$	2.84^{a}	13.07^{a}	26.71^{a}	57.18^{c}	83.92^{c}
	F_2	$.30^{a}$	3.39^{a}	19.23^{b}	40.03^{cd}	37.05^{b}	77.09^{b}

Percentages within each column not followed by the same letter are significantly different from each other ($P \leq 0.05$) as determined by Duncan's Multiple Range Test (1955).

IN - Incross INX - Incrossbred BX - Crossbred.

over, INX-1 showing no significant difference.

Body Weight

The average body weights of the pullets at 140 and 500 days of age are given in Table VII. The F_2 generation pullets of IN-1, INX-1 and BX-1 were lighter at housing with the F_1 generation of IN-2 weighing slightly less than the F_2. Only IN-1 showed a significant difference between the F_1 and F_2 generation. The F_1 generations of IN-1 and BX-1 were more variable than their respective F_2's as indicated by the larger standard deviation; the reverse being true for IN-2 and INX-1.

At marketing the differences between the respective F_1's and F_2's of INX-1 and BX-1 were highly significant,[2] with the F_2 of INX-1 weighing more and the F_1 of BX-1 being the heaviest. The F_1 generations of IN-1 and IN-2 were heavier and more variable than the F_2's, but the respective differences were not significant. The respective F_2's of INX-1 and BX-1, as indicated by their larger standard deviations, were the more variable generation for body weight at 500 days of age.

Feed Consumption and Feed Efficiency

The pounds of feed per hen housed, per 24 ounces of eggs, per pound of eggs and per dozen eggs are presented in Table VIII. The F_2 generations of IN-1, INX-1 and BX-1 consumed 2.2, 2.1 and .2 pounds, respectively, more feed than their F_1 generation, with the F_1 of IN-2 consuming 4.0 pounds more than its F_2 generation.

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[2]The term highly significant denotes significance at the .01 probability level throughout this paper.

TABLE VII

COMPARISON OF BODY WEIGHTS BETWEEN THE F_1 AND F_2 GENERATION[1]--TEST 1

Breeding system		Body weights (gms.) At housing Average		At housing Std. dev.	At marketing Average		At marketing Std. dev.
IN-1	F_1	1424.9	*	204.9	2076.4	NS	350.9
	F_2	1344.1		142.5	1926.7		178.1
IN-2	F_1	1322.9	NS	127.1	2349.1	NS	379.7
	F_2	1369.8		154.0	2184.6		311.7
INX-1	F_1	1465.8	NS	142.5	1945.9	**	263.4
	F_2	1322.4		152.4	2245.0		372.6
BX-1	F_1	1693.1	NS	168.9	2543.4	**	294.7
	F_2	1535.3		133.4	2335.2		349.6

[1]Significant differences between the respective F_1 and F_2 generations determined by a nested analysis of variance (Snedecor, 1956).

*Averages significantly different from each other ($P \leq 0.05$).

**Averages significantly different from each other ($P \leq 0.01$).

[NS]Averages not significantly different from each other ($P \leq 0.05$).

IN - Incross INX - Incrossbred BX - Crossbred.

TABLE VIII

FEED CONSUMPTION AND FEED EFFICIENCY--TEST 1

Breeding system		Pounds of feed: Per hen housed	Per 24 oz. of eggs	Per pound of eggs	Per dozen eggs
IN-1	F_1	80.6^{a}	4.38^{a}	2.92^{a}	4.54^{ab}
	F_2	82.8^{a}	4.33^{a}	2.89^{a}	4.23^{ab}
IN-2	F_1	83.3^{a}	4.04^{a}	2.69^{a}	4.35^{ab}
	F_2	79.3^{a}	4.15^{a}	2.71^{a}	4.26^{ab}
INX-1	F_1	81.4^{a}	4.04^{a}	2.69^{a}	4.31^{ab}
	F_2	83.5^{a}	4.42^{a}	2.95^{a}	4.82^{b}
BX-1	F_1	87.6^{a}	3.81^{a}	2.54^{a}	4.12^{a}
	F_2	87.8^{a}	4.49^{a}	3.00^{a}	4.56^{ab}

Averages within each column not followed by the same letter are significantly different from each other ($P \leq 0.05$) as determined by Duncan's Multiple Range Test (1955).

IN - Incross   INX - Incrossbred   BX - Crossbred.

None of these differences were significant. Within none of the stocks tested were there any significant differences exhibited for pounds of feed per 24 ounces, per pound or per dozen eggs produced.

Income Over Feed and Chick Cost

The income over feed and chick cost for the stocks tested are summarized in Table IX. The F_1 generation of BX-1 had an income over cost of $.87 greater than its F_2, which was the only comparison exhibiting a statistical significant difference. The F_1's of IN-2 and INX-1 earned, respectively, $.27 and $.62 more than their F_2 generation, with the F_2 generation of IN-1 earning $.54 more than its respective F_1 generation.

Test 2

Egg Production and Laying House Mortality

The percent hen-day production, eggs per pullet housed and the days to 50 percent production for Test 2 are presented in Table X. The F_2 generation of IN-2 showed a significant increase in percent hen-day production and the F_2 of INX-2 exhibited a significant decrease. There were no significant differences found between the first and second generations of the other stocks tested for percent hen-day production.

The F_1 generation of both INX-2 and SX-1 produced significantly more eggs per bird housed, 24.7 and 24.0, respectively. The F_2 generation of IN-1 produced 15.4 more eggs per hen housed than its F_1 but this difference and the differences between the respective

TABLE IX

INCOME OVER FEED AND CHICK COST--TEST 1

Breeding system		Cost per hen housed			Income per hen housed			Income over cost[4]
		Feed[1]	Chick[2]	Total	Eggs	Hens[3]	Total	
IN-1	F_1	$3.43	$.37	$3.80	$6.86	$.28	$7.14	$3.34[c]
	F_2	3.47	.37	3.83	7.44	.28	7.72	3.88[abc]
IN-2	F_1	3.71	.32	4.03	7.89	.32	8.21	4.18[abc]
	F_2	3.34	.32	3.66	7.26	.32	7.57	3.91[ab]
INX-1	F_1	3.41	.49	3.90	7.45	.29	7.73	3.83[abc]
	F_2	3.48	.49	3.97	6.86	.32	7.18	3.21[c]
BX-1	F_1	3.83	.36	4.20	8.35	.38	8.73	4.53[a]
	F_2	3.74	.36	4.10	7.41	.35	7.76	3.66[bc]

Averages not followed by the same letter are significantly different from each other ($P \leq 0.05$) as determined by Duncan's Multiple Range Test (1955).

[1]Feed cost to 500 days of age.

[2]Chick price obtained from breeder as price per 1000 day-old pullet chicks.

[3]Income from sale of hens at end of 360 days of production.

[4]Income over chick and feed cost.

TABLE X

EGG PRODUCTION AND DAYS TO 50 PERCENT PRODUCTION--TEST 2

Breeding system		Production		
		Hen-day	Hen-housed	Days to 50 percent
		percent	number	days
IN-1	F_1	64.35^{bcd}	204.3^{c}	176.0^{ab}
	F_2	67.97^{abc}	219.7^{bc}	168.5^{bc}
IN-2	F_1	62.29^{d}	203.5^{c}	172.8^{abc}
	F_2	69.05^{ab}	202.5^{c}	184.2^{a}
INX-1	F_1	60.88^{d}	201.8^{c}	160.8^{cd}
	F_2	64.31^{bcd}	199.3^{c}	179.5^{ab}
INX-2	F_1	69.88^{a}	228.5^{ab}	172.2^{abc}
	F_2	63.41^{cd}	203.8^{c}	184.2^{a}
SX-1	F_1	70.25^{a}	242.0^{a}	149.5^{d}
	F_2	65.37^{abcd}	218.0^{bc}	160.5^{cd}

Averages within each column not followed by the same letter are significantly different from each other ($P \leq 0.05$) as determined by Duncan's Multiple Range Test (1955).

IN - Incross INX - Incrossbred SX - Strain cross.

F_1 and F_2 generation of IN-2 and INX-1 were not significant.

All F_2's with the exception of IN-1 took longer to reach 50 percent production. The F_2 of INX-1 took a significantly longer time than its F_1, 18.7 days.

The days to first egg, laying house mortality, and egg production per survivor are given in Table XI. The sexual maturity, measured as days to first egg, followed the same pattern as days to 50 percent production with the F_2 of INX-1 taking significantly more days than its F_1. In every case the F_2 generation was more variable than it's respective F_1 as shown by the larger standard deviations.

Average egg production of survivors gave differences of 8.7 and 12.7 more eggs for the F_2 generations of IN-1 and IN-2 with the 12.7 being significant. The F_1 generations of INX-1, INX-2 and SX-1 laid 2.4, 22.3, and 15.4, respectively, more eggs than their F_2 generation, with 22.3 and 15.4 eggs being significant. The F_2's of IN-1, INX-1 and SX-1 were less variable than their respective F_1 for this trait, with the F_1's of IN-2 and INX-2 being less variable than their F_2. IN-2 and SX-1 show significant increases in percent laying house mortality in the F_2 generations. There were no significant differences found within the other stocks tested for laying house mortality.

Egg Quality Characteristics

Average egg weight, specific gravity score, Haugh units and meat and blood spot data are presented in Table XII. There

TABLE XI

DAYS TO FIRST EGG[1], EGG PRODUCTION PER SURVIVOR[1], AND LAYING HOUSE MORTALITY[2]--TEST 2

Breeding system		Days to first egg Average		Std. dev.	Average egg production of survivors[3] Average		Std. dev.	Percent laying house mortality[4]	
IN-1	F_1	165.0	NS	15.3	223.2	NS	44.7	11.67	NS
	F_2	164.5		21.9	231.9		32.5	8.33	
IN-2	F_1	175.7	NS	26.6	214.4	*	42.5	6.66	***
	F_2	176.6		24.1	227.1		44.0	20.00	
INX-1	F_1	155.2	**	16.5	221.0	NS	35.1	8.33	NS
	F_2	172.7		20.0	218.6		31.4	10.00	
INX-2	F_1	166.9	NS	22.8	240.8	*	35.2	3.33	NS
	F_2	170.3		24.1	218.5		44.9	6.67	
SX-1	F_1	147.6	NS	9.6	251.7	*	38.7	6.66	*
	F_2	154.5		13.3	236.3		37.7	16.00	

[1]Significant differences between the respective F_1 and F_2 generations determined by a nested analysis of variance (Smedecor, 1956).

[2]Significant differences between the respective F_1 and F_2 generations determined by Chi-Square test.

[3]Individual egg production for birds completing 360 days in the laying house and laying over 100 eggs.

[4]Based on hens housed.

[NS]Not significantly different from each other ($P \leq 0.05$).

*Significantly different from each other ($P \leq 0.05$).

**Significantly different from each other ($P \leq 0.01$).

***Significantly different from each other ($P \leq 0.001$).

TABLE XII

EGG QUALITY CHARACTERISTICS--TEST 2

Breeding system		Average egg weight (gms.)	Average specific gravity score[1]	Average Haugh unit[2]	Meat and blood spots[3]	
					Percent	Chi-Square
IN-1	F_1	56.93^{cd}	4.06^{abc}	72.75^{abc}	16.55	4.10*
	F_2	56.77^{d}	3.97^{abcd}	70.75^{cd}	9.87	
IN-2	F_1	60.17^{abc}	4.19^{ab}	75.06^{ab}	5.16	.33 NS
	F_2	57.01^{cd}	4.31^{a}	68.44^{d}	4.08	
INX-1	F_1	61.48^{ab}	3.80^{bcd}	72.12^{bc}	3.38	.83 NS
	F_2	59.11^{abcd}	3.68^{cd}	75.88^{a}	4.78	
INX-2	F_1	61.74^{a}	4.00^{abcd}	71.50^{bcd}	0.63	18.68***
	F_2	60.39^{ab}	3.98^{abcd}	72.06^{bc}	3.50	
SX-1	F_1	58.28^{bcd}	3.53^{de}	73.12^{abc}	4.85	1.15 NS
	F_2	59.50^{abcd}	3.13^{e}	71.75^{bcd}	2.86	

Averages within each column not followed by the same letter are significantly different from each other ($P \leq 0.05$) as determined by Duncan's Multiple Range Test (1955).

[1,2,3] Calculated from quarterly breakouts during the 360 day test period.

[NS] Not significantly different from each other ($P \leq 0.05$).

*Significantly different from each other ($P \leq 0.05$).

***Significantly different from each other ($P \leq 0.001$).

IN - Incross   INX - Incrossbred   SX - Strain cross.

were no significant differences found for egg weight or specific gravity score within any of the stocks tested.

The F_2 of IN-2 exhibited a significant reduction in Haugh units score as compared to its F_1 generation, with the F_2 of INX-1 showing a significant improvement over its F_1. There were no significant differences found within the other stocks tested for Haugh unit score.

The F_2 of IN-1 laid significantly fewer eggs containing meat and blood spots than its F_1, the difference being 6.68 percent. The F_2 of INX-2 laid 2.97 percent more eggs with meat and blood spots than its F_1, the difference being highly significant in this case.

The shell color score and distribution is given in Table XIII. Only the difference between the F_1 and F_2 generations of INX-2 is significantly different with the F_2 having the higher score. The F_2 of INX-1 and the F_1 of INX-2 laid significantly more eggs with a shell color score of one, the reverse being true for these two stocks for eggs receiving a score of two. The F_2 of SX-1 laid significantly more eggs which received a score of three or more than its F_1. There were no significant differences within the other stocks tested for percent eggs receiving scores one, two, three or over.

__Egg Size Distribution__

The percentages of eggs within each egg size class; peewee, small, medium, large, and extra large, and percentages of large

TABLE XIII

SHELL COLOR SCORE AND DISTRIBUTION--TEST 2

Breeding system		Average shell color score	Distribution by shell color scores		
			Score 1[1]	Score 2	Score 3 or over
				percent	
IN-1	F_1	1.66^{ab}	57.56^{b}	26.34^{a}	16.10^{a}
	F_2	1.45^{abc}	65.36^{b}	26.51^{a}	8.13^{abcd}
IN-2	F_1	1.70^{a}	59.98^{b}	24.31^{a}	15.71^{a}
	F_2	1.63^{abc}	60.76^{b}	26.15^{a}	13.09^{abc}
INX-1	F_1	1.42^{abcd}	61.86^{b}	35.00^{a}	3.14^{cd}
	F_2	1.16^{de}	88.81^{a}	7.96^{b}	3.23^{bcd}
INX-2	F_1	1.08^{e}	92.90^{a}	6.60^{b}	0.50^{d}
	F_2	1.39^{bcd}	69.04^{b}	24.06^{a}	6.89^{abcd}
SX-1	F_1	1.34^{cde}	71.33^{b}	25.51^{a}	3.16^{cd}
	F_2	1.63^{abc}	57.30^{b}	29.17^{a}	13.53^{ab}

Averages within each column not followed by the same letter are significantly different from each other ($P \leq 0.05$) as determined by Duncan's Multiple Range Test (1955).

[1]Score 1 - chalk white Score 9 - light brown.

IN - Incross INX - Incrossbred SX - Strain cross.

and over are given in Table XIV. Within the stocks tested there were no significant differences for percent peewee, small and medium egg size. Only the difference between the F_1 and F_2 generations of INX-2 was significant for the percent large, with the F_2 laying 6.07 percent more large size eggs. The F_1 generations laid a higher percent extra large eggs than their respective F_2's, with the difference between the F_1 and F_2 generations of IN-2 being significant. There were no significant differences within any of the stocks tested for the percent of eggs large and over.

Body Weight

Table XV presents the average body weights of the pullets at 140 and 500 days of age. The average weight per pullet of the F_2 generation of each stock tested was lighter at housing than its respective F_1. The F_1 generations of IN-1 and INX-2 were significantly heavier at housing than their respective F_2's, 67.8 grams and 124.5 grams respectively. The difference between the F_1 and F_2 of INX-1, 142.6 grams, is highly significant. The F_2's of IN-2, INX-1 and SX-1 were more variable for body weight at housing as indicated by a larger standard deviation.

At marketing time (500 days) only the difference, 190.4 grams, between the F_1 and F_2 generation of IN-1 was highly significant with the F_1 being the heavier. Differences within the other stocks tested were not significant. The F_1's of INX-1 and INX-2 had a larger standard deviation than their respective F_2's,

TABLE XIV

EGG SIZE DISTRIBUTION--TEST 2

Breeding system		Egg size					
		Peewee	Small	Medium	Large	Extra large	Large and over
		percent					
IN-1	F_1	.16^{a}	5.82^{ab}	21.17^{a}	43.35^{a}	29.50^{c}	72.85^{bc}
	F_2	.68^{a}	6.94^{a}	20.49^{a}	42.76^{a}	29.12^{c}	71.88^{c}
IN-2	F_1	.05^{a}	2.37^{cd}	13.32^{a}	35.80^{a}	48.46^{a}	84.26^{a}
	F_2	.24^{a}	4.28^{bc}	17.92^{a}	45.27^{a}	32.29^{bc}	77.56^{abc}
INX-1	F_1	.18^{a}	4.27^{bc}	16.39^{a}	35.19^{a}	43.97^{ab}	79.16^{abc}
	F_2	.40^{a}	3.55^{bcd}	17.23^{a}	37.68^{a}	41.14^{abc}	78.82^{abc}
INX-2	F_1	.22^{a}	1.67^{d}	11.52^{a}	34.41^{a}	52.18^{a}	86.59^{a}
	F_2	.23^{a}	2.65^{cd}	14.52^{a}	40.48^{c}	42.12^{abc}	82.60^{ab}
SX-1	F_1	.20^{a}	5.38^{ab}	16.32^{a}	36.81^{a}	41.29^{abc}	78.10^{abc}
	F_2	.24^{a}	4.19^{bc}	16.80^{a}	37.84^{a}	40.93^{abc}	78.77^{abc}

Percentages within each column not followed by the same letter are significantly different from each other ($P \leq 0.05$) as determined by Duncan's Multiple Range Test (1955).

IN - Incross INX - Incrossbred SX - Strain cross.

TABLE XV

COMPARISON OF BODY WEIGHTS BETWEEN THE F_1 AND F_2 GENERATIONS[1]--TEST 2

Breeding system		Body weights (gms.) At housing Average		At housing Std. dev.	At marketing Average		At marketing Std. dev.
IN-1	F_1	1372.8	*	148.0	2060.4	**	261.7
	F_2	1305.0		131.7	1870.0		272.0
IN-2	F_1	1372.3	NS	353.1	2059.3	NS	283.8
	F_2	1343.7		407.1	2077.7		308.6
INX-1	F_1	1435.6	***	116.0	1982.7		323.3
	F_2	1293.0		132.7	1886.8		280.3
INX-2	F_1	1388.7	*	134.3	1809.5	NS	283.8
	F_2	1264.2		108.1	1811.1		279.6
SX-1	F_1	1436.2	NS	144.9	1918.9	NS	306.6
	F_2	1379.3		146.6	1912.2		327.4

[1]Significant differences between the respective F_1 and F_2 generations determined by a nested analysis of variance (Snedecor, 1956).

[NS]Averages not significantly different from each other ($P \leq 0.05$).

*Averages significantly different from each other ($P \leq 0.05$).

**Averages significantly different from each other ($P \leq 0.01$).

***Averages significantly different from each other ($P \leq 0.001$).

IN - Incross INX - Incrossbred SX - Strain cross.

with the reverse being true in the other stocks.

Feed Consumption and Feed Efficiency

The pounds of feed per hen housed, per 24 ounces of eggs, per pound of eggs and per dozen eggs are presented in Table XVI. The F_1 generations of all stocks tested consumed more feed per hen than their respective F_2's; .57, 3.60, 5.00, 5.30 and 2.60 pounds more for IN-1, IN-2, In-1, Inx-2 and SX-1, respectively. These differences are not significant. There were no significant differences found within any of the stocks tested for pounds of feed per 24 ounces of eggs or per pound or per dozen eggs produced.

Income Over Feed and Chick Cost

Table XVII presents the income over feed and chick cost for the stocks tested. The F_1 generation of SX-1 had a significantly greater income than its F_2 generation, earning $.65 more per bird. The F_2's of IN-1 and INX-1 earned $.43 and $.06 more per hen housed than their respective F_1 generation. The F_1 generations of IN-2 and INX-2 had a greater income over cost than their respective F_2 generation, $.04 and $.55 respectively. The differences between the respective F_1's and F_2's of IN-1, IN-2, INX-1 and INX-2 were not significant.

Test 3

Egg Production and Laying House Mortality

Table XVIII presents data for percent hen-day production, eggs per pullet housed and the days to 50 percent production. The

TABLE XVI

FEED CONSUMPTION AND FEED EFFICIENCY--TEST 2

Breeding system		Pounds of feed: Per hen housed	Per 24 oz. of eggs	Per pound of eggs	Per dozen eggs
IN-1	F_1	76.92^{c}	4.53^{a}	3.02^{a}	4.54^{a}
	F_2	76.25^{bc}	4.16^{ab}	2.78^{ab}	4.16^{a}
IN-2	F_1	80.85^{ab}	4.51^{a}	3.01^{a}	4.78^{a}
	F_2	77.22^{bc}	4.56^{a}	3.04^{a}	4.58^{a}
INX-1	F_1	79.90^{abc}	4.30^{ab}	2.86^{ab}	4.64^{a}
	F_2	74.90^{c}	4.36^{ab}	2.90^{ab}	4.54^{a}
INX-2	F_1	81.45^{ab}	3.94^{b}	2.63^{b}	4.28^{a}
	F_2	76.15^{bc}	4.22^{ab}	2.81^{ab}	4.48^{a}
SX-1	F_1	83.58^{a}	4.04^{b}	2.69^{b}	4.14^{a}
	F_2	80.98^{ab}	4.26^{ab}	2.84^{ab}	4.47^{a}

Averages within each column not followed by the same letter are significantly different from each other ($P \leq 0.05$) as determined by Duncan's Multiple Range Test (1955).

IN - Incross   INX - Incrossbred   SX - Strain cross.

TABLE XVII

INCOME OVER FEED AND CHICK COST--TEST 2

Breeding system		Cost per hen housed			Income per hen housed			Income over cost[4]
		Feed	Chick[2]	Total	Eggs	Hens[3]	Total	
IN-1	F_1	$3.30	$.37	$3.67	$6.51	$.28	$6.79	$3.12[c]
	F_2	3.23	.37	3.60	6.89	.26	7.15	3.55[abc]
IN-2	F_1	3.42	.32	3.74	6.65	.30	6.95	3.21[c]
	F_2	3.28	.32	3.60	6.52	.25	6.77	3.17[c]
INX-1	F_1	3.34	.49	3.83	6.51	.28	6.79	2.96[c]
	F_2	3.18	.49	3.67	6.43	.26	6.69	3.02[c]
INX-2	F_1	3.44	.44	3.88	7.50	.27	7.77	3.89[ab]
	F_2	3.14	.44	3.58	6.66	.26	6.92	3.34[bc]
SX-1	F_1	3.55	.36	3.91	7.77	.28	8.05	4.14[a]
	F_2	3.43	.36	3.79	7.03	.25	7.28	3.49[bc]

Averages not followed by the same letter are significantly different from each other ($P \leq 0.05$) as determined by Duncan's Multiple Range Test (1955).

[1]Feed cost to 500 days of age.

[2]Chick price obtained from breeder as price per 1000 day-old pullet chicks.

[3]Income from sale of hens at end of 360 days of production.

[4]Income over chick price and feed cost.

TABLE XVIII

EGG PRODUCTION AND DAYS TO 50 PERCENT PRODUCTION--TEST 3

Breeding system		Production		
		Hen-day	Hen-housed	Days to 50 percent
		percent	number	
IN-1	F_1	69.90[abc]	239.7[ab]	167.2[a]
	F_2	62.10[cde]	215.2[abcd]	166.2[a]
IN-2	F_1	63.22[cde]	192.6[cd]	172.0[a]
	F_2	59.68[de]	199.3[bcd]	178.0[a]
INX-2	F_1	60.12[de]	198.1[cd]	167.0[a]
	F_2	61.66[cde]	213.0[abcd]	167.8[a]
SX-1	F_1	66.61[abcd]	222.1[abcd]	164.8[a]
	F_2	72.16[a]	242.7[a]	163.2[a]
SX-2	F_1	68.35[abc]	240.2[ab]	168.8[a]
	F_2	61.88[cde]	207.3[abcd]	171.8[a]
SX-3	F_1	69.42[abc]	229.7[abc]	166.8[a]
	F_2	65.24[abcd]	224.9[abcd]	170.0[a]
BX-2	F_1	70.42[ab]	242.4[a]	162.5[a]
	F_2	57.02[e]	188.0[d]	173.0[a]

Averages within each column not followed by the same letter are significantly different from each other ($P \leq 0.05$) as determined by Duncan's Multiple Range Test (1955).

IN - Incross INX - Incrossbred SX - Strain cross BX - Crossbred.

F_2 generations of IN-1, IN-2, SX-2, SX-3 and BX-2 all show a reduction in percent hen-day production as compared to their respective F_1's. The reduction of 13.40 percent is the only significant change observed.

The F_2 generation of BX-2 laid 54.4 eggs per pullet housed less than its F_1 generation, this difference being significant. The F_1 of IN-1, SX-2 and SX-3 laid 24.5, 32.9 and 4.8 more eggs, respectively, than their F_2 generation. The F_2 for IN-2, INX-2 and SX-1 laid 6.7, 14.9 and 20.6 more eggs, respectively, than their F_1 generation.

The number of days to 50 percent production increased in all F_2 generations with the exception of IN-1 and SX-1, none of the differences, however, were found to be significant.

Days to first egg, average egg production of survivors and percent laying house mortality are given in Table XIX. Days to first egg follows a similar pattern as days to 50 percent production. There were no significant differences found in days to first egg and in only one case was there more than a week's difference between the respective F_1's and F_2's, that being 11.4 days difference in BX-2. The F_2 generation of IN-1, INX-2, SX-2, SX-3 and BX-2 exhibited a greater variability than their respective F_1 generation as reflected by a larger standard deviation.

The F_2 generations of IN-1 and SX-2 laid significantly less and BX-2 highly significantly less eggs per survivor than their respective F_1's. The F_2 generation of SX-1 laid significantly more eggs than its F_1, there were no significant differences

TABLE XIX

DAYS TO FIRST EGG,[1] EGG PRODUCTION PER SURVIVOR,[1] AND LAYING HOUSE MORTALITY[2]--TEST 3

Breeding system		Days to first egg: Average		Days to first egg: Std. dev.	Average egg production of survivors[3]: Average		Average egg production of survivors[3]: Std. dev.	Percent laying house mortality[4]	
IN-1	F_1	162.6	NS	8.8	252.9	*	19.2	10.00	NS
	F_2	161.8		12.9	228.9		29.4	5.00	
IN-2	F_1	166.4	NS	12.1	228.1	NS	62.1	27.50	*
	F_2	172.2		10.8	228.9		37.1	10.00	
INX-2	F_1	163.6	NS	11.5	219.9	NS	69.4	15.00	NS
	F_2	160.8		11.9	227.2		34.7	12.50	
SX-1	F_1	159.5	NS	10.6	243.0	*	30.0	10.00	NS
	F_2	158.3		8.7	264.8		23.9	10.00	
SX-2	F_1	162.2	NS	9.8	251.6	*	20.3	2.50	**
	F_2	168.2		14.0	227.6		36.7	10.00	
SX-3	F_1	160.7	NS	8.6	255.0	NS	6.5	15.00	NS
	F_2	164.2		9.5	239.4		37.2	7.50	
BX-2	F_1	157.4	NS	13.9	257.5	**	32.1	10.00	NS
	F_2	168.8		14.2	220.1		36.2	15.00	

[1]Significant differences between the respective F_1 and F_2 generations determined by a nested analysis of variance (Snedecor, 1956).

[2]Significant differences between the respective F_1 and F_2 generations determined by a Chi-Square test.

[3]Individual egg production for birds completing 360 days in the laying house and laying over 100 eggs.

[4]Based on hens housed.

[NS]Not significantly different from each other ($P \leq 0.05$).

*Significantly different from each other ($P \leq 0.05$).

**Significantly different from each other ($P \leq 0.01$).

within the remaining three stocks. The F_2 generation of IN-1, SX-2, SX-3 and BX-2 were more variable than their respective F_1 generations for eggs produced per survivor, they also had the larger standard deviation of the two generations compared.

For percent laying house mortality only the differences between the respective F_1's and F_2's of IN-2 and SX-2 were significantly different. The F_1 generation of IN-2 suffered a mortality 17.50 percent greater than its F_2 generation and the F_1 of SX-2 had 7.5 percent less laying house mortality than its F_2 generation.

Egg Quality Characteristics

Table XX presents data for egg weight, specific gravity score, Haugh units and the percent eggs having meat and blood spots. There were no significant differences within the stocks tested for egg size or specific gravity score.

Only the difference of 5.0 Haugh units between the F_1 and F_2 generations of IN-1 was significant within the stocks tested, the F_1 having the higher Haugh unit.

The F_2 generation of SX-1 exhibited a highly significant reduction in the percent meat and blood spots, whereas, the F_2 of SX-2 showed a highly significant increase over its F_1 in the percent meat and blood spots. Within other stocks tested there were no significant differences for percent meat and blood spots.

Table XXI summarizes the data collected concerning egg shell color. There were no significant differences found within stocks for shell color score. The F_2's on IN-1, INX-2, SX-1 and BX-2

TABLE XX

EGG QUALITY CHARACTERISTICS--TEST 3

Breeding system		Average egg weight (gms.)	Average specific gravity score[1]	Average Haugh units[2]	Meat and blood spots[3] Percent	Chi-Square
IN-1	F_1	53.02^{a}	3.77^{ab}	78.00^{cde}	5.93	.10 NS
	F_2	52.48^{a}	3.90^{ab}	73.00^{h}	6.74	
IN-2	F_1	52.67^{a}	3.48^{abc}	77.50^{cdef}	5.62	3.74 NS
	F_2	50.36^{a}	3.81^{ab}	78.00^{cde}	1.01	
INX-2	F_1	51.69^{a}	3.68^{abc}	75.25^{defgh}	5.56	.76 NS
	F_2	53.00^{a}	3.55^{abc}	73.50^{gh}	3.60	
SX-1	F_1	53.21^{a}	3.22^{bcd}	74.00^{efgh}	16.36	9.16 **
	F_2	53.56^{a}	3.46^{abc}	77.00^{cdefg}	5.08	
SX-2	F_1	52.54^{a}	3.92^{ab}	83.50^{ab}	1.78	75.69 ***
	F_2	51.70^{a}	4.17^{a}	85.50^{a}	13.68	
SX-3	F_1	53.51^{a}	3.34^{bcd}	79.50^{bc}	5.17	.61 NS
	F_2	53.72^{a}	2.76^{d}	78.50^{cd}	3.51	
BX-2	F_1	58.53^{a}	2.99^{cd}	73.75^{fgh}	3.60	2.10 NS
	F_2	50.12^{a}	2.68^{d}	74.50^{defgh}	6.45	

Averages within each column not followed by the same letter are significantly different from each other ($P \leq 0.05$) as determined by Duncan's Multiple Range Test (1955).

[1,2,3]Calculated from quarterly breakouts during the 360 day test period.

[NS]Not significantly different from each other ($P \leq 0.05$).

*Significantly different from each other ($P \leq 0.05$).

**Significantly different from each other ($P \leq 0.01$).

***Significantly different from each other ($P \leq 0.001$).

IN - Incross INX - Incrossbred SX - Strain cross BX - Crossbred.

TABLE XXI

SHELL COLOR SCORE AND DISTRIBUTION--TEST 3

Breeding system		Average shell color score	Distribution by shell color scores		
			Score 1[1]	Score 2	Score 3 or over
			percent		
IN-1	F_1	1.25[a]	80.24[abc]	14.70[a]	5.06[a]
	F_2	1.12[a]	88.55[ab]	10.49[a]	.96[a]
IN-2	F_1	1.24[a]	78.92[bc]	19.02[a]	2.06[a]
	F_2	1.25[a]	84.36[abc]	9.34[a]	6.30[a]
INX-2	F_1	1.17[a]	86.37[ab]	10.03[a]	3.60[a]
	F_2	1.10[a]	90.13[ab]	9.87[a]	0.00[a]
SX-1	F_1	1.24[a]	82.20[abc]	13.91[a]	3.89[a]
	F_2	1.11[a]	91.96[a]	6.53[a]	1.61[a]
SX-2	F_1	1.13[a]	87.29[ab]	11.82[a]	.89[a]
	F_2	1.30[a]	79.79[abc]	14.40[a]	5.81[a]
SX-3	F_1	1.20[a]	87.70[ab]	8.59[a]	3.71[a]
	F_2	1.29[a]	78.32[bc]	15.40[a]	6.28[a]
BX-2	F_1	1.33[a]	74.04[c]	19.79[a]	6.17[a]
	F_2	1.25[a]	80.00[abc]	14.58[a]	5.42[a]

Averages within each column not followed by the same letter are significantly different from each other ($P \leq 0.05$) as determined by Duncan's Multiple Range Test (1955).

[1]Score 1 - chalk white   Score 9 - light brown.

IN - Incross   INX - Incrossbred   SX - Strain cross   BX - Crossbred.

had a slightly lower average score than their respective F_1 generations. Within stocks tested there were no significant differences for the percentages of eggs laid within each of the three color classifications, that is, the percent of eggs receiving scores 1, 2 and 3 or more.

Egg Size Distribution

The percentages of eggs within each egg size class; peewee, small, medium, large and extra large and the percent large and over are presented in Table XXII. The only significant difference in the percentage of eggs laid within the egg size class, within a stock was between the F_1 and F_2 of SX-1, with the F_1 generation laying 1.83 percent more small eggs than its F_2 generation. The F_1 generations of IN-1, INX-2, SX-2 and BX-2 laid 1.05, 1.44, 5.14 and 2.60 percent, respectively, more eggs large and over than their F_2's. The F_2 generations of IN-2, SX-1 and SX-3 produced, respectively, 2.48, 4.03 and .85 percent more eggs in the large and over class than their F_1 generations.

Body Weight

Table XXIII summarizes the data concerning body weights at 140 and 500 days of age. The average body weight at housing time of the IN-2, F_2 generation was 212.2 grams lighter than its F_1, a highly significant difference. The F_2's of SX-1, SX-2, SX-3 and BX-2 all had a lighter body weight at housing than their respective F_1's, but none of these differences were significant. All F_2's

TABLE XXII

EGG SIZE DISTRIBUTION--TEST 3

Breeding system		Peewee	Small	Medium	Large	Extra large	Large and over
		Egg size					
		percent					
IN-1	F_1	.07[a]	2.78[abc]	15.08[a]	27.87[a]	54.20[bcd]	82.07[cd]
	F_2	.32[a]	3.26[a]	15.40[a]	30.43[a]	50.59[d]	81.02[d]
IN-2	F_1	.00[a]	2.73[abcd]	14.25[a]	28.42[a]	54.60[bcd]	83.02[bcd]
	F_2	.00[a]	1.62[bcde]	12.88[a]	32.86[a]	52.64[bcd]	85.50[abcd]
INX-2	F_1	.18[a]	1.20[cde]	9.53[a]	26.65[a]	62.44[a]	89.09[a]
	F_2	.00[a]	.98[de]	11.37[a]	24.56[a]	63.09[a]	87.65[abc]
SX-1	F_1	.16[a]	3.21[ab]	12.51[a]	28.06[a]	56.06[abcd]	84.12[bcd]
	F_2	.20[a]	1.38[cde]	10.27[a]	29.12[a]	59.03[ab]	88.15[ab]
SX-2	F_1	.00[a]	2.35[abcde]	10.46[a]	31.16[a]	56.03[abcd]	87.19[abc]
	F_2	.09[a]	2.20[abcde]	15.66[a]	30.74[a]	51.31[cd]	82.05[cd]
SX-3	F_1	.24[a]	1.88[abcde]	12.03[a]	27.97[a]	57.88[abcd]	85.85[abcd]
	F_2	.00[a]	1.45[bcde]	11.85[a]	27.81[a]	58.89[ab]	86.70[abcd]
BX-2	F_1	.00[a]	.92[e]	10.76[a]	24.76[a]	63.56[a]	88.32[ab]
	F_2	.20[a]	1.42[bcde]	12.66[a]	27.16[a]	58.56[abc]	85.72[abcd]

Percentages within each column not followed by the same letter are significantly different from each other ($P \leq 0.05$) as determined by Duncan's Multiple Range Test (1955).

IN-Incross INX-Incrossbred SX-Strain cross BX-Crossbred.

TABLE XXIII

COMPARISON OF BODY WEIGHTS BETWEEN THE F_1 AND F_2 GENERATIONS--TEST 3

Breeding system		Body weights (gms.)					
		At housing			At marketing		
		Average		Std. dev.	Average		Std. dev.
IN-1	F_1	1540.5	NS	206.3	2097.5	NS	332.2
	F_2	1596.7		123.5	2103.4		339.3
IN-2	F_1	1621.7	**	171.8	2341.4	**	400.3
	F_2	1409.5		132.0	2030.8		235.3
INX-2	F_1	1443.2	NS	173.3	1912.4	NS	268.2
	F_2	1459.0		160.7	2010.8		218.5
SX-1	F_1	1509.7	NS	85.1	2132.5	NS	295.3
	F_2	1487.7		158.4	2028.3		216.7
SX-2	F_1	1454.2	NS	158.4	1927.7	*	236.0
	F_2	1425.5		205.3	2014.2		329.4
SX-3	F_1	1511.7	NS	152.0	2043.2	NS	291.2
	F_2	1486.7		151.2	2039.4		299.7
BX-2	F_1	1825.7	NS	193.6	2356.4	NS	294.3
	F_2	1725.5		135.2	2344.1		305.3

[1] Significant differences between the respective F_1 and F_2 generations determined by a nested analysis of variance [1] (Snedecor, 1956).

[NS] Averages not significantly different from each other ($P \leq 0.05$).

*Averages significantly different from each other ($P \leq 0.05$).

**Averages significantly different from each other ($P \leq 0.01$).

IN-Incross INX-Incrossbred SX-Strain cross BX-Crossbred.

with the exception of the F_2 generations of SX-1 and SX-2 had a smaller standard deviation than their respective F_1's.

The F_2 generation of IN-2 was still highly significantly lighter by 310.6 grams at marketing than its F_1. The F_2 of SX-2 weighed 86.5 grams more at 500 days of age than its F_1, and this difference was significant. There were no significant differences found within the other stocks. The F_2 generations of four of the stocks tested had a larger standard deviation; IN-1, SX-2, SX-3 and BX-2, while the three stocks, IN-2, INX-2 and SX-1 had a smaller standard deviation.

Feed Consumption and Feed Efficiency

The pounds of feed per hen housed, per 24 ounces of eggs, per pound of eggs and per dozen eggs are presented in Table XXIV. The F_2 generations of IN-1, IN-2, SX-1, SX-2 and BX-2 consumed 5.70, 1.87, 2.97, 6.37 and 11.70 pounds less feed, respectively, per bird housed than their respective F_1 generations. The F_2's of INX-1 and SX-3 consumed 4.95 and 10.15 pounds more feed per hen housed than their F_1's. There were no significant differences found within any of the stocks for pounds of feed per 24 ounces of eggs or per pound of eggs or per dozen eggs.

Income Over Feed and Chick Cost

Table XXV presents the data for income over feed and chick cost. The F_2 generations of IN-2, INX-2 and SX-1 had an income over cost per pullet housed of $.46, $.33 and $.80, respectively,

TABLE XXIV

FEED CONSUMPTION AND FEED EFFICIENCY--TEST 3

Breeding system		Pounds of feed			
		Per hen housed	Per 24 oz. of eggs	Per pound of eggs	Per dozen eggs
IN-1	F_1	89.90[a]	4.82[cde]	3.22[cde]	4.50[bc]
	F_2	84.20[a]	5.08[bcde]	3.39[bcde]	4.70[abc]
IN-2	F_1	84.65[a]	5.78[ab]	3.86[ab]	5.34[a]
	F_2	82.78[a]	5.66[abc]	3.77[abc]	5.02[abc]
INX-1	F_1	86.80[a]	5.78[ab]	3.85[ab]	5.24[ab]
	F_2	91.75[a]	5.60[abcd]	3.73[abcd]	5.21[ab]
SX-1	F_1	91.52[a]	5.06[bcde]	3.38[bcde]	4.95[abc]
	F_2	88.55[a]	4.68[de]	3.12[de]	4.41[c]
SX-2	F_1	88.35[a]	4.98[bcde]	3.32[bcde]	4.43[c]
	F_2	81.98[a]	5.24[abcde]	3.50[abcde]	4.76[abc]
SX-3	F_1	85.00[a]	4.66[e]	3.11[de]	4.60[abc]
	F_2	95.15[a]	5.47[abcde]	3.65[abcde]	4.94[abc]
BX-2	F_1	95.20[a]	4.62[e]	3.08[e]	4.71[abc]
	F_2	83.50[a]	6.05[a]	4.03[a]	5.32[a]

Averages within each column not followed by the same letter are significantly different from each other ($P \leq 0.05$) as determined by Duncan's Multiple Range Test (1955).

IN-Incross INX-Incrossbred SX-Strain cross BX-Crossbred.

TABLE XXV

INCOME OVER FEED AND CHICK COST--TEST 3

Breeding system		Cost per hen housed Feed[1]	Chick[2]	Total	Income per hen housed Eggs	Hens[3]	Total	Income over cost[4]
IN-1	F_1	\$3.81	\$.37	\$4.18	\$7.81	\$.30	\$8.11	\$3.93[a]
	F_2	3.65	.37	4.02	6.98	.31	7.29	3.27[abc]
IN-2	F_1	3.68	.32	4.00	6.28	.26	6.54	2.54[c]
	F_2	3.50	.32	3.82	6.54	.28	6.82	3.00[abc]
INX-2	F_1	3.66	.44	4.10	6.55	.25	6.80	2.70[bc]
	F_2	3.84	.44	4.28	7.04	.27	7.31	3.03[abc]
SX-1	F_1	3.84	.36	4.20	7.29	.30	7.59	3.39[abc]
	F_2	3.74	.36	4.10	8.00	.29	8.29	4.19[a]
SX-2	F_1	3.72	.35	4.06	7.89	.29	8.18	4.12[a]
	F_2	3.48	.35	3.83	6.76	.28	7.04	3.21[abc]
SX-3	F_1	3.63	.35	3.98	7.53	.27	7.80	3.82[ab]
	F_2	3.95	.35	4.30	7.61	.29	7.90	3.60[abc]
BX-2	F_1	4.14	.30	4.44	8.01	.33	8.34	3.90[a]
	F_2	3.67	.30	3.97	6.24	.31	6.55	2.58[c]

Averages not followed by the same letter are significantly different from each other ($P \leq 0.05$) as determined by Duncan's Multiple Range Test (1955).

[1]Feed cost to 500 days of age.

[2]Chick price obtained from breeder as price per 1000 day-old pullet chicks.

[3]Income from sale of hens at end of 360 days of production.

[4]Income over chick price and feed cost.

greater than their respective F_1's. The F_1's of IN-1, SX-2, and BX-2 earned, respectively, \$.66, \$.91, \$.22 and \$1.32 more than their F_2's, with the \$1.32 difference being the only significant difference found.

Tests 1, 2 and 3

Summary of the Tests Conducted

Table XXVI presents the performance of the F_2 generation, given as the percentage of its respective F_1 generation, for the three separate tests.

TABLE XXVI

THE PERFORMANCE OF THE F_2 GENERATIONS[1]

Breeding system	IN-1			IN-2			INX-1		INX-2		SX-1		SX-2	SX-3	BX-1	BX-2
test number	1	2	3	1	2	3	1	2	2	3	2	3	3	3	1	3
% Hen Day Prod.	97	106	89	*90	*111	94	*92	106	*91	103	93	108	90	94	**89	*81
Hen Housed Prod.	110	108	90	92	100	104	92	99	*89	108	*90	109	86	98	*90	*78
Days to 50% Prod.	101	96	99	*104	107	104	*105	*112	107	100	107	99	102	102	*111	106
Days to First Egg	100	100	100	*106	100	104	*106	**111	102	98	105	99	104	102	*109	107
Av. Egg Prod. Surviv.	105	104	*90	*90	*106	100	93	99	*91	103	*94	*109	*90	94	*91	**86
% Laying House Mort.	42	71	50	57	***300	**36	150	120	200	83	*240	100	**400	50	100	150
Av. Egg Wt. (gms.)	*96	100	99	*95	95	96	102	96	98	102	102	101	98	100	*94	86
Av. Spec. Grav. Score	98	98	103	112	103	110	*80	97	100	96	89	107	106	83	100	90
Av. Haugh Units	100	97	*94	*86	*91	101	*102	*105	101	98	98	104	102	99	*102	101
% Meat & Blood Spots	81	*60	114	*40	79	18	134	141	***556	65	59	**31	***768	68	179	179
Shell Color Score	89	87	90	93	96	101	103	82	*129	94	122	90	115	108	82	94
% Score 1	113	114	110	109	101	107	100	*144	*74	104	80	112	91	89	127	108

TABLE XXVI (Continued)

Breeding system	IN-1			IN-2			INX-1		INX-2		SX-1		SX-2	SX-3	BX-1	BX-2
test number	1	2	3	1	2	3	1	2	2	3	2	3	3	3	1	3
% Score 2	90	99	71	82	108	49	86	*23	*364	98	114	47	122	179	46	74
% Score 3 & Over	*20	50	19	48	83	306	00	103	1378	00	*428	41	653	169	*46	88
% Peewee	174	425	457	70	480	00	108	222	104	00	120	125	00	00	150	00
% Small	129	119	117	140	181	59	51	83	159	82	78	*43	94	77	119	154
% Medium	*128	97	102	*141	134	90	103	105	79	119	103	82	150	98	*147	118
% Large	118	99	109	*137	126	116	101	107	118	92	103	104	99	99	*150	110
% Extra Large	*65	99	93	*65	*67	96	100	94	81	101	99	105	92	102	*65	92
% Large & Over	*110	99	99	*93	92	103	103	100	95	98	101	105	94	101	*92	97
Body Wt.-Housing	*94	*95	104	104	98	**87	90	***90	*91	101	96	98	98	98	91	94
Body Wt.-Market	93	**91	100	93	101	**87	**115	95	100	105	100	95	*105	100	**92	100
Lbs. Feed/Hen Housed	103	99	94	95	96	98	103	94	93	106	97	97	93	112	100	88
Lbs. Feed/Lbs. Eggs	99	92	105	101	101	98	110	101	107	97	106	92	105	117	118	*131
Lbs. Feed/Doz. Eggs	93	92	104	98	96	94	112	98	105	99	108	89	107	107	111	113

TABLE XXVI (Continued)

Breeding system	IN-1			IN-2			INX-1		INX-2		SX-1		SX-2	SX-3	BX-1	BX-2
test number	1	2	3	1	2	3	1	2	2	3	2	3	3	3	1	3
Income Over Cost	116	114	83	94	99	118	84	102	86	112	84*	124	78	94	81*	66*

[1]Expressed as the percentage of their respective F_1 generation.

*Denotes significant difference found between the F_1 and F_2 generation of their respective stocks in that test ($P \leq 0.05$).

**Denotes significant difference found between the F_1 and F_2 generation of their respective stocks in that test ($P \leq 0.01$).

***Denotes significant difference found between the F_1 and F_2 generation of their respective stocks in that test ($P \leq 0.001$).

DISCUSSION

These data do not agree completely with the hypothesis that replacement stock produced from the *inter se* breeding of commercial hybrid chickens will perform at a lower level than the hybrids themselves.

From Table XXVI, page 54, it can be seen that the F_1 generation of all breeding systems does not consistently outperform its respective F_2 generation. Furthermore the variation of performance within a stock between tests for certain traits make conclusions more complicated.

One of the traits which the F_2 generation was exceeded by the F_1 generation in practically every breeding system and test was body weight at housing, 140 days. The average of the F_2 as a percentage of its F_1 generation was 98, 96, 90, 96, 97, 98, 98, 91 and 94 percent for IN-1, IN-2, INX-1, INX-2, SX-1, SX-2, SX-3, BX-1 and BX-2 respectively. This reduction in body weight might be expected, however, in some of the tests the F_2 was less variable for body weight. It would be expected that the F_2 generation be more variable than the F_1.

Other traits which exhibited a consistent reduction, with a few exceptions, in performance in the F_2 generations were measures of sexual maturity, such as days to 50 percent production and days to first egg. The measurements of sexual maturity can be related to body weight at housing, therefore, it is not too surprising that they follow a similar pattern. The trait days to first egg, also exhibited a decrease in variance in some of the F_2 generations.

Another trait related to body weight at housing is egg weight. There was a reduction of the egg weight in most of the comparisons of the F_2 generations to their respective F_1 generations. The reduction in egg weight was not as consistent nor as great as the reduction in body weight at housing. A similar pattern, as that concerning egg weight, was exhibited in regard to the percent eggs laid which fall in the class extra large. The F_2 generations generally laid a higher percent of medium eggs than their F_1 generations, but they also laid more large eggs than their F_1's.

The pounds of feed per hen housed can also be considered a reflection of the smaller body weight and egg size. The value of this performance trait is slightly reduced in the F_2 generations of several of the stocks tested, but could not be considered a reduction in performance. When the pounds of feed and egg size are combined in measurements, as in the pounds of feed per pound of eggs, the F_2 generation generally did not perform as well as their F_1 generation. The F_2 generation birds did not consume as much feed as their F_1 generation and they did not produce as large an egg but what they did eat was not converted into eggs as efficiently as their F_1's. This may also be a reflection on the F_2 generations' body weight as 500 days of age. In several cases although the F_2 generations were lighter birds at housing, they had a similar or greater weight than their F_1 generation at marketing. Here again it should be pointed out that the F_2 generation was not always the more variable generation, in regard to body weight at marketing.

Egg shell color is a characteristic which might be expected to become more variable in an F_2 generation. This increase in variation was not realized, but instead there was generally a reduction in the shell color scores and an increase in the percentage of chalk white eggs laid by the F_2 generations.

There was generally an increase in the percent laying house mortality and percent meat and blood spot eggs laid by the F_2 generations. These two traits, however, exhibited a great deal of variation between tests probably due to the relatively small numbers used in the experiment thus this variation makes it difficult to make a generalization.

The percent hen-day production, hen-housed production and average egg production of survivors generally were lower in the F_2 generations. The average decreases for these traits were slight in IN-1, IN-2, INX-1, INX-2 and SX-1, less than a 3 percent decrease. In SX-2 and SX-3 the decreases were greater, with the largest decrease realized in the F_2 generations of the breed crosses.

Income over chick and feed costs, which takes into consideration all economically important traits, was used as an index to compare the two generations in their ability to perform. The F_2 generations of INX-1, INX-2, SX-2, SX-3, BX-1 and BX-2 performed at 93, 99, 78, 94, 81 and 66 percent, respectively, of the level at which their F_1's performed. The F_2 generations of IN-1, IN-2, and SX-1 all averaged 104 percent of their F_1's index.

There was in the case of many of the traits within a stock a variation from test to test. This could be due to chance matings of individuals.

These variations could be due to the breeder making a change in the parental stock while maintaining the same breeding system, but without the breeder changing the commercial stock's designation.

There were several cases where the F_2 generation performance equalled or bettered its F_1 generation. These results are inconsistent with the general theory regarding the performance of a F_2 generation. Possible explanations of ways whereby F_2 generations could equal or exceed their respective F_1 generations should be considered.

Theoretically the F_2 generation could possibly outperform its F_1 generation due to transgressive segregation. As an example, if the F_1 generation is the result of crossing two lines, each of which is composed of individuals with similar genetic constitutions, but differing from each other, the F_1's would all have similar genotypes. When these F_1's, of similar genotypes, are bred _inter se_, their offspring would contain individuals with genotypes unlike either of the parental lines or the F_1's. These F_2's could contain individuals of superior, inferior and identical genotypes found in the F_1 Individuals. If the individuals with genotypes inferior for the traits measured were also inferior for livability, as might be expected, these birds may not have survived to be considered in the test, thereby making the F_2's a selected population with a potential for outperforming thei F_1 generation.

A type of genetic homeostasis could play a role in the ability of an F_2 generation to outperform its F_1. If it is assumed, as above that the F_1 generation individuals all have a similar genotype, then genotypes different from either of the parental or F_1 stock will be formed in the F_2 generation. The F_1 would be a homogenous population and the F_2 a heterogenous population. Assuming that all F_1's would react in a similar manner to changes in their environment, it could be assumed that the F_2 population might be buffered against changes in the environment. It would be possible for the F_1's to outperform their F_2's in a given environment, but if subjected to a change from that particular environment (disease, cold, heat) then they might not perform as well under this new environment. The F_2's in the ideal environment of the F_1's might not perform as well as the F_1 generation, but it is possible that change in environment might not have as much effect in lowering their performance as it did their F_1's. It would be possible, therefore, for the F_2 generation to outperform its F_1 generation under certain environmental conditions.

A type of epistatic gene action could possibly allow the F_2 generation to outperform the F_1. If in the F_1 there are gene combinations common to all F_1 individuals which mask the expression of some other genes, in the F_2 these combinations might be broken apart into new combinations allowing the desirable effects of the previously masked genes to express themselves. This would make it possible for the F_2 to outperform the F_1. It is more likely, however, that a type of epistasis, an interaction of nonallelic genes, be more favorable to an F_1 generation than to a F_2 generation.

It is possible that an F_2 generation could outperform its F_1 generation due to maternal effects. The F_1 would not exhibit full hybrid vigor for a trait which was under some maternal influence; unless the dam was already a hybrid, as in the female side of birds used to produce double cross hybrid. A trait under maternal influence would not exhibit any hybrid vigor until the F_2 generation was produced. The F_1 being produced from a female having no hybrid vigor for the trait but the F_2 coming from a F_1 possessing hybrid vigor for the trait.

Linkage could play a part in the F_2 being superior to its F_1 generation. It is accepted that if there was complete linkage of the gene combinations effecting the performance traits it would be possible for the F_2 to remain at the same performance level as the F_1. If there was any deterioration of the linkage groups influencing the performance traits, the F_2 would decrease in performance. If this deterioration was slight it would be possible to obtain samples from the population of F_2's which were superior to their F_1 generation.

The most plausible explanation may be low hybrid vigor in the F_1 generations. Lush (1945) points out that hybrid vigor in animals expresses itself only as a five to seven percent increase in performance. The experimental evidence concerning hybrid vigor in poultry varies in the amount expressed or whether it is expressed at all. The egg production traits would probably fall within this five to seven percent increase over the pure lines. Furthermore, many of the traits concerned with egg production show a high degree of additive gene action. If there is a low degree of heterosis expressed in the F_1 and the desired traits are controlled by additive gene action, it would increase the possibility of the F_2 generation outperforming its F_1. If the F_1 generation exhibited only five percent hybrid vigor then theoretically in the F_2 generation this might be reduced to 2.5 percent and by chance matings and sampling of the F_2 population the F_2 could not out-perform the F_1 generation. It is possible that many of the factors may play a role in producing a F_2 generation superior to its F_1.

SUMMARY

Three tests were conducted over a 30 month period, employing 1568 mature pullets. The advance generation pullets were produced by _inter se_ random matings of nine different commercial stocks representing four different breeding systems; crossbred, incross, incrossbred, and strain cross. Mature pullets were maintained in laying cages, one bird per cage until 500 days of age.

Data were collected on egg production, egg quality, feed consumption, mortality, body weight, and egg shell color. The performance of the F_2 generation of each stock was compared with its respective F_1 generation hatched at the same time.

The data do not completely agree with the general concept that a F_2 generation will be more variable and will invariably exhibit a decrease in performance. The data indicate that the type of breeding system used to produce the F_1 pullets has an effect on the performance of an advanced generation produced from these pullets. It seems evident that the hybrid vigor expressed in poultry is not as great as that expressed in the well known corn hybrids, and as a consequence, there was not a drastic reduction of performance in the F_2 generation.

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