Effects of Selection and Outbreeding On Hatchability In Chickens

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Hatchability breeding experiments have received the attention of investigators from the beginning of present day poultry breeding. Early work centered around determining whether or not the "hatching quality" of eggs was a separate and heritable trait. Pearl (1910) first undertook this study. He obtained a correlation coefficient for 87 dam-daughter pairs which led to the conclusion that "hatching quality in eggs" is definitely inherited in the female line and probably inherited in the male line.

Jull (1931) divided a mixed group of Rhode Island Reds and White Leghorns into two groups. One group's eggs had hatchability above the population mean, the other group below. He then compared the hatching performance of the two groups of offspring. In both breeds, the higher performing daughters were from the higher performing group of dams.

These and other early workers determined that hatchability is an inherited trait. Other evidence to support this conclusion could be drawn from the observed differences in hatchability among various breeds, strains, lines and families.

Normal hatchability expected in commercial strains of chickens, particularly within the broiler breeds, is in the range of 65 to 85 percent of all eggs set. Discovery of means to increase this to 90 percent or above would be a definite contribution to the poultry industry.

Many factors have been found to influence hatchability. These can be grouped under management, nutrition and breeding. Management and nutrition studies are the bases for much of the improvement in hatchability. However, there remains the problem of low hatchability due apparently to the genetic constitution of the stock involved.

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To improve hatchability by breeding will require much information concerning the genetic aspects of this trait. There are many gaps in our knowledge of this complex trait. The breeder needs to know the heritability of the trait in order to decide upon the type of selection best suited to his problem.

This bulletin deals with an experiment on selection for hatchability. Objectives of the work are to indicate the population change per generation and relate certain results for the purpose of obtaining heritability estimates. An intra-sire comparison of inter- and intra-line offspring is presented.

Experimental Procedure

This study was conducted through five generations and five hatching seasons; the two were completely confounded. That is, no part of any one generation was used more than one year. Presented herein by generations are the means for both the unselected offspring generations and the selected parents. Results are also presented from another phase of the study comparing the inter- and intra-sire performance of the offspring (pullets) from the selected fourth generation birds. Heritability estimates obtained from an analysis of variance of the four groups of the unselected fifth generation pullets are included in the results.

The experimental material used in this study was a strain of New Hampshires that had been a closed flock under selection for body weight, mortality, egg production and egg quality values for a number of years. Inbreeding had been avoided as much as possible (Brunson, 1955). The initial population consisted of 930 daughters from 16 sires and 150 dams. These daughters were then tested for hatchability and fertility by being mated to a random sample of intra-line males in the fall. In the spring of 1955 these daughters were separated into three groups, known as Line 1, Line 2 and Controls. Preliminary heritability of hatchability of all eggs set averaged 9 percent, based on about 14 eggs per pullet and an average of 6.4 daughters per dam family (Godfrey *et al.,* 1955). On the basis of these heritability estimates, family selection was indicated as the preferred breeding method to improve hatchability. In the fall of 1955, 731 pullets of Lines 1 and 2 and 300 Control pullets were housed and tested. From this, 10 sires and 70 dams were selected to continue both lines.

Essentially, the same procedure was followed the next year. In September of 1957, 820 pullets from Lines 1 and 2 and 100 pullets of the Control stock were housed. Lines 1 and 2 were tested and females of outstanding performance from superior families were selected for the individual male breeding pens.

Inter-line crosses were also made from these dams the following spring. Two hatches each were made from the inter- and intra-line matings. The egg production obtained in two weeks was used for all hatches. The inter-line chicks hatched February 27 and March 12, 1958. As soon as the last eggs for the second hatch were collected, the cross-matings were made by switching the Line 1 and Line 2 males. Two weeks later, paternity was credited to the new males. The cross-mated progeny hatched on April 9 and on April 23. Therefore, there was a time differential between the inter- and the intra-line offspring of four, six, and eight weeks, according to which hatches are compared.

The pullets then, were of four kinds. Besides the Lines 1 and 2, the Line 1 males X Line 2 females-cross was designated as Line 4, and its reciprocal, Line 3.

The Line 1 and Line 2 pullets were housed together, but separated by hatches. The Line 3 and Line 4 pullets were also housed together, and separated by hatches. The pullets were all mated to random samples of intra-line males, and as they reached the uniform age of 200 days were tested on "hatching power of eggs". Two hatches of two weeks' eggs were then made to test these pullets. These test results are reported as the average of both hatchs.

Prior to transferring, the eggs were candled. All "clears" were broken out and microscopic examination provided the basis for classifying the eggs as either infertile or dead germ.

Results and Discussion

Results from the selection phase of the experiment are presented in Table I. This was conducted by applying selection pressure for the same traits through four generations. The mean fertility and the percentage hatch of fertile eggs of the three groups, Line 1, Line 2 and Controls, are listed by generations. As the generations are completely separate, they are identified by year.

The data listed under "Spring-Breeders" were obtained from the hatches which produced the next generation. All live pullets were then housed in the fall and flock-mated to test for hatching performance. This performance is given under "Fall-Total Offspring Generation".

Table I—Performance in Selected Traits by Generation

Generation:	1954			1955			1956			1957			1958		
Line:	1	2	Con.	1	2	Con.	1	2	Con.	1	2	Con.	1	2	Con.
Spring-Breeders															
% F:[1]	88.8	88.8	---	93.8	94.2[2]	90.9	95.9	97.9	93.4	95.5	97.0	94.0	97.6	98.1	96.8
% H of F:[3]	83.6	83.6	---	88.5	89.0[2]	88.6	80.5	75.4	76.7	93.4	90.7	85.7	90.6	90.5	88.5
Fall-Total Offspring Generation															
% F:[1]	---	---	---	96.8	94.2	95.2	94.9	95.1	94.7	98.8	99.4	95.8	97.6	97.6	92.1
% H of F:[3]	---	---	---	89.7	87.6	91.1	93.8	94.1	88.8	91.0	90.9	89.9	90.6	92.8	82.7
Fall-Selected to be Breeders															
% F:[1]	99.4	99.4	---	99.9	99.3	95.2	99.0	98.7	94.7	99.7	99.6	95.8	99.3	97.6	92.1
% H of F:[3]	97.8	97.6	---	97.4	96.7	91.1	98.2	97.9	88.8	96.2	97.1	89.9	99.2	99.9	82.7

[1] % F = percentage fertility.
[2] One pen, number 32, was left out of these data, as fertility was approximately 5%.
[3] % H of F = percentage hatch of fertile eggs.

From this test the parents of the next generation were selected. For the purpose of comparison, the record made by those breeders is also presented. The difference between analogous elements under "Fall-Selected to be Breeders" and "Fall-Total Offspring Generation" is a measure of the selection differential of each generation.

As the population was not separated into different breeding groups until Spring 1954, the performance of all groups was identical for that year. The percentage fertility of the breeders in the spring exhibited a trend of higher performance each year, including the Control group. The average fertility of Lines 1 and 2 moved from 88.8 percent in 1954 to 97.8 percent in 1958. The two selected lines averaged approximately one to two percent higher fertility each spring than the Controls. The performance in percentage hatch of fertile eggs for all three groups varied rather markedly from year to year. The average performance of the two selected lines, however, is approximately one to two percent higher than the Control group each year. It will also be noted that the performance of the selected lines averaged 83.6 percent hatch of fertile eggs in 1954 and 90.6 percent in 1958.

An important criterion as to the effectiveness of selection experiments is the performance of the unselected, or total, offspring generation. The average fertility for the selected groups is very similar to that of the Control group through 1956. A spread of approximately one and two percent for the 1957 and 1958 generations, respectively, appeared in fertility between the selected lines and the Controls.

The first offspring generation after selection was begun in 1955. The Controls averaged approximately 2.5 percent greater hatch of fertile eggs than the average of Lines 1 and 2. After this first generation, the selected groups performed better than the Controls in this trait. The amount by which the selected groups exceeded the Controls in percentage hatch of fertile eggs was one to nine percent each year.

The percentage fertility exhibited in the fall selected breeders is relatively high through all five generations, averaging approximately 98 percent. The difference in performance between the Controls and the selected lines average approximately four percent, although the Control breeders decline so that there was a difference of 6.3 percent the last generation. The selected lines also performed better with respect to percent hatch of fertile eggs. This difference was approximately 5.5 percent until the last generation, 1958, when a difference of 16.9 percent appeared.

The data presented in Table I indicate a trend for the birds under selection pressure to improve their performance during the duration of this study. This rather slow but, in general, consistent improvement is accompanied by the reverse trend in the group that was mass-mated without any artificial selection having been applied.

Any interpretation of the results of this study, which includes a comparison of different generations, should be made with caution. This is because the environmental conditions may vary from year to year. Some possible sources of variation which would be confounded with generations are: weather, ration, housing, disease and whether an egg which was "clear" upon candling was called infertile or dead embryo when broken out by different personnel. The difficulty imposed by yearly environmental variations may be somewhat alleviated by also considering the Controls. The possibility of genetic drift in the Controls is also present.

The interpretation is that the trend for the selected lines to be superior in performance to the unselected group is representative of the results of genetic improvement due to breeding.

In Table II are presented various heritability estimates based on variance components. For the two traits, percentage fertility and percentage hatch of fertile eggs, all data were analyzed using the original percentage values and also the transformation arcsin percentage values. Since the possibility of hatch effect was indicated, all data were subjected to a separate analysis of variance for each hatch as well as an analysis of variance which included both hatches.

The heritability estimates for percentage fertility ranged from —0.251 to 1.420. The mean of the heritability estimates for fertility in the intra-line birds, designated as Lines 1 and 2 in Table II, is 0.284. The mean of the heritability estimates for fertility in the inter-line offspring, designated as Lines 3 and 4 in Table II, is 0.085. The transformed data produced heritability estimates with means of 0.132 and 0.114 for the intra- and inter-line offspring, respectively. The range of the heritability estimates using transformed data was only —0.203 to 0.406.

The arcsin transformation not only stabilized the variance (Federer, 1955) but also seemed to lower the range in the heritability estimates. The result of the transformation was that, in general, the higher heritability estimates were reduced somewhat and some of the lower estimates were raised. Using the transformed data, the means of the heritability estimates for fertility were approximately 0.13 in the Lines 1 and 2, and 0.11 in the Lines 3 and 4.

Table II—Heritability Estimates Based on Variance Components

		% Fertility			Arcsin $\sqrt{\text{\% Fertility}}$		
Line	Hatch[1]	h^2_S	h^2_D	$h^2_{(S+D)}$	h^2_S	h^2_D	$h^2_{(S+D)}$
1	H1	.130	1.420	.800	.088	.146	.333
1	H2	—.021	.458	.222	—.012	.246	.117
1	H1 & 2	.026	.724	.382	.024	.338	.182
2	H1	.124	.748	.441	.087	.466	.279
2	H2	.030	—.251	—.110	.053	—.116	—.032
2	H1 & 2	.052	—.055	.000	.064	.063	.063
3	H3	.079	.242	.161	.161	.009	.085
3	H4	—.131	.099	—.016	—.163	.532	.184
3	H3 & 4	—.079	.429	.175	—.019	.302	.142
4	H3	.165	—.181	—.008	.188	.053	.121
4	H4	—.212	.410	.099	—.203	.296	.046
4	H3 & 4	—.061	.254	.097	—.018	.223	.102
		% Hatch of F[2]			Arcsin $\sqrt{\text{\% Hatch of F}}$		
1	H1	—.080	.378	.076	—.125	.234	.056
1	H2	—.061	.414	.179	.008	.184	.096
1	H1 & 2	—.072	.325	.129	—.056	.208	.077
2	H1	.321	—.004	.034	.198	.211	—.006
2	H2	.100	.061	.081	.236	.065	.151
2	H1 & 2	.213	—.004	.068	.219	—.050	.085
3	H3	.092	.122	.107	.108	.438	.273
3	H4	—.127	—.383	—.255	—.252	.268	.008
3	H3 & 4	—.102	.330	.114	—.023	.092	.034
4	H3	.176	.000	.088	.113	.243	.178
4	H4	—.090	.748	.329	—.044	.419	.094
4	H3 & 4	.096	.175	.136	.054	.287	.170

[1] H1, H2, H3, H4, H1 & 2, and H3 & 4 = h^2 estimated from variance components obtained from an AOV of hatch 1, hatch 2, hatch 3, hatch 4, hatches 1 and 2 combined, and hatches 3 and 4 combined, respectively.
[2] % Hatch of F = percentage hatch of fertile eggs.

The mean heritability estimates for hatchability, using transformed data, were approximately 0.10 in the Lines 1 and 2, and approximately 0.14 in the Lines 3 and 4. It will be noted that transforming the data to degrees again decreased the range of the heritability obtained. The heritability for percentage hatch of fertile eggs had a range of —0.383 to 0.748, while the heritability of the transformed data had a range of only —0.252 to 0.438. When it is recalled that the percentage data produced one obviously incorrect estimate of 1.420, it would appear that, with these data at least, heritability estimated from variance components might be more meaningful when percentages are transformed to degrees.

Brunson (1955) found that a rather large maternal effect was present in the dam's contribution to the variance. He stated that any heritability estimates based on the dam or combination of sire and dam variance components will be in excess of the true estimate. Further, heritability estimates based on the sire components of variance would reflect more accurately the true additive genetic variance.

From this experiment, the heritability estimates for fertility from transformed data, based on the sire component, averaged 0.05 for Lines 1 and 2, and zero (negative 0.009) for Lines 3 and 4. These same values for hatchability averaged 0.08 for the Lines 1 and 2, and also zero (negative 0.008) for the Lines 3 and 4. King and Henderson (1954) pointed out that a difference between the two estimates might also be accounted for by the greater selection differential in the males.

A definite hatch effect in these data was indicated by the variation between analogous heritability estimates obtained from different hatches. Even so, the heritability estimates for the traits studied in this

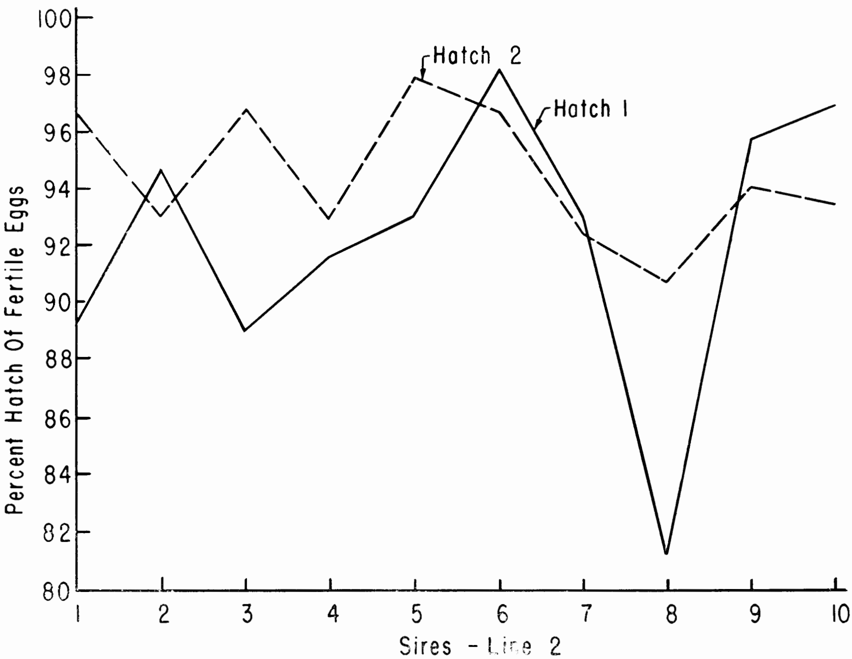

Figure 1. Graph of Sire X Hatch Interaction

experiment are of a magnitude which indicates that the family selection method is preferred. Lerner (1958) is cited for a more thorough discussion. Also, any interpretation of these heritability estimates should be made with the realization that the variance components used were obtained from an analysis based on a mathematical model that did not allow for the presence of any sire-hatch interaction. A possibility of sire-hatch interaction is shown by the crossing of the lines in Figure 1. Since lines crossed in seven of the eight comparisons, only one comparison was illustrated here.

In Table III are presented the results of an intra-sire comparison in fall performance of Intra- and Inter-line offspring. The average fertility of the two groups of Inter-line offspring was approximately one percent higher than the average of the Intra-line offspring. The average hatch of fertile eggs of the Inter-line offspring was approximately 3 percent higher than the average of the Intra-line offspring. Also, in all cases, the offspring from Line 2 sires (Y) exhibited superior performance.

Table III—Intra-Sire Comparison in Fall Performance of Intra-Line and Inter-Line Offspring

Sire	% Fertility Intra-	% Fertility Inter-	%Hatch of Fertile Intra-	%Hatch of Fertile Inter-
D30-5	97.9	97.7	94.4	91.9
D47-3	96.6	95.2	93.4	95.8
D30-10	96.8	95.7	90.4	91.4
D3-3[1]	95.0	---	91.6	---
D45-4	92.3	95.7	94.0	95.7
D54-13	97.2	95.4	88.4	92.6
D59-12	92.3	95.4	92.1	96.1
D72-8	92.2	97.9	91.1	96.0
D31-9	94.1	98.9	86.6	96.6
D48-7	93.3	98.3	85.9	94.0
Average	94.8	96.7	90.8	94.4
Y32-15	96.9	97.8	97.1	95.1
Y47-2	98.6	97.2	94.6	95.4
Y7-12[1]	98.1	---	94.8	---
Y5-1[1]	98.2	---	93.9	---
Y2-5	98.1	99.3	93.1	96.8
Y39-17	98.4	95.9	92.5	93.3
Y76-7	95.3	98.8	94.8	96.8
Y11-9	96.6	96.8	92.3	94.4
Y20-9	99.0	98.1	86.9	94.8
Y44-4	97.2	98.9	85.8	93.8
Y45-1[1]	---	97.5	---	96.0
Average	97.6	97.8	92.6	95.2

[1] As these males did not produce both kinds of offspring because of death or other reasons, none of their offspring's performance is used in obtaining the average.

No statistical test was applied to these data because, as pointed out earlier, there was a difference in hatch dates between the Inter- and Intra-line offspring. However, the interpretation of these data is that the advantage of the line-crossed chickens is probably real. Experimental evidence that crossing tends to improve the traits which make up hatchability has been presented earlier.

Summary and Conclusions

Three different phases of an investigation involving hatchability, fertility and outbreeding were conducted with New Hampshire chickens. (1) The selection phase was conducted by applying selection for fertility and hatchability on a closed flock which was split into two separate lines for four generations. A Control (unselected) line was also maintained. (2) The outbreeding phase was conducted by crossing, at the fourth generation, the two lines that had been under selection pressure. (3) Heritabilities were estimated by using variance components of the performance records of each of the four groups (Line 1, Line 2, and their crosses) of approximately 350 pullets each.

The conclusions resulting from these data are as follows:

1. The performance of the selected lines was superior to that of the control line. This was due to the trend of improved performance exhibited by the selected lines, accompanied by the reverse trend in the control line.

2. The progeny resulting from the inter-line matings performed better than their intra-line half sibs.

3. The heritability estimates obtained were of a magnitude that would suggest that family selection is the preferred method of selection. Definite indications of an effect of hatch date were found. A possibility of Sire X Hatch interaction was also present. Further heritabilities estimated from variance components might be more meaningful when percentages are transformed to degrees.

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