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**Effects of Inbreeding on Fecundity  
In Rhode Island Reds**

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**Inbreeding has been used extensively for establishing uniformity in herds and flocks. This report covers the results of inbreeding poultry for high fecundity characters when rigid selection of female breeding stock was practiced.**

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## EFFECTS OF INBREEDING ON FECUNDITY IN RHODE ISLAND REDS

By F. A. Hays, Research Professor of Poultry Husbandry

### INTRODUCTION

Two experiments previously reported by Hays (1924 and 1929) have shown that inbreeding reduces egg production. The birds in these experiments failed to exhibit many of the characters that make high production possible. In view of these results it is conceivable that the standards for selecting the foundation stock as well as for the selection of breeders each year were not so rigid but that many undesirable characters became intensified through inbreeding. In order to overcome these possible defects, a new experiment was started in the spring of 1929 using very rigid standards of selection.

The new project was made up of three lines of essentially unrelated birds. Line A breeding pen consisted of three groups of three full sisters each. These three groups of sisters had the same sire, but their dams were essentially unrelated. A check group was made up of three females selected at random from the high fecundity flock but not related to the inbred birds. All females were pullets, and the entire group was mated to the sire of the inbred pullets. Line B and line C breeding pens were made up in the same general way as line A, but the birds used in each line were not related to the birds in either of the other lines.

The 1930 matings consisted of pullets from the three lines mated to a cockerel of their own line and three check pullets selected from the general flock. There was one full-brother x sister mating each in lines A and B and two in line C. The other inbred matings were half-brother x sister matings. Daughters were retained from one inbred mating (half-brother x sister) and from one check mating in each of the three lines.

The 1931 matings consisted in line A of one half-brother x sister mating and five full-brother x sister matings with three check matings. For line B there were four full-brother x sister matings and three check matings. Line C had three full-brother x sister matings and two check matings.

Matings for 1932 in line A consisted of four full-brother x sister matings, two matings with line C and two check matings. Line B was discontinued with the 1931 generation because none of the females in this generation qualified for breeding in 1932. In line C there were two full-brother x sister matings, three matings with line A birds and two check matings.

The matings of 1933 to produce the last generation were as follows: An inbred line A male was mated to one of his full sisters, to two A and C line cross females, to four check females from line C, to five check daughters from the 1932 check matings in line A, and to one female selected from the general flock. In line C a male from a cross of lines A and C was mated to four of his full sisters, to one inbred line C female, to four line C 1932 check females, and to one female from the general flock.

### Standard for Selecting Female Breeders

A careful study was made of the flock as a whole to discover those families

that were free from undesirable weaknesses as far as known characters affecting egg production are concerned. The foundation stock used in this experiment was made up of the highest class of birds available with respect to known fecundity characters.

A standard for selecting pullet breeders was drawn up and followed as closely as possible throughout the experiment. Since the standard deals with the entire pullet laying year, it was necessary to place pullets in the breeding pens that had qualified up to the breeding season and to retain offspring from those that met the standard when their laying year closed.

Previous experience has shown that pullets and cockerels are more satisfactory for breeding in restricted projects where specific matings are desired. This is especially true for males where the death rate is very high, and to no small extent for females also. This explains why young untested males and females were used for breeding in this experiment, and why offspring were retained from but a small proportion of the pullet breeders used.

The standard for selecting each year was as follows:

Sexual maturity—215 days or less.

Weight at first egg—5 pounds or more.

Winter pause—not over 4 days.

Winter clutch size—2.6 or over.

Broodiness—none during the pullet year.

Persistency—315 days or more.

Hatchability—85 per cent or more.

Egg size—a minimum average of 52 grams to January 1.

Range mortality—not above 10 per cent in family.

In selecting breeding stock for a considerable number of characters, more difficulties exist than might be anticipated in an improved flock. Rather early in this experiment, it became necessary oftentimes to use birds for breeding that most nearly conformed to the standard. When, however, breeding females deviated widely from the standard set up for breeders, progeny was no longer maintained.

## EXPERIMENTAL RESULTS

### Character of Female Breeders

Table 1 shows the degree of conformity to the standard, by inbreds, checks, and birds from the inbred lines crossed as the experiment progressed.

Range mortality represents the death losses in families from the age of one day up to September 1. Hatching dates range at weekly intervals between March 25 and May 15 each year. All chicks were taken from the incubators at one day of age and placed in 10 x 12 portable brooder houses on the chick range. The chicks in this experiment were brooded along with other pedigreed Rhode Island Red chicks of the same age, in units of about 200. It is evident from the data obtained that the mortality rate was increasing in the inbred lines as the inbreeding became more intense, and that crossing lines A and C reduced the mortality rate in the last generation of breeding females.

Age at sexual maturity has been observed to increase under inbreeding by Dunn (1923), Dunkerly (1930), and Jull (1933); but Hays (1929 loc. cit.) failed to discover a consistent increase in age at sexual maturity when inbreeding Rhode Island Reds. This study, however, shows a rather consistent increase in the age at sexual maturity in the inbred mothers as the experiment progressed. The

TABLE 1.--PERCENTAGE OF BREEDERS QUALIFYING FOR STANDARD IN INBRED MATINGS AND CHECK MATINGS.

| Year | Matings                | Percentage Qualifying        |                                  |                                    |                              |                                |                 |                              |                          | Egg Weight to Jan. 1 Average of 52 grams | Number Kept          | Annual Production |                            | Laying-House Mortality Percent |
|------|------------------------|------------------------------|----------------------------------|------------------------------------|------------------------------|--------------------------------|-----------------|------------------------------|--------------------------|--|----------------------|-------------------|----------------------------|--------------------------------|
|      |                        | Range Mortality not over 10% | Sexual Maturity 215 days or less | Weight at First Egg 5 lbs. or more | Winter Pause not over 4 days | Winter Clutch Size 2.6 or over | Broodiness none | Persistence 315 days or more | Hatchability 85% or more |  |                      | Average           | Coefficient of Variability |                                |
| 1929 | Inbred                 | 33.33                        | 96.30                            | 88.89                              | 59.26                        | 81.48                          | 86.96           | 91.30                        | 11.11                    | 96.30                                    | <i>Families</i><br>6 | 231.04            |                            |                                |
|      | { Check                | 75.00                        | 100.00                           | 100.00                             | 50.00                        | 87.50                          | 75.00           | 75.00                        | 12.50                    | 87.50                                    | 3                    | 213.50            |                            |                                |
| 1930 | Inbred                 | 30.77                        | 92.31                            | 84.62                              | 30.77                        | 46.15                          | 88.89           | 77.78                        | 15.38                    | 84.62                                    | 3                    | 183.50            |                            |                                |
|      | { Check                | 77.78                        | 88.89                            | 100.00                             | 100.00                       | 77.78                          | 100.00          | 83.33                        | 22.22                    | 88.89                                    | 3                    | 207.83            |                            |                                |
| 1931 | Inbred                 | 0                            | 61.54                            | 76.92                              | 7.69                         | 30.77                          | 91.67           | 91.67                        | 0                        | 61.54                                    | 2                    | 171.83            |                            |                                |
|      | { Check                | 12.50                        | 100.00                           | 87.50                              | 37.50                        | 75.00                          | 100.00          | 100.00                       | 0                        | 87.50                                    | 2                    | 224.17            |                            |                                |
| 1932 | Inbred                 | 46.15                        | 53.85                            | 100.00                             | 23.08                        | 15.38                          | 87.50           | 12.50                        | 9.09                     | 61.54                                    | 2                    | 154.00            |                            |                                |
|      | { Check                | 25.00                        | 100.00                           | 100.00                             | 100.00                       | 75.00                          | 100.00          | 100.00                       | 25.00                    | 100.00                                   | 7                    | 241.00            |                            |                                |
| 1933 | Inbred                 | 0                            | 66.67                            | 33.33                              | 33.33                        | 33.33                          |                 |                              | 0                        | 66.67                                    | 0                    |                   |                            |                                |
|      | { Inbred Lines Crossed | 100.00                       | 100.00                           | 100.00                             | 16.67                        | 83.33                          | 100.00          | 50.00                        | 33.33                    | 100.00                                   | 4                    | 196.50            |                            |                                |
|      | { Check                | 60.00                        | 100.00                           | 100.00                             | 61.54                        | 69.23                          | 80.00           | 40.00                        | 7.69                     | 93.33                                    | 5                    | 207.00            |                            |                                |

TABLE 2.--PERCENTAGE OF OFFSPRING QUALIFYING FOR STANDARD EACH YEAR IN INBREDS AND IN CHECKS.

| Year | Matings                | Percentage Qualifying        |                                  |                                    |                              |                                |                       |                              |                          | Egg Weight to Jan. 1 Average of 52 grams | Number Kept            | Annual Production |                            | Laying-House Mortality Percent |
|------|------------------------|------------------------------|----------------------------------|------------------------------------|------------------------------|--------------------------------|-----------------------|------------------------------|--------------------------|--|------------------------|-------------------|----------------------------|--------------------------------|
|      |                        | Range Mortality not over 10% | Sexual Maturity 215 days or less | Weight at First Egg 5 lbs. or more | Winter Pause not over 4 days | Winter Clutch Size 2.6 or over | Broodiness none       | Persistence 315 days or more | Hatchability 85% or more |  |                        | Average           | Coefficient of Variability |                                |
| 1929 | Inbred                 | 19.05                        | 50.82                            | 78.33                              | 32.73                        | 20.37                          | 97.37                 | 52.63                        | 15.38                    | 72.22                                    | <i>Daughters</i><br>63 | 172.19            | .2049                      | 20.63                          |
|      | { Check                | 100.00                       | 77.78                            | 97.22                              | 39.39                        | 60.60                          | 83.33                 | 44.44                        |                          | 42.42                                    | 38                     | 179.00            | .2402                      | 42.11                          |
| 1930 | Inbred                 | 0                            | 56.52                            | 78.26                              | 17.39                        | 26.09                          | 95.00                 | 80.00                        | 0                        | 63.64                                    | 26                     | 170.60            | .1617                      | 11.54                          |
|      | { Check                | 78.13                        | 84.38                            | 81.25                              | 38.71                        | 58.06                          | 100.00                | 87.50                        | 33.33                    | 68.75                                    | 32                     | 202.75            | .1798                      | 15.63                          |
| 1931 | Inbred                 | 35.29                        | 41.18                            | 100.00                             | 33.33                        | 13.33                          | 87.50                 | 12.50                        | 9.09                     | 61.54                                    | 17                     | 154.00            | .1858                      | 25.00                          |
|      | { Check                | 52.94                        | 88.23                            | 100.00                             | 88.23                        | 82.35                          | 78.57                 | 85.71                        | 0                        | 41.18                                    | 17                     | 227.79            | .1854                      | 11.76                          |
| 1932 | Inbred                 | 0                            | 50.00                            | 25.00                              | 33.33                        | 33.33                          |                       |                              | 0                        | 75.00                                    | 5                      |                   |                            | 100.00                         |
|      | { Inbred Lines Crossed | 100.00                       | 91.67                            | 91.67                              | 45.45                        | 63.64                          | 100.00                | 66.67                        | 28.57                    | 91.67                                    | 12                     | 215.00            | .1319                      | 66.67                          |
|      | { Check                | 60.98                        | 90.24                            | 97.56                              | 55.55                        | 75.00                          | 100.00                | 72.22                        | 14.29                    | 68.29                                    | 41                     | 225.22            | .1619                      | 51.21                          |
| 1933 | Inbred                 |                              |                                  |                                    |                              |                                | No offspring retained |                              |                          |  |                        |                   |                            |                                |
|      | { Inbred Lines Crossed | 15.38                        | 72.73                            | 72.73                              | 20.00                        | 20.00                          |                       |                              | 100.00                   | 70.00                                    | 13                     |                   |                            |                                |
|      | { Check                | 61.77                        | 57.70                            | 100.00                             | 15.79                        | 57.90                          |                       |                              | 50.00                    | 76.19                                    | 34                     |                   |                            |                                |

percentage of inbred mothers that met the standard for early maturity fell as low as 53.85 per cent in 1932. When inbred lines were crossed, all of the mothers selected were genetically early maturing. The check mothers showed early maturity consistently throughout the period.

Weight at first egg is almost entirely dependent upon age at first egg in Rhode Island Reds, as Hays (1933a) has shown. This relation apparently did not hold true when inbreeding was practiced, using 5 pounds as a minimum weight. For example, all the inbred mothers used in 1932 qualified, while in 1933 only one-third of the mothers attained a 5-pound weight at first egg, which indicates that inbreeding did tend to decrease body weight. Crossing inbred lines A and C resulted in a return to satisfactory body weight. The check group of mothers showed satisfactory body weight throughout the experiment.

A cessation of egg production exceeding four days between November 1 and March 1 was considered a winter pause. The data show no consistent relation between inbreeding and the percentage of birds with winter pause. The check group of mothers was more satisfactory than the inbreds, but these failed to qualify as a whole for absence of pause in three years of the experiment. In general, inbreeding did not appear to greatly affect the proportion of birds with winter pause.

Highly intense birds will show a mean winter clutch size of 2.6 or more, according to previous studies on this flock (Hays and Sanborn 1927). The data presented in Table 1 show a progressive decrease in intensity of the inbred mothers throughout the experiment, while the intensity of the check mothers remained at a rather constant level. Crossing inbred lines A and C restored intensity to the original level of the foundation females. These results indicate clearly that inbreeding does reduce intensity of laying.

The failure of the broody instinct to appear during the first laying year indicates a low degree of broodiness, but is not a safe criterion of its absence, as Hays (1933b) showed. Since most of the birds in this experiment were retained for only one laying year, it was possible to employ only this partial criterion of the presence or absence of the broody instinct. Individuals that went broody the first year were known to carry the two complementary genes for broodiness and were selected against. The standard called for no broodiness in the pullet year, and the character of both the inbred and the check mothers remained rather stable in this respect throughout the experiment.

The proportion of highly persistent mothers had a marked falling off toward the end of the experiment in the inbred lines. Crossing two inbred lines failed to restore persistency to the level of the foundation females. The check females were satisfactory through the five years, except in the concluding year. There is no explanation for the inferior character of the check females of the last generation, other than mere chance. The data in general show a downward trend of persistency following inbreeding.

The hatchability of the foundation inbred females was unsatisfactory, since only 11.11 per cent gave a record of 85 per cent or more of fertile eggs hatched. This was followed by a still further decline as might be anticipated. In 1931 and 1933 none of the breeders qualified in hatchability. Crossing inbred lines did improve the hatchability. The check females were also an inferior lot from the standpoint of hatchability, but there was no significant decline throughout the experiment. There is, in general, a downward trend in hatchability of the inbred females used.

In mean egg weight to January 1, there is a significant decline in the inbred females. Crossing two inbred lines restored the winter egg size to its original level. Check females showed an almost constant conformity to the standard for egg size throughout the experiment. Inbreeding seemed to reduce winter egg size in this experiment.

The annual production of the inbred female breeders began with 231 eggs and showed a consistent decline to 154 eggs. Crossing inbred lines A and C increased the egg production level but not to the original figure. The check female breeders did not decline in production but were rather consistent high producers during the five-year period. Inbreeding did consistently reduce egg production because the selection of breeding females each year was based on anticipated superiority.

### Character of Female Offspring Produced

All female offspring from the inbred lines, from lines A and C crossed, and from the check matings are classified in Table 2 according to the standard. The three inbred lines are combined.

The 63 first-generation daughters produced by father x daughter matings showed only about 20 per cent qualifying with a family range mortality to September 1 of less than 10 per cent. In the following year the inbred daughters came from half-brother x sister matings in the three lines, and none of these daughters came from families with a range mortality as low as 10 per cent. The third generation of inbred daughters came from one half-brother x sister mating and one full-brother x sister mating. No daughters from the first mating qualified and all daughters from the second mating qualified giving about 35 per cent of all daughters qualifying. The fourth generation of inbred daughters from one brother x sister mating and two half-brother x sister matings all exceeded 10 per cent in range mortality. No inbred daughters were retained in the last generation. It is evident that range mortality did increase under inbreeding.

Check daughters showed a variable percentage qualifying for low range mortality. The minimum figure was about 53 per cent and this occurred in 1931. Two later generations of check daughters showed 61 and 62 percent qualifying.

Crossing inbred lines in 1932 gave only daughters with low range mortality, while in 1933 mortality in such daughters rose to a very high figure.

The age at sexual maturity of the inbred daughters did not change significantly in four generations. Crossing inbred lines in two generations greatly increased the percentage of early maturing daughters as compared with the inbreds. The check daughters showed a higher percentage of early maturing birds than the inbreds in every generation. These data indicate in a rather limited way that inbreeding does immediately retard sexual maturity but that continued inbreeding does not increase this effect.

Inbreeding had little effect on the weight at first egg. The last generation of inbreds showed only 25 per cent qualifying for the weight standard, but the number of daughters concerned is entirely too small to be conclusive. The first cross of inbred lines gave a high percentage of daughters of satisfactory weight, but this result did not appear in the second generation produced by crossing inbred lines. Uniformly heavy weight was observed in the check daughters. It is evident, therefore, from these data that inbreeding did not greatly influence body weight at sexual maturity.

The percentage of daughters lacking winter pause did not change perceptibly under continued inbreeding. The first cross of inbred lines gave some improve-

ment but the second generation was scarcely equal to the inbreds. A high variability in proportion of daughters free from winter pause occurred in the checks, probably due to environmental factors. In general, the proportion of females with winter pause does increase immediately with inbreeding and this increase is maintained by continued inbreeding.

High intensity showed neither an increase nor decrease under continued inbreeding. As compared with the check group and the first generation of inbred lines crossed, the inbred daughters were significantly lower in intensity. The data show that the first generation of inbred daughters exhibited very low intensity which was maintained through four generations.

There were no recognizable effects of inbreeding on the proportion of non-broody daughters produced, as shown by a comparison of inbreds with checks. This result might have been anticipated in a flock which is made up largely of non-broody individuals.

A cumulative effect of continued inbreeding on persistency was observed. The first generation inbred daughters showed about 53 per cent genetically highly persistent. In the third generation only 42.5 per cent were persistent. In the fourth generation only 12.5 per cent were persistent and in the fourth generation all daughters died before completing their laying year. Crossing inbred lines stimulated persistency to some extent.

Pullet-year hatching records were obtained on part of each generation of daughters, but the data are too inadequate to furnish much evidence on the relation between inbreeding and hatchability. They indicate, however, that inbreeding immediately lowers hatchability and the effect of inbreeding on hatchability appears to be cumulative. Crossing inbred lines resulted in a decided increase in the proportion of pullets hatching 85 per cent or more of fertile eggs.

Mean egg weight to January 1 tends to run heavier in the inbred daughters than in the checks. This difference is in part genetic and in part due to the greater age of inbreds when they lay their first egg. The first cross of inbred lines gave a still greater increase in egg size.

The first generation of inbred daughters gave a mean annual egg record of 172.29. The second generation showed about the same mean production, but the third generation fell to 154 eggs. In the fourth generation all pullets died before the end of their laying year. The check daughters sired by the same male as the inbred daughters showed a consistent increase in annual production as the experiment progressed, reaching a mean of about 228 eggs in 1931. Daughters from crossing inbred lines A and C gave higher annual egg records than any generation of inbred daughters. In this experiment inbreeding significantly reduced egg production in the first generation and in later generations.

The coefficients of variation in annual egg production show no reduction in variability that may be credited to inbreeding. No significant differences of variability between checks and inbreds is apparent. The apparent low variability from crossing the inbred lines in 1932 is not significantly lower than the other constants as judged by its probable error, due to small numbers of birds. There is, therefore, no evidence in these studies to indicate that inbreeding is effective in reducing variation in annual egg production.

The last column of Table 2 records the laying-house mortality of daughters for a 365-day period from date of housing. The mortality rate for inbred daughters had an upward trend during the experiment and all daughters of the last inbred generation died before the end of the year. Mortality rate was also excessive when the inbred lines were crossed. Inbreeding very definitely increased the mortality rate in the laying house in this experiment.

## SUMMARY

1. Three inbred lines were established using the following standard in the selection of female breeders:

|  |  |
|--|--|
| Sexual maturity—215 days or less.                | Broodiness—none during the pullet year.                |
| Weight at first egg—5 pounds or over.            | Persistency—315 days or more.                          |
| Winter pause—not over 4 days.                    | Hatchability—85 per cent or more.                      |
| Winter clutch size—2.6 or over.                  | Egg weight—a minimum average of 52 grams to January 1. |
| Range mortality—not above 10 per cent in family. |  |

Check females were selected each year from the general flock according to these standards and were mated to the inbred males. Female offspring from the most desirable families were retained and trapnested for a full year. One of the inbred lines failed to give any satisfactory breeding females in the third generation and was discontinued. The other two inbred lines were intercrossed in 1932 and 1933 and also bred as such.

2. Inbreeding increased range mortality, retarded sexual maturity, increased the percentage of birds with winter pause, reduced intensity, had no effect on broodiness, decreased persistency, reduced hatchability, increased winter egg weight, consistently reduced annual egg production without reducing its variability, and increased laying-house mortality.

3. Crossing inbred lines decreased range mortality in the first cross only, hastened sexual maturity, reduced the proportion of birds with pause, greatly increased intensity over that of the inbreds, improved persistency, increased hatchability, improved egg size, raised the annual egg production level above that of the inbreds but did not affect variability in egg production, and reduced the laying house mortality rate over that of the inbreds.

4. In no respect were the inbreds or inbreds crossed found to be superior to the general flock. Apparently nothing is to be gained from the standpoint of fecundity by inbreeding.

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