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Hereditary and Environmental  
Factors Affecting  
Variability in Egg Production

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It is generally conceded that the egg production of fowls is influenced by heritage and environment. There are, however, many factors that contribute to these influences, and it should be of scientific interest and economic importance to evaluate some of them. This investigation and the results reported here constitute such an attempt.

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# HEREDITARY AND ENVIRONMENTAL FACTORS AFFECTING VARIABILITY IN EGG PRODUCTION

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## INTRODUCTION

It is a well-known fact that both hereditary and environmental influences affect the number of eggs laid by a hen. Evidence is not conclusive on many points, however, and experimental data have not been reported to furnish information concerning the quantitative variation of specific fecundity traits from generation to generation. There is at present an outstanding need of a clear-cut distinction between the effects on fecundity of heritage and environment. Such a problem offers many difficulties, the most outstanding of which is the lack of any measure of fecundity in males.

This report concerns itself with results obtained in carrying three lines of birds through four generations. Consideration is given to variability in five inherited fecundity characters; sexual maturity, intensity, winter pause duration, total days broody, and persistency.

The variability in winter and annual egg records is also reported. Such environmental influences as hatching date, increase or decrease in body weight, and daily house temperature are considered in relation to egg production and the relative importance of each is discussed.

## PLAN OF EXPERIMENT

### 1928 Matings

In the spring of 1928 three pens of yearling hens were selected for this experiment. Pen A consisted of six hens from three unrelated families mated to an unrelated yearling male. The breeding females and the male were chosen with special reference to uniformity within the family for age at first egg, length of winter pause, intensity, days broody and persistency.

Pen B contained two unrelated yearling hens. These two hens came from families that were especially uniform in annual egg records. The male used in this pen was a half brother to one hen and not related to the other. His sisters were very uniform in annual egg records.

Pen C included four yearling hens from three families that had very high annual egg records. Three of the hens were half-sisters and the fourth was unrelated. These half sisters were mated to their half brother and the unrelated hen was not related to this male.

### 1929 Matings

Selection of breeding stock in 1929 to produce generation three in Pen A was on the basis already indicated, of family uniformity in the second generation of this line. Since pullet breeders were used, it was only possible to consider in selection, age at sexual maturity, intensity and winter pause. The male was

a yearling and was chosen according to stipulations for line A. Two of the pullet breeders were not related to the male and one was his half sister.

The 1929 selection for line B consisted of two pullets, half sisters to each other, selected from the previous generation. A yearling male from the preceding generation and unrelated to the pullets was mated to them.

Pen C in 1929 contained two full sisters and these were mated to a yearling male of the previous generation but unrelated to them.

### 1930 Matings

In line A for the 1930 matings, four pullets were bred from. Three of these were half sisters to the cockerel used and one was his full sister.

Line B was made up of four pullet sisters mated to their full brother.

Line C carried one pullet mated to a cockerel. These birds were full brother and sister.

In all cases where pullet breeders were made use of, selection of breeders was limited to the characters of early maturity, winter pause and intensity, or to egg production during the early months of the laying year. In this experiment the most definite selection on the basis indicated was made on the parental generation where all birds were yearlings. All birds were pedigreed Rhode Island Reds.

### Related Matings

The foundation stocks were hatched in 1926 and these were mated in 1928 to produce the second generation. Generations three and four were hatched in 1929 and 1930, each from the previous generation pullets.

In line A the foundation male was not related to the foundation females selected. The six females came from three unrelated families giving diversity of ancestry in this line with no inbreeding in the second generation hatched in 1928. The third generation hatched in 1929 came from three pullets mated to a yearling male. Two of these pullets were not related to the male and the third was his half-sister. There were 22 daughters produced, only four of which were from the inbred mating. The fourth generation of 23 daughters was produced by mating three pullet sisters to their half-brother and a fourth pullet half-sister to her half-brother. This last generation is rather closely bred and may be compared for variability with the first two generations which were not inbred.

In line B two foundation hens were used as breeders. They were not related to each other, one was not related to the male used and the other was his half-sister. This gave a second generation of 15 daughters, eight from the unrelated mating and seven from the related mating. The third generation of 12 daughters came from two half-sisters mated as pullets to an unrelated yearling male. The fourth generation gave 19 daughters. Sixteen of these were from full brother-sister matings and 3 from half brother-sister matings. The foundation females in line B were unrelated and there was some inbreeding in the second generation, none in the third generation and close inbreeding in the fourth generation.

Line C was founded by four yearling hens and a yearling male. Three of these hens were half-sisters representing two families and the fourth was unrelated. The male was a half-brother to the three half-sisters and unrelated to the other hen. The matings for 1929 were between two pullet full-sisters and an unrelated yearling male. The fourth generation came from a single mating of a cockerel and pullet that were full brother and sister giving only two daughters.

In general, the degree of relationship increases in successive generations. This method of breeding might be expected to reduce the amount of variability for inherited characters in the later generations. There are no reasons to assume, however, that inbreeding would reduce variability in egg records produced by environmental influences.

### VARIABILITY IN HEREDITARY CHARACTERS AFFECTING FECUNDITY

The five hereditary characters—age at sexual maturity, winter intensity, winter pause, broodiness, and persistency—are known to have significant effects on the annual egg records of the flock studied. Results of breeding for three generations from three selected foundations may be studied with respect to variability in the above five characters and in winter and annual egg production. Table 1 records the coefficients of variation of the four generations in this experiment with respect to the five inherited characters and for winter and annual egg records.

The check group is made up of 1695 birds hatched in the five years from 1925 to 1929. These birds compose the general flock being developed for high fecundity and are used as checks on all records, except winter production. Flocks hatched from 1916 to 1925 including 3867 birds furnish the check coefficient of variation in winter egg production.

TABLE 1—COEFFICIENTS OF VARIATION IN CHARACTERS AFFECTING FECUNDITY AND IN WINTER AND ANNUAL PRODUCTION.

Year Hatched	Generation	Number of Birds	COEFFICIENTS OF VARIATION—PER CENT						
			Age at First Egg	Intensity	Pause Days	Broody Days	Persistency Days	Winter Production	Annual Production
<b>Line A</b>									
1926	1	15	6.72	60.77	75.51	69.23	4.36	29.07	14.92
1928	2	46	11.29	35.20	67.79	0	9.74	29.08	17.16
1929	3	13	8.38	31.32	65.76	0	12.11	23.53	18.51
1930	4	23	11.79	30.10	44.49	15.56	16.07	37.24	22.41
<b>Line B</b>									
1926	1	4	12.09	59.11	0	0	0	16.57	5.52
1928	2	15	9.23	27.44	63.48	0	14.22	19.45	17.28
1929	3	12	14.10	33.27	66.67	33.33	11.94	31.87	12.72
1930	4	19	12.74	48.49	80.87	75.38	14.87	33.11	19.16
<b>Line C</b>									
1926	1	15	8.63	46.95	69.85	67.86	15.82	24.52	14.45
1928	2	48	10.33	28.72	65.32	41.82	12.63	27.05	13.66
1929	3	3	6.10	8.80	0	0	3.98	46.77	11.66
1930	4	2	5.14	0	0	0	4.58	11.43	2.27
<b>Checks</b>									
1925-29		1695	10.64	47.65	67.57	75.94	14.41	.....	19.82
1916-25		3867	.....	.....	.....	.....	.....	41.24	.....

### Age at First Egg

Line A had the lowest variability in age at sexual maturity in the first generation. The coefficients of variation in the three lines for the first generation were 6.72, 12.09 and 8.63 per cent, respectively. The variability in age increased in subsequent generations in line A and was greater in the fourth generation than the normal of 10.64 per cent shown by the check group.

Line B showed a wider variation in age at first egg than the check group in all generations, except the second. It is clearly evident that neither the method of selecting breeders nor the degree of relationship reduced the age variability in this line. In fact, 19 of the 22 daughters in the fourth generation actually came from full brother-sister matings.

Line C exhibited a very significant reduction in variability of age at sexual maturity in the last two generations. This line actually had a variability in the fourth generation about half as great as the check group. The low variability was evident in the third generation resulting from unrelated matings as well as in the fourth generation from a brother-sister mating.

In general, these data indicate that non-heritable influences are constantly operating to reduce or increase the age at sexual maturity in genetically early pullets so that a reduction in age variability below 10 per cent by breeding methods does not seem feasible. More carefully controlled environmental conditions are likely to reduce variability but the possibilities here are limited.

### Intensity

Intensity is here measured by mean winter clutch size. The first generation of females in lines A and B show a variability of intensity of about 60 per cent. Line C has a variability of about 47 per cent in the first generation and is comparable with the check group. The results of breeding are shown in generations two, three and four.

Line A was selected each year for uniform high intensity. It will be observed that the clutch size showed a consistent decrease in variability with each generation and the last three generations are lower in variability than the check group.

Line B exhibited a high degree of uniformity in intensity in the second generation; but without specific selection for uniformity generations three and four show decreased uniformity.

Line C gave a highly significant decrease in variability in each succeeding generation. The number of birds concerned in the last generation is too small to give the zero value significance, however. Results in this line illustrate that in the selection of very high producers for breeding, the variability of winter intensity is reduced. It is probable that almost every bird in the first generation of this line carried both genes I and I' for high intensity and such a genetic make-up should produce increased uniformity in succeeding generations.

The data point in general to the effect of inheritance upon uniformity of intensity and demonstrate clearly that breeding is more important than environment in controlling variation in intensity.

### Duration of Winter Pause

In duration of winter pause only birds ceasing to lay for four or more days in the winter season are considered. Such birds presumably carry the dominant

gene M. This being the case, no consistent lowering of variability in succeeding generations might be anticipated as long as controllable environmental influences remain constant.

Table 1 shows that both lines A and C were highly variable in pause duration in the first generation. The number of pause birds in line C is too small to give a value for this line.

Line A had a consistent decrease in variability for length of pause in generations two, three and four. Line B did not decrease in variability in successive generations and showed greater variability than the checks in the fourth generation. A sufficient number of birds with pause in line C occur only in the first two generations. There is no significant change of variability in these two generations.

The records on variability in pause duration in line C suggest that there may be minor hereditary factors modifying pause duration. More data are necessary before definite conclusions may be drawn.

### Days Broody

The sum of the non-productive days associated with broody periods during the pullet laying year may be used as a measure of degree of broodiness. In this report only birds exhibiting broodiness in the first laying year are considered. Goodale, Sanborn and White (1920) offer a two-factor hypothesis to explain the presence or absence of the broody instinct, but the causes of variation in degree of broodiness have not been reported.

Table 1 shows a large coefficient of variation for degree of broodiness in the first generation for lines A and C. Line B included so few broody birds in the first and second generations that the variation could not be determined.

In general, there appears to be a decline in variability in degree of broodiness in two of the lines. Since breeding females were selected in each line for freedom from broodiness, it seems probable also that there may be heritable modifiers affecting degree of broodiness. Further data are being secured on this particular point.

### Persistency of Laying

Persistency is a character which, like age at sexual maturity, has a relatively low variability. Generation one in lines A and B had very little variability. Line C, however, gave a coefficient of variation in the first generation amounting to 15.82 per cent, while the normal for the flock is 14.41 per cent.

In succeeding generations line A continued to increase in variability, strongly suggesting that environmental influences were operating because selection of breeders was based upon uniformity in the family.

Line B changed but little in variability of persistency in the last three generations, but there was a marked increase from the first to succeeding generations.

Line C began with high variability and there was a decrease with each generation to the very low constants of 3.98 and 4.58 per cent, respectively, in generations three and four. The probable explanation of this improved uniformity lies in the fact that very high production is not possible without high persistency, and in the selection of breeders on high annual egg records, the line approached genetic purity for persistency.

These data give evidence that in selection for uniformity in persistency in the three lines, environmental forces appear to be more potent than heredity in affecting variability in strains where most individuals carry gene P for high persistency.

To sum up, the data presented in Table 1 concerning the variability of five inherited characters affecting fecundity indicate the following: Age at first egg in pullets is modified by environmental influences in a genetically early maturing population so that there is a variation of about 10 per cent that is not produced by hereditary differences. Winter intensity is highly variable, and the response to selection for low variability in all three lines indicates that the observed high variability is largely due to genetic differences. The data further point to the possibility of reducing the variation of intensity to a figure comparable with age at sexual maturity. Winter pause duration is modified but little by selection. Some evidence that degree of broodiness is governed by hereditary factors appears. High persistency behaves like early sexual maturity in that a moderate degree of variation occurs that does not appear to be genetic.

#### VARIATION IN WINTER PRODUCTION

Winter production depends largely upon the three inherited characters; age at sexual maturity, winter pause and intensity. Line A was constantly selected for uniformity in the above characters along with non-broodiness and high persistency. Lines B and C were not selected for uniformity in these inherited characters. Variation in winter egg records was not consistently reduced in any of the lines, but all three lines were less variable than the check group.

#### VARIATION IN ANNUAL PRODUCTION

Annual egg records depend upon five inherited characters already indicated as well as upon many environmental influences both controllable and otherwise. Line A was selected for uniformity in inherited characters affecting fecundity, line B was selected for uniformity of annual egg records, and line C was selected for high egg records. All three lines were carried under the same environmental conditions.

The data in Table 1 show that line C alone decreased in variability with each generation. This fact would indicate that selection for high annual records decreased the variation in annual records. The data as a whole show that both heredity and environment are operating to affect variation in annual egg records.

#### ENVIRONMENTAL FACTORS IN RELATION TO VARIATION IN ANNUAL PRODUCTION

##### Hatching Date

Birds used in this experiment were regularly hatched in eight weekly hatches beginning March 25. It is conceivable that these rather restricted hatching dates may affect the variation in annual egg production because unequal numbers of birds in the three lines were hatched on the same date.

In Table 2 the three lines are combined and the number of individuals hatched on each date in each generation is recorded. The coefficients of variation of the mean production records of each hatch are recorded in the four generations to serve as a rough measure of variation in production attributable to differences in hatching dates.

TABLE 2—HATCHING DATE IN RELATION TO ANNUAL PRODUCTION.  
(Lines A, B, and C combined.)

Hatch No.	1926 FIRST GENERATION		1928 SECOND GENERATION		1929 THIRD GENERATION		1930 FOURTH GENERATION	
	Number of Birds	Mean Production	Number of Birds	Mean Production	Number of Birds	Mean Production	Number of Birds	Mean Production
		<i>Eggs</i>		<i>Eggs</i>		<i>Eggs</i>		<i>Eggs</i>
1	4	218.00	26	217.65	5	238.00	9	173.89
2	5	238.40	14	221.21	4	246.50	8	204.50
3	0	.....	9	226.67	7	240.29	8	163.38
4	1	171.00	11	234.18	3	239.00	9	169.67
5	4	249.25	20	232.35	5	218.20	7	191.71
6	5	236.00	11	248.00	4	171.50	2	194.50
7	8	244.88	12	235.75	0	.....	1	225.00
8	7	241.00	6	225.67	0	.....	0	.....
Total	34		109		28		44	
Mean		237.00		228.72		226.86		181.61
<b>Coefficients of Variation of Means—Per Cent</b>								
		6.06 ± .50		4.05 ± .18		10.70 ± .97		8.94 ± .64

The coefficients of variation in mean production due to differences in hatching date are recorded at the end of Table 2. These, together with the gross data presented in the table, show clearly that hatching date does affect annual production and variability in production. Hatching date also appears to have had a greater effect upon variation in the last two generations. The data indicate that about 7 per cent of the variation in annual records may be assigned to differences in hatching date.

#### Change in Body Weight During the Laying Year

All birds were weighed approximately 365 days after the mean date of first egg to discover how body weight behaves near the close of the laying year. The total population consisted of 149 individuals that showed a weight increase after the first pullet egg, 54 individuals that showed a loss of weight, and 2 individuals having no weight change. The mean annual egg record of the gaining group was 225.98. The mean production of the group losing weight was 211.28. Table 3 gives the detailed data.

The coefficient of variation for the twelve mean production records in the gaining group is  $9.86 \pm .39$  per cent. The coefficient for the losing group is  $11.09 \pm .72$  per cent. The difference is  $1.23 \pm .82$  per cent. This difference is not statistically significant and indicates that the variation in annual production is independent of gain or loss in weight during the laying year. The data show that body weight change is not a factor affecting variability of annual egg records.



VARIABILITY IN EGG PRODUCTION

TABLE 3—BODY WEIGHT INCREASE OR DECREASE IN RELATION TO ANNUAL PRODUCTION.

Generation and Line	BIRDS SHOWING INCREASE IN WEIGHT			BIRDS SHOWING DECREASE IN WEIGHT			BIRDS SHOWING NO CHANGE IN WEIGHT		
	No. of Birds	Mean Increase	Mean Production	No. of Birds	Mean Decrease	Mean Production	No. of Birds	Mean Weight	Mean Production
		<i>Pounds</i>	<i>Eggs</i>		<i>Pounds</i>	<i>Eggs</i>		<i>Pounds</i>	<i>Eggs</i>
1 { A	13	0.67	231.54	2	-0.71	233.00	0	.....	.....
B	3	.31	268.67	1	-.35	279.00	0	.....	.....
C	11	.78	233.00	4	-.42	233.50	0	.....	.....
2 { A	39	.80	233.85	7	-.57	227.14	0	.....	.....
B	9	.57	209.11	5	-.64	229.00	0	.....	.....
C	34	.65	236.35	13	-.33	215.08	1	4.65	196
3 { A	9	.64	253.00	4	-.51	209.50	0	.....	.....
B	7	.72	225.14	4	-.28	217.00	0	.....	.....
C	2	.59	225.50	1	-.33	177.00	0	.....	.....
4 { A	13	.89	170.00	6	-.39	161.67	0	.....	.....
B	8	.60	198.63	7	-.51	192.29	1	5.50	122
C	1	.55	151.00	0	.....	.....	0	.....	.....
Total Mean	149		225.98	54		211.28	2		159
<b>Coefficient of Variation of Means—Per Cent</b>									
			9.86 ± .39			11.09 ± .72			

House Temperature

Graham (1930) presented data suggesting that house temperature and egg production seem to vary together. His data show in general that a fluctuation in house temperature is likely to be followed by a fluctuation in the production of the birds. Smith (1930) reported that higher house temperatures within limits increased winter egg production.

In the charts the relation of house temperature to egg production is shown. The weekly percentage production together with the mean daily house temperature are illustrated graphically for the laying years 1926-27, 1928-29, 1929-30 and 1930-31. The period begins September 11 and closes November 26 each year.

Mean house temperature readings were taken at 7 A.M. and 6 P.M. daily with thermometers located on the roost level immediately in front of the roosts. The mean daily house temperature used in the charts is the mean of the two

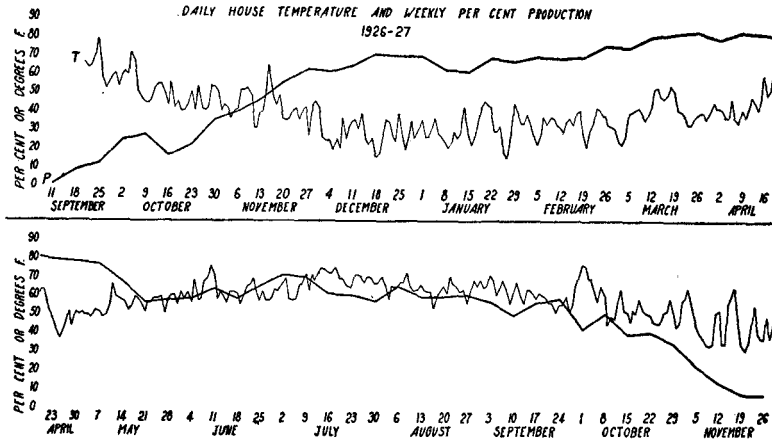


Chart 1. Relation of House Temperature to Egg Production, 1926-27.

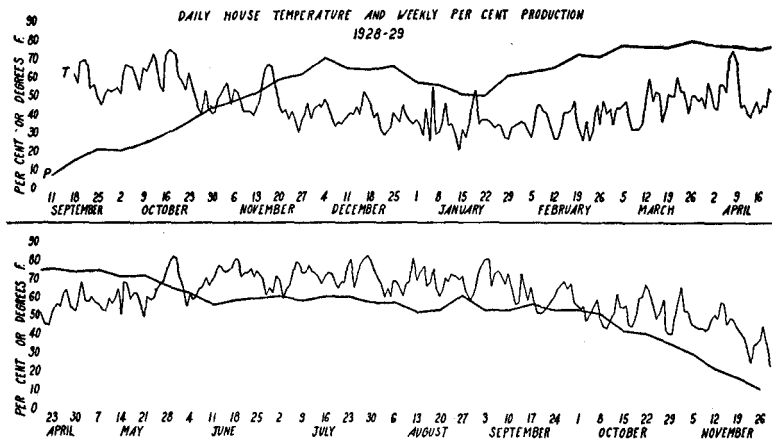


Chart 2. Relation of House Temperature to Egg Production, 1928-29.

The flocks included in the four years reported do not show any clean-cut response in production to house temperature changes. The data do indicate, however, that a house temperature near the freezing point was accompanied by decreased production in three years out of four in the month of January. In the summer season there is evidence that house temperatures above 70° react

unfavorably on egg production. Production responses to temperature changes seem to follow soon after the temperature changes. On the whole, the effects of variation in house temperature on variation in egg production are not very significant for the birds studied, and house temperature may be placed among the minor causes of variability in production.

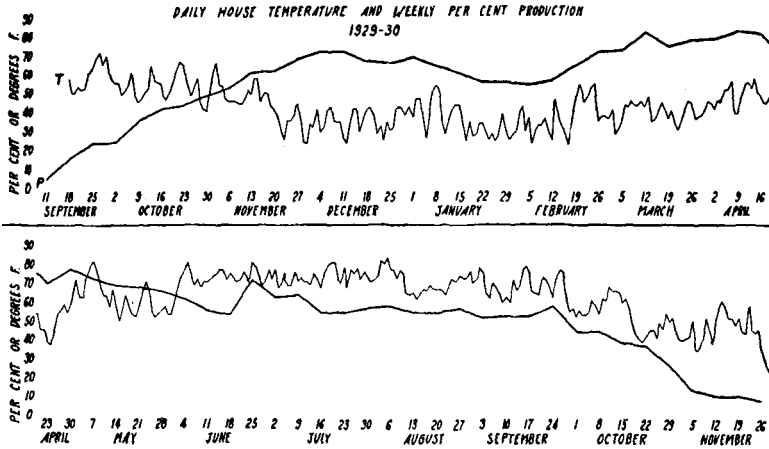


Chart 3. Relation of House Temperature to Egg Production, 1929-30.

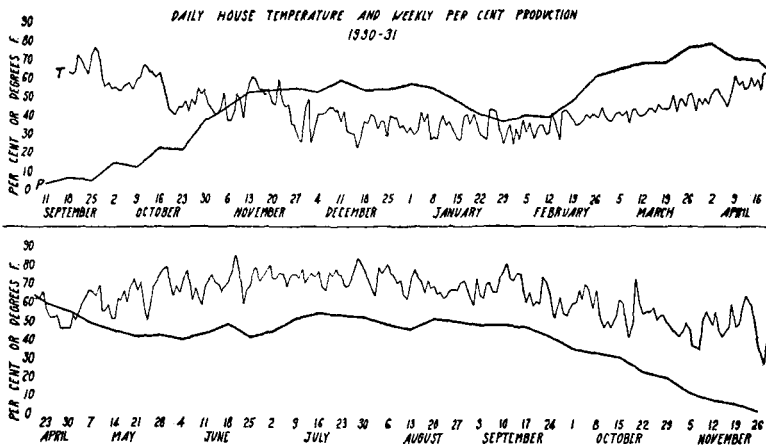


Chart 4. Relation of House Temperature to Egg Production, 1930-31

## SUMMARY

Three lines were established, each on a different selection basis: Line A, for uniformity in inherited characters affecting fecundity; Line B, for uniformity of annual egg records; and Line C, for high annual records. Each line was carried through four generations to study variability of inherited characters affecting fecundity and the effect of some environmental influences upon variability in egg production.

Age at sexual maturity shows a coefficient of variation of about 10 per cent produced by environment in birds of the same genetic constitution for sexual maturity.

Winter intensity is highly variable in a flock, due to genetic differences. In this experiment the variability was greatly reduced by selection of breeders in four generations. There is no evidence to indicate that environment influences clutch size.

Winter pause duration may be reduced by constant selection and is also greatly affected by environmental influences.

There is evidence that degree of broodiness measured by total days broody may be influenced by hereditary modifiers.

Persistency shows a variation of about 10 per cent that may be ascribed to environmental influences.

Variability in winter egg production decreased only in Line C, and increased inbreeding in successive generations did not reduce the variation in winter egg records.

Variation in annual egg records was less in Lines B and C than in Line A.

Differences in hatching dates are responsible for about 7 per cent of the variation in annual egg records.

Neither increase nor decrease in body weight of the pullets during the laying year affected the annual egg records.

House temperature near the freezing point reduces egg production; house temperatures above 70 to 75° may perceptibly reduce production; and production changes are likely to follow soon after temperature changes.

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