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Standard Egg Weight
in Rhode Island Red Pullets**

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In breeding for *egg size* an important consideration is the time required by pullets to attain 24-ounce egg weight. This report is concerned with a number of factors that vitally influence this time interval.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

TIME INTERVAL FROM FIRST EGG TO STANDARD EGG WEIGHT IN RHODE ISLAND RED PULLETS

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

INTRODUCTION

In a preliminary report Hays (1930) has shown that the time required by pullets to attain an egg weight of 57 grams, or about 24 ounces per dozen, varies widely and is influenced by such hereditary traits as age at sexual maturity, weight at sexual maturity, and intensity of laying. The ability to lay 57-gram eggs in a short time after sexual maturity was pointed out as being highly desirable economically.

This report is concerned with the relation between time required to attain standard (24 ounces per dozen) egg weight and various fecundity characters, as well as number of eggs laid in the winter season and during the pullet laying year. A study is also reported on fecundity traits and egg production of the birds that failed to attain standard egg weight the first year. The partial or net correlation has been determined between time required and the following independent variables: hatching date, age at sexual maturity, weight at sexual maturity, winter clutch size, winter pause duration, total days broody, and annual persistency; also the multiple correlation between these seven variables and time required. Greater variability in time required than can be ascribed to the seven variables studied may be assigned largely to hereditary factors that affect the time required to reach standard egg weight.

Data Available

Records are available on 409 birds that attained standard egg weight during the pullet laying year and 140 individuals that failed to attain standard egg weight. These birds were hatched from 1928 to 1932, and were all pedigreed Rhode Island Reds bred for high fecundity. The birds included in this study were all genetically early-maturing individuals, that is, beginning to lay at 215 days of age or younger. Each individual was considered as having attained standard egg weight when she had produced five successive eggs averaging 57 grams each.

EXPERIMENTAL RESULTS

Population Attaining Standard Egg Weight

A frequency distribution with respect to time to standard egg weight (the dependent variable) was made on the 409 individuals attaining standard egg weight. The X^2 test showed the lack of a normal distribution. When, however, 21 individuals that required less than 16 days to reach standard egg weight and 5 individuals that required more than 255 days were omitted, the distribution

became sufficiently close to normal, giving a P value of .5143. It seemed desirable, therefore, to use for the correlation studies only the 383 birds that gave a normal distribution with respect to the dependent variable. Three independent variables showed essentially normal distribution; four—hatching date, winter pause, winter clutch, and persistency—did not. The partial or net coefficient of correlation differs from the simple correlation coefficient in that in the calculation of the former all other variables are held constant. For example, in calculating the net correlation between hatching date (2) and time to standard egg weight (1); age at first egg (3), weight at first egg (4), clutch size (5), pause duration (6), days broody (7), and persistency (8) are all made constant. In calculating simple correlations no allowance is made for variability in any of these characters.

Correlation Between Hatching Date and Time to Standard Egg Weight

In each of the five years covered by these studies, the birds were hatched in eight weekly hatches beginning about March 25 and ending about May 15. Yearly egg weight records are available only upon birds from the first three hatches. The simple correlation between hatching date and days from first egg to standard egg weight gave the following constants:

Number of birds	383
Mean hatching date (March 31)	1.8
Hatching date standard deviation	±.74
Mean time to standard egg weight, days	106.93
Time to standard egg weight standard deviation	±48.33
Coefficient of correlation	-.1111 ±.0340

The standard deviation in time to standard egg weight shows that the population was highly variable and suggests that this character must be influenced by a large number of factors that may be both hereditary and environmental.

The coefficient of correlation is negative and of sufficient magnitude to be barely significant according to the criterion of Wallace and Snedecor (1931). Its squared value, however, indicates that only about 1 per cent of the variation in time required is due to differences in hatching dates. The regression was found to be strictly linear, but the magnitude of the correlation coefficient in these limited data does not signify an intimate relationship.

The partial correlation coefficient between hatching date and time to standard egg weight was calculated, keeping age at first egg, weight at first egg, clutch size, pause days, broody days, and persistency constant. The value obtained was $r_{12.345678} = -.5323$, which indicates that hatching date does have an important influence upon the time required to reach standard egg weight, and that early hatching tends to increase the time necessary to attain standard egg weight.

Correlation Between Age at First Egg and Time to Standard Egg Weight

Early sexual maturity is known to be dominant to late sexual maturity. The dividing line between genetically early and genetically late pullets falls at about 215 in the experiment station flock. Unpublished data indicate no genetic difference with respect to age at sexual maturity between birds that begin to lay when less than 216 days of age even though the range may extend from 140 to

215 days. It is assumed, therefore, that such variability in age is due to environmental forces.

The simple correlation coefficient was calculated between age at first egg and time to standard egg weight using only genetically early-maturing birds. The constants obtained are as follows:

Number of birds	383
Mean age at first egg, days	178.76
Age at first egg standard deviation	± 16.28
Mean time to standard egg weight, days	106.93
Time to standard egg weight standard deviation	± 48.33
Coefficient of correlation	$-.4174 \pm .0285$

The variability in age at first egg amounts to about 9 per cent in the population. As already stated, it is probable that this variability is due entirely to environmental causes.

The coefficient of correlation is negative and indicates that age differences play an important role in time to standard egg weight. The regression in this case is strictly linear.

The partial correlation between these two variables, when the other six variables are held constant is $r_{13.245678} = -.6419$, which clearly indicates that age at sexual maturity greatly influences the time to standard egg weight.

In the population studied, the mean average age at which standard egg weight was attained was found to be 285.21 days. This fact indicates that the Rhode Island Red pullets used in these studies tend to begin laying 24-ounce eggs at not far from ten months of age. It seems probable, according to the work of Waters (1931) with Leghorns and Brahmas, that this may also be the age when complete body growth is attained.

Correlation Between Weight at First Egg and Time to Standard Egg Weight

Each pullet was weighed on the day that she laid her first egg. Since there is a positive correlation between body weight and egg size, there may also be an association between weight at first pullet egg and time to standard egg weight. The correlation was calculated for the population being studied.

Number of birds	383
Mean weight at first egg, pounds	5.40
Weight at first egg standard deviation	$\pm .56$
Mean time to standard egg weight, days	106.93
Time to standard egg weight standard deviation	± 48.33
Coefficient of correlation	$-.2317 \pm .0326$

Body weight shows a variability of about 10 per cent, probably due largely to age differences, as Hays (1933) pointed out. The coefficient of correlation is negative and indicates by its value squared that about 5 per cent of the variability in time required is due to weight differences at first egg. The regression was essentially linear.

The partial correlation between weight at first egg and time to standard egg weight was $-.3307$. This constant indicates further that body weight at sexual maturity does not have a very great influence upon the time to standard egg weight.

Correlation Between Winter Clutch Size and Time to Standard Egg Weight

Mean winter clutch size is a very good measure of individual intensity. Furthermore, clutch size is governed by inheritance. Hays (1930) showed that the gene for highest intensity is linked with a gene for small egg size. It seems desirable, therefore, to determine by means of the correlation coefficient the relation between winter clutch size and time to standard egg weight. The constants calculated are as follows:

Number of birds.....	383
Mean winter clutch, eggs.....	3.49
Winter clutch standard deviation.....	± 1.31
Mean time to standard egg weight, days.....	106.93
Time to standard egg weight standard deviation.....	± 48.33
Coefficient of correlation.....	$+ .3001 \pm .0314$

The mean winter clutch indicates that the average individual carries the highest degree of inherited high intensity, yet the variability in intensity is very high.

The simple correlation shows a positive association between clutch size and time to standard egg weight. In other words, a little less than 10 per cent of the variability in time required may be accounted for through variable intensity. The regression is strictly linear.

Determination of the partial correlation between clutch size and time required gave the constant $r_{15.234678} = +.1609$, which indicates that less than 3 per cent of the variation in time required is directly traceable to intensity variations.

Correlation Between Winter Pause Duration and Time to Standard Egg Weight

Winter pause as used in these studies means the cessation of egg laying for four or more days between November 1 and March 1. In case there are several periods of non-production, these periods are added together to arrive at the pause duration. In the total population there were 146 birds showing no winter pause, and these are omitted in calculating the correlation between pause duration and time to standard egg weight.

Number of birds.....	237
Mean winter pause, days.....	27.07
Winter pause standard deviation.....	± 20.78
Mean time to standard egg weight, days.....	106.04
Time to standard egg weight standard deviation.....	± 46.66
Coefficient of correlation.....	$+ .1340 \pm .0430$

Duration of winter pause shows extreme variation in the population studied. This fact suggests that there must be many influences affecting pause duration. The data show further that the mean time interval for the pause birds is essentially identical with the time interval for the entire population.

The coefficient of correlation is positive but is not significant by Wallace and Snedecor's (1931, loc. cit.) criterion, and is of such small absolute magnitude as to be of little or no value as a guide in selection. The regression is strictly linear.

The net correlation between pause duration and time to standard egg weight was $-.0582$, showing that little, if any, association exists between pause duration

and time interval to standard egg weight.

Correlation Between Total Days Broody and Time to Standard Egg Weight

There were only 49 individuals showing broodiness during the pullet laying year. The total days broody for each bird were determined by adding together the non-productive days associated with broody periods. The simple correlation between total days broody and time to standard egg weight was calculated, giving the following constants:

Number of birds	49
Mean days broody	31.42
Broody days standard deviation	± 25.94
Mean time to standard egg weight, days	119.75
Time to standard egg weight standard deviation	± 45.36
Coefficient of correlation	$+ .2679 \pm .0894$

Standard deviation in days broody shows striking variability. This is in agreement with the observation previously reported by Hays (1933) that degree of broodiness is inherited. Mean time to standard egg weight was slightly greater in the broody population than in the group that did not show broodiness the first year. The means are 119.73 and 104.90 respectively.

The correlation coefficient between days broody and time to standard egg weight is positive but not significant as judged by its probable error or by Wallace and Snedecor's criterion. The regression is strictly linear. From these limited data, the time required to standard egg weight does not appear to be associated with non-productive time due to broodiness.

The partial correlation between days broody and time to standard egg weight does, however, show a significant relationship. This constant was found to be $+ .4210$, which indicates that about 18 per cent of the variation in time required is due to differences in degree of broodiness.

Correlation Between Annual Persistency and Time to Standard Egg Weight

Annual persistency records are available on 297 birds in the population studied. The remaining 86 individuals failed to complete their 365-day egg record, generally because of death or disease. Annual persistency was represented by the time from first pullet egg to a 30-day pause after March 1 or to the close of the 365-day laying year, if no 30-day pause occurred previously. Thus the maximum persistency was 365 days even though the bird may have continued to lay. Calculation of the correlation between annual persistency and time to standard egg weight gave the constants below:

Number of birds	297
Mean annual persistency, days	344.51
Annual persistency standard deviation	± 33.44
Mean time to standard egg weight, days	107.34
Time to standard egg weight standard deviation	± 48.21
Coefficient of correlation	$- .0100 \pm .0391$

Annual persistency, like age at sexual maturity, showed a variability of about 9 per cent. The mean persistency of 344.51 days indicates that most of the birds were genetically highly persistent. The mean time to standard egg weight

is almost identical in this group of 297 birds with the mean for the entire 383 birds previously considered.

No simple correlation exists between persistency and time to standard egg weight, and the regression is strictly linear.

A calculation of the net correlation between annual persistency and time to standard egg weight gives a constant of $-.6241$ which is highly significant. This constant indicates that about 39 per cent of the variation in time to standard egg weight is attributable to differences in persistency. This relation is largely obscured by the linkage relations between early sexual maturity and high persistency pointed out by Hays (1927).

Correlation Between Winter Egg Production and Time to Standard Egg Weight

Winter egg production includes all eggs laid from the first pullet egg in the fall or winter to March 1. The entire population of 383 birds was used to calculate the simple correlation between winter egg production and time to standard egg weight. The constants determined are as follows:

Number of birds	383
Mean winter production, eggs	100.71
Winter production standard deviation	± 22.55
Mean time to standard egg weight, days	106.93
Time to standard egg weight standard deviation	± 48.33
Coefficient of correlation	$+.2599 \pm .0321$
Correlation ratio3373

A mean winter production of slightly over 100 eggs shows that the birds studied were very heavy winter layers. There is a variability of about 22 per cent which is rather high.

The regression of time required on winter production is not strictly linear so that the correlation ratio of .3373 really measures the association. Its value squared shows that about 11 per cent of the variation in time required is due to variation in winter production and that heavy winter layers tend to require a longer time interval to attain standard egg size.

Correlation Between Annual Production and Time to Standard Egg Weight

Egg size has been shown by a number of workers to be essentially independent of the number of eggs laid in a year. It is important to learn whether annual production affects the time interval to standard egg weight. Annual production used in this report represents the number of eggs laid by each individual in 365 days beginning with the first pullet egg. The correlation coefficient was calculated with the following constants:

Number of birds	297
Mean annual production, eggs	221.12
Annual production standard deviation	± 37.87
Mean time to standard egg weight, days	107.34
Time to standard egg weight standard deviation	± 48.21
Coefficient of correlation	$+.0429 \pm .0391$
Correlation ratio3015

Annual egg production was rather high in the population studied, and the

coefficient of variation was about 17 per cent. There was no difference in the average time interval to standard egg weight in the 297 birds that completed the year and the 86 birds that failed to complete the year.

The coefficient of correlation is positive and of no significance, but the regression is non-linear. The correlation ratio of .3015, therefore, expresses the association between annual production and time to standard egg weight. This constant shows that about 9 per cent of the variation in the time interval is due to variation in annual egg production. In other words, heavy producers tend to require more time to attain standard egg weight.

Correlation Between Mean Annual Egg Weight and Time to Standard Egg Weight

Mean annual egg weight was obtained for each bird by taking the average weight of all eggs laid from October 1 to September 30 each year. The simple correlation between annual egg weight and time to standard egg weight was calculated, with the constants shown below:

Number of birds	306
Mean annual egg weight, grams	55.45
Annual egg weight standard deviation	± 2.59
Mean time to standard egg weight, days	108.15
Time to standard egg weight standard deviation	± 48.41
Coefficient of correlation	$-.6532 \pm .0221$

The data show that the mean annual egg weight was 55.45 grams, or the equivalent of 23.5 ounces to the dozen. Variability in egg weight was relatively slight, showing a coefficient of variation of about 4.6 per cent.

The coefficient of correlation between annual egg weight and time to standard egg weight was negative and of rather high magnitude. On the basis of its value squared, about 43 per cent of the variation in time required is due to variation in annual egg weight. The regression in this case was strictly linear. The data show that the time to standard egg weight very significantly affects the mean egg weight for the year; and if the mean egg weight for the year is to be 56.7 grams or 24 ounces to the dozen, pullets must reach standard egg weight in about 85 days, as calculated by the regression coefficient.

Multiple Correlation Between Time to Standard Egg Weight and Factors Affecting It

This study has demonstrated by means of the simple and the partial coefficients of correlation that the following factors affect the time to standard egg weight: hatching date, age at first egg, weight at first egg, winter clutch size, winter pause duration, total days broody, and annual persistency. With the possible exception of winter pause duration, all exert a significant effect on time to standard egg weight. These constants are placed together in Table 1.

Multiple correlation is resorted to in order to determine the combined effect of these seven factors (Nos. 2, 3, 4, 5, 6, 7, 8 in Table 1). Calculations show $R = .7641$. By squaring R , the value .5839 is obtained, which indicates that about 58 per cent of the variation may be accounted for by variation in the seven factors considered, leaving 42 per cent that appears to depend on undetermined hereditary factors. In view of this fact it seems probable that time to standard egg weight does depend upon hereditary factors and that poultry breeders can very likely make progress in breeding for large egg size by selecting only female breeders that attain standard egg weight in 75 days or less after the first pullet egg.

TABLE 1.--SIMPLE AND PARTIAL CORRELATION COEFFICIENTS BETWEEN TIME TO STANDARD EGG WEIGHT AND FACTORS AFFECTING IT

	Correlation Coefficients	
	Simple	Net
Correlation between Time to Standard Egg Weight (1) and		
2. Hatching date.....	-.1111 ± .0340	-.5323
3. Age at first egg, days.....	-.4174 ± .0285	-.6419
4. Weight at first egg, pounds.....	-.2317 ± .0326	-.3307
5. Winter clutch size, eggs.....	+.3001 ± .0314	+.1609
6. Winter pause, days.....	+.1340 ± .0430	-.0582
7. Broodiness, days.....	+.2679 ± .0894	+.4210
8. Persistency, days.....	-.0100 ± .0391	-.6241
9. Winter production, eggs.....	+.3373*	
10. Annual production, eggs.....	+.3015*	
11. Annual egg weight, grams.....	-.6532 ± .0221	

*Correlation Ratio.

Character of the Population Not Reaching Standard Egg Weight

During the five years covered by this study a significant proportion of the birds failed to attain standard egg weight during the first laying year. It seems desirable, therefore, to study this group in order to discover if possible some of the reasons why they continued to lay small eggs. Table 2 gives a series of means for the population failing to reach standard egg weight, together with the means for the population attaining standard egg weight.

TABLE 2.--A COMPARISON OF THE POPULATION FAILING TO REACH STANDARD EGG WEIGHT WITH THE POPULATION ATTAINING STANDARD EGG WEIGHT PULLET YEAR.

	<u>Population Failing</u>		<u>Population Attaining</u>	
	<u>Number of Birds</u>	<u>Mean</u>	<u>Number of Birds</u>	<u>Mean</u>
Age at first egg, days.....	140	175.50	383	178.76
Weight at first egg, pounds.....	140	5.10	383	5.40
Winter clutch size, eggs.....	140	3.66	383	3.49
Winter pause, days.....	83	26.09	237	27.07
Broodiness, days.....	17	40.21	49	31.42
Persistency, days.....	126	336.02	297	344.51
Winter production, eggs.....	140	106.71	383	100.71
Annual production, eggs.....	126	222.01	297	221.12
Annual egg weight, grams.....	131	49.91	306	55.45

The significance of differences in means recorded in Table 2 was determined by means of the probable error where the frequency distribution was essentially normal; in other cases by consistency.

There was no significant difference in age at sexual maturity between the two populations.

The two populations showed a significant difference in mean weight at first egg. It seems evident, therefore, that lack of body weight at sexual maturity is in part responsible for small egg size in the population that failed to reach standard egg weight.

Larger winter clutch size stood out in the small-egg population compared with the large-egg population. Extreme winter intensity accounted in part for the failure of one population to attain standard egg size.

The two groups of birds were identical in mean pause duration, and the small-egg group showed 59 per cent with winter pause compared with 62 per cent in the other group.

The small-egg group showed more intense broodiness, but the percentage of broody birds was essentially identical in the two populations.

In persistency, the small-egg group showed a significantly lower mean than the large-egg group. This fact appears to suggest that low persistency was in part responsible for small egg size.

The small-egg population showed slightly higher winter production and the same annual production as the large-egg group. The fact is therefore evident that number of eggs is not a factor governing egg size.

The group failing to reach standard egg weight gave a decidedly lower annual egg weight than the other group. The small-egg group gave an annual egg weight average of 21.1 ounces per dozen compared with 23.5 ounces for the large-egg group.

SUMMARY

A study of the records of Rhode Island Red pullets hatched over a five-year period, where every egg was weighed from the trapnest, leads to the following deductions with respect to characters affecting the time interval between first pullet egg and standard egg weight or the failure to attain standard egg weight during the first laying year.

1. Early hatching greatly increased the time to standard egg weight.
2. Extreme early maturity within a genetically early-maturing population tended to greatly increase the time interval to standard egg weight.
3. Small body weight at first egg also increased the time interval but to a lesser extent than hatching date or age at sexual maturity.
4. Very high winter intensity was associated in some degree with a longer period to standard egg size.
5. Pause duration had little or no effect on the time interval.
6. Intense broodiness prolonged the period to standard egg weight.
7. High persistency very greatly reduced the time to standard egg weight.
8. High winter egg production slightly increased the time interval, but high annual production had no effect.
9. Annual egg weight was intimately negatively association with the time interval to standard egg weight.

10. The multiple correlation coefficient shows that about 58 per cent of the variation in time to standard egg weight was due to variation in the following seven variables: hatching date, age at first egg, weight at first egg, winter clutch size, winter pause, broodiness and persistency.

11. Probably about 42 per cent of the variation in the time interval to standard egg weight was due to unknown hereditary factors.

12. The birds failing to reach standard egg weight were handicapped by lack of body weight, extremely high intensity, intense broodiness, and lack of persistency.

13. In breeding practice to increase egg size, it seems advisable to select breeding females exclusively from those which attain standard weight egg in less than 75 days after the first pullet egg.

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