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# The Significance of Length of Biological Laying Year in Production Breeding

By F. A. Hays and Ruby Sanborn

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High persistency has long been recognized as an important factor in breeding for egg production. In previous studies, however, persistency has been considered only within the limits of the 365-day pullet laying year. The studies here reported were undertaken to discover whether birds that continue to lay without interruption for 13, 14, or 15 months are superior for breeding purposes to birds laying for 9 to 12 months before molting.

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MASSACHUSETTS STATE COLLEGE  
AMHERST, MASS.

# THE SIGNIFICANCE OF LENGTH OF BIOLOGICAL LAYING YEAR IN PRODUCTION BREEDING

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in Poultry Husbandry

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## Introduction

High persistency as indicated by late molting at the end of the pullet laying year has long been recognized as very desirable from the standpoint of high annual egg production. A review of the literature on this point scarcely seems necessary. Suffice it to note that Hays and Sanborn (1927 c) report a net correlation of  $+.7501 \pm .0063$  between annual persistency and annual egg production in Rhode Island Reds at the Massachusetts Agricultural Experiment Station.

This report is concerned with the duration of the biological laying year; that is, the period from first pullet egg to a 30-day cessation of production after March 1. In those birds which did not stop laying for as long as 30 days after they had passed the 365-day production date, the onset of a pause of 8 or more days was considered as the termination of the biological year. In the 12 generations studied there were 11 individuals that showed no cessation of production as great as 8 days at the close of the pullet year, and these were omitted.

The studies reported below were undertaken to discover whether birds that continue to lay without interruption for 13, 14, or 15 months are actually superior for breeding purposes to birds laying for 9 to 12 months before molting. The report is divided into three parts: (1) Correlation studies showing the relation of length of biological year to characters affecting fecundity and to egg production; (2) The relation between the length of the biological year and other desirable characteristics; and (3) The relation between the duration of the biological year in mothers and annual persistency and production of their daughters.

## Birds Used for the Study

All birds used were Rhode Island Reds from the Station flock that has been developed since 1913, and include females hatched in the non-broody line, the high-production line, the hatchability experiment, the experiment on variability in production, the experiment on egg size and egg character, and the studies on the relation of intensity to feather color. Twelve generations, hatched in 1917 and from 1920 to 1930 inclusive, were used in Parts 1 and 2. The twelve generations of daughters reported in Part 3 were hatched in 1918 and from 1921 to 1931 inclusive. Two generations were omitted in both cases because the birds were discarded without complete records on account of disease epidemics. Only birds retained for two full laying years are included in Parts 1 and 2.

## Part 1. Correlation Studies

The relation of the length of biological laying year to some important inherited characters known to affect egg laying is considered, as well as the relation of length of the biological year to the egg record made during the biological year and the annual egg record. The coefficient of correlation was used to measure the association by tabulating each bird with respect to the two characters being considered. Each correlation was tested for linearity by Blakeman's (1905) test. In those

cases where the difference between the squared values of the correlation ratio and the correlation coefficient was less than three times its probable error, the relation was considered linear and the correlation coefficient alone is reported. When the regression was non-linear, the correlation ratio is used as the measure of association. Only pullet-year records are included in the correlation tables.

### 1. *Relation Between Age at First Egg and Length of Biological Year.*

The correlation between age at first egg and annual persistency in earlier flocks was reported as  $-.6146 \pm .0090$  (Hays and Sanborn, 1926.) In such cases persistency is terminated within 365 days from the date of the first pullet egg. Now the question arises whether the earlier maturing birds are also more likely than the later maturing birds to continue to lay after the termination of the 365-day period.

Records are available on 911 individuals upon which the correlation between age at first egg and length of biological year was calculated.

Number of birds.....	911
Mean age at first egg — days.....	190.47
Age standard deviation.....	$\pm 21.32$
Mean biological year — days.....	363.62
Biological year standard deviation.....	$\pm 43.16$
Coefficient of correlation.....	$-.5661 \pm .0152$

The mean length of the biological year is very close to 365 days. The range for this character was from 80 to 484 days. The standard deviation amounts to 11.87 per cent of the mean, which should not be considered large in view of the combined effects of environment and heredity.

The relation between age at first egg and duration of biological year is linear by Blakeman's test and is therefore measured by the coefficient of correlation. The squared value of this constant is .3193, indicating that about 32 per cent of the variation in duration of the biological year is due to variation in age at first egg. The correlation table also shows that almost 50 per cent of the birds studied had a biological year equal to or greater than 365 days. The correlation coefficient reported here does not differ greatly from that reported by Hays and Sanborn (1926) as the measure of the relation between age at sexual maturity and persistency within the 365-day laying year, namely  $-.6146 \pm .0090$ . The data indicate that early sexual maturity is rather intimately associated with a long laying year.

### 2. *Relation Between Winter Pause Duration and Length of Biological Year.*

Winter pause marks a period of non-productivity between the date of the first pullet egg and March 1. The duration of the pause varied from 4 to 113 days in the population studied. Only those birds having a winter pause of 4 days or more are considered in this section. If the winter pause represents a period of recovery for the reproductive system, there may be some relation between pause duration and the duration of the biological year. A total of 494 pause birds are available in the population studied. These were tabulated in a correlation table and the following constants derived:

Number of birds.....	494
Mean winter pause — days.....	21.03
Winter pause standard deviation.....	$\pm 15.19$
Mean biological year — days.....	365.84
Biological year standard deviation.....	41.37
Coefficient of correlation.....	$+.1744 \pm .0294$

The correlation between pause duration and length of the biological year is of questionable value since its squared value (.0304) indicates that only about 3 per cent of the variation in duration of the biological year is associated with variation in pause duration. As a selection unit for increasing the length of the biological year, pause duration is of very little value.

### 3. *Relation Between Winter Clutch Size and Length of Biological Year.*

Mean winter clutch size has been used extensively at this Station as a measure of intensity or rate of laying. Rate of laying is distinctly an inherited character as Hays and Sanborn (1927b) have shown. Correlation studies have been made to discover whether the rate of winter laying shows any relation to the length of the biological year. The constants calculated are as follows:

Number of birds.....	910
Mean winter clutch — eggs.....	3.49
Winter clutch standard deviation.....	$\pm 1.77$
Mean biological year — days.....	363.92
Biological year standard deviation.....	$\pm 42.19$
Coefficient of correlation.....	$+ .0590 \pm .0223$
Correlation ratio.....	$.2251 \pm .0212$

Blakeman's test indicates that the regression of biological year on clutch size is non-linear. Hence the correlation ratio measures the association between the two variables. The association is positive, indicating that to some extent the more intense winter layers tend to lay for a longer period than the less intense layers. The squared value of the correlation ratio is .0507, which suggests that only 5 per cent of the variation in duration of biological year is due to clutch size variation.

### 4. *Relation Between Days Broody and Length of the Biological Year.*

The total number of non-productive days spent in broody periods during the pullet laying year is an indication of degree of broodiness. There is evidence in this flock that degree of broodiness depends upon inheritance. If a broody period serves as a recuperative period for the reproductive system, the anticipated result might be a greater duration of the biological year in the more intense broody individuals. In this study only individuals showing one or more broody periods are included in the correlation table. The constants derived are as follows:

Number of birds.....	191
Mean total days broody.....	33.04
Total days broody standard deviation.....	$\pm 26.28$
Mean biological year — days.....	358.26
Biological year standard deviation.....	$\pm 50.57$
Coefficient of correlation.....	$-.0633 \pm .0486$
Correlation ratio.....	$.2907 \pm .0447$

The extreme variability in degree of broodiness is very striking. The mean is 33.04 days with a standard deviation of 26.28, making the coefficient of variation 79.5 per cent.

The negative coefficient of correlation is statistically insignificant, but the regression is non-linear. The correlation ratio indicates that the more intensely broody birds are likely to exhibit a shorter biological year. The squared value of the correlation ratio shows that about 8.45 per cent of the variation in length of biological year is due to variation in degree of broodiness.

### 5. *Relation Between Annual Persistency and 365-Day Egg Record.*

The correlation between annual persistency within a 365-day period from first pullet egg and the 365-day egg record has been shown to be intimate in the generations of birds hatched at the Massachusetts Station from 1916 to 1924 (Hays and Sanborn, 1926). This study is repeated using the 911 birds considered in this report. In the earlier report the authors pointed out that the birds were divided into two genetic classes: namely, those laying for a shorter period than 315 days and those laying for 315 days or longer before the annual molt. In this earlier report and in this section the duration of egg production beyond the 365-day limit is not considered. The fact should be noted in connection with these correlation studies that the birds used represent a selected group that was kept for two laying years because of superior pullet-year records. The following constants were derived from the correlation table:

Number of birds.....	911
Mean annual persistency — days.....	342.11
Annual persistency standard deviation.....	$\pm 33.98$
Mean annual production — eggs.....	229.92
Annual production standard deviation.....	$\pm 32.72$
Coefficient of correlation.....	$+ .5798 \pm .0148$
Correlation ratio.....	$.6257 \pm .0136$

The relation between annual persistency and annual egg production proved not to be linear by Blakeman's test. The correlation ratio shows in this population an intimate association between persistency and production. Its squared value is .3915 indicating that about 40 per cent of the variation in production is associated with variation in persistency. As a unit in selection persistency is of great value.

### 6. *Relation Between Length of Biological Year and the Egg Record for the Biological Year.*

It is desirable to know whether the egg record during the biological year is intimately associated with the duration of the biological year. In other words, is there high probability that a long period of laying previous to molt is likely to be associated with a high egg record? By tabulating each bird in a correlation for length of biological year and egg production in the same period, the constants below were obtained:

Number of birds.....	911
Mean biological year — days.....	363.62
Biological year standard deviation.....	$\pm 43.16$
Mean egg record for biological year.....	237.52
Egg record standard deviation.....	$\pm 38.57$
Coefficient of correlation.....	$+ .6999 \pm .0114$

Mean egg production during the biological year is 237.52 compared with 229.29 for the 365-day year. The variability of production is also somewhat greater in the biological year. The regression of egg production on duration of biological year is found to be linear. The coefficient of correlation is highly significant and by its squared value indicates that 48.99 per cent of the variation in egg record for the biological year is due to variation in duration of the biological year. This value is highly significant in biological data and attaches considerable importance to the length of the biological year.

### 7. *Relation Between Length of Biological Year and Annual Egg Record.*

Annual egg record as used throughout this report covers the period from first pullet egg to 364 days thereafter for each individual. It is highly desirable to know whether the bird possessing the ability to lay continuously for more than a year is more likely to be a heavier layer in the first 365 days of production. By tabulating the length of the biological year and the annual egg record of each individual, the following constants were obtained:

Number of birds.....	911
Mean biological year — days.....	363.62
Biological year standard deviation.....	$\pm 43.16$
Mean annual production — eggs.....	229.92
Annual production standard deviation.....	$\pm 32.72$
Coefficient of correlation.....	$+ .4715 \pm .0174$
Correlation ratio.....	$.5520 \pm .0155$

The regression of production on duration of biological year is found to be non-linear by Blakeman's test; consequently the correlation ratio measures the association between these two variables. The actual value of length of biological year as a selection unit may be determined by squaring the correlation ratio which gives .3047. Stated simply, this means that 30 per cent of the variation in annual production is due to variation in duration of biological year.

In general, the data presented in Part 1 of this report indicate that the ability to lay for a long period of time is desirable from the standpoint of egg production.

### Part 2. — Relation of Length of Biological Year to Some Important First- and Second-Year Characteristics

In this part consideration is given to several desirable characteristics not specifically related to first-year egg production but very important in breeding for high fecundity. Further evidence is presented to show whether or not a long biological year may be considered of sufficient significance to take an important place in the breeding program. The length of biological year is considered in relation to first- and second-year hatchability, to body weight at first egg, to body weight at the close of the pullet year, and to second-year egg production.

In the generations used in this report there were 426 birds with complete two-year records. This group was divided into three classes with respect to duration of biological year; those with persistency of less than 315 days; those with persistency ranging from 315 to 365 days; and those with persistency exceeding 365 days.

TABLE 1 — RELATION OF LENGTH OF BIOLOGICAL LAYING YEAR TO HATCHABILITY, BODY WEIGHT, AND SECOND-YEAR EGG PRODUCTION

Length of biological year	Number of birds	Hatchability per cent		Body weight pounds		Second-year egg production
		First year	Second year	At first egg	At end of pullet year	
Under 315 days.....	26	67.60	72.50	5.53	5.95 (2)*	156.50
From 315 to 365 days.....	159	78.30	78.21	5.44	5.89 (25)	147.84
Over 365 days.....	241	71.72	77.35	5.30	6.09 (69)	160.91

\*Only a part of the 426 birds were weighed at the close of their laying year. The figures in parenthesis show the number of such birds in each class.

1. *Relation of Length of Biological Year to First- and Second-Year Hatchability.*

The mean hatchability of the three persistency classes during the first and second laying years is shown in Table 1. The data do not show any relation between duration of biological year and percentage of fertile eggs hatched during the period from March 25 to May 15 of each year. Hatchability therefore seems to be independent of those factors concerned with the duration of the laying year. The data do indicate, however, that in general the same individuals have a higher hatching record as yearlings than as pullets.

2. *Relation of Length of Biological Year to Body Weight at First Egg.*

Body weight at first egg is a measurement that may be taken at the beginning of the bird's productive period. The value of such a record as a criterion of later fecundity traits needs to be determined. Body weight of each of the 426 birds was recorded on the day she laid her first pullet egg, and the mean for each of the three persistency classes is shown in Table 1. These data indicate that greater duration of the biological laying year is associated with a smaller body weight at first egg. This smaller body weight at first egg has been shown by Hays (1933) to be an explicit function of age at first egg.

3. *Relation of Length of Biological Year to Body Weight at the Close of the Pullet Year.*

Only a part of the 426 birds considered in sections 2 and 3 were weighed at the close of their laying year, the number being 96. These meager data are presented (Table 1) to furnish a small amount of information on the relation between body weight at the close of the 365-day laying year and duration of biological year. These weight records were taken on a date averaging 365 days after the first pullet egg for the birds housed together.

The data suggest that birds with heavy weight at the close of their 365-day production year are more likely to continue to lay than are smaller individuals. In other words, birds that lay at the expense of body weight are likely to lay fewer eggs as Hays (1932) pointed out, and they are also likely to have a shorter productive year.

4. *Relation of Length of Biological Year to Second-Year Egg Production.*

In the Rhode Island Red flock of the Massachusetts Agricultural Experiment Station, the mean second-year production amounts to about 70 per cent of the first-year production. Second-year records on this flock are begun immediately at the conclusion of the 365-day record. By this system of records the second-year record of a bird with a biological year of 365 days or more is penalized, in that all of the non-productive period usually accompanying molt falls in the second laying year. On the other hand, individuals with a short biological year show a part of the molt period at the close of the 365-day first-year record and a part in the beginning of the second-year record. The fact should also be noted that late molting reduces the length of the molt period as Hays and Sanborn (1930) and Marble (1930) have pointed out.

The second-year egg records of the 426 birds studied are shown in Table 1. The differences in mean annual egg records are not great for the three groups. In general, the data indicate that great length of the first biological year is likely to be followed by a higher second-year egg record than might be anticipated if the duration of the first biological year falls below 365 days.

### Part 3. — The Inheritance of Persistency

High persistency has been reported by Hurst (1921) to be inherited as a recessive trait in White Leghorns and White Wyandottes. He measured high persistency by the ability to lay at the rate of 30 per cent from July 1 to the close of the laying year, no birds being considered high in persistency unless they laid for at least 50 days after July 1. This period would end on August 19 as the earliest date. Using Hurst's dividing age between early- and late-maturing birds at 270 days, the absolute length of the biological laying year for the highly persistent birds would be about 9 months or 270 days.

Hays and Sanborn (1926) report that the Massachusetts Station flock shows two general classes with respect to duration of the laying year — those laying for less than 315 days and those laying for more than 315 days. Hays (1927a) presented evidence to indicate that the ability to lay for 315 days or more depends upon a dominant autosomal gene P.

This part of the report is concerned with the ability of dams to transmit persistency to their daughters. The obvious weakness of such a study lies in the fact that genetic records of the sires are not available. In a general way, however, the data will be useful to show whether or not selection of dams alone for duration of biological year increases the length of laying year in resulting daughters.

Twelve generations of daughters consisting of 2311 individuals are included from 427 dams that had been retained in the flock for two or more full laying years. These dams are the birds that have already been considered in Parts 1 and 2. They are divided into three classes with respect to duration of their biological year. In tabular form are presented the number of dams and daughters concerned, together with the daughters' mean annual persistency records and their mean annual egg records and the mean annual egg record of the dams.

TABLE 2 — RELATION OF THE LENGTH OF BIOLOGICAL YEAR OF DAMS TO THEIR ANNUAL EGG PRODUCTION AND TO THEIR DAUGHTER'S ANNUAL PERSISTENCY, ANNUAL EGG PRODUCTION, AND LAYING HOUSE MORTALITY.

Length of biological year of dams	Dams		Daughters			
	No.	Annual production Eggs	No.	Annual persistency Days	Annual production Eggs	Mortality in laying house Per cent
Under 315 days.....	26	201.38	124	320.02 $\pm$ 3.62	195.89	36.40
From 315 to 365 days.....	159	236.69	879	325.60 $\pm$ 1.28	201.49	26.55
Over 365 days.....	242	245.10	1308	330.75 $\pm$ 0.99	207.24	27.76

Table 2 shows that in the selection of breeders emphasis was laid on length of biological year so that the number of dams concerned in the low class is small, and the majority fall in the group with a biological year greater than 365 days. The mean annual egg records of the dams are also closely associated with the length of the biological year.

Daughters' annual persistency includes the productive period from first pullet egg either to the onset of a 30-day cessation of production after March 1 or to the end of the 365-day laying year. It is evident that this method of calculating persistency does not take cognizance of the actual persistency of birds that lay beyond the 365-day period. The difference in mean annual persistency of classes 1 and 2 is 5.58 $\pm$ 3.84, and of classes 2 and 3 is 5.15 $\pm$ 1.62. The data therefore show no significant difference in the mean annual persistency of daughters from dams with a biological year of less than 315 days and those from dams with a biological year



of 315 to 365 days. Daughters from dams with a biological year greater than 365 days show a significantly higher mean annual persistency than do daughters with a shorter biological year. Mean annual first-year egg records of daughters from the three persistency classes of dams increase with the persistency of the dams.

These data indicate the general superiority of birds with a long biological year over birds with a shorter biological year in breeding for high fecundity.

The mortality in the laying houses is distinctly higher for the daughters from dams with persistency records below 315 days. The mortality of daughters from dams with persistency between 315 and 365 days and from dams with a persistency greater than 365 days is essentially the same. These facts indicate that high persistency is a partial measure of vigor which is one of the vital essentials in successful breeding.

*Progress Throughout the Experiment*

Chart 1 presents graphically the mean annual persistency of daughters by generations throughout the experiment. Class 1 represents the daughters from dams with a biological year under 315 days; Class 2, the daughters from dams with a biological year of from 315 to 365 days; and Class 3, the daughters from dams with a biological year greater than 365 days. Data are not available for the hatching year of 1919 and 1920.

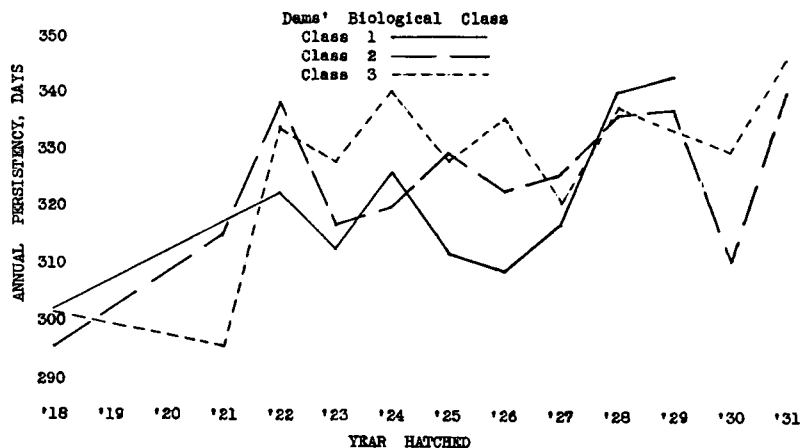


Chart 1. Annual Persistency of Daughters by Years.

In general, there is a progressive increase in the annual persistency of daughters from year to year. For the most part the daughters from the two classes of dams with superior length of biological year excel the daughters from dams with a biological year under 315 days. There is an apparent advantage from the standpoint of annual persistency in selecting female breeders whose biological year exceeds 365 days. The high trend in the solid line in 1928 and 1929 has little significance because it represents the daughters from but four dams in 1928 and one dam in 1929.

Chart 2 presents the mean yearly egg records of daughters from the three classes of dams with respect to length of biological year. Here again there is progressive increase throughout the experiment in daughters of dams that belonged to the

two upper classes with respect to duration of biological year. The egg records of daughters from dams with short biological year did not increase up to 1927, and the last two yearly means are not significant because of small numbers. The superiority of the egg records of daughters from dams with a biological year exceeding 365 days appears to warrant the selection of such birds for breeding to increase fecundity.

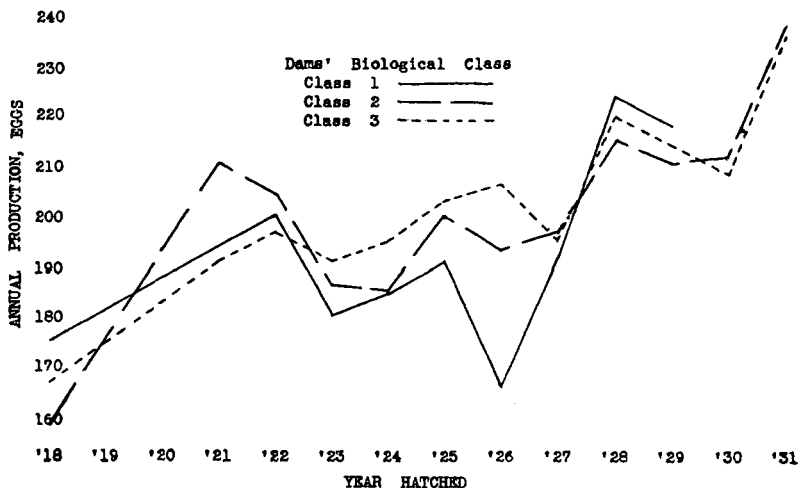


Chart 2. Annual Egg Production of Daughters by Years.

### Summary

A study is made on 911 Rhode Island Red females of twelve generations that were trapnested for two full laying years and on a total of 2311 of their daughters representing twelve generations.

1. Duration of biological year is intimately associated with early sexual maturity.
2. There is no significant relation between duration of winter pause and length of biological year.
3. Large winter clutch size or high intensity shows a small but significant positive correlation with length of biological year.
4. Degree of broodiness shown by the number of nonproductive broody days gives a negative correlation with duration of biological year.
5. Annual persistency shows an intimate correlation with annual egg record.
6. The egg record for the biological year is intimately correlated with the duration of the biological year.
7. First- and second-year hatchability are independent of duration of biological year.
8. Small body weight at first egg is associated with great length of biological year.
9. Heavy body weight at the close of the 365-day laying year is associated with greater duration of biological year.
10. Second-year egg production tends to be higher in birds showing a biological laying year greater than 365 days.

11. Annual persistency of daughters from dams with a biological year greater than 365 days is distinctly higher than in daughters from dams with a biological year of from 315 to 365 days or from dams with a shorter biological year than 315 days.

12. Annual egg records of daughters from dams with extended biological year are superior to those from dams with shorter biological year.

13. Great duration of biological year in dams indicates superior vigor as measured by the lower mortality rate for their daughters in the laying houses.

14. In general, the selection for breeding purposes of females having the ability to lay continuously for more than 365 days is a commendable practice.

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