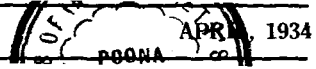


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Breeding for Egg Production

By F. A. Hays and Ruby Sanborn

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During the last twenty years the Poultry Husbandry Department has conducted numerous investigations to determine the influence of various factors, controllable through breeding, on the egg-producing ability of Rhode Island Reds. This compilation of results obtained up to the present date is intended as a guide to assist the poultry breeder in directing his operations.

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BREEDING FOR EGG PRODUCTION

By F. A. Hays, Research Professor, and Ruby Sanborn, Research Assistant,
in Poultry Husbandry

In a study of the mode of inheritance of high fecundity, Rhode Island Reds have been bred experimentally at the Massachusetts Agricultural Experiment Station for a period of twenty-one years. The data presented in this report cover the birds hatched from 1913 to 1932, inclusive, and are based very largely on pullet-year records.

A number of significant discoveries related to the inheritance of fecundity have been made from time to time as this experiment progressed and these have already been reported. This report summarizes the methods of breeding and the results accomplished up to the present time and may serve in a measure as a guide to poultry breeders.

The General History of the Flock¹

The initial flock consisted of 144 single-comb Rhode Island Red pullets purchased in the fall of 1912. The major portion of the birds came from one prominent exhibition flock and the remainder from another well-known exhibition flock. These pullets were housed in two units and trapnested throughout the year. The original records include date of first egg, hour of laying, broody records, nesting records, and sickness or injury notes, together with egg records to March 1 and for 365 days from first pullet egg.

The males used to produce the first generation in 1913 came, with one exception, from the same breeding farm as the major portion of the original females. The generation produced in 1914 was sired largely by the original males or their sons, but in addition four outside males from different sources were used for breeding. The results obtained with the generations hatched in 1913 and 1914 were not considered satisfactory because the birds were lacking in vigor. For this reason, ten outside males from widely different sources were used for breeding in 1915, besides a few of the foundation males and a number of their sons. Since the breeding season of 1915, outside stock has not been used in this experiment. Since 1920 all males used as breeders have been found to trace back exclusively either to one original male used in 1913 or to one outside male introduced in 1915.

The first generation of offspring was hatched in 1913 between March 25 and May 15, at weekly intervals. The same hatching dates with eight weekly hatches have been maintained through 1932. The method of feeding and management has been changed only gradually to conform to modern developments.

Artificial methods such as confinement rearing have never been employed, the chicks when taken from the incubators being placed in 6 × 6 colony brooder houses heated by kerosene brooders up to 1917; after 1917 in 10 × 12 colony brooder houses heated by stoves. Up to 1921 pullets were regularly housed when about six months of age in units of about 100. Beginning in 1922, pullets

¹The experimental work reported here was planned and directed by H. D. Goodale from 1912 to 1922. Since 1922 the work has been carried on by F. A. Hays.

were housed in units of 250 at the new experimental poultry farm. Artificial lights have never been used.

Modern methods for disease control, such as range rotation, complete separation of growing and adult stock, and cleaning and disinfecting of houses and equipment, have been regularly employed. For many years all birds have been tested yearly for pullorum disease, and in recent years chicken-pox vaccination has been practiced regularly either at housing time or on the range at about twelve weeks of age. Up to the fall of 1926 all birds in the laying houses were self-fed laying mash in hoppers and grain twice daily in the litter. On November 19, 1926, self-feeding whole corn, oats, and laying mash was begun.

The Qualities of an Improved Flock

In general, an improved flock should consist of birds very uniform for all the known desirable characters from the standpoint of fecundity; the birds should be free from standard defects; there should be very high hatchability, low mortality, and a high degree of prepotency.

An ideal hen should possess the following qualities: Standard weight; early sexual maturity; high intensity; no winter pause; non-broodiness; high persistency; large egg size; first quality color, shape and shell texture of eggs; high hatchability; strong vigor; trueness to breed standard; and prepotency. When these requirements are considered individually in view of what is known regarding their inheritance, the fact becomes very evident that the development of an improved flock possessing all the desirable qualities is a gigantic undertaking requiring large numbers of birds, careful observation, complete records, and a knowledge of genetic principles involved. The measure of success in poultry breeding is the degree of uniformity in the flock with respect to all the characters bred for.

The Plan of Breeding

The description of the plan of breeding may logically begin with the method of selecting breeders. Since the male contributes to the inheritance of a greater number of offspring than does the female, his selection may be considered first.

Males have been selected in part each year by three different standards. Aged males that were physically fit and that had sired a superior group of daughters were used, and satisfactory matings were repeated as far as possible. Cockerel breeders were selected each year both on their pedigree and on the performance of their sisters with respect to characters affecting fecundity up to the breeding season. Each male was selected on physical characters as far as available birds permitted. In the earlier years not much attention was paid to plumage color or to physical defects in comb, shank, feathering, split wings, etc. During the past five years great care has been exercised not to breed from either males or females with physical defects, and some attention has been given to improving plumage color.

All hen breeders were selected on their fecundity characters and on the performance of their daughters. Pullet breeders were chosen on pedigree and on their performance up to the breeding season. Heavy body weight has always

been emphasized. Each year a surplus of pullet breeders has been placed in the mating pens in order that the offspring from such as proved unsatisfactory in hatchability, in egg character, in broodiness, or in lack of persistency might be discarded.

After the discovery that five specific characteristics were associated with high fecundity, the method of breeding was directed toward the establishment of these in the entire flock. The characters bred for were early sexual maturity, high intensity, no winter pause, non-broodiness, and high persistency. The early efforts were directed toward establishing early sexual maturity by the selection of female breeders that began to lay at an early age, and this standard has been rigidly adhered to. Efforts were next made to reduce broodiness through the use of non-broody females or females with a low degree of broodiness for breeding. High intensity was the third character sought for, and was established in the flock by one hen, B785, hatched in 1917 and used first for breeding in 1918 and again in 1919 and 1920. Seven of the daughters of this hen and one son were also used. Efforts to eliminate winter pause entirely followed the establishment of high intensity. Breeding females were selected as far as possible that showed no cessation of production between November 1 and March 1. The last character to be established was high persistency. Selection of breeders for this purpose was based on ability to lay late in the fall before undergoing annual molt.

Throughout the experiment attention has been given to high hatchability, and during the past five years special attention has been given to egg size and egg character and to mortality rate as well as to the elimination of physical defects and to the improvement of plumage color.

All matings made since 1913 have been pedigree matings, and a complete hatching record has been kept of all eggs set. Infertile eggs were removed on the fifth day. All eggs carrying dead germs were removed on the fifth day or on the eighteenth day, broken, and the embryos checked. Eggs were placed in pedigree baskets on the eighteenth day and the chicks taken out on the twenty-second day. All remaining unhatched eggs were then broken and the embryos examined. Chicks were banded from the incubator using No. 3 pigeon bands placed around the leg and transferred to the wing at two weeks of age to serve as the permanent number of the bird. Sexes were separated at about eight weeks of age, and pullets placed in the laying houses according to hatching date at about 150 days of age. Complete pullet families were housed, except crippled or diseased birds.

The Changes in the Average Character of the Flock

Progress in breeding for particular characters can best be measured by averages from year to year, provided the number of birds concerned is sufficiently large to be representative. In Table 1 are presented the averages for a considerable number of characters throughout the experiment. The table includes only birds bred for high fecundity in the flocks hatched from 1916 to 1932. Annual records are not available on the flock hatched in 1919 because the birds were disposed of after the hatching season on account of disease and parasites.

The table shows that early sexual maturity was rather well established in the 1917 flock, and that the fluctuation in mean age at first egg has ranged from 185 to 212 days in a 16-year period. The fact should be stated that the mean age at first egg of the 1913 flock was 255.61 days.

TABLE 1.--YEARLY AVERAGES SHOWING PROGRESS IN BREEDING FOR PARTICULAR CHARACTERS.

(Includes all pullets or breeders each year in the flock bred for high production. The number of birds in the different columns varies somewhat.)

Year Hatched	Number of Birds Put in Laying House	Age at First Egg Days	Weight at First Egg Pounds	Birds with Winter Pause Per cent	Winter Clutch Size Eggs	Broody Birds Per Cent	Broody Periods per Broody Hen		Persistency Days	Annual Production Eggs	Laying House Mortality Per cent	Hatchability	
							Number	Length-Days				Per cent	No. of Birds
1916	330	229.71	6.07	56.99	2.5	86.31	3.5	14.29	247.53	133.67	9.37	65	(62)
1917	432	212.96	5.68	60.97	2.3	48.84	2.7	16.36	280.74	165.85	15.05	62	(78)
1918	474	194.44	5.75	67.34	2.3	61.40	2.9	15.06	287.98	169.19	56.54	65	(89)
1919	157	212.04	5.42	64.97	2.8	69	(56)
1920	162	199.99	5.48	74.67	2.7	46.03	2.9	12.85	330.86	199.73	26.09	70	(45)
1921	440	211.51	5.27	35.05	3.3	44.56	2.7	15.03	303.94	198.40	29.09	73	(67)
1922	565	196.60	5.39	64.06	2.7	28.91	1.9	14.17	321.92	199.55	31.68	71	(83)
1923	472	208.77	5.57	76.98	2.4	27.35	1.9	15.57	323.54	189.09	26.06	73	(62)
1924	422	196.26	5.53	65.80	2.5	32.90	2.3	15.10	326.57	196.41	50.00	54	(142)
1925	553	192.05	5.39	80.77	3.1	41.55	2.7	14.81	330.24	205.21	22.97	63	(130)
1926	479	198.56	5.35	70.00	2.7	19.31	2.3	15.03	331.36	205.26	32.57	64	(124)
1927	551	185.30	5.40	70.73	3.5	9.55	1.2	18.19	320.67	197.38	23.23	57	(150)
1928	560	195.82	5.33	58.33	3.4	18.44	2.5	13.67	335.20	214.82	14.29	60	(174)
1929	507	197.08	5.50	61.93	3.1	12.69	1.8	13.74	329.87	208.40	33.73	75	(108)
1930	461	191.24	5.41	50.49	3.7	22.52	2.3	14.51	339.60	214.34	29.28	74	(79)
1931	462	188.77	5.58	39.54	3.8	16.52	2.1	14.23	344.40	234.23	17.10	70	(90)
1932	377	201.69	5.88	57.05	3.3	11.70	2.1	12.90	337.79	222.14	35.54	66	(83)

Each pullet was weighed on the day she laid her first egg. The table shows that this mean weight has not fluctuated widely throughout the experiment and that the birds hatched in 1932 were slightly heavier than any other flock except the 1916 flock. This latter flock owes its greater weight to a greater age as Hays (1933a) has pointed out. The data in general indicate that breeding for high fecundity has no significant effect on body weight at first egg.

The nature of winter pause is fully discussed in a later section of this report. The table shows that the percentage of birds showing a winter pause of four or more days has fluctuated from a minimum of 35.05 in 1921 to a maximum of 80.77 in 1925. During the last five years there is some progress apparent in eliminating the trait, but on the whole this character has not responded well to breeding methods used.

Intensity, measured by winter clutch size, shows a highly significant improvement. This is especially noticeable during the last six years, during which winter clutch size has been used as the sole measure of intensity in the selection of breeders. The mean clutch size in recent years shows that the majority of the birds carry both genes I and I' for large clutch size.

Broodiness is measured by the percentage of birds broody the first year, by the mean number of broody periods for broody individuals, and by the mean length of broody periods. The data show clearly that broodiness may be greatly reduced by selection of non-broody breeding stock. In the flock of 1916 slightly over 86 per cent of the females became broody in the first laying year, while in the 1932 flock 11.7 per cent exhibited the trait. Quantitatively broodiness as measured by the number of broody periods per broody individual has decreased from an initial mean of 3.5 periods to a mean of 2.1 periods. The mean length of broody periods, measured by the non-productive time interval, remained unchanged throughout the experimental period and ranged very close to 15 days.

Annual persistency within a 365-day laying year has increased significantly during the experimental period. The mean initial persistency was about 248 days, and the mean persistency at the close of the experiment about 340 days. The most notable progress since 1920 has been made during the last five years. This increase is due in large measure to the more rigid selection of breeders for greater duration of laying and to the use of more aged breeders with greater length of biological laying year. This latter basis of selection is very effective according to Hays and Sanborn (1933).

Mean annual egg production stood at about 134 eggs in 1916. It increased rather rapidly to 200 eggs in 1920. The production then remained at the 200-egg level for five years. Beginning with 1925, the trend has been upward to the highest mean of 234 in 1931. Production has not advanced a little each year but has increased by rather abrupt advances at intervals accompanying the establishment of a desirable character in a large percentage of the flock. Attention is called to the fact that these egg records represent the mean of all normal birds in each family that lived to complete a 365-day record, and that no culling was done during the laying year.

Mortality in the laying houses has varied widely throughout the period reported. The records do not show that mortality has increased as the breeding work progressed and as the egg production level was raised. Records during the

last eight years, in the absence of specific disease outbreaks, have fallen as low as 15 per cent in only one year. Experience and observation indicate that a laying-house mortality above 15 per cent is excessive. It is probable that selection of breeders for low family mortality has not been rigid enough because of efforts to establish other desirable characters. Another possibility is that, since no outside stock has been introduced since 1915, the flock may be restricted to too close relationships even though inbreeding has been avoided. There is no experimental proof to support this possibility, however.

The last double column gives the mean percentage of fertile eggs hatched, together with the number of females used (in parentheses). Hatchability has improved very slightly during the whole period. It seems probable that more attention should be given to this character in the selection of breeders.

The Relation Between Fecundity Characters and Egg Production

Goodale and Sanborn (1922) pointed out that there are five prominent characteristics that tend to increase the annual egg production of Rhode Island Reds. These characters are early sexual maturity, high intensity, no winter pause, non-broodiness, and high persistency. Hays (1924 and 1927) showed that these characters are inherited and that a total of eight genes is concerned. If the five characters are considered as units, there are thirty-one types of birds each representing a different combination of the five. There are five types of individuals each carrying one of the five desirable characters; ten types, each carrying two desirable characters; also ten types, each carrying three desirable characters; five types, each carrying four desirable characters; and one type having all five desirable characters combined. A rough measure of the degree of improvement in the flock for egg production would be the percentage of birds combining either four or five of these desirable characters. Table 2 shows that the average egg record of birds increases as the number of desirable characters increases. The table includes 2300 birds hatched from 1928 to 1932.

TABLE 2.--RELATION OF NUMBER OF DESIRABLE CHARACTERS TO ANNUAL PRODUCTION.

Number of Characters	Number of birds	Per cent of Birds	Average egg Production
0	31	1.35	149.03
1	158	6.87	156.73
2	375	16.30	173.78
3	717	31.17	200.83
4	648	28.17	227.32
5	371	16.13	252.15

Table 2 shows that the 31 birds classed as having neither early maturity, high intensity, no winter pause, non-broodiness, nor high persistency averaged 149 eggs, showing that they must have been maintained under good laying conditions. No doubt a number of these individuals are improperly classified because of the variability in each character that always occurs. The table shows further that the group of 158 birds carrying only one of the five characters averaged to lay about 157 eggs. From this class on, the addition of any one character increased

the mean production about 25 eggs, so that the group having all five desirable characters averaged to lay 252 eggs a year.

The rate of progress in establishing these characters in the flock during the last five years is rather definitely indicated by the percentage of birds in the different groups. The classes showing three and four of the desirable characters make up 59.34 per cent of the entire population. The classes having two of the characters and those having all of the characters are equally represented with about 16 per cent. Theoretically the flock is improved only to the extent of about one-sixth of what may be anticipated, for there is no known reason why 100 per cent of the birds cannot carry all five desirable characters. There are at present 65,496 genetically different classes of birds in the flock with respect to the five characters considered. This fact shows why progress is slow in establishing characters in a small flock, and it is very evident that little progress can be made in flocks consisting of fewer than 500 individuals.

Early Sexual Maturity

Unpublished data show that the regression of annual egg production on age at first egg is not strictly linear and that the correlation ratio shows a value of $.6056 \pm .0112$. Hays and Sanborn (1927b) have shown, however, that the net correlation between age at first egg and annual egg production is insignificant and that early-maturing birds generally lay more eggs only because they tend to be more intense layers and are generally more persistent.

Even though early sexual maturity in itself is not essential to high annual production, its association with other essential characters gives it a high value as a selection unit in production breeding. This character was the first to be selected for in this experiment, was reasonably well established first in the flock hatched in 1917, and has behaved with a high degree of constancy up to the present time.

Early maturity behaves in inheritance as a dominant to late maturity as Hays (1924) showed. Two independent dominant genes,² E and E', are concerned, either of which will enable pullets to begin laying at 215 days or less. Gene E is sex-linked and is transmitted by males to both sons and daughters and by females to their sons alone. Gene E' is autosomal and is transmitted equally by both parents. No cumulative effect has been discovered for these genes.

High Intensity

High winter intensity (large clutch size) is an inherited character that has a very significant effect on annual egg production. Winter clutch size was shown by Hays and Sanborn (1927a) to be significantly correlated with production, giving a value of $+.3544 \pm .0117$. The same workers (1932) showed that the regression of annual production on winter clutch size is non-linear, giving a correlation ratio of .4214. Hays and Sanborn (1927b) found the net correlation between winter clutch size and annual egg production to be $+.4944 \pm .0101$ which shows clearly that high intensity is essential to maximum egg production.

²In genetic terminology capital letters stand for dominant genes and small letters for recessive genes. Individuals are said to be homozygous for a gene when they carry two doses as HH or hh and heterozygous when they carry two different genes as Hh. The first class of individuals breeds true for the character in question—they are prepotent. The second class gives two types of offspring, one carrying H and one carrying h, in equal proportions. The same general principles apply to other genes discussed in this report.

The mode of inheritance of intensity has been reported by Hays and Sanborn (1927b). Two dominant genes I and I' are concerned. Hens carrying gene I alone have an average winter clutch size greater than 2 but less than 2.6. Gene I' gives a clutch size of about 2.6. Both genes together increase the clutch size up to 3 or more eggs throughout the winter season. There is no sex linkage for clutch size. Improvement in clutch size has been made possible through the use of breeding stock showing the ability to lay large numbers of eggs in succession throughout the winter season. The minimum winter clutch size for breeders should be 3 eggs, and males should be constantly selected for the ability to transmit large clutch size to their daughters.

Winter Pause

Winter pause or the cessation of laying for four or more days between November 1 and March 1 of the pullet year reduces the number of eggs laid in a year. The simple correlation between length of pause and annual production is reported by Hays and Sanborn (1926b) to be $-.2107 \pm .0176$, and the net correlation was given as $-.5487 \pm .0128$ (Hays and Sanborn, 1927b). The fact is very evident, therefore, that the appearance and duration of the pause exercises a very significant influence on the number of eggs laid.

The data from this station point rather definitely to both inheritance and environment as responsible for winter pause. There is very great difficulty in separating the two causes, and this retards progress in eliminating pause from the flock. The fact that, in full sisters hatched on the same date and housed together, some exhibit pause and some lack it, rather strongly suggests that inheritance is concerned. Furthermore, the average duration of pause per family has been reduced by selection even though the proportion of birds without the four-day pause has not significantly changed during the last twenty years. There appears to be one dominant factor M concerned in hereditary pause, as Hays (1924) points out. The logical procedure in eliminating this character consists in the constant selection of pause-free breeders and in hatching and housing under optimum conditions at all times.

Broodiness

Broody periods represent periods when production ceases. On the average, each broody period occasions a loss of about fifteen days of egg production. Hays and Sanborn (1926a) reported that, of the original flock hatched in 1912, 89.6 per cent were broody during the first laying year. As the experiment has progressed the percentage of broody birds has greatly decreased, reaching a minimum of 11.7 per cent in 1932. Along with the decrease in percentage of broody birds there has occurred a high reduction in number of broody periods per broody individual. For example, the 1913 flock averaged 5.4 periods per individual broody bird, while the 1923 flock averaged but 1.9 periods per broody bird. Hays (1933b) presents definite experimental evidence showing that degree of broodiness measured by number of broody periods depends on inheritance.

The presence of broodiness has been shown by a number of workers to greatly reduce egg production. Jull (1932) reports that 494 non-broody Rhode Island Red birds averaged 204.78 eggs, compared with 179.65 eggs for 477 broody birds. Hays (1933b) reported that 267 birds in a non-broody line averaged 209.81 eggs, while 259 birds in a broody line averaged 179.02 eggs. The net

correlation between days broody and egg production in the pullet year is $-.5630 \pm .0097$ in the station flock.

Broodiness is inherited on a two-factor basis according to Goodale, Sanborn and White (1920). Two dominant complementary genes, A and C, are necessary to produce broodiness. There is no evidence of sex linkage, and non-broody birds are of three general classes: (1) those lacking both A and C; (2) those carrying A and lacking C; (3) those carrying C and lacking A. Classes 2 and 3 are very troublesome to the breeder because such females, though not exhibiting broodiness, will produce broody offspring if mated with males carrying the gene that they lack. This is one of the chief reasons why broodiness has never been completely eliminated from any flock. Another obstacle in eliminating broodiness lies in the problem of deferred broodiness. In such cases the instinct may not appear in many females during the first or second laying years. This fact renders an accurate progeny test of males almost impossible with the American breeds.

A constructive breeding program calls for the constant use of non-broody hens for breeding and the use of progeny-tested males to the greatest extent possible.

Persistency

Persistency at the close of the pullet laying year has been shown by Hays and Sanborn (1927b) to be the most important inherited character affecting annual egg production. The net correlation between length of laying year and annual production is $+.7501 \pm .0063$. This fact indicates that more than 56 per cent of the variation in annual egg records is due to differences in persistency. Hays and Sanborn (1933) have pointed out further that persistency higher than 365 days is desirable in breeders from the standpoint both of increasing egg production and of reducing mortality in daughters.

Hays (1927) has presented some evidence concerning the mode of inheritance of high persistency. His data indicate that high persistency depends upon one dominant autosomal gene, P. According to this report the dividing point between birds genetically high and low in persistency lies at about 315 days from the first pullet egg. In breeding for persistency, no females laying for a shorter period than 315 days should be used for mating, and male breeders should carry an equally good or superior inheritance for persistency.

The Hatchability Problem

Extensive experimental observations by many investigators indicate a wide range in percentage of fertile eggs hatched by different birds. Experience also furnishes evidence that constant selection for high hatchability is necessary in improved flocks in order that hatchability may not decline. Experimental workers are agreed that hatchability is an individual trait depending upon both inheritance and environment.

Egg size does not affect hatchability as Jull (1932) shows from his own studies as well as from the work of other investigators. The physical characters of eggs such as shape and shell texture do not influence hatchability if the eggs are normal. On the basis of these facts, the selection of hatching eggs for size and physical characters does not seem to have any significant effect on hatchability.

Age of birds used does not consistently affect hatchability. Hays (1928) presents some evidence that for identical matings there is a slight increase in hatchability of yearlings compared with pullets. When different groups of pullets, yearlings, and old hens are compared for mean hatchability, the station records from 1924 to 1931 show the following means: 65 per cent for pullets, 75 per cent for yearlings and 65 per cent for old hens. In the experiment station flock there is, therefore, some evidence indicating that females are likely to hatch the highest percentage of fertile eggs during their second laying year.

The most potent factors affecting hatchability are inherited factors, according to the work of Hays and Sanborn (1924). They have clearly demonstrated that the hatching record of a hen depends largely upon her inheritance and upon the character of the male to which she is mated. In other words, the embryo's inheritance from its sire and dam either equips or fails to equip it to emerge normally from the shell.

Studies at the Massachusetts Station indicate that one major gene, H, is concerned in high hatchability. This gene is transmitted equally by males and females and has a cumulative effect. The three general classes of birds with respect to hatchability are: (1) HH birds which, if mated to either HH or Hh males, give hatching records of 85 per cent or more; (2) Hh birds which usually have a hatchability range from 55 to 84 per cent and may produce no hatchable eggs; and (3) hh birds which generally range in hatchability from 0 to 54 per cent. Females that have shown a hatchability of 85 per cent or more are HH in genetic make-up, and breeding birds should always be selected on this basis. Males should be chosen on the hatching record of their female ancestors and insofar as possible upon the actual hatching records of their daughters.

By giving some attention to hatchability in the station flock, the mean has been raised from about 58 per cent in 1914 to a maximum of about 82 per cent in 1933. A portion of this increase may be attributed to improved incubation facilities, but in general there has been an upward trend under the same system of incubation. Attention should be called to the fact that all eggs have been pedigree hatched which necessitates considerable extra handling and exposure to temperature changes and has been shown to lower the hatching records from 10 to 15 per cent over ordinary incubation in this flock.

The Vigor Problem

High vigor in a production-bred flock may be defined as the ability to live and produce heavily for a long period of time under intensive conditions. Records of the mortality rate in families on the growing range and in pullets in the laying houses show striking differences between families. It is a reasonable assumption that the great proportion of these losses come from lack of vigor, because diagnostic records show the flock to be relatively free from specific disease outbreaks. The flock has been free from pullorum disease for many years, and pox and roup have been controlled by vaccination. Coccidiosis has been held in check by a four-year range rotation and by quarantining against visitors or caretakers of adult fowls.

From October 1, 1932 to September 30, 1933, complete post-mortem records were made by the Department of Veterinary Science on all pullets of the experimental flock hatched in 1932. The records begin at the time the birds were

housed and continue for one year. The causes of mortality have been grouped into fourteen general classes, and the original number of pullets housed was 751.

	Per cent
Ruptured or obstructed oviduct.....	2.53
Ruptured egg yolks, peritonitis.....	1.33
Tumors.....	2.93
Worms.....	1.86
Leukemia.....	3.20
Visceral gout, nephritis.....	2.26
Impaction.....	1.20
Paralysis.....	2.66
Chronic coccidiosis.....	.27
Prolapsus.....	.93
Cannibalism.....	6.79
Injury.....	.67
Miscellaneous.....	4.13
No recognized cause.....	9.99
<hr/>	
Total loss.....	40.75

Examination of these records does not point to any specific diseases as predominant causes. The greatest percentage of birds died from miscellaneous causes not common in the flock. Almost 10 per cent of birds showed no specific cause on post mortem. Leukemia, tumors, paralysis and ruptured or obstructed oviduct appear as most potent specific disorders in the flock. The loss of 6.79 per cent from cannibalism cannot be due to lack of vigor but is probably due entirely to faulty management.

From the standpoint of breeding to reduce mortality, the logical procedure is to select breeders from families with the lowest mortality. Neither breeding males nor breeding females should be used from families with a greater mortality than 10 per cent between hatching and housing in the fall. The yearly mortality in pullet families in the laying houses should not exceed 15 per cent including those culled. The mortality from housing time in the fall up to the breeding season in February or March should not be greater than 5 per cent.

The Influence of Inbreeding

Inbreeding is a useful tool of the breeder in securing uniformity because the mating of closely related individuals tends to increase homozygosity. This method of breeding has been extensively used in developing new breeds and varieties where the chief concern is uniformity in type and plumage character and color.

Inbreeding in production-bred flocks has not given encouraging results according to the work of a number of investigators. Dunn, Hays, Dunkerly and Jull have all reported that inbreeding decreases egg production. Extensive studies by Hays (1929b) show the following undesirable results from inbreeding Rhode Island Reds: sexual maturity was retarded, winter pause increased, intensity lowered, persistency lowered, egg production decreased, fertility lowered, hatch-

ability decreased, and vigor reduced. No significant gain in uniformity of annual egg production was observed under inbreeding. The deduction is made from these studies that only flocks made up of very diverse foundation stocks will tolerate inbreeding. As a rule, for ordinary improved flocks, much greater progress will be made by selection on the basis of individual fecundity characters and the avoidance of matings closer than cousins in the flock.

Breeding For Egg Size

Egg size depends indirectly upon a great many inherited characters. Some of these characters are age at first egg, body weight at first egg, and intensity of laying. Hays (1930a) showed the correlation between age at first egg and mean egg weight to January 1 to be $+0.4280 \pm 0.0148$ in Rhode Island Reds. The correlation between body weight at first egg and egg weight to January 1 was $+0.4314 \pm 0.0147$. Hays (1930b) presented evidence that egg size is not linked with either factor for early sexual maturity and this fact suggests that the reason why there is a significant correlation between age at first egg and winter egg size is due to the direct relation between age and weight at first egg. Hays (1930b) demonstrated a specific linkage between gene A for small egg size and gene I' for highest intensity. In view of these findings, it is evident that poultrymen should take great care in selecting breeders for high intensity that they do not carry the gene for small egg size.

Parkhurst (1933) reviews the effect of nutrition on egg size and shows that in general either inadequate food supply or lack of proper protein in the ration may reduce egg size. Parkhurst's data indicate that birds fed rations deficient in vitamin D lay small eggs, that the addition of milk to the ration increases egg size, but that minerals added to the ration do not affect egg size. The differences observed in egg size in all cases are rather small.

A number of workers including Jull, Parkhurst, and (according to Jull, 1932) Atwood and Clark, Thompson, Asmundson, and Marble present data indicating that egg weight and number of eggs laid in a year are independent entities. But the experience of breeders of heavy laying flocks indicates rather universally that egg size will decrease as the mean production of the flock increases unless careful attention is given to egg size. Hays (1929a) pointed out that very heavy winter laying in Rhode Island Reds is accompanied by small egg size. A number of other workers including Lippincott, Jull, and Parkhurst report that early sexual maturity, which is related to annual egg production, is associated with small egg size. Hadley and Caldwell, Atwood, Jull and Rynehart have substantiated the findings with Rhode Island Reds at this station — that heavy body weight is associated with large egg size.

In considering the question of breeding for large egg size, it becomes necessary to lay down certain standards for egg size. Hays (1929a) has assumed that pullet eggs weighing 56.7 grams each or 24 ounces to the dozen in February are satisfactory. On such a basis all eggs laid the first year will average about 23.5 ounces per dozen. Egg weight in such birds will increase about 7 per cent in the second laying year, or from 1.5 to 2 ounces per dozen.

Working on this basis, Hays (1929a) has reported two major genes as largely responsible for the differences in egg weight. Gene A produces an egg size in February of considerably less than 24 ounces per dozen; gene B alone gives an

egg weight of 24 ounces or more; when genes A and B are present in the same individual, the egg weight in February falls below 24 ounces. There are thus three general classes of birds with respect to egg size. The A class may lay 22-ounce or smaller eggs, the AB class will approximate 23 ounces, and the B class will lay eggs weighing 24 ounces or more. The breeding problem lies in the constant selection of pullet breeders laying 24-ounce or heavier eggs and yearlings laying 25.5- to 26-ounce eggs, and the constant use of males carrying the inheritance for large egg size.

The Selection of Superior Males

Selection of superior males for breeding has always been a troublesome problem. The reason is evident, because there are no measures of the male's performance with respect to the characters affecting egg production. Young males are selected either on the performance of their female ancestors or on the partial records of performance of their sisters. In the light of the many genetic factors concerned, it is evident that either method is very unreliable. Aged males may be selected on the performance records of their daughters, and satisfactory matings should be repeated. Even though progeny-tested males are used as far as possible, the system requires that at least three times as many males be used as cockerels each year as will be required for breeding when three years of age because of high mortality in males. Males must be at least three years of age before the fecundity records of their daughters are known. This fact greatly limits the use of this method with the medium breeds where the reproductive life of males is relatively short.

Since complete progeny testing has such pronounced limitations, a system of partial progeny testing has been suggested by Warren (1932). He recommends that cockerels for breeding be selected from families where the sisters show such desirable characters as early maturity, high intensity, etc., early in the season. This method is of some value in selection but falls far short of being an accurate method.

Unpublished data from the Massachusetts Experiment Station flock of Rhode Island Reds show that during the past five years only 3 (5 per cent) of the 60 males used have raised the mean egg production of the daughters over their dams. These males were mated to females laying from 226 to 250 eggs during their pullet year. Since the average egg production of birds in this experiment is 235 eggs, such dams are truly representative.

The method of evaluating males for breeding purposes which the authors believe to be genetically sound is based on the relative proportions of early maturing, non-pause, highly intense, non-broody, and highly persistent daughters produced by the males compared when mated to females carrying these characters. Thus individual males may be directly compared in their ability to transmit any or all of these five characters which are so vitally related to high production. By this method it is possible to use partially tested males with considerable confidence when they are two years of age rather than to wait until the male is three years of age. This method of selection has proved superior to any other method used to fix the five high fecundity characters in the flock. Under all conditions males can be compared on the progeny test only when each is mated to the same character of females.

The Introduction of Outside Stock

From the genetic standpoint almost any flock of birds is very heterogeneous, especially with respect to genes concerned in the inheritance of high fecundity. The fact has already been pointed out, however, that close inbreeding is detrimental to increasing the egg production as a rule. The method of improving the station flock has avoided inbreeding; at the same time, there has been no outside stock introduced since 1915. Under this system of breeding there arises a high degree of relationship which may eventually produce the same effects as close inbreeding. Limited experimental studies on the value of introducing outside production-bred males have given negative results so far.

Practical breeders desire to know how long they may continue breeding within their own flocks and what specific developments indicate that outside stock should be introduced. In answer to these question, experience here tends to show that there are two specific indications that new blood may be beneficial. (1) If hatchability is on the decline even though incubation methods are good and attention is given to hatchability in selecting breeders, it is probable that the stock is too closely related. (2) If there is excessive mortality in the families on the range and in the pullets during the first laying year from no specific disease outbreaks but largely from many functional disturbances, this is evidence of close relationship. Close inbreeding very often produces low hatchability and late sexual maturity as well as lack of persistency.

When there is evidence that outside stock is needed, it is especially important that such stock should be selected from flocks bred systematically for the characters being sought, and that the birds should be free from undesirable defects. Probably the most satisfactory procedure is to obtain pedigreed hatching eggs from two or three different sources and to hatch and rear the chicks with the regular flock. Pullets may then be housed with the home flock and trapnested until the hatching season to obtain some evidence of their behavior under existing conditions. Preliminary crosses can be made between those families that appear to be satisfactory, and the offspring checked against the home flock. Crossing should not be undertaken on too large a scale until there is evidence of its value, yet numbers should be sufficiently large to give a true measure of results.

The Types of Records Kept

One of the essentials in a successful breeding program is a complete and accurate system of records. Such records should be kept up to date and should be constantly used as a guide to the breeder. Trapnesting and record keeping are expensive and are of little value unless the records are studied and analyzed regularly. The two greatest essentials of a good set of records are simplicity and completeness.

The record forms used for the experimental flock are rather complete and are presented here not as suitable for commercial flocks, but rather as suggestive material to guide the breeder. It is easily possible to modify and combine these record forms to reduce labor and yet meet practical needs.

MASSACHUSETTS EXPERIMENT STATION—Hatching Record

0 O—INFERTILE 42 TOTAL EGGS SET XN—DEAD AT FULL TERM, NORMAL
 1 E—DIED EARLY 100% FERTILITY XH—DEAD AT FULL TERM, HENORRHAGE
 3 V—DIED LATE 86% HATCHABILITY XP—DEAD AT FULL TERM, ABNORMAL POSITION
 36 H—HATCHED 2 XY—DEAD AT FULL TERM, YOLK NOT ABSORBED

YEAR 1933

PROJECT 2

FEMALE L34

MATE L2

INCUBA-TOR	DATE SET	DATE EGG							LAID WEIGHT	NUMBER SET	REMARKS
	2/11	π	π	π	π	π	π	π		6	
	2/18	π	π	π	π	π	π	π		5	
	2/25	π	π	π	V	XY				5	
	3/4	π	π	π	π	E				5	
	3/11	Y	π	π	π	π				5	
	3/18	XY	π	π	π	π				5	
	3/25	π	π	π	π	π				5	
	4/1	π	π	Y	π	π	π			6	

Figure 1.—Individual Hatching Record

There should be one small sheet for each female. The record includes date set, date on which each egg was laid, number infertile, number dying early, number dying late, and number of chicks hatched. At the close of the hatching season these data may be summarized for each female.

	Dam	Sire	Exp.	Feathering	Weight	Notes
♀ 501	L 2967	M 991	1	+	5.22	Light ear lobes, light red, black mottled
♀ 502			1	-	5.72	
♀ 503	L 2967	M 991	1	+	4.80	
♀ 504	L 2775	M 897	2	-	5.10	Black mottled
♀ 505			2	+	2.74	Pale and thin $\frac{9}{16}$
♂ 506			2	-	5.28	Very light red
♀ 507			2	-	4.83	Light ear lobes
♀ 508			2	-		D $\frac{1}{69}$
♀ 509	L 2775	M 897	2	-	4.80	
♀ 510	L 3003	L 646	2	+	4.95	
♀ 511			2	+		
♀ 512			2	+	4.90	Light red
♀ 513			2	+	4.76	
♀ 514	L 3003	L 646	2	+		Colled $\frac{1}{55}$
♂ 515	L 2980	L 646	2	-	4.98	Very light red, slabs
♀ 516			2	+		D $\frac{1}{15}$
♀ 517			2	+		D $\frac{1}{21}$
♀ 518			2	+		
♀ 519	L 2980	L 646	2	-		Very light red
♂ 520	M 159	M 2741	7	-	5.32	
♂ 521			7	-	5.00	
522			7			D $\frac{5}{11}$
♂ 523			7	-	5.48	
♀ 524	M 159	M 2741	7	+	4.88	
♀ 525	M 399	M 1115	4	-	4.50	

Figure 2.—Double Page from General Record Book

A well-bound book with ruled pages about $5\frac{1}{2} \times 8\frac{1}{2}$ is very convenient and may be purchased at any bookstore. Numbers may be stamped in consecutive order on the left side of each left page, and all the rest of the space to the right used for records. As the chicks are taken from the incubator they are banded and the mother's number placed after the chick's band number. These bands remain the permanent number of the chick.

YEAR 1933

1M 629. N. 5947.

PARENTAGE M2741 MATING DATES MATING NO. M2244
M2244

From To

avg. egg

Chick Band No.	Sex	Date Hatched	EGG RECORD						Wt. of Egg to Hatch Days Jan. 1	Chick Broody Periods Feathering	MATINGS USED IN NOTES
			S	O	N	D	J	TOT.			
N 403	♀	Mar. 5	23	28	23	25		53.4 g.	+	Blatard breast	
404	♀	"			21	18		52.9	-		
405	♂	"							-	6.36 lbs. Brooder Bla. feet	
406	♀	"		8	7	11		67.2	+	St. ear lobes	
407	"	"	D	3/4							
408	♂	"							-	5.90 B.	
835	♀	Mar. 12	19	28	26	22		51.1	+		
836	♀	"	4	9	0	0		51.9	+		
837	♀	"	D	3/4					+		
838	♀	"	16	25	21	23		58.3	+		
839	♂	"	D	3/4					-		
1234	♂	Mar. 19							+	5.85 Bv. Very lt. red. Bla. feet	
1235	♀	"	13	23	24	20		61.2	+		
1236	♂	"							-	5.25 Bv. Wavy comb	
1237	♀	"	12	28	26	17		51.0	+		
1238	♂	"							-	5.20 Bv. Light red	
1678	♀	Mar. 26	2	20	27	19		58.1	-		
1679	♀	"	4	22	29	20		53.5		St. ear lobes	
1680	♀	"	6	24	25	13		52.6	-		
1681	♀	"	1	14	18	11		62.0	+	White in wings	
1682	♂	"							-	5.40 Bv. Bla. feet	
2166	♂	Apr. 2							-	5.85 Bv. Bla. feet	
2167	♂	"							-	5.56 Bv. Bla. feet	
2168	♂	"							-	5.12 Strake	
2169	♀	"	3	27	24	20		55.3	-	St. ear lobes	
2605	♂	Apr. 9							-	4.97 Wavy comb, Bla. feet	
2606	♂	"							-	5.28 Wavy comb, very lt. red	
2607	♀	"	14	24	19			54.8	+	St. ear lobes	
2608	♀	"	17	21	16			53.1	+	St. ear lobes	
2609	♀	"							+	St. ear lobes	
2941	♀	Apr. 16	14	25	19			52.3	+	St. ear lobes	
2942	♀	"	7	26	23			50.7	+	St. ear lobes	
2943	♂	"									
2944	♂	"									
2945	♂	"									

Mating Sheet, Mass. Agr. Exp. Station

Figure 3.—Complete Mating Record

The mating book consists of loose sheets each 8 3/8 x 10 7/8 inches, held in a ring binder. At the close of the hatching season all chicks from each hen are entered on this sheet, which gives the sex, date hatched, the partial egg record for pullets, pause days, broody periods, and other notes taken. The disposal of pullets and cockerels is also recorded on this sheet along with the mortality records.

Male J347

Exp. 2

No.	Date Hatched 1931	Age at 1st. Egg	Wt. at 1st. Egg	Winter Fause Days	Winter Clutch	Eggs to M.r. 1st.	Egg Wt. to Jan. 1	Time to St. Egg Wt.	Spr-ing Clutch	Per-sis-tency	Times Bro-ody	Annual Pro-ductn	Notes
J1363	Apr. 7 1929	184	4.20	0	3.7	108	54.5	75	5.0	365+	0	273	
L 26	Mar. 29	163	5.75	0	4.5	137	51.5	202	3.1	366+	5	243	
L 28	Mar. 29	167	4.45	0	4.7	139	51.3	—	4.1	326	0	258	
L 30	Mar. 29	157	4.77	0	4.5	140	49.7	—	5.2	366+	0	274	
L 631	Apr. 5	202	5.95	0	4.6	106	54.3	81	3.8	366+	0	300	
L 632	Apr. 5	234	5.90	0	1.9	64	60.1	0	2.5	335	0	219	
L1026	Apr. 12	185	5.60	34	2.9	78	54.8	24	2.4	366+	2	200	
L1027	Apr. 12	187	5.40	0	6.2	118	55.6	3	3.9	261	0	258	
L1028	Apr. 12	165	4.82	0	2.8	118	55.6	5	3.6	366+	0	270	
L1434	Apr. 19	195	6.75	6	4.9	93	54.9	38	6.0	366+	0	256	
L1436	Apr. 19	186	5.90	4	4.2	104	54.8	20	2.6	366+	0	257	
L1821	Apr. 26	172	6.15	0	6.5	118	52.3	88	6.4	366+	1	282	
L1825	Apr. 26	192	6.50	9	2.4	78	54.6	177	2.7	345	0	229	
L2697	May 10	175	5.08	0	4.8	100	55.0	56	3.3	366+	1	262	
L2698	May 10	167	6.20	0	4.3	100	52.5	149	4.4	366+	0	271	
L2699	May 10	194	5.95	35	3.8	60	55.3	34	5.5	366+	0	260	
L3034	May 17	236	7.00	0	2.8	36	—	—	—	—	—	—	D Apr. 1
L3038	May 17	179	5.75	0	5.3	93	54.7	96	3.5	366+	0	264	
No. dau.		17	17	5+	17	17	16	14	16	16	4+	16	
Average.		185.6	5.76	12-	4.2	98.9	54.2	69.5	3.9	353.7	12-	256.4	

Figure 4.—Pullet Family Record.

When the pullets are housed in the fall, the laying-house record sheets are made. Sheets $8\frac{1}{2} \times 11$ inches are used, and as many families as space will permit placed on each sheet, with the sire's number at the top of the sheet. Complete records on characters affecting fecundity are recorded for each daughter throughout the laying year.

MASSACHUSETTS AGRICULTURAL COLLEGE--Daily Egg Record

PEN NUMBER	2	MONTH OF	YEAR		ATTENDANT	H--ON NEST BUT DID NOT LAY		D--DIED		L--REMOVED		L--OLD		M--MOLT		B--BROOD		REMARKS																
			1933	1933		X--SPOKE EGG	P--FLOOR NESTING	A--REMOVED	LD--MOVED TO SUMMER HOUSE	C--CLUCKS	DB--DROPPING BOARD																							
Female's Numbers	Total	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31		
M1489	10	7	10	11	4			9	9	9	2	8	1																					
1490	25	3	9	10	2	3		8	8	10	2	4		8	10	3		8	11	3		8	10	11	1		7	9	10	10	10			
1509	26	7	8	9	10	10	1	3		8	9	11	2	8	8	8	9	9	9	10	9	8		1		9	9	8		8	7			
1549	22	8	2		8			1		8	2		8	1	8	8	9	10	10	10	1		7	10	8	1		8	9	10				
1550	4	10	2		9	10																												
1554	30	7	8	9	9	10	10	11	10	10	10	11	9	11	11	2	11	11	10	11	10	10	11	10	11	10	10	10	11	1				
1567	23		7	9	11	5		8	9	10	3		7	9	10	10	1	3		8	9	10	11			8	11	4		7	9			
1568	1					10																												
1571	28	9	10	9	9	9	9	9	1		9	8	9	9	9	9	9	11	3		8	8	10	11	1	1	7	7	7	7	7			
1576	19	9	9		9	9	9	11	5		8	3		9	9	3		8	9	1		10				3		3		9				
1578	27	10	10	10	9	8	9	11	10	11	10	11	4	3		8	8	9	9	10	9		5		7	8	8	10	9	10	10			
1579	29		8	9	9	9	9	9	9	9	9	9	9	9	10	9	9	9	9	10	9	9	10	10	10	9	8	8	1		7	8		
1581	11	11	11	3		8	10	1			8	8	9	9																	9			
1582	22	11	11	3		8	9	9			8	9	10	11	11	1					8	9	10	10	10	11	1		7	8	9			
1583	27	9	11	10		11	10	10	1		10	9	10	10	11	11	11	1		10	11	11	11	11	10	10	10	10	10	10	9	8		
1585	24	10	10	11	11	2		8	10	11	2		7	8	10	2		8	10	11	1		7		9	11	2		8	10	1			
1588	23	11	2		8	11	1		8	10	2		8	1		8	1	4				7	10	1		8	11	1		10				
1589	-	9	2		9	9														D														
1592	26		8	9	11	11	1	3		8	8	9	9		9	9	9	1	4		7	7	10	10	10	10	11	1		7	9			
1593	25	11	2		9	8	9	10	11	3		9	9	10		9	10	11	1	11	1		8	10	1		7	8	10	10	10			
Unidentified Eggs																																		
TOTALS																																		

Figure 5.—Trapnest Record

The trapnest sheets used are 9 1/2 x 15 inches, with space for 20 birds. Each alternate line is heavy, to guard against errors in putting in trapnest records. A record is kept of the hour of laying, nesting, broken eggs, death of bird, floor nesting, removals, returns, sales, removal to summer houses, molt, clucking, broodiness, and eggs laid on dropping boards. The body weight at first egg is also recorded and notes regarding injury or disease.

MASSACHUSETTS EXPERIMENT STATION—Individual Record

NO. *M 896* HATCHED *Apr. 10, 1932* VARIETY *R.1. Red* K327 K2463 J422 J347

PEN 1 AGE AT FIRST EGG *211* PARENTAGE *L153* *L597*

Mate's No. *M 482*

DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	TOTALS	
<i>1932</i> SEPT.																																	
OCT.																																	
NOV.								<i>50</i>	<i>56</i>	<i>58</i>	<i>57</i>	<i>58</i>	<i>57</i>	<i>57</i>	<i>58</i>	<i>58</i>	<i>56</i>	<i>56</i>	<i>58</i>	<i>57</i>	<i>56</i>	<i>60</i>	<i>57</i>								<i>16</i>	<i>56.8</i>	
DEC.	<i>59</i>	<i>57</i>	<i>60</i>	<i>55</i>	<i>58</i>	<i>60</i>	<i>56</i>	<i>60</i>	<i>57</i>	<i>59</i>	<i>57</i>	<i>55</i>	<i>58</i>	<i>62</i>	<i>57</i>	<i>57</i>	<i>60</i>	<i>55</i>	<i>58</i>	<i>62</i>	<i>58</i>	<i>58</i>	<i>58</i>								<i>23</i>	<i>58.2</i>	
JAN.	<i>60</i>	<i>58</i>	<i>58</i>	<i>58</i>	<i>58</i>	<i>61</i>	<i>62</i>	<i>64</i>	<i>56</i>	<i>58</i>	<i>11</i>																					<i>19</i>	<i>57.6</i>
FEB.	<i>11</i>	<i>11</i>	<i>11</i>	<i>11</i>	<i>11</i>	<i>11</i>	<i>11</i>	<i>11</i>	<i>11</i>	<i>11</i>	<i>11</i>	<i>11</i>	<i>11</i>	<i>11</i>	<i>11</i>	<i>11</i>	<i>11</i>	<i>11</i>	<i>11</i>	<i>11</i>	<i>11</i>	<i>11</i>	<i>11</i>	<i>11</i>	<i>11</i>	<i>11</i>	<i>11</i>	<i>11</i>	<i>11</i>	<i>11</i>	<i>11</i>	<i>19</i>	<i>75</i>
MAR.								<i>11</i>	<i>11</i>	<i>14</i>	<i>9</i>	<i>2</i>	<i>18</i>	<i>10</i>	<i>10</i>	<i>9</i>	<i>8</i>	<i>8</i>	<i>10</i>	<i>11</i>	<i>4</i>	<i>8</i>	<i>11</i>	<i>4</i>								<i>18</i>	
APR.	<i>10</i>	<i>9</i>	<i>10</i>	<i>2</i>	<i>8</i>	<i>8</i>	<i>8</i>	<i>10</i>	<i>10</i>	<i>2</i>				<i>62</i>	<i>57</i>	<i>58</i>	<i>56</i>	<i>62</i>	<i>62</i>	<i>62</i>	<i>60</i>	<i>61</i>	<i>58</i>	<i>54</i>	<i>55</i>							<i>24</i>	
MAY	<i>60</i>	<i>58</i>	<i>58</i>	<i>58</i>	<i>59</i>	<i>58</i>	<i>60</i>	<i>53</i>	<i>57</i>	<i>62</i>	<i>59</i>	<i>58</i>	<i>58</i>							<i>62</i>	<i>60</i>	<i>58</i>	<i>56</i>	<i>60</i>	<i>60</i>	<i>58</i>	<i>59</i>	<i>62</i>	<i>60</i>	<i>60</i>		<i>24</i>	
JUNE	<i>62</i>	<i>60</i>	<i>58</i>	<i>58</i>	<i>60</i>	<i>60</i>	<i>60</i>	<i>59</i>	<i>61</i>	<i>58</i>	<i>57</i>	<i>54</i>							<i>58</i>	<i>59</i>	<i>58</i>	<i>57</i>	<i>59</i>	<i>56</i>	<i>59</i>	<i>55</i>	<i>56</i>				<i>58</i>	<i>60</i>	<i>23</i>
JULY	<i>58</i>	<i>55</i>			<i>62</i>	<i>62</i>	<i>60</i>	<i>62</i>	<i>60</i>	<i>58</i>	<i>60</i>	<i>58</i>	<i>60</i>	<i>60</i>	<i>60</i>	<i>60</i>	<i>58</i>	<i>56</i>	<i>58</i>	<i>56</i>	<i>56</i>	<i>56</i>	<i>56</i>	<i>56</i>	<i>56</i>	<i>56</i>	<i>56</i>	<i>58</i>	<i>58</i>	<i>58</i>		<i>22</i>	
AUG.	<i>58</i>	<i>56</i>	<i>58</i>	<i>58</i>	<i>59</i>	<i>56</i>	<i>55</i>	<i>60</i>	<i>62</i>	<i>60</i>	<i>60</i>	<i>59</i>	<i>56</i>	<i>60</i>	<i>57</i>	<i>56</i>	<i>54</i>	<i>58</i>	<i>62</i>	<i>60</i>	<i>60</i>	<i>56</i>	<i>59</i>	<i>55</i>	<i>57</i>							<i>62</i>	<i>26</i>
SEPT.	<i>59</i>	<i>57</i>	<i>56</i>	<i>60</i>	<i>62</i>	<i>60</i>	<i>59</i>	<i>59</i>	<i>58</i>	<i>66</i>	<i>57</i>	<i>56</i>	<i>57</i>	<i>60</i>	<i>56</i>	<i>58</i>	<i>59</i>	<i>62</i>	<i>60</i>	<i>56</i>	<i>60</i>	<i>60</i>	<i>59</i>									<i>24</i>	
OCT.	<i>60</i>	<i>59</i>	<i>58</i>		<i>60</i>	<i>61</i>	<i>59</i>	<i>58</i>	<i>61</i>	<i>63</i>	<i>60</i>	<i>62</i>	<i>62</i>	<i>59</i>	<i>60</i>	<i>59</i>	<i>60</i>	<i>60</i>	<i>60</i>	<i>59</i>	<i>60</i>	<i>60</i>	<i>59</i>	<i>63</i>	<i>56</i>						<i>63</i>	<i>61</i>	<i>23</i>
NOV.	<i>4</i>	<i>8</i>	<i>1</i>	<i>9</i>	<i>1</i>	<i>9</i>	<i>11</i>			<i>11</i>	<i>10</i>	<i>11</i>	<i>10</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>1</i>	<i>17</i>	

EGGS SET	<i>37</i>	<i>11</i> —Hatched	<i>34</i>	TIMES BROODY	<i>01</i>
O—INFERTILE	<i>0</i>	X—DEAD AT FULL TERM	<i>0</i>	WINTER PAUSE DAYS	
FERTILE	<i>37</i>	% FERTILE	<i>100</i>	ANNUAL PERSISTENCY	
E—DIED EARLY	<i>0</i>	% FERTILE EGGS HATCHED	<i>92</i>	BODY WEIGHT	<i>6.58</i>
V—DIED LATE	<i>3</i>	DAYS BROODY	<i>1</i>	Nov. 1, 1933	<i>6.65</i>

CLUTCH SIZE	YEAR'S TOTAL (365 DAYS)	<i>263</i>
Nov. 1, 1933 To	TOTAL	
Home 4		

Egg *7*

5M-11-'29 No. 7247

Figure 6.—Individual Record Sheet

These sheets are 5 x 8 inches and include a complete egg record of each female, together with egg-weight records and hatching record. These records are especially valuable in studying the characters of the individual in detail, and make a direct comparison of individuals possible.

The Breeding Procedure Recommended for Increasing Egg Production

Egg production of each succeeding generation in the flock can be increased only by using a superior class of breeding stock to produce each generation. The outstanding experiment to support this view was carried on by Gowell at the Maine Agricultural Experiment Station with Barded Plymouth Rocks. The detailed results in relation to egg production are reported by Pearl and Surface (1909a and b) and by Pearl (1911). Each year Gowell selected for breeding yearling hens with records of 150 or more eggs in the pullet year. Each year these hens were mated to cockerels from mothers laying 200 eggs or more. All daughters were trapnested from November 1 to October 30 each year. The standard for breeders was not raised as the experiment progressed. The mean annual egg records of the daughters hatched from 1899 to 1906 were 136, 143, 156, 135, 118, 134, 140, and 113 in the respective years. The variation in annual production did not decline and there was actually a significant decline in egg production of daughters in the eight-year period. A very great decrease was observed in winter egg production during this period, the means ranging from 41 eggs in 1899 to 16 eggs in 1907.

Pearl and Surface (1909a) hatched 250 pullets from hens that had laid 200 eggs during their pullet year. These pullets were sired by cockerels whose female ancestors had laid not less than 200 eggs for seven generations. These pullets were trapnested from November 1 to July 1 and compared with 600 pullets from the line previously developed by Gowell. The mean winter production of the first group of pullets was about 16 eggs compared with about 19 eggs for the second group. The notation is made by the authors that the pullets from 200-egg dams were inferior to those of the other group. It is very evident, in view of modern information, that neither method of selection of breeders was rigid enough to increase the production of the daughters.

Marble and Hall (1931) report results in breeding high- and low-producing lines of White Leghorns. The mean annual egg production of the high line was raised by careful breeding from 127 eggs in 1908 to 196 eggs in 1927. Egg weight and body weight did not decrease, and length of cycle increased as egg production increased. Mean age at first egg did not change significantly after ten or eleven years of breeding.

Lippincott (1920) mated three lines of mongrel pullets and their daughters to purebred cockerels and one line to mongrel cockerels for three generations, with the following results:

Average Percentage of Increase or Decrease in First-Year Egg
Production of Each Generation of Offspring Compared with the
Original Mongrel Pen

	First Generation	Second Generation	Third Generation
Single Comb White Leghorn Grades . . .	115.62	160.85	166.39
Barded Plymouth Rock Grades	34.51	51.87	57.97
White Orpington Grades	49.52	24.76	-6.13
Mongrels	8.55	51.56	35.28

These data show that mongrel flocks may be greatly improved in egg production through the use of purebred males from flocks improved for production.

Extension projects in flock improvement carried on by the Massachusetts Agricultural Extension Service show very definitely that the egg production of ordinary flocks may be greatly increased through the use of outside males from flocks highly improved for egg production.

A method of breeding within the flock that will raise the mean annual egg production from 114 eggs to 235 eggs in twenty years without any culling in the laying houses may be considered rather satisfactory. Such a result has been accomplished in the Massachusetts Station flock using the system outlined below. As previously indicated the flock was started by purchasing mature pullets from two different sources, and males that were not closely related to the pullets were obtained from one of these flocks. The foundation stock was not improved for fecundity but represented improved breeding from the exhibition standpoint. These birds were late maturing, low in intensity, high in broodiness, and not persistent layers.

Early in the history of the flock it was decided by Goodale after much study that selective breeding to be effective must be based not upon egg records as a unit but upon inherited characters that directly affect egg production.

The first character bred was for early sexual maturity. Female breeders that began to lay at the youngest age were made use of and mated to males whose sisters had laid earlier than the average. The fourth generation, hatched in 1916, showed the character of early maturity to be rather well established, with a flock mean of 213 days. Since that time only early-maturing females have been used, and the flock mean age has fluctuated between 185 and 210 days.

Genetically early-maturing birds begin laying at 215 days of age or younger. On account of the advantages of large size so intimately associated with egg size, the selection of extremely early-laying breeders has been avoided. In recent years preference has been given to females that began laying at from 200 to 210 days of age.

The elimination of broodiness in the flock was undertaken next, without sacrificing any progress in breeding for early maturity. Progress was made by selecting as many female breeders as possible that were free of broodiness in the pullet year. This was followed by the exclusive use of male breeders from this class of dams. Some males and females tested for non-broodiness were made use of from time to time. Selection has since been based on the greatest freedom from broodiness within the family. As previously indicated, the percentage of individuals broody in the first laying year has fallen from 90 per cent to about 11 per cent.

Intensity of laying or the ability to lay a large number of eggs in a specific time interval was the third character to be considered in improving the flock. This character was established largely through one female and her descendants. Since high intensity depends upon dominant genes, it was not necessary to practice close inbreeding to establish the character. In the early part of the experiment breeding females were selected for the ability to lay a large number of eggs up to March 1, or for the ability to lay many eggs (26 or more) in a winter month like December. In recent years intensity has been measured by mean winter clutch size. A clutch represents the number of eggs laid on successive days, and the average size of clutches from first pullet egg up to March 1 gives

a measure of the rate of functioning of the egg-producing organs. Winter clutch size has increased from under two to about three and one-half at present. For holding high intensity no breeders showing a winter clutch size under three should be used.

Winter pause may be reduced by the constant use of breeders free from this undesirable character. The system of management, housing, and feeding should be the most favorable at all times.

High persistency has been the last character to be developed in the station flock. Through the selection of female breeders that lay late in the fall and of yearling breeders that have laid for as much as thirteen or fourteen months, mean flock persistency has been raised from about 250 days to about 340 days at present. No breeder with a persistency record of less than 315 days from first egg should be used. A recent study shows clearly that the ability to lay for more than 365 days is highly desirable in breeding birds.

Persistency is linked in inheritance with early maturity. For this reason it is very advantageous to select early maturing and persistent birds early in the breeding program. The ultimate goal is a flock breeding true for these five desirable fecundity factors as well as for desirable breed characters and free from all recognized defects.

From what has gone before it is evident that such a breeding program should not be attempted on a small scale. Only breeders that handle relatively large flocks can hope to make consistent progress from year to year.

The ideal hen is of very complex genetic nature and the probability of obtaining any significant proportion of such individuals is very remote in small flocks. As far as present information is concerned, the genetic formula of an ideal breeding hen is essentially as follows: EoE'E'III'I'mmaaccPPaaBBHH. In this formula the known genes for early sexual maturity, high intensity, no winter pause, non-broodiness, high persistency, large egg size, and high hatchability are considered.

The following standard has been used in selecting female breeders in the Rhode Island Red flock at the Massachusetts Station:

Age at first egg.....	215 days or less.
Weight at first egg.....	5.5 pounds or more.
Intensity (winter clutch size).....	3 or more eggs.
No winter pause of more than 3 days.	
No broodiness.	
Persistency.....	315 days or more.
Egg size.....	{ Not under 24½ ounces for pullets.
	{ Not under 26 ounces for hens.
Laying-house mortality.....	Not over 15 per cent.

The standard should be raised as the work progresses.

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