

MASSACHUSETTS  
AGRICULTURAL EXPERIMENT STATION

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Bulletin No. 316

January, 1935

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**Crossing  
Production and Exhibition  
Rhode Island Reds**

By F. A. Hays

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GIPE-PUNE-047525

In this five-year study an attempt was made to determine whether, through crossing exhibition-bred and production-bred Rhode Island Reds, the characters necessary for high egg production might be retained without the sacrifice of plumage color.

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MASSACHUSETTS STATE COLLEGE  
AMHERST, MASS.

# CROSSING PRODUCTION AND EXHIBITION RHODE ISLAND REDS

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

## INTRODUCTION

It is a widely recognized fact that production-bred Rhode Island Reds differ markedly from exhibition-bred birds of the same variety in a number of important characters. Hays (1933), in a preliminary report, pointed out characteristic differences in fecundity characters. Another important question constantly before breeders of Rhode Island Reds is the relationship between plumage color and desirable fecundity traits.

This report includes the results of a five-year study in crossing production-bred birds with exhibition-bred birds. The character of the parental stocks is considered and later the character of offspring from eight different types of matings. Attention is first given to fecundity traits and finally the behavior of plumage color is considered.

The production-bred stock was selected from the station flock bred for high fecundity since 1913. Exhibition-bred stock came from hatching eggs furnished in 1930 by one of the world's leading breeders. Hybrid offspring were hatched over a one-year period from 1930 to 1933.

## CHARACTER OF PARENTAL STOCKS

In these studies females are classified as follows:

Early maturing—laying their first egg at 215 days of age or younger.

Highly intense—having a mean winter clutch size of 3 or more eggs.

Winter pause—showing no cessation in egg production as great as 4 days between Nov. 1 and March 1.

Non-broody—exhibiting no broodiness during the first laying year.

Highly persistent—laying for not less than 315 days from first pullet egg.

The characters reported in Table 1 are of importance in production breeding.

Table 1 presents an interesting and valuable comparison between the parental stocks used for crossing in this experiment. A study of the two populations gives a general picture of the differences that are most likely to occur so far as fecundity or related characters are concerned.

Exhibition birds were heavier at first egg, but this difference was almost if not entirely due to their greater age. The production birds were decidedly superior in early maturity, the exhibition birds being characteristically late maturing. The production birds were greatly superior in intensity, only one bird of the exhibition group showing high intensity. The percentage of birds with winter pause was about the same in the two lines. Because of earlier maturity, the production birds laid for a much longer period during the winter season than did the exhibition birds, which gave greater opportunity for pause to occur in the production line. The mean egg weight from first egg to January first was considerably

greater in the exhibition line. In the birds tested, hatchability was very much higher in the production line. The proportion of non-broody birds, measured by first-year records, was essentially the same in the two lines. The percentage of highly persistent birds was nearly three times as great in the production line as in the exhibition line. The mortality rate for 365 days in the laying houses was significantly higher in the production line. Mean annual egg production was about 207 eggs for production birds compared with 130 eggs for exhibition birds.

Table 1 shows in general that the production line was superior for early sexual maturity, intensity, hatchability, persistency, and annual egg production. The exhibition line excelled in egg size and for low laying-house mortality only. Differences in body weight at first egg are of questionable significance because of great differences in age at first egg.

### CHARACTER OF HYBRIDS

Hybrids produced were derived from the following classes of matings:

1. Exhibition males X production females
  2. Production males X exhibition females
- } F<sub>1</sub>
3. F<sub>2</sub> generation.
  4. F<sub>1</sub> males X production females.
  5. Production males X F<sub>1</sub> females.
  6. Exhibition males X F<sub>1</sub> females.
  7. Production males X F<sub>2</sub> females.
  8. Exhibition males X F<sub>2</sub> females.
  9. Miscellaneous hybrid matings.

Check birds include the general flock bred for high fecundity in the same year or years in which the different hybrid matings were made. All birds were hatched, reared, and housed together in order to reduce the effects of environmental influences. In Table 2 the data are summarized for comparative study. Some interesting differences are shown between the various classes of hybrids and the checks, which represent production-bred lines.

Class 1 hybrids, representing the F<sub>1</sub> generation from mating exhibition males to production females, were decidedly superior to the checks in body weight at first egg, showing the effects of heterosis. Early sexual maturity was observed in a greater percentage of the check birds than of the F<sub>1</sub> daughters, which accounts in part for the greater weight of the hybrids at sexual maturity. The hybrids were not quite equal to the checks in intensity, but there was very little difference between the two groups with respect to pause. Winter egg weight was averaged slightly over 24 ounces the hybrids were slightly superior non-broody birds was somewhat intensity was decidedly lower in the not well established in the pro-ow persistency were transmitted e laying houses were very similar a difference great enough to be ids fell below the checks, due in lower intensity, more broodiness,

decidedly greater in the h  
per dozen up to January 1  
to the checks in hatchabil  
less in the hybrids than  
hybrids, suggesting either  
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TABLE 1.--CHARACTER OF PARENTAL STOCKS HATCHED IN 1929 .

Class of Birds	Number of Birds	Mean Weight at First Egg, pounds	Number of Birds	Per cent Early Maturing	Number of Birds	Per cent Highly Intense	Number of Birds	Per cent Non-pause	Number of Birds	Mean Egg Weight to Jan. 1, grams	Number of Birds	Mean Hatchability, Per cent	Number of Birds	Per cent Non-broody	Number of Birds	Per cent Highly Persistent	Number of Birds	Laying House Mortality, Per cent	Number of Birds	Mean Annual Egg Production, eggs
Production line.....	177	5.48	178	82.02	165	35.76	165	33.33	164	50.08	18	81.95	114	86.48	114	71.05	186	27.42	114	206.57
Exhibition line.....	35	6.42	39	2.56	31	3.23	31	29.03	20	55.78	10	51.09	32	84.38	32	25.00	43	16.28	32	130.09

TABLE 2.--CHARACTER OF HYBRID OFFSPRING AND CHECKS

1. F <sub>1</sub> —Exhibition males X Production females	64	6.27	64	67.19	64	54.69	64	65.63	62	57.14	6	88.00	52	46.15	52	38.46	64	18.75	52	197.65
Checks (1).....	391	5.44	391	89.00	374	63.37	373	60.59	376	50.60	33	81.29	283	80.21	283	85.51	399	20.80	283	236.51
2. F <sub>1</sub> —Production males X Exhibition females	22	6.67	22	81.82	22	40.91	22	63.64	21	56.21	2	79.41	19	73.68	19	57.89	22	9.09	19	207.74
Checks (2).....	224	5.37	224	94.20	217	66.36	217	65.44	218	50.70	17	79.97	180	85.00	180	90.00	227	15.42	180	245.26
3. F <sub>2</sub> Generation.....	90	6.12	90	45.56	81	14.81	81	34.57	79	56.01	10	65.12	52	67.31	53	43.40	103	31.07	53	168.28
Checks (3).....	406	5.66	406	84.48	391	57.03	390	56.67	390	52.15	33	75.72	276	85.51	276	83.70	420	23.81	276	235.04
4. F <sub>1</sub> males X production females	16	6.25	16	68.75	15	33.33	15	13.33	16	53.78	3	75.86	12	91.67	12	66.67	16	18.75	12	184.33
Checks (4).....	224	5.37	224	94.20	217	66.36	217	65.44	218	50.70	17	79.97	180	85.00	180	90.00	227	15.42	180	245.26
5. Production males X F <sub>1</sub> females.....	61	6.45	64	56.25	56	60.71	56	62.50	53	55.03	7	66.54	28	75.00	28	64.29	71	50.70	28	228.68
Checks (5).....	182	6.01	182	73.53	174	45.40	173	45.66	172	53.99	16	71.60	96	86.46	96	71.88	193	33.68	96	215.86
6. Exhibition males X F <sub>1</sub> females.....	16	5.80	17	47.06	16	18.75	15	53.33	14	55.79	3	60.40	7	57.14	7	14.29	21	28.57	7	175.57
Checks (6).....	224	5.37	224	94.20	217	66.36	217	65.44	218	50.70	17	79.97	180	85.00	180	90.00	227	15.42	180	245.26
7. Production males X F <sub>1</sub> females.....	22	5.87	22	72.73	21	52.38	21	61.90	22	57.55	2	47.37	19	89.47	19	57.89	23	13.04	19	211.26
8. Exhibition males X F <sub>1</sub> females.....	11	5.75	11	45.45	10	0	10	30.00	9	54.77	2	40.58	9	55.56	9	22.22	11	18.18	9	171.67
9. Miscellaneous hybrid matings.....	39	6.14	39	82.05	38	42.11	38	42.11	38	56.36	5	52.04	30	76.67	30	40.00	42	21.43	30	198.73
Checks (7, 8 and 9).....	182	6.01	182	73.53	174	45.40	173	45.66	172	53.99	16	71.60	96	86.46	96	71.88	193	33.68	96	215.86

Class 2 hybrids, representing the  $F_1$  generation from mating production males to exhibition females, are comparable with class 1 hybrids produced by the reciprocal cross. The group of class 2 hybrids showed heavier weight at first egg along with a greater percentage of early maturing birds than appeared in class 1 hybrids. Class 2 hybrids showed lower intensity, somewhat lower hatchability, and a mortality rate about half that of class 1. Class 2 hybrids were equal to class 1 in freedom from winter pause and in winter egg weight, and were decidedly superior in freedom from broodiness, persistency, and to some extent in annual egg production. Class 2 hybrids compared with their checks showed almost the same differences that were observed between class 1 hybrids and checks, except that laying-house mortality was much lower in class 2 hybrids than in their checks.

Class 3 hybrids are the  $F_2$  generation produced by mating of  $F_1$  birds. In hybrid matings the  $F_2$  generation shows the maximum variability because of segregation of characters. In such crosses as are considered in this report, the  $F_2$  generation may be inferior to the  $F_1$  generation because of segregation of undesirable genes and because of high variability in characteristics affecting fecundity.

Table 2 shows that the  $F_2$  pullets were heavier than the checks at first egg but less than half of the birds were early maturing compared with 84.48 per cent early maturing in the checks. In comparison with the checks,  $F_2$  birds were also decidedly low in intensity, showed more winter pause, larger winter egg size, lower hatchability, a decreased percentage of non-broody birds, lower persistency, increased mortality, and greatly decreased egg production.

Class 4 hybrids, produced by mating  $F_1$  males to production females, were superior to the checks in body weight at sexual maturity, but their age at sexual maturity was greater and the percentage of genetically early-maturing birds lower. These hybrids were decidedly inferior to the checks in intensity, winter pause, persistency, and egg production; they were superior in egg weight, and about equal to the checks in hatchability, non-broodiness, and mortality rate. Compared with the first hybrid generation, they were superior only in freedom from broodiness and in persistency.

Class 5 hybrids represent the reciprocal type of mating to class 4; namely, mating production males on  $F_1$  females. Daughters produced were somewhat heavier at first egg than check daughters and showed a significantly lower percentage of early-maturing individuals. They were superior to the checks in intensity, non-pause, winter egg weight, and annual egg production. The hatchability of hybrids and checks differed significantly and the percentage of non-broody birds was lower in the hybrids, but the laying-house mortality was very high. Compared with the hybrids of class 4, the class 5 hybrids were greatly superior in intensity and in the absence of winter pause, enabling them to average 229 eggs compared with 184 eggs for class 4 hybrids. Class 5 hybrids were decidedly low in vigor as judged by the high mortality rate in the laying houses.

Class 6 daughters came from crossing exhibition males on  $F_1$  females. This generation of hybrids was inferior to their checks in all respects except winter egg size and body weight. They averaged to lay 176 eggs compared with 245 eggs for the checks. Compared with the daughters in class 5 where production males were mated to  $F_1$  females, they were decidedly inferior except in vigor.

In class 7 the daughters of production males mated to  $F_2$  females are considered. Compared with the checks, these females were smaller at first egg but

showed the same percentage of early-maturing birds; they were slightly superior in intensity and non-pause, decidedly superior in winter egg weight, greatly superior in mortality, and equal in egg production, but were low in hatchability and in persistency.

Class 8, representing the daughters of exhibition males mated to  $F_2$  females was not equal to class 7 daughters in weight at sexual maturity, and there was a much higher proportion of late-maturing birds. Class 8 contained no highly intense and very few non-pause birds, and was inferior to class 7 in egg size, hatchability, non-broodiness, high persistency, mortality rate, and egg production. Compared with the checks, class 8 birds were inferior in all respects except winter egg size and mortality rate.

Class 9 includes daughters from various types of matings not already considered. They were superior to the checks in body weight, sexual maturity, winter egg weight, and mortality rate; they were inferior in hatchability, non-broodiness, persistency, and annual egg production.

In general, Table 2 indicates that hybridization increases body weight, especially in the  $F_1$  generation; that early sexual maturity dominates late sexual maturity; that high intensity depends on dominant genes; that winter pause is little affected by crossing; that winter egg size is increased; that hatchability is improved only in the first generation; that broodiness may be increased by hybridization; that persistency is lowered by crossing; that laying-house mortality is reduced only in the first generation cross; that annual egg production is above intermediate between the two parent stocks in the first hybrid generation and tends to decrease in the  $F_2$  generation, but that production can be raised to a high level by back crossing  $F_1$  and  $F_2$  females on production-bred males.

## PLUMAGE COLOR<sup>1</sup>

The general behavior of plumage color in the various crosses between the characteristically light-colored production fowls and the essentially bay-colored exhibition birds is of economic and scientific interest. Breeders often desire to darken the shade of red because of market demands but definite information on the behavior of color in inheritance is lacking. In Table 3 the surface color of males and females is listed separately for the exhibition stock and for nine different types of hybrid offspring. All records on plumage color were taken when the birds were from five to six months of age.

### Surface Color

Table 3 presents a summary of the adult surface color of male and female hybrid offspring from ten different types of mating.

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<sup>1</sup>It is a well-known fact that in many Rhode Island Red fowls the surface color and under color vary in different body regions. There is, however, a rather intimate association between shades of color in surface and feather fluff on the same bird in different body regions. For the sake of simplicity in this study the plumage color has been consistently considered only in the mid-back region which has been taken as representative of the plumage color in general. This method of procedure would seem to be justified by the studies of Warren and Gordon (1933).

TABLE 3.--DISTRIBUTION OF OFFSPRING WITH RESPECT TO SURFACE PLUMAGE COLOR. 1930-1933.

Type of Mating	Males					Females				
	Very Light	Light	Medium	Dark	Standard	Very Light	Light	Medium	Dark	Standard
Exhibition line			2	35	93			7	27	70
1. F <sub>1</sub> —Exhibition males X Production females		3	37	15	15		14	27	10	1
2. F <sub>1</sub> —Production males X Exhibition females		5	16	3			12	21	6	1
3. F <sub>2</sub> Generation		15	47	31	2	2	15	49	32	6
4. F <sub>1</sub> males X Production females		3	16	2			6	8	2	
5. Production males X F <sub>1</sub> females		35	28	1		5	44	33	8	
6. Exhibition males X F <sub>1</sub> females		2	11	13	10	2	6	9	15	5
7. Production males X F <sub>1</sub> females	2	10	6			1	17	11	1	
8. Exhibition males X F <sub>2</sub> females			1	6	6		2	4	6	9
9. Miscellaneous		3	19	24	6	1	19	28	42	20

The exhibition stock of both sexes was described as about 70 per cent standard in color with about 30 per cent dark or medium. The production stock showed no standard-colored birds, very few dark, with the great majority medium or light in color.

Reciprocal crosses to produce the F<sub>1</sub> generation gave significantly different results with respect to plumage color of male offspring but not of female offspring. Male offspring produced by mating exhibition males to production females were significantly darker in surface color than those from production males mated to exhibition females. In Table 2 the female offspring from the second type of mating showed a greater proportion of early maturing offspring than the first. It is probable also that the male progeny of this second type of mating were somewhat earlier maturing than those from the first type of mating. Since the lighter shades of red are more likely to occur in males than in females (Hays, 1932), it is probable that the males from the second type of mating were lighter because of physiological relations between sexual maturity and plumage color.

F<sub>2</sub> generation males on the average were slightly lighter in plumage color than either type of F<sub>1</sub> males. The segregation observed in this generation was not marked and this would indicate that neither parental type was homozygous for the factors affecting plumage color. This fact also accounts for the wide range in plumage color observed in the F<sub>1</sub> generation and renders difficult the establishment of uniform color by crossing exhibition and production birds. F<sub>2</sub> females showed about the same range in surface color as F<sub>1</sub> females.

In matings 4 and 5 the character of progeny from reciprocal crosses of F<sub>1</sub> hybrids on parental stocks is shown. Both sexes were lighter in color when the sire was of pure production ancestry. This fact suggests possible dominant sex-linked modifiers for lighter shades of plumage.

A comparison of progeny from matings 5 and 6, where production males and exhibition males were mated to  $F_1$  females, indicates a dominant tendency of the light color carried by the production male. Here sex-linked relations do not stand out, however.

In progeny from matings 7 and 8, where production males and exhibition males were mated to  $F_2$  females, the dominant nature of modifiers for light color is very evident. There again appear to be no sex-linked relationships.

Class 9 hybrids came from such matings as  $F_1 \times F_2$ ,  $F_1$  and parental stock, and others. The plumage color of this progeny was essentially the same in both sexes and in general was similar to that obtained in the  $F_2$  generation.

In general, these data on plumage color suggest dominance of light modifiers for color. The character of the progeny indicates further that color may be restored to the  $F_1$  level by mating pure exhibition males on either  $F_1$  or  $F_2$  females. The general plumage color of  $F_1$  hybrids is about intermediate between that of production-bred and exhibition-bred stocks.

### Surface Color and Under Color

The under color of Rhode Island Reds should be of the same rich red color as the surface plumage. In breeding for color it is important to know whether different shades of surface color are associated with different shades of under color. Table 4 summarizes the combinations of surface and under color found in the exhibition stock and in the hybrid offspring from various types of mating.

The exhibition stock used in this experiment showed a rather intimate association between standard surface color and dark under color. In the males 74 per cent of those with standard surface color showed dark under color compared with about 79 per cent of the females. Of the total males, 70 per cent had standard surface color, and of the females 67 per cent.

In the class 1 progeny, 11 out of 15 standard-colored males also carried dark under color, and the single standard-colored female carried dark under color. A marked tendency is also observed for medium surface color to be associated with medium under color in both sexes. None of the light-colored males or females showed dark under color.

$F_1$  hybrids of class 2 were characteristically lighter in surface color than  $F_1$  hybrids from the reciprocal class as noted in Table 3. There is here considerable association between surface and under color in both sexes.

If both sexes of  $F_2$  hybrids are combined in studying under color, it will be observed that there were 30 light, 150 medium, and 68 dark, or a ratio of approximately 1-5-2. By combining the light and the medium classes, a 3 to 1 ratio appears. These facts suggest that under color may show a blending inheritance and that both the light and the dark phenotypes may be homozygous while the medium class is heterozygous for genes affecting under color. An examination of the  $F_1$  progeny from exhibition males with dark under color mated to production hens with light under color showed essentially nothing but medium color, again suggesting a blending inheritance of under color. Several genes appear to be concerned in the inheritance of under color. An association between dark surface color and dark under color still appears in this generation.

From what has been said regarding the behavior of light and dark under color in crosses, the majority of class 4 progeny would be expected to be medium or



TABLE 4.--CLASSIFICATION OF EXHIBITION STOCK AND OF HYBRID OFFSPRING ACCORDING TO SURFACE COLOR AND UNDER COLOR

Under Color	Surface Color—Males					Surface Color—Females				
	Very Light	Light	Medium	Dark	Standard	Very Light	Light	Medium	Dark	Standard
<b>Exhibition Line</b>										
Very light					3					1
Light			1	18	21			5	9	14
Medium			1	17	69			2	18	55
Dark										
<b>1. F<sub>1</sub> Progeny from Exhibition Males X Production Females</b>										
Very light										
Light		1	2					5	5	
Medium		2	30	11	4			9	20	6
Dark			5	4	11			2	4	1
<b>2. F<sub>1</sub> Progeny from Production Males X Exhibition Females</b>										
Very light										
Light		2	1					10	5	1
Medium		3	13	2				3	24	6
Dark		1	5	2						1
<b>3. F<sub>1</sub> Hybrids</b>										
Very light										
Light		4	1			3	13	7	2	
Medium		8	37	24	1		7	48	24	1
Dark		2	16	16	1			7	20	6
<b>4. Progeny of F<sub>1</sub> Males X Production Females</b>										
Very light										
Light		1	1					6	5	
Medium		2	14	1						
Dark			1	1				3	2	
<b>5. Progeny of Production Males X F<sub>1</sub> Females</b>										
Very light										2
Light			17	4				8	43	11
Medium			18	17				12	25	8
Dark				7	1					1
<b>6. Progeny of Exhibition Males X F<sub>1</sub> Females</b>										
Very light										
Light				1				2	1	1
Medium				1	14	13	9	5	7	9
Dark				1	3	10	12		2	10
<b>7. Progeny of Production Males X F<sub>1</sub> Females</b>										
Very light										
Light			1	2				4	2	
Medium			2	9				3	4	2
Dark				2	1					
<b>8. Progeny of Exhibition Males X F<sub>1</sub> Females</b>										
Very light										
Light					3	2	1	3	6	12
Medium					3	4			1	8
Dark				1	3					8

light in under color. Only those females that carried the gene for dark under color could produce progeny showing dark. Although the numbers are small, there is substantial agreement to expectation. Dark under color did not occur in birds classed as light in surface color.

Class 5 progeny were lighter in under color and also in surface color than class 4 progeny from the reciprocal cross. The data show very few individuals with dark under color, and none are classed as standard in surface color. Females from this particular cross tend to be lighter in under color than males.

In class 6 progeny, all birds with standard surface color carried either dark or medium under color. This group of birds showed decidedly darker surface and under color than the class 5 progeny. About 95 per cent of the birds from the exhibition males carried either medium or dark under color compared with about 51 per cent of those from the production males.

The number of birds concerned in class 7 is inadequate to furnish much information regarding surface and under color. The data suggest that males tend to be darker in under color than females when the dams carry dark color and the sires lack it.

The progeny of exhibition males X  $F_2$  females were all medium or dark in under color. Surface color was also largely dark or standard. There is also some evidence that males showed darker under color than females. This fact would lend support to the idea that some sex-linked genes are concerned in under color.

In general, a study of the relation of surface and under color in various crosses of Rhode Island Reds indicates that dark surface and dark under color show considerable association. There is also evidence that light modifiers for under color are dominant to dark modifiers. Some evidence is also available which indicates sex-linked inheritance for at least part of the under color modifiers.

#### Surface Color and Smut

A smutty or slatey coloring in the feather fluff of Rhode Island Reds is an undesirable character. Nevertheless, breeders of exhibition birds find this character not at all uncommon and often use female breeding stock showing some smut for the purpose of improving surface color in the offspring. It is therefore important that consideration be given to the relation of smut and surface color in the various types of stock available. Table 5 presents a summary of the relation between surface color and smut in the exhibition stock and hybrid progeny.

Of the exhibition males of standard surface color, half carried smut in under color and half lacked smut. Of the females with standard color, only about one-fifth carried smut. These same proportions hold regardless of surface color, and suggest that smut is much more prevalent in the male sex.

Since none of the production birds used for crossing were of standard surface color and very few carried smut, there is opportunity to study the behavior of smut in crosses.

Of the  $F_1$  offspring in class 1, males with either dark or standard surface color carried smut or were free from smut in almost equal numbers. Females with the same surface color showed about 36 per cent with smut. Of the 40 males classed as medium or light in surface color, about 32 per cent carried smut. Of the 41 females belonging to the medium or light classes, about 49 per cent showed smut. The  $F_1$  generation as a whole was made up of 27 smutty males to 43 not smutty and of 24 smutty females to 28 not smutty. There was, therefore, a greater proportion of smutty individuals in the female progeny, suggesting that sex linkage may play a part in the transmission of smut.

The  $F_1$  progeny in class 2 were distinctly lighter in surface color and freer from smut than the  $F_1$  progeny from the reciprocal cross (class 1). Only 10 per cent of the male progeny from production males carried smut and 24 per cent of the females, while 39 per cent of the  $F_1$  males and 46 per cent of the  $F_1$  females

TABLE 5.--CLASSIFICATION OF EXHIBITION STOCK AND OF HYBRID OFFSPRING ACCORDING TO SURFACE COLOR AND SMUT

	Surface Color—Males					Surface Color—Females				
	Very Light	Light	Medium	Dark	Standard	Very Light	Light	Medium	Dark	Standard
	<b>Exhibition Line</b>									
Smut			1	13	48			2	7	15
No Smut			1	22	45			5	20	55
	<b>1. F<sub>1</sub> Progeny from Exhibition Males X Production Females</b>									
Smut	1	12	5	9		8	12		4	
No Smut	2	25	10	6		6	15		6	1
	<b>2. F<sub>1</sub> Progeny from Production Males X Exhibition Females</b>									
Smut			3			1	8		2	1
No Smut		6	16	4		12	21		5	
	<b>3. F<sub>2</sub> Hybrids</b>									
Smut	4	19	21		2	2	11	22	16	1
No Smut	10	35	19			1	9	40	30	
	<b>4. Progeny of F<sub>1</sub> Males X Production Females</b>									
Smut			10	2		4	5		2	
No Smut		3	6			2	3			
	<b>5. Progeny of Production Males X F<sub>1</sub> Females</b>									
Smut	5	7				23	13		3	
No Smut	30	21	1			8	34	23	6	
	<b>6. Progeny of Exhibition Males X F<sub>1</sub> Females</b>									
Smut			8	16	13		4		4	2
No Smut		2	10	7	8	2	6	6	15	5
	<b>7. Progeny of Production Males X F<sub>1</sub> Females</b>									
Smut	1	5	1			3	4		1	
No Smut	2	8				4	2		1	
	<b>8. Progeny of Exhibition Males X F<sub>1</sub> Females</b>									
Smut			4	4			3	4	8	7
No Smut			1	2	2	1	3	3	12	6

from exhibition males showed smut. Smutty birds were confined almost exclusively to the group with medium or darker surface color.

In the F<sub>2</sub> generation there was something of a tendency for smut to segregate with light surface color, but the majority of males and females carrying smut were classed as having medium or darker surface color. In this second generation 42 per cent of the males and 39 per cent of the females showed smut. Thus the proportion of smutty birds in the second generation was about midway between that of the two classes of F<sub>1</sub> progeny.

The data for class 4 progeny are very limited but they suggest that smut is more likely to occur in birds with the darker shades of surface color.

When production males were mated to F<sub>1</sub> females (class 5), there was a tendency for smut to occur with the dominant lighter shades of surface color, especially in female progeny.

The same general situation with respect to smut and surface color was noted in the class 6 progeny from exhibition males and F<sub>1</sub> females; namely, that when smut occurred in birds with light surface color it appeared first in females.

The limited data presented for class 7 also give evidence that smut is more likely to appear with light surface color in females than in males.

The data for class 8 indicate greater freedom from smut in females than in

males, also a greater tendency for smut to occur in females with the lighter shades of plumage color.

In general, the study of the exhibition stock showed that smut was more common in the male sex. When exhibition stock was crossed with production stock, observation of the progeny from eight different types of matings showed that, when smut appeared in birds with light surface color, it was more likely to be in the females. Possible sex-linked inheritance of smut is therefore suggested, but the tendency for the smut character to be more prevalent in the male sex regardless of surface color persisted in the different crosses. There was some evidence that smut is associated with dark surface color.

### Under Color and Smut

Smut may be so extensive in the under color as to almost completely displace the normal red color. On the other hand, smut may be confined to a very narrow band in the feather fluff and may be observed only in certain body regions. Between these two extremes there are many gradations. As a rule, smut in under color is most likely to occur in the back; consequently all birds in these studies were carefully examined in the back region between the points of attachment of the wings. No attempt was made to record the different degrees of smut-tiness. Under color was grouped into four shades of red. The relation between smut and under color in the exhibition stock and in the hybrid progeny is summarized in Table 6.

In the exhibition stock the under color was essentially the same for the smutty and the non-smutty groups of males. Among the females, however, there were more than three times as many non-smutty as smutty, and the great majority of non-smutty females showed dark under color. There is also some evidence in the females that smut in under color may lighten the shade of red pigment in the feather fluff.

In class 1 of the  $F_1$  generation, medium and dark under color were more prevalent in non-smutty individuals in both sexes. There was still a greater proportion of females than males with dark under color and no smut. Furthermore there was evidence of blending in shade of under color in both sexes.

The greater percentage of non-smutty progeny in class 2, when production males were used, suggests sex-linked relations for the transmission of smut. The fact that all males showing dark under color were free from smut indicates that smut is not a necessary accompaniment of dark red under color.

The  $F_2$  offspring of both sexes averaged intermediate in under color, while 42 per cent of the males and 38 per cent of the females showed smut. The original exhibition stock showed 48 per cent of males with smut and 23 per cent of females. The combined  $F_1$  generation gave 30 per cent of the males and 36 per cent of the females with smut. The gross data suggest that smut segregated as a dominant in the  $F_2$  generation. Dark under color was prevalent in  $F_2$  birds of both sexes that were free from smut.

The limited data for class 4 indicate that smut is rather commonly associated with light under color in females. In the male progeny this relation does not hold, in these hybrids at least.

Progeny from the back cross, class 5, are rather similar to those in class 4. The data do not indicate, however, that light under color and smut are more

common in the female offspring. Only 19 per cent of the males were smutty compared with 35 per cent of the females. Under color was also somewhat lighter in the females.

In the class 6 back-cross population, the greater proportion of both males and females with dark under color were free from smut. Smut was more prevalent in birds with medium or light under color. As a whole, 58 per cent of the males and 41 per cent of the females were smutty. Under color was darker than that of the class 5 progeny of production males mated to F<sub>1</sub> females.

The back-cross progeny from production males, class 7, were about 50 per cent smutty in each sex. The data are inadequate to bring out any relation between smut and under color.

The class 8 progeny from back crossing F<sub>2</sub> females with exhibition males gave only medium and dark under color. These progeny were essentially the same in under color as the exhibition stock; but the females were equally divided into smut and non-smut classes, while exhibition females were very low in smut.

The general results of the study of the relation of under color and smut in these hybrid offspring showed some evidence that sex-linked dominant genes are concerned in the transmission of smut, that smut in under color may lighten the shade of red pigment in the feather fluff, and that lighter shades of under color appear to be governed by dominant genes.

TABLE 6.--CLASSIFICATION OF EXHIBITION STOCK AND OF HYBRID OFFSPRING ACCORDING TO UNDER COLOR AND SMUT

	Under Color--Males				Under Color--Females			
	Very Light	Light	Medium	Dark	Very Light	Light	Medium	Dark
	<b>Exhibition Line</b>							
Smut		2	21	39			12	12
No Smut		1	19	48	1		16	63
	<b>1. F<sub>1</sub> Progeny from Exhibition Males X Production Females</b>							
Smut			21	6			8	16
No Smut		3	26	14		2	19	6
	<b>2. F<sub>1</sub> Progeny from Production Males X Exhibition Females</b>							
Smut			3			2		9
No Smut		3	15	8		14	24	1
	<b>3. F<sub>2</sub> Hybrids</b>							
Smut		2	31	13		13	31	8
No Smut		3	39	22		12	49	25
	<b>4. Progeny of F<sub>1</sub> Males X Production Females</b>							
Smut			11	1		7		4
No Smut		2	6	1		4		1
	<b>5. Progeny of Production Males X F<sub>1</sub> Females</b>							
Smut		2	9	1		1	14	24
No Smut		19	26	7		1	48	21
	<b>6. Progeny of Exhibition Males X F<sub>1</sub> Females</b>							
Smut			28	9		3	10	5
No Smut		1	9	17		1	16	9
	<b>7. Progeny of Production Males X F<sub>1</sub> Females</b>							
Smut			5	2		4		4
No Smut		3	6	1		2		5
	<b>8. Progeny of Exhibition Males X F<sub>1</sub> Females</b>							
Smut			5	3			14	8
No Smut				5			13	9

### GENERAL SUMMARY

Exhibition stock and production stock and their hybrid offspring were compared in fecundity characters, characters related to fecundity, and egg production; also in plumage color, shade of under color, and the occurrence of smut.

Compared with the production-bred stock, the exhibition stock used were characteristically late maturing, low in intensity, good in egg weight, low in hatchability, low in broodiness, low in persistency, low in mortality, and low in egg production.

In surface plumage color the exhibition stock showed about 70 per cent meeting standard requirements and about 30 per cent classed as dark or medium in color. The production stock had no standard-colored birds, very few dark red, and the majority were either medium or light red in color. Practically all exhibition birds ranked as dark or medium in under color, while all production stock ranked as light or medium. Half of the exhibition males and about one-fifth of the females carried smut in under color. Very few production birds showed smut.

The study of the hybrid offspring obtained from the various matings yielded the following conclusions:

1. Crossing the two lines gave somewhat diverse results with respect to fecundity traits in reciprocal crosses. When the production stock was used for the male parent, the progeny were superior to those from the reciprocal cross, and such  $F_1$  hybrids gave slightly greater egg production during the year.
2. Segregation in the  $F_2$  generation gave a high percentage of late-maturing birds, more low-intensity birds, more individuals with winter pause, more broody birds, decreased persistency, and increased mortality. Egg production was decidedly lower than in the checks.
3. Back crossing either  $F_1$  or  $F_2$  females with production males raised the egg production to near the level of production-bred birds.
4. In surface plumage color the  $F_1$  generation was essentially intermediate between standard and production color, but the hybrids from exhibition mothers were decidedly darker in color than those from the reciprocal cross.
5. Lighter shades of surface color appear to dominate the darker shades.
6. The surface color may be restored to the  $F_1$  medium color by back crossing either  $F_1$  or  $F_2$  females on exhibition males. The development of a line of birds with standard surface color from such crosses would be exceedingly difficult.
7. Dark surface and dark under color were rather intimately associated. Light modifiers for under color seemed to dominate, and there was some evidence of sex-linked modifiers.
8. Smut was more common in the male sex. Smut in the females was most likely to be associated with the lighter shades of surface color. There was some evidence that smut tends to be associated with dark surface color in males.
9. The inheritance of smut depends in part upon sex-linked dominant genes.
10. Smut tends to lighten the shade of red pigment in feather fluff.
11. Lighter shades of red in under color appear to be governed by dominant genes.
12. By crossing light-colored production-bred Rhode Island Reds with exhibition-bred birds, followed by careful matings, a flock may be built up with rather uniform medium red plumage color and high egg production.

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