# INHERITANCE OF SMUT IN NEW HAMPSHIRE CHICKENS

by

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Thesis submitted to the Graduate Faculty of the
Virginia Polytechnic Institute
in candidacy for the degree of
MASTER OF SCIENCE
in
POULTRY HUSBANDRY

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Head of Department

Supervisor or Major Professor

August, 1955

Blacksburg, Virginia

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# I. INTRODUCTION

During recent years poultry processors have been complaining about a dark slate undercolor in many strains of New Hampshire chickens. This dark slate or slaty-black under-color is generally known as smut, and shall be called that in this research problem. Broiler growers with such smutty chickens have had difficulty selling them to advantage. Broiler producers do not readily purchase chicks from New Hampshire strains that have a tendency towards a high incidence of smut.

Because of the previously mentioned conditions, hatchery flock inspectors remove from the breeding flocks birds having smut. Many breeders of New Hampshire chickens have thought that the smutty under-color problem must be complicated in its mode of inheritance. Often a high incidence of smut occurred even though no birds with smut had been used as breeders for several years.

The question is, did some birds that had smut in their chick or in their junior plumage but did not in their adult plumage contribute to the relatively high incidence of smut that occurs after several years of selective breeding against smut.

The purpose of this investigation was to obtain information concerning the cause, practical method of selection and breeding to control smut in New Hampshires, and/or to

give background information which will be helpful in carrying on further investigation concerning the matter. The specific objectives were: (1) to study the mode of inheritance of smut, in New Hampshire chickens, (2) to learn if there is a relationship between the amount of black in the down and/or chick feathers and the adult plumage under-color, (3) to study the changes in the plumage under-color from baby chick to maturity, and (4) to search for a practical method of breeding to control smut in New Hampshire chickens.

## II. REVIEW OF LITERATURE

Though no previous work could be found dealing with smut in New Hampshires, some work had been done with Rhode Island Reds. The American Standard of Perfection (1953), in its history of the New Hampshire breed, states that it arose from that breed known as the Rhode Island Red from the Little Compton area. So far as is known there has been no new blood introduced. According to the Standard, the New Hampshire breed arose from the constant selection of birds for early maturity, quick feathering, large brown-shelled eggs, strength and vigor.

Edward Brown (1929) reported in his book, "Poultry Breeding and Production," that among the best producing females the under-color of Rhode Island Reds was lighter. Others have reported that hens with lighter under-color usually have produced chicks with lighter down color. Warren (1929) working with Rhode Island Red chickens reported that a high percentage of light-colored chicks developed into adults with light under-color. Also he reported that adults with darker shades of under-color showed dark-red down as chicks. He observed that the lightest colored chicks also showed a tendency to develop into adults with under-color showing much smut and white.

It is easy to see how the color of the New Hampshire became lighter on the surface than that of the Rhode Island

Red since selection naturally pulled it that way though no attempt was made at first to select for color but for production.

Since the New Hampshire has no other blood reported than that of the Rhode Island Red, the work that has been done with Rhode Island Reds is discussed here. Hays (1926) reported that autosomal gene "B" for reddish-brown pigment in the presence of "L", a sex-linked gene for gold pattern and gold color, and "E", an autosomal gene for the extension of melanic pigment throughout the feathers produced smutty under-color with a red surface color. He also reported that when genes "L" and "E" are present in the same chicken, smutty under-color will be obtained regardless of whether the bird was "BB", "Bb", or "bb". Drevenstedt (1911) reported that many poultry men have had the idea that smut was necessary to obtain the deep rich red that the Standard calls for and that from a breeding standpoint bluish slate in under-color of the back is what might be termed a "desirable defect." He also reported that white in the under-color was a much more serious defect than smut and advised poultry breeders to get rid of serious cases of smut and all cases of white in the under-color. In the same book, Kaufman and Windheim (1911) reported that under-color must be red as the day of smut had passed; also many breeders thought smut helped to get rich surface color but they were mistaken. They stated further

that smut is usually associated with a dirty, dark surface color, rather than the clean rich shade that is desired.

Punnett (1923) stated that the genetic analysis of white fowls is a relatively simple matter in comparison with that of colored birds. He further states that one could only offer suggestions as to the probable relationships of a few of the color types to one another.

Powell-Owen (1953) reported that a young Rhode Island Red may reveal smut (black or dark grey in under-color), but that its adult feathers may come clean. Also he reported that as a black and red breed, Rhode Island Reds depend upon black points in the tail and wings (or smut in the under-color) to produce the rich, lustrous red desired in the surface color.

McGrew (1926) reported that red was seldom if ever seen alone in the plumage of fowls, since it usually is accompanied by black. Brown (1929) gave the following chart as to the history of the Rhode Island Red:

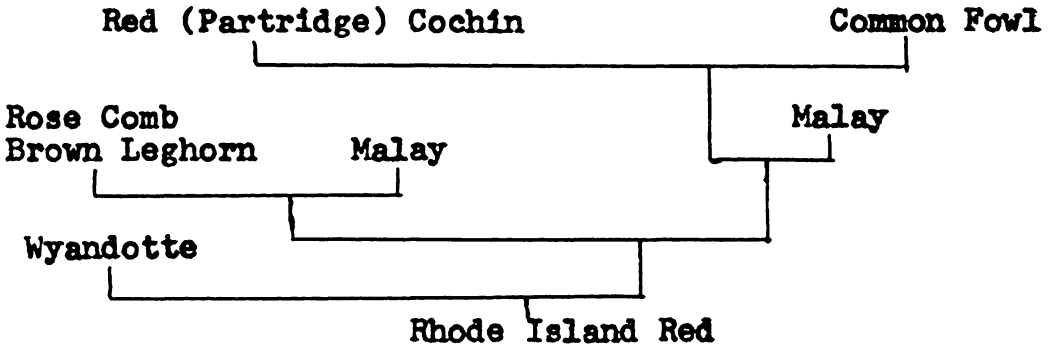


FIGURE 1.

In the Standard of Perfection, it is stated that the under-color of the Malay, Brown Leghorn, Partridge Cochin and many varieties of Wyandottes are slate. It is, therefore, not surprising that many Rhode Island Reds and New Hampshires have smut in their under-color.

## III. EXPERIMENTAL PROCEDURE

Before beginning the experimental procedure, the author wishes to set forth a few definitions which may facilitate the reading of the text. $P_1$ as used in this report means the original parent stock, both male and female. $F_1$ are the sons and daughters of any $P_1$ mating with $P_1$. $F_2$ are the sons and daughters of any $F_1$ mating with $F_1$. Backcrosses are those matings in which one side of the mating is an $F_1$ and the other side is a $P_1$.

A. Group I. Three original $P_1$ matings were made using New Hampshires from Pine Top Poultry Farms. All chickens were individually pedigreed. No. 1 mating was a clean male (no smut in his family anywhere) mated to eight non-smutty females and seven smutty females. No. 2 and No. 3 matings were headed by a smutty male mated to three smutty females and three non-smutty females.

The progeny were pedigree hatched and records were kept on each bird up to four months or more depending upon the hatch date. The feather score (amount of black until smut appeared, then amount of smut) was taken each week. The amount of black was recorded for the head, back, wing, and tail. It was graded as very little black, little black, moderate black, or very black. As soon as smut appeared (fourth week for some) it was recorded very little, little, moderate, or very much. Each week an impartial rating was

taken by alternating the inspectors. The chicks were all fed the same ration and brooded under similar conditions. Birds that died before reaching an age when smut usually appears were not counted in the results.

B. Group II. When the progeny reached maturity four new matings were made which consisted of $F_2$ and backcrosses.

In pen B-1 the original male with most smut was used with ten females whose sires were smutty. In pen B-2 the original non-smutty male was used with ten females (six being his progeny and four being from the smutty males). In selecting females in this part of the experiment care was taken to obtain only those whose family records showed the most smut or no smut. Since the selection was so strict pen B-2 lacked enough females to be complete; thus some females from the smutty male matings ($P_1$) were used.

In pen Q-3 a clean male (from the clean $P_1$ male's progeny) was mated to five non-smutty females of the $P_1$ generation and also 12 of his own generation (all $F_1$'s from the clean $P_1$ male).

In pen Q-4 a smutty male (from the smutty $P_1$ male's progeny) was mated to five smutty females of the $P_1$ generation and also ten of his own generation (all $F_1$'s from the smutty $P_1$ males).

Progeny of these four matings were hatched together and records were kept on the individually pedigreed birds. The birds were scored at two, five and six weeks of age. All of

these chickens were handled as in the first part of this experiment.

C. Group III. While waiting for the $F_1$ to mature the clean male of the $P_1$ generation was mated to the $P_1$ females which had been mated to the smutty $P_1$ males. The chicks from this mating were handled as in Group 2 of this experiment except that scores were also taken on third and fourth weeks.

D. Field Observations. One group of New Hampshires on the V.P.I. poultry plant were handled so as to judge the amount of smut that would occur in a flock in which no attempt had been made to limit or control the amount of smut in their last selection. These were also Pine Top strain.

Many flocks of the Pine Top Hatchery have been examined in the past and records of these flocks have given invaluable aid.

## IV. RESULTS

In the first mating with the clean $P_1$ male there were two smutty males in 19 male progeny and two smutty females in 16 female progeny from clean $P_1$ females. There were six smutty males in 20 males and seven smutty females in 23 female progeny from smutty females. In the matings of the smutty $P_1$ males there were 15 smutty males in 22 male progeny and ten smutty females in 14 female progeny when mated to smutty females, and 12 smutty males in 27 male progeny and seven smutty females in 15 female progeny when mated to clean females.

In the $F_2$ generation using a clean $F_1$ male from the original clean male and mating it only to clean females ($F_1$) there was only one smutty chick out of five progeny. When the clean $F_1$ male was backcrossed to only clean $P_1$ females there was only one smutty progeny in 18 chicks. When the reciprocal backcross was made there were only two smutty progeny in nine chicks.

In the $F_2$ generation from the smutty males using a smutty $F_1$ male crossed with only smutty $F_1$ females there were ten smutty progeny in 11 chicks. In the backcross of smutty $F_1$ male to smutty $P_1$ females all 28 progeny were smutty.

In the backcross to the smutty $P_1$ male there were seven smutty progeny in 11 chicks when smutty $F_1$ females were used. When smutty $P_1$ male was mated to clean $F_1$ females only two of 11 chicks were smutty.

In the second $P_1$ mating with the clean male and clean females there were only five smutty progeny in 40 chicks. When the clean $P_1$ male was mated to smutty females there were 25 smutty progeny in 32 chicks.

In the field observation there were 17 smutty females in 62 hens. Of the four males, two were smutty. The smutty hens had averaged 109 eggs whereas the clean hens had averaged 156 eggs in seven months.

Of all chicks handled only seven were noticed whose down was very light. Of these only one had smut as an adult. Only two showed real dark down and one of these was smutty as an adult. Seventeen chicks were noticed in the first five weeks to have had black spots on their heads or necks. Of these 13 showed smut some time after the fifth week. One of the remaining chickens had white undercolor.

Using black in the wings as a guide, 41 out of 86 that showed black had smut. Four out of 21 whose wings were normal in color had smut. If just the matings with the clean male are considered, only seven of 39 chicks with black in the wing feathers ever had smut, and only one of ten chicks with normal wing color ever had smut. These results were for $F_1$ chicks.

The amount of smut varied from week to week and some birds either lost or obtained smut as their plumage was replaced from chick to juvenile or from juvenile to adult. All birds had black in their tails by the sixth week.

The egg records of the $P_1$ females showed that females with smut averaged 108.4 eggs for the seven month period. The clean females averaged 130 eggs for the same period.

## V. PROPOSED THEORY OF MODE OF INHERITANCE

In this experiment one cannot explain the mode of inheritance on the basis of the action of one pair of autosomal genes, since crossing smut with smut gave some non-smutty progeny and crossing clean with clean gave some smutty progeny. However, the data does not fall into the expected ratio of sexes to be sex-linked either, since progeny that had smut were just as likely to be males as females (39.7% total males, 38.1% total females in the first three matings).

Two autosomal genes acting independently of one another would more adequately explain the mode of inheritance of smut in this strain of New Hampshires. Dunn (1929), Lippincott (1923) and Hays (1926) have reported that there is a gene "E", an autosomal gene for the extension of melanic pigment throughout the feathers. Then as Hutt (1949) stated, the red color characteristic of New Hampshires has many autosomal genes for red, which have not yet been satisfactorily analyzed. The author proposes that one of these genes that shall be called "Y" prohibits gene "E" from showing in the under-color. Its allele "y" allows for the expression of "E" thus giving smut. When "E" appears in the homozygous condition the smut will appear to be much darker.

The recessive allele "y" is for white undercolor as is the recessive of "E" ("e"). When both pairs of genes are in

the homozygous recessive condition the under-color of the bird will be very light or white. When "Y" appears in the heterozygous condition there may be a possibility for the smallest amount of smut to appear (one or two feathers) since its epistatic power may be reduced (Knox, 1927).

The possible genotypes of clean or non-smutty chickens are:

| | | | | |
|---|---|---|---|---|
| Y/Y | E/E | Y/y | E/E | (one smutty feather) |
| Y/Y | E/e | Y/y | E/e | |
| Y/Y | e/e | Y/y | e/e | y/y e/e |

The possible genotypes of smutty chickens are:

y/y E/E (very smutty)

y/y E/e

Two out of the nine genotypes show smut. The results showed 35% of all chickens tested had smut. This is a higher percent than would be expected through random mating. However, using smutty males as often as clean males makes this a selected population with a much higher percent of smut expected.

## VI. DISCUSSION OF RESULTS

Other experiments have demonstrated that color patterns of red colored birds are rather complex. For this reason the author has dealt only with that part of the pattern that affects smut.

In order to give proof of the proposed theory the author has selected the individual matings in which there were a larger number of offspring so that the chance of error is smaller. In the first mating with the clean $P_1$ male (Y/y E/e) were 15 females. Of those hens H3900 (little smut, y/y E/e), H4139 (clean, Y/y E/e), H4205 (smut, y/y E/E) H4058 (little smut, y/y E/e), and H4297 (clean, Y/Y e/e) have been selected.

Progeny of H3900 would be expected to have three smut in every eight chicks. The actual results had two smutty chicks in four. Applying the chi-square test this would have a probability of 60%.

H4139 would be expected to have three smutty progeny in every 16 chicks. She had one smutty chick in seven. This has a probability of about 35%.

H4205 would be expected to have one smutty chick in every two. She had five smutty chicks in 14 progeny. This has a probability of 29%.

H4058 would be expected to have three smutty progeny in every eight chicks. She had four smutty chicks in nine progeny. This has a probability of about 75%.

H4297 would be expected to have no smutty progeny. She had no smut in six progeny. This has a probability of 100%.

In the second and third matings smutty males (y/y E/e) were mated to a total of six smutty and six clean females. Selected for proof of theory were H4189 (clean, Y/y E/E), H4017 (smutty, y/y E/e), H4114 (clean, y/y e/e), H4193 (clean, Y/y E/e), H3951 (little smut, y/y E/e), and H4194 (clean, Y/y e/e).

H4189 would be expected to have one smutty chick in every two. She had seven smutty progeny in 13 chicks. The probability for this is 75%.

H4017 would be expected to have three smutty progeny in every four. She had nine smutty chicks in 11 progeny. This probability is 70%.

H4114 would be expected to have one smutty chick in every two progeny. She had five smutty chicks in seven progeny. The probability of this is 25%.

H3951 would be expected to have three smutty chicks in four progeny. She had all eight chicks smutty. The probability of this is 12%, but two of these chicks were recorded only very little <u>one</u> time which may mean they were actually Y/y E/e. That probability would be 100%.

H4193 would be expected to have three smutty chicks in eight progeny. She had five smutty chicks in ten progeny. The probability of this is 40%.

H4194 would be expected to have one smutty chick in every four. She had two smutty chicks in nine progeny. This probability is 85%.

In the matings with the $F_1$ male (clean, Y/y E/e) both $F_1$ and $P_1$ females were used. Those with the larger progeny are H904K (clean, Y/y E/E), H4119 (clean, Y/y E/E), H4194 (clean Y/y e/e), and H4114 (clean y/y e/e).

H904K would be expected to have one smutty progeny in every four chicks. She had one smutty chick in three progeny. This has a probability of 75%.

H4119 would be expected to have one smutty progeny in every four chicks. She had one smutty chick in four. This has a probability of 100%.

H4194 would be expected to have one smutty chick in every eight progeny. She had all six progeny clean. This has a probability of 40%.

H4114 would be expected to have one smutty chick in every four progeny. She had all four clean progeny. This has a probability of 25%.

In the matings with the $F_1$ male (very smutty, y/y E/E) both $F_1$ and $P_1$ females were used. Those selected as representative are H931B (smutty, y/y E/e), H944I (smutty, y/y E/e), H4017 (smutty, y/y E/e), H3964 (smutty, y/y E/e), and H4067 (smutty, y/y E/E).

All progeny from these matings would be expected to be smutty. The results gave a total of 30 smutty progeny in 30 chicks. This has a probability of 100%.

In the backcross matings with the clean $P_1$ male (Y/y E/e) females H93$^4$B (smutty, y/y E/e) and H93$^4$D (clean, Y/y E/e) were selected.

H93$^4$B would be expected to have three smutty chicks in every eight progeny. She had two smutty progeny in four chicks. This has a probability of 60%.

H93$^4$D would be expected to have three smutty chicks in 16 progeny. She had four progeny all clean. This has a probability of 33%.

In the backcross matings with the smutty $P_1$ male (y/y E/e) females H931F (smutty, y/y E/e), H9$^4$2B (clean, Y/y e/e), and H9$^4$3A (smutty, y/y E/e) were selected.

H931F would be expected to have three smutty chicks in four progeny. She had three smutty chicks in five progeny. This has a probability of $^4$5%.

H9$^4$2B would be expected to have one smutty chick in every four progeny. She had one smutty chick in five progeny. This has a probability of 80%.

H9$^4$3A would be expected to have three smutty chicks in every four progeny. She had three smutty chicks in five progeny. This has a probability of $^4$5%.

The $P_1$ clean male (Y/e E/e) was mated to the same original females that the $P_1$ smutty males were mated with. Those females selected from this group were H396$^4$ (smutty, y/y E/E), H3997 (clean, Y/y E/e), H$^4$119 (clean, Y/y E/e), and H$^4$067 (very smutty, y/y E/E).

H3964 would be expected to have one smutty progeny in every two. She had six smutty progeny in seven progeny. This has a probability of 18%.

H3997 would be expected to have three smutty chicks in 16 progeny. She had three smutty chicks in 14 progeny. This has a probability of 80%.

H4119 would be expected to have three smutty chicks in 16 progeny. She had one smutty chick in five progeny. This has a probability of more than 90%.

H4067 would be expected to have one smutty chick in every two. She had six smutty chicks in eight progeny. This has a probability of 15%.

Only one mating was noticed to have fallen below the 5% significant level for the chi-square test and this had a probability of 4.7%. This could have been caused by gene "Y" losing some of its epistatic power in the heterozygous state, thus causing more progeny to appear smutty.

Chicks that had black spots on their necks and/or heads usually were smutty or white in their adult under-color. Thirteen of the 17 chicks with black in head or neck had smut as adults and another had white under-color. The shade of down doesn't seem to affect the amount of smut in the adult. Those chicks that had black in their wings had a greater percentage of smut as adults. Of those with black in wings 47.6% had smut as adults while only 19% of those

with no black in wings showed smut as adults. This would be stricter selection than most breeders could afford.

Those chickens that showed smut only in one observation in the test must actually have carried the heterozygous gene "Y" which does not completely inhibit gene "E" especially when "E" is in the homozygous condition.

## VII. SUMMARY AND CONCLUSIONS

Of the 372 chicks 35% showed smut. The $P_1$ matings clean male X clean females gave 11.4% smutty progeny, clean male X smutty females gave 30.2% smutty progeny. The smutty male X clean females gave 45.2% while smutty male X smutty females gave 69.4% smutty progeny. Of the chicks that had black heads or necks 76% showed smut as adults, but there was no relationship found between shade of down and smut in adult undercolor. Chicks with black in wings gave 47.6% smutty adults, while only 19% of the non-black were smutty as adults.

From the results obtained in this experiment smut depends upon two independent pairs of autosomal genes. At one locus there is "E" gene for the extension of black throughout the feathers, or "e", recessive allele which gives no color. At the other locus is gene "Y", for red color in the under-color, or its recessive allele "y" which gives no color.

Birds of genotypes Y/Y E/E, Y/Y E/e, Y/Y e/e, Y/y E/E, Y/y E/e, Y/y e/e, and y/y e/e give no smut. Those with genotypes y/y E/E and y/y E/e have smut. The amount of smut depends upon whether the gene "E" is in the E/E or E/e condition. Some chickens with genotype Y/y E/E may show smut since the epistatic condition is weakened when gene "Y" is in the heterozygous condition.

Theoretically, the most desirable genotype for producers of broilers and processors would be y/y e/e since the

under-color would be white. However, this is not the color called for in the Standard. Nevertheless, breeders should select that type of bird that will satisfy his customers. Selecting birds homozygous for "e" would be a breeder's best insurance against having smut. This, however, is not easy to do. Selecting for lighter colors, both surface and under-color, would be the best way since black helps to make the shade somewhat darker. Lighter colored birds are not as likely to have "E" at all.

It was noted in both field observation and actual experiment that those birds that had smut, layed fewer eggs during a seven month period. The $P_1$ smutty females averaged 108.4 eggs; the $P_1$ clean females averaged 130 eggs. The smutty females of the observed flock averaged 109 eggs; the clean females of the observed flock averaged 156 eggs.

On the basis of this experiment and the author's field observation it is concluded that:

1. Smut in this strain of New Hampshires is caused by the interaction of two genes, one a recessive allele of "Y", red under-color, and the other a dominant allele "E", the extension of black throughout the feathers.
2. Although a higher percent of those chicks showing black in the wings have smut as adults, one can't be sure whether smut will show or not.

3. A high percent of those chicks having black on head or neck will have smut as adults (76%).
4. Hens of this strain that have no smut will usually lay more eggs than smutty hens during a given period.
5. It is necessary to check for smut much more often than usually done to accomplish any great improvement.
6. Progeny testing is the best procedure to follow in attempts to control smut.

## VIII. ACKNOWLEDGMENT

The author wishes to express his sincere appreciation to Dr. Clayton E. Holmes, under whose supervision this work was done, for his help not only in planning and carrying on the work but also for his kind aid in the writing of this thesis. The author also wishes to thank Calvin C. Craighead and the workers of the V.P.I. plant for taking care of the test birds. Thanks are extended to Dr. James H. Bywaters, Harry L. Moore, and John McDevitt III for their friendly assistance and encouragement during the course of this study. Finally the author wishes to thank his wife whose record keeping made this thesis possible.

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Appendix Table 1. $F_1$ from Clean Male

| WING BAND | AGE IN WEEKS 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | SEX |
|---|---|---|---|---|---|---|---|---|---|---|
| H901A | L | L | M | L | VL | VL | M | VL | VL | M |
| H901C | N | V | VL | N | N | N | N | N | M | F |
| H901E | M | M | M | N | N | N | N | N | N | M |
| H901F | V | M | M | N | N | N | N | N | N | F |
| H902A | VL | L,W | VL | N | N | N | N | N | N | M |
| H902B | N | V | VL | N | N | N | N | N | N | F |
| H902C | M | M | M | N | N | N | N | N | N | M |
| H902D | N | VL | N | N | N | N | N | N | N | M |
| H902E | V | V | V | N | N | N | N | N | N | F |
| H903A | V | V | V | N | N | N | N | N | VL | F |
| H903B | V | V | V | N | N | N | N | N | N | F |
| H903E | W | N | N | N | N | N | N | N | N | M |
| H903F | L | L | L | N | N | N | N | N | N | M |
| H903G | V | M | M | N | N | N | N | N | N | F |
| H903H | V | V | V | N | N | N | N | N | N | F |
| H903J | M | M | M | N | N | N | N | N | N | M |
| H904A | L | M | V | V | V | V | M | VL | VL | M |
| H904B | N | VL | VL | N | N | N | N | N | N | F |
| H904C | M | M | M | N | N | N | VL | VL | M | F |
| H904D | M | M | L | N | N | N | N | N | VL | F |
| H904E | N | L | L | N | N | N | N | N | N | F |
| H904F | N | N | W | N | N | N | N | N | N | M |
| H904G | N | M | L | N | N | N | N | N | N | F |
| H904H | N | N | N | N | N | N | N | N | N | F |
| H904I | M | M | M | N | N | N | N | N | N | M |
| H904J | VL | L | L | N | N | N | VL | VL | VL | M |
| H904K | V | M | M | N | N | N | N | N | N | F |
| H904L | L | N | N | N | N | N | N | N | N | M |
| H904M | N | W | N | N | N | N | N | N | N | M |
| H904N | N | N | L | VL | VL | M | N | N | N | M |
| H905A | L | L | L | N | N | N | N | N | N | M |
| H905B | M | V | M | N | N | N | N | N | N | F |
| H905C | M | M | M | N | N | N | N | N | N | F |
| H905D | M | M | M | N | N | N | N | N | N | M |
| H905E | L | L | L | N | N | N | N | N | N | F |
| H906A | L | L | VL | N | N | N | N | N | VL | F |
| H906B | M | M | M | N | N | D | - | - | - | M |
| H906C | N | L | L | N | N | N | N | N | N | M |
| H906D | N | M | M | N | N | N | N | N | N | F |
| H906F | N | M | V | M | VL | VL | VL | VL | VL | F |

L - little
M - moderate
V - very
W - white down
VL - very light
N - normal
D - dead

Readings for first through fifth week are for amount of black in wing feathers. All others are for smut.

Appendix Table 1 (continued)

| WING BAND | AGE IN WEEKS 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | SEX |
|---|---|---|---|---|---|---|---|---|---|---|
| H906G | M | M | M | N | N | N | D | - | - | F |
| H906H | M | M | M | N | VL | M | VL | VL | N | F |
| H906I | L | M | L | VL | M | M | M | VL | VL | M |
| H906J | M | M | M | N | N | N | N | D | - | M |
| H907A | V | M | M | N | N | N | L | L | L | F |
| H907C | M | M | M | N | N | N | N | N | N | M |
| H908A | M | M | M | N | N | N | N | N | N | F |
| H908B | L | L | L | N | N | N | N | VL | N | M |
| H908C | M | M | M | N | N | N | M | V | V | F |
| H908D | M | M | M | N | N | D | - | - | - | F |
| H921A | M | M | M | N | N | N | VL | VL | M | M |
| H921B | M | V | V | M | VL | N | N | N | N | F |
| H921C | N | L | VL | N | N | N | N | N | N | F |
| H921D | M | M | M | N | N | N | N | N | N | M |
| H922A | M | M | L | N | N | N | N | N | N | F |
| H922B | N | L | VL | N | N | N | N | N | N | M |
| H922C | VL | L | L | N | N | N | N | N | N | M |
| H922D | V | M | M | N | N | N | N | N | N | F |
| H922E | M | M | M | N | N | N | N | N | N | F |
| H922F | V | M | M | N | N | N | N | N | N | F |
| H923A | M | M | VL | N | N | N | N | N | N | F |
| H923B | N | V | L | N | N | N | N | N | N | M |
| H923C | N | V | VL | N | N | N | N | N | N | F |
| H923F | N | N | N | N | N | N | N | N | N | F |
| H923G | L | M | M | N | N | N | N | N | N | F |
| H924A | L | VL | VL | N | N | N | N | N | N | M |
| H924B | VL | L | VL | N | N | N | N | N | N | F |
| H924C | N | N | N | N | N | N | N | N | N | M |
| H924E | L | L | L | N | N | N | N | N | N | M |
| H924F | V | M | M | M | V | V | V | V | V | M |
| H925A | N | N | N | N | N | N | N | N | N | M |
| H925B | N | N | N | N | N | N | N | N | D | M |
| H926A | L | VL | VL | N | N | N | N | N | N | M |
| H926C | N | N | N | N | N | N | N | N | N | M |
| H926D | L | N | N | N | N | N | D | - | - | M |
| H927B | N | L | VL | N | N | N | N | VL | VL | F |

L - little
M - moderate
V - very
W - white
VL - very light
N - normal
D - dead

Readings for first through fifth week are for amount of black in wing feathers. All others are for smut.

Appendix Table 2. $F_1$ from Smutty Males

| WING BAND | AGE IN WEEKS 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | SEX |
|---|---|---|---|---|---|---|---|---|---|---|
| H931A | N | VL | VL | M | V | V | V | V | V | M |
| H931B | N | V | V | N | N | N | M | V | V | F |
| H931C | M | V | V | V | M | M | V | V | V | F |
| H931D | N | V | V | V | M | V | V | V | V | M |
| H931E | N | V | V | N | N | N | VL | N | V | F |
| H931F | V | V | V | N | N | N | V | V | V | F |
| H931G | V | M | M | N | N | N | VL | VL | D | M |
| H931H | L | M | M | N | N | N | N | N | N | M |
| H931I | V | M | M | N | N | N | N | N | N | M |
| H931J | V | M | S | M | VL | VL | M | V | V | F |
| H931K | V | V | S | M | VL | VL | M | V | V | F |
| H932A | N | M | M | N | N | N | N | N | VL | M |
| H932C | V | M | M | N | N | N | VL | N | VL | M |
| H932D | V | M | M | N | N | M | M | V | V | M |
| H932E | L | M | M | N | N | N | N | N | N | M |
| H932F | V | M | S | VL | VL | VL | D | - | - | M |
| H933A | M | V | V | N | N | N | N | M | M | F |
| H933C | M | M | M | N | N | N | N | N | N | M |
| H933D | M | M | M | N | N | N | N | N | N | F |
| H934A | N | VL | VL | N | N | N | N | N | N | M |
| H934B | N | M | V | N | N | N | N | N | V | F |
| H934C | N | V | V | N | N | N | N | N | VL | M |
| H934D | N | V | V | N | N | N | N | N | N | F |
| H934E | N | VL | VL | N | N | N | N | N | N | M |
| H934F | VL | M | M | N | N | N | L | L | N | M |
| H934G | L | M | M | N | N | N | N | N | N | M |
| H934H | V | M | M | N | M | L | M | M | M | M |
| H934I | L | M | M | VL | N | M | M | M | M | F |
| H934J | V | M | M | N | VL | V | V | V | V | M |
| H934K | L | M | M | VL | N | N | N | N | N | F |
| H934L | V | M | M | N | N | N | N | N | N | M |
| H934M | M | M | M | N | N | N | N | VL | VL | F |
| H941A | N | L | L | N | N | VL | M | M | L | M |
| H941B | L | M | M | N | VL | M | VL | M | M | M |
| H941C | M | M | M | N | N | N | N | N | N | F |
| H941D | N | N | N | N | N | N | N | N | N | M |
| H941E | L | M | L | N | N | N | N | N | N | M |
| H941F | VL | N | N | N | N | N | N | D | - | M |
| H941G | N | L | N | N | N | N | N | N | N | M |
| H941H | N | N | N | N | N | N | N | N | N | F |

L - little
M - moderate
V - very
D - dead
W - white
VL - very little
N - normal
S - smut

Readings for first through fifth weeks are for amount of black in wing feathers. All others are for smut.

Appendix Table 2 (continued)

| WING BAND | AGE IN WEEKS 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | SEX |
|---|---|---|---|---|---|---|---|---|---|---|
| H941I | VL | L | L | N | N | N | N | D | - | M |
| H942B | N | VL | VL | N | N | N | N | N | N | F |
| H942C | L | L | L | N | N | M | V | V | V | F |
| H942D | N | L | N | N | VL | N | N | N | N | M |
| H942E | M | M | M | N | M | L | M | M | VL | M |
| H942F | VL | N | N | N | N | N | N | N | N | F |
| H942G | N | VL | N | N | N | N | N | N | N | F |
| H942H | N | N | N | M | VL | VL | VL | N | VL | M |
| H942I | N | N | N | N | N | N | N | N | N | M |
| H942J | L | M | M | V | V | V | V | V | D | M |
| H942K | N | N | N | N | N | N | N | N | N | M |
| H943A | N | M | VL | V | V | V | V | M | M | F |
| H943B | N | M | VL | V | V | V | V | V | V | F |
| H943C | N | M | L | M | L | VL | N | VL | VL | M |
| H943D | V | M | M | V | V | V | V | V | V | M |
| H943E | M | M | M | VL | N | VL | N | N | N | F |
| H943F | V | M | M | M | V | V | V | V | V | M |
| H943G | L | M | M | M | VL | VL | N | N | N | F |
| H944B | N | VL | N | V | V | M | VL | VL | VL | M |
| H944F | N | N | N | VL | N | N | N | N | N | M |
| H944G | M | M | M | V | V | V | V | V | V | M |
| H944I | M | M | M | V | V | V | V | V | V | F |
| H944J | N | N | N | N | N | N | N | N | N | M |
| H944K | L | M | M | M | V | V | V | V | M | M |
| H944L | M | M | M | M | V | V | V | V | V | F |
| H945A | N | VL | V | V | V | V | V | V | V | M |
| H945B | N | L | VL | N | VL | VL | N | N | VL | F |
| H945C | L | M | M | V | V | V | V | M | N | F |
| H945D | L | M | N | V | V | V | V | V | V | M |
| H945E | VL | M | M | VL | M | VL | VL | VL | VL | M |
| H945F | VL | M | M | N | N | N | VL | N | N | M |
| H945G | M | M | M | V | L | M | M | M | L | F |
| H945H | V | M | M | N | N | N | N | VL | N | M |
| H946A | N | VL | VL | N | N | N | N | N | N | M |
| H946B | VL | M | M | N | N | N | N | N | N | F |
| H946C | VL | M | M | N | VL | VL | VL | M | VL | M |
| H946D | M | M | M | N | N | N | N | N | N | F |
| H946E | N | M | L | M | M | V | V | V | V | M |

L - little
M - moderate
V - very
D - dead
W - white
VL - Very little
N - normal

Readings for first through fifth week are for amount of black in wing feathers. All others are for smut.

Appendix Table 3a. Backcrosses to Clean $P_1$ Male

| WING BAND | AGE IN WEEKS 2 | 5 | 6 | SEX |
|---|---|---|---|---|
| I1141A | V | N | W | M |
| I1146A | L | N | N | M |
| I1146C | M | N | M | M |
| I1146D | M | N | N | F |
| I1146E | L | N | V | M |
| I1147A | V | N | N | F |
| I1147B | M | N | N | F |
| I1147C | N | N | N | F |
| I1147D | M | N | N | F |

Appendix Table 3b. Backcrosses to Smutty $P_1$ Male

| WING BAND | AGE IN WEEKS 2 | 5 | 6 | SEX |
|---|---|---|---|---|
| I1126A | V | Dk | V | F |
| I1126B | V | N | N | F |
| I1126C | V | M | V | M |
| I1126G | V | V | V | M |
| I1126H | V | N | N | M |
| I1127B | V | N | N | M |
| I1128A | V | N | N | F |
| I1128B | V | N | N | F |
| I1128C | M | N | N | F |
| I1128D | N | N | L | M |
| I1129A | V | N | N | M |
| I1130A | M | N | N | F |
| I1130B | V | N | W | M |
| I1130C | M | N | W | M |
| I1130D | V | N | L | M |
| I1130F | M | N | N | F |
| I1131A | V | N | VL | F |
| I1131B | V | N | VL | F |
| I1131E | V | N | N | F |
| I1131F | M | N | N | F |
| I1131I | V | N | VL | F |
| I1132A | V | V | M | F |
| I1133A | V | N | N | F |

L - little
V - very
Dk- Dark surface
W - white
N - normal
VL - very little
M - Moderate
D - dead

Readings for the second week are for the amount of black in the wing feathers. Others are for the amount of smut in the feathers of the back of the bird.

Appendix Table 3c. $F_2$ from Clean Male ($P_1$)

| WING BAND | AGE IN WEEKS 2 | 5 | 6 | SEX |
|---|---|---|---|---|
| I1175A | V | N | W | M |
| I1175B | V | L | VL | F |
| I1175C | N | N | N | M |
| I1176A | M | N | N | F |
| I1177A | M | N | N | M |

Appendix Table 3d. Backcrosses to $P_1$ Females (Clean Male)

| WING BAND | AGE IN WEEKS 2 | 5 | 6 | SEX |
|---|---|---|---|---|
| I1171A | V | N | N | F |
| I1171B | V | V | N | M |
| I1171C | W | N | N | F |
| I1171D | L | N | N | M |
| I1172A | M | N | N | M |
| I1172B | W | N | N | F |
| I1172C | N | N | N | M |
| I1172D | V | N | N | F |
| I1172E | M | N | N | F |
| I1172F | V | N | N | F |
| I1173A | V | N | N | M |
| I1173B | V | N | W | F |
| I1173C | L | N | N | F |
| I1173E | V | N | N | F |
| I1174A | V | N | N | M |
| I1174B | V | N | N | M |
| I1174C | V | N | N | F |
| I1174D | L | N | N | M |

Appendix Table 3e. $F_2$ from Smutty Male

| WING BAND | AGE IN WEEKS 2 | 5 | 6 | SEX |
|---|---|---|---|---|
| I1158A | V | V | V | M |
| I1158B | V | V | V | M |
| I1158C | V | N | VL | F |
| I1158D | V | V | V | M |
| I1158E | V | V | V | F |
| I1158F | V | VL | M | F |
| I1159A | M | N | N | F |
| I1159B | M | N | M | F |
| I1161B | N | M | V | F |
| I1161C | M | V | V | M |
| I1161D | L | N | VL | F |

L - little
V - very
M - moderate
N - normal
VL - very little
W - white

Readings for second week are for amount of black in wing feathers. Others are for amount of smut in feathers of back of bird.

Appendix Table 3f. Backcrosses to $P_1$ Females (Smutty Male)

| WING BAND | AGE IN WEEKS 2 | 5 | 6 | SEX |
|---|---|---|---|---|
| I1151A | M | N | VL | F |
| I1151B | L | M | M | M |
| I1151C | W | N | V | F |
| I1151D | M | V | V | M |
| I1151E | M | V | V | F |
| I1151F | V | V | V | M |
| I1151G | V | V | V | M |
| I1151H | M | V | V | F |
| I1151I | V | V | V | M |
| I1152A | M | V | V | F |
| I1152B | V | M | M | M |
| I1152C | L | V | V | M |
| I1152D | V | V | V | M |
| I1152E | M | V | V | M |
| I1152F | M | N | VL | M |
| I1152G | N | VL | M | F |
| I1155A | V | V | V | F |
| I1155B | V | V | V | F |
| I1155C | VL | M | V | F |
| I1155D | V | V | V | M |
| I1155E | V | V | V | F |
| I1156A | N | V | V | F |
| I1156B | M | V | V | F |
| I1156C | M | V | V | M |
| I1157A | L | N | VL | F |
| I1157B | L | N | VL | M |
| I1157C | L | M | M | F |
| I1157D | L | M | VL | F |

L - little
V - very
M - moderate
N - normal
VL - very little
W - white

Readings for the second week are for the amount of black in the wing feathers. Others are for the amount of smut in the feathers of the back of the bird.

Appendix Table 4. $F_1$ from Clean Male (Females from Smut Mating)

| WING BAND | AGE IN WEEKS 2 | 3 | 5 | 7 | 9 | SEX |
|---|---|---|---|---|---|---|
| IB1101A | VL | VL | N | N | N | M |
| IB1101B | M | V | L | N | N | ? |
| IB1101C | M | V | V | V | V | M |
| IB1101D | V | V | VL | VL | N | F |
| IB1101E | V | VL | N | N | N | F |
| IB1101F | VL | M | M | V | M | M |
| IB1101G | | | | | VL | F |
| IB1101H | | | | | M | M |
| IB1101I | | | | | N | F |
| IB1101J | | | | | VL | F |
| IB1101K | | | | | V | M |
| IB1101L | | | | | N | F |
| IB1101M | | | | | N | M |
| IB1101N | | | | | M | M |
| IB1102A | N | N | N | N | N | M |
| IB1102B | M | M | N | N | N | M |
| IB1102C | M | M | N | N | N | F |
| IB1102D | | | | | N | F |
| IB1102E | | | | | N | M |
| IB1102F | | | | | N | M |
| IB1102G | | | | | N | F |
| IB1102H | | | | | N | M |
| IB1102I | | | | | N | F |
| IB1102J | | | | | VL | M |
| IB1102K | | | | | V | M |
| IB1102L | | | | | N | M |
| IB1102M | | | | | N | M |
| IB1102N | | | | | N | F |
| IB1103A | M | M | V | VL | N | F |
| IB1103B | | | | | VL | M |
| IB1103C | | | | | V | F |
| IB1103D | | | | | M | F |
| IB1103E | | | | | N | M |
| IB1103F | | | | | V | M |
| IB1103G | | | | | V | F |
| IB1104A | VL | M | N | N | N | F |
| IB1104B | M | L | N | N | D | ? |
| IB1104C | M | M | N | VL | D | ? |
| IB1104F | | | | | N | M |
| IB1104G | | | | | M | M |
| IB1104H | | | | | N | F |

L - little VL - very little
M - moderate V - very
D - dead N - normal
Readings for second and third weeks are for black in wing feathers. All others are for smut.

Appendix Table 4 (continued)

| WING BAND | AGE IN WEEKS 2 | 3 | 5 | 7 | 9 | SEX |
|---|---|---|---|---|---|---|
| IB1105A | N | N | N | N | D | ? |
| IB1105B | VL | VL | N | N | D | ? |
| IB1105C | VL | VL | VL | N | N | F |
| IB1105D | VL | VL | N | N | N | M |
| IB1105E | | | | | N | F |
| IB1105G | | | | | N | M |
| IB1105H | | | | | N | M |
| IB1105I | | | | | N | M |
| IB1105J | | | | | N | M |
| IB1106A | L | L | N | N | N | M |
| IB1106B | L | L | N | N | VL | F |
| IB1106C | L | M | N | N | N | F |
| IB1106D | VL | VL | N | N | N | M |
| IB1106F | VL | VL | N | N | N | F |
| IB1106G | | | | | N | F |
| IB1106H | | | | | N | F |
| IB1107A | L | L | N | N | N | F |
| IB1107B | L | L | N | N | N | F |
| IB1107C | | | | | N | F |
| IB1107D | | | | | N | M |
| IB1108A | L | L | N | N | N | M |
| IB1108C | V | M | V | VL | N | F |
| IB1109A | V | V | V | V | V | M |
| IB1109B | M | M | N | VL | VL | M |
| IB1109E | M | M | VL | VL | M | F |
| IB1109D | | | | | N | F |
| IB1109E | | | | | VL | M |
| IB1109F | | | | | N | F |
| IB1109G | | | | | V | M |
| IB1109H | | | | | M | M |
| IB1111A | | | | | VL | F |
| IB1111B | | | | | V | M |

L - little
M - moderate
D - dead
VL - very little
V - very
N - normal

Readings for second and third weeks are for amount of black in wing feathers. All others are for smut.

This table lacks data because many of the chicks were used in another experiment and were not checked for the first eight weeks.

Appendix Table 5. Field Observation at V. P. I.

| WING BAND | EGGS | SCORE | SEX | WING BAND | EGGS | SCORE | SEX |
|---|---|---|---|---|---|---|---|
| H1241 | 146 | N | F | H1215 | 81 | V | F |
| H1193 | 160 | N | F | H1184 | 158 | N | F |
| H1174 | 170 | N | F | H1177 | 138 | N | F |
| H1216 | 140 | N | F | H1204 | 176 | ? | F |
| H1175 | 155 | N | F | H1222 | 149 | N | F |
| H1189 | 114 | N | F | H1232 | 152 | N | F |
| H1237 | 145 | N | F | H1206 | 139 | N | F |
| H1202 | 143 | N | F | H1197 | 139 | N | F |
| H1205 | 121 | VL | F | H1212 | 125 | N | F |
| H1208 | 127 | N | F | H1195 | 146 | VL | F |
| H1183 | 110 | N | F | H1210 | 77 | N | F |
| H1182 | 119 | VL | F | H1209 | 125 | N | F |
| H1236 | 145 | VL | F | H1211 | 82 | N | F |
| H1176 | 140 | N | F | H1221 | 17 | VL | F |
| H1185 | 114 | N | F | H1235 | 141 | N | F |
| H1242 | 51 | V | F | H1188 | 161 | N | F |
| H1226 | 125 | N | F | H1203 | 183 | N | F |
| H1207 | 122 | VL | F | H1227 | 111 | VL | F |
| H1243 | 135 | N | F | H1194 | 122 | N | F |
| H1201 | 156 | N | F | H1217 | 109 | N | F |
| H1228 | 9 | VL | F | H1172 | 139 | N | F |
| H1188 | 161 | N | F | H1190 | 113 | N | F |
| H1192 | 130 | M | F | H1231 | 130 | VL | F |
| H1219 | 126 | N | F | H1187 | 122 | N | F |
| H1223 | 123 | V | F | H1225 | 103 | N | F |
| H1238 | 143 | N | F | H1181 | 131 | VL | F |
| H1191 | 122 | ? | F | H1220 | 97 | VL | F |
| H1196 | 152 | V | F | H1218 | 123 | N | F |
| H1179 | 148 | N | F | 4HB812K | | VL | M |
| H1229 | 124 | N | F | 4HB8040 | | VL | M |
| H1173 | 122 | N | F | 4HB802R | | N | M |
| H1234 | 95 | N | F | 4HB811V | | N | M |
| H1200 | 167 | VL | F | | | | |
| H1233 | 125 | N | F | | | | |
| H1214 | 121 | N | F | | | | |
| H1240 | 144 | N | F | | | | |

M - moderate
V - very
VL - very light
N - normal
All scores are for the amount of smut in the feathers of the bird's back. These birds were adults which had been laying for seven months.

Appendix Table 6. Index to Chickens

| WING BAND | SMUT | MATING NUMBER | CHICKS | MALE IN MATING |
|---|---|---|---|---|
| H4119 | No | H933 | A-D | H3842 Smutty |
| H4189 | No. | H934 | A-M | " |
| H4017 | Yes | H931 | A-K | " |
| H3964 | Yes,L | H932 | A-F | " |
| H4207 | Yes,L | H946 | A-E | H3788 Little Smut |
| H4194 | No | H941 | A-I | " |
| H4114 | No | H944 | A-M | " |
| H4193 | No | H942 | A-K | " |
| H3951 | Yes,L | H945 | A-H | " |
| H4067 | Yes,V | H943 | A-G | " |
| H3839 | Yes | H908 | A-D | H3011 Clean |
| H3900 | Yes,L | H901 | A-H | " |
| H4058 | Yes,L | H906 | A-K | " |
| H4109 | Yes | H907 | A-C | " |
| H4205 | Yes | H904 | A-N | " |
| H4299 | Yes.L | H905 | A-E | " |
| H3886 | Yes | H902 | A-F | " |
| H4253 | No | H924 | A-F | " |
| H4111 | No | H923 | A-G | " |
| H4112 | No | H926 | A-D | " |
| H4116 | No | H927 | A-D | " |
| H4139 | No | H903 | A-K | " |
| H4192 | No | H925 | A-B | " |
| H4206 | No | H921 | A-E | " |
| H4297 | No | H922 | A-F | " |
| H4017 | Yes | IB1101 | A-N | " |
| H3997 | No | IB1102 | A-N | " |
| H3964 | Yes,L | IB1103 | A-G | " |
| H4119 | No | IB1104 | A-H | " |
| H4194 | No | IB1105 | A-J | " |
| H4193 | No | IB1106 | A-H | " |
| H4114 | No | IB1107 | A-F | " |
| H3951 | Yes,L | IB1108 | A-C | " |
| H4067 | Yes,V | IB1109 | A-H | " |
| H4207 | Yes,L | IB1111 | A-B | " |

L - little
V - very

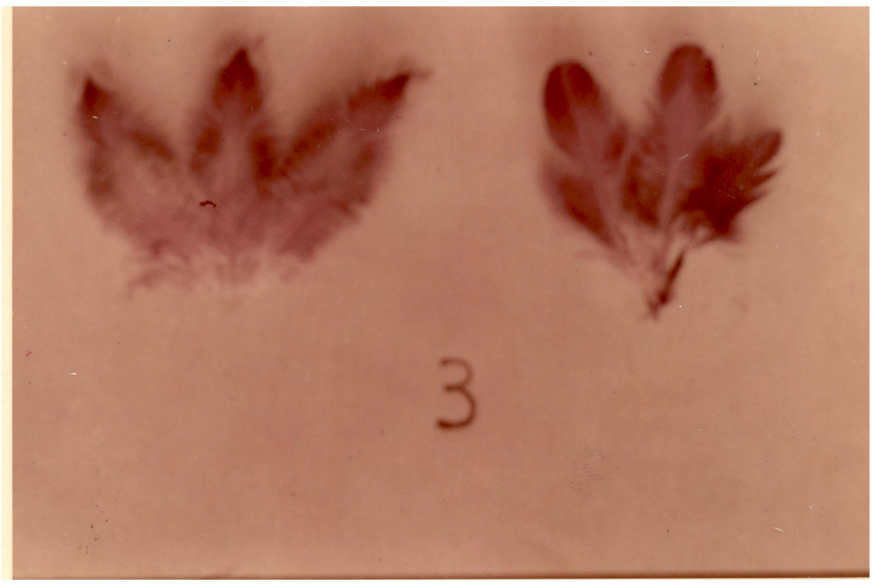
Appendix Table 6 (continued)

| WING BAND | SMUT | MATING NUMBER | CHICKS | MALE IN MATING |
|---|---|---|---|---|
| H931F | Yes | I1126 | A-H | H3842 Smutty |
| H934K | No | I1127 | A-D | " |
| H941C | No | I1128 | A-D | " |
| H941H | No | I1129 | A-B | " |
| H942B | No | I1130 | A-F | " |
| H943A | Yes | I1131 | A-I | " |
| H945B | Yes | I1132 | A | " |
| H946B | Yes | I1133 | A | " |
| H901F | Yes | I1141 | A-B | H3011 Clean |
| H934B | Yes | I1148 | A-G | " |
| H934D | No | I1147 | A-D | " |
| H943G | Yes | I1148 | A | " |
| H931B | Yes | I1158 | A-G | H945A Smutty |
| H931C | Yes | I1159 | A-F | " |
| H9441 | Yes | I1161 | A-D | " |
| H4017 | Yes | I1151 | A-I | " |
| H4067 | Yes | I1155 | A-E | " |
| H3951 | Yes | I1156 | A-C | " |
| H3964 | Yes | I1152 | A-G | " |
| H4207 | Yes | I1157 | A-D | " |
| H4119 | No | I1171 | A-D | H905A Clean |
| H4194 | No | I1172 | A-F | " |
| H4193 | No | I1173 | A-E | " |
| H4114 | No | I1174 | A-E | " |
| H904K | No. | I1175 | A-C | " |
| H905B | No | I1176 | A | " |
| H923C | No | I1177 | A | " |

FEATHERS SHOWING DIFFERENT AMOUNTS OF SMUT


Male Female
No Smut (Clean)


Male Female
Moderately Smutty




Male Female
Very Smutty


Male Female
Little Smutty

Note: All feathers came from the backs of the New Hampshires.