August 5th, 1949

To the Committee on Graduate Study:

I am submitting to you a thesis written by Jack Thomas Tumlin entitled "Fertility and Hatchability of Inbred Barred Plymouth Rocks." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Poultry.

O. E. Goff
Major Professor

We have read this thesis
and recommend its acceptance:

Donald E. Saapenuidu

O. E. Goff

Accepted for the Committee

E. A. Waters
Dean of the Graduate School

FERTILITY AND HATCHABILITY OF INBRED BARRED PLYMOUTH ROCKS

A THESIS

Submitted to
The Committee on Graduate Study
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science

by

Jack Thomas Tumlin

August 1949

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ABSTRACT

Data are reported on fertility and hatchability studies for the 1948 and 1949 hatching seasons. This study was carried out with open-bred New Hampshire, White Plymouth Rock, Single Comb White Leghorn, and inbred Barred Plymouth Rock chickens, involving 11,112 eggs from 62 open-bred birds and 295 inbred birds. During these two years, data were recorded on fertility, hatchability and the number of malpositions and anomalies encountered in 1919 broken out embryos.

The fertility of all eggs set in 1948 was 75.1 percent compared to 58.9 in 1949. This is a decrease of 16.2 percent. The percent fertility for the open-bred lines in 1949 was 79.4 which approximated that for 1948. The percent fertility was found to decrease as the intensity of inbreeding increased.

Hatchability studies for the inbred lines revealed a 55.2 percent hatch of all eggs set in 1948 compared to 35.3 percent for 1949, a decrease of 16.9 percent. The percent hatch of all eggs set in 1949 for the open-bred stock was 61.7 percent. The inbred lines showed a 73.5 percent hatch of all fertile eggs in 1948 compared to 58.9 for the 1949 season. The open-bred lines gave an 82.4 percent hatch of all fertile eggs. It was found that as the intensity of inbreeding increased the percent hatch of all eggs set decreased. The same was true when percent hatch of all fertile eggs was considered.

Of all the broken out embryos in 1948, 51 percent exhibited some malposition. Position 2, head in large end over right wing, and position

22, head in small end covered with both feet, were found most frequently. Of the reported 22 malpositions described for both hatching seasons, 19 were found in 1948.

Similar results were obtained in a study of broken out embryos during 1949. A total of 51.3 percent of all broken out embryos from the inbred lines were in malposition. The incidence of position 2 again occurred frequently, being found in 9.6 percent of all broken out embryos. Position 13, head in small end under right wing, was observed in 10.6 percent of all broken out embryos while position 22 occurred in 7.4 percent. Of the 22 reported malpositions described for both years, 20 occurred in 1949.

The incidence of malpositions failed to increase as the degree of inbreeding increased.

Studies in 1948 revealed that 6.0 percent of all broken out specimens showed some abnormal condition. Of this total, 15.0 percent were found in condition 1, thin spindle and undeveloped. This condition was observed most frequently during the 1949 hatching season. Of the 50 abnormal conditions reported and described for both years, 20 were found in 1948.

Recorded data on the inbred lines for 1949 revealed that 11.3 percent of all broken out embryos exhibited some abnormality. Of this total, 38.1 percent were found in a thin spindly and undeveloped condition. Micromelia was found in 13.5 percent and Chondrodystrophy in 21.2 percent of all broken out embryos. Of the 50 abnormal conditions reported and described in 1948 and 1949, 34 were found in 1949.

The incidence of abnormalities for the inbred stock of 1949 was considerably higher than that for the inbred stock of 1948. This factor is considered as evidence that breeding is an important factor in the occurrence of abnormal embryos.

Studies of embryo malpositions from the 18th day through the 22nd day showed that 17.5 percent of all broken out embryos were ina normal hatching position. This figure increased from 32.5 percent for the 20th day to 77.7 percent for the 22nd day.

The mortality curve for all dead embryos showed minor peaks of mortality on the 8th, 12th and 15th days of incubation. A major period of mortality was encountered from the 18th to 22nd days of incubation. A total of 85.9 percent of all dead embryos died during this major mortality period.

In 1949, the production of malpositions and anomalies by daughters could not be associated with the performance of their dams.

On the basis of the data presented, it was concluded that selective inbreeding must be practiced in order to obtain desired inbred lines.

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INTRODUCTION

Since 1849 when the first poultry show was held in the United States, the poultry industry has resorted to the use of pure-bred or standard-bred poultry for increased meat and egg production.

For the last several years relative little progress has been made by the use by standard-bred poultry in increasing egg production. The broiler and egg producing industry, in an effort to secure greater gains, increased production, and more efficient feed utilization, has resorted to cross breeding. Many of these crosses have given significantly greater production.

To secure more uniform breeding stock inbreeding of various strains has been resorted to. These strains have been crossed in the same manner as the corn breeders have crossed inbred lines of corn. Little experimental evidence has been presented giving the value of inbreeding or the recombining value of inbred lines.

To study the desirable and undesirable features of an inbreeding program, and the recombining value of inbred lines, this study was initiated. This breeding project is a portion of the Southern Regional Poultry Breeding Project which was approved in 1947. The data reported in this study involved a study of fertility, hatchability and the occurrence of anomalies and embryos in malposition. The breeds involved were inbred Barred Plymouth Rocks and open bred New Hampshires, White Rocks, and Single Comb White Leghorns.

REVIEW OF LITERATURE

From the number of investigations reported, it is evident that physical, chemical and nutritional factors as well as genetic factors influence fertility, hatchability and the production of abnormal embryos.

Studies by Olsen and Haynes (1948), working on the optimal temperatures for the storage of hatching eggs, led to the conclusion that eggs stored at a temperature of 30° F. for a period of 2 to 8 days gave an increase in the incidence of embryo abnormalities.

Landauer and Baumann (1943) reported a decrease in hatchability of eggs due to shipping and that the incidence of all types of commonly occurring malformations was increased after the shaking of eggs prior to incubation.

Taylor, Gunns and Moses (1933) observed that after twelve hours of cooling during the stages of incubation, the number of deformed and weak chicks was about doubled. Romanoff and Faber (1933) further reported that incubating eggs at sub-normal temperatures from the sixteenth day through the balance of the incubation period resulted in delayed and irregular hatches.

Romanoff (1930) found that carbon dioxide concentration above a 1.0 percent level resulted in slow growth, formation of abnormalities and early embryonic death.

A number of studies on the effects of inbreeding in fowl have revealed some interesting information on problems concerned with hatchability. Cole and Halpin (1922), Dunn (1923), Jull (1929a), 1929b), (1933), Dunkerly (1930), Hays (1929, 1934), Warren (1934), and Shoffner (1948) reported a decrease in hatchability as the coefficient of inbreeding increased. Waters and Lambert (1936a) (1936b), citing results of a ten year inbreeding experiment, found no general decrease in hatchability due to inbreeding. Waters (1945) and Knox (1946) indicated that lines of inbreds could be produced without a decrease in hatchability provided selection was initiated and maintained to control the direction of homosygosity during the inbreeding experiments.

Dunkerly (1930) and Hays (1929) found a decrease in fertility for certain inbred lines as the degree of inbreeding was increased. Waters and Lambert (1936a), (1936b), and Jull (1933) reported no apparent decrease in fertility as a result of close inbreeding. Waters (1945) and Knox (1946) indicated that lines of inbreds could be produced without a general decrease in fertility if selection was rigidly maintained.

Jull (1929a), (1929b), (1933) reported that close inbreeding affected embryo mortality from the 18th to the 21st days to a greater extent than embryo mortality from the 1st to 17th days. He also found that hatchability was affected to a greater extent during the first year of inbreeding when the inbreeding coefficient was from 0 to 12.5 percent. From data collected on various breeds and lines, Shoffner (1948) calculated that the regression of hatchability on inbreeding was $-.436 \pm .132$, which indicated that for each 10 percent increase in the coefficient of inbreeding there was an average decrease of 4.4 percent in hatchability.

Warren (1934, 1942) observed that crossing breeds improved hatchability as compared with intra-breed matings. Similar data were reported by Horlacher, Smith and Wiley (1941) and Byerly, Knox and Jull (1934) who worked with birds in which the initial hatchability was low. If hatchability in matings within breeds was high, crossbreeding was as likely to decrease hatchability as to increase it. More recent work by Dudley (1944) supported this viewpoint.

Intercrossing of inbred lines of chickens has in most instances given favorable results. Jull (1933), Hays (1934), Waters (1945), and Knox (1946) all reported an increase in hatchability by crossing certain inbred lines. Jull (1933) also reported a decrease in fertility due to the crossing in inbred lines.

Waters (1938) produced evidence which showed that the crossing of highly inbred White Leghorn cocks to open-bred or random-bred White Leghorn females improved hatchability. He further stated that from the evidence presented on this subject, it would seem that results in inbreeding could be determined by the amount of success in selection accompanying inbreeding, rather than on any other factors already discussed.

Landauer (1948) described what is commonly known as the normal position of the embryo before time of hatch.

> Before hatching, chicken embryos normally assume a characteristic position within the egg so that the long axis of the embryo coincides with the long axis of the egg and the beak is located underneath the right wing, with the tip of the beak directed toward the air space in the blunt end of the egg.

It was first recognized by Sanctuary (1925) that among chicken embryos which had either died after the eighteenth day of development, or which were still alive at the end of the incubation period but had not emerged from the shell, somewhat more than 50 percent were found to be in positions different from that described as normal, just prior to hatching time.

On the basis of Sanctuary (1925), Hutt (1929), Smith (1931), Dove (1935), Waters (1935) and Byerly and Olsen (1936), the following classification of malpositions has been accepted by the majority of investigators working on these problems.

Malposition I	Head between thighs
Malposition II	Head in small end of egg
Malposition III	Head to left instead of under right wing
Malposition IV	Embryo rotated with beak away from air cell
Malposition V	Feet over head
Malposition VI	Beak above right wing instead of under it

Byerly and Olsen (1936) observed that among embryos which had died between the eighteenth day and the end of incubation period, that 41.2 percent assumed a normal position before death and that 25.7 percent were found in malposition II.

There is serious disagreement among various investigators regarding the consistency with which malpositions prove lethal to the developing embryo. Hutt (1929) and Hutt and Cavers (1931) concluded that malpositions I, II, III, IV, or VI almost invariably proved lethal. Dove (1935) and Byerly and Olsen (1936) reported that position as such is not always, and may only occasionally, be the real cause for failure to hatch. Waters (1935) revealed that an examination of live embryos from inbred and out-bred lines of poultry showed that nearly all were in one of the so-called malpositions during about the 18th day of incubation, and, if death occurred at this state of development, the embryo would not be in a normal hatching position. Thus embryonic changes in position took place after the 18th day of incubation and certain alleged malpositions were actually normal in the development of the embryo.

Other more general factors which increased the occurrence of some of the malpositions have been reported. Byerly (1938) reported that excessively high incubation temperatures would raise the frequency of malpositions I and III, whereas malposition II was found to be more than ordinarily common at temperatures below as well as above the optimum. Insko and Martin (1933) observed that frequent turning of eggs during incubation tended to reduce the incidence of malpositions.

Smith (1931) revealed that low hatchability, induced by poor parental rations, was accompanied by an increase in the occurrence of malpositions. Byerly and Olsen (1934) were in agreement with Smith, especially in regard to malposition III. Polk and Sipe (1940) observed that vitamin A deficient diets caused a higher frequency of all malpositions except malposition VI. Similiarly, Insko (1934) found that dietary vitamin D, from cod liver oil, would decrease the frequency of malpositions. Upp (1934) found that inbreeding tended to increase the incidence of malpositions.

As many as sixteen lethal mutations, or hereditary factors causing death of the embryo, have been reported at various times. One of the most common and well known lethals, the Creeper fowl, was reported by Dunn and Landauer (1926), Landauer and Dunn (1930) and Landauer (1932). The characteristic external trait of Creeper chickens was described as being a shortness of their extremities. Due to the histological features of the long bones, the Creepers were placed in the category of skeletal abnormalities known as chondrodystrophy. They further observed that true-breeding Creeper chickens failed to materialize, an indication that the Creeper mutation was lethal in a homozygous state. Their work with outcrosses to normal stock showed that the Creeper traits were due to a dominant mutation but that inter se matings of Creepers produced Creeper and normal offspring in the ratio of 2:1 instead of the expected 3:1. This suggested a lack of the homozygous class of Creepers. Landauer (1932) further observed that most of the homozygous Creepers died after only three days of incubation but that a few of these were able to live into the late stages of embryonic development, with none ever hatching. The older embryonic homozygous Creepers showed extensive abnormalities of the eyes, the head in general and especially of the extremities.

Asmundson (1936) reported a lethal mutation in poultry in which the embryos exhibited deformed maxillae. The maxillae were absent or much reduced in size, while the pre-maxillae were present but often reduced in size. The mode of inheritance appeared to be a simple autosomal recessive. A suggested reason for the lethal nature of this condition was that the beak of the embryo was too weak to pip the shell, thus preventing the chick from hatching.

A mutation producing a variable reduction in the length of the upper beak and a shortening of the long bones of extremities was reported by Landauer (1941). The majority of the "short upper beak" embryos died during the last days of incubation although a few did manage to hatch. This condition suggested the presence of a semi-lethal genetic factor. The multiple characteristics of this mutation were reported as being caused by a single, autosomal, recessive factor.

Asmundson (1939, 1942) observed a lethal micromelia which appeared to be a homozygous expression of two recessive genes. An embryo in this condition was marked by very short extremities, a short and curved upper beak and a defective lower beak. A large number of these embryos survived to the third week but none ever hatched.

Waters and Bywaters (1943) described a lethal mutation of the fowl which they designated as "wingless". The wings were generally entirely lacking but occasionally wing vestiges could be found on one or both sides of the body. Many of these "wingless" embryos survived to the end of the incubation period but none ever hatched. This condition was thought to be brought about by one recessive gene substitution.

Marble, Hammers and Harper (1944) described a lethal mutation in poultry in which Cerebral hernia was a regular feature and the lower mandible usually missing. The upper mandible was usually abnormal, being reduced in size and curving upwards. The eyes were generally abnormal and the facial parts reduced in size. This condition was inherited as an autosomal recessive.

A lethal mutation in poultry involving a shortening of the lower mandible was reported by McGibbon (1946). The shortened lower mandible rarely exceeded one half the length of the upper mandible in unhatched embryos. This condition was considered semi-lethal since approximately one-half of the affected embryos hatched, though many perished immediately following hatching. This condition was inherited as an autosomal recessive.

It is of interest that Landauer (1946) reported successful attempts to select against expression of the "short upper beak" mutation in fowl. He found that by selecting against the lethal action of and the production of beak defects by the "short upper beak" mutation he was able to increase the percentage of hatched chicks to nearly normal showing little if any of the beak defects previously mentioned. He concluded that "modifiers" were a part of the normal genic make-up of beak development, particularly in White Leghorns.

Embryo mortality is not distributed at random over the entire incubation period but occurs more frequently at certain periods of development than at others. Byerly (1930) found three mortality peaks, occurring mainly on the third, tenth, and last three days of incubation. Byerly, Knox and Jull (1934), working with various inbred lines, reported two principal peaks of mortality, one on the third day of incubation and the other during the last three days of incubation. They concluded that the effects of crossbreeding and inbreeding could be seen at these two critical peaks in embryo development. Upp (1934), working with various types of matings, reported two principal periods of embryo mortality, one during the first five days of development and a second from the 17th to 21st days.

MATERIALS AND METHODS

The source of the Barred Plymouth Rocks used in this study originated from the Wilcox and Cochran strains. Prior to 1947, these two strains were crossed and recrossed with inadequate records kept regarding the parentage of each individual. For this reason, it was considered that this project was initiated with open-bred stock.

During 1948, pens consisted of brother x sixter, son x dam, and half-brother x half-sister matings. Pen matings consisted of 10 pens containing a total of 150 hens. Individual pen matings ranged from 8 to 22 hens per male.

During 1949, pens consisted of second generation brother x sister, son x dam, son x grandam, and half-brother x sister matings. During 1949, open-bred stock of New Hampshires, Single Comb White Leghorns, and White Plymouth Rocks were included. Pen matings consisted of 14 pens of inbred Barred Plymouth Rocks involving 145 hens, one pen of White Plymouth Rocks consisting of 16 females, one pen of New Hampshires consisting of 15 hens, and two pens of Single Comb White Leghorns consisting of 31 birds were used. Individual pen matings ranged from 8 to 16 females per male.

An all-purpose ration, considered adequate for the various nutrients, was fed to all birds during the two years reported here. In 1948, the birds were kept in semi-confinement, but in 1949, complete confinement during the breeding season was resorted to.

Eggs were set at weekly intervals. The hatching season for 1948 extended from February 23 to May 4, and for the 1949 hatching season from February 3 to June 24. All eggs were identified as to parentage and date of production. Each egg was pedigreed hatched. All clear eggs, at time of testing on the 18th day of incubation, were considered infertile and discarded. At completion of the hatch, chicks were removed from the pedigree baskets, wing banded and the number of strong and weak chicks recorded. All unhatched eggs were broken out to determine the position, age at embryonic death and physical appearance of each embryo and data recorded for future analysis. A total of 11,112 eggs were set during the two year period.

For ready reference and clarification, some of the terms used in this thesis are defined or described:

Chondrodystrophy - a condition where the embryo exhibits a parrot-like beak, shortened extremities, bent bones and the long bones of the leg are more reduced in length than those of the wing.

Club down - A tight matting or curling of the down which gives the appearance of a number of small knobby clubs over the body of the chick.

Cranial hernia - An incomplete enclosure of the brain, part of which may be seen exuding.

Inbred - Mating of related individuals.

Micromelia - Abnormal smallness of the limbs.

Open-bred - Refers to stock that is not related but within the same breed or variety.

Out-bred - Refers to a mating of inbred individuals to those unrelated.

EXPERIMENTAL

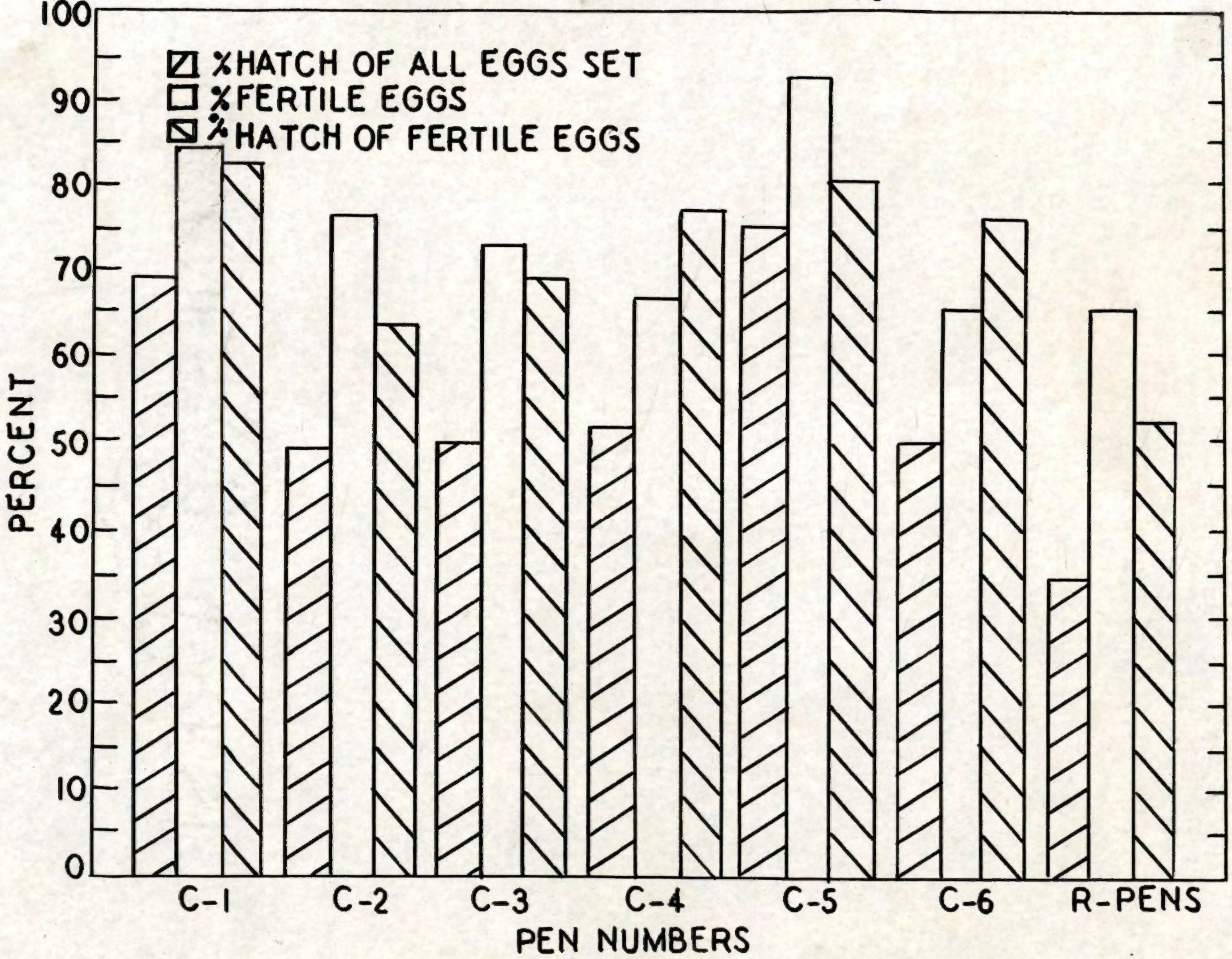
Results and Discussion

During the 1948 hatching season, a total of 3968 eggs were set from 10 pens of inbred Barred Plymouth Rocks, representing 150 hens. The fertility of all eggs set was found to be 75.1 percent. This figure is somewhat lower than is normally expected from open-bred stock in commercial hatcheries. Fertility records for individual pens ranged from a low of 51.1 percent for pen R-7, to a high of 93.3 percent for pen C-5. Individual pen records on fertility are presented in Graph I.

During the 1949 hatching season, a total of 5170 eggs were set from 14 pens of inbred Barred Rocks, a total of 145 hens. In addition to eggs used from the inbred lines, there were included 1974 eggs from four pens of open-bred birds, consisting of New Hampshires, White Plymouth Rocks, and Single Comb White Leghorns, a total of 62 hens. Fertility for the inbred lines was found to be 58.9 percent as compared to 74.9 percent for the open-bred stock. The fertility figures for the inbred lines are considerably lower than figures for a similar period in 1948. Attention should be called to the fact that the percent fertility for 1948 approximated the percent fertility for the open-bred stock in 1949. The degree of inbreeding in 1948 was small and may account for this condition. The open-bred lines gave a percent fertility somewhat lower than is normally expected, but it was still much higher than that produced by the inbred lines in 1949. On the basis of this limited data, it may be expected that the percent fertility would decrease as the coefficient of inbreeding increased. This is in agreement with Hays

GRAPH I

FERTILITY AND HATCHABILITY - 1948



(1929) and Dunkerly (1930). Fertility figures for individual pens in the inbred lines for 1949 ranged from a low of 18.2 percent for pen L-2 to a high of 86.4 percent for pen L-5. Fertility recorded for the open-bred lines ranged from a low of 48.9 percent for the White Rock pen to a high of 92.2 percent for White Leghorn pen (3-2). Individual pen records for 1949 are presented in Graph II.

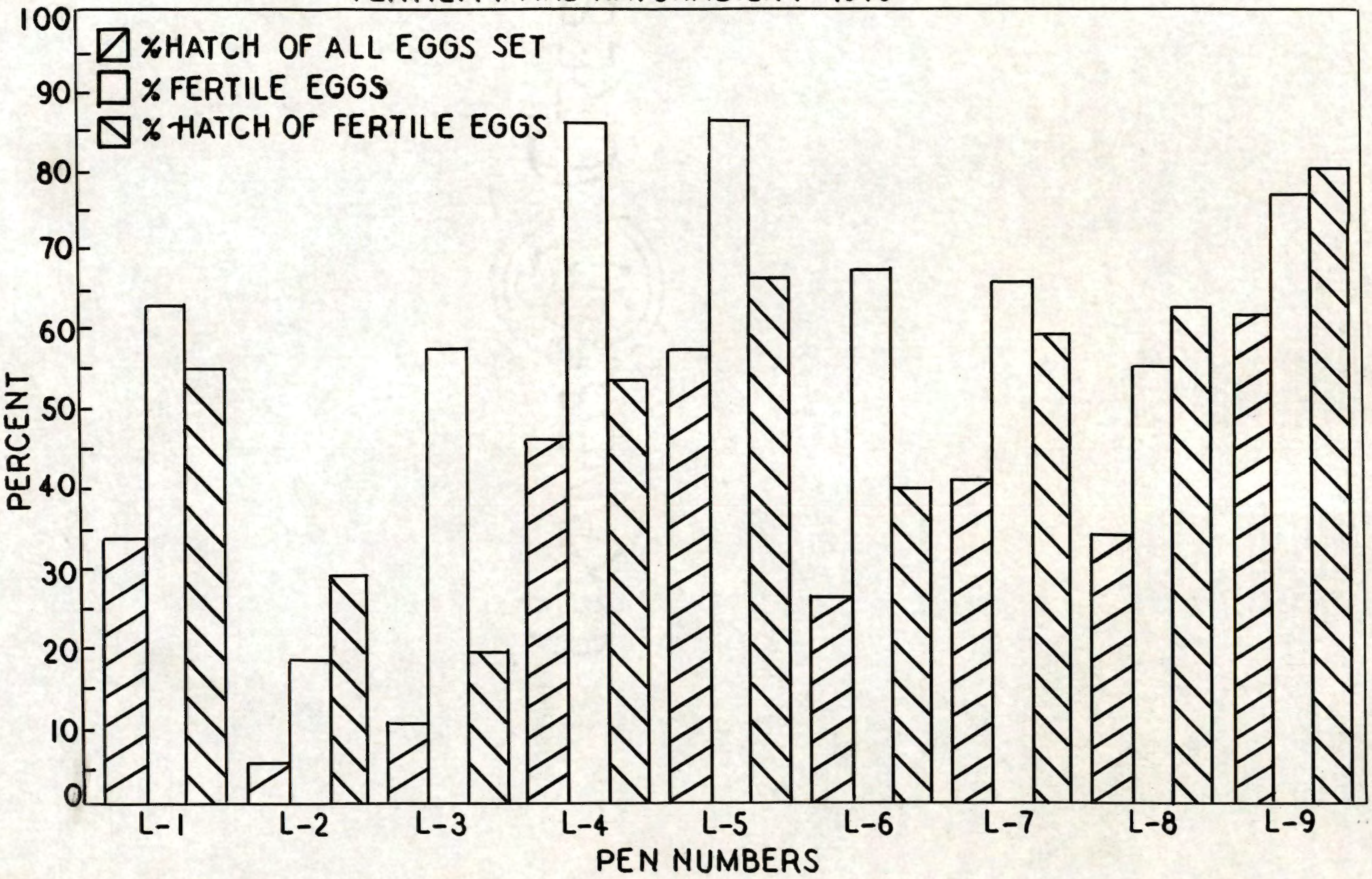
The commercial hatcheryman is interested in the total number of chicks that hatch from all eggs set and usually expects at least a 70 percent hatch under ordinary operating conditions. In a study of hatchability, it is essential to consider the percent hatch of fertile eggs set as well as the percent hatch of all eggs set.

For the ten inbred pens of 1948, the percent hatch of all eggs set was 55.2 while the percent hatch of all fertile eggs was 73.5. This reveals that even though only a little over one-half of the total eggs set actually hatched, almost three-fourths of all fertile eggs set hatched. The percent hatchability of all eggs set ranged from a low of 9.7 for pen R-7 to a high of 76.1 percent for pen C-5. The percent hatch of all fertile eggs set ranged from a low of 18.9 for pen R-7 to a high of 82.9 for pen C-1. Individual pen records for percent hatch of all eggs set and for percent hatch of fertile eggs are presented in Graph I.

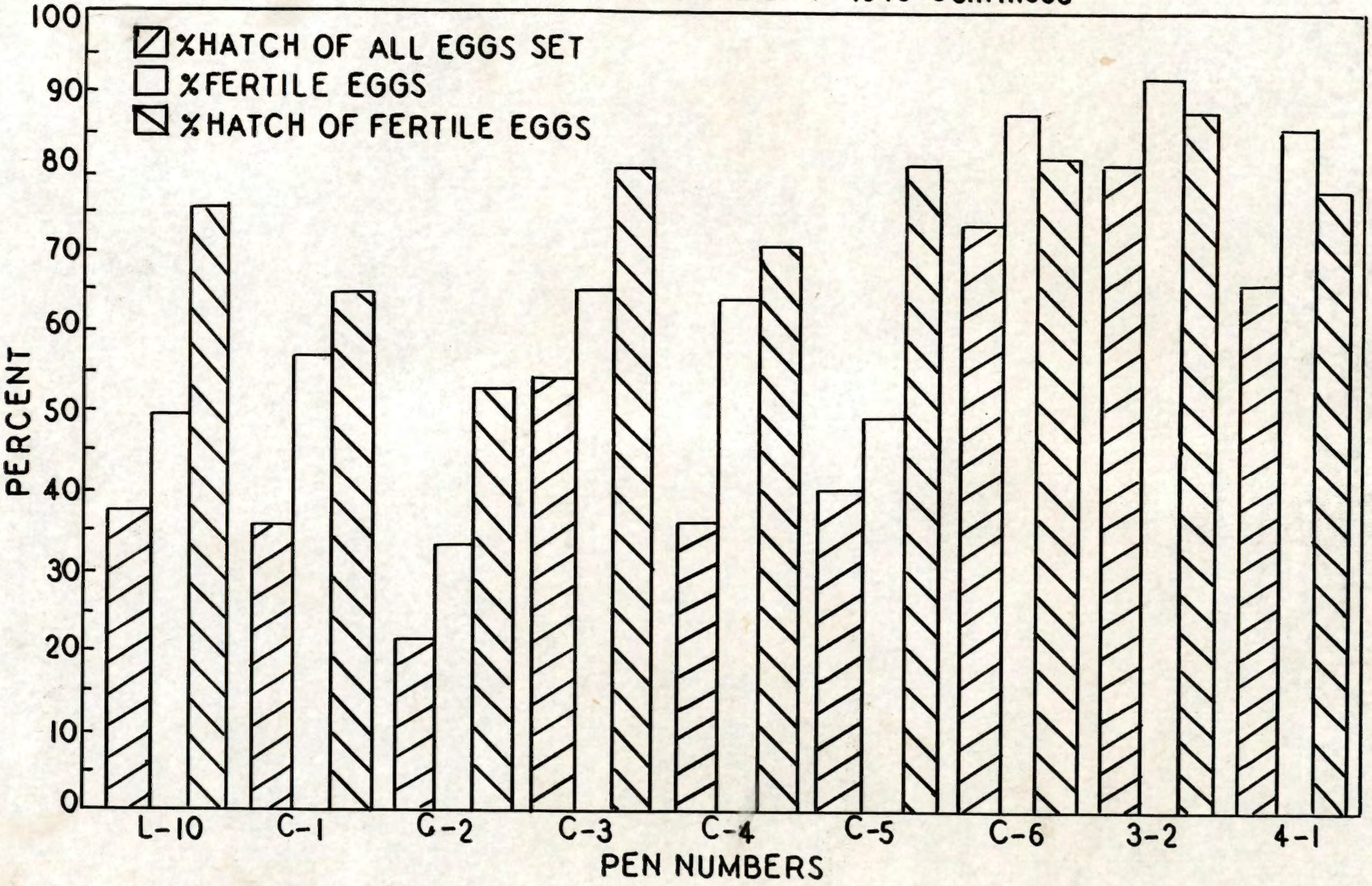
From the 14 pens of inbred birds used during the 1949 season, the percent hatch of all eggs set was only 35.3 while the percent hatch of all fertile eggs was 58.9. This shows a severe decline in hatchability from 1938 to 1949. This is in agreement with Cole and Halpin (1922),

GRAPH 2

FERTILITY AND HATCHABILITY - 1949



GRAPH 2
FERTILITY AND HATCHABILITY - 1949 Continued



Dunn (1923), Jull (1929a), (1929b), (1933), Dunkerly (1930), Hays (1929), (1934), Warren (1934), and Shoffner (1948), who reported that a decline in hatchability was observed as the coefficient of inbreeding increased. The percent hatchability of all eggs set for the inbred lines ranged from a low of 5.3 for pen L-2 to a high of 60.5 for pen L-9. It is of interest to note that pen L-5 which was high in percent fertility was second high in this category with a 57.4 percent hatch of all eggs set. The percent hatch of all fertile eggs for the inbred lines ranged from a low of 18.6 for pen L-3 to a high of 80.7 for pen C-3.

For the four pens of open-bred birds, the percent hatch of all eggs set was 61.7, while the percent hatch of all fertile eggs was 82.4. These results are lower than considered desirable for breeders, but definitely higher than either of the two inbred groups in 1948 or 1949. The percent hatch of all eggs set ranged from a low of 39.8 for the White Rocks to a high of 80.5 for one pen of White Leghorns (3-2). The percent hatch of all fertile eggs ranged from a low of 75.9 for one pen of White Leghorns (pen 4-1) to a high of 87.4 for a second pen of White Leghorns (pen 3-2). Individual pen records for both inbred and open-bred lines may be found in Graph II.

After all chicks were removed from the incubator, each egg that failed to hatch was broken out to determine the embryo position, age at embryonic death and physical appearance. A total of 1919 eggs were broken out during the two year period. A complete list of all embryo positions and abnormalities was compiled for 1948 and 1949, summarized and described in Tables I and V.

TABLE I

POSITION OF CHICK EMBRYO IN BROKEN EGGS AT END OF INCUBATION PERIOD DURING HATCHING SEASON OF 1948 AND 1949

Position Number	Description
1	Embryo in normal position
2	Head in the large end - over the right wing
3	Head in the large end - on the right side
4	Head in the large end - under the right foot
5	Head in the large end - under the right thigh
6	Head in the large end - under the left wing
7	Head in the large end - under the left foot
8	Head in the large end - on the left side
9	Head in the large end - over the left wing
10	Head in the large end - under the left thigh
11	Head in the large end - covered over with both feet
12	Head in the small end - over the right wing
13	Head in the small end - under the right wing
14	Head in the small end - on the right side
15	Head in the small end - under the right foot
16	Head in the small end - under the right thigh
17	Head in the small end - over the left wing
18	Head in the small end - under the left wing
19	Head in the small end - on the left side
20	Head in the small end - under the left thigh
21	Head in the small end - under the left foot
22	Head in the small end - covered over with both feet

TABLE II

OCCURRENCE AND INCIDENCE OF EMBRYONIC POSITIONS - 1948

Position	Days on Which Embryonic Death Occurred																				Totals	
Number	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	SA*	Number	Percent
1	2	5	3	4		8	4	8	3	5	1	2	3		3	17	18	29	78	113	306	49.0
2													3		2	9	4	6	23	29	76	12.2
3												2	3		1		3	4	6	3	22	3.5
4																	2	1			3	0.5
5																5	1	1			7	1.1
6													1			4		1	1	1	8	1.3
7																	1				1	0.2
11										1		1	3		1	4	3				13	2.1
12																1	2	1	2	1	7	1.1
13													2		2	15	7	4	4	3	37	5.9
14								1		1			1			2	2	2			9	1.4
15															1		3	2	1	2	9	1.4
16															1	2	9	2			14	2.2
17															1						1	0.2
18													1		1	3	5	4	2		16	2.6
19																		1		1	2	0.3
20															1	4	10	1			16	2.6
21																1	1	1			3	0.5
22												1	5	3	4	20	23	14	2	3	75	12.0
Totals	2	5	3	4		8	4	9	3	7	1	6	22	3	18	87	94	74	119	156	625	100.0

*SA - Refers to embryos alive at end of incubation period

Occurrence, and incidence of embryonic positions are presented in Tables II and III, while the occurrence and incidence of abnormal embryos are presented in Tables IV and VI.

It is of interest to note that 49.0 percent of all broken out embryos in 1948 were found in a "normal" hatching position, while 51 percent of the embryos exhibited some malposition. Position 2, head in large end over right wing, was observed most frequently, being found in 12.2 percent of all broken out embryos. Another malposition of frequent occurrence during 1948 was position 22, head in small end covered with both feet, found in 12.0 percent of all broken out embryos. Positions 1 and 22 may be observed in Figures 1 and 6, Plate I. Of the reported 22 positions described for both years, nineteen were found in broken out embryos during 1948.

Similar results for the 1949 hatching season were obtained for broken out embryos. The inbred lines for 1949 had 48.7 percent of all broken out embryos in a normal hatching position. This left 51.3 percent of the embryos showing some form of malposition. The incidence of position 2 again occurred frequently, being found in 9.6 percent of all broken out embryos. Position 13, head in small end under right wing, was observed in 10.6 percent of all broken out embryos, while position 22 occurred in 7.4 percent. Of the 22 reported positions described for both years, 20 occurred in 1949.

Results for the open-bred lines showed that 45.8 percent of all broken out embryos were found in a normal hatching position.

Plate 1

Explanation

Top row - left to right

Fig. 1 - Embryo in so-called normal hatching position
Fig. 2 - Embryo with head in large end of egg-under left wing
Fig. 3 - Embryo with head in small end of egg-on right side

Botton row - left to right

Fig. 4 - Embryo with head in large end of egg-over right wing
Fig. 5 - Embryo with head in large end of egg-twisted to the left and turned away from air cell.
Fig. 6 - Embryo with head in small end of egg-covered with both feet.

Table III

OCCURRENCE AND INCIDENCE OF EMBRYONIC POSITIONS - 1949

Position Number	Days On Which Embryonic Death Occurred																				Totals	
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	SA*	Number	Percent
1	1	3	12	14	5	26	4	6	11	15	1	1	1			6	46	78	157	162	549	49.0
2												1				2	37	39	22	6	107	9.6
3																	1	3			4	0.4
4																	5	6			11	1.0
6															1	3	31	35	6	4	80	6.7
7																1					1	0.1
8																				1	1	0.1
9																1	3	1			5	0.5
10																1					1	0.1
11																	2	5			7	0.6
12																1	7	5	1	4	18	1.6
13													1	1	2	9	56	25	13	12	119	10.6
14																2	6	1	1		9	0.8
15																	10	2	2	1	15	1.3
16												1				1	11	8			21	1.9
18																4	21	19	4	2	50	4.5
19															1	2	3	3			9	0.8
20																1	9	9	1	1	21	1.9
21																	7	1	1		9	0.8
22															1	6	41	30	3	2	83	7.4
Totals	1	3	12	14	5	26	4	6	11	15	1	3	2	1	5	40	295	270	211	195	1120	100.0

*SA - Refers to embryos alive at end of incubation period

TABLE IV

OCCURRENCE AND INCIDENCE OF ABNORMAL EMBRYOS - 1948

Condition Number	Days On Which Embryonic Death Occurred																			Totals	
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	SA*	Number	Percent
1										2	2		1	1							6	15.0
2																		1	1		2	5.0
3																1	1				2	5.0
5															1						1	2.5
7											1										1	2.5
12																	1				1	2.5
13																			1	1	2	5.0
14																	1				1	2.5
15															1						1	2.5
16																1	1				2	5.0
17																1					1	2.5
18																	1				1	2.5
20																			1	5	6	15.0
22									2	2					1	1					6	15.0
23																				1	1	2.5
24													1								1	2.5
26													1								1	2.5
40																1					1	2.5
46													1				1				2	5.0
47													1								1	2.5
Totals									2	4	3		5	1	3	5	7	1	3	7	40	100.0

*SA - Refers to embryos alive at end of incubation period

This figure is slightly under that of the inbred stock for both years of inbreeding. Position 2 appeared most often in the open-bred stock, being found in 12.7 percent of all broken out embryos. Position 13 was found in 5.7 percent of all broken out embryos, while Position 9 was observed in 5.2 percent of the cases. Of all the broken out embryos for both years, Positions 2, 13, and 22 were found most often, accounting for 28.4 percent of all malpositions.

A study was made of embryo malpositions from the 18th day through the 22nd day of incubation for the purpose of detecting possible changes in embryo position during this period. On the 18th and 19th days of incubation, it was found that of all embryos broken out, approximately 17.5 percent were in a normal hatching position. From the 19th day through the 22nd there was a definite increase in the percent of embryos in normal hatching position. This figure increased from 32.5 percent for the 20th day to 77.7 percent for the 22nd day. This is in partial agreement with Waters (1935) who observed that nearly all live embryos examined were in one of the so-called malpositions during about the 18th day of incubation.

The incidence of malpositions in 1949 did not materially increase over that for a similar period in 1948. From the limited data available, it appeared that close inbreeding did not increase the incidence of malpositions from one generation to another. This observation fails to agree with Upp (1934) who stated that close inbreeding resulted in an increase of embryos in malposition. However, it should be pointed out that the 1949 breeders were selected from dams producing a low incidence of embryos in malposition.

From a total of 1919 broken out embryos for both 1948 and 1949, there were found 50 so-called abnormalities, many of which have been described by other investigators as being of a lethal nature. Insufficient work has been initiated to determine the mode of inheritance or genetic background of many of these reported anomalies. Due to a lack of exacting information, workers have made certain assumptions regarding the nature and lethality of certain reported malformations or abnormalities. A complete list and description of all abnormal embroyos observed in this study and their positions is given in Table V.

Studies in 1948 revealed that a total of 40 embryos, or 6.0 percent of all broken out specimens showed some abnormal condition. Of this total 15.0 percent were found in condition 1, i.e., thin, spindly and undeveloped embryo. This condition is illustrated in Plate II, Figure 1. Conditions 20 and 22 were also found in 15.0 percent of all abnormal embryos. Together, these three conditions make up about one-half of all anomalies observed. Of the 50 abnormal embryos reported and described during the two years, 20 were found in 1948.

Studies of the inbred lines for 1949 showed that a total of 118 specimens, or 11.3 percent of all broken out embryos, exhibited some abnormality. Of this total, 38.1 percent were found in condition 1. This condition by far exceeded any that was reported during 1949. Condition 20 was observed in 4.2 percent of all abnormal embryos. Condition 44 occurred in 5.1 percent and condition 48 in 13.5 percent of all abnormal embryos. Both of these conditions were concerned with short shanks. Condition 49, described as chondrodystrophy, was observed in 21.2 percent of all abnormal embryos. None of these hatched.

TABLE V

ABNORMALITIES AND POSITIONS OF EMBRYOS IN BROKEN EGGS AT END OF INCUBATION PERIOD DURING HATCHING SEASONS 1948-49

Condition Number	Description
1	Thin, spindly and undeveloped embryo
2	Cross beak - embryo in normal position
3	Cross beak - head in large end-over right wing
4	Cross beak - head in small end-over right wing
5	Cross beak - head in small end-covered over with both feet
6	Cross beak - head in small end-under left foot
7	Cross beak - thin, spindly, undeveloped embryo
8	Cross beak - left eye missing-head in small end-covered over with both feet
9	Cross beak - right eye missing-head in small end-covered over with both feet
10	Cross beak - both eyes missing-embryo in normal position
11	Cross beak - cranial hernia-left eye missing-one toe only to each foot-viscera protruding-embryo in normal position
12	Cross beak - four legs-two bodies-head in small end-over left wing
13	Parrot beak - head in large end-over right wing
14	Parrot beak - thin, spindly, undeveloped embryo
15	Head through the yolk sac - in the large end-over the right wing
16	Head through the yolk sac - in the large end-covered over with both feet
17	Head through the yolk sac - in the small end-on the right side
18	Head through the yolk sac - in the small end-on the left side
19	Head through the yolk sac - in the small end-covered over with both feet
20	Unabsorbed yolk sac - embryo in normal position
21	Unabsorbed yolk sac - head in small end-on right side
22	Club down - embryo in normal position
23	Club feet - head in small end-under left wing

TABLE V

ABNORMALITIES AND POSITIONS OF EMBRYOS IN BROKEN EGGS AT END OF INCUBATION PERIOD DURING HATCHING SEASONS 1948-49 (Continued)

Condition Number	Description
24	Cranial hernia - head in small end-covered over with both feet
25	Cranial hernia - both eyes missing-thin, spindly, undeveloped
26	Cranial hernia - club down-head in small end-under right foot
27	Cranial hernia - parrot beak-head in small end-on left side
28	Cranial hernia - thin, spindly, undeveloped embryo
29	Short upper mandible - both eyes missing-head in large end-over the right wing
30	Upper mandible and both eyes missing-head in small end-covered over with both feet
31	Upper mandible and both eyes missing-head in small end-under lift thigh
32	Upper mandible and both eyes missing-thin, spindly, undeveloped embryo
33	Short lower mandible - thin, spindly, undeveloped embryo
34	Lower mandible missing - head in large end-on left side
35	Right wing missing - head in large end-over right wing
36	Headless embryo - right wing missing-head in large end-over right wing
37	Short shanks - head in large end-over right wing
38	Short shanks - head in large end-under right thigh
39	Short shanks - both eyes and upper mandible missing-head in large end-over right wing
40	Short shanks - head in small end-on the right side
41	Short shanks - head in small end-over right wing
42	Short shanks - head in small end-under right wing
43	Short shanks - head in small end-under right foot
44	Short shanks - head in small end-on left side
45	Short shanks - head in small end-under left wing
46	Short shanks - head in small end-covered over with both feet
47	Short shanks - parrot beak-cranial hernia-head in small end on right side
48	Micromelia
49	Chondrodystrophy
50	Chondrodystrophy - head through yolk sac

TABLE VI

OCCURRENCE AND INCIDENCE OF ABNORMAL EMBRYOS - 1949

Condition	Days on Which Embryonic Death Occurred																				Totals	
Number	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	SA*	Number	Percent
1					1	1		1	3	6	2	2	12		10	9		1			48	35.8
2																			1		1	0.7
3																		1			1	0.7
6																				1	1	0.7
8																	1				1	0.7
9																1					1	0.7
10															1						1	0.7
11													1								1	0.7
19																1					1	0.7
20																				5	5	3.7
21																				1	1	0.7
24																		1			1	0.7
26															1						1	0.7
28																1					1	0.7
29																	1				1	0.7
30																1					1	0.7
31																	1				1	0.7
32															1						1	0.7
33																1					1	0.7
34																		1			1	0.7

*SA - Refers to embryos alive at end of incubation period

TABLE VI

OCCURRENCE AND INCIDENCE OF ABNORMAL EMBRYOS - 1949 (Continued)

Condition	Days on Which Embryonic Death Occurred																					
Number	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	SA*	Number	Percent
35																		1			1	0.7
36										1											1	0.7
37																	1				1	0.7
38																		1			1	0.7
39															1						1	0.7
40													1								1	0.7
41																	1				1	0.7
42																	2				2	1.5
43																1	1				2	1.5
44																		6		1	7	5.2
45																1					1	0.7
48								1		1				1		5	7	1			16	11.9
49													2			3	19	1			25	18.7
50																2	1				3	2.2
Totals				1	1			2	3	8	2	2	16	1	14	26	35	14	1	8	134	100.0

*SA - Refers to embryos alive at end of incubation period

Plate 2

Explanation

Top row - left to right

Fig. 1 - Thin spindly undeveloped embryo
Fig. 2 - Cranial hernia - Micromelia - Club down
Fig. 3 - Embryo choked with yolk sac

Botton row - left to right

Fig. 4 - Cranial hernia - thin spindly undeveloped embryo
Fig. 5 - Crossed beak - Micromelia
Fig. 6 - Micromelia

Conditions 1 and 48 may be seen in Figures 1 and 6 of Plate 2. Condition 49 is illustrated in Figure 4, Plate 3. Of the total, 50 abnormal embryonic conditions reported and described for 1948 and 1949, 34 of these were found in 1949.

Studies of the open-bred stock in 1949 revealed that 7.5 percent of all broken out embryos were found in some abnormal condition. Only 16 of 212 embryos exhibited any abnormal condition when broken out. Condition 1 was most often observed, this occurring 3 times or 19.0 percent. The frequence at which abnormal embryos might occur in these breeders cannot be predicted due to the small numbers available for study.

The incidence of abnormalities for the inbred stock of 1949 was considerably higher than that for the inbred stock of 1948. This factor is considered as evidence that breeding is an important factor in the occurrence of abnormal embryos.

The age of the embryo at time of death for both years was determined and recorded. This information is presented as a mortality curbe in Graph III. Two minor peaks of mortality were observed on the 8th and 12th days of incubation. A third peak of mortality occurred on the 15th day of incubation. It is of interest to note that a large number of thin, spindly and undeveloped embryos died on this day of incubation. A fourth period of mortality occurred from the 18th through the 22nd days of incubation, with the peak reached on the 19th day. Of all the embryos broken out for both years, 22.5 percent died on the 19th day. All embryos that were still alive

Plate 3

Explanation

Top row - left to right

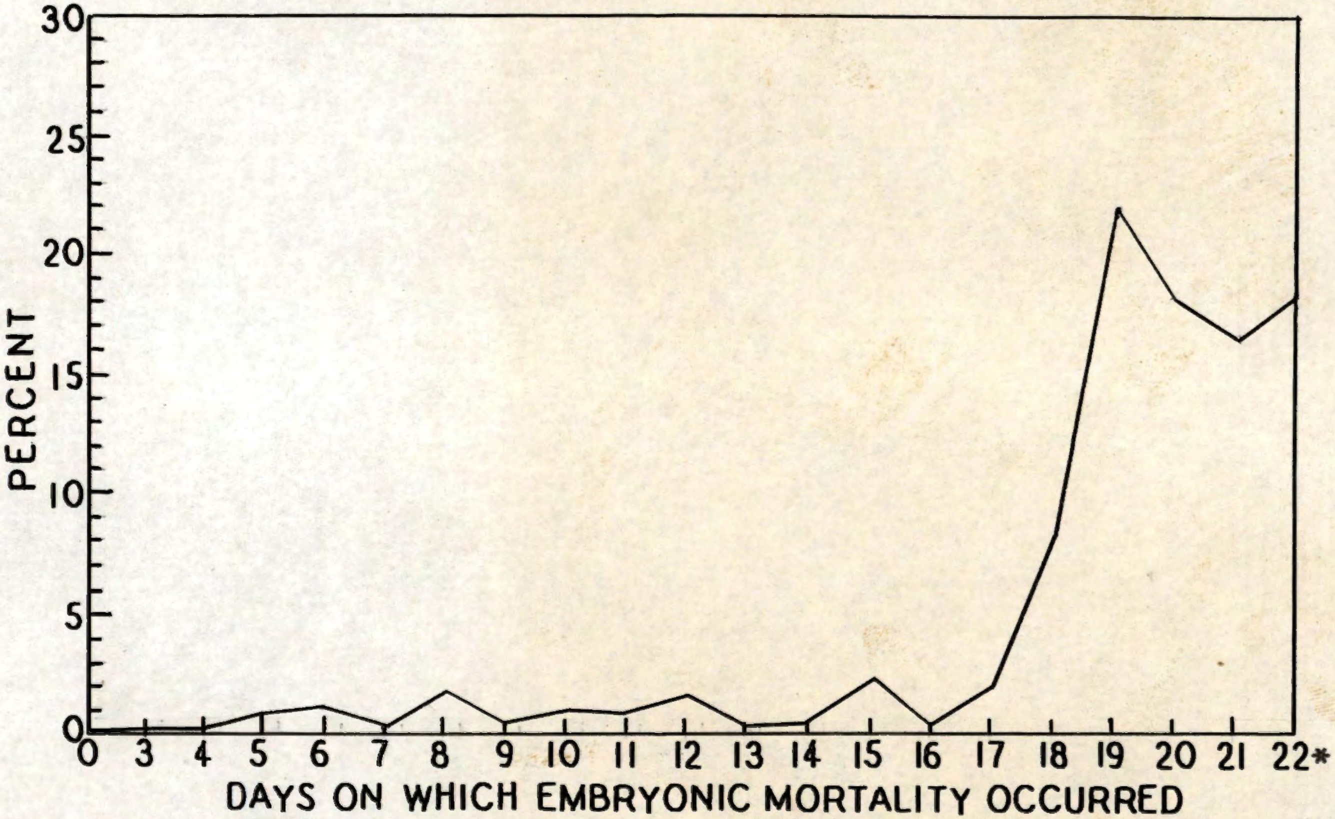
Fig. 1 - Left wing missing - vestige remains
Fig. 2 - Upper mandible missing
Fig. 3 - Lower mandible missing

Botton row - left to right

Fig. 4 - Chondrodystrophy
Fig. 5 - Fifteen day old headless embryo
Fig. 6 - Cross beak - one toe only to each foot-viscera protruding

GRAPH 3

EMBRYONIC MORTALITY - 1948-49



* This includes all embryos still alive at end of incubation period

when broken out were listed as dying on the 22nd day as it was felt that these embryos would never have hatched under conditions generally accepted as good incubation operations. Of the embryos broken out on the 22nd day, 19.1 percent were still alive. Of all the embryos broken out 85.9 percent died during the fourth period of mortality. Byerly (1930), Byerly, Knox and Jull (1934) and Upp (1934) reported a similar period of mortality. Byerly (1930), Byerly, Knox and Jull (1934) and Upp (1934) reported one period of embryo mortality on the 3rd, 4th, and 5th days. This early embryonic mortality period failed to materialize in this study. This was probably due to the fact that examinations were made only on the 22nd day, thus few embryos dying at an early age were suitable for examination at that time.

In 1949 breeders were selected on the basis of performance. All poor breeders were discarded. In 1949, the production of malpositions and anomalies by daughters could not be associated with the performance of their dams. In this respect, it should be noted that hens number 695, 1109, and 1168, all full sisters from dam number 389, produced a large number of embryos showing chondrodystrophy. All fertile eggs from this dam (389) hatched and thus no dead embryos were available for examination.

On the basis of the data presented in this study, selective inbreeding must be practiced to obtain the desired results.

The technique in using inbred lines of poultry to secure homozygous lines of breeding stock is a relative new procedure in poultry breeding work but has been well established by corn breeders. The success that a poultry breeder might expect in initiating an inbreeding program will depend on the genetic constitution of the original stocks. The data presented indicate a high percentage of malpositions and abnormal embryos might be expected within the first two generations of an inbreeding program. Through rigid selections more uniform breeding stock should develop, free from those characteristics which appear to be carried as recessive factors.

More rapid progress in producing efficient individuals should logically be expected if one might predict the performance of a future generation. This would reduce to a degree the necessity for the time consuming practice of progeny testing. Theoretically it might be possible to produce outstanding offspring through recombining or crossing inbred lines within a given breed. Another use of inbred lines that looks highly practical is crossing inbred lines of different breeds.

This problem is merely a basis for such a program, the results of which will not be known until good inbred lines have been developed and the recombining value of the lines determined by locating desirable lines with which the inbreds will be compatible.

SUMMARY

Data are reported on fertility and hatchability studies for 1948 and 1949 involving 11,112 eggs from open-bred New Hampshires, White Plymouth Rock, Single Comb White Leghorn and inbred Barred Plymouth Rock chickens.

In the inbred lines, the percent fertility decreased 16.2 percent from 1948 to 1949. It was found that as the intensity of inbreeding increased, the percent fertility decreased.

The percent hatch of all eggs set decreased 16.9 percent from the 1948 to the 1949 hatching season, while the percent hatch of all fertile eggs decreased 14.6 for this same period. A definite decrease in hatchability occurred as the degree of inbreeding increased.

A total of 22 malpositions and 50 abnormal embryo conditions were recorded and described for both hatching seasons, involving 1919 broken out eggs. The incidence of malpositions in 1949 failed to exceed those of 1948. The data indicated that close inbreeding did not increase the incidence of malpositions.

A study of embryonic positions revealed that on the 18th and 19th days, 17.5 percent of all broken out embryos were in a normal hatching position; this figure increased from 32.5 percent for the 20th day to 77.7 percent for the 22nd day.

Position 2, head in large end over right wing, and position 22, head in small end covered with both feet, occurred most frequently during the two years study.

The incidence of abnormal embryos in 1949 increased 5.3 percent over those found in 1948. Abnormal condition 1 (thin spindly and undeveloped), condition 48 (Micromelia), and condition 49 (Chondrodystrophy) were found most frequently in broken out embryos during both hatching seasons. The incidence of abnormal embryos increased as the intensity of inbreeding increased.

Three minor peaks of embryo mortality were observed on the 8th, 12th, and 15th days of incubation. A major period of embryo mortality occurred from the 18th through the 22nd days. The mortality peak was reached on the 19th day of incubation. Of all broken out embryos, 85.9 percent died during the latter mortality period.

In 1949, the production of malpositions and anomalies by daughters could not be associated with the performance of their dams.

On the basis of the data presented in this study, it is believed that rigid selective inbreeding must be practiced to secure optimum or desired results.

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