GENETIC AND ENVIRONMENTAL FACTORS INFLUENCING GROWTH IN THE CHICKEN

by

MICHAEL CAMPBELL DELAND

B.S.A., University of British Columbia, 1963

A THESIS SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF SCIENCE

in the Department
of
Poultry Science

We accept this thesis as conforming to the required standard

THE UNIVERSITY OF BRITISH COLUMBIA

AUGUST, 1965

In presenting this thesis in partial fulfilment of the requirements for an advanced degree at the University of British Columbia, I agree that the Library shall make it freely available for reference and study. I further agree that permission for extensive copying of this thesis for scholarly purposes may be granted by the Head of my Department or by his representatives. It is understood that copying or publication of this thesis for financial gain shall not be allowed without my written permission.

Department of Poultry Science

The University of British Columbia,
Vancouver 8, Canada

Date August 10th, 1965

ABSTRACT

A comparison was made of rates of growth and body weights between pre- and post-hatching stages of development of the chicken as affected by strains or strain crosses, egg storage, egg weights, time of hatch, sex and post-hatching nutritional environment. The interrelationships of these factors were also investigated.

The results of the investigation indicate that practically all of the variation of six-week body weight in this data was successfully accounted for by the combined effects of six-week growth rate, hatching weight and embryonic growth rate between eight and twelve days. The data also indicate that gains in six-week body weight may be made by selecting for early growth rate without concomitant change in other traits.

Hatching time, hatching weight and post-hatching growth appear to be affected by egg storage only if some form of stress is present during incubation. In the absence of stress it appears that a compensatory increase in rate of embryonic growth overcomes the effect of a delayed initiation of growth caused by egg storage.

A significant influence of sex on embryo weight in favour of the male embryos was observed.

TABLE OF CONTENTS

Page

LIST OF TABLES

ACKNOWLEDGEMENT

The writer wishes to express his appreciation to Dr. C.W. Roberts, Assistant Professor, and Dr. J.R. Richards, Assistant Professor, Department of Poultry Science, for their criticism of this manuscript, and to those members of the Faculty who read the manuscript and offered their advice.

The writer is also indebted to Mr. Herbert Ellis, Farm Supervisor, and others who provided essential help in gathering and recording the data.

INTRODUCTION

Breeding programmes for the development of broiler strains of chickens have generally placed primary emphasis on improvement of body weight and conformation at market age. The use of body weights as the criteria for selection to increase early growth has tended over the years to increase egg size and lower egg production. It would accordingly be of value if some other trait, independent of egg size or production, could be utilized in selection programmes to achieve body weight gains.

Recent work (Roberts, 1964) has indicated that growth from hatching to seven weeks of age may be represented by a power function $y = at^b$; where y is the body weight of an individual at time t, a is equal to the body weight of that individual at time zero and b represents the growth rate of the individual. In theory, then, this function is independent of any other trait such as egg size and it is possible that selection for increase of the individual growth rate may be unassociated with change in other traits.

The present study was undertaken to investigate further the value of the individual growth rate, as a measure of genetic worth, in the pre-hatching stage as compared to the post-hatching stage when measured over a number of strains and strain crosses. Also investigated were the interrelationships of duration of preincubation storage, egg weights before and after storage, hatching time and level of nutrition during post-hatching growth, and their effects on the individual growth rate.

REVIEW OF THE LITERATURE

Halbersleben and Mussehl (1922), among the earliest investigators of egg weight:chick weight relationships, reported that when eggs were grouped according to weight, the average hatching weight of chicks from these groups, with minor exceptions, were ranked in the same order as the average egg weights. However, thirty-five days after hatching, the average weights of chicks from small egg groups were approximately the same as those of chicks from large egg groups. Upp (1928) reported that egg weight and chick weight at hatching were highly correlated but that neither observation formed a reliable index of chick weights at two, four or twelve weeks of age. Jull and Hewang (1930) pointed out that yolk material forms about 18 per cent of chick weight at hatch and that the correlation of egg and embryo weights increases during yolk assimilation.

A study by Wiley (1950b) showed that the correlation coefficients between egg weight and body weight diminished gradually from the third to the twelfth week, however, they were highly significant until after the ninth week in three out of four tests. In contrast, Godfrey et al. (1953) concluded that egg size exerts a rapidly diminishing effect on body weight and has no appreciable effect on broiler weight. They mentioned that this relationship might not hold true for all breeds.

O'Neil (1950) reported that better feed consumption, lower mortality and higher body weights at eight weeks of age were achieved by chicks which had the highest percentage body weight of egg weight at hatching. Godfrey and Williams (1955), however, argued that the day-old chick weight as a percentage of egg weight accounted for only about 5 per cent of the variation in twelve-week body weight and was therefore of no value as an index to predict growth rate.

Skoglund et al. (1952) reported that chicks from larger eggs were heaviest at twelve weeks of age when all birds were reared together and the differences in weight corresponded to those obtained in an earlier study in which chicks from different sized eggs were reared separately. In contrast, Tindel and Morris (1964) agreed that the chicks from heavy egg groups were heaviest at broiler age, regardless of whether they were reared separately or intermingled. However, they reported a strong tendency for chicks from any egg weight group to show increased weight gains when the groups were reared separately.

In order to determine the influence of egg size on the intrinsic growth of the chick, Kosin et al. (1952) used body weight gain during intervals between weighing as a measure of growth rate. They concluded that egg size frequently exerts an influence on subsequent growth up to twelve weeks, the effects of which are more prominent in the early stages, but that breed and sex differences preclude any generalization.

Regression analysis was used by Goodwin (1961) to investigate the effect of egg size or hatching weight on body weight at nine weeks. He found a greater effect of egg size between strains than within and suggested that chick size at hatching does have an important effect on its growth to nine weeks.

Bray and Iton (1962) studied the interrelationships of parental weight, embryo weights, egg weights and chick weights during the interval from six days of incubation to eight weeks after hatching by ranking strains according to these traits and determining the correlations of the ranks. They observed that egg weight exerted a temporary effect which concealed genetic differences in late embryonic and early post-hatching growth.

Reports in the literature indicate that there is no doubt about the effect of egg size on hatching weight but opinions vary as to the duration of this influence on subsequent body weight.

The effect of breed on embryos has been studied almost as extensively as the effect of egg weight on embryo weight. Henderson (1930) was unable to detect any difference between the embryo weight of White Leghorns, Dark Cornish and the reciprocal crosses of these two breeds from four to twenty days of incubation. His observations consisted of duplicate samples of from four to six embryos, and, in addition, the experimental error was possibly increased by incubating the pure line embryos and the crossbred embryos at different times.

In a study involving two strains and their reciprocal crosses, Byerly (1930) reported slight differences in size of embryos at the same stage of incubation and from eggs of the same size. These differences tended to disappear at hatching. Continuing his studies of egg weight, breed and embryo weight interrelationships, Byerly (1932) proposed that each embryo has an inherent rate of growth which is modified in direct proportion to a function of egg size. He thought, however, that the rate, function and proportion were each identical for all breeds, regardless of egg size.

Blunn and Gregory (1935) were able to detect embryological differences between White Leghorns and Rhode Island Reds when compared by cell number and number of mitotic figures, but they were unable to demonstrate significant differences in weight. Some of these different findings were resolved by Byerly et al. (1938) when they presented critical data which indicated that embryos of four genetic classes differed significantly in size during the eleven- to seventeen-day period, even in eggs of similar weight.

A comparison of embryo weights, cell counts and cell size of two lines of Barred Plymouth Rock which had been selected for large and small egg size, respectively, was made by Wiley (1950a). He did not find consistent differences in embryo weight between the two lines, but did demonstrate that egg size was positively related to cell number per unit area of embryo tissue and negatively related to the cell size.

McNary et al. (1960) reported that significant genetic differences were found between embryos of White Leghorns, Rhode Island Reds and New Hampshires in the number of somites present after thirty-eight hours and in embryo weights at one week and at two weeks of incubation. Bray and Iton (1962), in a previously mentioned paper, also observed genetic differences in embryo weights from the tenth to nineteenth day of incubation.

Coleman et al. (1964) found embryo weights of a line selected for high body weight were significantly greater than those of a line selected for low body weight, during the fourteen- to nineteen-day period of incubation. However, at forty-two hours of incubation the low weight line had significantly higher somite counts. Interestingly, significant correlations between egg weight and embryo weight were found with far greater frequency in the low weight line.

Early investigators of embryonic growth rates tended in general to assume that growth rate was constant during incubation. Thus Murray (1925), plotted the log of embryo weight against log of time and observed an apparently straight line. He calculated the least squares line of best fit to the data and reported that: "The average weight of chicken embryos between 5 and 19 days of incubation as found by over 600 weighings may be expressed by a simple exponential equation, $W = Kt^{3.6}$ where $K = 0.668$". In this formula W expresses embryo weight and t refers to time in days from start of incubation. Lerner (1939) examined the deviations from linearity present in the data of Murray and others and reported that: "While individual sets of data may produce a satisfactory fit to a logarithmic straight line, small deviations in the same direction and appearing at the same time in the majority of sets of reliable data cannot be disregarded".

Byerly et al. (1938), in a previously mentioned paper, used equations which relate log of weight to log of time to investigate genetic differences in embryonic growth during the period two to twenty days of incubation. They also used a least squares estimation and reported that they were unable to detect any genetic differences in growth of embryos from eggs of the same size. Examination of his figures, however, reveals a considerable difference in the pattern of distribution of points along the lines of best fit, among the four genotypic classes and one could question the validity of using this method to solve for growth constants during this period.

In general, the more recent papers seem to agree that providing enough genetic diversity in parental body weight exists, genetic differences in embryo weight may be distinguished. Opinions seem to differ as to the duration of these genetic differences in embryo weight, and the work that has been done on genetic differences in embryo growth rates does not appear to be very critical.

Lerner and Asmundson (1938), summarized the work that had been done on growth constants and used Schmalhausen's growth constants, which are based on the postulate that growth is inversely proportional to elapsed time, to compare post-hatching growth rates obtained from various sets of data. The use of these growth constants gave evidence of sex linkage and differences between strains, breeds and sexes. As in the embryo studies, however, investigators were basing their calculations on the premise that growth curves could be divided into sections which, when reduced to logarithmic scale, would yield straight lines.

Roberts (1964) investigated the power function $y = at^b$ related to that originally proposed by Schmalhausen (as cited by Lerner and Asmundson, 1938). He used the power function to calculate weekly individual growth rates directly from the data during the period from hatch to ten weeks of age. In this formula, age was expressed as time from conception. The results showed that the weekly growth rates reflected a degree of linearity up to seven or eight weeks of age, and that when these weekly values to seven weeks of age are averaged, the seven-week growth rate provides a useful estimate for comparison of genetic worth of individuals or strains.

Investigation of the effect of sex on embryo or hatched chick weight began with Jull and Quinn (1925). They were unable to find sex differences in the hatching weight of chicks from eggs of hens or pullets of Rhode Island Red or Barred Plymouth Rock breeds.

Monro and Kosin (1940), however, found that the hatching weight of male chicks was significantly heavier than that of female chicks when expressed as a percentage of egg weight. Kagiama (cited by Monro and Kosin, 1940) reported significant sex differences in oxidation and reduction powers of male and female embryos which became apparent at thirteen days of incubation. This occurred at the same time as a sex difference in embryo weight gain (no statement of significance) was observed.

An investigation of sex differences in weight of chicks hatched from eggs of similar weight was made by Godfrey and Jaap (1952), who showed that genotype may effect hatching weight of chicks (crossbreds versus purebreds) out of eggs from the same dam line. They also claimed first conclusive evidence that genotype may effect hatching weight within each sex.

The evidence in the literature indicates that both sex and genotype effect the weights of chicks at hatching, but doubt remains as to the effect of sex on embryo weights during incubation.

A study of the effect of rapidity of hatching on growth, egg production, mortality and sex ratios in chickens showed that early emerging chickens grew slightly faster if removed from incubator and given feed and water soon after hatching (Williams et al., 1951). In a later study, Bohren et al. (1961) reported that hatching time was linearly related to length of preincubation egg storage. Merrit (1963) was able to show that mean body weights at 42, 63, 147 and 315 days were decreased by storage of hatching eggs for longer than two weeks prior to incubation, and that hatchability and viability of hatched chicks decreased in relation to storage time.

The literature indicates that little work has been done on sex differences in embryonic weights or embryonic growth rates. Neither have the interrelationships of length of egg storage, growth before and after incubation and hatching time been investigated. A study of these factors was therefore incorporated into the present investigation.

MATERIALS AND METHODS

Three strains (lines) of chicken were used in this study: White Leghorn (WL), White Rock (WR) and New Hampshire (NH). The WL line has been a closed breeding population since 1958 and random bred since 1959. It is characterised by good egg production, light body weight, a high degree of livability and large egg size. The WR line has been maintained at The University of British Columbia Genetics Unit as a random mating unit since 1960. It is a typical broiler stock, being characterized by heavy body weight, a high degree of livability and large egg size, but low egg production. The NH line has been maintained at The University of British Columbia as a random mating unit for at least twelve years. It combines medium body weight with fairly good egg production.

Experiment 1

The breeding pens for the production of the crosses, their reciprocals and the pure lines used in Experiment 1 were set up as follows. Eighty-four hens represented each of the NH and WL lines whereas between seventy-two and seventy-five hens represented the WR line. Hens of each line were randomized into six breeding pens, and four males of each genotype were randomly assigned in pairs to these six pens. By repeating this distribution for each line, each of the nine possible "genotypic" matings was duplicated. Ten days after the mating pens were established, a thrice weekly rotation of the males among the six pens which contained the same male strain, was commenced. It was assumed that this male rotation technique would minimize individual male effects.

Commencing at this time and during the following three weeks, eggs were gathered twice daily, dated, identified as to origin and placed directly into a room maintained at approximately 55^{o}F. The collection regime was instituted to reduce embryonic development occurring prior to storage of the eggs. Each day's collection was removed from storage on the following morning and fifteen eggs of each "genotype" were randomly selected. The number fifteen was determined by the average production of the poorest producing pens. The selected eggs were then individually weighed and recorded to the nearest gram before being returned to storage.

After three weeks of collection, all eggs were reweighed and trayed for incubation. In this manner, individual records of week of lay, "genotype" and weight before and after storage were obtained for more than 2,700 eggs. Before traying, the eggs of each "genotype" were randomly divided into two groups; those that were assigned for hatching and those that were assigned for embryo weighing during incubation.

The eggs that were assigned for embryonic test were further subdivided randomly into seven subsets, with the restriction that approximately seven eggs of each week of lay were present in each "genotypic" subset. One of the seven subsets would be broken out and the embryos weighed on each of the alternate days from 6 to 18 days of incubation, inclusive. The corresponding subsets of each genotype were then brought together and randomly distributed into incubator trays. This meant that all eggs within any one tray would be withdrawn for embryonic examination on the same day, thus minimizing heat loss during incubation. The trays were then randomly distributed into two Jamesway Model 2940 incubators. In order to minimize growth occurring between withdrawal of the trays and the actual weighing of the embryos the assigned trays were withdrawn at forty-eight hour intervals and refrigerated overnight.

Prior to weighing, each embryo was separated from its extra-embryonic membranes by cutting the umbilical cord at its juncture with the abdomen. The excised embryo was then placed on a piece of absorbent paper for a few seconds in order to drain off excess moisture before weighing. Infertile eggs and embryos which had died prior to removal from the incubator, as well as obviously deformed embryos, were discarded. Embryo weights were taken to the nearest thousandth of a gram, and the sex was determined and recorded starting on the twelfth day of incubation. Approximately 1,350 eggs were broken out over the seven weighing periods.

Those eggs that were assigned for hatching were divided at random within each genotype into two groups corresponding to the two nutritional environments on which the hatched chicks would be reared. Eggs from each genotype, within a treatment, were then randomized throughout the incubators.

The eggs assigned for hatching were candled at eighteen days and viable eggs were transferred into hatching trays. Each transferred egg was placed under an inverted polythene basket, and wire frames were placed over the baskets to hold them down. In this fashion, individual hatching data could be obtained. The hatching time of each chick was recorded as occurring in one of three periods; prior to the end of the twentieth day, or within one of the following two successive twelve-hour periods (i.e. early twenty-first and late twenty-first day). The hatching periods were evaluated as 1, 2 and 3 respectively. During the late twenty-first and early twenty-second day periods the hatched chicks were individually wing-banded and weighed to the nearest gram.

Distribution of the chicks into the brooding pens was done late on the twenty-second day, the chicks for each treatment being randomized into duplicate pens so that each of the four pens contained a random sample of chicks of each genotype. The nutritional environments were provided by a commercial broiler ration and a commercial starter ration from the same source. The hover-type brooders were encircled with a cardboard guard for the first three days to keep the chicks close to the source of heat. Antibiotic was added to the drinking water for the first three days in recommended amounts. Individual body weights were recorded weekly to six weeks of age and the sex, determined by visual inspection, was recorded at eight weeks of age. The birds were given an ocular vaccine for Newcastle disease and infectious bronchitis at fourteen days of age. A mild outbreak of coccidiosis was noted during the sixth week and treated promptly with a coccidiostat. Seven hundred and ninety-three birds were successfully raised out of eight hundred and six started, thus giving a total mortality of less than 2 per cent.

Experiment 2

The procedures of Experiment 2 were standardized to those of Experiment 1, except for the following variations:

1) The number of dam genotypes and therefore the number of eggs collected and incubated was doubled by the inclusion of crossbred pullets which were carried over from the first test. Each of the three groups of crossbred dams was made up of equal numbers of the single and its reciprocal cross. It was assumed that no adverse effect on the measured traits would result by combining the single cross and its reciprocal to use as a single dam line. Eighty-four dams of each strain and strain cross were available for breeding.

2) A fertility check prior to the commencement of the collection period was made by incubating for twenty-four hours a sample of one day's collection of eggs from each breeding pen. The eggs were broken and the degree of fertility for each pen determined. This check showed that a replacement of a pair of males from each of the WL and WR lines was needed.

3) The sex of the embryos was recorded starting at the tenth day of incubation, two days earlier than in Experiment 1.

4) The chicks were randomized into nine, four-tiered

battery brooders with two compartments per level, with the restriction that one bird of each genotype would be placed in each compartment if sufficient representatives were available. A separate battery brooder was used to rear excess chicks, and any bird that died in the first two weeks was replaced by a bird of the same genotype and nutritional environment.

5) The two nutritional environments were of the same type and from the same source as in Experiment 1. Although the rations were intended to be identical with those of Experiment 1, it was noted that the chick starter ration was of a much finer texture. During the test, a number of birds on the starter ration developed a crossed beaked condition which was diagnosed as being due to impaction of the finer textured feed. These crossed beaked chicks were recorded, with a subjective differentiation being made between a slight twisting of the beak and a serious deformity. It was assumed that the slight twisting of the beak would not affect the subsequent performance, but that a serious deformity would. Therefore, those birds with a markedly deformed beak were not included in the analysis of the data.

STATISTICAL METHODS

The body weights of individual chicks during the growth phase between hatch and six weeks of age were assumed to follow the power function, $y = at^b$, where y is equal to the body weight of the individual at time t, a is equal to the body weight of the individual at time zero and b represents the growth rate of the individual.

Weekly growth rate estimates were calculated between hatching and six weeks of age for each individual. The averaged weekly values provided a single estimate of growth rate from hatch to six weeks of age.

As only one body weight observation could be made for any embryo, it was impossible to calculate individual embryonic growth rate. It was assumed, however, that the growth rates between two embryonic weighing periods could be estimated for any experimental cell by using the average of the embryonic weights of those individuals within a genotype, sex (when recorded) and egg storage period. In the few instances (once in Experiment 1 and twice in Experiment 2) where no embryo weight was available within a particular subclass an estimate was calculated, based on the average weight ratios of other subclasses and the embryo weights immediately preceding and following the missing value. Embryonic growth rate estimates were calculated for each of the two-day periods between six and eighteen days of incubation. In addition, the two-day estimates were averaged in different combinations to provide values for the following embryo growth periods; 6-10, 6-12, 6-14, 6-16, 6-18, 8-12, 8-14, 8-16 and 8-18 days.

The general model assumed to explain the sources of variation in the embryonic body weights and growth rates was:

$$E_{ijkl} = \mu + s_i + d_j + (sd)_{ij} + p_k + (sp)_{ik} + (dp)_{jk} + (sdp)_{ijk} + f_l + (sf)_{il} + (df)_{jl} + (pf)_{kl} + (sdf)_{ijl} + (spf)_{ikl} + (dpf)_{jkl} + e_{ijkl}$$

The sire effect; $s(i = 1 - n_s)$, the dam effect; $d(j = 1 - n_d)$, the storage period effect; $p(k = 1 - n_p)$ and the sex effect; $f(l = 1 - n_f)$ were considered to be fixed, whereas the residual term $\underline{e}$ was considered to be of a random nature. Table I shows the particular models used in the analyses of embryo data. The models in this table will be referred to consistently in the text and tables throughout this thesis.

In the analyses of variance of the post-hatch data, the average value within genotype, treatment and replication was used as the sample observation, and the two sexes were analyzed separately. Assuming that if differences did exist within the batteries of Experiment 2 they would be more likely to occur between the top and bottom tiers, the top two tiers and the bottom two tiers were combined as replications 1 and 2 respectively. The statistical model assumed to explain the sources of variance of the average body weight observations at hatching and at weekly intervals thereafter was:

$$Y_{ijkl} = \mu + s_i + d_j + (sd)_{ij} + t_k + (st)_{ik} + (dt)_{jk} + (sdt)_{ijk} + e_{ijkl}$$

Model (i)

The sire effect; $s(i = 1 - n_s)$, the dam effect; $d(j = 1 - n_d)$ and the treatment effect; $t(k = 1 - n_t)$ were considered to be fixed effects and $e_{ijk}(l = 1 - 2)$ was considered to be a random effect of replication within genotype and treatment.

The model assumed to describe each of the growth periods was:

$$b_{ijkl} = \mu + s_i + d_j + (sd)_{ij} + t_k + (st)_{ik} + (dt)_{jk} + (sdt)_{ijk} + e_{ijkl}$$

Model (j)

which differed from model (i) only in the phenotype analyzed.

In addition, simple correlations and the coefficients of determination based on simple linear regressions and multiple linear regressions were calculated from individual chick data as well as from averaged data within genotype and treatment.

Calculations of the analyses of variance, regressions and correlations were done on The University of British Columbia I.B.M. 7040 computor, according to the methods presented by Ralston and Wilf (1960). Duncan's new multiple range test (Steele and Torrie, 1960) was used to test differences between means within the main effects of the analyses of variance ($P \leq .05$). It should be noted here that Duncan's test is independent of the analysis of variance and can demonstrate differences between particular means, when the main effect (as shown by analysis of variance) is non-significant.

The words "significant" and "highly significant" were used to refer to differences among sample means which, on the basis of statistical analysis, are expected to reflect true differences among the population means with a probability of not more than .05 and .01 respectively of being incorrect.

RESULTS AND DISCUSSION

Table II contains the F values and their significance level calculated from the analyses of variance of embryo weights at 12, 14, 16 and 18 days of incubation for Experiments 1 and 2, using statistical model (a). It can be seen that only the main effects; sex, age, sire and dam, and the interaction between sire and dam were significant at 5 or 1 per cent probability levels with any appreciable consistency. For this reason the other interactions were included with the residual variance in all subsequent analyses of variance of embryonic data.

Experiment 1

Embryo Weights

The percentage of the total sums of squares attributed to each of the partitioned effects, their significance and the models used for the analyses of embryo weights at each of the weighing periods are presented in Table III.

The effect of storage period was highly significant at each of the embryo weighings. Duncan's test indicated that, almost without exception, each week of storage resulted in a significant and cumulative depression of mean embryo weight within each incubation period (Table IV). Storage period seemed to account for relatively more of the variation in the earlier stages of incubation than at later stages, as evidenced by the decreasing percentage sums of squares in Table III.

The effects of sire and dam lines on embryo weight were less consistent and of smaller magnitude than the effect of egg storage, however, both sire and dam line effects were highly significant at twelve and fourteen days of incubation, and the sire line effect also showed significance at ten days of incubation (Table III). The results in Table V indicate that at twelve and at fourteen days of incubation, the mean weight of embryos from each sire line was significantly different (Duncan's test) from those of the other two sire lines, and that the order of means from lowest to highest was WL, NH and WR. Similar results can be seen in Table VI for the dam line effects.

A highly significant interaction between the sire and dam lines occurred on the tenth day of incubation (Table III), however, as this interaction did not approach significance at any other time, it was assumed due to sampling error. A significant sex difference was observed at fourteen days, but the proportion of total variance due to sex was reduced and non-significant at sixteen days and almost non-existent at eighteen days (Table III). Table VII indicates that, with the single exception of embryos at the twelfth day of incubation, the average weight of male embryos was greater than that of females.

Embryo Growth Rates

The per cent of the total sums of squares attributed to each of the partitioned effects from the analyses of variance of growth rates for two-day intervals between each embryo weighing day are presented in Table VIII. The effect of storage period on embryonic growth rate was highly significant during the 6-8 day interval, significant for each of the periods 8-10 and 10-12, highly significant again during the 12-14 day interval and non-significant thereafter. Duncan's test, when applied to the mean growth of embryos from the three storage periods (Table IX) indicated that, in the growth periods 6-8, 10-12 and 12-14 days, a general pattern can be seen in that embryos from eggs stored for three weeks prior to hatching had a significantly greater growth rate than those from eggs stored for one week. However, only for the 6-8 day interval did two-week storage result in an embryo growth rate which was both intermediate to and significantly different from the growth rates resulting from one and three-week storage. For the 8-10 day incubation interval a disproportionately high embryo growth rate for the one-week storage group was evident. If the growth rates during the different intervals are compared it can be seen that growth appeared to be inhibited during this same period,(perhaps due to some fault in incubation). It may be that the higher growth rate of the embryos from the one-week storage group was due to a higher resistance of this group to the incubation stress.

Neither sire nor dam lines had any significant effect on growth rate during the intervals 6-8 and 8-10 days of incubation (Table VIII). Both effects, however, were highly significant during the 10-12 day interval, at which time each of the mean growth rates of the WR line sires and dams were significantly superior to those of the sires and dams of the NH or WL lines respectively (Tables X and XI). The effect of sires or dams disappeared during the 12-14 day interval but reappeared significantly in the case of sires during the 14-16 day interval, however, at this interval the WL sire line was now superior to the WR line, and the NH sire line was intermediate to but not significantly different from either.

The sire x dam line interaction effect on the two-day growth rates was highly significant during the 8-10 and the 10-12 day periods. Both of these growth rate intervals, however, involve the ten-day embryo and it was considered that if experimental error was the cause of the significant sire x dam interaction of embryo body weights, then this same error would be reflected in the 8-10 and 10-12 day growth rates. Similarly, the significant effect of sex on growth rate during the 12-14 day interval corresponded to the sex effect on fourteen-day embryo weight.

The two-day growth rate estimates for the different intervals of incubation were averaged to provide estimates for the periods beginning at 6 and ending at 10, 12, 14, 16 and 18 days, as well as those beginning at 8 and ending at 12, 14, 16 and 18 days of incubation. The results of the analyses of variance of these averaged growth rate estimates are presented in Table XII.

The effect of egg storage on these average growth rates was generally highly significant, and only the average estimates for the period 8-12 days were not significantly different. It can be seen from Table IX that the values of growth rates for the different storage periods during the 10-12 day interval were inversely related to the depressed values of the 8-10 day interval. It would seem reasonable, therefore, to suggest that a compensatory effect on growth during the interval following the depression was enough to mask any effect of egg storage on the average growth rate during the 8-12 day interval.

The results in Table XIII indicate that the average growth rates of embryos from eggs held for three weeks prior to incubation were significantly higher than the average growth rates of embryos from eggs held for only one week, for all growth periods calculated except the 8-12 day period mentioned above. In addition, it can be seen that during the growth periods beginning at 6 days and ending at 12, 14, 16 and 18 days of incubation, the average growth rates of embryos from eggs held for two weeks prior to incubation were intermediate to and significantly different from the average growth rates of embryos from eggs held for one or three weeks. These findings are contrary to those of Kaufman (as cited by Bohren et al., 1961), who reported that, though initiation of embryo growth was delayed by pre-incubation storage of eggs, subsequent embryo growth was unaffected. As mentioned previously, storage periods appeared to account for relatively more variation in embryo weight during early stages of incubation than during later stages. The compensatory growth of embryos from the eggs which were held for longer periods provides a reasonable explanation for reduced relative differences due to storage effects on embryo weights observed during later stages of incubation.

Sire and dam line effects on average growth rates were significant during some periods and non-significant during others (Table XII). Duncan's test (Tables XIV and XV), however, indicated that there was a high degree of inconsistency when the means of the various sire or dam lines were compared and no meaningful interpretation was apparent.

Post-hatching Body Weights (Males)

The percentage of the total variation attributable to the partitioned effects, their significance and the models used in the analyses of variance of post-hatching body weights of the male progeny are presented in Table XVI. The effect of sires was significant at one week of age and highly significant at each week from two to six weeks of age. Table XVII indicates that the mean weights of chicks from the three sire lines were significantly different from each other from the third week onwards, and that the order from lowest to highest was WL, NH and WR.

The effect of the dam lines was highly significant at all weighings (Table XVI), including the hatch weight where the effect was evidently due to the maternal influences of the differences in egg weights from the three dam lines (Table XVIII). The data of Table XIX indicates that the mean weights of chicks from the three dam lines were not significantly different from each other until the third week. The order of magnitude was the same as for chicks from the three sire lines.

The ration effect (Table XVI) was highly significant at the second week's weighing, non-significant at the third week and highly significant from the fourth week on. It is interesting to note that the significant thirteen gram differential that existed in favour of the broiler ration at two weeks was reduced to a non-significant difference of four grams at three weeks before increasing again during later weighings (Table XX). As the chickens were vaccinated at two weeks it seems reasonable to suppose that the loss of significance of treatment effects was due to a differential response to the vaccination. An inhibition of growth rate by ocular vaccination take was noted by Roberts (1965).

The sire x dam and the dam x ration interactions attained significance at different weighing periods. The sire x dam interaction may be real, but the random allotment of eggs to rations prior to incubation attests to the spurious nature of the dam x ration interaction of hatching weights.

Post-hatching Growth Rates (Males)

The effect of sire lines on post-hatching growth rate of the male chicks was highly significant for all weekly periods between hatching and five weeks of age and remained significant for the period between five and six weeks of age (Table XXI). During the hatch to one week interval the growth rate of the WL sire line males was significantly superior to that of the NH sire line males and not significantly different from that of the WR line (Table XXII). Duncan's test indicated that growth rate of male chicks from the WL sire line was significantly lower than that of the NH or WR sire line males during each weekly interval from one to five weeks of age. The NH and WR sire line male growth rates were not significantly different except during the hatch to one week interval when the WR line was superior. The six-week growth rate of male chicks from these two sire lines differed by only 0.01 (not significant). It would seem, therefore, that the thirty-two gram difference in six-week body weight in favour of the WR line (Table XVII) was mainly due to the significant difference in growth during the first week after hatching. However, the rate of growth during this interval is not always indicative of final body weight or growth rate in subsequent periods. It can be seen from Tables XXII and XVII that in spite of the fact that chicks from the NH male line had a first week growth rate that was significantly lower than that of male chicks of the WL line, this former group achieved a significantly higher six-week body weight and six-week growth rate. However, this may be a natural condition existing between light and heavy breeds of chicken.

Table XXI indicates that the effect of dam line on weekly growth rate of male chicks was highly significant during the first week of post-hatching growth, and significant from then until the end of the fourth week. The effect of dam line on six-week growth rate was highly significant. The results of Duncan's test on the mean growth rates of male chicks from the three dam lines (Table XXIII) indicate that the differences between them compare very closely with those observed for the sire lines (Table XXII). Apparently the only genetic difference in weekly growth rates between the NH and WR lines occurred during the first week's growth period, since for both sire and dam lines no significant difference was found in subsequent growth periods. In contrast to the male lines there was a significant difference between the six-week growth rates of all three dam lines, their relative order; WL, NH and WR being the same as was observed for their six-week body weights.

The ration effect on weekly growth rates (Table XXI) was highly significant during the second, third and fourth weeks of post-hatching growth, significant during the fifth and non-significant during the first and sixth weeks. The effect on six-week growth rate was highly significant. Comparisons of the ration means (Table XXIV) indicated that for each weekly interval between one and five weeks of age, with the exception of the two to three week interval, the broiler ration was superior to the starter. The significantly greater growth rate achieved on the starter ration during the two to three week period was due to a differential response to the effect of vaccination at the beginning of this period.

It is interesting to note that the sire x dam interactions which showed some significance when body weights were analyzed were not significant.when the same data was placed in a different frame of reference. Possibly many genetic inferences which in the past have been based on the appearances of a sire x dam interaction in body weight data would be changed, since the interaction appears to arise from the non-additivity associated with body weight.

Post-hatching Body Weights (Females)

The percentage sums of squares attributable to the partitioned effects obtained in the analyses of variance of post-hatching female chick weights are presented in Table XXV. It can be seen that there was a highly significant effect of dam lines on hatching weight and that the effects of both dam lines and sire lines on body weights were highly significant thereafter. Tables XXVI and XXVII indicate that for both of these main effects the mean weights of chicks from each line were significantly different after two weeks' growth and increased in the order WL, NH and WR, as did the male progeny.

The effect of ration on the weekly weights of female chicks was very similar to the effect observed on the males. Again the effect disappeared at the third week's weighing and reappeared with a high significance during the subsequent weighings. As in the case of the male chicks, the mean weight of females fed the broiler ration was significantly greater than that of the female chicks fed the starter ration at all weighings except those at hatch and at three weeks of age (Table XXVIII).

The sire x dam interaction accounted for a fairly high (8.52%) but non-significant proportion of the variance of female body weights at hatching (Table XXV). At all subsequent weighings this effect was highly significant and warrants further consideration. Table XXIX contains the mean body weights of female chicks from each combination of sire and dam lines at each of the weighing periods. It can be seen that within both the WL and WR sire lines, the mean weights of female chicks from the NH dam line were generally intermediate to those of the WL and WR dam lines. Within the NH sire line, however, there appears to be very little difference between the WL and NH dam lines, in fact, until the sixth week the mean weight of chicks from the NH dam line was slightly less than that from the WL dam line.

Genetically these data indicate a relatively constant non-additive effect, however, caution should be placed on this interpretation since the non-additivity of body weight per se was established in the male data.

Post-hatching Growth Rates (Females)

The effect of sire lines on weekly and six-week growth rates was generally highly significant (Table XXX) and lost all significance only during the sixth weekly period. The loss of significance during the sixth week may have been due to the outbreak of coccidiosis at this time. Table XXXI indicates that the six-week growth rate of the WR sire line was significantly greater than that of the NH sire line during the first week only, however, the average growth rates of the three sire lines were significantly different from each other and in the ascending order WL, NH, WR.

The dam effect on growth rate of female chicks was very similar to the sire effect (Table XXX), except that there was a highly significant difference during the second week and no significant difference during the third week. Table XXXII indicates that the only significant difference between weekly growth rates of female chicks from the NH and WR dam lines occurred during the first week of post-hatching growth, however, the average growth rates of the three dam lines were significantly different from each other and in the same order as observed for the sire lines. Apparently the first week's growth of both males and females is the deciding factor in the six-week body weight differences of these heavy lines.

The ration effect on weekly and average growth rates of female chicks (Table XXX) was essentially identical to the effect of ration on male chick growth rates. Again the growth rate of the chicks fed the broiler ration was more seriously affected by vaccination than that of chicks fed on the starter ration (Table XXXIII).

Embryo Correlations

The simple correlations of pre- and post-storage egg weights, embryo weights and date of lay at each incubation period are presented in Table XXXIV. The correlations between pre-storage egg weights and embryo weights showed no significance until the fourteenth day of incubation, at which time the coefficient was positive and highly significant and continued to increase during the sixteenth and eighteenth days of incubation. The correlation coefficients between post-storage egg weight and embryo weight were also highly significant and positive and increased from the fourteenth to the eighteenth day. However, at the earlier stages of incubation the coefficients appeared to be contradictory. The relationship between embryo weight and date of lay was highly significant at all stages of incubation recorded in this experiment (and may partly explain this contradiction). Thus the significant correlation between date of lay and post-storage egg weight in conjunction with the high correlation between embryo weight and date of lay, evidently contributed to the high correlation and embryo weight and post-storage egg weight observed at the tenth day of incubation. The highly significant correlation between embryo weight and post-storage egg weight at six days of incubation appeared to be contradictory to the general trend and may be spurious.

Post-hatching Correlations

Table XXXV presents the simple correlations of time of hatch, storage period and pre- and post-storage egg weights with weekly chick body weights from hatch to six weeks of age as calculated from the individual data of Experiment 1. The correlation between time of hatch and chick body weight was highly significant at all weighings. With hatching weight the coefficient was positive, however, from one week on it became negative, reaching a minimum of -.290 at two weeks and increasing very slowly thereafter. The positive correlation of time of hatch and hatching weight was presumably due to dehydration of earlier hatched chicks prior to weighing. The negative relationship at subsequent weighings indicates that the later hatching chicks were smaller except when first hatched.

The correlations between storage period and chick weights were highly significant with the single exception of the coefficient between hatch weight and storage period. Again it is probable that drying out of earlier hatched chicks obscured any relationship between the recorded traits at hatching, for the correlation between storage period and hatching time (r = .452) was highly significant and indicated that the eggs which were stored for less time prior to incubation tended to hatch earlier. These data are substantially in agreement with the report of Bohren et al. (1961) who showed that storage period and hatching time were linearly related. The negative coefficients between storage period and subsequent chick body weights may be partially due to the highly significant correlations of storage period with pre- and post-storage egg weights ($r = -.114$ and $r = -.211$ respectively), although Merrit (1963) has reported that storage of hatching eggs for longer than two weeks decreases subsequent body weight.

Both the pre- and post-storage egg weights were highly correlated ($P \leq .01$) with weekly body weights from hatch to six weeks of age, the coefficients being extremely high at hatching (.855 and .847) and declining steadily thereafter. Most of the more recent work in the literature (Wiley, 1950b, O'Neil, 1950, Skoglund et al., 1952 and Tindel and Morris, 1964) agree that egg weight exerts an influence on body weight at broiler age, although some (Godfrey et al., 1953 and Godfrey and Williams, 1955) de-emphasize the importance of this effect.

Table XXXVI contains the correlation coefficients of hatching time, storage period, pre- and post-storage egg weights and six-week body weight with the individual weekly growth rates. The correlations between time of hatch and the weekly growth rates were negative for all periods except the last, and were highly significant during the first and second period. These data indicated that those chicks which hatched first tended to have higher growth rates.

The correlation between storage period and weekly growth rates indicated that those chicks from eggs which were layed later in the collection and storage period tended to have higher growth rates during the early post-hatching period, but lower growth rates during the later stages.

Pre- and post-storage egg weights were negatively correlated with weekly growth rates indicating that the chicks from larger eggs tended to have lower growth rates. The coefficients were highly significant during the second and third weeks' growth and generally significant during the remaining periods. Kosin et al. (1952), using body weight gain as a measure of intrinsic growth, concluded that chicks from larger eggs had the greater growth. If the present investigation had used the same frame of reference to measure growth, the conclusion would not have been different.

The correlation coefficients between six-week body weight and weekly growth rate were positive and highly significant from hatch to six weeks. It is interesting to note that the highest coefficient was obtained during the second week's growth at the same time as the most negative value occurred for the correlations between egg weights and weekly growth rates. The implications of this are that it may be possible to improve six week body weight by selecting for early growth rate, without increasing egg size. Further work is needed to determine if similar results can be obtained with other strains and strain crosses.

Correlations of Embryo and Post-hatching Data Within "Genotypes"

Embryo weights and growth rates were averaged within each strain and strain cross to obtain "genotypic" estimates for these traits. In addition, "genotypic" estimates were obtained for post-hatching body weights and growth rates and these data were also separated as to sex and ration. Within sex and ration the six-week body weights were correlated with each of the other corresponding "genotypic" estimates. The correlation coefficients thus obtained are presented in Table XXXVII.

The six-week growth rate and weekly body weights from the end of the second week on bore a highly significant relationship with six-week body weight. Weekly growth rates, with the exception of the sixth week's growth, were generally significantly related and within each sex and ration the highest significance occurred during the second week's growth.

The six-week body weights of females receiving either ration and of males receiving the starter ration were significantly correlated with twelve-day embryo weight and highly significantly correlated with fourteen-day embryo weight. The six-week body weight of males on the broiler ration was significantly correlated with embryo weights only on the fourteenth day of incubation.

None of the embryo growth rates was significantly correlated with six-week body weight (Table XXXVII) or six-week growth rate (Table XXXVIII), however, this may be due to too few degrees of freedom (7) and the difficulty of obtaining accurate growth rate estimates during the embryonic stage of growth.

Although the correlations between six-week body weight and embryo growth rates were insignificant it should be noted that the highest correlations were obtained during the intervals 6-14 and 8-12 days of incubation; the same intervals during which the sire and dam effects together were of the highest magnitude in the analyses of variance (Table XII).

Experiment 2

Embryo Weights

The percentage sums of squares attributable to the partitioned effects, their significance and the models used for the analyses of variance of embryo weights at each of the weighing periods are presented in Table XXXIX.

With respect to the effects of egg storage on embryo weights, the results of Experiment 2 were similar to those of Experiment 1. The effect of storage was highly significant at each of the embryo weighings (Table XXXIX) and Duncan's test on the mean weights of embryos from eggs stored for one, two or three weeks showed that at each weighing period each week of storage resulted in a significant and cumulative depression of embryo weight (Table XL). As in Experiment 1, the percentage sums of squares indicated that storage period appeared to account for a larger proportion of the variation in the early stages of incubation than in the later stages.

The effect of sire line on embryo weight was significant at eight and twelve days of incubation and highly significant at ten and at eighteen days. Table XLI indicates that at ten, twelve and at eighteen days of incubation, the mean weights of embryos from the NH and WR sires was significantly greater than the mean weight of embryos from the WL sires, but not significantly different from each other. At eight and again at twelve days of incubation the mean weight of embryos from the NH sire line was significantly greater than those of the WL or WR sire lines.

The dam effects were generally highly significant from the eighth day through to the fourteenth, however, at twelve days this effect was only significant at the .05 probability level (Table XXXIX). At eight, ten and fourteen days of incubation the mean weight of embryos from the WL dam line was significantly smaller than that of embryos from any other dam line including the crossbreds (Table XLII). The means of the other dam lines appear to have no constant relationship to each other, except that the embryos from the NH line were generally smaller than, but not significantly different from embryos from the WR dam line. The general lack of significant differences between the mean weights of embryos from the different dam lines as compared to Experiment

1, could be due to the lack of genetic diversity of the crossbred dams.

The sire x dam interaction was significant at eight, ten and twelve days and highly significant at eighteen days of incubation. A complete interpretation of these results would require more precision in estimating the "genotypic" means than this experiment provides, however, the presence of the sire x dam interaction indicates that non-additivity is found during embryonic development.

Significant effects of genotype on embryo weight in both experiments were restricted mainly to the period between eight and fourteen days of incubation. There seems to be a general agreement in the literature that genetic differences in embryo weights do exist, although there is some variation in the incubation interval during which they were found to be significant. Most investigators have observed significant effects of breed or strain during intervals which commence later and last longer than those mentioned above (Bray and Iton, 1962, Byerly et al., 1938 and Coleman et al., 1964). Negative evidence such as Henderson (1930) may be due to too small sample size or failure to take account of the variation due to holding of eggs prior to incubation.

The effect of sex on embryo weights was highly significant at ten days, and significant at twelve (Table XXXIX). Table XLIII, however, indicates that at the other periods also, the mean weight of the males was greater than the mean weight of the females. Combining the results of Experiment 1 (Table VII) and Experiment 2, the mean weight of male embryos was observed to be greater than that of female embryos on eight out of nine occasions. The binomial probability of this happening by chance is less than 0.01 which indicates that for the total of observations a highly significant difference existed between the sexes.

Embryo Growth Rates

The percentage sums of squares from the analyses of variance of growth rates for the two-day intervals between each embryo weighing day are presented in Table XLIV. The effect of storage was highly significant during the 6-8 day period and during the 14-16 day period, but was non-significant during all other two-day intervals. Comparison of the mean growth rate of embryos from eggs stored for one, two or three weeks (Table XLV) indicated that during the 6-8 day interval, each week of storage resulted in a significant increase of the mean growth rate. Although the mean 14-16 day growth rate of embryos increased with each week of storage, no significant differences were observed between one and two week storage.

The sire effect on two-day growth rate was highly significant during the 8-10 day period, slightly earlier than in Experiment 1. Table XLVI indicates that the means could be ranked in the ascending order WL, NH and WR during this interval, although only the WR mean was significantly different from the other two.

The dam effect, significant during the 14-16 day interval, occurred somewhat later than in Experiment 1. When the mean growth rates of the dam lines were compared (Table XLVII), it could be seen that during this period the mean of the WR line was significantly less than that of the WL line and the mean of the NH line was intermediate to but not significantly different from either. It will be remembered that this same order and significance was observed for the sire line embryos during the 14-16 day interval of Experiment 1. It seems reasonable to suggest that during the later stages of incubation, larger embryos may be more subject to growth restriction by limit of shell size or by exhaustion of nutrients, and thus the ranking of sire lines or dam lines on the basis of early embryonic growth rate or embryo size could be reversed when ranking was based on late embryonic growth rate. In general, the same observation can be made when the means of embryos from the NHxWR line are compared with those of the other two crossbred dam lines.

As in Experiment 1, the two-day estimates of growth rate were averaged to provide estimates for the periods beginning at 6 and ending at 10, 12, 14, 16 and 18 and beginning at 8 and ending at 12, 14, 16 and 18 days of incubation. Table XLVIII contains the percentage sums of squares from the analyses of variance of these averaged growth rate estimates. The effect of pre-incubation egg storage on the averaged growth rates was highly significant for all periods beginning at 6 days of incubation and for the periods 8-16 and 8-18 days of incubation. Duncan's test (Table XLIX) indicated that for each of the growth intervals in which the storage period had a significant effect on the embryo growth rate, each week of storage resulted in a significant increase in growth rate except the increase between one and two weeks' storage within the 8-18 day growth interval. These results agree very closely with the results of Experiment 1.

The effect of sire line on the averaged growth rates was significant only during the 8-12 day period (Table XLVIII) and during this period the mean growth rate of the embryos from the WR sire line was greater than that of the embryos from either the NH or WL lines, but these latter means were not significantly different from each other (Table L).

The data in Table XLVIII indicate that the effect of dams on the averaged embryo growth rates was significant during the 6-14 and 8-18 day intervals, highly significant during the 6-16, 6-18, 8-14 and 8-16 day intervals and non-significant during the remaining periods. Duncan's test, however, indicated that even during the periods when the dam effect was highly significant, there was no clear relationship between the dam means (Table LI). Again, perhaps the lack of genetic diversity masked any clear understanding.

The sire x dam interaction of averaged growth rates was significant during a number of the analyzed periods and probably had a connection with the lack of definition of the sire and dam line means, however, in view of the probable sampling errors in each subclass within the interaction means, a meaningful interpretation of this effect was not possible.

Byerly et al. (1938) were unable to detect significant genetic differences in embryonic growth with the use of a function which related log weight to log time during the period two to twenty days of incubation. In the present investigation, however, both experiments demonstrated significant genetic differences in growth during intermediate embryonic stages. There were also indications that growth during the later stages of incubation was inversely related to growth during earlier stages. Consideration of this contrast in growth between early and late stages of incubation would seem to satisfactorily account for the lack of genetic difference reported by the previous authors, for they considered the data from two to twenty days of incubation as a whole and used the least squares solution to obtain the lines of best fit for each genetic class. The inhibition of growth during the later stages would tend to wipe out any genetic differences which might exist in earlier stages.

Post-hatching Body Weights (Males)

The percentage sums of squares and the significance of the partitioned effects obtained from the analyses of variance of the weekly body weights of male chicks are presented in Table LII. The effect of sires on body weight was highly significant at all weighings except that at hatch. Duncan's test (Table LII) indicated that from hatch to two weeks of age the mean weights of chicks from the NH and WL sire lines were not significantly different from each other, but were both significantly smaller than that of the WR sire line. During the remaining weeks of the test, the means of each sire line were significantly different from each other and increased in the order WL, NH, WR, as observed in the same period of Experiment 1.

The dam effect was significant at hatching weight and highly significant during the remainder of the test. As in Experiment 1, the mean weights of chicks from the three "pure" dam lines did not become consistently different from each other until the end of the third week (Table LV). Beginning at the third week the means of chicks from the WLxNH and the WLxWR dam lines were generally intermediate to the means of the WL and NH dam lines, whereas the mean weight of chicks from the NHxWR dam line was intermediate to the means of the NH and WR dam lines at all weighings except the first. Except for hatching weight the mean weight of the WR dam line was consistently and significantly heavier than that of any other dam lines. With respect to their effect on six-week body weight, the dam lines were ranked in the ascending order WL, WLxNH, WLxWR, NH, NHxWR, WR.

The ration effect on weekly body weights was highly significant from the end of the first week on, and the data indicated that the difference in the mean weights of chicks in favour of the broiler ration increased steadily with age (Table LVI).

Other factors which had significant effect on weekly body weights were the sire x dam and dam x ration interactions. As the main effects of ration and sire were well defined, it is probable that these interactions were caused by differential responses of the dam lines within each sire or ration, as was observed for the sire x dam interaction of female body weights in Experiment 1.

Post-hatching Growth Rates (Males)

In Table LVII are presented the percentage sums of squares and significance of the partitioned effects from the analyses of variance of weekly and average growth rates of male chicks. The significance of the sire effect was identical to that observed in Experiment 1. Sires were highly significant in all instances except the 5-6 week growth period during which the effect was significant at the .05 level of probability. Comparison of the means by Duncan's test (Table LVIII) indicated that, as in Experiment 1, the only time that the mean weekly growth rate of the WR sire line was significantly greater than that of the NH line was during the first week. However, this difference in one-week growth, and probably the non-significant differences in favour of the WR line occurring in later weeks, were enough to cause a significant difference in the six-week growth rate of these two sire lines. For the six-week growth rate and for growth rates during each weekly interval, except hatch to one week, the WL sire line males were significantly inferior to males from the other two sire lines.

The effect of dams on weekly growth rates (Table LVII) was generally significant, and as in Experiment 1, the dam effect on the six-week growth rate was highly significant. Comparison of the means again indicated that only during the first week was the mean growth rate of chicks from the WR dam line significantly greater than all other dam line means, and only in the sixth week was the mean growth rate of chicks from the WL dam line significantly smaller than all other means. The dam line means of the hatch to six-week average growth were in the ascending order; WL, WLxWR, WLxNH, NH, NHxWR and WR. However, the second, third and fourth means were not significantly different from each other.

The effect of ration on weekly growth rates of male chicks was highly significant during the first four weeks, significant during the fifth and non-significant during the sixth. The ration effect on six-week growth rate was also highly significant. Comparison of the means (Table LX) indicated that the weekly growth rate of chicks on the broiler ration was greater than that of chicks on the starter ration only during the first three weeks. During the remaining three weekly periods the situation was reversed. It will be remembered from Table LVI, however, that the difference in body weight in favour of the broiler-fed chicks continued to increase during this period, indicating again that early growth is more important than later growth in determining body weight advantage.

Post-hatching Body Weights (Females)

Table LXI contains the percentage sums of squares and their significance, from the analyses of variance of weekly body weights of female chicks. The significance of the sire effect was similar to that observed for male chicks. Table LXII indicates that the mean weight of chicks from the WL sire line was significantly greater at one week of age than that of the NH sire line, although this difference was non-significant at two weeks. From three weeks on the means of each sire line resumed the order and significance that had been observed previously.

Except at hatch, the effect of dam lines was highly significant (Table LXI), and, as observed with the male chicks, the three "pure" dam lines were significantly different from each other after three weeks of growth (Table LXIII). During most of the growing period the mean weights of the dam lines assumed groupings in which the WL and WLxNH dam lines were not significantly different from each other, but were both significantly less than the NH, WLxWR and NHxWR dam lines. These three lines in turn were significantly less than the WR dam line, but not significantly different from each other. As with the male chicks, the dam lines were ranked in the order; WL, WLxNH, WLxWR, NH, NHxWR and WR with respect to their effect on six-week body weight. However, the WLxWR, NH and NHxWR dam lines were not significantly different from each other.

The effect of ration on body weights of female chicks corresponded very closely to the effect observed with male chicks. Again the mean weights of the two rations were significantly different after the first week's growth, and again the margin in favour of the broiler ration increased at each weighing (Table LXIV).

The sire x dam interaction was consistent and prominent (Table LXI) and again is assumed to be due to differential response of dams within each sire.

Post-hatching Growth Rates (Females)

The percentage sums of squares of the weekly and six-week growth rates of the female chicks are presented in Table LXV. The effect of sire line on growth rate was highly significant in every instance, including the 5-6 week growth period, where the sire line effect on male growth rates had declined. It can be seen from Table LXVI that the significant difference between the NH and WR sire lines extended into the second week's growth, whereas in Experiment 1 it had existed only during the first week. Also in Table LXVI it can be seen that during the hatch to one-week interval the mean growth rate of the WL sire line was significantly greater than that of the NH sire line. In the analyses of first-week growth rates of both male and female chicks in Experiment 1 and of male chicks in Experiment 2, the mean growth rate of the WL sire line was always greater than the growth rate of the NH sire line, however, in these previous instances, the difference was not significant.

The effect of dams on weekly growth rate was highly significant during the first, third and fifth weeks, but non-significant during the other weekly periods. The effect on the six-week growth rate was also highly significant. Comparison of the means by Duncan's test (Table LXVII) revealed that for each weekly interval and for the hatch to six-week period the dam effect was largely attributable to differences between the WL or WLxNH dam lines and the WR dam line. On the basis of average growth rate from hatch to six weeks the dam lines were ranked in the ascending order; WL, WLxNH, WLxWR, NH, NHxWR and WR, the same order that was observed for the average growth rate of the male chicks, and for the six-week body weight of the male and female chicks. As in Experiment 1, the body weight differences between the heavy lines at six weeks of age were primarily due to the differing growth rates between hatch and one week of age.

In both Experiments 1 and 2 the analyses of growth rates indicated that for each sex the first week's growth rate of the WL dam line was always less than that of the NH dam line, although these differences were not significant. When these observations are compared with those of the WL and NH sire lines where the reverse situation holds, it seems that the difference in growth pattern may have some bearing on the sire x dam growth rate interaction that occurred during early periods in Experiments 1 and 2.

The appearance of this early interaction during the first week's growth and the subsequent loss during the later stages infers that the presence of the consistent sire x dam interaction in body weight data has its origin at this early age. In-so-far as weekly growth rate does not give any evidence of non-additivity during these later stages of growth it would appear that selection programmes based on growth rate from one to six weeks of age, or perhaps less, would have the advantage of a high degree of additive genetic variance when compared with selection programmes based on body weight alone. Some caution must be placed on this interpretation since the evidence is based on "pure" lines and their crosses, although in this case the evidence appears conclusive.

Rations had a highly significant effect on growth rate during the first three and the last weekly periods as well as on the six-week growth rate. Of the two remaining weekly periods the ration effect was significant during the three to four week interval and non-significant during the four to five week interval. Comparison of the means, however, (Table LXVIII) revealed that the advantage of the broiler ration was reversed after the first three weeks, as was the case with male chicks, although again the body weight margin in favour of the broiler-fed chicks continued to increase. This reversal in growth rates (of chicks fed on the two rations) did not occur in Experiment 1 except during the third week's growth, where the effect was considered to be due to a differential response to vaccination. The two sets of observations can be reconciled if it is considered that each chicken and/or its line has a certain genetic and therefore limited capacity for growth and that environment affects only the rate at which this capacity is being expended at any given time. Thus, when the reaction to vaccination delayed the growth of the broiler-fed chicks they still had enough capacity in reserve to be able to expend it at a faster rate than the starter-fed chickens, at least for the duration of the six-week test period.

Embryo Correlations

The simple correlations of pre- and post-storage egg weights, embryo weights and date of lay at each incubation period are presented in Table LXIX. The correlation coefficient of pre-storage egg weight with embryo weight was significant at eight and sixteen days of incubation and highly significant at fourteen and eighteen days. The coefficient of post-storage egg weight with embryo weight showed the same fluctuating pattern of significance except that it was also significant at twelve days of incubation. As in Experiment 1, these differences can be explained on the basis of the extremely high correlation between date of lay and embryo weight, in conjunction with significant relationships between date of lay and pre- and post-storage egg weights that existed at eight and fourteen days of incubation. The fact that these latter correlations existed for the eggs which were broken out at some stages of incubation and not at others is inexplicable except as experimental error. Partial correlations between embryo weight and egg weight were not calculated, however, it is believed by the author that such calculations would have shown that if the effect of date of lay was removed, the relationship between embryo weight and egg weights would have become significant around twelve days of incubation and shown an increasing correlation thereafter. These observations therefore agree fairly closely to those of Bray and Iton (1962), although the methods of determining the correlation between egg weight and embryo weight were different. In contrast to the results in Experiment 1, the amount of variation of embryo weight due to age of egg was relatively constant during the different stages of incubation.

Post-hatching Correlations

Table LXX presents the simple correlations of time of hatch, storage period and pre- and post-storage egg weights with weekly body weights from hatch to six weeks of age. Time of hatch showed no significant correlation with body weights, whereas in Experiment 1 a highly significant negative correlation was found. It is possible that the relationship observed between these traits in Experiment 1 depended on the incubation stress that occurred in that experiment.

The correlation between storage period and chick weight was negative during all weighings and essentially in agreement with the results in Experiment 1. They were highly significant for the first three weighings and significant until the fifth week's weighing. It seems probable, however, that this relationship was due to the highly significant correlations of pre- and post-storage egg weights with chick weights at each weighing, in conjunction with the highly significant correlations of pre- and post-storage egg weights with storage period (-.126 and -.154 respectively). A gradual increase in egg size during the collection and storage period accounts for the significant correlation of pre-storage egg size and storage period. The fact that the magnitude of the correlation of storage period with hatching weight was not proportional to that of egg weight with hatching weight could have been due to the loss of weight, by drying, of the earlier hatched chicks, although the coefficient between time of hatch and storage period (-.051) was not significant. The highly significant relationship between storage period and time of hatch observed in Experiment 1 may have been another effect of the incubation stress which apparently occurred in that experiment.

The correlations between egg weight and weekly body weights seem to be in general agreement with reports in the literature (Wiley, 1950b, Skoglund et al., 1952, Tindel and Morris, 1964), and conflict directly only with reports of Halbersleben and Mussel (1922) and Upp (1928), although differences in strains could explain the conflict.

The correlation coefficients of hatching time, storage period, pre- and post-storage egg weights and six-week body weight with weekly growth rates from hatch to six weeks of age are presented in Table LXXI. Neither time of hatch nor storage period bore any significant relationship with weekly growth rate, whereas in Experiment 1 both of these traits were found to have a negative correlation up to two weeks of age. It was observed in Experiment 1 that incubation stress may have given a temporary advantage in growth rate to embryos from those eggs which had been stored for less time and thus could have maintained the differences in development of embryos that were attributable to storage period effects until hatching. In this way the incubation stress by increasing the variation in time of hatch due to storage of eggs, could have magnified the relationships of time of hatch and storage period with weekly growth rates or body weights.

Pre- and post-storage egg weights bore a highly significant negative relationship to first week's growth rate, whereas the correlation coefficients of egg weights with other weekly growth rates were all negative but non-significant. However, in Experiment 1 the direction of correlation agrees completely with that of Experiment 2, indicating that a small but definite relationship may exist.

As in Experiment 1, the highest correlation between six-week body weight and weekly growth rates occurred with the second week's growth. The coefficients declined thereafter, although all, including the first week's, were highly significant. As previously observed the early growth periods (hatch to one week and one to two weeks) have considerable influence on six-week body weight.

Correlations of Embryo and Post-hatching Data Within "Genotypes"

As in Experiment 1, "genotypic" estimates of weight and growth rate were obtained for embryo stages and post-hatching (within sex and ration) stages of development. The correlation coefficients of six-week body weight with each of the other corresponding "genotypic" estimates are presented in Table LXXII.

Six-week growth rate and weekly body weights from the end of the first week on were highly significantly correlated with six-week body weight. The "genotypic" hatching weight estimates of both male and female chicks on the starter ration were also significantly correlated with six-week body weight estimates.

The correlation coefficients of six-week body weights with embryonic growth rates during two-day periods from six to eighteen days increased until significance was reached at the ten to twelve day interval, and then became negative and non-significant during the remainder of the incubation period. This pattern was in general similar to that of Experiment 1. The change to a negative relationship after twelve days was presumably due to the growth restriction of those "genotypes" that had grown faster in the early stages either by limit of shell size or exhaustion of nutrients as mentioned before. The smaller embryos at six and eight days were much more subject to experimental error in weighing and it is considered that the increase in the magnitude of the coefficients up to twelve days could be due more to a reduction of sampling error than to an actual increase in the biological correlation.

The correlation of eight to twelve-day averaged embryo growth with six-week body weight was highly significant and the coefficients of correlation of embryo weight from twelve to eighteen days, inclusive, with six-week body weight were in general highly significant. In connection with these observations it is of interest to note the following statement by Bray (1965):

"The usefulness of embryonic weight as an aid to altering

> the post embryonic growth of any species of birds seems real though it will have to be carefully evaluated in each situation."

It should be noted that the apparent relationship between the growth periods which gave the highest significance to "genotypic" effects and the higher correlation values between embryo growth and six-week weight (observed in Experiment 1) did not hold for the data of Experiment 2.

Between 81 and 92 per cent of the variation in "genotypic" six-week body weight was explainable in terms of six-week growth rate alone, and between 34 and 42 per cent of the variation was explainable in terms of only the eight to twelve-day embryo growth.

Table LXXIII contains the "genotypic" correlation coefficients of six-week growth rate with embryo growth rates. The pattern was very similar to that obtained in the correlation of six-week body weight. Again, generally significant coefficients were obtained with ten to twelve-day embryo growth and highly significant correlations were obtained with eight to twelve-day averaged embryo growth rates.

As in Experiment 1, the eight to twelve-day embryonic growth period gave the highest positive correlation and it should be noted that a general agreement between the two experiments exists for the six to twelve-day period of incubation. To the author's knowledge, this is the first instance where embryonic growth has been correlated with either post-hatching growth or body weights of the same "genotypes".

Table LXXIV contains the coefficients of determination (i.e. the percentage of the variation of the dependent variable that can be attributed to the multiple variation of the independent variables) obtained from simple and multiple linear regressions of the "genotypic" estimates of six-week body weight within each sex and ration on selected variables. The selected variables were; six-week growth rate (X_1), embryo growth rate during the eight to twelve-day interval (X_2), embryo weight at fourteen days (X_3), hatch weight (X_4) and one-week body weight (X_5).

The data in Table LXXIV indicates that hatch weight (X_4) was the lowest single contributor among the selected variables and explained on the average only 22.1 per cent of the variation in six-week body weight. Embryo growth (X_2) and embryo weight (X_3) explained an average of 39.2 and 43.2 per cent of the variation respectively. Six-week growth rate (X_1) was the highest single contributor to the six-week body weight (86.6 per cent of the variation was explained). Six-week growth rate, having the highest correlative value with six-week body weight, was retained in all multiple linear regression analyses and the effects of adding the other variables, as well as one-week body weight (X_5), were tested. Embryo growth rate (X_1 and X_2) gave a noticeable increase in the average proportion of variation explained (89.2 per cent), although curiously, it caused a reduction in the explained variance of six-week body weights of female chicks on the broiler ration. The cause of this reduction is unknown. The further addition of embryo weight (X_1, $X_2$and X_3) made very little difference to the explained variation, however, the use of hatch weight instead of the embryo weight (X_1, X_2 and X_4) raised the amount of the explained variance to an average of 92.1 per cent. Six-week growth, embryo growth, hatch weight and embryo weight (X_1, X_2, X_3 and X_4) explained no more of the variation than when only the first three variables were considered. The substitution of one-week body weight for hatch weight and embryo weight (X_1, X_2 and X_5) raised the proportion of variance explained to 96.3 per cent, however, it should be noted that six-week growth rate and one-week body weight are not unrelated variables. Re-inclusion of embryo weight did not raise the proportion of variance explained, however, with 96.3 per cent of the variation in this data explained in terms of only three variables; six-week growth rate, eight to twelve-day embryonic growth and one-week body weight, there is very little variation in six-week body weight left unexplained.

The effects of each variable, considered either singly or in combination, were fairly consistent within each sex and ration. Considerably more of the six-week body weight variation of female chicks was explained in terms of their six-week growth rate than in the case of the male chicks, however, and in most other regressions, less of the variation in six-week body weight was explained in the case of female chicks on the broiler ration.

The data suggest that a multiple linear regression analysis, using one-week body weight, one to six-week growth rate and eight to twelve-day embryo growth rate as the independent variables should effectively explain practically all the variation in six-week body weight. It should be recognized, however, that in this data six-week growth rate alone explains the majority of the variation.

Further Discussion of Storage Effects on Embryo Weights and Growth Rates

In both experiments, each week of egg storage gave a significant and cumulative depression of embryo weight at each stage of incubation. However, when growth rates of embryos were compared for eggs from each storage period, a trend of increase in the measured growth rate was observed for each week of storage. Averaged embryo growth rates over different periods of incubation generally confirmed this trend.

The apparent interpretation of these observations is that those embryos whose growth rates were retarded by storage effects in the early stages of incubation have a compensatory increase in growth rate at later stages, which would tend to overcome the earlier effect. Kaufman, as cited by Bohren et al., 1961, holds that only initation of growth is delayed by storage and that once started, the growth rates of the different storage groups of embryos are the same. To reconcile this belief with the present data it is necessary to assume that the embryos from the different storage groups are supplying a different time scale to the function $y = at^b$ and that the growth of embryos of the different groups at equivalent points of biological time are equal. This latter interpretation also requires the assumption that the growth rate (b) has a maximum value early in the incubation period and declines thereafter.

Had the results of Experiment 1 only been considered, Kaufman's hypothesis would have been entirely acceptable, for in this case the highly significant correlation of hatching time and duration of egg storage ($r = .452$) indicated that eggs that were stored longer, hatched later. In Experiment 2, however, the correlation between these two factors (-.051) was non-significant and indicates that the eggs from each storage period hatched at approximately the same time. As Experiment 2 gave no evidence of any incubation stress, the first interpretation seems more likely, for the compensatory growth would seem to have been sufficiently great to overcome the effects of delayed initiation of growth. It would seem from these results that special care must be taken to ensure that incubation conditions are uniform during any experiment involving egg storage effects on embryonic or subsequent growth.

SUMMARY

A comparison was made of rates of growth and body weights between pre- and post-hatching stages of development of the growing chicken as affected by strains or strain crosses, egg storage,

egg weights, time of hatch, sex and post-hatching nutritional environment. The interrelationships of these factors were also investigated.

The three "pure" strains used in the study were: White Leghorns (bred for high egg production), White Rocks (bred for meat) and New Hampshires (an intermediate type). In Experiment 1, progeny of the nine possible combinations of the three pure strains were used. In Experiment 2 nine extra genotypes were obtained by including the three line crosses (single and reciprocal crosses) in the dam lines.

Eggs were gathered and stored over a three week period, individually recorded as to "genotype", date of lay and pre- and post-storage egg weights. One-half of the eggs in each experiment were broken out and the embryos weighed on alternate days from six to eighteen days of incubation. The sex of each embryo was recorded beginning at twelve days of incubation in Experiment 1 and beginning at ten days of incubation in Experiment 2.

The hatched chicks were divided and raised on two nutritional environments provided by a commercial starter ration and a commercial broiler ration. Rearing was done in duplicate floor pens for each ration in Experiment 1 and in nine battery brooders, each containing eight compartments, in Experiment 2. Chicks were weighed at hatch and at weekly intervals thereafter.

The power function $y = at^b$ (Roberts, 1964) was used to calculate weekly and six-week growth rates for each hatched chick and for each "genotype". The same function was used to calculate "genotypic" estimates of embryonic growth. Analyses of variance were calculated on body weights and growth rates during the pre- and post-hatching stages. Correlations between recorded traits were calculated and "genotypic" estimates of six-week body weight were regressed on selected "genotypic" variables.

The following points were brought out in the results and discussion:

1. Embryonic growth between eight and twelve days of incubation was found to be significantly correlated with both six-week body weight and six-week growth rate. In addition, both six-week growth rate and six-week body weight were found to be significantly correlated with embryo weight at fourteen days of incubation.

2. A highly significant correlation was found between averaged estimates of six-week growth rate and six-week body weight ($r^2 = .866$).

3. Multiple linear regression based on averaged values showed that a high proportion (92 per cent) of the variation in six-week body weight could be associated with the combined variation of eight to twelve day embryo growth rate, hatching weight and six-week growth rate.

4. Each week of egg storage was associated with a significant and cumulative depression of embryonic weights and

generally significant and cumulative increments in embryonic growth rate during the six to eighteen day interval.

5. An apparent incubation stress was observed in Experiment 1 which temporarily but significantly modified the effects of egg storage in Experiment 1 in favour of the eggs stored for one week or less.

6. Significant 'genotypic' effects on embryo weight were observed, concentrated mainly in the period of eight to fourteen days of incubation.

7. Significant 'genotypic' effects on embryo growth were observed during various stages of incubation and a tendency for growth rates during early and late stages of incubation to be inversely related was discussed.

8. A significant sex effect in embryonic weight in favour of the males was observed.

9. Significant maternal effects on hatching weight and significant genetic effects on subsequent body weights up to six weeks of age were obtained.

10. Genetic differences in weekly and average growth rates were significant. The differences in six-week body weight between the two heavy lines were mainly due to differences in growth rate during the first week of age.

11. A sire x dam interaction, significant and consistent throughout most analyses of post-hatching body weight, was found to be primarily due to a sire x dam interaction present in the first week of growth. The advantages of a relative lack of non-additive effects in growth rates from one to six weeks of age, as compared to the presence of non-additive effects in body weights was discussed in relation to selection programmes.

12. Rations exerted an influence on weekly body weights in favour of the broiler ration. This difference became significant and continued to increase after the first week's weighing.

13. Rations exerted a significant effect on growth rate during all but one of the growth intervals calculated. In Experiment 2 the advantage of the broiler ration in the early periods was reversed during the latter half of the six-week growth period.

14. A concept of a genetically limited potential for growth in relation to environmental influences was discussed.

15. A significant relationship between pre- and post-storage egg weights and embryo weights which commenced around twelve days of incubation and increased during the later stages was noted.

16. Pre- and post-storage egg weights bore a relationship with body weight which diminished with age but remained

highly significant at least until six weeks in both experiments.

17. Hatching time was found to be correlated with length of egg storage in Experiment 1 but not in Experiment 2. Hatching time was significantly and negatively correlated with weekly chick body weights in Experiment 1 but not in Experiment 2. Hatching time and storage period were significantly and negatively correlated with weekly growth rate to two or three weeks of age respectively in Experiment 1 but no relationship was evident in Experiment 2. These differences were mainly attributed to the incubation stress which was evidenced in Experiment 1.

18. In general, six-week body weight of individuals bore highly significant relationships with all weekly growth rates. In both experiments the peak of significance occurred during the second week's growth period.

19. The relationship between weekly growth and pre- and post-storage egg weights was negative and in some instances significant. The implications of the two results mentioned above were discussed as factors in a selection programme based on early growth rate.

These results indicate that practically all of the variation of six-week body weight in this data was successfully accounted for by the combined effects of six-week growth rate, hatching weight and embryonic growth rate between eight and twelve days. The data also indicate that gains in six-week body weight may be made by selecting for early growth rate without concomitant changes in other traits.

BIBLIOGRAPHY

Blunn, C.T. and P.W. Gregory. 1935. The embryological basis of size inheritance in the chicken. J. Exp. Zool. 70: 397-414.

Bohren, B.B., L.B. Critterden and R.T. King. 1961. Hatching time and hatchability in the fowl. Poultry Sci. 40: 620-632.

Bray, D.F. and E.L. Iton. 1962. The effect of egg weight on strain differences in embryonic and post embryonic growth in the domestic fowl. British Poultry Sci. 3: 175-188.

Byerly, T.C. 1930. The effects of breed on the growth of the chick embryo. J. Morph. and Physiol. 50: 341-359.

__________. 1932. Growth of the chick embryo in relation to its food supply. J. Exp. Biol. 9: 15-44.

Byerly, T.C., W.C. Helsel and J.P. Quinn. 1938. Growth in weight and cell number. Genetic effects in the chick embryo and chick. J. Exp. Zool. 78:185-203.

Coleman, J.W., H.S. Siegel and P.B. Siegel. 1964. Embryonic development of two lines of White Rocks. Poultry Sci. 43: 453-458.

Godfrey, E.F. and R.G. Jaap. 1952. Evidence of breed and sex differences in the weight of chicks hatched from eggs of similar weights. Poultry Sci. 31: 1108-1109.

Godfrey, G.F. and C. Williams. 1955. Unsuitability of chick weight:egg weight ratio as an indicator of post natal growth. Poultry Sci. 34: 164-166.

Godfrey, G.F., C. Williams and C.E. Marshall. 1953. The relative influence of egg size, age at sexual maturity and mature body weight on growth to twelve weeks of age. Poultry Sci. 32: 496-500.

Goodwin, K. 1961. Effect of hatching egg size and chick size upon subsequent growth rate in chickens. Poultry Sci. 40: 1408.

Halbersleben, D.L. and F.E. Mussehl. 1922. Relation of egg weight to chick weight at hatching. Poultry Sci. 1: 143-144.

Henderson, E.W. 1930. Growth and development. XVI. The influence of temperature and breeding upon the rate of growth of chick embryos. Univ. Missouri Agric. Exp. Sta. Res. Bull. 149: 5-47.

Jull, M.A. and B.W. Heywang. 1930. Yolk assimilation during the embryonic development of the chick. Poultry Sci. 9: 393-404.

Jull, M.A. and J.P. Quinn. 1925. The relationship between the weight of eggs and the weight of chicks according to sex. J. of Agricultural Research pp. 223-226.

Kosin, I.L., H. Abplanalp, J. Gutierrez and J.S. Carver. 1952. The influence of egg size on subsequent early growth of the chick. Poultry Sci. 31: 247-254.

Lerner, I.M. 1939. The shape of the chick embryo growth curve. Science 89: 16-17, No. 2297.

Lerner, I.M. and V.S. Asmundson. 1938. Genetic growth constants in domestic fowl. Poultry Sci. 17: 286-294.

McNary, H.W., A.E. Bell and C.H. Moore. 1960. The growth of inbred and hybrid chicken embryos. Poultry Sci. 39: 378-384.

Monro, S.S. and I.L. Kosin. 1940. The existance of a sex difference in the weight of day-old chicks, with further data on egg weight-chick weight relationship. Sci. Agr. 20: 586-591.

Murray, H.A. Jr. 1925. Physiological ontogeny. A. Chicken embryos. III. Weight and growth rate as functions of age. J. Gen. Physiol. 9: 39-48.

O'Neil, J.B. 1950. Relationship of chick size to egg size and its effect upon growth and mortality. Poultry Sci. 29: 774.

Ralston, A. and H.S. Wilf. 1962. Mathematical methods for digital computors. London: Clapman and Hall Ltd.

Roberts, C.W. 1964. Estimation of early growth rate in the chicken. Poultry Sci. 43: 238-252.

____________. 1965. One week body weight and bi-weekly early growth rate as related to 7 week body weight in the chicken. Poultry Sci. 44: (4) In Press.

Skoglund, W.C., K.C. Seegar and A.T. Ringrose. 1952. Growth of broiler chicks hatched from various sized eggs when reared in competition with each other. Poultry Sci. 31: 796-799.

Steel, R.G.D. and I.H. Torrie. Principles and procedures of statistics. 1960. New York: McGraw-Hill Book Co., pp. 107-109.

Tindel, D. and D.R. Morris. 1964. The effects of egg weight on subsequent broiler performance. Poultry Sci. 43: 534-539.

Upp, C.W. 1928. Egg weight, day old chick weight and rate of growth in Single Comb Rhode Island Red chicks. Poultry Sci. 7: 151-155.

Wiley, W.H. 1950a. The influence of egg weight on the pre-hatching and post-hatching growth rate in the fowl. I. Egg weight-embryonic development ratios. Poultry Sci. 29: 570-574.

__________. 1950b. The influence of egg weight on the pre-hatching and post-hatching growth rate in the fowl. II. Egg weight-chick weight ratios. Poultry Sci. 29: 595-604.

Williams, C., G.F. Godfrey and R.B. Thompson. 1951. The effect of rapidity of hatching on growth, egg production, mortality and sex ratios in the domestic fowl. Poultry Sci. 30: 599-606.

TABLE I

STATISTICAL MODELS FOR ANALYSES OF VARIANCE OF EMBRYO DATA

Model	Observation	Component Effects														
General	E	s_i	d_j	$(sd)_{ij}$	p_k	$(sp)_{ik}$	$(dp)_{jk}$	$(spd)_{ijk}$	f_l	$(sf)_{il}$	$(df)_{jl}$	$(pf)_{kl}$	$(sdf)_{ijl}$	$(spf)_{ikl}$	$(dpf)_{jkl}$	*
a	Ew_{ijkl}	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
b	Ew_{ijk}	+	+	+	+	+	+	-								+
c	Eb_{ijk}	+	+	+	+	+	+	-								+
d	Ew_{ijkl}	+	+	+	+	-	-	-	+	-	-	-	-	-	-	+
e	Eb_{ijkl}	+	+	+	+	-	-	-	+	-	-	-	-	-	-	+
f	Eb_{ijkl}	+	+	+	+	-	-	-	-	-	-	-	-	-	-	+
g	Ew_{ijk}	+	+	+	+	-	-	-								+
h	Eb_{ijk}	+	+	+	+	-	-	-								+

* The residual effect
Effects Analyzed
\- Included within the residual effect
Ew Embryo weight
Eb Embryo growth rate

TABLE II

F VALUES FROM THE ANALYSES OF VARIANCE OF EMBRYO WEIGHTS RECORDED AT 12, 14, 16 AND 18 DAYS OF INCUBATION USING STATISTICAL MODEL (a): EXPERIMENTS 1 AND 2

		Days of Incubation							
		12		14		16		18	
		Experiment							
Sources of Variation	df	1	2	1	2	1	2	1	2
Sex (Sx)	1	0.09	5.81*	13.19**	2.65	3.66	1.29	0.10	2.52
Storage Period (P)	2	93.50**	75.09**	74.85**	106.06**	39.91**	26.01**	38.86**	117.37**
Sire (S)	2	18.80**	5.62*	41.95**	2.69	2.39	2.21	1.73	13.74*
Dam (D)	2	15.67**	3.74*	29.88**	11.05**	3.79	1.41	7.85*	3.26*
Sx x P	2	0.78	1.42	0.68	0.24	2.07	0.27	0.88	1.56
Sx x S	2	0.50	1.63	0.01	1.64	0.06	0.36	2.36	3.09
Sx x D	2	1.62	1.13	2.08	0.71	0.71	1.21	0.75	1.60
P x S	4	0.50	1.12	1.47	1.27	2.88	1.72	4.29*	0.78
P x D	4	0.33	2.65*	0.96	1.04	2.41	0.74	0.09	1.07
S x D	4	1.21	2.38*	2.31	0.91	1.61	1.22	3.17	6.32**

TABLE II (Continued)

		Days of Incubation							
		12		14		16		18	
		Experiment							
Sources of Variation	df	1	2	1	2	1	2	1	2
Sx x P x S	4	0.30	0.58	1.87	1.08	1.00	0.10	2.86	2.45
Sx x P x D	4	0.33	1.02	1.21	0.83	1.35	1.15	1.34	1.87
Sx x S x D	4	1.02	0.93	3.18	1.58	1.41	0.58	1.04	2.58*
P x S x D	8	3.31	0.94	4.24*	0.87	1.30	0.69	4.73*	1.44
Residual	8								

* Significant at .05 probability
** Significant at .01 probability

TABLE III

PERCENTAGE SUMS OF SQUARES FROM THE ANALYSES OF VARIANCE OF EMBRYO WEIGHTS AT TWO DAY INTERVALS FROM 6 TO 18 DAYS OF INCUBATION: EXPERIMENT 1

Statistical Model	g	d	g	d	g	d	d	d	d
			Days of Incubation						
Source of Variation	df	df	6	8	10	12	14	16	18
Sex		1	#	#	#	0.03	3.31*	2.25	0.05
Storage Period	2	2	79.10**	56.88**	60.60**	60.13**	37.61**	49.12**	38.50**
Sire	2	2	3.36	6.21	5.09*	12.09**	21.08**	2.94	1.71
Dam	2	2	4.39	6.44	1.92	10.08**	15.02**	4.67	7.77
Sire x Dam	4	4	2.91	7.88	21.97**	1.55	2.32	3.96	6.27
Residual	16	42	10.22	22.58	10.41	16.12	20.66	37.07	45.70

\# Not Measured
* Significant at .05 probability
** Significant at .01 probability

TABLE IV

EFFECT OF DURATION OF PREINCUBATION EGG STORAGE ON EMBRYO WEIGHTS RECORDED AT TWO DAY INTERVALS FROM 6 TO 18 DAYS OF INCUBATION: EXPERIMENT 1

Days of Incubation	Mean Embryo Weights (Grams) Duration of Storage (Weeks) 1	2	3
6	.432	.346	.244
8	1.262[a]	1.197[a]	.992
10	2.587	2.186	1.896
12	6.032	5.492	4.710
14	11.554	10.420	9.698
16	17.818	17.047	15.295
18	25.542	23.893	22.418

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE V

EFFECT OF SIRE LINE ON EMBRYO WEIGHTS RECORDED AT TWO DAY INTERVALS FROM 6 TO 18 DAYS OF INCUBATION: EXPERIMENT 1

Days of Incubation	Mean Embryo Weights (Grams)		
	Sire Line		
	WL	NH	WR
6	.323[a]	.361[b]	.338[ab]
8	1.101[a]	1.194[a]	1.157[a]
10	2.178[ab]	2.338[b]	2.152[a]
12	5.132	5.377	5.725
14	9.938	10.417	11.318
16	16.388[a]	16.755[ab]	17.017[b]
18	23.919[a]	23.639[a]	24.295[a]

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE VI

EFFECT OF DAM LINE ON EMBRYO WEIGHTS RECORDED AT TWO DAY INTERVALS FROM 6 TO 18 DAYS OF INCUBATION: EXPERIMENT 1

Days of Incubation	Mean Embryo Weights (Grams) Dam Line		
	WL	NH	WR
6	.315[a]	.349[ab]	.357[b]
8	1.104[a]	1.199[a]	1.148[a]
10	2.175[a]	2.293[a]	2.201[a]
12	5.150	5.391	5.693
14	10.074	10.383	11.216
16	16.386[a]	16.612[ab]	17.161[b]
18	23.152	24.231[a]	24.470[a]

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE VII

EFFECT OF SEX ON EMBRYO WEIGHTS RECORDED AT TWO DAY INTERVALS FROM 12 TO 18 DAYS OF INCUBATION: EXPERIMENT 1

Days of Incubation	Mean Embryo Weights (Grams)	
	Males	Females
12	5.400[a]	5.423[a]
14	10.784	10.331
16	16.946[a]	16.494[a]
18	23.996[a]	23.906[a]

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE VIII

PERCENTAGE SUMS OF SQUARES FROM THE ANALYSES OF VARIANCE OF EMBRYO GROWTH RATES DURING SUCCESSIVE TWO DAY INTERVALS BETWEEN 6 AND 18 DAYS OF INCUBATION: EXPERIMENT 1

Statistical Model	h	f	h	h	f	f	f	f
			Intervals (Days of Incubation)					
Source of Variation	df	df	6-8	8-10	10-12	12-14	14-16	16-18
Sex		1	#	#	0.08	9.44*	0.94	1.22
Storage Period	2	2	50.68**	15.20*	6.16*	17.76**	5.22	3.32
Sire	2	2	1.18	5.59	26.75**	1.09	12.82*	2.45
Dam	2	2	5.09	1.19	10.27**	1.15	6.98	1.76
Sire x Dam	4	4	7.12	51.42**	25.66**	12.41	6.07	6.60
Residual	16	42	35.93	26.59	31.08	58.19	67.98	84.66

Not Measured
* Significant at .05 probability
** Significant at .01 probability

TABLE IX

EFFECT OF DURATION OF PREINCUBATION EGG STORAGE ON EMBRYO GROWTH RATES DURING SUCCESSIVE TWO DAY INTERVALS FROM 6 TO 18 DAYS OF INCUBATION: EXPERIMENT 1

Incubation Intervals (Days)	Mean Embryo Growth Rates Duration of Storage Period (Weeks) 1	2	3
6-8	3.725	4.326	4.923
8-10	3.210[a]	2.688[b]	2.906[ab]
10-12	4.662	5.055[a]	4.997[a]
12-14	4.217[a]	4.141[a]	4.678
14-16	3.253[a]	3.704[a]	3.441[a]
16-18	3.061[a]	2.867[a]	3.236[a]

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE X

EFFECT OF SIRE LINE ON EMBRYO GROWTH RATES DURING SUCCESSIVE TWO DAY INTERVALS FROM 6 TO 18 DAYS OF INCUBATION: EXPERIMENT 1

Incubation Intervals (Days)	Mean Embryo Growth Rates — Sire Lines: WL	NH	WR
6-8	4.37^{a}	4.22^{a}	4.38^{a}
8-10	3.06^{a}	2.99^{a}	2.76^{a}
10-12	4.70^{a}	4.60^{a}	5.41
12-14	4.30^{a}	4.30^{a}	4.43^{a}
14-16	3.76^{a}	3.56^{ab}	3.07^{b}
16-18	3.23^{a}	2.93^{a}	2.99^{a}

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE XI

EFFECT OF DAM LINE ON EMBRYO GROWTH RATES DURING SUCCESSIVE TWO DAY INTERVALS FROM 6 TO 18 DAYS OF INCUBATION: EXPERIMENT 1

Incubation Intervals (Days)	Mean Embryo Growth Rates Dam Lines		
	WL	NH	WR
6-8	4.52[a]	4.32[a]	4.14[a]
8-10	3.02[a]	2.88[a]	2.91[a]
10-12	4.77[a]	4.72[a]	5.22
12-14	4.35[a]	4.27[a]	4.42[a]
14-16	3.68[a]	3.55[a]	3.17[a]
16-18	2.94[a]	3.20[a]	3.03[a]

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE XII

PERCENTAGE SUMS OF SQUARES FROM THE ANALYSES OF VARIANCE OF EMBRYO GROWTH RATES WHEN AVERAGED FOR INTERVALS BEGINNING AT 6 OR 8 DAYS OF INCUBATION: EXPERIMENT 1

Statistical Model	h	f	h	f	f	f	f	f	f	f	f
			Intervals (Days of Incubation)								
Source of Variance	df	df	6-10	6-12	6-14	6-16	6-18	8-12	8-14	8-16	8-18
Storage Period	2	2	32.22*	38.07**	48.78**	56.87**	53.58**	1.83	15.88**	14.43*	24.41**
Sire	2	2	3.01	13.79**	12.05**	4.72*	8.28*	22.45**	16.67**	4.29	12.17*
Dam	2	2	8.23	4.58	4.91*	6.43*	2.19	18.27**	14.38**	5.25	0.61
Sire x Dam	4	4	19.53	4.95	10.63**	2.59	2.16	11.88*	16.60*	9.54	7.38
Residual	16	43	37.01	38.61	23.63	29.39	33.84	45.58	36.46	66.49	55.43

* Significant at .05 probability
** Significant at .01 probability

TABLE XIII

EFFECT OF EGG STORAGE ON AVERAGED TWO DAY EMBRYO GROWTH RATES: EXPERIMENT 1

Range of Intervals Averaged (Days)	Mean Averaged Embryo Growth Rates Storage Period (Weeks) 1	2	3
6-10	3.47[a]	3.51[a]	3.91
6-12	3.87	4.02	4.28
6-14	3.95	4.05	4.38
6-16	3.81	3.98	4.19
6-18	3.69	3.80	4.03
8-12	3.94[a]	3.87[a]	3.95[a]
8-14	4.03[a]	3.96[a]	4.19
8-16	3.84[a]	3.90[ab]	4.01[b]
8-18	3.68[a]	3.69[a]	3.85

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE XIV

EFFECT OF SIRE LINE ON AVERAGED TWO DAY EMBRYO GROWTH RATES: EXPERIMENT 1

Range of Intervals Averaged (Days)	Mean Averaged Embryo Growth Rates		
	Sire Line		
	WL	NH	WR
6-10	3.71[a]	3.60[a]	3.57[a]
6-12	4.04[a]	3.94[a]	4.18
6-14	4.11[a]	4.03[a]	4.25
6-16	4.04[a]	3.93[b]	4.01[ab]
6-18	3.91[a]	3.77[b]	3.84[ab]
8-12	3.88[a]	3.79[a]	4.08
8-14	4.02[a]	3.96[a]	4.20
8-16	3.96[a]	3.86[a]	3.92[a]
8-18	3.81[a]	3.68[b]	3.73[ab]

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE XV

EFFECT OF DAM LINE ON AVERAGED TWO DAY EMBRYO GROWTH RATES: EXPERIMENT 1

Range of Intervals Averaged (Days)	Mean Averaged Embryo Growth Rates: Dam Line WL	NH	WR
6-10	3.77[a]	3.60[a]	3.52[a]
6-12	4.10[a]	3.97[a]	4.09[a]
6-14	4.16[a]	4.04	4.17[a]
6-16	4.07	3.95[a]	3.97[a]
6-18	3.88[a]	3.82[a]	3.81[a]
8-12	3.89[a]	3.80[a]	4.07
8-14	4.05[a]	3.96[a]	4.18
8-16	3.95[a]	3.85[a]	3.93[a]
8-18	3.75[a]	3.72[a]	3.75[a]

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE XVI

PERCENTAGE SUMS OF SQUARES FROM THE ANALYSES OF VARIANCE OF MALE BODY WEIGHTS AT WEEKLY INTERVALS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 1

Statistical Model	i	i	i	i	i	i	i	i
		Time of Weighing						
Source of Variance	df	Hatch	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Sires (S)	2	0.42	11.35*	12.67**	20.26**	27.50**	31.13**	33.44**
Dams (D)	2	46.14**	58.37**	55.09**	60.56**	57.27**	53.70**	51.00**
Rations (R)	1	0.99	0.27	13.86**	0.43	3.47**	4.56**	5.98**
S x D	4	11.61	6.22	6.86*	6.56*	4.78**	3.85*	3.13*
S x R	2	0.19	0.19	0.09	0.70	0.58	0.69	0.52
D x R	2	11.84*	3.31	1.94	3.28*	1.58	1.53	1.40
S x D x R	4	6.07	1.24	0.24	0.30	0.51	0.58	0.57
Residual	18	22.75	19.08	9.25	7.90	4.31	3.95	3.97

* Significant at .05 probability
** Significant at .01 probability

TABLE XVII

EFFECT OF SIRE LINE ON BODY WEIGHTS OF MALE CHICKS AT WEEKLY INTERVALS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 1

	Mean Body Weights of Chicks (Grams)		
	Sire Line		
Time of Weighing	WL	NH	WR
Hatch	43.0[a]	42.8[a]	42.8[a]
1 Week	71.2[a]	67.6	72.8[a]
2 Weeks	139.6[a]	139.8[a]	152.8
3 Weeks	231.2	249.7	266.6
4 Weeks	326.4	368.7	391.5
5 Weeks	447.6	520.7	551.8
6 Weeks	580.7	690.8	722.9

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE XVIII

MEANS AND STANDARD DEVIATIONS OF PRE- AND POST-STORAGE EGG WEIGHTS, ACCORDING TO DAM LINE AND SEX OF HATCHED CHICKS

		Sex of Hatched Chicks			
		Males		Females	
		Mean	Standard Deviation	Mean	Standard Deviation
WL	Pre-storage Egg Wt.	60.5	3.51	60.6	3.64
	Post-storage Egg Wt.	59.7	3.42	59.7	3.67
NH	Pre-storage Egg Wt.	62.2	4.57	62.1	4.44
	Post-storage Egg Wt.	61.6	4.60	61.5	4.41
WR	Pre-storage Egg Wt.	59.0	3.86	59.0	4.23
	Post-storage Egg Wt.	58.2	3.92	58.2	4.30

TABLE XIX

EFFECT OF DAM LINE ON BODY WEIGHTS OF MALE CHICKS AT WEEKLY INTERVALS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 1

	Mean Body Weights of Chicks (Grams)		
	Dam Line		
Time of Weighing	WL	NH	WR
Hatch	42.5[a]	41.9[a]	44.2
1 Week	66.7[a]	67.4[a]	77.5
2 Weeks	132.2[a]	138.1[a]	162.0
3 Weeks	223.5	241.0	283.1
4 Weeks	319.7	353.1	413.8
5 Weeks	442.5	495.8	581.7
6 Weeks	557.1	656.3	760.9

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE XX

EFFECT OF RATION ON BODY WEIGHTS OF MALE CHICKS AT WEEKLY INTERVALS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 1

	Mean Body Weight of Chicks (Grams)	
	Rations	
Time of Weighing	Broiler	Starter
Hatch	42.7[a]	43.0[a]
1 Week	70.9[a]	70.2[a]
2 Weeks	150.5	137.6
3 Weeks	251.3[a]	247.1[a]
4 Weeks	371.8	352.6
5 Weeks	523.4	490.0
6 Weeks	690.6	639.0

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE XXI

PERCENTAGE SUMS OF SQUARES FROM THE ANALYSES OF VARIANCE OF WEEKLY AND AVERAGE GROWTH RATES OF MALE CHICKS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 1

Statistical Model	j	j	j	j	j	j	j	j
		Period of Growth (Weeks)						
Source of Variance	df	Hatch-1	1-2	2-3	3-4	4-5	5-6	Hatch-6
Sires (S)	2	20.25**	20.51**	29.65**	30.98**	39.31**	21.25*	48.65**
Dams (D)	2	43.54**	12.15*	8.66*	9.87*	10.07	9.65	32.30**
Rations (R)	1	1.42	39.69**	38.90**	23.46**	8.02*	10.03	7.75**
S x D	4	10.41	3.70	1.50	5.14	7.04	3.00	2.95
S x R	2	0.43	0.16	2.57	0.07	0.47	1.50	0.18
D x R	2	0.65	1.39	0.93	4.09	0.95	5.72	1.60
S x D x R	4	1.40	1.15	1.48	1.55	2.87	3.35	1.16
Residual	18	21.89	21.25	16.32	24.84	31.27	45.51	5.40

* Significant at .05 probability
** Significant at .01 probability

TABLE XXII

EFFECT OF SIRE LINE ON GROWTH RATES OF MALE CHICKS DURING WEEKLY INTERVALS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 1

Growth Intervals (Weeks)	Mean Growth Rates, Sire Lines: WL	NH	WR
Hatch-1	1.72[a]	1.56	1.84[a]
1-2	3.00	3.24[a]	3.31[a]
2-3	2.76	3.18[a]	3.06[a]
3-4	2.21	2.52[a]	2.48[a]
4-5	2.35	2.58[a]	2.57[a]
5-6	2.22[a]	2.41[b]	2.29[ab]
Hatch-6	2.38	2.58[a]	2.59[a]

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE XXIII

EFFECT OF DAM LINE ON GROWTH RATES OF MALE CHICKS DURING WEEKLY INTERVALS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 1

Growth Intervals (Weeks)	Mean Growth Rates Dam Lines WL	NH	WR
Hatch-1	1.56[a]	1.62[a]	1.94
1-2	3.05[a]	3.20[ab]	3.30[b]
2-3	2.86	3.07[a]	3.07[a]
3-4	2.30	2.47[a]	2.45[a]
4-5	2.43	2.53[a]	2.55[a]
5-6	2.25[a]	2.38[b]	2.28[ab]
Hatch-6	2.41	2.55	2.60

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE XXIV

EFFECT OF RATION ON GROWTH RATES OF MALE CHICKS DURING WEEKLY INTERVALS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 1

Growth Intervals (Weeks)	Mean Growth Rates Rations Broiler	Starter
Hatch-1	1.74[a]	1.68[a]
1-2	3.37	3.00
2-3	2.80	3.20
3-4	2.52	2.29
4-5	2.55	2.46
5-6	2.36[a]	2.25[a]
Hatch-6	2.56	2.48

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE XXV

PERCENTAGE SUMS OF SQUARES FROM THE ANALYSES OF VARIANCE OF FEMALE BODY WEIGHTS AT WEEKLY INTERVALS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 1

Statistical Model		i	i	i	i	i	i	i
		Time of Weighing						
Source of Variance	df	Hatch	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Sires (S)	2	6.21	13.47**	14.31**	25.28**	31.93**	36.52**	39.39**
Dams (D)	2	51.79**	63.23**	60.11**	62.27**	55.30**	51.11**	49.41**
Rations (R)	1	0.39	1.67*	11.62**	0.04	2.10**	3.41**	3.96**
S x D	4	8.52	12.91**	9.65**	8.63**	6.06**	4.92**	3.33**
S x R	2	1.35	0.02	0.44	0.56	0.73	1.10*	0.62
D x R	2	1.30	0.13	0.10	0.10	0.03	0.10	0.00
S x D x R	4	1.31	3.00	0.92	1.05	0.67	0.72	0.53
Residual	18	29.12	5.56	2.83	2.07	3.19	2.12	2.75

* Significant at .05 probability
** Significant at .01 probability

TABLE XXVI

EFFECT OF SIRE LINE ON BODY WEIGHTS OF FEMALE CHICKS AT WEEKLY INTERVALS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 1

	Mean Body Weights of Chicks (Grams)		
	Sire Line		
Time of Weighing	WL	NH	WR
Hatch	42.9[a]	42.3[a]	42.0[a]
1 Week	67.6[a]	66.2[a]	70.9
2 Weeks	126.9	130.8	140.4
3 Weeks	205.0	223.0	238.0
4 Weeks	278.9	318.1	340.6
5 Weeks	373.5	443.1	474.7
6 Weeks	478.2	573.9	619.0

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE XXVII

EFFECT OF DAM LINE ON BODY WEIGHTS OF FEMALE CHICKS AT WEEKLY INTERVALS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 1

	Mean Body Weights of Chicks (Grams)		
	Dam Line		
Time of Weighing	WL	NH	WR
Hatch	42.0[a]	41.5[a]	43.8
1 Week	64.9[a]	65.5[a]	74.3
2 Weeks	122.3	126.8	149.0
3 Weeks	202.1	212.5	251.3
4 Weeks	277.3	302.6	357.7
5 Weeks	375.1	420.0	496.2
6 Weeks	480.0	550.4	640.7

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE XXVIII

EFFECT OF RATION ON BODY WEIGHTS OF FEMALE CHICKS AT WEEKLY INTERVALS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 1

	Mean Body Weight of Chicks (Grams)	
	Rations	
Time of Weighing	Broiler	Starter
Hatch	42.5[a]	42.3[a]
1 Week	68.9	67.5
2 Weeks	137.8	127.6
3 Weeks	222.5[a]	221.5[a]
4 Weeks	319.1	306.0
5 Weeks	443.3	417.5
6 Weeks	575.6	538.4

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE XXIX

EFFECTS OF THE SIRE X DAM INTERACTION ON WEEKLY BODY WEIGHTS OF FEMALE CHICKS: EXPERIMENT 1

Sire Line	Mean Body Weights (Grams) WL			NH			WR		
Dam Line	WL	NH	WR	WL	NH	WR	WL	NH	WR
Time of Weighing (Weeks)									
Hatch	41.9^{a}	42.7^{ab}	44.0^{b}	42.2^{ab}	41.2^{a}	43.6^{b}	41.9^{a}	40.5^{a}	43.7
1	61.9	67.2	73.7	65.8	60.0	72.7	67.0^{a}	69.4^{a}	76.4
2	110.0	126.9	143.8	127.1	116.9	148.2	129.6	136.7	154.9
3	176.1	205.7	233.1	212.8	198.8	257.5	217.6	233.0	263.3
4	229.5	280.0	327.1	295.4^{a}	288.5^{a}	370.5	307.1	339.2	375.4
5	302.4	377.5	440.5	403.9^{a}	403.4^{a}	522.1	419.0	478.8	526.2
6	389.3	488.1	557.1	514.3^{a}	533.5^{a}	674.0	536.3	629.7	690.9

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE XXX

PERCENTAGE SUMS OF SQUARES FROM THE ANALYSES OF VARIANCE OF WEEKLY AND AVERAGE GROWTH RATES OF FEMALE CHICKS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 1

Statistical Model	j	j	j	j	j	j	j	j
		Period of Growth (Weeks)						
Source of Variance	df	Hatch-1	1-2	2-3	3-4	4-5	5-6	Hatch-6
Sires (S)	2	25.83**	17.49*	23.28**	29.94**	42.59**	8.54	53.62**
Dams (D)	2	36.54**	20.96**	2.64	18.29**	17.88**	16.42	34.74**
Rations (R)	1	1.33	24.54**	53.09**	17.11**	7.85*	3.87	3.86**
S x D	4	16.60**	3.04	1.23	7.13	1.33	11.04	1.91
S x R	2	0.19	1.14	1.81	0.89	3.17	8.52	0.31
D x R	2	0.25	2.05	0.33	1.21	0.89	5.38	0.03
S x D x R	4	4.28	1.94	0.62	2.06	8.55	2.72	1.71
Residual	18	14.99	28.85	17.01	23.38	17.74	43.51	3.81

* Significant at .05 probability
** Significant at .01 probability

TABLE XXXI

EFFECT OF SIRE LINE ON GROWTH RATES OF FEMALE CHICKS DURING WEEKLY INTERVALS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 1

Growth Intervals (Weeks)	Mean Growth Rates Sire Lines WL	NH	WR
Hatch-1	1.56[a]	1.54[a]	1.80
1-2	2.80	3.04[a]	3.04[a]
2-3	2.63	2.93[a]	2.90[a]
3-4	1.97	2.29[a]	2.32[a]
4-5	2.17	2.47[a]	2.48[a]
5-6	2.11[a]	2.20[a]	2.25[a]
Hatch-6	2.21	2.41	2.47

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE XXXII

EFFECT OF DAM LINE ON GROWTH RATES OF FEMALE CHICKS DURING WEEKLY INTERVALS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 1

Growth Intervals (Weeks)	Mean Growth Rates Dam Lines WL	NH	WR
Hatch-1	1.50^{a}	1.57^{a}	1.83
1-2	2.82^{a}	2.95^{ab}	3.12^{b}
2-3	2.76^{a}	2.84^{a}	2.87^{a}
3-4	2.01	2.28^{a}	2.28^{a}
4-5	2.25	2.44^{a}	2.44^{a}
5-6	2.10^{a}	2.29^{b}	2.16^{ab}
Hatch-6	2.24	2.40	2.45

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE XXXIII

EFFECT OF RATION ON GROWTH RATES OF FEMALE CHICKS DURING WEEKLY INTERVALS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 1

Growth Intervals (Weeks)	Mean Growth Rates — Rations: Broiler	Starter
Hatch-1	1.66[a]	1.61[a]
1-2	3.09	2.83
2-3	2.62	3.02
3-4	2.31	2.07
4-5	2.44	2.31
5-6	2.22[a]	2.14[a]
Hatch-6	2.39	2.33

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE XXXIV

SIMPLE CORRELATIONS OF PRE AND POST STORAGE EGG WEIGHTS AND DATE OF LAY WITH EMBRYO WEIGHTS AND DATE OF LAY AT TWO DAY INTERVALS BETWEEN 6 AND 18 DAYS OF INCUBATION: EXPERIMENT 1

Days of Incubation

	6		8		10		12		14		16		18	
No. of Viable Eggs	112		116		123		131		114		127		115	
	Embryo Weight	Date of lay	Embryo Weight	Date of lay	Embryo Weight	Date of lay	Embryo Weight	Date of lay	Embryo Weight	Date of lay	Embryo Weight	Date of lay	Embryo Weight	Date of lay
Pre Storage Egg Wt.	.172	.021	.068	.057	.170	.095	.123	.015	.275**	.072	.331**	.182*	.412**	.016
Post Storage Egg Wt.	.251**	.116	.117	.168	.242**	.193*	.178*	.120	.319**	.162	.364**	.258**	.461**	.111
Date of lay	.743**		.600**		.677**		.542**		.579**		.499**		.479**	

* Significant at .05 probability
** Significant at .01 probability

TABLE XXXV

CORRELATION COEFFICIENTS OF HATCHING TIME, STORAGE PERIOD AND PRE- AND POST-STORAGE EGG WEIGHTS WITH CHICK BODY WEIGHTS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 1

Weekly Body Weights	Time of Hatch	Storage Period	Pre-storage Egg Weight	Post-storage Egg Weight
Hatch	.146**	.013	.855**	.847**
1	-.269**	-.207**	.443**	.466**
2	-.290**	-.218**	.292**	.318**
3	-.284**	-.172**	.223**	.241**
4	-.270**	-.154**	.172**	.187**
5	-.253**	-.123**	.144**	.155**
6	-.241**	-.111	.122**	.134**

Degrees of freedom = 790

** Probability less than .01

TABLE XXXVI

CORRELATION COEFFICIENTS OF HATCHING TIME, DATE OF LAY, PRE- AND POST-STORAGE EGG WEIGHTS AND 6 WEEK BODY WEIGHT WITH WEEKLY GROWTH RATES BETWEEN HATCH AND 6 WEEKS OF AGE: EXPERIMENT 1

Weekly Growth Rates	Time of Hatch	Storage Period (Weeks)	Pre-Storage Egg Weight	Post Storage Egg Weight	6 Week Body Weight
Hatch-1	-.391**	-.214**	-.076*	-.045	.480**
1-2	-.134**	-.092*	-.150**	-.136**	.606**
2-3	-.024	.078*	-.109**	-.123**	.306**
3-4	-.064	-.016	-.078*	-.079*	.480**
4-5	-.017	.085*	-.069	-.083*	.371**
5-6	.037	.043	-.091	-.084*	.176**

Degrees of freedom = 790

* Probability less than .05
** Probability less than .01

TABLE XXXVII

CORRELATION COEFFICIENTS OF 6 WEEK BODY WEIGHT WITH EMBRYO WEIGHTS, EMBRYO GROWTH RATES, CHICK WEIGHTS AND CHICK GROWTH RATES WITHIN EACH SEX AND RATION. CALCULATIONS BASED ON GENOTYPIC AVERAGES: EXPERIMENT 1

		6 Week Body Weight			
		Males		Females	
		Broiler Ration	Starter Ration	Broiler Ration	Starter Ration
	Time of Weighing				
Embryo Weight (Days of Incubation)	6	.294	.342	.342	.336
	8	-.073	-.211	-.025	-.108
	10	.160	.073	.168	.194
	12	.657	.676*	.736*	.752*
	14	.743*	.831**	.839**	.828**
	16	.305	.431	.331	.407
	18	.594	.604	.638	.593
Chick Weight (Weeks)	Hatch	.464	.439	.072	.520
	1	.628	.697*	.711*	.785*
	2	.832**	.887**	.864**	.910**
	3	.972**	.949**	.937**	.956**
	4	.989**	.989**	.984**	.984**
	5	.997**	.996**	.996**	.994**
	6	1.000	1.000	1.000	1.000
	Intervals				
Embryo Growth Rate (Days of Incubation)	6-8	-.265	-.402	-.258	-.314
	8-10	.328	.373	.273	.404
	10-12	.251	.353	.286	.273
	12-14	.133	.226	.157	.128
	14-16	-.465	-.469	-.528	-.479
	16-18	.180	.099	.190	.108

* Significant at .05 probability
** Significant at .01 probability

TABLE XXXVII (continued)

		6 Week Body Weight			
		Males		Females	
		Broiler Ration	Starter Ration	Broiler Ration	Starter Ration
	Intervals				
Averaged Embryo Growth Rates (Days of Incubation)	6-10	.011	-.101	-.036	.013
	6-12	.298	.326	.306	.335
	6-14	.332	.413	.352	.360
	6-16	-.297	-.152	-.379	.267
	6-18	-.015	-.011	-.054	-.069
	8-12	.507	.648	.505	.583
	8-14	.404	.542	.414	.452
	8-16	.035	.201	-.011	.082
	8-18	.200	.298	.155	.182
Chick Growth Rate (Weeks)	Hatch-1	.578	.721*	.830**	.766*
	1-2	.934**	.931**	.922**	.906**
	2-3	.784*	.792*	.782*	.772*
	3-4	.800**	.637	.816**	.804**
	4-5	.761*	.789*	.835**	.793*
	5-6	.068	.455	-.103	.598
Average Chick Growth Rate (Weeks)	Hatch-6	.950**	.919**	.953**	.944**

* Significant at .05 probability
** Significant at .01 probability

TABLE XXXVIII

CORRELATION COEFFICIENTS OF HATCH TO 6 WEEK AVERAGE GROWTH RATE WITH EMBRYO GROWTH RATES WITHIN EACH SEX AND RATION: EXPERIMENT 1

		Growth Rate Hatch to 6 Weeks			
		Males		Females	
	Intervals	Broiler Ration	Starter Ration	Broiler Ration	Starter Ration
Embryo Growth Rates (Days of Incubation)	6-8	-.084	-.154	-.093	-.565
	8-10	.249	.422	.202	.214
	10-12	.079	.104	.149	.551
	12-14	.023	-.000	.057	.219
	14-16	-.412	-.385	-.488	-.121
	16-18	.229	.200	.276	-.296
Averaged Embryo Growth Rates (Days of Incubation)	6-10	.121	.189	.073	-.396
	6-12	.206	.299	.244	.286
	6-14	.185	.253	.239	.374
	6-16	-.475	-.297	-.517	.470
	6-18	-.063	.009	-.455	-.332
	8-12	.246	.413	.306	.751
	8-14	.189	.278	.234	.607
	8-16	-.175	-.039	-.192	.619
	8-18	.257	.143	.046	.377

TABLE XXXIX

PERCENTAGE SUMS OF SQUARES FROM THE ANALYSES OF VARIANCE OF EMBRYO WEIGHTS AT TWO DAY INTERVALS FROM 6 TO 18 DAYS OF INCUBATION: EXPERIMENT 2

Statistical Model	g	d	g	g	d	d	d	d	d
			Days of Incubation						
Source of Variance	df	df	6	8	10	12	14	16	18
Sex		1	#	#	2.10**	1.85**	0.71	0.86	0.53
Storage Period	2	2	77.74**	69.66**	59.38**	47.97**	56.82**	34.67**	49.07**
Sire	2	2	0.27	3.22*	3.78**	3.59*	1.44	2.95	5.74**
Dam	5	5	3.96	9.09**	6.28**	5.97*	14.81**	4.71	3.41
Sire x Dam	10	10	6.78	8.19*	6.46*	7.60*	2.44	8.13	13.20**
Residual	34	87	11.24	9.84	21.99	33.02	23.78	48.68	28.04

\# Not Measured
* Significant at .05 probability
** Significant at .01 probability

TABLE XL

EFFECT OF DURATION OF PREINCUBATION EGG STORAGE ON EMBRYO WEIGHTS RECORDED AT TWO DAY INTERVALS FROM 6 TO 18 DAYS OF INCUBATION: EXPERIMENT 2

Days of Incubation	Mean Embryo Weights (Grams) Duration of Storage (Weeks) 1	2	3
6	.429	.333	.239
8	1.203	1.082	.931
10	2.867	2.560	2.213
12	5.991	5.457	4.764
14	12.057	11.141	9.581
16	18.797	17.974	16.490
18	27.084	24.843	22.819

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE XXLII

EFFECT OF SIRE LINE ON EMBRYO WEIGHTS RECORDED AT TWO DAY INTERVALS FROM 6 TO 18 DAYS OF INCUBATION: EXPERIMENT 2

Days of Incubation	Mean Embryo Weights (Grams) Sire Line		
	WL	NH	WR
6	.328[a]	.339[a]	.335[a]
8	1.063[a]	1.105	1.048[a]
10	2.451	2.591[a]	2.597[a]
12	5.211	5.480[a]	5.520[a]
14	10.698[a]	11.063[a]	11.019[a]
16	17.369[a]	18.018	17.873[a]
18	24.073	25.325[a]	25.348[a]

Those means within the same row which carry the same superscript are not significantly sifferent at .05 probability.

TABLE XLIII

EFFECT OF DAM LINE ON EMBRYO WEIGHTS RECORDED AT TWO DAY INTERVALS FROM 6 TO 18 DAYS OF INCUBATION: EXPERIMENT 2

	Mean Embryo Weights (Grams)					
	Dam Line					
Days of Incubation	WL	NH	WR	WLxNH	WLxWR	NHxWR
6	.306^{a}	.327^{ab}	.321^{ab}	.344^{b}	.349^{b}	.356^{b}
8	.999	1.067^{a}	1.106^{ab}	1.057^{a}	1.126^{b}	1.076^{ab}
10	2.370	2.530^{a}	2.577^{a}	2.564^{a}	2.589^{a}	2.651^{a}
12	5.098^{a}	5.425^{abc}	5.666^{c}	5.293^{ab}	5.423^{ac}	5.517^{bc}
14	9.915	11.063^{abc}	11.560^{c}	10.928^{ab}	10.761^{a}	11.331^{bc}
16	17.336^{a}	18.195^{a}	17.945^{a}	17.433^{a}	17.468^{a}	18.143^{a}
18	24.687^{ab}	24.792^{ab}	25.667^{b}	24.221^{a}	24.834^{ab}	25.292^{ab}

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE XLIII

EFFECT OF SEX ON EMBRYO WEIGHTS RECORDED AT TWO DAY INTERVALS FROM 10 TO 18 DAYS OF INCUBATION: EXPERIMENT 2

Days of Incubation	Mean Embryo Weights (Grams)	
	Males	Females
10	2.597[a]	2.496[a]
12	5.503[a]	5.305[a]
14	11.041[a]	10.813[a]
16	17.903[a]	17.604[a]
18	25.095[a]	24.736[a]

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE XLIV

PERCENTAGE SUMS OF SQUARES FROM THE ANALYSES OF VARIANCE OF EMBRYO GROWTH RATES DURING SUCCESSIVE TWO DAY INTERVALS BETWEEN 6 AND 18 DAYS OF INCUBATION: EXPERIMENT 2

Statistical Model	h	e	h	e	e	e	e	e
			Intervals (Days of Incubation)					
Source of Variance	df	df	6-8	8-10	10-12	12-14	14-16	16-18
Sex		1	#	3.94*	0.04	0.65	0.00	0.02
Storage Period	2	2	48.87**	0.12	1.94	0.48	14.12**	4.17
Sire	2	2	0.49	9.68**	0.03	1.56	0.04	0.68
Dam	5	5	2.32	4.79	4.09	5.54	11.38*	3.50
Sire x Dam	10	10	19.62*	18.70*	8.48	8.76	6.37	12.12
Residual	34	87	28.69	62.77	85.42	83.01	68.09	79.52

\# Not Measured
* Significant at .05 probability
** Significant at .01 probability

TABLE XLV

EFFECT OF DURATION OF PREINCUBATION EGG STORAGE ON EMBRYO GROWTH RATES DURING SUCCESSIVE TWO DAY INTERVALS FROM 6 TO 18 DAYS OF INCUBATION: EXPERIMENT 2

Incubation Intervals (Days)	Mean Embryo Growth Rates Duration of Storage Period (Weeks) 1	2	3
6-8	3.60	4.11	4.75
8-10	3.89[a]	3.85[a]	3.87[a]
10-12	4.02[a]	4.16[a]	4.20[a]
12-14	4.56[a]	4.64[a]	4.53[a]
14-16	3.33[a]	3.59[a]	4.07
16-18	3.11[a]	2.73[a]	2.78[a]

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE XLVI

EFFECT OF SIRE LINE ON EMBRYO GROWTH RATES DURING SUCCESSIVE TWO DAY INTERVALS FROM 6 TO 18 DAYS OF INCUBATION: EXPERIMENT 2

Incubation Intervals (Days)	Mean Embryo Growth Rates Sire Lines		
	WL	NH	WR
6-8	4.20[a]	4.17[a]	4.09[a]
8-10	3.74[a]	3.81[a]	4.06
10-12	4.14[a]	4.12[a]	4.13[a]
12-14	4.65[a]	4.57[a]	4.47[a]
14-16	3.64[a]	3.68[a]	3.66[a]
16-18	2.79[a]	2.87[a]	2.96[a]

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE XLVIII

EFFECT OF DAM LINE ON EMBRYO GROWTH RATES DURING SUCCESSIVE TWO DAY INTERVALS FROM 6 TO 18 DAYS OF INCUBATION: EXPERIMENT 2

Incubation Intervals (Days)	Mean Embryo Growth Rates					
	Dam Lines					
	WL	NH	WR	WLxNH	WLxWR	NHxWR
6-8	4.20^{a}	4.18^{a}	4.33^{a}	4.04^{a}	4.15^{a}	4.03^{a}
8-10	3.87^{ab}	3.88^{ab}	3.79^{ab}	3.94^{ab}	3.72^{a}	4.03^{b}
10-12	4.22^{a}	4.16^{a}	4.31^{a}	4.00^{a}	4.04^{a}	4.04^{b}
12-14	4.30^{a}	4.67^{a}	4.66^{a}	4.72^{a}	4.42^{a}	4.67^{a}
14-16	4.20^{a}	3.75^{ab}	3.31^{b}	3.53^{b}	3.67^{b}	3.53^{b}
16-18	3.00^{a}	2.61^{a}	3.03^{a}	2.76^{a}	3.02^{a}	2.82^{a}

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE XLVIII

PERCENTAGE SUMS OF SQUARES FROM THE ANALYSES OF VARIANCE OF EMBRYO GROWTH RATES WHEN AVERAGED FOR INTERVALS BEGINNING AT 6 OR 8 DAYS OF INCUBATION: EXPERIMENT 2

Statistical Model	f	f	f	f	f	f	f	f	f	f
		Intervals (Days of Incubation)								
Source of Variance	df	6-10	6-12	6-14	6-16	6-18	8-12	8-14	8-16	8-18
Storage Period	2	42.30**	39.98**	37.87**	55.89**	48.07**	1.45	1.73	22.21**	11.82**
Sire	2	1.64	1.10	0.26	0.08	0.61	5.75*	1.43	0.71	3.12
Dam	5	1.28	4.45	7.76*	5.49**	7.41**	4.46	14.63**	10.36**	10.47*
Sire x Dam	10	12.79	10.47*	10.76*	11.02**	7.33	12.76	9.58	15.96**	17.49**
Residual	88	41.99	44.00	43.35	27.52	36.58	75.59	72.57	50.75	57.10

* Significant at .05 probability
** Significant at .01 probability

TABLE XLIX

EFFECT OF EGG STORAGE ON AVERAGED TWO DAY EMBRYO GROWTH RATES: EXPERIMENT 2

Range of Intervals Averaged (Days)	Mean Averaged Embryo Growth Rates		
	Storage Period (Weeks)		
	1	2	3
6-10	3.75	3.98	4.31
6-12	3.84	4.04	4.28
6-14	4.09	4.19	4.34
6-16	3.88	4.07	4.29
6-18	3.75	3.85	4.04
8-12	3.96[a]	4.01[a]	4.09[a]
8-14	4.16[a]	4.22[a]	4.20[a]
8-16	3.95	4.06	4.17
8-18	3.78[a]	3.79[a]	3.89

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE L

EFFECT OF SIRE LINE ON AVERAGED TWO DAY EMBRYO GROWTH RATES: EXPERIMENT 2

Range of Intervals Averaged (Days)	Mean Averaged Embryo Growth Rates		
	Sire Line		
	WL	NH	WR
6-10	3.97[a]	3.99[a]	4.08[a]
6-12	4.03[a]	4.03[a]	4.09[a]
6-14	4.19[a]	4.17[a]	4.19[a]
6-16	4.08[a]	4.07[a]	4.08[a]
6-18	3.87[a]	3.87[a]	3.90[a]
8-12	3.94[a]	3.96[a]	4.10
8-14	4.19[a]	4.17[a]	4.22[a]
8-16	4.05[a]	4.05[a]	4.08[a]
8-18	3.80[a]	3.81[a]	3.86[a]

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE LI

EFFECT OF DAM LINE ON AVERAGED TWO DAY EMBRYO GROWTH RATES: EXPERIMENT 2

Range of Intervals Averaged (Days)	Mean Averaged Embryo Growth Rates					
	Dam Line					
	WL	NH	WR	WLxNH	WLxWR	NHxWR
6-10	4.03[a]	4.08[a]	4.06[a]	3.99[a]	3.94[a]	4.03[a]
6-12	4.10[a]	4.07[a]	4.15	3.99[a]	3.97[a]	4.03[a]
6-14	4.15[ab]	4.22[bc]	4.27[c]	4.17[abc]	4.08[a]	4.19[abc]
6-16	4.16[b]	4.13[bc]	4.08[abc]	4.05[ac]	4.00[a]	4.06[ac]
6-18	3.96[b]	3.87[a]	3.91[ab]	3.83[a]	3.84[a]	3.85[a]
8-12	4.05[a]	4.02[a]	4.05[a]	3.97[a]	3.88[a]	4.04[a]
8-14	4.13[ab]	4.24[ac]	4.25[a]	4.22[a]	4.06[b]	4.25[a]
8-16	4.18[c]	4.11[bc]	4.02[ab]	4.05[ab]	3.96[a]	4.07[ab]
8-18	3.92	3.81[a]	3.82[a]	3.79[a]	3.77[a]	3.81[a]

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE LII

PERCENTAGE SUMS OF SQUARES FROM THE ANALYSES OF VARIANCE OF MALE BODY WEIGHTS AT WEEKLY INTERVALS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 2

Statistical Model		i	i	i	i	i	i	i
		Time of Weighing						
Source of Variance	df	Hatch	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Sires (S)	2	6.87	30.45**	25.34**	30.97**	36.24**	40.17**	42.31**
Dams (D)	5	21.17*	28.84**	19.77**	18.36**	20.78**	22.35**	26.26**
Rations (R)	1	0.19	7.71**	26.79**	28.21**	21.37**	17.83**	16.61**
S x D	10	12.93	14.18**	10.91**	9.62**	8.89**	7.25**	5.77**
S x R	2	0.87	0.41	0.50	0.28	0.42	0.52	0.74
D x R	5	3.85	5.61**	4.76*	3.82**	3.25*	2.93*	1.95
S x D x R	10	10.65	1.61	1.68	1.26	0.82	0.73	0.41
Residual	36	43.48	11.20	10.26	7.48	8.23	8.22	5.96

* Significant at .05 probability
** Significant at .01 probability

TABLE LIII

EFFECT OF SIRE LINE ON BODY WEIGHTS OF MALE CHICKS AT WEEKLY INTERVALS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 2

	Mean Body Weights of Chicks (Grams)		
	Sire Lines		
Time of Weighing	WL	NH	WR
Hatch	41.8[a]	41.8[a]	42.7
1 Week	79.0[a]	78.5[a]	85.7
2 Weeks	148.1[a]	151.1[a]	167.1
3 Weeks	240.1	255.4	283.6
4 Weeks	348.1	377.5	419.9
5 Weeks	472.1	519.4	579.6
6 Weeks	614.3	683.7	761.3

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE LV

EFFECT OF DAM LINE ON BODY WEIGHTS OF MALE CHICKS AT WEEKLY INTERVALS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 2

	Mean Body Weights of Chicks (Grams)					
	Dam Lines					
Time of Weighing	WL	NH	WR	WLxNH	WLxWR	NHxWR
Hatch	41.5^{ab}	43.2^{c}	42.2^{abc}	41.0^{a}	42.0^{abc}	42.6^{bc}
1 Week	77.7^{a}	80.9^{b}	86.6	77.0^{a}	81.9^{b}	82.4^{b}
2 Weeks	149.0^{ab}	154.5^{bc}	168.6	145.4^{a}	157.1^{c}	158.0^{c}
3 Weeks	245.4^{a}	259.9^{b}	285.2	243.7^{a}	258.2^{b}	265.9^{b}
4 Weeks	356.3^{a}	382.2^{c}	423.3	360.1^{ab}	376.6^{bc}	392.5^{c}
5 Weeks	483.5^{a}	524.3^{cd}	581.3	493.1^{ab}	513.9^{bc}	546.0^{d}
6 Weeks	622.2^{a}	691.4^{b}	765.9	646.0^{a}	672.8^{b}	720.2

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE LVI

EFFECT OF RATION ON BODY WEIGHTS OF MALE CHICKS AT WEEKLY INTERVALS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 2

	Mean Body Weight of Chicks (Grams)	
	Rations	
Time of Weighing	Broiler	Starter
Hatch	42.2[a]	42.0[a]
1 Week	82.8	79.5
2 Weeks	164.0	146.9
3 Weeks	276.9	242.5
4 Weeks	404.5	359.2
5 Weeks	553.0	494.4
6 Weeks	724.0	648.8

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE LVII

PERCENTAGE SUMS OF SQUARES FROM THE ANALYSES OF VARIANCE OF WEEKLY AND AVERAGE GROWTH RATES OF MALE CHICKS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 2

Statistical Model	j	j	j	j	j	j	j	j
		Period of Growth (Weeks)						
Source of Variance	df	Hatch-1	1-2	2-3	3-4	4-5	5-6	Hatch-6
Sires (S)	2	21.97**	9.55**	34.18**	14.56**	15.62**	7.85*	44.83**
Dams (D)	5	25.24**	3.18	11.00*	11.13*	16.28**	16.61*	25.77**
Rations (R)	1	7.76**	47.02**	9.01**	10.04**	3.18*	0.67	9.81**
S x D	10	14.67*	9.91	11.22	14.65	18.36	12.57	5.03
S x R	2	0.83	2.59	1.17	3.16	0.97	1.63	0.65
D x R	5	4.77	1.90	5.19	3.83	3.90	6.90	0.51
S x D x R	10	1.92	3.37	3.56	10.67	11.09	11.21	1.65
Residual	36	22.84	22.48	24.67	31.96	30.60	42.56	11.74

* Significant at .05 probability
** Significant at .01 probability

TABLE LVIII

EFFECT OF SIRE LINE ON GROWTH RATES OF MALE CHICKS DURING WEEKLY INTERVALS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 2

Growth Intervals (Weeks)	Mean Growth Rates Sire Lines WL	NH	WR
Hatch-1	2.20[a]	2.19[a]	2.42
1-2	2.79	2.91[a]	2.97[a]
2-3	2.64	2.87[a]	2.91[a]
3-4	2.41	2.53[a]	2.55[a]
4-5	2.28	2.39[a]	2.41[a]
5-6	2.24	2.34[a]	2.32[a]
Hatch-6	2.43	2.54	2.60

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE LIX

EFFECT OF DAM LINE ON GROWTH RATES OF MALE CHICKS DURING WEEKLY INTERVALS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 2

Growth Intervals (Weeks)	Mean Growth Rates					
	Dam Lines					
	WL	NH	WR	WLxNH	WLxWR	NHxWR
Hatch-1	2.16[a]	2.17[ab]	2.49	2.18[ab]	2.31[b]	2.30[ab]
1-2	2.89[a]	2.89[a]	2.97[a]	2.82[a]	2.89[a]	2.89[a]
2-3	2.72[a]	2.85[b]	2.88[b]	2.81[ab]	2.71[a]	2.86[b]
3-4	2.41[a]	2.49[ab]	2.57[b]	2.53[ab]	2.44[ab]	2.53[ab]
4-5	2.28[a]	2.37[a]	2.38[ab]	2.35[a]	2.33[a]	2.47[b]
5-6	2.16	2.35[a]	2.34[a]	2.30[a]	2.30[a]	2.36[a]
Hatch-6	2.44	2.52[a]	2.60	2.50[a]	2.50[a]	2.57

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE LX

EFFECT OF RATION ON GROWTH RATES OF MALE CHICKS DURING WEEKLY INTERVALS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 2

Growth Intervals (Weeks)	Mean Growth Rates Rations Broiler	Starter
Hatch-1	2.33	2.21
1-2	3.05	2.73
2-3	2.87	2.75
3-4	2.44	2.55
4-5	2.33	2.39
5-6	2.29[a]	2.31[a]
Hatch-6	2.55	2.49

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE LXI

PERCENTAGE SUMS OF SQUARES FROM THE ANALYSES OF VARIANCE OF FEMALE BODY WEIGHTS AT WEEKLY INTERVALS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 2

Statistical Model		i	i	i	i	i	i	i
		Time of Weighing						
Source of Variance	df	Hatch	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Sires (S)	2	5.96	16.36**	17.23**	22.62**	29.68**	31.22**	37.14**
Dams (D)	5	7.73	28.43**	17.14**	19.10**	22.28**	27.73**	29.92**
Rations (R)	1	2.59	11.07**	32.32**	34.78**	28.47**	23.42**	18.43**
S x D	10	22.11*	27.42**	20.09**	13.81**	12.07**	9.37**	6.90**
S x R	2	6.11	0.25	0.48	0.44	0.14	0.46	0.29
D x R	5	4.88	1.43	0.96	0.75	0.21	0.24	0.60
S x D x R	10	16.37	3.72	3.05	1.52	1.41	1.49	1.65
Residual	36	34.24	11.31	8.74	6.99	5.75	6.06	5.07

* Significant at .05 probability
** Significant at .01 probability

TABLE LXII

EFFECT OF SIRE LINE ON BODY WEIGHTS OF FEMALE CHICKS AT WEEKLY INTERVALS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 2

	Mean Body Weights of Chicks (Grams)		
	Sire Line		
Time of Weighing	WL	NH	WR
Hatch	41.6[a]	41.4[a]	42.3[a]
1 Week	77.5	75.3	81.0
2 Weeks	142.1[a]	140.6[a]	154.9
3 Weeks	226.1	233.4	258.1
4 Weeks	319.5	338.9	374.9
5 Weeks	422.2	457.3	502.7
6 Weeks	538.6	593.7	656.0

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE LXIII

EFFECT OF DAM LINE ON BODY WEIGHTS OF FEMALE CHICKS AT WEEKLY INTERVALS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 2

	Mean Body Weights of Chicks (Grams)					
	Dam Line					
Time of Weighing	WL	NH	WR	WLxNH	WLxWR	NHxWR
Hatch	41.0[a]	42.2[b]	42.1[ab]	41.5[ab]	41.9[ab]	42.0[ab]
1 Week	74.4[a]	76.9[b]	84.2	75.9[ab]	77.7[b]	78.4[b]
2 Weeks	139.0[a]	144.4[ab]	158.5	140.0[a]	146.3[b]	147.2[b]
3 Weeks	224.4[a]	237.3[b]	262.9	227.6[a]	238.8[b]	244.3[b]
4 Weeks	319.4[a]	342.3[b]	380.6	326.6[a]	342.7[b]	355.2[b]
5 Weeks	419.2[a]	461.1[b]	517.1	434.4[a]	458.1[b]	474.4[b]
6 Weeks	536.6	597.9[a]	672.0	558.5	595.2[a]	616.4[a]

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE LXIV

EFFECT OF RATION ON BODY WEIGHTS OF FEMALE CHICKS AT WEEKLY INTERVALS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 2

	Mean Body Weights of Chicks (Grams)	
	Rations	
Time of Weighing	Broiler	Starter
Hatch	42.0[a]	41.6[a]
1 Week	79.8	76.0
2 Weeks	154.7	137.1
3 Weeks	256.2	222.3
4 Weeks	366.9	322.0
5 Weeks	489.3	432.2
6 Weeks	629.9	562.3

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE LXV

PERCENTAGE SUMS OF SQUARES FROM THE ANALYSES OF VARIANCE OF WEEKLY AND AVERAGE GROWTH RATES OF FEMALE CHICKS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 2

Statistical Model	j	j	j	j	j	j	j	j
		Period of Growth (Weeks)						
Source of Variance	df	Hatch-1	1-2	2-3	3-4	4-5	5-6	Hatch-6
Sires (S)	2	10.86**	13.68**	43.45**	28.40**	15.11**	21.26**	46.96**
Dams (D)	5	24.45**	2.69	10.82**	9.29	24.59**	9.79	28.15**
Rations (R)	1	9.12**	56.74**	9.37**	4.96*	2.72	6.12*	8.25**
S x D	10	29.73**	7.69*	7.25	2.30	13.88	14.92	4.81*
S x R	2	2.51	0.66	0.75	5.21	4.26	6.68*	0.28
D x R	5	2.08	1.33	3.37	12.11*	4.98	4.72	0.99
S x D x R	10	5.14	5.73	6.98	8.52	3.54	6.35	2.62
Residual	36	16.12	11.48	18.02	29.21	30.92	30.15	7.94

* Significant at .05 probability
** Significant at .01 probability

TABLE LXVI

EFFECT OF SIRE LINE ON GROWTH RATES OF FEMALE CHICKS DURING WEEKLY INTERVALS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 2

Growth Intervals (Weeks)	Mean Growth Rates		
	Sire Lines		
	WL	NH	WR
Hatch-1	2.15	2.07	2.25
1-2	2.69	2.78	2.89
2-3	2.53	2.78[a]	2.80[a]
3-4	2.24	2.42[a]	2.43[a]
4-5	2.09	2.24[a]	2.19[a]
5-6	2.08	2.21[a]	2.28[a]
Hatch-6	2.30	2.42	2.47

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE LXVII

EFFECT OF DAM LINE ON GROWTH RATES OF FEMALE CHICKS DURING WEEKLY INTERVALS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 2

Growth Intervals (Weeks)	Mean Growth Rates					
	Dam Lines					
	WL	NH	WR	WLxNH	WLxWR	NHxWR
Hatch-1	2.06[a]	2.08[a]	2.40	2.09[a]	2.14[a]	2.16[a]
1-2	2.77[ab]	2.80[ab]	2.83[b]	2.72[a]	2.83[b]	2.80[ab]
2-3	2.61[a]	2.72[bc]	2.77[c]	2.65[ab]	2.68[abc]	2.78[c]
3-4	2.28[a]	2.37[a]	2.40[b]	2.34[ab]	2.34[ab]	2.44[b]
4-5	2.04[a]	2.23[bc]	2.30[c]	2.13[ab]	2.16[b]	2.16[b]
5-6	2.10[a]	2.22[b]	2.24[b]	2.13[ab]	2.23[b]	2.22[b]
Hatch-6	2.31[a]	2.40[b]	2.49	2.34[a]	2.40[b]	2.43[b]

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE LXVIII

EFFECT OF RATION ON GROWTH RATES OF FEMALE CHICKS DURING WEEKLY INTERVALS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 2

Growth Intervals (Weeks)	Mean Growth Rates — Rations: Broiler	Starter
Hatch-1	2.22	2.09
1-2	2.96	2.62
2-3	2.76	2.64
3-4	2.32	2.40
4-5	2.14[a]	2.20[a]
5-6	2.14	2.23
Hatch-6	2.43	2.36

Those means within the same row which carry the same superscript are not significantly different at .05 probability.

TABLE LXIX

SIMPLE CORRELATIONS OF PRE AND POST STORAGE EGG WEIGHTS AND DATE OF LAY WITH EMBRYO WEIGHTS AND DATE OF LAY AT TWO DAY INTERVALS BETWEEN 6 AND 18 DAYS OF INCUBATION: EXPERIMENT 2

Days of Incubation

	6		8		10		12		14		16		18	
No. of Viable Eggs	301		272		231		230		228		237		169	
	Embryo Weight	Date of lay	Embryo Weight	Date of lay	Embryo Weight	Date of lay	Embryo Weight	Date of lay	Embryo Weight	Date of lay	Embryo Weight	Date of lay	Embryo Weight	Date of lay
Pre Storage Egg Wt.	-.112	-.098	.131*	.118*	.013	.015	.111	.001	.193**	.137*	.138*	.054	.333**	.119
Post Storage Egg Wt.	-.091	-.063	.153*	.155*	.036	.056	.134*	.036	.223**	.162*	.163*	.085	.376**	.153*
Date of lay	.699**		.629**		.682**		.591**		.619**		.486**		.635**	

* Significant at .05 probability
** Significant at .01 probability

TABLE LXX

CORRELATION COEFFICIENTS OF HATCHING TIME, STORAGE PERIOD AND PRE- AND POST-STORAGE EGG WEIGHTS WITH CHICK BODY WEIGHTS FROM HATCH TO 6 WEEKS OF AGE: EXPERIMENT 2

Weekly Body Weights	Time of Hatch	Storage Period	Pre-storage Egg Weight	Post-storage Egg Weight
Hatch	.038	-.118**	.825**	.773**
1	-.018	-.116**	.322**	.313**
2	-.004	-.098**	.232**	.234**
3	.011	-.077*	.201**	.216**
4	.013	-.060*	.190**	.198**
5	.032	-.059	.168**	.175**
6	.041	-.051	.158**	.168**

Degrees of freedom = 1208

* Significant at .05 probability
** Significant at .01 probability

TABLE LXXI

CORRELATION COEFFICIENTS OF HATCHING TIME, DATE OF LAY, PRE- AND POST-STORAGE EGG WEIGHTS AND 6 WEEK BODY WEIGHT WITH WEEKLY GROWTH RATES BETWEEN HATCH AND 6 WEEKS OF AGE: EXPERIMENT 2

Weekly Growth Rates	Time of Hatch	Storage Period (Weeks)	Pre-Storage Egg Weight	Post-Storage Egg Weight	6 Week Body Weight
Hatch-1	-.047	-.025	-.276**	-.250**	.456**
1-2	.020	-.019	-.035	-.017	.508**
2-3	.045	.033	-.024	-.012	.452**
3-4	.005	.051	-.008	-.033	.298**
4-5	.067	.012	-.051	-.054	.276**
5-6	.036	.028	-.022	-.010	.144**

Degrees of freedom = 1208

** Significant at .01 probability

TABLE LXXII

CORRELATION COEFFICIENTS OF 6 WEEK BODY WEIGHTS WITH EMBRYO WEIGHTS, EMBRYO GROWTH RATES, CHICK WEIGHTS AND CHICK GROWTH RATES WITHIN EACH SEX AND RATION. CALCULATIONS BASED ON GENOTYPIC AVERAGES: EXPERIMENT 2

		6 Week Body Weight			
		Males		Females	
		Broiler Ration	Starter Ration	Broiler Ration	Starter Ration
	Time of Weighing				
Embryo Weight (Days of Incubation)	6	.202	.071	.086	-.000
	8	.034	.025	.065	.099
	10	.320	.290	.331	.380
	12	.607**	.597**	.575*	.623**
	14	.716**	.563*	.671**	.669**
	16	.524*	.535*	.426	.468*
	18	.620**	.625**	.595**	.567*
Chick Weight (Weeks)	Hatch	.443	.604**	.188	.537*
	1	.789**	.821**	.751**	.784**
	2	.904**	.873**	.879**	.841**
	3	.955**	.953**	.960**	.946**
	4	.986**	.978**	.972**	.984**
	5	.997**	.989**	.793**	.992**
	6	1.000	1.000	1.000	1.000
	Intervals				
Embryo Growth Rate (Days of Incubation)	6-8	-.149	-.046	-.042	.040
	8-10	.293	.272	.273	.296
	10-12	.522*	.519*	.467#	.492*
	12-14	-.226	-.318	-.215	-.283
	14-16	-.257	-.077	-.304	-.262
	16-18	-.036	-.044	.043	-.027

* Significant at .05 probability
** Significant at .01 probability
\# Approaches significance at .05 probability

TABLE LXXII (Continued)

		6 Week Body Weight			
		Males		Females	
	Intervals	Broiler Ration	Starter Ration	Broiler Ration	Starter Ration
Averaged Embryo Growth Rates (Days of Incubation)	6-10	.100	.176	.198	.296
	6-12	.375	.441	.412	.506*
	6-14	.295	.281	.367	.425
	6-16	.033	.167	.055	.132
	6-18	-.053	.124	.087	.096
	8-12	.651**	.636**	.590**	.626**
	8-14	.496*	.353	.436	.387
	8-16	.185	.221	.094	.094
	8-18	.148	.178	.135	.063
Chick Growth Rate (Weeks)	Hatch-1	.780**	.488**	.720**	.646**
	1-2	.812**	.702**	.734**	.836**
	2-3	.812**	.554*	.865**	.517*
	3-4	.629**	.568*	.565*	.564*
	4-5	.462	.378	.759**	.347
	5-6	.645**	.578*	.402	.559*
Average Chick Growth Rate (Weeks)	Hatch-6	.899**	.905**	.960**	.956**

* Significant at .05 probability
** Significant at .01 probability

TABLE LXXIII

CORRELATION COEFFICIENTS OF HATCH TO 6 WEEK AVERAGE GROWTH RATE WITH EMBRYO GROWTH RATES WITHIN EACH SEX AND RATION: EXPERIMENT 2

		Growth Rate Hatch to 6 Weeks			
		Males		Females	
	Intervals	Broiler Ration	Starter Ration	Broiler Ration	Starter Ration
Embryo Growth Rates (Days of Incubation)	6-8	-.113	-.006	-.014	.057
	8-10	.258	.233	.231	.296
	10-12	.524*	.547*	.408	.510*
	12-14	-.271	-.344	-.214	-.259
	14-16	-.354	-.165	-.336	-.327
	16-18	.018	-.011	.153	.010
Averaged Embryo Growth Rates (Days of Incubation)	6-10	.141	.211	.220	.356
	6-12	.388	.472*	.374	.530*
	6-14	.255	.294	.306	.490*
	6-16	-.073	.110	-.020	.135
	6-18	-.070	.092	.116	.132
	8-12	.632**	.637**	.512*	.642**
	8-14	.413	.318	.341	.440
	8-16	.031	.117	-.012	.080
	8-18	.051	.109	.139	.088

* Significant at .05 probability
** Significant at .01 probability

TABLE LXXIV

COEFFICIENTS OF DETERMINATION ($100R^2$) OF THE GENOTYPIC ESTIMATES OF 6 WEEK BODY WEIGHT WITHIN EACH SEX AND RATION, MULTUPLY REGRESSED ON SELECTED "GENOTYPIC" TRAITS: EXPERIMENT 2

	Males		Females	
Regression Variables	Broiler Ration	Starter Ration	Broiler Ration	Starter Ration
X_1	80.8	81.9	92.2	91.4
X_2	42.4	40.4	34.8	39.2
X_3	51.2	31.7	45.0	44.8
X_4	19.6	36.5	3.5	28.8
X_1 X_2	91.0	91.4	82.0	92.3
X_1 X_2 X_3	92.6	91.5	83.8	92.5
X_1 X_2 X_4	95.8	92.7	86.1	94.0
X_1 X_2 X_5	98.4	98.3	92.5	96.1
X_1 X_2 X_3 X_4	95.8	92.8	86.4	94.2
X_1 X_2 X_3 X_5	98.7	98.5	94.0	96.8

X_1 = 6-week Growth Rate
X_2 = 8-12 day Embryo Growth Rate
X_3 = 14-day Embryo Body Weight
X_4 = Hatching Weight
X_5 = 1-week Body Weight