GENETIC CHARACTERISATION OF GROWTH AND PRODUCTIVE TRAITS IN FULL-SIB AND CONTROL POPULATION OF WHITE LEGHORN

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पूज्यनीय
माँ-पिता जी
एवं
भैया-भाभी को
सादर समर्पित

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CERTIFICATE

This is to certify that the thesis entitled **"GENETIC CHARACTERISATION OF GROWTH AND PRODUCTIVE TRAITS IN FULL-SIB AND CONTROL POPULATION OF WHITE LEGHORN"**, submitted in partial fulfillment of the requirements for the degree of **Doctor of Philosophy** in **Animal Breeding,** of the Post Graduate College, G.B. Pant University of Agriculture & Technology, Pantnagar, is a record of *bona fide* research carried out by **Mr. Pramod Kumar Sharma, Id. No. 21341**, under my supervision and no part of the thesis has been submitted for any other degree or diploma.

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We, the undersigned. members of the Advisory committee of **Mr. Pramod Kumar Shamra, Id. No. 21341**. a candidate for the degree of **Doctor of Philosophy** with major of **Animal Breeding,** agree that the thesis entitled **"GENETIC CHARACTERISATION OF GROWTH AND PRODUCTIVE TRAITS IN FULL-SIB AND CONTROL POPULATION OF WHITE LEGHORN"** may be submitted by Mr. Pramod Kumar Sharma in partial fulfilment of the requirement for the degree.

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CONTENTS

INTRODUCTION

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As a general rule continued inbreeding increases the homozygosity of the gene pool. This was adequately and statistically demostrated by Wright (1922, 1923). The earlier reports of Cole and Haplin (1916, 1922), Goodale (1927), Dunn, 1923, 1928), Jull (1929, 1930), Dumon (1930), Dunkerly (1930), Warren (1934), British Ministry of Agriculture and Fisheries (1934), Byerly *et al.* (1934), Hays (1929, 1934) and others involving inbreeding have been very discouraging as they observed its depressive effect on fitness and production traits.

The genotype is not simply a collection of independently acting genes. Rather it is an integrated complex which has arisen during the course of evolution under natural selection acting on an essentially heterozygous system. The action of three forces-natural selection, artificial selection and inbreeding produces changes in the genetic composition of a population until an equilibrium between them is reached. This results in an apparent stability of the mean of the population. Further observable changes are then dependent either on an alteration of the relative pressures of these forces or on fundamental changes in the genetic structure. However, the underlying genetic basis for the equilibrium may be changing even though such changes are not reflected on the phenotypic level.

The use of inbreeding and hybridization has revolutionized the plant and livestock including poultry industry. Inbred lines have numerous uses viz:

1. for theoretical genetic studies.
2. elimination of undesirable recessive characters.
3. for producing in-crosses.
4. for producing in crossbreds.
5. for producing top incrosses.
6. as an aid to selection.

Inbreeding and hybridization have two important phases. First development and maintenance of inbred lines and second best possible use of inbred lines. The general loss in overall vigour and performance is perhaps the most important single limiting factor in the development and maintenance of inbred lines.

Knowledge of the effect of inbreeding on performance is essential for the poultry breeder to make intelligent decisions regarding number and size of inbred lines to be developed and maintained, relative emphasis that should be placed on different traits, rate of inbreeding per generation, ultimate level of inbreeding to be attained, ways of testing inbred lines and eventual commercial use of surviving lines. As an example, if the egg production and fitness are not greatly affected, the most efficient method will tend toward starting with many small lines using intense inbreeding carried to high level, practicing selection between lines and expanding surviving lines rapidly. On the other hand, if the egg production performance and fitness are greatly affected, selection within lines would be emphasized instead of selection between lines. The lines would need to be larger and the process of making and testing lines would be slower. It was with this view, the present investigation was undertaken with the following objectives:

- to determine the means performance of different growth and production traits in inbred and control population.
- to estimate the heritability, genetic, phenotypic and environmental correlations among traits under study.
- to study the simple and partial correlations of different growth and production trait under study.
- comparison of growth and production traits if two inbreds with control population.
- to estimate the coefficient of determination using simple and multiple regression.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Economic traits of poultry are very complex with respect to their manifestation, because they are product of very intricate net work of a large number of genetic, nutritional, physiological and environmental processes. The improvement of poultry for increased egg production through inbreeding and hybridization is an accepted breeding practices. Although this method has its demerits and seems to be time consuming but has fast improvement rate per unit of time. As inbreeding progresses its depressive effects are exhibited on the performance.

(A) Means and heritability estimates

(i) Growth traits

The body weight of a bird, or its growth rate, indicates its genetic constitution with respect to the specific environment, and gives an indication, how best it is adaptable to that environment. Since a optimum body weight is a pre requisite for the future performance of a bird, it is essential that optimum body weight is achieved during the early period of age.

Waters and Lambert (1936) study involving inbreeding of various intensities extending over 10 year period reported that increased inbreeding did not decrease the adult body weight in WLH. They also concluded that their study suggested the practical application of the principles in poultry.

Dumon (1938) estimated that certain lines did not show depressive effects of inbreeding. The body weight at 3 and 6 months of age failed to reveal any definite effect of close inbreeding in fact the highest mean and best individual weight occurred in offsprings from brother × sister matings.

Shoffner (1948b) reported that C.V. values of body weight did not show an obvious tendency to decline as the inbreeding progressed from 0 to 60 per cent in 10 generations in white leghorn. When these 10 generations were grouped in two categories, lower inbred group and higher inbred group (F=13.2 and 52.2 per cent, respectively) the later group was found to have move C.V. than the former.

Kusner and Kitaeve (1951) estimated that live body weight up to 5 weeks was low in white leghorn birds produced by mating related birds than that of birds produced by mating unrelated birds. When the matings of related birds were considered, the performance of birds produced by cock reared at another farm was better than that of birds produced by the cock reared at the same farm as the hens. They concluded that deleterious effects of inbreeding were counter acted by rearing the sire under different conditions.

Waters (1951) studied on 6 inbred lines of white leghorn for a period extending over 8 years. As the inbreeding coefficient increased the mean body weights at 10 months of age and their standard deviation of 2 lines remained relatively constant at higher levels of inbreeding, and in another two lines it showed considerable variation from year to year. In one of the lines, there was a more or less steady increased whereas in other line (the most intensely inbred) there was a progressive decrease. He concluded that intensive inbreeding will not necessarily decrease the body weight of chicken and that with some selection body weight may be maintained and in some instances increased.

Kusner (1958) studying the effect of inbreeding in two groups of pullets obtained by crossing leghorns and general purpose hens respectively with inbred leghorn cocks produced by 6 generations of close inbreeding and out bred leghorn cocks. He reported that body weights were lowest in the inbred group.

Abplanalp and Woodard (1967) observed that continued full-sib mating in turkeys only 3 lines survived with F=50 per cent in the first set and 12 lines survived with F= 37.5 per cent in the second set out of 15 lines. The body weight of toms declined from 15.5 kg of controls to 14.1 kg in inbred with F=50 per cent.

Kinney *et al.* (1968) studying the data of random bred white leghorn population for several generations and reported heritability estimates ranging from 0.315 to 0.655 with a pooled average of 0.450.

Du Plessis *et al.* (1970) studied full sib mating for over 13 generations and when inbreeding coefficient ranged from initial 3.3 per cent to 92.9 per cent, the body weight tends to decline.

Krishna (1970) estimated the average body weight from 0, 4, 8, 12, 16, 20 and 24 weeks in two successive generation to be 33.9, 134.5, 319.1, 556.2, 833.4, 1050.7, 1233.8 and 35.0, 112.8, 226.5, 496.9, 756.7, 996.1 and 1192.3 g respectively. The heritability estimates ranged between 0.06 to 1.26 in first generation and 0.18 to 1.50 in the second generation in a white leghorn flock selected for egg production.

Mac taury and Johanson (1971) studying on Athens-Canadian chickens for another purpose found that inbred birds (F=0, 25, 37 and 50 per cent) were lighter in 8 week body weight when compared with contemporary non-inbred from a mass matings.

Banerjee (1972) observed the averages and heritability of body weights from hatch to 24 weeks in two successive generations, in a white leghorn flock selected for egg number. The averages were 35.7, 98.5, 250.3, 470.5, 726.7, 955.3, 1183.3 and 35.4, 101.0, 274.0, 518.7, 809.6, 1065.2, 1272.1g respectively, while the heritability estimates ranged between 0.17 to 1.44 in first year and 0.09 to 1.22 in the second year.

Kulenkamp *et al.* (1973) arranged five consecutive full sib matings in japanese quail leading to extinction of 6 inbred lines out of 17 in beginning. The inbreeding coefficients of 5 generations were 25, 38, 50, 59 and 67 per cent, respectively. Body weights were second to suffer most, the first being the egg production. They concluded that the performance as a whole for all inbred lines was always less than control lines and most of the traits showed depression after the first generation of full sib mating, with performance remaining fairly stable thereafter.

Bashnakov (1974) compaired the inbred progenies of white plymouth rock and cornish (F= 0.125 and 0.25) with out bred birds of the same breeds and found that outbreds averaged highest for body weight from 2nd to 20th weeks of age.

Hala *et al.* (1975) established an inbred line after 10 generations of sib mating. They found a marked decrease in body weight as inbreeding progressed.

Singh (1976) reported that the average monthly body weights ~~which~~ were found to be 32.8, 126.6, 269.0, 497.1, 692.5, 938.4 and 1155.7g with a C.V. of 16.05, 25.15, 27.88, 24.49, 41.94, 21.52 and 15.71 per cent in the Ist year and 36.61, 195.98, 584.87, 816.14, 1004.51 and 1189.43 g with a C.V. of 9.32, 35.77, 20.27, 15.46, 17.66 and 1.77 per cent in the second year respectively form hatch to 24-weeks of age except 8-week in second year in WLH.

The heritability for the same traits, except for 8-week body weight were 0.67 ± 0.26, 0.38 ± 0.16, 0.32 ± 0.07, 0.41 ± 0.18, 0.27 ± 0.06, 0.46 ± 0.19 and 0.70 ± 0.22 in the first year and 0.66 ± 0.21, 0.27 ± 0.09, 0.36 ± 0.12, 0.37 ±

0.08, ~~0.27 ± 0.09, 0.36 ± 0.12~~, 0.37 ± 0.08, 0.27 ± 0.06 and 0.61 ± 0.18 in the second year from sire components of variance respectively.

Kumar (1983) studied on half and full sib (F_1) populations of White Leghorn. He found 0, 4, 8 weeks body weights to be 35.53 ± 0.20, 148.57 ± 2.81 and 382.65 ± 5.07g, respectively in full sib population. The heritability estimates for these traits were 0.08 ± 0.03 (sire), 0.51 ± 0.27 (sire + dam), 0.17 ± 0.16 (sire), 0.16 ± 0.08 (sire + dam) and 0.19 ± 0.11 (sire), 0.17 ± 0.07 (sire + dam). The maternal influences were 0.035, 0.024 and 0.036 in the same order. He concluded that mean of these traits were more or less similar for half sib and full sib populations and heritability values computed from sire components of variance were lower than those computed form sire + dam components of variance.

Bhushan (1984) reported means of 0, 4, 8, 12, 16, 20 and 24 week body weights as 35.65 ± 0.42, 152.96 ± 0.13, 366.06 ± 0.35, 599.81 ± 11.58, 769.13 ± 16.83, 933.56 ± 20.88 and 1212.21 ± 28.43g respectively in inbred population of WLH. The heritability estimates of these traits were found to be 0.34 ± 0.026, 0.02 ± 0.01, 0.09 ± 0.01, 0.10 ± 0.01, 0.01 ± 0.01, 0.08 ± 0.01 and 0.46 ± 0.032 respectively in the same order. He concluded that body weights upto 20 weeks were more or less similar in control and inbred and heritabilities of all traits were lower in inbreds.

Chaitanyam and Singh (1985) conducted experiment on white leghorn to study the effect of five generations of close mating (full-sib mating) on economic traits. They found 10 week body weights to be 403, 375, 360, 320 and 376g, respectively for five generations having inbreeding coefficient of 25, 37.5, 47.96, 48.13 and 55.36 per cent. They concluded that the differences among these means were non-significant as selection might had have compensated the effects of inbreeding to some extent. The overall 10 week body weight of inbreds (372g) was less than that of base population (543g).

Kushwaha (1987) expected mean values of 0, 4, 8, 12, 16, 20 and 24 week body weights as 34.28 ± 0.12, 169.13 ± 2.69, 367.88 ± 6.02, 668.78 ± 8.18, 898.09 ± 9.33, 1079.73 ± 9.38 and 1241.27 ± 10.63g, respectively in F_4 generation of full sib in WLH. The heritability estimates were found to be 0.098 ± 0.08, 0.048 ± 0.08, 0.097 ± 0.085, 0.043 ± 0.085, 0.000 ± 0.000, 0.083 ± 0.085 and 0.067 ± 0.085 in the same order. He concluded that all the traits were under the influence of inbreeding and most of the heritability values reduced or did not show improvement as inbreeding increased.

Singh (1987) experimented on F_3 inbred flock of WLH, and found the average values of 16, 20 and 24 week body weights to be 729.15 ± 3.8, 918.71 ± 3.4 and 1223.44 ± 8.8g, respectively. The heritability values of the same traits were 0.25 ± 0.08, 0.08 ± 0.07 and 0.13 ± 0.07. He also concluded that all the characters were influenced by inbreeding.

Rai (1988) concluded the impact of inbreeding in full-sib populations of WLH and reported mean values of 0, 4, 8, 12, 16, 20 and 24 week body weights to be 34.44 ± 0.20, 182.78 ± 1.23, 341.75 ± 3.71, 603.13 ± 6.34, 897.78 ± 1.90, 1065.01 ± 6.34 and 1245.26 ± 6.77g, respectively. The heritability estimates for the same traits were 0.021 ± 0.07, 0.009 ± 0.07, 0.665 ± 0.25, 0.887 ± 0.29, 0.153 ± 0.01, 0.020 ± 0.07 and 0.128 ± 0.11.

Kumar (1989) experimented on white leghorns to study the effect of four generations of inbred (F=0.38, 0.50, 0.59 and 0.67) population. The overall mean values of 0, 4, 8, 12, 16, 20 and 24 week body weights to be 34.57 ± 0.10, 163.13 ± 0.95, 356.55 ± 2.79, 611.30 ± 3.42, 816.53 ± 3.30, 997.28 ± 3.98 and 1217.14 ± 4.84g respectively. The heritability values for the same traits were -0.076 ± 0.059, 0.131 ± 0.069, 0.417 ± 0.158, 0.317 ± 0.113, 0.132 ± 0.067, 0.162 ± 0.078, 0.148 ± 0.077 and 0.244 ± 0.066, 0.053 ± 0.056, 0.694 ± 0.101, 0.298 ± 0.074, 0.024 ± 0.054, 0.112 ± 0.059, 0.131 ± 0.060 from sire and sire + dam components respectively.

Khare (1991) refered the mean estimate of body weight at day old, 4, 8, 12, 16 and 20 weeks of age to be 35.65, 150.95, 367.18, 604.70, 787.95 and 967.50g, respectively while the heritability estimate of day old, 4, 8, 12, 16 and 20 weeks body weight were 0.28 ± 0.162, 0.267 ± 0.150, 0.330 ± 0.178, 0.042 ± 0.062, 0.196 ± 0.140 and 0.206 ± 0.137 respectively based on sire components of variance in white leghorn population.

Rai *et al.* (1992) estimated the average body weight at day old, 4, 8, 12, 16 and 20 weeks of age as 34.44 ± 0.20, 182.79 ± 1.23, 341.76 ± 3.71, 603.13 ± 6.24, 897.78 ± 1.90 and 1065.01 ± 6.34g, respectively in full-sib population of white leghorn.

Singh (1992) reported average body weight at 4, 8, 12, 16 and 20 weeks of age to be 112.69, 273.91, 756.09, 996.76 and 1125.86g, respectively in white leghorn population.

Sharma *et al.* (1994) observed the heritability estimates based on paternal half sib analysis. The heritability of body weight at 20 week was 1.47 ± 0.088.

Mani (1994) concluded the average body weight at day old 4, 8, 12, 16 and 20 weeks of age as 37.38 ± 0.04, 92.27 ± 0.66, 304.38 ± 8.27, 609.81 ± 13.65, 908.30 ± 33.55 and 1117.17 ± 33.79g, respectively in white leghorn population. The heritability estimates for day old to 20 week of age were found as 0.027 ± 0.086, -0.051 ± 0.037, 1.883 ± 0.656, 1.348 ± 0.602, 1.043 ± 0.531 and 1.056 ± 0.533 respectively.

Khatkar *et al.* (1995) reported the average body weight at 20 week of age in two strain PL_1 and PL_2 of layer chicken was 1012 ± 1.82 and 1074 ± 1.85 respectively. The heritability estimates was 0.469 ± 0.09 and 0.445 ± 0.09 respectively in PL_1 and PL_2 layer chicken.

Sharma (1996) estimated the mean body weight at 4, 8, 12, 16 and 20 weeks of age as 168.023 ± 1.780, 374.981 ±4.155, 654.469 ± 5.879, 880.021 ±

7.725 and 1161.896 ± 9.498g, respectively. The heritability estimates at 4, 8, 12, 16 and 20 weeks of age for sire and sire + dam components of variance were 0.148 ± 0.114, 0.161 ± 0.118, 0.139 ± 0.112, 0.219 ± 0.133, 0.220 ± 0.134 and 0.219 ± 0.138, 0.164 ± 0.122, 0.094 ± 0.102, 0.175 ± 0.125, 0.190 ± 0.130, respectively.

(ii) Body weight at sexual maturity

It is an important economic character, however, in laying chickens it is considered more with its relation to feed consumption and sexual maturity than with its direct effect on economic return. Large birds consume more feed for dozen of eggs produced due to their greater demand for maintenance, on the other hand the salvage value of a large bird is more. Further, any breed or strain has an optimum body weight for egg production. There seems to be no material advantage in increasing the body weight over the optimum level, whereas any lowering of the body weight results in lowered egg production and small eggs. Because of this variable effect of body weight on egg production, there are conflicting reports in the literature.

Shibata (1965) reported the heritablity estimates for adult body weight of white leghorn as 0.248 ± 0.083 and 0.579 ± 0.056 based on sire and dam components of variance.

Saeki *et al.* (1966) estimated the heritability of body weight at sexual maturity which was 0.71 ± 0.09 from sire components of variance.

Krishna (1970) concluded the mean body weight at sexual maturity to be 1416.0, 1477.3 and 1372.4g in base, selected and control flock of white leghorn, respectively. The heritability of body weight at sexual maturity was 0.78 ± 0.28, 0.40 ± 0.08 and 0.59 ± 0.14 from sire, dam and sire + dam components of variance, respectively.

Banerjee (1972) estimated the mean body weights at sexual maturity as 1411.0 and 1450.9g during first year for selected and control flock respectively and 1500.9 and 1515.2g for the second year selected and control flock respectively. The heritability estimate of body weight at sexual maturity was 0.68 ± 0.19 in white leghorn flock.

Iqbaluddin *et al.* (1975) compared the performance of random bred and F_1 full-sib population (F=25%) of WLH and found that weight at sexual maturity was lower in inbreds (1325.19 ± 6.81g) as compared to random breds (1442.10 ± 6.54g) with a C.V. of 13.06 and 11.37 per cent respectively. The heritability estimates based on sire and sire + dam components of variance were 0.723 ± 0.127 and 0.720 ± 0.128, respectively. He concluded that the high S.E. and heritability value showed that inbreds had more variability than random bred.

Singh (1976) investigated the effects of full-sib mating by producing F_2 (F=0.375) and F_3 (F=0.50) from F_1 in WLH and found that mean body weight at maturity reduced from 1326.99 ± 3.79g in F_2 to 1264.49 ± 6.82g in F_3 progenies with a corresponding C.V. of 13.29 and 13.04 per cent. The heritability estimates based on sire components of variance were 0.236 ± 0.120 and 0.668 ± 0.144, respectively for F_2 and F_3 generations. He concluded that S.D. and C.V. values for most of the traits reduced in F_3 indicating reduction in variability and that improvement in heritability for mature body weight from F_2 to F_3 showed the scope of practicing selection to improve the traits during inbreeding process.

Singh (1977) estimated the data of F_4 full-sib generation (F=59%) to study the inbreeding depression resulting from 4 generations of full-sib matings in WLH. The mean weight at maturity and its heritability were found to be 1092.31 ± 5.42g and 0.163 ± 0.019, respectively. He further concluded that weight at sexual maturity was adversely affected by increased inbreeding from F_1 to F_4 generation.

Singh *et al.* (1982) estimated the average weight at sexual maturity as 1488.01 ± 253.30 and 1467.65 ± 175.34 g in selected and control population of WLH population.

Bhushan (1984) concluded that average weight at sexual maturity and its heritability were 1281.25 ± 41.91g and 0.13 ± 0.015, respectively in a F_2 inbred population (F=37.5%) of WLH; controls had a lower weight at maturity.

Kushwaha (1987) analysed the data of inbred flock of WLH (F=59%) and reported average weight at maturity as 1437.30 ± 9.26g. The heritability of weight at sexual maturity was found to be zero.

Singh (1987) concluded the average of 1389.44 ± 10.0g and a heritability value of 0.02 ± 0.07, for weight at sexual maturity was recorded in an inbred flock of WLH (F=50%).

Kumar (1989) estimated the data of 4 inbred generations (F=37.5, 50, 59 and 67 per cent). The average weight at sexual maturity were 1508.07 ± 11.60, 1354.00 ± 8.64, 1360.16 ± 8.35, and 1371.08 ± 7.77g respectively. The heritability estimates were 0.210 and 0.102 form sire and sire + dam components of variance respectively.

Thangaraju *et al.* (1990) concluded that heritability of two strain of white leghorn were 0.62 ± 0.15 and 0.47 ± 0.13 respectively for body weight at sexual maturity.

Khare (1991) observed the heritability of body weight at sexual maturity as 0.234 ± 0.03 in inbred white leghorn population.

Rai *et al.* (1992) estimated the average body weight at sexual maturity as 1422.28 ± 8.48 in a full sib population of white leghorn. The heritability estimates was found to be 0.187 ± 0.12.

Mani (1994) concluded the average body weight at sexual maturity as 1695.60 ± 10.40g. The heritability estimates was recorded as 0.533 ± 0.246 in white leghorn.

Sabri (1999) analysed the data on white leghorn. The heritability estimates was 0.02 for body weight at sexual maturity.

(iii) Age at sexual maturity

The age at sexual maturity is the number of days after hatching that an individual lays the first egg i.e. a pullet is said to be sexually mature when she lays her first egg. The earlier the pullet comes in to the production, the more would be her genetic multiplication as it would be possible for her to lay more eggs in a specified period.

King (1961) studied the inheritance of economic traits in white leghorn population. The average sexual maturity were 180.9 and 183.5 days for the year 1957 and 1958 respectively. The heritability for the same traits was estimated as 0.26, 0.57 and 0.40 from sire, dam and sire + dam components of variance respectively.

Van Vleck *et al.* (1963) estimated the average age at sexual maturity to be 176, 179, 184 and 186 days in white leghorn controls from two locations, in four successive hatches in a year. The heritability estimates of 0.04 and 0.34 for age at sexual maturity, based on sire and dam components of variance respectively was recorded in white leghorn.

Shibata (1965) reported heritability estimates of age at sexual maturity from sire and dam components of variance, as 0.306 ± 0.64 and 0.316 ± 0.057, respectively in a white leghorn closed flock.

Saeki *et al.* (1966) concluded the average age at sexual maturity to be 199 days in two strain of white leghorn. The heritability was 0.39 ± 0.16 for the same trait based on sire + dam components of variance.

Abplanalp and Woodard (1967) observed that age at sexual maturity remained unaffected by continued full-sib mating (F=37.5 and 50%).

Kinney *et al.* (1968) studied the age at sexual maturity in a random bred leghorn control flock over several generations and found the range of averages as 173.6 to 185.6 days and range of heritability estimates between 0.145 to 0.520.

Acharya *et al.* (1969) estimated the average age at sexual maturity as 176.6 ± 0.35 days with a coefficient of variation of 9.9 per cent. The heritability estimate of same trait was 0.37 ± 0.003 and 0.224 ± 0.04 based on sire and sire + dam components of variance respectively in white leghorn flock.

Krishna (1970) concluded that the average age at sexual maturity of the first year, second year and control flock of white leghorn under selection to be 191.7, 209.9 and 201.2 days respectively. The heritability estimates based on the sire and sire + dam components of variance for the above traits were 0.32 ±0.13 and 0.23 ± 0.07 for first year and 0.33 ± 0.15 and 0.28 ± 0.08 for second year respectively.

Iqbaluddin *et al.* (1975) analysed the data on random breds and 25 per cent inbred flock of WLH and found that age at sexual maturity of 199.38 ± 0.44 days in the random bred flock was increased to 215.53 ± 0.92 days after full-sib mating. The heritability estimates based on sire and sire + dam components of variance were 0.458 ± 0.102 and 0.442 ± 0.120, respectively for inbreds and were higher than the corresponding values for random bred flock.

Singh (1976) compared the performance of F_2 (F=37.5%) and F_3 (F=50%) generations of WLH and found that average age at sexual maturity reduced from 211.16 ± 0.85 days in F_2 to 205.83 ± 0.85 days in F_3 with a coefficients of variation of 10.45 and 9.26 per cent, respectively. The heritability estimates based on sire component of variance decreased from 0.251 ± 0.064 in F_2 to zero in F_3 generation of full sib mating.

Johari *et al.* (1977) observed the average age at sexual maturity to be 170.2 days in a white leghorn flock and the heritability estimate for the same trait was found to be 0.19.

Singh *et al.* (1982) studied white leghorn hens selected for high egg production and reported the age at sexual maturity to be 203.39 ± 32.71 and 215.23 ± 17.09 days in a selected and non-selected control flock respectively. The heritability estimates of age at sexual maturity was found to be 0.78 ± 0.21 from the sire component of variance in their white leghorn population.

Plachy *et al.* (1983) studied 4 inbred lines of fowl and reported mean age at first egg to be 208, 197, 269 and 252 days, respectively.

Bhushan (1984) reported that average age at sexual maturity and its heritability estimates were 178.75 ± 5.77 days and 0.36 ± 0.02, respectively in a F_2 inbred population (F=37.5%) of WLH. Control birds matured earlier than the inbreds.

Chaitanyam and Singh (1985) estimated mean age at sexual maturity to be 223, 229, 260, 237, 192, 233 and 199 days respectively for F_1 (F=25%), F_2 (F=37.5%), F_3 (F=47.9%), F_4 (F=48.13%), F_5 (55.36%), in ibreds and base flock of WLH breed. They further observed that age at maturity showed a declining trend at higher levels of inbreeding but the overall change was not significant as selection might have compensated the effects of inbreeding to some extent.

Kushwaha (1987) studied the average of 196.42 ± 1.86 days for age at sexual maturity in a inbred flock (F=59%) of WLH. He also determined the heritability as 0.128 ± 0.085 for the same trait.

Singh (1987) estimated the average and heritability as 209.74 ± 1.3 days and 0.06 ± 0.07, respectively for age at maturity in an inbred flock (F=50%) of WLH.

Rai (1988) reported the average age at sexual maturity of 345 birds of white leghorn (F=67%) to be 186.66 ± 1.03 days, while its heritablity value was very low.

Kumar (1989) estimated mean age at sexual maturity to be 216.12 ± 1.77, 190.78 ± 1.32, 193.93 ± 1.27, 193.14 ± 1.19, and 198.41 ± 0.81 days respectively for F_2 (F=37.5%), F_3 (F=50%), F_4 (59%), F_5 (67%) inbred flock of WLH breed. The heritability were found as 0.040 ± 0.065 and 0.147 ± 0.060 from sire and sire + dam components of variance for overall inbred.

Kumararaj *et al.* (1990) observed the average age at sexual maturity in white leghorn as 160 ± 0.61 days and heritability was found to be -0.069.

Yadav *et al.* (1991) computed the average age at sexual maturity as 166.42 ± 0.92 and 164.92 ± 0.86 days in two strains of white leghorn.

Rai *et al.* (1992) estimated the average age at sexual maturity as 186.66 ± 1.03 days and heritability was 0.038 ± 0.08 in an inbred white leghorn population.

Mahesh (1993) reported the average age at sexual maturity as 151.53 ± 0.18 days and heritability as 0.50 in 'C' strain of white leghorn.

Khathar *et al,* (1994) estimated the average age at sexual maturity as 167.80 ± 0.28 and 165.80 ± 0.27 days in PL_1 and PL_2 strains of white leghorn.

Sharma *et al.* (1994) analysed the heritability as 0.67 for age at sexual maturity in white leghorn.

Brah *et al.* (1995) reported the average age at sexual maturity as 164.80 ± 0.23 and 157.70 ± 0.23 days in PL_1 and PL_2 strain of white leghorn.

Sharma *et al.* (1995) estimated the heritability as 0.67 for age at sexual maturity in white leghorn.

Jeena (1996) analysed the data on three generations (G_1, G_2 and G_3) and average of age at sexual maturity was observed as 161.14 ± 0.84, 147.07 ± 0.98 and 151.76 ± 0.77 days, respectively in white leghorn.

Singh (1996) reported the heritability age at sexual maturity as 0.44 in white leghorn.

Bais *et al.* (1997) estimated the heritability of age at sexual maturity as 0.21 in white leghorn.

Sharma and Krishna (1998) concluded the average age at sexual maturity as 164.00 ± 0.25 days in white leghorn.

Reddy *et al.* (1999) reported the average age at sexual maturity as 141.00 days. The heritability was estimated as 0.46 in white leghorn.

(iv) Weight of the first egg

The egg weight is mostly related to the layer's body weight. The large body weight birds produce big size eggs and smaller body weight birds produce small size of egg. The egg weight is lowest during the start of lay and then it rapidly attains its weight by 7 to 8 months of age after which the increase is not significant. After 40 weeks of age, there would not be much increase in the size of the egg. The egg size may, however, vary with temperature, nutrition and other environmental conditions.

Kusner (1958) studied the two groups of pullets obtained by crossing leghorns and general purpose hens with highly inbred leghorn and outbred leghorn cocks; control group consisted of purebred Russian whites and found that egg weights were lowest in the inbred group.

Shibata (1965) reported heritability estimates, calculated from sire components of variance, of egg weight to be 0.197 ± 0.065 in a closed flock of WLH.

Sittmann *et al.* (1966) estimated the heritability (Full-sib method) of egg weight to be 0.65 for 9th generation in inbred Japanese quail.

Abplanalp and Woodard (1967) observed that egg size remained unaffected in two sets of inbred lines (F=50 and 37.5 per cent) of Turkeys.

Smetnev and Mymrin (1967) found that 3 generations of paternal half sibbing decreased the egg weight in successive generations in Russian white and moscow breeds.

Laanmal (1968) reported that inbreeding in 2 lines for several years decreased egg weight but the performance was improved by crossing inbred lines.

Du Plessis *et al.* (1970) practiced full-sib matings over 13 generations raising F from 3.3 to 92.9 per cent and found that egg weight tended to decline with increase in inbreeding in WLH.

Moiseeva (1970) reported that two years average egg weight was significantly lower (49.19g) in inbreds (F=70%) in comparison to outbreds (55.02g) in a strain of Russian whites. The heritability estimates was lower in inbreds (0.202) than that of outbreds (0.707).

Macha *et al.* (1971) observed that egg weight was not significantly affected in closely inbred hens of 5 WLH lines as compared to out breds.

Bashnakov (1974) analysed the inbred progenies of white plymouth rock and cornish (F=0.25 and 0.125) with outbred birds of two breeds and found that differences in egg weight were not significant.

Thak *et al.* (1975) studied the average initial egg weight and mature egg weight to be 36.2 and 49.5g, respectively. The heritability estimates of initial and mature egg weight was 0.16 and 0.40 respectively in white leghorn.

Cahaner *et al.* (1980) concluded that egg weight seem to be unaffected consistently by mild inbreeding in two generations of male line in broad breasted white Turkey. In female line also no trait was strongly and consistently affected.

Anil Kumar (1983) studied the average egg weight as 34.44 ± 0.107g and 55.08 ± 0.125g in half sib and full-sib populations of white leghorn. The heritability estimates of egg weight was found to be 0.101 and 0.270 in half-sib and full-sib populations, respectively.

Nirmal (1983) estimated the heritability estimates of egg weight to be 0.28, 0.61, 0.53 from sire components and 0.46, 0.39, 0.33 from sire + dam components of variance in the selected population for different generations. Corresponding heritability in the control group were 0.95, 0.51, 0.61, 0.37, 0.95, 0.66, 0.73 and 0.49 in the different generations, respectively.

Plachy *et al.* (1983) reported the average egg weight to be 49, 49, 46 and 52g, respectively in four inbred lines of fowl and their line crosses had an average egg weight of 52 to 55g.

Tayyab (1983) estimated the average first egg weight as 42.050 ± 0.235g with a C.V. of 9.751 per cent and the heritability of the same trait recorded as 0.216 ± 0.008 in half-sib population of white leghorn.

Bhushan (1984) studied weight of first egg and its heritability value as 44.40 ± 1.48g and 0.10 ± 0.01, respectively in a inbred (F=37.5%) flock of WLH; control flock had lower egg weight.

Chaitayam and Singh (1985) found the average egg weight as 47.5, 49.3, 48.1, 47.0, 51.4, 48.5 and 48.6g, respectively for F_1 (F=25%), F_2 (37.50%), F_3 (47.96%), F_4 (F=48.13%), F_5 (F=55.36%), overall inbreds and base population of WLH breed.

Kushwaha (1987) reported the average weight of first egg to be 42.88 ± 0.30g in an inbred flock of WLH (F=59%) and the heritability estimate being zero.

Singh (1987) estimated the mean weight of first egg as 41.98 ± 0.33g with a low heritability value of 0.06 ± 0.07 in a F_3 full-sib population of WLH.

Rai (1988) found average weight of first egg to be 42.38 ± 0.30g. The heritability estimate of this trait was reported very low (0.06 ± 0.07) in a flock of inbred leghorns (F=67%).

Kumar (1989) estimated the average egg weight as 47.57 ± 0.36, 41.43 ± 0.27, 36.57± 0.26, 47.86 ± 0.24 and 43.43 ± 0.16g, respectively for F_2 (F=0.38), F_3 (F=0.50), F_4 (F=0.59), F_5 (F=0.67) and overall inbreds. The overall heritability estimates of egg weight was 0.012 ± 0.052 and 0.026 ± 0.053, respectively for sire and sire + dam components of variance in a WLH population.

Thangaraju and Ulaganathan (1990) analysed the data on two strains of white leghorn. The heritability estimates of egg weight recorded as 0.90 ± 0.20 and 0.84 ± 0.19.

Brahmkhshatri *et al.* (1992) reported the heritability estimate of egg weight as 0.31 ± 0.15 based on sire components of variance in white leghorn.

Ledur *et al.* (1993) concluded that the average egg weight was 56.4g. The heritability estimate for egg weight was 0.51 and 0.40 respectively based on full-sib and half-sib analysis of variance.

Anand Mani (1994) estimated the average first egg weight as 40.92 ± 0.063g. The heritability estimate was 0.426 ± 0.299 based on sire components of variance in white leghorn.

Chaudhary *et al.* (1996) reported the heritability as 0.55 ± 0.10 and 0.45 ± 0.06, respectively in pure bred and cross bred strain of white leghorn.

Bais *et al.* (1997) observed the heritability as 0.22 ± 0.06, 0.55 ± 0.07 and 0.41 ± 0.04 for egg weight from sire, dam and sire + dam components of variance in white leghorn.

(IV) Egg production

A number of analysis of economic data have been made in an attempt to identify the characters of importance for egg production. These studies revealed that egg numbers alone can account for upto 90 per cent of the variation in economic return. The numbers of eggs produced in a time interval e.g. 90 days or a whole year, is generally used as a measure of production capacity of a hen under specified environmental conditions. Hens generally reached their egg yield in the first laying year and selection is based mainly on records of the first part production as it has been seen that the heritability of the part year records is almost as high as that for yearly records and their genetic correlation is also significantly high.

Kusner (1958) reported that egg production in the first year was higher in inbred group (6 generations of close inbreeding) than the control group consisting of purebred Russian whites.

Shibata (1965) estimated heritability estimates of egg production to be 0.232 ± 0.065 and 0.397 ± 0.077, respectively from sire and dam components of variance in a close flock of WLH.

Abplanalp and Woodard (1967) initiated two sets of 15 inbred lines of Turkeys'. The continued full sib mating left only 3 lines of first set survived with F=50 and 12 lines of second set with F=37.5 per cent. They found that 50 week egg production of inbred hens for 2 or 3 generations was equal or better than that of non-inbreds. They concluded that this may be due to selection for egg production partly through the elimination of lines by natural selection and suggested that establishment of inbred lines would require strong selection between and within lines. ~~of probably a program of crosses and renewed inbreeding among lines surviving 4 or 5 generations of sibbing.~~

Laanmae (1968) observed that inbreeding for several years in two lines decreased egg production in fowl and was improved by crossing inbred lines.

Dogadaev (1969) reported that the egg production of 10 months old Russian whites was 12.2 per cent low in inbred (Coefficient of inbreeding = 55.60%) than outbreds. The hens from top-crossing produced 22.3 per cent more eggs than inbreds and the progeny of outbred male x inbred female produced 10.4 per cent more eggs than inbreds.

Krishna (1970) found that average egg production in the base population, selected and control white leghorn flock was 62.2, 57.2 and 52.9 per cent respectively.

Kulenkamp *et al.* (1973) estimated that continued full-sib mating of 5 generations (F ranged from 25 per cent in F_1 to 67 per cent in F_5) in Japanses quail reduced the initial 17 lines to 6. They further observed that egg production suffered most followed by body weight and egg weight. Most of the traits showed biggest change after the first generation with performance remaining fairly stable thereafter.

Iqbaluddin *et al.* (1975) compared the performance of random bred and full-sib population (F=25%) of WLH and found that 90 days egg production which was significantly lower in inbred (47.69 ± 0.78%) as compared to randombreds (57.08 ± 0.25%) with C.V. a of 17.06 and 11.16 per cent. The heritability estimates of egg production, computed from sire and sire + dam components of variance were observed as 0.370 ± 0.081 and 0.365 ± 0.080, respectively for inbreds. He concluded that high S.E. and heritability estimates in inbreds showed that inbreds had more variability than random breds.

Singh (1976) reported that per cent 90 day egg production showed an improvement from 46.22 ± 0.25 per cent in F_2 (F=37.5%) to 52.75 ± 0.32 per cent in F_3 (F=50%) in WLH whereas its heritability value reduced greatly from 0.536 ± 0.291 in F_2 to 0.015 ± 0.002 in F_3.

Singh (1977) estimated the 90 day egg production as 51.72 ± 0.45 per cent in F_4 generation (F=59%) of WLH. The heritability estimate of the same trait was found to be 0.499 ± 0.036. He concluded that egg production was adversely affected as inbreeding progressed for F_1 to F_4.

Mahtoa *et al.* (1980) reported that the average egg production of selected group was 57.03 ± 1.04 eggs and for unselected group it was 50.60 ± 1.20 eggs.

Singh (1981) estimated the average 90 days egg production to be 46.15 ± 0.25 and 52.75 ± 0.34 per cent for 37.5 per cent and 50 per cent inbred flock of white leghorn.

Bhushan (1984) studied average 90 days egg production and its heritability estimates as 48.30 ± 1.93 eggs and 0.18 ± 0.00, respectively in a inbred (F=37.5%) flock of WLH; control population found to have lower egg production.

Chaitanyam and Singh (1985) found average 100 days egg production to be 49, 45, 38, 36, 37, 42 and 55 eggs, for F_1 (F=25%), F_2 (F=37.5%), F_3 (F=47.96%), F_4 (F=48.13%), F_5 (F=55.36%), overall inbreds and base population of WLH breed, respectively.

Kushwaha (1987) studied the performance of inbred flock of WLH (F=59%) and found an average of 49.03 ± 0.59 eggs for 90 day egg production. He estimated a very low heritability value (0.011 ± 0.085) for this trait.

Singh (1987) reported the average 90 day egg production of 41.67 ± 0.61 eggs with a heritability estimate of 0.10 ± 0.07 in inbred flock (F=50%) of WLH.

Rai (1988) estimated average egg production of first 90 day to be 51.85 ± 0.30 eggs with a heritability value of 45.146 ± 0.11 in an inbred flock 9
(F=67%) of WLH.

Kumar (1989) recorded the average egg production of first 90 days as 53.21 ± 0.63, 47.24 ± 0.47, 48.41 ± 0.45, 48.26 ± 0.42 and 49.28 ± 0.28 eggs for F_2 (F=0.38), F_3 (F= 0.50), F_4 (F=0.59), F_5 (F=0.67) and overall inbred population of WLH respectively. The heritability for the same trait and same inbreds were -0.091 ± 0.048 and 0.131 ± 0.059 for the sire and sire + dam components of variance respectively.

Tayyab *et al.* (1990) conducted the experiment on white leghorn and estimated the heritability of half sib family for 90 days egg production which was 0.06 ± 0.04.

Rai *et al.* (1992) reported the heritability of egg production which was found to be 0.15.

Yadav *et al.* (1993) estimated the heritability of 90 day egg production in white leghorn as 0.21 and genetic correlation among the trait were non-significant.

Sharma *et al.* (1994) computed the heritability of egg production upto 280 days of age which was high as 0.64 in white leghorn.

Sharma *et al.* (1995) reported the average 90 days egg production as 38.111 ± 0.267g. The heritability estimate were 0.338 ± 0.164 and 0.312 ± 0.164 respectively from sire and sire + dam components of variance in white leghorn.

Bais *et al.* (1997) estimated the heritability from sire and sire + dam components of variance as 0.07 ± 0.03 and 0.11 ± 0.02 respectively for 280 days egg production in IWH strain of white leghorn.

Sharma *et al.* (1999) computed the average 90 days egg production as 38.111 ± 0.267g. The heritability estimates was decreased as 0.314 ± 0.164 based on sire + dam components of variance in white leghorn.

(V) Clutch size

The clutch is the number of consecutive eggs laid by a bird and the rate of laying is determined by clutch size which in turn is determined by the interval between successive eggs. Good layers usually lay eggs in clutches of three or four eggs and the intervals between the clutches are usually not more than one day. One of the longest clutches on record being that of a white leghorn that laid 22.3 eggs in as many days in an officially conducted canadian egg laying test.

Hays (1934) using 23 inbreds.lines of RIR found that inbreeding tended to decrease mean winter clutch size and crossing inbred lines restored the intensity to the original level of foundation females. He concluded that the data in general show the down ward trend of persistency following inbreeding and their crosses were not superior than general flock.

Waters and Lambert (1935) could not found any clear evidence that the ability to lay during the winter months in WLH has been diminished as the inbreeding coefficient increased.

Wezyk (1970) studied on a flock of sussex fowls closed for 6 generations and observed the genetic progress in rate of lay. The heritability value of rate of lay declined over successive generations indicating a decrease in genetic variation.

Bhushan (1984) reported average clutch size of 1.46 ± 0.05 and its heritability value to be 0.17 ± 0.01 in an inbred flock (F=37.5%) of WLH. He concluded higher clutch size than those of controls indicated poor laying intensity in the inbreds.

Kushwaha (1987) estimated an average clutch size of 1.93 ± 0.03 days in an inbred flock of WLH (F=59%) with a very low heritability value (0.012 ± 0.085).

Table 5: Heritability estimates of the growth and production traits based on sire components of variance by earlier workers.

Reported by	Year	Day old weight	4-week body weight	8-week body weight	12-week body weight	16-week body weight	20- week body weight	24-week body weigh	W.S.M.	A.S.M.	W.F.E.	90- day E.P.	C.S.
Shibata	1965	-	-	-	-	-	-	-	0.248 ± 0.083	0.306 ± 0.64	0.197 ± 0.065	0.232 ± 0.065	-
Saeki *et al.*	1966	-	-	-	-	-	-	-	0.71 ± 0.09	-	-	-	-
Iqbaluddin *et al.*	1975	-	-	-	-	-	-	-	0.723 ± 0.127	0.458 ± 0.102	-	0.370 ± 0.081	-
Singh	1976	0.67 ± 0.26	0.38 ± 0.16	0.32 ± 0.07	0.41 ± 0.18	0.27 ± 0.06	0.46 ± 0.19	0.70 ± 0.22	-	-	-	0.536 ± 0.291	-
Anil Kumar	1983	-	-	-	-	-	-	-	-	-	0.101	-	-
Kumar	1983	0.08 ± 0.03	0.17 ± 0.16	0.19 ± 0.11	-	-	-	-	-	-	-	-	-
Bhushan	1984	0.34 ± 0.026	0.02 ± 0.01	0.09 ± 0.01	0.10 ± 0.01	0.01 ± 0.01	0.08 ± 0.01	0.46 ± 0.032	0.13 ± 0.015	0.36 ± 0.02	0.10 ± 0.01	0.18 ± 0.00	0.17 ± 0.01
Kumar	1989	-0.076 ± 0.059	0.131 ± 0.069	0.417 ± 0.158	0.217 ± 0.113	0.132 ± 0.067	0.162 ± 0.078	0.148 ± 0.077	0.210 ± 0.083	0.147 ± 0.060	0.012 ± 0.052	-0.091 ± 0.048	-0.097 ± 0.440
Khare	1991	0.28 ± 0.162	0.267 ± 0.150	0.330 ± 0.178	0.042 ± 0.062	0.196 ± 0.140	0.206 ± 0.137	-	0.234 ± 0.03	-	-	-	-
Ledur *et al.*	1993	-	-	-	-	-	-	-	-	-	0.40	-	-
Mani	1994	0.027 ± 0.086	-0.051 ± 0.037	1.883 ± 0.656	1.348 ± 0.602	1.043 ± 0.531	1.056 ± 0.533	-	0.533 ± 0.246	-	0.426 ± 0.299	-	-
Sharma *et al.*	1994	-	-	-	-	-	1.47 ± 0.088	-	-	-	-	0.64	-

Table 6: Heritability estimates of the growth and production traits based on sire + dam components of variance by earlier workers.

Reported by	Year	Day old weight	4-week body weight	8-week body weight	12-week body weight	16-week body weight	20- week body weight	24-week body weigh	W.S.M.	A.S.M.	W.F.E.	90- day E.P.	C.S.
King	1961	-	-	-	-	-	-	-	-	0.57	-	-	-
Acharya *et al.*	1969	-	-	-	-	-	-	-	-	0.224 ± 0.04	-	-	-
Iqbaluddin *et al.*	1975	-	-	-	-	-	-	-	0.720 ± 0.128	0.442 ± 0.120	-	0.365 ± 0.080	-
Anil Kumar	1983	-	-	-	-	-	-	-	-	-	0.270	-	-
Kumar	1983	0.51 ± 0.27	0.16 ± 0.08	0.17 ± 0.07	-	-	-	-	-	-	-	-	-
Kushwaha	1987	0.098 ± 0.08	0.048 ± 0.08	0.097 ± 0.085	0.043 ± 0.085	0.000 ± 0.000	0.083 ± 0.085	0.067 ± 0.085	0.000 ± 0.00	0.128 ± 0.085	0.00 ± 0.00	0.011 ± 0.085	0.012 ± 0.085
Singh	1987	-	-	-	-	-	-	-	-	-	0.06 ± 0.07	-	-
Rai	1988	0.021 ± 0.07	0.009 ± 0.07	0.665 ± 0.25	0.887 ± 0.29	0.153 ± 0.01	0.020 ± 0.07	0.128 ± 0.11	-	-	0.06 ± 0.07	45.146 ± 0.11	0.00 ± 0.00
Kumar	1989	0.244 ± 0.066	0.053 ± 0.056	0.694 ± 0.101	0.298 ± 0.074	0.024 ± 0.054	0.112 ± 0.059	0.131 ± 0.060	0.102 ± 0.060	0.040 ± 0.065	0.026 ± 0.053	0.131 ± 0.059	0.088 ± 0.057
Rai *et al.*	1992	-	-	-	-	-	-	-	0.187 ± 0.12	-	-	-	-
Ledur *et al.*	1993	-	-	-	-	-	-	-	-	-	0.51	-	-
Sharma	1996	-	0.148 ± 0.114	0.161 ± 0.118	0.139 ± 0.112	0.219 ± 0.133	0.220 ± 0.134	-	-	-	-	-	-
Bais *et al.*	1997	-	-	-	-	-	-	-	-	-	0.41 ± 0.04	-	-

Singh (1987) concluded mean clutch size of 2.28 ± 0.03-days with a heritability estimate of 0.12 ± 0.07 in a inbred flock (F=50%) of WLH.

Rai (1988) studied the effects of inbreeding in an inbred flock (F=67%) of WLH and found average clutch size of 1.74 ± 0.01 days with a heritability estimate of zero.

Kumar (1989) reported the effects of inbreeding at 4 levels of inbreeding coefficient (F=0.38, 0.50, 0.59 and 0.67), respectively. The average clutch size was 2.04 ± 0.03, 1.85 ± 0.02, 1.83 ± 0.02, 1.84 ± 0.02 and 1.89 ± 0.01 for F_2, F_3, F_4, F_5 and overall inbred, resepctively. The heritability for same ~~traits~~ trait was found to be -0.097 ± 0.440 and 0.088 ± 0.057 for sire and sire + dam component of variance, respectively.

Correlation's estimates

Shibata (1965) reported that age at sexual maturity was genetically correlated with egg production (-0.749 ± 0.121), and adult body weight with egg weight (0.652 ± 0.106) in a closed flock of WLH.

Kinney *et al.* (1968) estimated that the genetic correlations of 8 weeks of age with egg weight, sexual maturity and part egg production ~~which~~ were 0.16, -0.01 and -0.01 respectively.

Krishna (1970) studied the phenotypic genetic and environmental correlations between cumulative body weights at different stages, from hatch to 24 weeks of age. These correlations were mostly positive and significant.

The genetic correlations were higher and environmental correlations were found to be smaller then the phenotypic correlations. The weight at sexual maturity was significantly correlated with egg production, while the correlations between age at sexual maturity and egg production was found as -0.17, 0.10, -0.52 and 0.32, -0.12, 0.05 for the first year and second years respectively.

Banerjee (1972) observed the phenotypic, genetic and environmental correlations between cumulative body weights at different stages from hatch to 24 weeks of age. All correlations were mostly positive and significant. The correlations between cumulative body weights and age at maturity were negative but significant. Genetic correlations were higher than the phenotypic correlations. The phenotypic correlations between age at sexual maturity with weight at sexual maturity and 90 days egg production were 0.17 and -0.41 respectively. The genetic correlations between age and weight at sexual maturity were 0.66 and 0.67 from sire and sire + dam components of variance covariance respectively. The phenotypic correlations of age with weight at sexual maturity and 90 days egg production were 0.00 and -0.12 respectively. The environmental correlations between age and body weights at sexual maturity were 0.21 and 0.22 from sire and sire + dam components of variance covariance respectively.

Iqbaluddin (1972) reported that the phenotypic, genetic (sire), genetic (sire + dam) and environmental correlations between age and weight at sexual maturity were significant with the values of 0.270, 0.508, 0.368 and -0.173, respectively in full-sib population. The corresponding correlations between age at sexual maturity and egg production were found to be significant, except the genetic (sire + dam) with their estimate of -0.196, -0.178, 0.045 and -0.467. The correlations between weight at sexual maturity and egg production were found to be 0.064, 0.106, 0.250 and -0.130 in the same order; all values being significant except first one.

Singh (1976) estimated that the phenotypic correlations of age at sexual maturity with weight at sexual maturity and egg production were negative and significant, with the values of -0.121and -0.408, respectively in 37.5 per cent inbred white leghorn flock as against the corresponding correlations of -0.060 and -0.0339 in 50 per cent inbred WLH flock and later being significant. The corresponding genetic correlations were also significant with the value of -0.207 and 0.638 in 37.5 per cent inbred flock and were 0.406 and 0.757 in 50 per cent inbreds.

The corresponding environmental correlations were -0.134 and -0.534 in 37.5 per cent inbreds and -0.145 and -0.329 in 50 per cent inbred flock. The correlations between weight at sexual maturity and egg production at phenotypic, genetic and environmental scale were found to be 0.009, -0.126 and 0.034, respectively in F_2 (F=37.5%); only the middle figure being significant, whereas the corresponding correlations in F_3 (F=50%) were all significant with the values of 0.141, 0.727 and 0.194. He also found that partial correlations of egg production with weight at maturity, keeping age at maturity constant, were 0.011 and 0.160 in F_2 and F_3 full-sib populations, respectively whereas the partial correlation between of egg production and age at maturity, keeping weight at sexual maturity as constant were significant with the value of -0.410 and -0.338, respectively in F_2 and F_3 generation.

Singh (1977) estimates the phenotypic, genetic and environmental correlations between age and weight at maturity which ~~was~~ were significant with the values of 0.469, 0.504 and 0.476, respectively in a full-sib population of WLH. The corresponding correlation between age at sexual maturity and egg production were also found to be significant with their estimates of -0.249, -0.228 and -0.311, respectively. Whereas weight at maturity and egg production were significantly correlated at genetic (0.608) and environmental (-0.119) levels.

Krishnan *et al.* (1977) concluded that age at maturity was highly significantly correlated with average clutch size in flock (-0.42). Average clutch size was also correlated with 40 weeks production in all 3 flocks (0.45, 0.71 and 0.47).

Thangaraju *et al.* (1978) reported the genetic correlation between clutch size and egg production which was 0.83 while clutch size with egg mass was 0.78, both the correlations were significant.

Avadhesh Kumar (1982) reported that genetic, phenotypic and environmental correlations between day old 4; 8, 12 and 16 weeks of body weight were found to be 0.340 ± 0.003, 0.077 ± 0.046 and -0.024, 0.473 ± 0.0003, 0.132 ± 0.05 and 0.024, 1.119, 0.039 ± 0.051 and -0.171, -0.502 ± 0.0015, 0.038 ± 0.051 and 0.125, 1.114, 0.570 ± 0.034 and 0.428, 1.019, 0.255 ± 0.048 and 0.156, 0.288 ± 0.0007, 0.169 ± 0.05 and 0.167, 0.949 ± 0.000, 0.512 ± 0.037 and 0.42, 0.016 ± 0.001, 0.209 ± 0.049 and 0.234, 0.1653 ± 0.0001, 0.6994 ± 0.058 ~~and 0.6815,~~ respectively in white leghorn.

Kumar (1983) estimated that the phenotypic, genetic environmental correlations between 0 and 4 week body weights were significant with the values of 0.567, -2.069, 0.513, 0.812, 0.586, 0.526 and 0.557, respectively in a full-sib population of WLH. The corresponding correlations between 0 and 8 week body weights and between 4 and 8 week body weight were all significant with their estimates of 0.559, -1.882, 1.312, 0.900, 0.582, 0.513 and 0.549, and 0.906, -1.094, 1.019, 0.987, 0.907, 0.900 and 0.904.

Tayyab (1983) concluded that the genetic, phenotypic and environmental correlation between age at sexual maturity and 90 days egg production were found to be -0.950 ± 0.002, 0.256 ± 0.53 and 0.237, respectively in half sib family of white leghorn.

Bhushan (1984) reported that day old body weight was significant and positively correlated with 8 week body weight and negative with most of the other traits at phenotypic and genetic levels (0.25 and 0.95, respectively). All the production traits viz. weight and age at sexual maturity, weight of the first egg, 90 day egg production and clutch size were found to be significantly correlated in all possible combinations at genetic, phenotypic and environmental scale; except genetic correlation between 90 day egg production and age at sexual maturity.

Rai (1988) found that most of the genetic and phenotypic correlations among the body weights from 0 to 24 weeks of age in all possible combinations were significant and same was the case among weight and age at sexual maturity, weight of first egg, 90 day egg production and clutch size.

Kushwaha *et al.* (1989) estimated that the genetic correlations among 0, 4, 8, 12, 16, 20 and 24 week body weight and also among weight and age at maturity, weight of the first egg, 90 day egg production and clutch size were all significant. Similarly most of the corresponding correlations at phenotypic level were found to be significant.

Kumar (1989) computed the genetic correlations as per sire components of variance and covariance were found to be correlated significantly among each other except that of 90 days egg production and clutch size which were significant and negatively correlated. The 0 week body weight with 8 week weight and thereafter initial body weights were correlated positively and significantly with their subsequent body weights from 4-week onwards except between 12 and 16 week body weight while the 90 days egg production with clutch size was negatively and significantly correlated.

Similarly most of the corresponding correlations at phenotypic level were found to be significant.

Thakur *et al.* (1989) reported that the environmental correlation was -0.137 ± 0.10 between age and body weight sexual maturity.

Anil Kumar and Verma (1990) observed the phenotypic correlations of day old body weight with body weight at 4 week as 0.57 and with 8 week body weight as 0.56. Body weight at 4 week had significant phenotypic correlation with 8-week body weight (0.91) in inbred population of white leghorn.

Khare (1991) reported the phenotypic correlations of 4 week body weight with 1 day, 12, 16, 20 week and weight at sexual maturity as 0.411, 0.82, 0.25, 0.83, 0.76 and -0.60, respectively while the genetic correlations of day old body weight with 4, 8, 12 and 20 week and weight at sexual maturity as 0.99 ± 0.40, 0.95 ± 0.38, 0.854 ± 0.52, 0.991 ± 0.42, 1.002 ± 0.01 and -0.769 ± 0.21 on the basis of sire + dam component of variance and covariance in inbred white leghorn population.

Singh (1992) estimated the phenotypic correlations of 4 week body weight with 8, 12, 16 and 20 week, age and age at sexual maturity as 0.80 ± 0.06, 0.66 ± 0.02, 0.59 ± 0.30, 0.49 ± 0.21 and -0.28 ± 0.20, respectively in white leghorn flock.

Mani (1994) observed the phenotypic genetic and environment correlations between day old with upto 20-week body weight, weight at sexual maturity, age at sexual maturity and weight of first egg. The phenotypic correlations among day old body weight was found positively and significantly correlated with 4 week (0.573 ± 0.44), 8th week body weight (0.154 ± 0.06), while day old body weight was not significantly correlated with other traits. The 4th week body weight with 8th , 12th , 16th and 20th week body weight was positive and significant, while with other traits it was negative and non significant. The most of the phenotypic correlations were positive and significantly correlated while genetic correlations were mostly negative and significant but environmental correlation were positive and non significantly correlated.

Sharma (1995) estimated that the genetic, phenotypic environmental correlations among day old, 4, 8, 12, 16 and 20 week body weight and also age at sexual maturity and 90 days egg production were mostly positive and significantly correlated while the phenotypic correlations were also mostly positive and significant except age at sexual maturity which was negative and non significantly correlated while the environmental correlations ~~are~~ were also positive except age at sexual maturity, as per sire components. The same trend was found for genetic, phenotypic and environmental correlations as per sire + dam components of variance and covariance.

Mandal and Mann (1998) observed the genetic correlations were found between body weight with 20 weeks and egg production upto 280 days (0.167

± 0.038), between age at first egg and egg production with 280 days (0.528 ± 0.051), between egg production upto 280 days and egg weight at 32 weeks (0.247 ± 0.046) and between egg weight at 32 weeks and body weight at 40 weeks (0.084 ± 0.040) on the basis of full-sib component of variance and covariance.

Sabri *et al.* (1999) reported the phenotypic and genetic correlation in white leghorn. The phenotypic correlations ranged from 0.80 to -0.13 and genetic correlations from 0.91 to -0.27.

Regressing estimates

Sittman *et al.* (1966) observed the inbreeding depression in Japanese quail, with four levels of inbreeding coefficient resulting from full-sib mating and reported that on the average 10 per cent increase in the inbreeding of dam reduced 6 week body weight by 2.8 g and delayed sexual maturity by 0.4 day. The same amount of increase in the inbreeding on progenies reduced 6 week body weight by 3.4 g, egg weight by 1.7 g and increased sexual maturity by 2.2 days.

Chung and Park (1969) analysed the data of 956 WLH reported that the regressing of production traits on every 10 per cent increase in inbreeding coefficient were observed : 8 week body weight by -5.95g; body weight at first egg by -25.76g, body weight at 300 days of age by -42.60g; laying rate by -0.94 per cent; winter pause by 2.33 days; age at sexual maturity by 0.50 days and egg weight by -0.30g.

Mac Laury and Johnson (1971) computed the regression of 8 week body weight on inbreeding coefficient (F=0, 25, 37 and 50) which was highly significant (-1.3197 ± 0.4368) in chickens. They concluded that depression in body weight due to a 12.5 per cent inbreeding could be counter balanced by saving the top 77 per cent of the unselected population.

Kulenkamp *et al.* (1973) observed the weighted linear regression coefficients of performance on inbreeding (F=25, 38, 50, 59 and 67 per cent, respectively for five generation expressed as deviations of inbred population from control in Japanese quail. The value were 0.060g, -0.062 g, -0.023 egg and 0.040g for 3 and 7 week body weights, average weekly production and egg weight, respectively. They concluded that egg production was affected most by inbreeding than the body and egg weights and that only egg weight was linear to inbreeding effects, other were non linear. Thus the regression coefficients of these can not be used as adequate predictors of performance of birds at any given level of inbreeding.

Goher and Gibbon (1974) found that increase in 10 per cent inbreeding caused reduction in body weight by 50 g in the domestic fowl.

Singh (1976) concluded that the regressions of age and weight at sexual maturity and egg production on inbreeding coefficient were found to be 0.147 days, -3.363g and -0.122 per cent, respectively.

Chaitanyam and Singh (1985) reported significant regression (for 10 per cent increase in F) of weight at maturity and 100 day egg production on inbreeding (F=25, 37.5, 47.06, 48.13 and 55.36 per cent), the values being -33.71g and -3.60eggs, respectively in WLH. The regression of 10 week body weight, age at sexual maturity and egg weight on inbreeding were found to be non-significant with their estimates of -31.40g, 1.08 days and 0.32 g, respectively.

Foster and Kilpatrick (1987) observed that 1 per cent increase in inbreeding delayed age at sexual maturity by 0.68 ± 0.179 days, 35 week egg weight by 0.19 ± 0.053g and 60 week egg weight by 0.32 ± 0.74g in the domestic fowl.

Rai (1988) found the significant regressions of 0, 4, 8, 16, 20 and 24 week body weights, weight and age at sexual maturity, 90 day egg production and clutch size on inbreeding to be 0.73, 0.95, 0.68, 0.79, 0.90, 0.91, 0.92, 0.78g, -0.71 days, -0.19 egg and 0.12 days, respectively in a F_5 full-sib population of white leghorn. Inbreeding did not affect weight of the first egg.

Kumar (1989) computed the linear regressions of weight at sexual maturity, age at sexual maturity, weight of first egg, 90 days egg production and clutch size on 0, 4, 8, 12 and 16 weeks body weight. The regression of weight at sexual maturity on 0, 4, 8, 12 and 16-week body weight were 4.507, 0.499, 0.288, 0.235 and 0.618, respectively. The 16-week body weight has highest contribution (R^2 value = 14.70 per cent) in weight at sexual maturity. The regression of age at sexual maturity on day old to 16 week body weight were 0.333, -0.059, -0.017, -0.041, -0.061 with higher R^2 value of 16-week body weight. Weight of first egg on 0, 4, 8, 12 and 16-week body weight, weight at sexual maturity and age at sexual maturity were 0.381, -0.002, 0.004, 0.0037, 0.0018 0.0070 and 0.0518 but age at sexual maturity determine the highest improvement in weight of first egg (R^2 value = 6.50 per cent). The regression of 90 day egg production and clutch size on 0, 4, 8, 12, 16 week body weight, weight at sexual maturity, age at sexual maturity, weight of first egg were 0.107, 0.029, 0.009, 0.0091, 0.0109, 0.0034, -0.0444, 0.0326 and -0.004, -0.0014, -0.0005, -0.003, -0.0004, -0.00005, 0.0027, 0.0046, respectively in inbred white leghorn population. Whereas 16-week body weight (R^2 value = 1.6 per cent) and age at sexual maturity (R^2 value = 2.0) highly contributed in improvement of egg production and clutch size, respectively.

The partial regressions of weight and age at sexual maturity and clutch size on 0, 4, 8, 12 and 16 week body weights were found to be 2.765, 0.090, 0.137, 0.149 and 0.656g; 0.442, -0.028, 0.0119, -0.019, -0.052 days and -0.001, -0.0009, -0.0002, -0.00006, -0.0003 days respectively with significant values as 0.158, 0.698 and 0.155, respectively while the partial regression of first egg weight on body weight at 0, 4, 8, 12, 16 week weight, weight at maturity and age at sexual maturity were found to be 0.336, -0.006, -0.0002, 0.004, -0.001, 0.005 and 0.044g, respectively with a significant R^2 value of 0.148 indicating a joint contribution of 14.8 per cent by all these independent traits towards weight of first egg. The partial regression of 90 days egg production on corresponding traits and first egg weight were 0.056, 0.018, 0.002, 0.002, 0.003, 0.002, -0.043 and 0.051 eggs, respectively. The R^2 value was 0.037 in inbred white leghorn population.

The linear regression of weight at maturity on 0, 4, 8, 12 and 16-weeks body weight individually were found to the highly significant with their value being 4.50, 0.49, 0.28, 0.23 and 0.61g, respectively having greatest contribution from 16-week weight (R^2 = 14.70%) whereas in case of age at sexual maturity the regression coefficients on 4, 12 and 16-week body weight were -0.059, -0.041 and -0.061 days, respectively; all the regressions were statistically significant.

The first egg weight was regressed over various economic traits then regression on 0, 8, 12, 16-week of age, weight and age at maturity; the highest R^2 being 6.5 per cent for age at maturity. The 90-days egg production and clutch size were significant at 4, 8, 12, 16-week age and age at maturity with ~~more~~ R^2 value (1.60 and 2.00 per cent, respectively) from age at maturity.

Mani (1994) computed the linear regression of weight at sexual maturity and first egg weight on age at sexual maturity were 6.3773 and 0.1290, respectively while the R^2 values were 0.3300 and 0.2256 respectively.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present study was undertaken on the inbred lines of white leghorn, maintained at Poultry Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar.

The development of inbred lines of white leghorn was initiated during the year 1985. Parents were selected from a random bred population and full brother × sister mating were arranged to get full-sib progenies of F_1. The same system of mating was followed to get F_2, F_3 and F_4 full –sib generations. We are considering here two full-sib generations for study with 50 and 59 per cent inbreeding coefficient respectively and comparing with control population.

The separate breeding pens were used for full-sib mating to ensure pedigreed breeding. After a pre-experimental period of 10 days trapnesting was done and eggs were set weekly for hatching. Floor, broken and abnormal eggs were discarded after visual examination and candling.

The eggs were candled on 4th day of incubation and all infertile eggs were removed. The eggs were again candled on 18th day of incubation and viable embroyed eggs were placed in the pedegree bages and were transferred to hatcher. The viable chicks after hatching on 21st day were using wing banded, weighed and vaccinated against Ranikhet F_1 strain and were transferred to floor brooders. The chicks were reared under floor brooder for 6 week, after which they were transferred to grower houses. The chicks were vaccinated at 8 and 10 weeks of age against Ranikhet and Fowl Pox disease. The birds were leg banded and transferred to layer houses at 20 weeks of age. All the birds were trapnested individually, for the first 90 days of laying year and only those birds who have completed 90 days egg production were included in the study.

All possible efforts were made to provide similar conditions throughout the two generations of inbred lines and control population also.

All the female birds were weighed to the nearest gram, from hatch to 24 weeks of age at 4 week intervals and also at sexual maturity.

The following observations were thus recorded on each bird for the present study.

1.	0-week weight of chick	(g)	(0-wk BW)	x_1
2.	4-week body weight	(g)	(4-wk BW)	x_2
3.	8-week body weight	(g)	(8-wK BW)	x_3
4.	12-week body weight	(g)	(12-wk BW)	x_4
5.	16-week body weight	(g)	(16-wk BW)	x_5
6.	20-week body weight	(g)	(20-wk BW)	x_6
7.	24-week body weight	(g)	(24-wk BW)	x_7
8.	Weight at sexual maturity	(g)	(W.S.M.)	x_8
9.	Age at sexual maturity	(days)	(A.S.M.)	x_9
10.	Weight of first egg	(g)	(W.F.E.)	x_{10}
11.	90-day egg production	(Nos.)	(90 days EP)	x_{11}
12.	Clutch size	(days)	(C.S.)	x_{12}

The clutch size was calculated for each bird by using following formula :

$$\text{Clutch size} = \frac{\text{Number of days in production}}{\text{Total number of eggs produced during the period}}$$

The generation wise distribution of records and details regarding flock size are given in Table 1.

Table 1 : Frequency distribution of individuals and particulars of flock size

Generation	No. of hatch	No. of sires	No. of dams	No. of female progenies
50 % inbred	15	20	78	342
59% Inbred	8	32	151	612
Pooled	23	52	229	954
Control population	11	16	46	174

Only those dams which has atleast three progenies were included in the study. This led to the reduction in number of dams.

Statistical analysis

The mean, standard error, standard deviation and coefficient of variance was calculated according to **Snedecor and Cochran (1968).**

$$\text{Mean } (\bar{y}) = \frac{\sum_i Y_i}{N}$$

$$\text{Standard Error} = \frac{\sigma}{\sqrt{N}}$$

Where,

Y_i = measurement of i^{th} individual

N = number of individual measured

$$\sigma = \frac{\sqrt{\sum \left(Y_i - \overline{Y}\right)^2}}{\sqrt{N - 1}}$$

$$\text{Standard deviation} = \sqrt{\text{variance}}$$

$$\text{Coefficient of. variance} = \frac{\sigma}{\overline{Y}} \times 100$$

The data of each generation of inbreeding and control population were corrected for hatch effects by using least squares analysis of variance as described by **Harvey (1975).**

$$Yij = \mu + hi + eij$$

Where,

Yij = the observation on j^{th} progeny under i^{th} hatch

μ = Over all mean

h_i = effect of i^{th} hatch (i = 1, 2, ------, p)

eij = random error assumed to be independent and normally distributed with mean zero and variance σ^2.

The least squares constants involved in the above model were computed directly from hatch means:

$$\text{Between hatches uncorrected sum of squares} = \frac{\sum Y_{i.}^2}{ni} = R\,(\mu + hi)$$

$$\hat{\mu} = \frac{1}{p}\left(\frac{y_{1.}}{n_1} + \frac{y_{2.}}{n_2} + \text{------}\frac{y_p}{n_p}\right) = \frac{1}{p_i}\,\overline{Y}_{i.}$$

$$\hat{h}_i = \hat{y}_{i.} - \hat{\mu}$$

The least squares constants (appendix II) for each hatch were subtracted from the individual observations of that hatch in all two inbred lines and control population.

After correcting the data for the hatch effects mentioned earlier the following linear model was used for least squares analysis for genetic studies and the corresponding analysis of variance and covariance are presented in Table 2 and 3.

$$Y_{ijk} = \mu + s_i + d_{ij} + e_{ijk}$$

$i = 1, 2,$ ------------------- s

$j = 1, 2,$ ------------------ d_i

$k = 1, 2,$ ------------------ n_{ij}

Where,

Y_{ijk} = the observation on the K^{th} progeny of j^{th} dam mated to i^{th} sire.

μ = oven all mean

S_i = effect of i^{th} sire (with $E(S_i) = 0$, $V(S_i) = \sigma^2 s$)

d_{ij} = effect of j^{th} dam mated to $_i{}^{th}$ sire

(with $E(d_{ij}) = 0$, $V(d_{ij}) = \sigma^2 d$)

e_{ijk} = random error (with $E(e_{ijk}) = 0$, $v(e_{ijk}) = \sigma^2 e$)

Computation of variance and covariance components

To obtain the variance and covariance components for sire, dams within sire and error, the expectations of mean squares were derived for the above model and are given in Table 4.

Table 2 : Analysis of variance

Source of variation	**d.f**	**Sum of square**
Between sires	S-1	$\Sigma_i N_i (Y_{i..} - \overline{Y})^2$
Between dams within sires	d-S	$\Sigma_i \Sigma_j n_{ij} (y_{ij} - \overline{Y}_i)^2$
Error	N - d	$\Sigma_i \Sigma_j \Sigma_k (Y_{ijk} K - \overline{Y}_{ij})^2$
Total	N-1	$\Sigma_i \Sigma_j \Sigma_k y^2_{ijk} - \overline{Y}$

Where,

$N_i = \Sigma_j n_{ij}$, $d = \Sigma di$

$N = \Sigma_i \Sigma_j n_{ij}$

Table 3: Analysis of covariance

Source of variation	d.f	Sum of square
Between sire	S-1	$\Sigma_i N_i (X_{i..} - \overline{X})^2 (Y_{i..} - \overline{Y})^2$
Between dams within sires	d-s	$\Sigma_i \Sigma_j n_{ij} (X_{ij} - \overline{X}_i)^2 (Y_{ij} - \overline{Y}_i)^2$
Error	N-d	$\Sigma_i \Sigma_j \Sigma_k (X_{ijk} - \overline{X}_{ij})^2 (Y_{ijk} - \overline{Y}_{ij})^2$
Total	N – 1	$\Sigma_i \Sigma_j \Sigma_k (X_{ijk} - \overline{X}) (Y_{ijk} - \overline{Y})$

Table 4: Expectations of mean squares.

Source of variation	d.f.	M.S.	Expectation means squares
Between sires	$n_S = (S-1)$	M_S	$\sigma^2_e + K_2\sigma^2 d + K_3\sigma^2_S$
Between dams within sires	$n_D = (d - s)$	M_D	$\sigma^2_e + K_1\sigma^2 d$
Error	$N_W = (N - d)$	M_W	σ^2_e

The K_i coefficients of different components were obtained during the process of expectations as follows:

$$\therefore \hat{\sigma}^2 e = M_W = V(E)$$

$$\hat{\sigma}^2 d = \frac{M_D - M_W}{K_1} = V(D)$$

$$\hat{\sigma}^2 S = \left(M_S - K_2 \sigma^2 d\right) / K_3 = V(S)$$

$$= \left(M_S - \frac{K_2}{K_1}\left(M_D - M_W\right)\right) / K_3$$

$$= \frac{K_1 M_S - K_2 M_D + K_3 M_W}{K_1 K_3}$$

$$\hat{\sigma}^2 p = \hat{\sigma}^2 S + \hat{\sigma}^2 d + \hat{\sigma}^2 e$$

$$= V(S) + V(D) + V(E)$$

$$K_1 = \frac{1}{d - S}\left(N_{..} - \sum_i \left(\sum_j \frac{n_{ij}^2}{N_i}\right)\right)$$

$$K_2 = \frac{1}{S - 1}\left(\sum_i \sum_j \frac{n_{ij}^2}{N_i} - \sum_i \sum_j \frac{n_{ij}^2}{N_.}\right)$$

$$K_3 = \frac{1}{S-1}\left(N - \frac{1}{N_{..}} \sum_i N_i^2\right)$$

Estimation of genetic parameters

The heritability estimates of the characters under study were determined according to **Falconer (1960)** using the sire, dam and sire + dam components of variance.

$$h_s^2 = \frac{4V(S)}{V(S)+V(D)+V(E)}$$

$$h_d^2 = \frac{4V(D)}{V(S) + V(D) + V(E)}$$

$$h_{(s+d)}^2 = \frac{2(V(S)+V)D))}{V(S) + V(D) + V(E)}$$

Where,

V(S), V(D) and V(E) are the variance components due to sire, dam and error, respectively.

The standard error of heritability estimates were estimates according to **Dickerson (1960)**

$$\text{S.E.}\left(h^2\right) = \frac{C}{Y}\sqrt{V(S)}$$

Where,

C = any constant multiplier of the numerator X, such as 4 used in estimating total genetic variance from the sire and dam components when } and 2 when sire + dam component was used

$$Y = \hat{\sigma}^2 s + \hat{\sigma}^2 d + \hat{\sigma}^2 e$$

$$V(S) = \frac{2}{K_{ss}^2}\left(\frac{M_s^2}{n_s} + \frac{M_m^2}{n_m}\right)$$

$$V(M) = \frac{2}{K_{mm}^2}\left(\frac{M_m^2}{n_m} + \frac{M_w^2}{n_w}\right)$$

Where,

K_{ss} = K_3 = Coefficient of variance components due to sire.

$K_{mm} = K_1$ = coefficient of variance due to dam.

M_s, M_m and M_w = Mean squares due to sire, dam and error components, respectively with degrees of freedom n_s, n_m and n_w.

The phenotypic correlations between different characters were determined according to **Bogart (1959) and Falconer (1960).**

$$r_{p_{xy}} = \frac{COV(S)_{xy} + COV(D)_{xy} + COV(E)_{xy}}{\sqrt{(V(S)_x + V(D)_x + V(E)_x)(V(S)_y + V(D)_y + V(E)_y)}}$$

Where,

$r_{p_{xy}}$ = is the phenotypic correlation's coefficients between character x and y.

cov (S), cov (D) and cov (E) are the covariance components due to sire, dam and error for the subscripted characters.

The genetic and environmental correlations between different characters were determined by the three methods using sire, dam and sire + dam components of variance and covariance according to **Bogart (1959) and Falconer (1960).**

$$r_{G(S)_{XY}} = \frac{COV(S)_{XY}}{\sqrt{V(S)_X . V(S)_Y}}$$

$$r_{G(D)_{XY}} = \frac{COV(D)_{XY}}{\sqrt{V(D)_X . V(D)_Y}}$$

$$r_{G(S+D)_{XY}} = \frac{COV(S)_{XY} + COV(D)_{XY}}{\sqrt{(V(S)_X + V(D)_X)(V(S)_Y + V(D)_Y)}}$$

Where,

$r_{G(S)}$, $r_{G(D)}$ and $r_{G(S+D)}$ are the genetic correlation coefficient based on sire, dam and sire + dam components of variance and covariance for the subscripted characters.

$$r_{E(S)XY} = \frac{COV(E)_{XY} + COV(D)_{XY} - 3COV(S)_{XY}}{\sqrt{(V(E)_X + V(D)_X - 3V(S)_X)\,(V(E)_Y + V(D)_Y - 3V(S)_Y)}}$$

$$r_{E(D)XY} = \frac{COV(E)_{XY} + COV(S)_{XY} - 3COV(D)_{XY}}{\sqrt{(V(E)_X + V(S)_X - 3V(D)_X)\,(V(E)_Y + V(S)_Y - 3V(D)_Y)}}$$

$$r_{E(S+D)XY} = \frac{COV(E)_{XY} + COV(D)_{XY} - COV(S)_{XY}}{\sqrt{(V(E)_X - V(D)_X - V(S)_X)\,(V(E)_Y - V(D)_Y - V(S)_Y)}}$$

Where,

r_E (S), r_E (D) and r_E (S+D) are the environmental correlations based on sire, dam and sire +dam components of variance and covariance for the subscripted characters.

The standard errors of genetic correlation coefficients were estimated according to **Robertson (1959).**

$$S.E.r_{G(S)XY} = \frac{1 - r^2_{G(S)XY}}{\sqrt{2}} \frac{\sqrt{(S.E.h^2(S)_X)\,(S.E.h^2(S)Y)}}{h^2(S)_X \cdot h^2(S)Y}$$

$$S.E.r_{G(D)XY} = \frac{1 - r^2_{G(D)XY}}{\sqrt{2}} \frac{\sqrt{(S.E.h^2(D)_X)\,(S.E.h^2(D)Y)}}{h^2(D)_X \cdot h^2(D)Y}$$

$$S.E.r_{G(S+D)XY} = \frac{1 - r^2_{G(D)XY}}{\sqrt{2}} \frac{\sqrt{(S.E.h^2(S+D)_X)\,(S.E.h^2(S+D)Y)}}{h^2(S+D)_X \cdot h^2(S+D)Y}$$

Where,

S.E. r_G is the standard error of genetic correlation for the subscripted character. S.E. h^2 is the standard error of h^2 for the subscripted characters.

The standard errors of the phenotypic correlation coefficient were determined as per the method of **Panse and Sukhatme (1967).**

$$S.E.\ r_{p_{xy}} = \frac{1 - r^2_{pxy}}{\sqrt{N-1}}$$

Where,

N = total number of observations

The significance of genetic and phenotypic correlations were tested by using their respective standard error values. The correlation coefficients which had twice or more than twice (and thrice or more than thrice) the value of its standard errors were taken as significant at 5.0 (and 1.0) per cent probability levels of significance, respectively.

The differences in the mean of characters of one generation with the other were tested according to **Panse and Sukhatme (1967).**

Partial correlation coefficient

The partial correlation coefficient of order 'p' (p = number of variables whose effects are eliminated) were computed according to **Gupta and Kapoor (1983).**

$$R = \begin{vmatrix} 1 & r_{12} & r_{13} \ldots\ldots r_{1p} \\ r_{21} & 1 & r_{23} \ldots\ldots r_{2p} \\ r_{31} & r_{32} & 1 \ \ldots\ldots r_{3p} \\ \hline r_{p1} & r_{p2} & r_{p3} \ldots\ldots r_{pp} \end{vmatrix}$$

$$R_{ij.p} = -\frac{R_{ij}}{\sqrt{R_{ii}\,R_{jj}}}$$

Where,

R = correlation matrix of x_1, x_2 -----------xp,

(R for the corresponding determinant)

$R_{ij.p}$ = partial correlation coefficient between variable i^{th} and j^{th} after eliminated the linear effect of 'p' variables.

R_{ij} = co-factor of r_{ij} in R.

R_{ii} = co-factor of r_{ii} in R.

R_{jj} = co-factor of r_{jj} in R.

The significance of simple and partial correlation coefficient was tested by using 'z' test according to **Elhance and Aggarwal (1996).**

(i) Conversion 'r' in to 'z'

$$z = \frac{1}{2}\log_e \frac{1+r}{1-r}$$

(The value of z for various values of 'r' are available in tables)

(ii) The standard error of z $= \frac{1}{\sqrt{N-3-p}}$

Where,

r = partial correlation

N = number of observations

p = number of variables whose effects are eliminated.

Simple and multiple regression

The simple regression of dependent economic characters on independent characters, of various traits and coefficient of determination (R) were computed as described by **Snedecor and Cochran (1967).**

The following linear regression model was used to find out dependent variables:-

$$Y = a + bx$$

Where,

y = dependent variables

x = independent variables

b = regression coefficient

a = point of intercept

The efficiency of simple linear regression equation was tested by significance of regression coefficient and their r^2 values.

Data were further subjected to multiple regression analysis, for knowing the relative importance of each independent variable to the dependent one, were calculated as per **Snedecor and Cochran (1967)**. Use the following regression model.

$$y = a + b_1x_1 + b_2x_2 + b_3x_3 \ldots\ldots\ldots\ldots\ldots\ldots\ldots b_nx_n$$

Where,

y = dependent variable

a = constant

x_1, x_2 ----x_n different independent variables.

b_1, b_2 ----b_n = regression coefficient with respective independent variables.

The significance of simple regression coefficient was tested by using 'F' test and multiple regression coefficient was tested by 't' test and coefficient of determination was tested by 'F' test (**Snedecor and Cochran, 1967**).

EXPERIMENTAL RESULTS

EXPERIMENTAL RESULTS

The present investigation was undertaken on two inbred (50% and 59% inbred level, respectively) flocks and a control population of white leghorn. The number of female progenies was 342 and 612 in 50% and 59% inbred population, respectively. While the control population has been 174 female progenies. There were 15, 8 and 11 hatches in 50%, 59% and control population, respectively. The effect of hatch was tested by least squares technique and the analysis of variance has been presented in Table 7. The analysis of variance of hatch effect indicated that effect of hatch in two inbred generations and control population was significant and thus after correction for hatch effects the data were used for the analysis of least squares for inbreds and control population along with populations mean and analysis of variance.

MEAN

The least squares mean, standard error and simple mean, standard error, standard deviation and coefficient of variation of all characters are presented in Table 8 and appendix I, respectively.

The least square mean of O-week body weight was obtained as 33.80±0.17g, 34.50±0.14g and 36.46±0.29g in two inbred generations and control population, respectively.

Table -7: Analysis of variance of hatch effect of character under study.

Source of variation	d.f	OWK. BW (g)	4^{th} WK. BW (g)	8^{th} WK. BW (g)	12^{th} WK. BW (g)	16^{th} WK. BW (g)	20^{th} WK. BW (g)	24^{th} WK. BW (g)	W.S.M. (g)	A.S.M. (days)	W.F.E. (g)	90-days EP (Nos.)	C.S. (days)
(A) 50% Inbred													
Hatch	14	46.54**	3161.40**	3898.00**	23511.00**	43339.00**	66216.00**	11785.00**	11414.00	3976.30**	52.02	234.60	1.02**
Error	327	10.86	457.38	1210.00	3646.00	10255.00	15976.00	37254.00	7225.00	1443.30	89.80	186.43	0.46
(B) 59% Inbred													
Hatch	7	18.71	5954.50**	14295.00	22232.00	57231.00**	24155.00	23322.00	49243.00*	1716.30**	57.58*	123.20*	0.45**
Error	604	12.38	1136.80	9974.40	15543.00	10739.00	15369.00	17795.00	21431.00	623.51	22.21	59.89	0.16
(C) Control population													
Hatch	10	95.19**	8911.80**	18828.00**	103880.00**	151040.00**	285820.00**	386000.00**	506530.00**	6986.60*	298.55	591.31	1.66**
Error	163	8.20	1109.30	5750.50	13512.00	21060.00	31991.00	54829.00	158670.00	3138.20	170.99	337.90	0.45

** Significant at 1% level
* Significant at 5% level

Table-8: Least squares means of the traits under study.

Characters	Levels of inbreeding						Control		
	50% inbred			59% inbred					
	Means ± SE	S.D.	C.V.	Means ± SE	S.D.	C.V.	Means ± SE	S.D.	C.V.
0-WK B.W. (g)	33.80 ± 0.17	3.23	9.55	34.50 ± 0.14	3.53	10.23	36.46 ± 0.29	3.87	10.60
4-WK B.W. (g)	157.37 ± 1.13	20.97	13.33	174.97 ± 1.36	33.52	19.16	149.00 ± 2.45	32.33	21.70
8-WK B.W. (g)	359.29 ± 2.00	37.03	10.31	360.33 ± 4.05	100.11	27.79	360.58 ± 5.58	73.60	20.41
12-WK B.W. (g)	606.07 ± 3.20	59.21	9.80	633.66 ± 5.05	124.98	19.72	638.74 ± 9.18	121.04	18.95
16-WK B.W. (g)	741.06 ± 5.37	99.23	13.39	887.51 ± 4.16	103.04	11.61	807.51 ± 10.68	140.87	17.44
20-WK B.W. (g)	920.88 ± 6.69	123.78	13.44	1073.47 ± 5.02	124.38	11.58	943.11 ± 14.81	195.39	20.72
24-WK B.W. (g)	1198.31 ± 10.28	190.24	15.88	1258.15 ± 5.40	133.63	10.62	1132.05 ± 17.23	227.29	20.08
W.S.M. (g)	1355.40 ± 14.71	271.98	20.07	1407.15 ± 5.89	145.60	10.35	1258.64 ± 29.31	386.65	30.72
A.S.M. (days)	201.19 ± 2.01	37.20	18.49	190.81 ± 1.00	24.83	13.01	173.03 ± 4.12	54.38	31.43
W.F.E. (g)	42.70 ± 0.50	9.39	22.00	41.09 ± 0.19	4.69	11.40	41.37 ± 1.01	13.36	32.28
90-days E.P. (Nos)	43.65 ± 0.74	13.73	31.45	50.90 ± 0.31	7.69	15.11	45.87 ± 1.42	18.78	40.93
C.S. (days)	2.10 ± 0.04	0.67	31.78	1.81 ± 0.01	0.40	21.78	1.55 ± 0.05	0.65	42.14

The maximum (174.97 ± 1.37g) weight at 4-week was observed in 59% inbred generation while the 50% inbred generation and control population was 157.37 ± 1.13g and 149.00 ± 2.45g respectively.

The body weight at 8-week of age was found to be 359.29 ± 2.00g, 360.33 ± 4.05g and 360.58 ± 5.58g respectively in 50%, 59% inbred and control population which has the same trend.

The body weight at 12-week of age was maximum (633.66 ± 5.05g) in the 59% level of inbred as comparised to 50% inbred level. It was 606.07 ± 3.20g while the control population has maximum (638.74 ± 9.18g) body weight as compaired with two inbred.

The mean body weight for 16-week of age were 741.06 ± 5.37g and 887.51 ± 4.16g in the two level of inbreeding respectively whereas the 807.51 ± 10.68g weight was observed in the control population. The 16-week body weight was highest in 59% level inbred and lowest in 50% inbred generation.

The mean for 20-week body weight was maximum (1073.47 ± 5.02g) in the 59% level of inbred and minimum (920.88 ± 6.69g) in the 50% level of inbred generation. It was observed that control population has lowest (943.11 ± 717.81g) body weight.

The mean for 24-week body weight and weight at sexual maturity were found to be 1258.15 ± 5.40g and 1407.15 ± 5.89g in 59% inbred which was higher than 50% inbred and control population. The 50% inbred and control population was 1198.31 ± 10.28g, 1355.40 ± 14.71g and 1132.05 ± 1723g, 1258.64 ± 29.31g respectively.

The means for age at sexual maturity were found to be 201.19 ± 2.01 days, 190.81 ± 1.00 days and 173.03 ± 4.12 days in 50 % inbred, 59 % inbred and control population, respectively. Where the birds matured earlier in control population than inbred flocks. But the 59% inbred matured early than 50% inbred.

The weight of the first egg was estimated to be 42.70 ± 0.50g, 41.09 ± 0.19 and 41.37 ± 1.01g in 50%, 59% inbred level and control population showed common trend.

The 90-days egg production in 59% level of inbred was higher (50.90 ± 0.31eggs) than control population (45.87 ± 1.42eggs) and 50% level of inbred generation was lower (43.65 ± 0.74eggs) than control population.

The clutch-size was highest (2.10 ± 0.04) in 50% inbred level which was higher than 59% inbred (1.81 ± 0.01days) and control population (1.55 ± 0.05days).

Heritability estimates: -

The analysis of variance with two-way nested classification (between sires and between dams with sire) are presented in Table 9. The heritability estimates based on sire and sire + dam components of variance for 50%, 59% inbred and control population data are presented in Table 11. The heritability value in 50 Percent inbred from sire components of variance for day-old body

Table-9: Analysis of variance for ~~two-way~~ nested model.

Source of variance	d.f.	Mean squares and components of variance											
		0-WK B.W	4-WK B.W	8-WK B.W	12-WK B.W	16-WK B.W	20-WK B.W	24-WK B.W	W.S.M.	A.S.M.	W.F.E.	90-days E.P.	C.S.
(A) 50% Inbred													
Between sires	19	33.058** (1.1780)	962.895** (31.646)	2265.053* (58.883)	6795.789** (239.773)	17152.842* (493.868)	30432.00** (1053.764)	122310.734** (5538.066)	46295.578** (1378.457)	4466.106** (185.587)	197.609** (9.314)	665.638** (31.290)	1.945** (0.083)
Between dam/sire	62	11.858** (0.860)	393.258 (-4.837)	1205.161 (-34.987)	2479.870 (-257.625)	8263.226 (-331.501)	11464.258 (918.059)	22625.549 (-2627.551)	21463.351 (-636.319)	11255.32 (23.733)	26.949** (1.788)	102.425** (5.862)	0.445** (0.026)
Error	260	8.418	412.604	1345.108	3510.369	9589.230	15136.762	33135.754	24029.832	1220.465	22.798	78.977	0.340
(B) 59% inbred													
Between sires	31	16.244** (-0.414)	2102.581** (49.424)	38643.356** (1194.275)	60220.387** (2277.234)	10590.968** (-11.395)	28777.291** (596.868)	26550.838** (1116.910)	49965.418** (1454.517)	1456.323** (38.534)	68.179** (2.340)	119.290** (2.027)	0.267** (0.004)
Between dam/sire	120	24.115** (3.740)	1163.533 (29.006)	15952.134** (2350.873)	16952.934** (1171.642)	10807.467 (59.675)	17436.800* (844.383)	22083.199** (1480.104)	22329.600 (844.939)	724.183** (48.089)	23.722* (1.336)	80.784** (7.816)	0.177* (0.008)
Error	460	9.156	1047.509	6548.644	12266.365	10568.766	14059.269	16162.782	18949.844	531.826	18.378	49.521	0.143
(C) Control													
Between sire	15	19.169 (0.596)	1561.100* (26.084)	1429.733 (-401.608)	17191.467 (139.747)	43214.934**(1004.191)	87472.000** (5548.5)	147892.266** (8033.426)	342743.469** (1936.025)	5214.600* (209.669)	140.677** (11.779)	210.348** (8.524)	0.869** (0.045)
Between dam/sire	32	13.206 (-0.418)	1300.258 (95.324)	5445.813 (-110.047)	15794.000 (433.833)	25139.500* (2356.097)	31987.000 (-472.456)	67558.000** (7847.786)	149141.000 (5638.268)	3117.906 (117.704)	22.890 (1.420)	125.108** (15.390)	0.419 (0.011)
Error	126	14.878	918.962	5886.000	14058.667	15715.113	33876.824	36166.856	126587.938	2647.091	17.211	63.550	0.376

** Significant at 1%; * Significant at 5%
Figures within the parenthesis are components of variance

Table-10: *Analysis of covariance for two way nested model.*

(A) 50% inbred

Source of variation	d.f	Mean products and components of covariance									
		X_1X_2	X_1X_3	X_1X_4	X_1X_5	X_1X_6	X_1X_7	X_1X_8	X_1X_9	X_1X_{10}	X_1X_{11}
Between sires	19	-60.41 (-3.534)	94.25 (2.53)	-92.03 (-8.199)	165.89 (7.687)	-163.42 (-9.836)	-1047.11 (60.638)	166.79 (2.823)	-208.49 (-11.377)	70.05 (3.752)	119.02 (6.673)
Between dam/sires	62	3.20 (0.23)	44.69 (9.70)	55.56 (12.64)	27.52 (2.76)	13.63 (-1.39)	44.37 (-0.44)	115.97 (26.85)	-3.70 (-2.41)	2.69 (0.74)	-1.10 (-0.19)
Error	260	2.30	5.91	5.01	16.48	19.18	46.13	5.57	5.92	-0.25	-0.36

Source of variation	d.f	Mean products and components of covariance									
		X_1X_{12}	X_2X_3	X_2X_4	X_2X_5	X_2X_6	X_2X_7	X_2X_8	X_2X_9	X_2X_{10}	X_2X_{11}
Between sires	19	17.50 (0.919)	852.11 (32.29)	1713.47 (57.10)	1536.42 (20.99)	2224.21 (42.25)	6450.74 (303.16)	2987.37 (187.980)	600.00 (36.874)	-152.79 (-8.84)	-319.03 (-16.08)
Between dam/sires	62	0.96 (0.12)	270.97 (-39.32)	685.61 (27.01)	1158.45 (156.44)	1463.68 (195.64)	993.87 (66.29)	-395.74 (-80.82)	-65.71 (-22.19)	6.31 (2.89)	-29.57 (-4.72)
Error	260	0.48	428.26	577.58	532.71	681.11	728.70	-72.45	23.06	-5.25	-10.71

Source of variation	d.f	Mean products and components of covariance									
		X_2X_{12}	X_3X_4	X_3X_5	X_3X_6	X_3X_6	X_3X_7	X_3X_8	X_3X_9	X_3X_{10}	X_3X_{11}
Between sires	19	17.50 (0.92)	2428.63 (82.54)	2564.63 (99.62)	781.47 (2.97)	1853.47 (76.71)	4536.42 (223.25)	64.95 (-10.61)	117.03 (5.45)	32.97 (1.71)	4.02 (0.19)
Between dam/sires	62	0.96 (0.12)	942.84 (-55.40)	771.48 (-116.85)	728.00 (-181.46)	472.77 (-203.57)	517.94 (71.96)	-256.00 (-73.33)	19.02 (4.47)	-2.13 (-2.79)	-0.52 (-0.36)
Error	260	0.48	1164.43	1238.86	1453.82	1287.04	230.12	37.31	1.13	9.04	0.90

Source of variation	d.f	Mean products and components of covariance									
		X_4X_5	X_4X_6	X_4X_7	X_4X_8	X_4X_9	X_4X_{10}	X_4X_{11}	X_4X_{12}	X_5X_6	X_5X_7
Between sires	19	3503.37 (21.63)	3071.16 (-87.24)	13840.84 (648.98)	8892.63 (490.54)	626.32 (19.39)	-501.95 (29.48)	-871.74 (-46.63)	37.43 (2.02)	14914.53 (337.37)	12296.42 (199.72)
Between dam/sires	62	3114.06 (161.95)	3594.58 (138.52)	2159.23 (159.86)	-62.97 (276.33)	-277.35 (-23.86)	28.69 (3.63)	-32.58 (-2.60)	1.08 (0.14)	8841.81 (349.58)	8701.42 (-698.34)
Error	260	2466.28	3040.49	2798.64	1042.36	-181.93	-14.15	-22.09	0.56	10240.12	11494.79

Source of variation	d.f	Mean products and components of covariance									
		X_5X_8	X_5X_9	X_5X_{10}	X_5X_{11}	X_5X_{12}	X_6X_7	X_6X_8	X_6X_9	X_6X_{10}	X_6X_{11}
Between sires	19	19031.58	-3800.84	711.11	1599.37	-61.93	40437.89	23132.63	-886.95	294.37	1108.82
		(871.96)	(-184.80)	(36.40)	(84.25)	(-3.49)	(1684.51)	(1197.72)	(-24.60)	(15.66)	(56.47)
Between dam/sires	62	3336.26	-474.39	55.98	-82.94	0.83	10116.65	1573.68	-444.19	12.47	-92.44
		(-609.23)	(-258.17)	(4.00)	(-9.19)	(-1.41)	(-1495.52)	(-754.22)	(-194.66)	(-1.89)	(-26.88)
Error	260	5773.13	558.24	39.99	-46.18	6.49	16098.72	4590.53	334.41	20.05	15.10

Source of variation	d.f	Mean products and components of covariance									
		X_6X_{12}	X_7X_8	X_7X_9	X_7X_{10}	X_7X_{11}	X_7X_{12}	X_8X_9	X_8X_{10}	X_8X_{11}	X_8X_{12}
Between sires	19	-8.76	46352.84	4382.32	-2237.47	-3760.53	203.98	-1299.79	33.05	-373.37	5.70
		(-0.59)	(1820.18)	(160.57)	(-129.94)	(-213.99)	(11.25)	(62.05)	(-11.44)	(-38.91)	
Between dam/sires	62	1.81	13589.68	-1492.13	101.52	91.42	-1.50	-182.97	238.90	327.06	-13.30
		(-1.59)	(20.60)	(-545.10)	(4.70)	(6.57)	(-4.23)	(-149.70)	(27.39)	(57.90)	(-1.91)
Error	260	8.15	13507.31	688.25	82.73	-65.14	15.41	415.84	129.32	-95.47	3.03

Source of variation	d.f	Mean products and components of covariance					
		X_9X_{10}	X_9X_{11}	X_9X_{12}	$X_{10}X_{11}$	$X_{10}X_{12}$	$X_{11}X_{12}$
Between sires	19	-104.71	-262.45	71.99	323.82	-11.64	-23.04
		(-5.80)	(-13.30)	(3.62)	(17.97)	(-0.66)	(-0.98)
Between dam/sires	62	-0.38	-23.06	6.83	0.31	0.18	-5.34
		(-5.44)	(-6.68)	(-0.23)	(-0.03)	(0.05)	(0.38)
Error	260	21.38	3.66	7.70	-0.44	-0.02	-3.87

(B) 59% Inbred

Source of variation	d.f	Mean products and components of covariance									
		X_1X_2	X_1X_3	X_1X_4	X_1X_5	X_1X_6	X_1X_7	X_1X_8	X_1X_9	X_1X_{10}	X_1X_{11}
Between sires	31	-10.18	-90.42	-410.16	-56.97	142.77	963.03	136.94	-5.94	-2.91	-9.10
		(-0.28)	(-12.15)	(-25.07)	(-2.27)	(3.66)	(7.87)	(4.15)	(-1.22)	(-0.83)	(-0.68)
Between dam/sires	120	-4.79	140.46	66.18	-13.82	73.18	27.58	57.90	17.15	12.84	3.86
		(-1.59)	(25.96)	(13.71)	(-6.40)	(-9.95)	(2.96)	(13.79)	(4.80)	(2.40)	(0.56)
Error	460	1.58	37.63	11.35	11.78	33.39	15.74	2.71	-2.04	3.25	1.63

Source of variation	d.f	Mean products and components of covariance									
		X_1X_{12}	X_2X_3	X_2X_4	X_2X_5	X_2X_6	X_2X_7	X_2X_8	X_2X_9	X_2X_{10}	X_2X_{11}
Between sires	31	0.17	1098.06	-1795.10	1714.58	-16.77	2091.35	1540.65	-501.10	-151.89	261.97
		(0.02)	(-33.79)	(-131.54)	(50.99)	(-41.04)	(65.92)	(48.60)	(-23.69)	(-7.99)	(13.04)
Between dam/sires	120	-0.11	1740.10	704.13	745.60	763.07	838.93	617.20	-50.92	-0.05	14.28
		(-0.002)	(108.31)	(-87.58)	(70.14)	(10.18)	(2.56)	(109.18)	(9.74)	(1.95)	(-7.15)
Error	460	-0.10	1306.88	1054.43	465.03	722.35	828.70	180.49	-89.89	-7.86	42.89

Source of variation	d.f	Mean products and components of covariance									
		X_2X_{12}	X_3X_4	X_3X_5	X_3X_6	X_3X_7	X_3X_8	X_3X_9	X_3X_{10}	X_3X_{11}	X_3X_{12}
Between sires	31	-14.08	22070.19	3731.10	7237.68	9084.90	14884.13	1072.65	460.10	173.52	-10.86
		(-0.64)	(803.85)	(25.28)	(159.65)	(243.67)	(516.36)	(42.54)	(18.13)	(-0.80)	(-0.006)
Between dam/sires	120	-1.84	6797.07	3250.80	4204.40	4455.20	5073.33	264.37	115.66	188.78	-10.73
		(0.005)	(437.43)	(62.94)	(133.30)	(274.60)	(1093.97)	(158.23)	(30.15)	(26.61)	(-1.73)
Error	460	-1.86	5047.34	2999.03	3671.20	3356.80	697.46	-368.53	-4.92	82.33	-3.81

Source of variation	d.f	Mean products and components of covariance									
		X_4X_5	X_4X_6	X_4X_7	X_4X_8	X_4X_9	X_4X_{10}	X_4X_{11}	X_4X_{12}	X_5X_6	X_5X_7
Between sires	31	6154.32	1911.74	-642.06	-503.74	605.94	1353.55	-282.19	22.05	10316.39	9519.48
		(-81.69)	(-375.97)	(-458.26)	(-237.66)	(59.79)	(68.95)	(-26.17)	(1.77)	(73.38)	(2.22)
Between dam/sires	120	7706.40	9055.20	8064.80	4011.73	-530.07	43.42	215.13	-11.56	8922.13	9477.33
		(283.18)	(545.16)	(359.78)	(328.12)	(-2.81)	(3.50)	(34.57)	(-2.18)	(126.26)	(237.37)
Error	460	6573.70	6874.57	6625.67	2699.27	-518.82	29.44	76.86	-2.83	8417.11	8527.86

Source of variation	d.f	Mean products and components of covariance									
		X_5X_8	X_5X_9	X_5X_{10}	X_5X_{11}	X_5X_{12}	X_6X_7	X_6X_8	X_6X_9	X_6X_{10}	X_6X_{11}
Between sires	31	11325.94	-94.71	160.71	460.84	-18.14	22348.39	19294.97	314.84	430.71	19.87
		(471.60)	(56.65)	(11.43)	(12.42)	(-0.36)	(337.97)	(675.23)	(72.37)	(20.60)	(-20.46)
Between dam/sires	120	2365.60	-1171.13	-56.43	224.78	-11.24	15926.93	6465.60	-1060.27	39.37	408.68
		(-477.51)	(-103.05)	(-14.04)	(29.07)	(-1.85)	(1046.39)	(131.50)	(-59.30)	(5.92)	(67.22)
Error	460	4275.62	-758.94	-0.27	108.51	-3.84	11741.36	5939.62	-823.06	15.71	139.79

Source of variation	d.f	Mean products and components of covariance									
		X_6X_{12}	X_7X_8	X_7X_9	X_7X_{10}	X_7X_{11}	X_7X_{12}	X_8X_9	X_8X_{10}	X_8X_{11}	X_8X_{12}
Between sires	31	-2.99	15108.13	-1276.90	46.58	380.65	-23.67	4462.97	510.58	-33.42	-0.18
		(0.90)	(416.11)	(23.92)	(4.25)	(2.78)	(-0.07)	(217.00)	(20.59)	(-17.48)	(0.56)
Between dam/sires	120	-20.15	7202.13	-1731.47	-34.15	327.83	-22.29	339.87	119.37	298.70	-10.81
		(-4.04)	(137.02)	(-119.07)	(-9.10)	(37.8)	(-4.00)	(-64.44)	(-0.79)	(81.74)	(-2.97)
Error	460	-3.99	6654.05	-1255.20	2.23	176.63	-6.29	597.63	122.54	-28.26	1.07

Source of variation	d.f	Mean products and components of covariance					
		X_9X_{10}	X_9X_{11}	X_9X_{12}	$X_{10}X_{11}$	$X_{10}X_{12}$	$X_{11}X_{12}$
Between sires	31	120.16	-175.68	5.88	-40.10	2.09	-5.27
		(4.79)	(-5.56)	(0.29)	(-1.99)	(0.10)	(-0.10)
Between dam/sires	120	29.15	-70.05	3.00	-2.12	0.15	-3.30
		(0.08)	(-8.13)	(0.36)	(-0.29)	(0.01)	(-0.30)
Error	460	28.84	-37.55	1.57	-0.98	0.10	-2.11

(C) Control population

Source of variation	d.f	Mean products and components of covariance									
		X_1X_2	X_1X_3	X_1X_4	X_1X_5	X_1X_6	X_1X_7	X_1X_8	X_1X_9	X_1X_{10}	X_1X_{11}
Between sires	15	-45.16	-68.78	-105.63	-450.83	-650.80	-130.20	108.07	74.10	32.56	38.64
		(-5.158)	(-3.263)	(-10.36)	(-41.34)	(-59.85)	(-15.52)	(7.74)	(8.56)	(3.03)	(4.58)
Between dam/sires	32	6.42	-36.15	-2.04	-37.48	-52.27	24.98	30.67	-11.45	2.29	-7.18
		(1.253)	(-14.47)	(-34.65)	(-7.63)	(-33.58)	(2.20)	(0.80)	(-0.76)	(0.71)	(-2.69)
Error	126	1.41	21.74	136.54	-6.95	82.04	16.20	27.48	-8.41	-0.54	3.56

Source of variation	d.f	Mean products and components of covariance									
		X_1X_{12}	X_2X_3	X_2X_4	X_2X_5	X_2X_6	X_2X_7	X_2X_8	X_2X_9	X_2X_{10}	X_2X_{11}
Between sires	15	-1.28	1057.00	1857.07	3236.93	2150.53	3007.87	8539.07	735.10	-109.35	75.94
		(-0.13)	(-42.32)	(73.22)	(222.88)	(77.63)	(204.90)	(723.88)	(84.56)	(-6.54)	(11.08)
Between dam/sires	32	0.06	1480.21	1114.88	1008.13	1374.25	958.90	1300.25	-110.53	-43.95	-34.87
		(0.01)	(103.18)	(-56.85)	(-51.91)	(-114.74)	(-33.84)	(277.00)	(4.03)	(-11.92)	(-12.84)
Error	126	0.11	1067.48	1342.29	1215.76	1833.22	1099.27	192.23	-126.64	3.71	16.50

Source of variation	d.f	Mean products and components of covariance									
		X_2X_{12}	X_3X_4	X_3X_5	X_3X_6	X_3X_7	X_3X_8	X_3X_9	X_3X_{10}	X_3X_{11}	X_3X_{12}
Between sires	15	1.90	2381.33	4190.13	3400.27	1513.07	5355.73	237.93	-188.45	-141.07	11.23
		(-0.03)	(-286.41)	(-383.99)	(-484.87)	(-745.88)	(76.37)	(80.87)	(-4.30)	(-9.19)	(0.60)
Between dam/sires	32	5.32	5245.38	8030.00	8249.00	8971.87	4592.00	-570.28	-145.43	-49.16	5.19
		(1.37)	(312.03)	(1127.67)	(1261.68)	(1151.03)	(849.50)	(-43.56)	(-40.32)	(-12.88)	(1.09)
Error	126	-0.16	3997.27	3519.33	3202.29	4367.74	1194.00	-396.03	15.86	2.37	0.84

Source of variation	d.f	Mean products and components of covariance									
		X_4X_5	X_4X_6	X_4X_7	X_4X_8	X_4X_9	X_4X_{10}	X_4X_{11}	X_4X_{12}	X_5X_6	X_5X_7
Between sires	15	21398.40	22739.73	21100.80	26109.87	397.60	-75.90	502.29	6.33	53237.33	31182.93
		(533.54)	(660.72)	(367.58)	(3061.24)	(305.75)	(8.41)	(30.44)	(1.15)	(2874.98)	(167.73)
Between dam/sires	32	16063.00	16132.50	17425.03	-4502.50	-2659.94	-160.02	197.89	-5.12	24487.50	29505.60
		(1454.39)	(992.49)	(2515.83)	(-1274.53)	(-399.90)	(-46.49)	(26.10)	(-0.23)	(2426.21)	(4620.72)
Error	126	10245.46	12162.54	7361.73	595.61	-1060.31	25.94	93.49	-4.22	14782.67	11022.72

Source of variation	d.f	Mean products and components of covariance									
		X_5X_8	X_5X_9	X_5X_{10}	X_5X_{11}	X_5X_{12}	X_6X_7	X_6X_8	X_6X_9	X_6X_{10}	X_6X_{11}
Between sires	15	29982.93	-1493.60	-962.50	-603.14	32.16	35747.20	52760.54	1627.33	-1211.13	-1173.93
		(2852.24)	(149.17)	(-73.04)	(-59.51)	(3.70)	(500.86)	(4447.75)	(403.05)	(-92.37)	(-118.46)
Between dam/sires	32	1460.50	-2985.25	-232.11	-8.07	-4.82	30738.58	8283.00	-2403.13	-287.41	10.66
		(396.84)	(-315.33)	(-47.35)	(-24.58)	(-0.41)	(3415.08)	(437.27)	(-240.59)	(-65.26)	(-40.77)
Error	126	-126.84	-1723.92	-42.71	90.24	-3.20	17078.27	6533.94	-1440.76	-26.38	173.72

Source of variation	d.f	Mean products and components of covariance									
		X_6X_{12}	X_7X_8	X_7X_9	X_7X_{10}	X_7X_{11}	X_7X_{12}	X_8X_9	X_8X_{10}	X_8X_{11}	X_8X_{12}
Between sires	15	83.27	61008.00	2058.13	-411.60	289.07	44.56	38311.46	2153.20	3280.93	371.81
		(8.52)	(5533.47)	(2429.64)	(-13.67)	(40.39)	(6.22)	(1980.91)	(205.99)	(390.65)	(24.66)
Between dam/sires	32	-1.91	5673.29	-3715.10	-274.91	-114.82	-17.59	18502.38	93.25	-625.54	125.21
		(1.08)	(-1862.52)	(-762.39)	(-56.68)	(-70.27)	(-6.05)	(787.99)	(-21.55)	(-163.01)	(4.92)
Error	126	-6.22	13123.38	-665.56	-48.20	166.24	6.60	15362.44	179.43	26.51	105.55

Source of variation	d.f	Mean products and components of covariance					
		X_9X_{10}	X_9X_{11}	X_9X_{12}	$X_{10}X_{11}$	$X_{10}X_{12}$	$X_{11}X_{12}$
Between sires	15	388.80	535.71	43.28	140.66	-1.73	-2.70
		(30.41)	(67.80)	(2.10)	(14.30)	(-0.25)	(0.27)
Between dam/sires	32	84.70	-142.25	22.28	-2.33	0.72	-5.43
		(14.72)	(25.36)	(1.61)	(-0.37)	(0.19)	(-0.65)
Error	126	25.83	-40.84	-0.84	-0.02	-2.83	828.70

Table-11: Heritability of various traits with their S.E. in different populations.

Traits	50% Inbred		59% Inbred		Control population	
	Sire component	Sire + dam component	Sire component	Sire + dam component	Sire component	Sire + dam component
0-WK B.W.	0.472 ± 0.236	0.398 ± 0.140	-0.156 ± 0.085	0.530 ± 0.530	0.162 ± 0.185	0.014 ± 0.132
4-WK B.W.	0.309 ± 0.165	0.133 ± 0.106	0.174 ± 0.101	0.139 ± 0.077	0.059 ± 0.224	0.248 ± 0.153
8-WK B.W.	0.187 ± 0.127	0.043 ± 0.092	0.456 ± 0.203	0.701 ± 0.129	-0.274 ± 0.099	-0.186 ± 0.116
12-WK B.W.	0.300 ± 0.145	0.006 ± 0.094	0.574 ± 0.201	0.439 ± 0.116	0.025 ± 0.181	0.083 ± 0.136
16-WK B.W.	0.215 ± 0.132	0.038 ± 0.093	-0.004 ± 0.058	0.009 ± 0.066	0.296 ± 0.302	0.431 ± 0.183
20-WK B.W.	0.301 ± 0.149	0.032 ± 0.096	0.150 ± 0.100	0.185 ± 0.080	0.549 ± 0.304	0.245 ± 0.174
24-WK B.W.	0.658 ± 0.248	0.187 ± 0.135	0.048 ± 0.084	0.191 ± 0.079	0.522 ± 0.385	0.620 ± 0.217
W.S.M.	0.246 ± 0.145	0.072 ± 0.099	0.271 ± 0.125	0.216 ± 0.086	0.470 ± 0.308	0.325 ± 0.179
A.S.M.	0.572 ± 0.238	0.252 ± 0.133	0.243 ± 0.126	0.279 ± 0.089	0.251 ± 0.247	0.221 ± 0.156
W.F.E.	1.179 ± 0.431	0.693 ± 0.224	0.420 ± 0.163	0.333 ± 0.100	1.579 ± 0.658	0.899 ± 0.335
90-day E.P.	1.164 ± 0.427	0.682 ± 0.222	0.127 ± 0.110	0.330 ± 0.090	0.332 ± 0.374	0.589 ± 0.218
C.S.	0.780 ± 0.317	0.504 ± 0.172	0.118 ± 0.093	0.167 ± 0.078	0.385 ± 0.277	0.253 ± 0.166

weight was higher (0.472 ± 0.236). It was low and negative (-0.156 ± 0.085) in the 59 per cent inbred flock while it was low (0.162 ± 0.185) in the control population. The heritability estimate from sire components of variance for 4, 8, 12, 16, 20, 24-week body weights, weight at sexual maturity, age at sexual maturity, weight of first egg, 90-days egg production and clutch size were found to be 0.309 ± 0.165, 0.187 ± 0.127, 0.300 ± 0.145, 0.219 ± 0.132, 0.301 ± 0.149, 0.658 ± 0.248, 0.246 ± 0.145, 0.572 ± 0.238, 1.179 ± 0.431, 1.164 ± 0.427 and 0.780 ± 0.317 respectively in 50 percent inbred generation. But the heritability estimates for same traits were 0.174 ± 0.101, 0.456 ± 0.203, 0.574 ± 0.201, -0.004 ± 0.058, 0.150 ± 0.100, 0.048 ± 0.084, 0.271 ± 0.125, 0.243 ± 0.126, 0.420 ± 0.163, 0.127 ± 0.110 and 0.118 ± 0.093, respectively in 59 percent level of inbred.

The heritability estimates in control population for 4, 8, 12, 16, 20, 24-week body weight, weight at sexual maturity, age at sexual maturity, weight of first egg, 90-days egg production and clutch size were observed as 0.059 ± 0.224, -0.274 ± 0.099, 0.025 ± 0.181, 0.296 ± 0.302, 0.549 ± 0.304, 0.522 ± 0.385, 0.470 ± 0.308, 0.251 ± 0.247, 1.579 ± 0.658, 0.332 ± 0.374 and 0.385 ± 0.227, respectively for sire component of variance.

The heritability estimates computed from sire + dam component of variance varied from 0.006 ± 0.094 to 0.398 ± 0.140 for growth traits and 0.252 ± 0.133 to 0.693 ± 0.224 for production traits in 50 percent inbred generation while the heritability estimates from sire + dam components of variance were between 0.009 ± 0.066 to 0.701 ± 0.129 and 0.167 ± 0.078 to 0.333 ± 0.100, respectively for growth and production traits in 59 percent inbred generation.

The heritability estimates computed from sire + dam components of variance in control population were between 0.014 ± 0.132 to 0.620 ± 0.217 and 0.221 ± 0.156 to 0.899 ± 0.335, respectively for growth and production traits.

Correlations

(i) Genetic correlations

The correlations between all pairs of traits were computed from sire (Table 9) and sire + dam components of variance and covariance (Table 10) among the traits under study. The genetic correlations are presented in Table 12 for 50% level of inbred flock. It can be seen from the table that the traits were ~~was~~ found to be mostly non-significant among each other except 0-week body weight with 20-week body weight, WSM, ASM (-0.279, 0.072, -0.778); 4-week body weight with WFE, 90-days egg production (-0.523, -0.521); 8-week body weight with 20-week body weight, 24-week body weight, ASM, 90-days egg production, clutch size; 12-week body weight with 16-week body weight, 20-week body weight, weight of first egg (0.077, -0.056, -0.626); 16-week body weight with 24-week body weight, ASM (0.119, -0.606); 20-week body weight with ASM and clutch size; 24-week body weight with weight of first egg, and age at sexual maturity; WSM with ASM, WFE, 90-days egg

Table-12: Genetic correlations of the traits under study computed from sire and sire + dam components of variance and covariance **(50% Inbred).**

Traits	0-WK B.W.	4-WK B.W.	8-WK B.W.	12-WK B.W.	16-WK B.W.	20-WK B.W.	24-WK B.W.	W.S.M.	A.S.M.	W.F.E.	90-day E.P.	C.S.
0-WK B.W.	-	-0.583	0.331	-0.486	0.319	-0.279*	-0.756	0.072**	-0.778**	0.961	0.735	-0.033
4-WK B.W.	-0.456	-	0.741	0.645	0.166	0.228	0.721	0.908	0.482	-0.523**	-0.521**	0.574
8-WK B.W.	0.592	-0.142**	-	0.680	0.574	0.012**	0.133**	0.786	0.170*	0.235	0.046**	0.115**
12-WK B.W.	0.800	0.108	0.958	-	0.077**	-0.056**	0.554	0.863	0.235	-0.626**	-0.543	0.453
16-WK B.W.	0.554	0.385	-0.113**	4.338	-	0.458	0.119**	0.058	-0.606**	0.541	0.761	-0.547
20-WK B.W.	-0.522**	0.786	-2.045	2.100	0.078**	-	0.688	0.993	-0.055**	0.159	0.372	-0.063**
24-WK B.W.	-0.777	0.237	-0.372**	2.908	-0.592*	0.364*	-	0.662	-0.321**	-0.579**	-0.522	0.539
W.S.M.	0.695	0.781	0.958	0.861	0.857	0.196	0.161	-	-0.124**	-0.100**	-0.188**	0.101**
A.S.M.	-0.762**	0.248	-0.739*	0.721	-0.496	-0.633	-0.241**	-0.551**	-	-0.142**	-0.178**	0.931
W.F.E.	0.972	-0.366**	0.557	-0.979**	0.930	0.281*	-0.684**	0.143**	-0.258**	-	-1.060**	-0.766**
90-day E.P.	0.788	-0.658**	-0.019**	-0.695	0.087	0.469	-0.534	0.333	-0.255**	0.913	-	-0.625**
C.S.	-0.698	0.609	-0.044*	0.160	-0.721	-0.415*	0.415	-0.292**	0.824	-0.579**	-0.680**	-

Above the diagonal are sire component correlations and below the diagonal are sire + dam component correlations.
* Significant at 5% level; ** Significant at 1% level.

Table-13: Phenotypic correlations among economic traits under study (50% Inbred).

Traits	0-WK B.W.	4-WK B.W.	8-WK B.W.	12-WK B.W.	16-WK B.W.	20-WK B.W.	24-WK B.W.	W.S.M.	A.S.M.	W.F.E.	90-day E.P.	C.S.
0-WK B.W.	-	-0.02**	0.014**	0.004**	0.010**	0.002**	0.004**	0.006**	-0.006**	0.020*	0.016**	-0.012**
4-WK B.W.		-	0.049	0.046	0.040	0.041	0.039	0.002**	0.006**	-0.011**	-0.017**	0.014**
8-WK B.W.			-	0.047	0.039	0.033	0.023*	0.008**	-0.001**	0.005**	0.002**	0.003**
12-WK B.W.				-	0.053	0.050	0.041	0.012**	-0.006**	-0.009**	-0.010**	0.006**
16-WK B.W.					-	0.098	0.081	0.045	0.003**	0.017**	0.005**	0.002**
20-WK B.W.						-	0.096	0.031	0.013**	0.006**	0.005**	0.009**
24-WK B.W.							-	0.071	0.010**	-0.007**	-0.017**	0.027
W.S.M.								-	0.005**	0.018**	-0.004**	0.000**
A.S.M.									-	0.008**	-0.014**	0.124
W.F.E.										-	0.064	-0.047**
90-day E.P.											-	-0.195**
C.S.												-

* Significance at 5% level;
** Significance at 1% level.

Table-14: Environmental correlations computed from sire and sire + dam components of variance and covariance (50% Inbred).

Traits	0-WK B.W.	4-WK B.W.	8-WK B.W.	12-WK B.W.	16-WK B.W.	20-WK B.W.	24-WK B.W.	W.S.M.	A.S.M.	W.F.E.	90-day E.P.	C.S.
0-WK B.W.	-	0.023	0.001	0.013	-0.000	0.016	0.053	0.000	0.029	-0.147	-0.130	0.051
4-WK B.W.	0.013	-	0.047	0.035	0.031	0.030	0.003	-0.019	-0.012	0.053	0.046	-0.023
8-WK B.W.	-0.006	0.054	-	0.041	0.035	0.039	0.023	-0.004	-0.000	-0.018	0.004	0.002
12-WK B.W.	0.001	0.036	0.045	-	0.052	0.054	0.019	-0.000	-0.016	0.049	0.039	-0.015
16-WK B.W.	0.003	0.021	0.041	0.045	-	0.097	0.086	0.031	0.042	-0.032	-0.098	0.046
20-WK B.W.	0.012	0.021	0.043	0.047	0.188	-	0.080	0.013	0.032	-0.009	-0.042	0.025
24-WK B.W.	0.032	0.012	0.028	0.028	0.098	0.094	-	0.047	-0.000	0.178	0.098	-0.019
W.S.M.	-0.004	-0.007	-0.001	0.007	0.042	0.025	0.054	-	0.016	0.021	-0.001	0.002
A.S.M.	0.017	0.001	0.07	-0.010	0.039	0.037	0.021	0.018	-	0.111	0.100	-0.002
W.F.E.	-0.040	0.003	-0.007	0.003	-0.002	0.001	0.049	0.015	0.041	-	-0.484	0.363
90-day E.P.	-0.032	0.011	0.004	0.008	-0.027	-0.005	0.016	-0.020	0.029	-0.118	-	-0.215
C.S.	0.022	-0.008	0.005	-0.006	0.031	0.022	0.012	0.015	0.049	0.079	-0.152	-

Above the diagonal sire component and below the diagonal sire + dam component correlations.

Table-15: Genetic correlations of the traits under study computed from sire and sire + dam components of variance and covariance **(59% Inbred).**

Traits	0-WK B.W.	4-WK B.W.	8-WK B.W.	12-WK B.W.	16-WK B.W.	20-WK B.W.	24-WK B.W.	W.S.M.	A.S.M.	W.F.E.	90-day E.P.	C.S.
0-WK B.W.	-	-0.058**	-0.515	-0.758	-0.922	0.218	0.184**	0.157*	-0.284*	-0.782	-0.715	0.305
4-WK B.W.	-0.118**	-	-0.143**	-0.396**	2.061	-0.244*	0.647	0.183	-0.553	-0.751	0.360	-0.358**
8-WK B.W.	0.129	0.144	-	0.499	0.211**	0.195	0.493	0.401	0.205	0.351	-0.017**	-0.003**
12-WK B.W.	-0.104*	-0.424	0.358	-	-0.486**	-0.328*	-0.662	-0.103**	0.205	0.954	-0.402	0.549
16-WK B.W.	-0.696	0.993	0.216**	0.505	-	0.860	0.043**	0.318	-0.610**	0.123	0.561	-0.510
20-WK B.W.	0.199	-0.092**	0.131	0.079**	0.767	-	0.962	0.739	-0.490**	0.562	-0.619	0.552
24-WK B.W.	0.065**	0.187	0.212	-0.039**	0.847	0.892	-	0.753	-0.268*	0.192**	-0.388**	-0.074**
W.S.M.	0.208	0.376	0.571	0.053**	0.266**	0.445	0.280	-	-0.820*	0.257	-0.226*	0.217
A.S.M.	0.216	-0.168*	0.367	0.104*	-0.741	-0.035**	-0.251	-0.566	-	0.513	-0.661	0.701
W.F.E.	0.460	-0.355	0.428	0.645	-0.211**	0.366	-0.063**	0.216	0.274	-	-0.959	0.991
90-day E.P.	-0.021**	0.209	0.141	0.048**	0.932	0.402	0.627	0.436	-0.474	-0.381	-	-1.111**
C.S.	0.061**	-0.632	-0.258	-0.066**	-2.824	-0.735**	-0.871	-0.447	0.616	0.523	-1.132**	-

Above the diagonal sire component and below the diagonal sire + dam component.

* Significant at 5%

** Significant at 1%

Table-16: *Phenotypic correlations among economic traits under study (59% Inbred).*

Traits	0-WK B.W.	4-WK B.W.	8-WK B.W.	12-WK B.W.	16-WK B.W.	20-WK B.W.	24-WK B.W.	W.S.M.	A.S.M.	W.F.E.	90-day E.P.	C.S.
0-WK B.W.	-	-0.000**	0.035	0.000**	0.001**	0.010**	0.004**	0.004*	0.002**	0.026*	0.005**	-0.006**
4-WK B.W.		-	0.099	0.034	0.017*	0.017*	0.018*	0.011**	-0.021**	-0.015**	0.032	-0.032*
8-WK B.W.			-	0.086	0.030	0.032	0.027	0.038	-0.016**	0.022*	0.034	-0.034
12-WK B.W.				-	0.053	0.046	0.036	0.027*	-0.026*	0.030	0.015*	-0.011**
16-WK B.W.					-	0.068	0.059	0.030	-0.032	-0.001**	0.019**	-0.015**
20-WK B.W.						-	0.073	0.038	-0.027**	0.007**	0.019*	-0.015
24-WK B.W.							-	0.034	-0.038*	-0.000**	0.023	-0.018**
W.S.M.								-	0.027	0.021*	0.004*	-0.005**
A.S.M.									-	0.029	-0.035*	0.043
W.F.E.										-	-0.012**	0.021*
90-day E.P.											-	-0.157
C.S.												-

Table-17: Environmental correlations computed sire and sire + dam component of variance covariance (59% Inbred)

Traits	0-WK B.W.	4-WK B.W.	8-WK B.W.	12-WK B.W.	16-WK B.W.	20-WK B.W.	24-WK B.W.	W.S.M.	A.S.M.	W.F.E.	90-day E.P.	C.S.
0-WK B.W.	-	0.003	0.046	0.026	0.005	0.007	0.003	-0.001	0.001	0.034	0.011	-0.009
4-WK B.W.	0.007	-	0.0106	0.058	0.012	0.021	0.016	0.003	-0.009	0.011	0.012	-0.008
8-WK B.W.	0.023	0.093	-	0.072	0.045	0.042	0.031	-0.006	-0.050	-0.026	0.029	-0.025
12-WK B.W.	0.013	0.056	0.095	-	0.075	0.070	0.060	0.033	-0.041	-0.039	0.026	-0.024
16-WK B.W.	0.008	0.011	0.052	0.067	-	0.065	0.058	0.026	-0.040	-0.006	0.012	-0.008
20-WK B.W.	0.007	0.020	0.050	0.058	0.065	-	0.068	0.029	-0.037	-0.006	0.022	-0.013
24-WK B.W.	0.003	0.017	0.036	0.050	0.056	0.064	-	0.032	-0.042	-0.001	0.020	-0.012
W.S.M.	-0.003	0.001	-0.017	0.027	0.032	0.032	0.033	-	0.008	0.014	0.001	-0.000
A.S.M.	-0.007	-0.018	-0.064	-0.037	-0.033	-0.032	-0.038	0.012	-	0.019	-0.021	0.022
W.F.E.	0.011	-0.002	-0.033	-0.015	0.001	-0.002	0.001	0.017	0.024	-	0.014	-0.014
90-day E.P.	0.007	0.029	0.021	0.015	0.010	0.012	0.011	-0.012	-0.019	0.006	-	-0.135
C.S.	-0.008	-0.017	-0.013	-0.009	-0.004	-0.002	-0.004	0.013	0.021	-0.002	-0.130	-

Above the diagonal sire component and below the diagonal sire + dam component.

Table-18: Genetic correlations of the traits under study computed from sire and sire + dam components of variance and covariance **(control population).**

Traits	0-WK B.W.	4-WK B.W.	8-WK B.W.	12-WK B.W.	16-WK B.W.	20-WK B.W.	24-WK B.W.	W.S.M.	A.S.M.	W.F.E.	90-day E.P.	C.S.
0-WK B.W.	-	-1.601	-0.207**	-0.329*	-0.307**	-0.980	-0.281**	0.071**	0.770	0.173	2.240	-0.832
4-WK B.W.	-0.923	-	-0.532*	0.864	0.398	0.257**	0.606	0.327	0.511	-0.503*	0.075	-0.421**
8-WK B.W.	-2.847	0.329	-	-0.488	-0.491	-0.328	-0.450	0.029**	0.295	-0.067**	-0.182**	0.152*
12-WK B.W.	-6.479	0.004**	0.187**	-	0.384	0.906	0.450**	2.320**	2.259	0.267**	0.221	0.583*
16-WK B.W.	-0.291	0.199	0.674	0.388	-	0.972	0.048**	0.533	-0.272*	-0.572	-0.588	0.464
20-WK B.W.	-4.392	0.082**	0.686	0.069	0.248	-	0.080**	0.439	-0.388	-0.382	-0.619	0.565
24-WK B.W.	-0.300**	0.108**	0.227	1.058	0.676	0.517	-	0.487	-0.496	-0.050**	0.186**	0.344
W.S.M.	0.167**	0.576	0.314	0.358	0.312	0.445	0.157*	-	-1.029	0.466	0.114	0.894
A.S.M.	1.251	0.416	0.061**	-0.428*	-0.201*	0.076**	-0.152**	-0.993	-	0.670	0.886	0.742
W.F.E.	3.375	-0.500	-0.636	-0.511	-0.547	-0.686	-0.174*	0.327	0.736	-	0.548	-0.352
90-day E.P.	0.875	-0.074**	-0.221*	0.502	-0.273	-0.490	-0.068**	0.254	0.420	0.746	-	0.510
C.S.	-1.961	0.490	0.363	0.148**	0.206	0.602	-0.049**	0.824	0.924	-0.029**	-0.434	-

Above the diagonal sire component and below the diagonal sire + dam component correlation's

* Significant at 5%

** Significant at 1%

Table-19: Phenotypic correlation among economic traits under study (control population)

Traits	0-WK B.W.	4-WK B.W.	8-WK B.W.	12-WK B.W.	16-WK B.W.	20-WK B.W.	24-WK B.W.	W.S.M.	A.S.M.	W.F.E.	90-day E.P.	C.S.
0-WK B.W.	-	-0.003**	0.001**	0.030*	-0.016**	-0.004**	0.001**	0.002**	-0.001**	0.015**	0.013	-0.002*
4-WK B.W.		-	0.087	0.057	0.046	0.050	0.030*	0.019**	-0.005**	-0.018**	0.007**	0.011**
8-WK B.W.			-	0.077	0.067	0.054	0.053	0.015**	-0.017**	-0.016**	-0.006**	0.011*
12-WK B.W.				-	0.113	0.108	0.069	0.007**	-0.033	-0.005**	0.023**	-0.008**
16-WK B.W.					-	0.135	0.091	0.009**	-0.041	-0.035**	-0.001**	-0.0009**
20-WK B.W.						-	0.085	0.029*	-0.024**	-0.034**	0.000008**	0.005**
24-WK B.W.							-	0.034*	-0.015**	-0.018**	0.010	0.007**
W.S.M.								-	0.234	0.029*	0.016**	0.196
A.S.M.									-	0.042	-0.001**	0.0203
W.F.E.										-	0.040*	-0.004**
90-day E.P.											-	-0.182
C.S.												-

* Significant at 5%
** Significant at 1%

Table-20: Environmental correlations computed from sire and sire + dam components of variance and covariance (control population)

Traits	0-WK B.W.	4-WK B.W.	8-WK B.W.	12-WK B.W.	16-WK B.W.	20-WK B.W.	24-WK B.W.	W.S.M.	A.S.M.	W.F.E.	90-day E.P.	C.S.
0-WK B.W.	-	0.018	0.019	0.058	0.021	0.049	0.010	0.001	-0.013	-0.062	-0.021	0.019
4-WK B.W.	0.007	-	0.095	0.056	0.029	0.052	0.018	-0.025	-0.038	0.038	-0.005	0.006
8-WK B.W.	0.027	0.086	-	0.077	0.057	0.047	0.055	0.009	-0.030	0.022	0.008	-0.002
12-WK B.W.	0.067	0.066	0.067	-	0.085	0.086	0.043	-0.026	-0.050	0.004	0.006	-0.019
16-WK B.W.	0.012	0.041	0.034	0.075	-	0.077	0.073	-0.022	-0.049	0.045	0.033	-0.024
20-WK B.W.	0.043	0.063	0.025	0.083	0.080	-	0.081	-0.007	-0.046	0.057	0.055	-0.045
24-WK B.W.	0.006	0.026	0.036	0.027	0.038	0.057	-	0.007	-0.030	-0.005	0.009	-0.008
W.S.M.	0.002	-0.017	0.001	-0.004	-0.012	0.005	0.026	-	0.193	-0.120	-0.260	0.105
A.S.M.	-0.008	-0.027	-0.023	-0.026	-0.035	-0.031	-0.005	0.197	-	-0.033	0.132	0.135
W.F.E.	-0.063	0.083	0.096	0.057	0.057	0.078	0.015	-0.002	-0.020	-	-0.197	0.094
90-day E.P.	0.008	0.020	0.011	0.007	0.032	0.052	0.027	-0.026	-0.056	-0.130	-	-0.246
C.S.	0.012	-0.017	-0.005	-0.014	-0.014	-0.029	0.013	0.0132	0.0136	0.001	-0.192	-

Above the diagonal sire component and below the diagonal sire + dam component correlation's

* Significant at 5%

** Significant at 1%

production and clutch size; ASM with WFE and 90-days egg production; weight of first egg with 90-days production while weight of first egg and 90-days egg production was also significant with clutch size whereas significant correlation were mostly negative from sire component of variance.

The genetic correlations based on sire + dam components of covariance among the traits for 50% inbred flock was found to be negatively and significantly correlated among 0-week to 20-week body weight and age at sexual maturity with a values of -0.522 and -0.762 respectively. While it was non significant with rest of the traits.

The 4^{th} week body weight was found to be negatively and significantly correlated with 8^{th} week body weight, WFE and 90-days egg production with a values of -0.142, -0.366 and -0.658, respectively while it was positively and non-significantly correlated with other traits.

The 8^{th} week body weight was negatively and significantly correlated with 16^{th}, 24^{th}, week body weight, age at sexual maturity, 90-days egg production and clutch size with the values as -0.113, -0.372, -0.739, -0.019 and -0.044 respectively while the genetic correlation among other traits was non significant.

From the sire + dam analysis 12^{th} week body weight was negatively and significantly correlated with WFE (-0.979) but it was non-significant among other traits.

The genetic correlation between 16th week body weight with 20th and 24th week body weight was 0.078 and -0.592 respectively which was positively and negatively significant while it was non-significant with other traits.

The 20th week body weight was found to be 0.364, 0.281 and -0.415 with 24th week body weight, WFE and clutch size, respectively which was significant but 20th week body weight has been non-significantly correlated among other traits.

It was further estimated that the 24th week body weight was also negatively and significantly correlated with age at sexual maturity and weight of first egg respectively (-0.241 and -0.684).

The weight at sexual maturity was found to be positively and significantly associated with weight of first egg (0.143) while it was negatively and significantly correlated with age at sexual maturity and clutch size with a values of -0.551 and -0.292, respectively but with other traits it was non-significantly correlated.

The genetic correlation of age at sexual maturity with weight of first egg and 90-days egg production were negative and significant (-0.258 and -0.255) while weight of first egg with clutch size (-0.579) and 90-days egg production with clutch size (-0.680) was also negatively and significantly correlated. Among other traits it was found to be non-significantly correlated with sire + dam components covariance.

The genetic correlations among the traits computed from sire and sire + dam components of variance and covariance for 59% inbred flock are presented in Table 15.

The genetic correlation between 0-week body weight with 24-week body weight and weight at sexual maturity was positively and significantly correlated with values as 0.184 and 0.157, respectively while it has been found to be negatively and significant with 4-week body weight and age at sexual maturity respectively (-0.058 and -0.284).

The 4th week body weight was negatively and significantly correlated with 8th week body weight, 20th week body weight and clutch size with values as -0.143, -0.244 and -0.358, respectively. Whereas 8th week body weight and 16th week body weight was positively and significantly correlated (0.211) while it was negative and significant with 90-days egg production and clutch size (-0.017 and -0.003). The 12th week body weight was also negatively and significantly correlated with 16th, 20th week body weight and weight at sexual maturity with values as -0.486, -328 and -0.103, respectively.

The genetic correlations between 16th week body weight with 24th week body weight and ASM; 20-week body weight with ASM; 24th week body weight with age at sexual maturity and weight of first egg was positively and significant (0.192) while the 24^{th} week body weight were also negatively significant with ASM, 90-days egg production and clutch size (-0.268, -0.388 and -0.074).

It was observed that weight at sexual maturity and 90-days production (-0.336); 90-days egg production with clutch size (-1.111) were also negatively and significantly correlated according to sire components of covariance. The genetic correlation between the traits from sire + dam components of covariance in 59% inbred flock, it was observed that o-week body weight was negative and significantly correlated with 4, 12, week body weight and 90-days egg production with values as -0.118, -0.104 and -0.021, respectively while it was found to be positively and significantly correlated with 24-week body weight and clutch size (0.065 and 0.061). But the 4-week body weight was negatively and significantly correlated with 20-week body weight and age at sexual maturity (-0.092 and -0.168).

It was revealed that 8-week body weight was positively and significantly correlated with 16-week body weight (0.216) while there was non-significant correlation among the rest of the traits. The 12-week body weight was significantly correlated with 20 to 24 week body weight and weight at sexual maturity age at sexual maturity, 90-days egg production and clutch size with values ranged from -0.066 to 0.104.

The genetic correlation between 16-week body weight with weight at sexual maturity was positive (0.266) and weight of first egg (-0.211) was negatively and significantly correlated while it was non-significantly correlated with rest of the traits.

The genetic correlation between 20- week body weight with age at sexual maturity (0.035) was found to be positively and significantly correlated while negatively and significantly correlated with clutch size (-0.735) whereas 24-week body weight with weight of first egg was negatively significant. The WSM with ASM and 90-days egg production was also negatively significant with clutch size (-1.132) as per sire + dam components of variance and covariance.

The trend of genetic correlations among the traits as per sire and sire + dam components of variance and covariance are presented in Table 18. For control population. The genetic correlation between 0-week body weight with 8, 12, 16 and 24-week body weight were found to be -0.207, -0.329, -0.307, and -0.281 respectively which was negatively and significantly correlated while it was positively and significantly correlated with weight at sexual maturity (0.071). The genetic correlation between 4-week body weight with 8-week body weight, weight of first egg and clutch size were found to be negatively and significantly correlated with values as -0.532, -0.503 and -0.421 respectively while the 4-week body weight with 20-week body weight

(0.257) was positively and significantly correlated except the associations of the other traits.

The 8-week body weight was positively and significantly correlated with weight at sexual maturity and clutch size with values 0.029 and 0.152, respectively whereas it was found to be significantly correlated with weight of first egg and 90-days egg production.

The 12-week body weight with 24-week body weight, weight at sexual maturity, weight of first egg and clutch size, with values as 0.450, 2.320, 0.267 and 0.583, respectively and 16-week body weight with 24-week body weight was positive and with age at sexual maturity was negative significant with values as 0.048 and -0.272, respectively; and 20-week body weight with 24-week body weight (0.080) were positively and significantly while it was negatively correlated with ASM (-0.388) at genetic scale as per sire components of variance and covariance.

The genetic correlation between 24-week body weight with ASM (-0.496) and weight of first egg (-0.050) was negative and significant while it was positively and significantly correlated with 90-days egg production (0.186); of and WSM with ASM was negative and significant from sire components of variance and covariance.

The correlations estimates from sire + dam components of variance and covariance at genetic scale for control population were determined among the traits (Table 18). The 0-week body weight was negatively and significantly correlated with 24-week body weight (-0.300) while it was positively and significantly correlated with weight at sexual maturity (0.167) where age it was non-significantly correlated with other traits.

The 4-week body weight with 12, 20 and 24-week body weight with values of 0.004, 0.082 and 0.108 respectively and 8-week body weight with 12-week body weight and age at sexual maturity with values of 0.187 and 0.061, respectively were found to be positively and significantly correlated with 4-week weight. The 8-week body weight was also negatively and significantly correlated with 90-days egg production with a value of -0.074 and -0.221, respectively at genetic scale.

The 12-week body weight and 16-week body weight with age at sexual maturity were found to be negatively and significantly correlated (-0.428 and -0.201) whereas 12-week body weight was positively and significantly correlated (0.148) with clutch size.

The 20-week body weight was positively and significantly correlated with age at sexual maturity (0.076) while the 24-week body weight was positively and significantly correlated with weight at sexual maturity (0.157) and it was negatively and significantly correlated with age at sexual maturity, weight of first egg, 90-days production and clutch size with the values as -0.152m -0.174, -0.068 and -0.049 respectively.

The weight of first egg was found to be negatively and significantly correlated with clutch size (-0.029) and the rest of the combinations of traits were non-significant at genetic scale from sire + dam components of variance and covariance in control population.

(ii) Phenotypic correlation

The presentation of phenotypic correlations among the traits for 50% inbred level, 59% inbred level flock and control population were given in Table 13, 16 and Table 19 respectively.

In case of 50% inbred flock, the phenotypic correlations between 0-week body weight with monthly body weight (0 to 24 week), WSM, ASM, WFE, 90-days egg production and clutch size were found to be significant. The correlations between 4-week body weight with WSM, ASM, SFE, 90-days egg production and clutch size were also found to be significant.

It was clear from the table that 8-week body weight was significantly correlated with 24-week body weight, weight at sexual maturity, age at sexual maturity, weight of first egg, 90-days egg production and clutch size while the 12-week body weight was significant with above traits except weight at sexual maturity.

The 16, 20 and 24-week body weight and weight at sexual maturity were found to be significant with age at sexual maturity, weight of first egg, 90-days egg production and clutch size at the phenotypic scale while the age at sexual maturity with weight of first egg and 90-days egg production and weight of first egg and 90-days egg production with clutch size was significant.

In 59% inbred flock the phenotypic correlation, the trend among the traits with 0-week body weight was significant with monthly body weight (4 to 24-week) except 8-week body weight and it was also significant with weight at sexual maturity, age at sexual maturity, weight of first egg, 90-days egg production and clutch size. The 4-week body weight with 16, 20 and 24 week body weight of and weight at sexual maturity, age at sexual maturity, weight of first egg, 90-days egg production and clutch size were found to be significantly correlated.

The 8-week body weight with age at sexual maturity and weight of first egg were significant while the 12-week body weight with WSM, ASM, 90-days egg production and clutch size were found to be significant. There after 16-week body weight was significant with weight of first egg, 90-days egg production and clutch size.

It was clear from the table that 20-week body weight with age at sexual maturity, weight of first egg and 90-days egg production; 24-week body weight with age at sexual maturity, weight of first egg and clutch size were found to be significant ~~and~~ phenotypic level.

The weight at sexual maturity with weight of first egg, 90-days egg production and clutch size; age at sexual maturity with 90-days egg production were found to be significant while it was seen that weight of first egg was also significant with 90-days egg production and clutch size.

The estimates of phenotypic correlations among the traits in control population are given in Table 17. The phenotypic correlation between 0-week body weight with monthly body weight (4 to 24 week), WSM, ASM, WFE, 90-days egg production and clutch size were found to be significant while the 4-week body weight was also significant with 24-week body weight, weight at sexual maturity, age at sexual maturity weight of first egg, 90-days egg production and clutch size.

The 8-week body weight with weight at sexual maturity, age at sexual maturity, weight of first egg, 90-days egg production and clutch size were found to be significant while the 12-week body weight has the significant expression with weight at sexual maturity, weight of first egg, 90-days egg production and clutch size.

The 16-week body weight with weight at sexual maturity, weight of first egg, 90-days egg production and clutch size were found to be significant. Whereas 20-week body weight also significant with WSM, ASM, WFE, 90-days egg production and clutch size at phenotypic level.

It was clear from the table that 24-week body weight with weight at sexual maturity, age at sexual maturity, weight of first egg, and clutch size; weight at sexual maturity with weight of first egg and 90-days egg production;

age at sexual maturity with 90-days egg production while the weight of first egg with 90-days egg production and clutch size were found to be significant in control population.

(iii) Environmental correlations

The environmental correlations computed from sire and sire + dam components of variance and covariance are produced in Table 14, 17 and 20 for 50% inbred, 59% inbred and control flocks respectively. Which showed that most of the environmental correlations from sire components of covariance were positive and of lesser magnitude except weight at sexual maturity, age at sexual maturity, weight of first egg, 90-days egg production and clutch size.

The environmental correlations as per sire + dam components of covariance were found to be of very low magnitude and mostly positive except with production traits, all traits three flocks.

Partial correlations

The simple and partial correlations among the traits were determined and given in Table 21, 22 and 23 for 50% inbred, 59% inbred and control flocks respectively. The partial correlations between 0-week body weight with 8-week body weight and weight of first egg was significantly correlated while keeping all other traits constant. The 4-week body weight with 8,12 and 24-week body weight was significant. It was also significant with weight at

Table-21: Simple and partial phenotypic correlations between different growth and production traits under study **(50% Inbred).**

Traits	0-WK B.W.	4-WK B.W.	8-WK B.W.	12-WK B.W.	16-WK B.W.	20-WK B.W.	24-WK B.W.	W.S.M.	A.S.M.	W.F.E.	90-day E.P.	C.S.
0-WK B.W.	-	-0.015	0.0150*	0.046	0.084	0.020	-0.013	0.009	-0.057	0.103	0.107*	-0.133*
4-WK B.W.	-0.072	-	0.545*	0.532*	0.338*	0.350*	0.294*	0.068	0.034	-0.035	-0.105	0.087
8-WK B.W.	0.141*	0.383*	-	0.545*	0.334*	0.280*	0.199*	0.100	-0.008	0.056	0.014	0.007
12-WK B.W.	0.006	0.248*	0.330*	-	0.451*	0.429*	0.318*	0.086	-0.068	-0.053	-0.101	0.064
16-WK B.W.	0.074	0.014	0.083	0.106	-	0.834*	0.584*	0.362*	0.043	0.192*	0.064	-0.011
20-WK B.W.	-0.067	0.043	-0.059	0.093	0.718*	-	0.703*	0.389*	0.129*	0.222*	0.153*	0.054
24-WK B.W.	0.008	0.138*	-0.052	-0.010	-0.138*	0.502*	-	0.596*	0.196*	0.237*	0.070	0.234*
W.S.M.	-0.018	-0.150*	0.048	0.021	0.251*	-0.259*	0.598*	-	0.695*	0.661*	0.393*	0.356*
A.S.M.	-0.068	0.185-	-0.067	-0.067	-0.174*	0.152*	-0.313*	0.525*	-	0.645*	0.415*	0.457*
W.F.E.	0.126*	-0.043	0.055	-0.089	0.092	0.022	-0.126*	0.280*	0.188*	-	0.556*	0.270*
90-day E.P.	0.032	-0.083	0.054	-0.011	-0.200*	0.204*	-0.081	0.103	0.190*	0.376*	-	-0.192*
C.S.	-0.076	-0.021	-0.002	0.094	-0.141*	0.010	0.144*	0.012	0.361*	0.193*	-0.485	-

Above the diagonal simple and below the diagonal partial correlations
* Significant at 5%

Table-22: Simple and partial phenotypic correlation's between different growth and production traits under study **(59% Inbred)**

Traits	0-WK B.W.	4-WK B.W.	8-WK B.W.	12-WK B.W.	16-WK B.W.	20-WK B.W.	24-WK B.W.	W.S.M.	A.S.M.	W.F.E.	90-day E.P.	C.S.
0-WK B.W.	-	-0.002	0.145*	0.002	0.009	0.107*	0.043	0.040	0.018	0.291*	0.056	-0.062
4-WK B.W.	-0.042	-	0.412*	0.201*	0.169*	0.166*	0.200*	0.069	-0.124*	-0.087*	0.188*	-0.187*
8-WK B.W.	0.163*	0.354*	-	0.500*	0.299*	0.318*	0.289*	0.156*	-0.069	0.090*	0.140*	-0.140*
12-WK B.W.	-0.146*	-0.010	0.395*	-	0.526*	0.454*	0.392*	0.157*	-0.149*	0.170*	0.089*	-0.066
16-WK B.W.	-0.027	-0.001	-0.026	0.321*	-	0.672*	0.637*	0.291*	-0.315*	-0.006	0.188*	-0.148*
20-WK B.W.	0.114*	-0.025	0.034	0.105*	0.299*	-	0.788*	0.371*	-0.263*	0.071	0.195*	-0.145*
24-WK B.W.	-0.047	0.049	0.030	-0.015	0.134*	0.584*	-	0.370*	-0.407*	-0.004	0.249*	-0.195*
W.S.M.	-0.037	0.015	0.028	-0.083*	0.115*	0.065	0.270*	-	0.233*	0.208*	0.032	-0.023
A.S.M.	-0.053	-0.021	0.057	-0.026	-0.131*	0.077	-0.356*	0.408*	-	0.288*	-0.267*	0.225*
W.F.E.	0.303*	-0.088*	-0.016	0.213*	-0.075	0.019	0.008	0.113*	0.223*	-	-0.088*	0.114*
90-day E.P.	-0.006	0.036	-0.004	-0.020	0.014	0.023	0.044	-0.005	-0.092	0.041	-	-0.824*
C.S.	-0.049	-0.38	-0.35	0.006	-0.001	0.025	0.005	-0.018	0.001	0.078	-0.806*	-

Above the diagonal simple and below the diagonal partial correlation

* Significant at 5%

Table-23: Simple and partial phenotypic correlations between different growth and production traits under study **(Control population)**

Traits	0-WK B.W.	4-WK B.W.	8-WK B.W.	12-WK B.W.	16-WK B.W.	20-WK B.W.	24-WK B.W.	W.S.M.	A.S.M.	W.F.E.	90-day E.P.	C.S.
0-WK B.W.	-	-0.014	0.011	0.192*	-0.094	-0.008	-0.066	0.032	0.000	-0.016	0.053	0.032
4-WK B.W.	-0.072	-	0.480*	0.343*	0.297*	0.281*	0.170*	0.103	-0.014	0.034	0.064	0.030
8-WK B.W.	0.002	0.391*	-	0.459*	0.426*	0.289*	0.308*	0.059	-0.108	-0.003	0.006	0.039
12-WK B.W.	0.373*	0.100	0.197*	-	0.721*	0.584*	0.332*	0.086	-0.142	-0.035	0.075	0.008
16-WK B.W.	-0.345*	-0.061	0.118	0.517*	-	0.723*	0.479*	0.095	-0.210*	-0.089	0.049	0.055
20-WK B.W.	0.069	0.134	-0.177*	0.108	0.460*	-	0.497*	0.174*	-0.096	0.124	0.178*	0.066
24-WK B.W.	-0.070	-0.082	0.171*	-0.063	0.089	0.230*	-	0.341*	0.080	0.175*	0.0175*	0.119
W.S.M.	0.167*	0.072	-0.013	-0.048	0.271*	-0.033	0.323*	-	0.853*	0.825*	0.610*	0.546*
A.S.M.	-0.103	0.025	-0.123	0.067	-0.176*	-0.217*	-0.128	0.607*	-	0.842*	0.580*	0.574*
W.F.E.	-0.127	-0.085	0.148	0.010	-0.249*	0.335*	-0.076	0.286*	0.383*	-	0.676*	0.489*
90-day E.P.	0.076	0.032	-0.072	0.023	0.049	0.027	-0.001	0.039	-0.001	0.348*	-	0.410*
C.S.	0.080	-0.034	0.079	-0.107	0.160*	0.014	-0.043	0.022	0.284*	-0.060	0.089	-

Above the diagonal simple and below the diagonal partial correlations

* Significant at 5%

sexual maturity and age at sexual maturity when other traits were kept constant.

It was clear from the estimates that 8-week body weight with 12-week body weight; 16-week body weight with 20 and 24 week body weight was significant. The 16-week body weight was also significant with weight at sexual maturity, age at sexual maturity, 90-days egg production and clutch size. The 20-week body weight was found to be significant ly correlated with 24-week body weight, weight at sexual maturity, age at sexual maturity and 90-days egg production when other traits considered as constant.

The 24-week body weight was found to be significantly correlated with weight at sexual maturity, age at sexual maturity, weight of first egg and clutch size. The weight at sexual maturity with age at sexual maturity and weight of first egg were found to be significant while age at sexual maturity with weight of first egg, 90-days egg production and clutch size were significant; of and weight of first egg with 90-days egg production and clutch size; of and 90-days egg production with clutch size were significantly correlated when other were kept constant in 50% inbred flock.

The simple correlations in 50% inbred for growth traits was mostly significant ~~when associated togetherly~~ but found non-significant with production traits.

In 59% inbred flock the partial correlation obtained as the 0-week body weight with 8, 12 and 20-week body weight were significantly correlated while the 4-week body weight was significantly correlated only with 8-week body weight and weight of first egg.

It was observed that 8-week body weight was significantly correlated with 12-week body weight. The 12-week body weight with 16-week body weight, 20-week body weight, weight at sexual maturity and weight of first egg were found to be significant.

The table showed to that 59% inbred flock has ~~been the~~ ~~significantly~~ significant correlation of 16-week body weight with 20 and 24-week body weight ~~but~~ it was also significantly correlated with weight at sexual maturity and age at sexual maturity. The 20-week body weight with 24-week body weight and 24-week body weight were also significantly correlated with weight at sexual maturity and age at sexual maturity.

The weight at sexual maturity with age at sexual maturity and weight of first egg; of and age at sexual maturity with weight of first egg; of and 90-days egg production with clutch size were found to be significantly correlated.

All partial correlations between two traits were calculated when all other traits were kept constant. The simple correlation in 59% inbred among the traits found to be mostly significant.

The partial correlations obtained from the control flock for 0-week with 12-week, 16-week and weight at sexual maturity were found to be significantly correlated while 4-week body weight with 8-week body weight;

of and 8-week body weight with 12-week, 20-week and 24-week body weight were found to be significantly correlated when other traits were kept constant.

The 12-week body weight with 16-week body weight was found to be significantly correlated when all other traits were kept constant. The 16-week body weight with 20-week body weight, weight at sexual maturity, age at sexual maturity, weight of first egg and clutch size were also significant when rest of the trait kept constant.

The 20-week body weight with 24-week body weight, age at sexual maturity and weight of first egg; of and 24-week body weight with weight at sexual maturity were found to be significantly correlated when all other traits were kept constant.

It was clear that weight at sexual maturity with age at sexual maturity and weight of first egg; of and age at sexual maturity with weight of first egg and clutch size were found to be significant while weight of first egg with 90-days egg production was also significantly correlated when all other traits were kept constant.

The simple correlations among the traits were found to be mostly significant and positive.

Regression

Simple linear regression

The simple regression coefficients were computed to determine the effect of independent economic traits on dependent traits individually and are

Table-24: Linear regression coefficients of dependent economic traits on independent traits. **(50% inbred)**

Independent variables (x)	Dependent variables (Y)									
	B. wt. at sex. Maturity (g)		Age at sex. maturity (days)		Wt. of first egg(g)		90-days egg prod. (Nos)		Clutch size (days)	
	b	r^2	b	r^2	b	r^2	b	r^2	b	r^2
0-WK B.W. (g)	0.727	0.00007	33.985**	0.0356	0.2987	0.0105	0.4549*	0.0114	1.0311**	0.0265
4-WK B.W. (g)	0.345	0.0064	-8.970**	0.9438	-0.0069	0.0022	-0.0293*	0.0180	-0.2998**	0.8531
8-WK B.W. (g)	0.263*	0.0165	-3.926**	0.8057	-0.0066	0.0088	-0.0206**	0.0399	-0.1316**	0.7325
12-WK B.W. (g)	0.194*	0.0164	-2.826**	0.7640	-0.0054	0.0108	-0.0160**	0.0441	-0.0949**	0.6972
16-WK B.W. (g)	0.329**	0.0366	-2.630**	0.5140	-0.0069*	0.0135	-0.0202**	0.0542	-0.0890**	0.4763
20-WK B.W. (g)	0.353**	0.0332	-3.186**	0.5936	-0.0053	0.0063	-0.0178**	0.0332	-0.1122**	0.5958
24-WK B.W. (g)	0.277**	0.0516	-2.094**	0.6472	-0.0034	0.0064	-0.0116**	0.0356	-0.0718**	0.6155
W.S.M. (g)	-	-	-	-	-0.0025	0.0036	-0.0129**	0.0444	-0.5408**	0.3529
A.S.M. (days)	-	-	-	-	0.0007	0.0017	0.0027*	0.0115	0.0329**	0.7912
W.F.E. (g)	-	-	-	-	-	-	0.0059**	0.0604	0.0191**	0.2834

* Significant at 5%; ** Significant at 1% level

Table-25: Linear regression coefficients of dependent economic traits on independent traits. **(59% inbred)**

Independent variables (x)	Dependent variables (Y)									
	B. wt. At sex. Maturity (g)		Age at sex. maturity (days)		Wt. of first egg(g)		90-days egg prod. (Nos)		Clutch size (days)	
	b	r^2	b	r^2	b	r^2	b	r^2	b	r^2
0-WK B.W. (g)	1.6485	0.0016	-0.6878	0.000023	0.3870**	0.0849	0.1222	0.0031	-0.0741	0.0002
4-WK B.W. (g)	-0.1401	0.0035	-7.8067**	0.8983	-0.0094**	0.0152	0.0162**	0.0170	-0.3191**	0.8731
8-WK B.W. (g)	-0.0957*	0.0070	-3.4002**	0.7178	-0.0070**	0.0355	0.0099**	0.0267	-0.1356**	0.6643
12-WK B.W. (g)	-0.05209*	0.0068	-1.8403**	0.6967	-0.0045**	0.0495	0.0055**	0.0277	-0.0726**	0.6317
16-WK B.W. (g)	-0.04007*	0.0073	-1.2178**	0.5494	-0.0039**	0.0672	0.0047**	0.0353	-0.0475**	0.4858
20-WK B.W. (g)	-0.0319	0.0050	-1.0146*	0.4110	-0.0039**	0.0721	0.0048**	0.0405	-0.0388**	0.3504
24-WK B.W. (g)	-0.0373*	0.0066	-1.0352**	0.4142	-0.0038**	0.0673	0.0050**	0.0420	-0.0396**	0.3535
W.S.M. (g)	-	-	-	-	-0.0043**	0.0630	0.0057**	0.0404	-0.0444**	0.3293
A.S.M. (days)	-	-	-	-	0.0009	0.0007	-0.0007	0.0013	0.0429**	0.7690
W.F.E. (g)	-	-	-	-	-	-	-0.0019**	0.0193	0.0227**	0.3730

* Significant at 5%; ** Significant at 1% level

Table-26: Linear regression coefficients of dependent economic traits on independent traits. **(Control population)**

Independent variables (x)	Dependent variables (Y)									
	B. wt. at sex. Maturity (g)		Age at sex. maturity (days)		Wt. of first egg(g)		90-days egg prod. (Nos)		Clutch size (days)	
	b	r^2	b	R^2	b	r^2	b	r^2	b	r^2
0-WK B.W. (g)	3.2119	0.00103	10.4685	0.0062	-0.0566	0.0003	0.2580	0.0028	0.3773	0.0044
4-WK B.W. (g)	-0.0953	0.0002	-7.6638**	0.7463	-0.0094	0.0017	0.0077	0.0006	-0.3225**	0.7101
8-WK B.W. (g)	-0.0764	0.00055	-3.4081**	0.6228	-0.0040	0.0012	-0.0016	0.0001	-0.1415**	0.5773
12-WK B.W. (g)	-0.1154	0.0025	-2.2601**	0.5447	-0.0070	0.0077	0.0003	0.000009	-0.0950**	0.5167
16-WK B.W. (g)	-0.0617	0.0007	-1.6557**	0.2673	-0.0100	0.0145	-0.0007	0.00004	-0.0690**	0.2491
20-WK B.W. (g)	0.1153	0.0030	-0.9890**	0.1236	-0.0008	0.0001	0.0093	0.0082	-0.0419**	0.1192
24-WK B.W. (g)	0.5493**	0.1036	-0.6078**	0.0722	0.0126**	0.0458	0.0186**	0.0503	-0.0280**	0.0821
W.S.M. (g)	-	-	-	-	0.0235**	0.2915	0.0256**	0.1750	-0.0102	0.0199
A.S.M. (days)	-	-	-	-	0.0025	0.0093	0.0018	0.0025	0.0409**	0.8976
W.F.E. (g)	-	-	-	-	-	-	0.0151	0.0028	0.3093**	0.8327

* Significant at 5%; ** Significant at 1% level

presented in Table 24, 25 and 26 for 50% inbred, 59% inbred and control population respectively.

The linear regression of 50% inbred the monthly body weight (0-week to 24 week) was considered as independent variables while body weight at sexual maturity and age at sexual maturity were considered as dependent variables. The simple linear regression values of body weight at sexual maturity on 0, 4, 8,12, 16, 20 and 24-week body weight were found to be 0.727, 0.345, 0.263, 0.194, 0.329, 0.353 and 0.277g, respectively and were mostly moderately significant except 0 and 4-week body weight, having greatest contribution from 24-week weight (R^2 = 5.16%). Whereas in case of age at sexual maturity the regression coefficients on 0, 4, 8, 12, 16, 20 and 24-week body weight individually were found to be statistical significant with their values being 33.985, -8.970, -3.926, -2.826, -2.630, -3.186, and –2.094 days, respectively. The highest R^2 recorded as 94.38 per cent for 4-week body weight.

In second set of analysis monthly body weights (0-week to 24-week), WSM and ASM was considered as independent variables while the weight of first egg as dependent variables. The simple linear regression coefficient was significantly obtained only for 16-week body weight while all other regressions values were mostly negative and non-significant. The highest R^2 value observed as 1.35 per cent for 16-week body weight.

In third set the monthly body weight (0- week to 24-week), WSM, ASM and weight of first egg was used as independent variables while the 90-days egg production and clutch size as dependent variables. The simple linear regression values ranged from –0.029 to 0.455 and found to be statistical significant and mostly negative when 90-days egg production regressed over various independent variables. The simple linear regression coefficient were also significant then clutch size regressed over the above mention independent variables with the ranged from –0.540 to 1.031. The highest R^2 values (6.04 and 85.31 per cent, respectively) from weight of first egg and 4-week body weight.

The similar combinations of traits were used for 59% inbred flock. The simple linear regressions coefficient for body weight at sexual maturity on 8, 12, 16 and 24-week body weight were found to be statistical significant with values as –0.096, -0.052, -0.040 and –0.037, respectively while the age at sexual maturity regressed over the 4, 8, 12, 16, 20 and 24-week body weight with significant values as –7.807, -3.400, -1.840, 1.217, -1.015 and –1.035 respectively.

In second set of analysis it ranged between –0.009 to 0.387 and significant except on age at sexual maturity. The highest R^2 being 8.5 per cent for 0-week body weight.

In third set of analysis the simple linear regression of 90-days egg production on various economic traits were found to be mostly significant except on 0-week body weight and age at sexual maturity which varied from –0.0019 to 0.1222 with highest R^2 value as 4.2 per cent for 24-week body weight. The regression coefficient of clutch size on different economic traits were significant for 4, 8, 12, 16, 24-week body weight, weight at sexual maturity, age at sexual maturity and weight of first egg with values as –0.319, -0.135, -0.072, -0.047, -0.038, -0.039, -0.044, 0.042 and 0.022, respectively with highest R^2 value (87.31 per cent) from 4-week body weight.

The simple linear regression in control flock was found to be non-significant and mostly negative except body weight at sexual maturity on 24-week body weight with highest R^2 value as 10.36 per cent. When age at sexual maturity was regressed over the 4, 8, 12, 16, 20 and 24-week body weight then negative and significant values as –7.664, -3.408, -2.260, -1.656, -0.989 and 0.608 g respectively were observed with highest R^2 value as 74.63 per cent for 4-week body weight during first set of analysis.

The weight of first egg was found to be significant only on 24-week weight and weight at sexual maturity with values as 0.0126 and 0.0235g, respectively. The weight at sexual maturity has the greatest contribution (29.15 per cent) in second set of analysis.

The simple linear regression coefficient were significant between 90-days egg production with 24-week body weight and weight at sexual maturity with values as 0.0186 and 0.0256 g, respectively while the clutch size was found to be mostly negative and significant with 4, 8, 12, 16, 20 and 24-week body weight, age at sexual maturity and weight of first egg with a values of –0.322, -0.142, -0.095, -0.069, -0.042, -0.028g, 0.0409 days and 0.309g, respectively. The age at sexual maturity has the highest R^2 values (89.76 per cent) during third set of analysis.

Multiple regression

The multiple regressions of two levels of inbred (50 and 59%) and a control population of white leghorn were estimated among the growth and production traits and is presented in Table 27, 28 and 29 for 50% inbred, 59% inbred and control flock, respectively.

In 50% inbred the monthly body weight (0-week to 24-week) considered as independent traits while the body weight at sexual maturity, age at sexual maturity and clutch size were considered as dependent traits. The multiple linear regression of body weight at sexual maturity on 4 and 12-week body weight was negative and significant with values as –1.4398 and –0.5523g, respectively while it was positively and significantly regressed over 24-week body weight (0.9331) with significant value of coefficient of determination (0.3846).

The age at sexual maturity was negatively and significantly regressed on 12-week body weight (-0.1082). The positively and significantly regression was obtained 24-week body weight (0.0404) with significant value of coefficient of determination (0.0700) while clutch size has significant R^2

Table-27: Multiple regression coefficient for different economic traits **(50% Inbred)**

Independent variables (x)	Dependent variable (Y)				
	Body weight at sexual maturity	Age at sexual maturity	Weight of first egg	90-days egg production	Clutch size
	b	b	b	b	b
0-WK B.W. (g)	-0.1682	-0.4676	0.2985	0.2761	-0.0228*
4-WK B.W. (g)	-1.4398*	0.0716	-0.0320	-0.0580	0.0016
8-WK B.W. (g)	0.5994	0.0356	0.0181	0.0244	-0.0004
12-WK B.W. (g)	-0.5523*	-0.1082*	-0.0142	-0.0161	0.0006
16-WK B.W. (g)	0.4269	-0.0626	0.0022	-0.0331**	-0.0012
20-WK B.W. (g)	-0.2900	0.0523	0.0119*	0.0446**	-0.0005
24-WK B.W. (g)	0.9331**	0.0404**	-0.0100**	-0.0181**	0.0013**
W.S.M. (g)	-	-	0.0166**	0.0094*	-
A.S.M. (days)	-	-	0.0859**	0.0090	-
W.F.E. (g)	-	-	-	0.6077**	-
R^2 value	0.3846**	0.0709**	0.5535**	0.3671**	0.1067**

* Significant at 5%;
**Significant at 1%

Table-28: Multiple regression coefficient for different economic traits **(59% Inbred)**

Independent variables (x)	Dependent variable (Y)				
	Body weight at sexual maturity	**Age at sexual maturity**	**Weight of first egg**	**90-days egg production**	**Clutch size**
	b	**b**	**b**	**b**	**b**
0-WK B.W. (g)	0.0344	0.0433	0.3740**	0.1248	-0.0058
4-WK B.W. (g)	-0.1090	-0.0503	-0.0131*	0.0273**	-0.0017**
8-WK B.W. (g)	0.0933	0.0190	-0.0011	0.0038	-0.0002
12-WK B.W. (g)	-0.0739	0.0011	0.0095**	0.0032	0.0002
16-WK B.W. (g)	0.0787	-0.0401**	0.0046	0.0027	-0.0003
20-WK B.W. (g)	0.2285**	0.0414**	0.0013	0.0005	0.0002
24-WK B.W. (g)	0.2086**	-0.0883**	0.0003	0.0067	-0.0005**
W.S.M. (g)	-	-	0.0038**	0.0010	-
A.S.M. (days)	-	-	0.0493**	-0.0587**	-
W.F.E. (g)	-	-	-	-0.0648	-
R^2 Value	0.1579**	0.1938**	0.2343**	0.1196**	0.0691**

* Significant at 5%;
**Significant at 1%

Table-29: Multiple regression coefficient for different economic traits **(Control population)**

Independent variables (x)	Dependent variable (Y)				
	Body weight at sexual maturity	**Age at sexual maturity**	**Weight of first egg**	**90-days egg production**	**Clutch size**
	b	**b**	**b**	**b**	**b**
0-WK B.W. (g)	4.4258	-0.3388	-0.1943	0.3234	0.0112
4-WK B.W. (g)	1.0593	0.1230	-0.0172	0.0144	0.0039
8-WK B.W. (g)	-0.3411	-0.0671	0.0138	-0.0153	0.001
12-WK B.W. (g)	0.02836	0.0200	0.0019	0.0026	-0.0060
16-WK B.W. (g)	-0.3979	-0.1386**	-0.0223**	0.0123	0.0027
20-WK B.W. (g)	0.1620	0.0067	0.0191**	0.0033	0.0008
24-WK B.W. (g)	0.6367**	0.0572**	-0.0028	-0.0003	0.0033
W.S.M. (g)	-	-	0.0132**	0.0038	-
A.S.M. (days)	-	-	0.1248**	0.0165	-
W.F.E. (g)	-	-	-	0.8107**	-
R^2 Value	0.1355**	0.0945*	0.7890**	0.4805**	0.0205

* Significant at 5%;
**Significant at 1%

value (0.1067) but it was also significantly regressed over 24-week body weight as 0.0013 in first set of analysis.

In second set of analysis monthly body weight (0-week to 24-week), WSM and ASM was considered as independent traits and the weight of first egg as dependent traits. The multiple linear regression values as 0.2985, 0.0119, -0.0100, 0.0166g, and 0.0859 days was significant for 0, 20, 24-week body weight, weight at sexual maturity and age at sexual maturity, respectively with the significant R^2 value as 0.5535.

In third set of analysis the monthly body weight (0-week to 24-week), WSM, ASM and weight of first egg was considered as independent traits while the dependent trait was 90-days egg production. The multiple linear regression were obtained as significant with 16, 20, 24-week body weight, weight at sexual maturity and weight of first egg and the values were found to be –0.0331, 0.0446, -0.0181, 0.0094 and 0.6077, respectively with coefficient of determination (R^2) as 0.3671 which was significant.

The similar trend of combination were used in 59% inbred flock. The multiple linear regression were obtained as body weight at sexual maturity on 20 and 24-week body weight were significant with values as 0.2285 and 0.2086, respectively with significant coefficient of determination (0.1579) while age at sexual maturity on 16, 20 and 24-week body weight were also significant (-0.0401, 0.0414 and –0.0883, respectively) with significant coefficient of determination (0.1938). The multiple linear regression of weight of first egg with 0, 4, 12 week body weight, weight at sexual maturity and age at sexual maturity were observed as significant (0.3740, -0.0131, 0.0095, 0.0038 g and 0.0493 days, respectively) with the significant coefficient of determination (0.2343).

The 90-days egg production were significantly regressed over the 4-week body weight and age at sexual maturity with values as 0.0273g and –0.0587 days, respectively and R^2 value being 0.1196 which was significant.

The multiple regression of clutch size on 4-week body weight and 24-week body weight were found to be significant with values as –0.0017 and –0.0005g, respectively whereas R^2 value (0.0691) was also significant.

The multiple regression in control flock were mostly non-significant. It was found that body weight at sexual maturity on 24-week body weight (0.6367g) and age at sexual maturity was regressed over 16 and 24-week body weight with values as –0.1386 and 0.0572g, respectively while the coefficient of determination were (0.1355 and 0.0945, respectively) found to be significant. The multiple regression of weight of first egg on 16, 20-week body weight, weight at sexual maturity and age at sexual maturity were obtained as significant with values as –0.0223, 0.0191, 0.0132g and 0.1248 days, respectively which constituted significant R^2 value as 0.7890. The 90-days egg production was significantly regressed over weight of first egg (0.8107) with R^2 value as 0.4805 which was significant. It was seen that clutch size were not significantly regressed with all economic traits and it has non-significant value of coefficient of determination (0.0205).

DISCUSSION

DISCUSSION

Means

Body weights

The least squares means of population with two levels (50 per cent and 59 per cent) of inbreeding coefficient and control population are presented in Table 8. The body weight of a bird effects its future performance. An attempt has been made to compare the performance of control and two levels (50 per cent and 59 per cent) of inbred population of White Leghorn by estimating the least squares means of body weight at day old to 24-week of age. It was found that the 0-week body weight of 50 per cent inbred and 59 per cent inbred populations was lower than the weights of control population. This indicated that inbreeding and maternal effects expressed their effect on day-old weight. There was paucity of early literature on this aspect as most of them did not specify the separate estimates on different levels of inbreeding coefficient. The reports of Kumar (1983) and Bhushan (1984) showed higher estimates and Kushwaha (1987) reported lower weight than the present study.

The body weight at 4-week of age was 157.37 ± 1.13, 174.97 ± 1.36 g and 149.00 ± 2.45g, for 50 per cent, 59 per cent and control populations, respectively. It showed that both inbred estimates were higher than the control population in the present study. While the 8-week body weight was 359.29 ± 2.00, 360.33 ± 4.05 and 360.58 ± 5.58 g in 50 per cent, 59 per cent and control populations, respectively. This indicated that inbreeding and maternal effect did not affected 4 and 8 week body weight. Earlier reports by Kumar (1983), Bhushan (1984), Kushwaha (1987), Rai (1988) and Kumar (1989) were not in agreement with these findings as they considered the over all means in their inbred population.

The body weight at 12-week of age were found to be 606.07 ± 3.20, 633.66 ± 5.05 and 638.74 ± 9.18 g, for 50 per cent , 59 per cent inbred and control population, respectively which indicated that inbreds had lower body weight at 12-weeks than control one. It was concluded that both inbreds have inbreeding effects. When compared, the two levels of inbreeding, 50 per cent showed its effect and no inbreeding effect was seen later.

The average body weight at 16-week of age were 741.06 ± 5.37, 887.51 ± 4.16 and 807.51 ± 10.68g, in 50 per cent, 59 per cent inbred and control populations, respectively. It was found that the 16-weeks body weight was lower in 50 per cent inbred and higher in 59 per cent inbred than the control flock. This expression indicated that the inbreeding affected the 16-week body weight till 50 per cent level of inbreeding thereafter, no change was observed.

The overall findings of Bhushan (1984) were higher than the present study at 50 per cent inbred but it was lower than 59 per cent inbred estimates while Kushwaha (1987) and Rai (1988) reported higher body weight than the present study in inbreds.

The mean for 20-week body weight was maximum (1073.47 ± 5.02 g) in the 59 per cent inbred generation and minimum 920.88 ± 6.69 g) in the 50 per cent level of inbred generation than control population (943.11 ± 14.81 g). It was concluded that inbreeding tended to decline the body weight in 50 per cent level but not much effect was observed in 59 per cent inbred population.

The estimates of 24-week body weight was 1198.31 ± 10.28, 1258.15 ± 5.40 and 1132.05 ± 17.23 g for 50 per cent, 59 per cent and control populations, respectively. It was observed that 50 per cent inbred body weight was lower than 59 per cent inbred and control populations had the lowest weight.

The findings of the present study on body weight from 0 to 24-weeks of age in all three populations showed that the on breeding depression was exhibited in 50 per cent level of inbreeding whereas no further reduction was seen in 59 per cent inbred generation. It could be concluded that inbreeding effect was observed on growth traits.

Weight at sexual maturity.

The weight at sexual maturity was found to be 1355.40 ± 14.71, 1707.15 ± 5.89 and 1258.64 ± 29.31 g in 50 per cent, 59 per cent and control populations, respectively (Table 6). When compared, the inbreds were of higher weight than the control flock which indicated that inbreeding did not reduce weight at sexual maturity in the present study.

Age at sexual maturity

The least squares means of age at sexual maturity were obtained to be 201.19 ± 2.01, 190.81 ± 1.00 and 173.03 ± 4.12 days for 50 per cent, 59 per cent and control flocks, respectively. The average age of S.M. in 50 per cent and 59 per cent inbred flock were higher than the control flock. The earlier findings indicated that inbreeding increased the age at sexual maturity. The results of Chaitanyam and Singh (1985) and Singh (1987) was in close agreement with the present study.

Weight of first egg

The leas squares mean of the weight of first egg was found to be 42.70 ± 0.50 g in 50 per cent inbred and 41.09 ± 0.19 g in 59 per cent inbred flock while it was observed to be 41.37 ± 1.01 g in the control flock. This was the indication that inbreeding had no effect on this trait in both inbred flock. It was in agreement with Bhushan (1984), Singh (1987) and Rai (1988).

Egg production

The average egg production was reduced to 43.65 ± 0.74 in 50 per cent inbred while it was higher 50.90 ± 0.31 in 59 per cent inbred flock than the control (45.87 ± 1.42) flock. This indicated that inbreeding did reduce the egg production in 50 per cent inbred flock but later on its effect was not noticed. This was in agreement with the findings of Singh (1976), Bhushan (1984) and Chaitanyam and Singh (1985).

Clutch size

A comparison of the 50 per cent and 59 per cent inbred flock with control population suggests that the clutch size in both the inbreds were higher (2.10 ± 0.04 and 1.81 ± 0.01 days) than the control flock (1.55 ± 0.05 days). Hays (1934) and Lambert (1935) did not find any effect of inbreeding on clutch size.

The least squares means of the growth and production traits in this study showed that most of the growth and population traits in 50 per cent inbred flock were reduced. It may be concluded that inbreeding affected growth and production traits at 50 per cent level of inbreeding and there after no further reduction was observed in the performance traits. Bhushan (1984) and Chaitanyam and Singh (1985) reported that inbreeding did not affect the growth characters after 51.0 per cent of inbreeding. There was a linear growth from day old to 24 weeks of age in all the three population which suggested that the same set of genes controlled the growth rate. Similar findings were reported by Bhushan (1984) and Chaitanyam and Singh (1985).

Heritability estimates

Body weight

The heritability estimates based on sire and sire + dam components of variance are presented in Table 11 for 50 per cent, 59 per cent inbreds and control flocks. The heritability value of 50 per cent inbred from sire component of variance at 0-weeks body weight was 0.472 ± 0.236 which was higher than heritability of 0-week body weight (0.162 ± 0.185) in a control flock but the 0-week body weight heritability was almost zero (-0.156 ± 0.085) in the 59 per cent inbred flock. This indicated that inbreeding depression might have role in inbred flock though the standard error for 50 per cent inbred population of above character were larger than the standard error of 59 per cent and control population indicating that 50 per cent inbred has more variability than 59 per cent inbred and control flock or there may be sampling error.

The heritability estimates of 4-week, 8-weeks body weights were found to be in lower to medium range (0.309 ± 0.165, 0.187 ± 0.127 and 0.300 ± 0.145) in 50 per cent inbred flock and 0.174 ± 0.101, 0.456 ± 0.203 and 0.574 ± 0.201 in 59 per cent flock, respectively while it was 0.059 ± 0.224, -0.274 ± 0.099 and 0.025 ± 0.181, respectively in control population which was almost zero. This higher trend of heritability for above traits in both inbred flock than control population showed that inbreeding depression was not present on the heritability of the inbred flocks. The above findings did not agree with Bhushan (1984), Kushwaha (1987), Rai (1988) and Kumar (1989).

The body weights at 16, 20 and 24-week of age were found to be intermediately heritable with the estimates of 0.215 ± 0.132, 0.301 ± 0.149 and 0.658 ± 0.248 from sire component of variance in 50 per cent flock while lower estimates of heritability were recorded in 59 per cent flock (-0.004 ± 0.058, 0.150 ± 0.100 and 0.048 ± 0.084). The present findings indicated that heritability in 50 per cent inbred was in close agreement with the control flock but 59 per cent inbred flock showed sampling variation.

Weight at sexual maturity

The heritability values of weight at sexual maturity from sire components of variance were obtained as 0.246 ± 0.145, 0.271 ± 0.125 and 0.470 ± 0.308 for 50 per cent, 59 per cent and control flocks, respectively. Inbred had lower estimates of heritability than the coreesponding estimates of control flock. This was the indication of inbreeding depression on h^2 of weight at sexual maturity. The control flock had more variability than inbred flock because standard error was higher.

The heritability values from sire + dam components of variance were much lower (0.072 ± 0.099) and lower (0.216 ± 0.086) than the control flock with 0.325 ± 0.176, respectively. Iqbaluddin *et al.* (1975) and Singh (1987) reported higher estimates for weight at sexual maturity in inbred flocks.

Age at sexual maturity

The heritability estimate age at sexual maturity based on sire components of variance was 0.572 ± 0.238 in 50 per cent inbred flock which higher than the control flock (0.251 ± 0.247).

The heritability values computed from sire + dam components of variance has the almost same trend of heritability in all three populations. The inbreds were well comparable with the control flock.

Weight of first egg

The first egg weight was found to be highly heritable in 50 per cent inbred and in control from sire components of variance (Table 11). The heritability value was more than one which may due to sampling error. While the heritability estimate in 59 per cent inbred flock was medium (0.420 ± 0.163) which was lower than the control flock and also from 50 per cent inbred. It have might been influenced by inbreeding coefficient.

The h^2 of weight of first egg were of medium magnitude (0.333 ± 0.100 and 0.693 ± 0.224) in 59 per cent and 50 per cent inbred flock, respectively while it was as high as 0.899 ± 0.335 in control flock as per the sire + dam components of variance. It could be reasonably concluded that the low heritability estimates observed in the inbreds than control population indicated that it might be due to inbreeding.

90-days egg production

The 90-days egg production had very high value of heritability (1.164 ± 0.427) in 50 per cent while the heritability estimates of 59 per cent inbred and control flock were found to be 0.127 ± 0.110 and 0.332 ± 0.374, respectively from sire components of variance. The low magnitude of heritability in 59 per cent inbred than control flock may be due to inbreeding depression.

Clutch size

The heritability estimate as per sire components of variance was found to be as high as 0.780 ± 0.317 in 50 per cent inbred with higher standard error but it was as low as 0.118 ± 0.093 in 59 per cent inbred flock. The heritability of clutch size was found to be slightly lower (0.385 ± 0.277) in control flock. The 59 per cent level of inbreeding coefficient decreased the heritability of clutch size. As the clutch size was more affected by light, nutrition and management the inbred population were more variable than base population.

Correlations

(i) Genetic correlations

The genetic correlations between different body weight and production traits computed from sire and sir + dam components of variance and covariance are presented in Table 9 and 10, respectively.

The genetic correlations among the different traits are presented in Table 12, 15 and 18 for 50 per cent, 59 per cent inbreds and control flock, respectively. The genetic correlations based on sire components of covariance were mostly non-significant in all three flocks between growth traits except that of negative and significant correlation between 0-week body weight with 20-week body weight and 12-weeek body weight with 20 week body weight. The genetic correlations of 8-week body weight with 20 and 24-week body weight; 12 week body weight with 16-week body weight and 16-week body weight with 24-week body weight were obtained as positive and significant in the 50 per cent level of inbreeding coefficient. This indicated that birds having higher body weight at early age, would achieve the fast growth.

The genetic correlations were found to be negative and significant between 0-weekbody weight with 4-week body weight; between 4-week body weight with 8 and 20-week body weight; and between 12-week body weight with 16 and 20 week body weight while the genetic correlations were obtained as positive and significant between 0-week body weight with 24-week body weight between 8-week body weight with 16-week body weight and between 16-week body weight with 24-week body weight. It could be concluded that early growth rate was responsible for later growth rate.

In control flock there has been negative and significant correlations between 0-week body weight with 8, 12, 16 and 24-week body weight and between 4-week body weight with 8-week body weight while the 4-week body weight with 20-week body weight; and 12, 16 and 20-week body weight with the 24-week body weight were obtained as positive and significant.

When the association between growth and production traits were considered in above three population from sire components of covariance then most of the association were achieved as non-significant. The genetic correlation based on sire components of variance and covariance showed that later growth traits were mostly significantly correlated with ASM.

Inbreeding did not seem to affect genetic association for majority of the characters but 59 per cent inbreeding coefficient was effective in changing correlations for some production traits. It was not in agreement with the findings of Kumar (1983), Bhushan (1984), Rai (1988) and Kushwaha *et al.* (1989) where they found that most of the correlations were significant while

Kumar (1989) reported most of the association as non-significant but he considered the values after elimination of the inbreeding effects.

The genetic correlations based on sire + dam components of covariance among different growth and production traits were presented in Table 12, 15 and 18 for 50 per cent inbred. 59 per cent inbred and control flock, respectively.

The body weight at day old with 20-week body weight and age at sexual maturity; of 4-week body weight with 8-week body weight, WFE and 90-days egg production were obtained as negative but significant.

The genetic correlations of 8-week body weight with 16 and 24-week body weight were negatively and significantly correlated similarly it was also correlated negatively and significantly with ASM, 90-days egg production and clutch size.

The body weight of 12-week with WFE; of 16-week body weight with 24 week body weight and between 20week and clutch size were found to be negative and significant. Similarly, 24-week body weight was achieved as correlated negatively and significantly with ASM and WFE, while negative and significant correlations were seen between WSM with ASM and clutch size. Age at sexual maturity was also found to have negative and significant genetic correlation with WFE and 90-days egg production; and weight of first egg with clutch size and between 90-days egg production and clutch size were also negatively and significantly correlated at 50 per cent level of inbreeding coefficient.

The positive and significant correlations were observed between 16-week body weight 20-week weight and between 20-week body weight with 24-week body weight and weight of first egg. Weight at sexual maturity was correlated positively and significantly with weight of first egg in 50 per cent inbred flock. This indicated that if pullets have achieved high body weight earlier then they were also expected to maintain higher weight at later stage and weight of first egg. Rest of the genetic correlations were non-significant.

In 59 per cent inbred flock the genetic correlations were obtained positive and significant among 0-week body weight with 24-week weight and clutch size and between 8 and 16-week of age. Similarly, 12-week body weight was correlated positively and significantly with 20-week body weight, WSM, ASM and 90-days egg production, 16-week body weight with WSM while correlations between 20-week body weight with age at sexual maturity was negative and significant. The negative and significant correlations were observed between other production traits in 59 per cent inbred flock.

The genetic correlations of control population from sire + dam component of variance were mostly non-significant except 0-week with WSM; and 4-week body weight with 12, 20 and 24-week body weight which were obtained as positive and significant. The positive and significant correlation were also found between 8-week with 12-week and age at sexual maturity.

Similarly, the 12-week body weight was correlated positively and significantly with clutch size. The 20-week was found to be positively and significantly correlated with age at sexual maturity.

The negative and significant correlations were obtained among 0-week with 24-week, between 4 and 8-week body weight with 90-days egg production; and between 12 and 16-week body weight with age at sexual maturity. Based on sire + dam components of variance the 24-week body weight was negatively and significantly correlated with age at sexual maturity, weight of first egg, 90-days egg production and clutch size. It was also observed that weight of first egg was negatively and significantly correlated with clutch size.

This indicated that inbreds did not exactly corroborate with the control flock. Most of the associations were non-significant but 59 per cent inbred and control flock had more positive correlations than 50 per cent inbred.

The result did not agree with the findings of Bhushan (1984), Rai (1988), Kushwaha *et al.* (1989), Khare (1991) and Sharma (1995), who found most of them significant when inbreeding effect and effects of nutritional, managemental and other environmental factors were eliminated.

(ii) Phenotypic correlations

The findings of phenotypic correlations are presented in Table 13, 16 and 19 for 50 per cent inbred, 59 per cent inbred and control flock, respectively.

The phenotypic correlation of 0-week weight with 4-week weight was negative and significant while it was correlated positively and significantly with other monthly body weights. Other body weights were non-significantly correlated except 8-week weight with 24 week weight.

The similar combinations of traits were used 59 per cent flock and correlations were found to be negative and significant between day old and 4-week weight while it was correlated positively and significantly with 12, 16, 20 and 24-week body weight. Four week body weight also showed positive and significant correlations with 16, 20 and24-weeks body weight.

In control flock the phenotypic correlations of 0-week with 4, 16 and 20-week body weight were obtained as negative and significant while it was correlated positively and significantly with 8, 12 and 24-week body weight

It is reasonable to conclude that most of the correlations were non-significant in all three flocks and same trends of correlations were observed in 50 per cent, 59 per cent inbreds and control flock. These finding did not corroborated with Kumar (1983). Bhushan (1984), Rai (1988), Kushwaha *et al.* (1989) and Kumar (1989).

The phenotypic correlations of 0 to 12-week body weight WSM were positive and significant while the phenotypic correlations of body weight at 4, 16, 20 and 24-weeks and WSM with age at sexual maturity were positive and significant. Negative and significant correlations of 0, 8 and 12-weeks body weight with age at sexual maturity in 50 per cent inbred were observed.

The positive and significant correlations were observed between 0, 8, 16 and 20-week body weight, weight at sexual maturity and age at sexual maturity with weight of first egg while the correlations between 4, 12 and 24-weeks weight with W.F.E. were negative and significant.

The phenotypic correlations were positive and significant between 0, 8, 16 and 20-week body weight and weight of first egg with 90-days egg production. The correlations were negative and significant among 4, 12 and 24-week body weight. WSM and age at sexual maturity with 90-days egg production. Similarly correlations of 4 to 20-weeks body weight and WSM with clutch size were positively significant and those of 0-week body weight, WFE and 90-days egg production with were negative and significant at 50 per cent level of inbreeding coefficient.

The estimation of phenotypic correlation in 59 per cent inbred flock was made. The correlation of 0, 4 and 12-week weight with weight at sexual maturity were positive and significant; whereas those of 4, 8, 12, 20 and 24-weeks weight with age at sexual maturity were negative and significant. The correlation of 0 week weight with age at sexual maturity was positive and significant.

The positive and significant correlations were found between 0, 8, 20-weeks weight and weight at sexual maturity with weight of first egg, but weight of 4, 16 and 24-week were correlated negatively and significantly with weight of first egg.

The 0, 12, 16 and 20-week body weight and weight at sexual maturity were positive and significant correlated with 90-days egg production while negative and significant correlation were seen between age at sexual maturity and weight of first egg with 90-days egg production.

The correlations of clutch size with 0, 4, 12, 16 and 24-weeks body weight and weight at sexual maturity were negative and significant except a positive and significant correlation between weight of first egg with clutch size. The rest associations were non-significant.

The above association signified the fact that higher the early body weights more would be the weight at maturity and thus reduce the age at sexual maturity. This also indicated that higher the body weight at maturity higher would be the weight of first egg. This was in close agreement with the findings of Bhushan (1984) and Kushwaha *et al.* (1989).

In control flock monthly body weights (0 to 24-weeks) and weight at sexual maturity were correlated positively and significantly. It indicated that higher the body weight, higher would be the weight at sexual maturity.

The phenotypic correlations between 4, 12, 20-weeks body weight, weight at sexual maturity and weight of first egg with 90-days egg production were found to be positive and significant while 8, 16-weeks body weight and age at sexual maturity were negatively and significantly correlated with 90-days egg production.

These findings indicated that most of the correlations were significant in all the three flocks but 59 per cent inbred flock had correlations of lesser magnitude than 50 per cent inbred and control flock. These findings were in agreement with Bhushan (1984) and Kushwaha *et al.* (1989).

Environmental correlations

The environmental correlations based on sire and sire + dam components of covariance are presented in Table 14, 17 and 20 for 50 per cent inbred, 59 per cent inbred and control flock, respectively.

Most of the environmental correlations among the growth and production traits as per sire and sire + dam components of covariance were positive in both inbreds and control flock.

The values of environmental correlations in 50 per cent inbred, 59 per cent inbred and control flock were similar but they are smaller than those reported by Iqbaluddin (1972), Singh (1977), Kumar (1983), Tayyab (1983) and Bhushan (1984).

Partial correlations

The simple and partial correlations among the traits are presented in Table 21, 22 and 23 for 50 per cent, 59 per cent inbred and control flock, respectively.

The simple correlations in 50 per cent inbred flock between growth traits were mostly significant while they were non-significant with production traits except 20 and24-week body weight which were mostly correlated with production traits.

The partial correlations between 0-week body weight with 8-week body weight and weight of first egg were significant while keeping all other traits constants. The partial correlations between 4-week body weight with 8, 12 and 24-week weight were also significant. It was also significant with weight at sexual maturity and age at sexual maturity when other traits were kept constant.

The result indicated that 8-week body weight with 12-week body weight and 16-week body weight with 20 and 24 week body weight had significant partial correlations. The 16-week body weight had also signficant partial correlation with weight at sexual maturity, age at sexual maturity, 90-days egg production and clutch size.

The 20-week body weight was significantly associated with 24-week body weight, weight at sexual maturity, age at sexual maturity and 90-days egg production when other traits were kept constant.

The 24-week body weight achieved signficant correlation with weight at sexual maturity, weight of first egg and clutch size. The weight at sexual maturity with age at sexual maturity and weight of first egg were significantly correlated while it was seen that age at sexual maturity with weight of first egg, 90-days egg production and clutch size were significantly correlated. Weight of first egg with 90-days egg production and clutch size had significant correlation.

In the present study the simple correlations among the traits in 59 per cent inbred flock were found to be mostly significant while the partial correlations of 0-week body weight with 8, 12 and 20-week body weight were significant. The 4-week body weight was significantly associated with 8-week body weight and weight of first egg.

The 20-week body weight with 24-week body weight and 24-week body weight with weight at sexual maturity were also correlated significantly when all other traits were eliminated.

It was found that weight at sexual maturity with age at sexual maturity and weight of first egg; and age at sexual maturity with weight of first egg significantly correlated. The weight of first egg with 90-days egg production was also significantly correlated when keeping all other traits constant.

The finding of present study did not agree with Iqbaluddin (1972) and Singh (1976) because they used the first order partial correlation while in the present study we used the 'p' order partial correlations and kept all other traits constant while estimating the partial correlations between any two traits.

In the control flock the simple correlations among the traits were mostly significant except growth traits with production traits. The partial correlations of 0-week with 12-week, 16-week and weight at sexual maturity were found to be significant. The 4-week body weight with 8-week body weight and 8-week body weight and 24-week body weight were found to be correlated significantly when other traits were kept constant.

The partial correlations of first order reported by Iqbaluddin (1972) and Singh (1976) and did not agree with the present study.

Regression

Linear regression

The linear regression coefficients were computed to determine the effect of independent economic traits on dependent traits individually and are presented in Table 24, 25 and 26 for 50 per cent, 59 per cent inbred and control flock, respectively.

In the 50 per cent inbred flock, the monthly body weights (0-week to 24-week) were considered as independent variable while body weight at sexual maturity and age at sexual maturity as dependent variable. The body weight at sexual maturity had significant regression on 8, 12, 16, 20 and 24-week body weight. In case of age at sexual maturity the regression coefficients on 0, 4, 8, 12, 16, 20 and 24-week body weight were statistically significant.

In second set of analysis monthly body weight (0-week to 24-week), WSM and ASM were considered as independent variable while the weight of first egg was considered as dependent variable. The weight of first egg had negative and significant regression over 16-week body weight. The highest R^2 value (1.35per cent) was observed for 16-week body weight.

When body weight (0-weight to 24-week), WSM, ASM and weight of first egg was considered as independent variable while the 90-dyas egg

In the present study the simple correlations among the traits in 59 per cent inbred flock were found to be mostly significant while the partial correlations of 0-week body weight with 8, 12 and 20-week body weight were significant. The 4-week body weight was significantly associated with 8-week body weight and weight of first egg.

The partial correlations of first order reported by Iqbaluddin (1972) and Singh (1976) and did not agree with the present study.

The 20-week body weight with 24-week body weight and 24-week body weight with weight at sexual maturity were also correlated significantly when all other traits were eliminated.

It was found that weight at sexual maturity with age at sexual maturity and weight of first egg; and age at sexual maturity with weight of first egg significantly correlated. The weight of first egg with 90-days egg production was also significantly correlated when keeping all other traits constant.

The finding of present study did not agree with Iqbaluddin (1972) and Singh (1976) because they used the first order partial correlation while in the present study we used the 'p' order partial correlations and kept all other traits constant while estimating the partial correlations between any two traits.

In the control flock the simple correlations among the traits were mostly significant except growth traits with production traits. The partial correlations of 0-week with 12-week, 16-week and weight at sexual maturity were found to be significant. The 4-week body weight with 8-week body weight and 8-week body weight and 24-week body weight were found to be correlated significantly when other traits were kept constant.

Regression

Linear regression

The linear regression coefficients were computed to determine the effect of independent economic traits on dependent traits individually and are presented in Table 24, 25 and 26 for 50 per cent, 59 per cent inbred and control flock, respectively.

In the 50 per cent inbred flock, the monthly body weights (0-week to 24-week) were considered as independent variable while body weight at sexual maturity and age at sexual maturity as dependent variable. The body weight at sexual maturity had significant regression on 8, 12, 16, 20 and 24-week body weight. In case of age at sexual maturity the regression coefficients on 0, 4, 8, 12, 16, 20 and 24-week body weight were statistically significant.

In second set of analysis monthly body weight (0-week to 24-week), WSM and ASM were considered as independent variable while the weight of first egg was considered as dependent variable. The weight of first egg had negative and significant regression over 16-week body weight. The highest R^2 value (1.35per cent) was observed for 16-week body weight.

When body weight (0-weight to 24-week), WSM, ASM and weight of first egg was considered as independent variable while the 90-dyas egg production and clutch size as dependent variable, all the regression values obtained were statistically significant but negative. The highest R^2 (6.04 per cent) was in weight of first egg and 90-days egg production combination (85.31 per cent) in 4-week body weight and clutch size combination.

The similar trait combinations were used for 59 per cent inbred flock. The body weight at sexual maturity had significant regression on 8, 12, 16, and 24-week body weight while the age at sexual maturity had significantly negative regression on monthly body weights (4-week to 24-week).

In second set of analysis all regression values were significant except at age at sexual maturity. In the third set of analysis, the linear regressions of 90-days egg production on various idependent traits were significant except on 0-week body weight and age at sexual maturity. The highest R^2 value of 4.2 per cent was for 24-week body weight. The regression coefficients of clutch size on 4, 8, 12, 16 and 24-week body weight, weight at sexual maturity, age at maturity and weight of first egg were significant with highest R^2 value (87.31 per cent) for 4-week body weight.

The simple linear regression were negative and non-significant except body weight at sexual maturity on 24-week body weight with highest R^2 value of 10.36 per cent in control flock.

In control flock the age at sexual maturity was regressed on the 4, 8, 12, 16, 20 and 24-week body weight and the regression values were obtained as negative and significant with highest R^2 value of 74.63 per cent for 4-week body weight during first set of analysis. The regression of first egg weight was found to be significant on 24-week weight and weight at sexual maturity. The weight at sexual maturity had the greatest R^2 value (29.15 per cent) in second set of analysis.

In the third set of analysis the 90-days egg production had significant regression on 24-week body weight and weight at sexual maturity. The clutch size had negative and significant regression on 4, 8, 12, 16, 20 and 24-week body weight age at sexual matrity and weight of first egg.

Thus, the linear regression analysis can be used in predicting the future performance of lines.

Multiple regression

The performance of two levels of inbred (50 and 59 per cent) and a control flock of White Leghorn were used and multiple linear regression analysis was estimated among the growth and production triats for the present study. The results are given in Table 27, 28 and 29 for 50 per cent inbred. 59 per cent inbred and control flock, respectively.

In 50 per cent inbred the monthly body weights (0-week to 24-week) were considered as independent traits while the body weight at sexual maturity, age at sexual maturity and clutch size were kept as dependent traits. The multiple linear regression of sexual maturity on 4 and 12-week body weight was negative and significant but it was positive and significant on 24-week body weight with significant value of coefficient of determination as (0.3846).

The age at sexual maturity showed negative and significant regression on 12-week body weight and positive and significant regression on 24-week body weight with significant R^2 value. The clutch size showed significant regression on 24-week body weight with significant R^2 value (0.1067).

In the second set of analysis monthly body weights (0-week to 24-week), WSM and ASM were considered as independent traits and weight of first egg was kept as dependent trait. The multiple linear regression was significant for 0, 20 and 24-week body weight, weight at sexual maturity and age at sexual maturity on first egg with the significant R^2 value (0.5535).

In the third set of analysis the monthly body weights (0-week to 24-week), WSM, ASM and weight of first egg were considered as independent trait while the dependent trait was 90-days egg production. The significant multiple linear regression were obtained with 16, 20, 24-week body weight, weight at sexual maturity and weight of first egg and coefficient of determination was also significant (R^2 value = 0.3671).

The similar combinations were followed in 59 per cent inbred flock. The multiple linear regression of body weight at sexual maturity on 20 and 24-week body weight were significant with significant value of coefficient of determination (R^2 value 0.1579) while age at sexual maturity on 16, 20 and 24-week body weight were significant with significant R^2 vaue (0.1938). The weight of first egg had significant regression on 0, 4, 12-week body weight,

weight at sexual maturity and age at sexual maturity with significant coefficient of determination (0.2343).

The significant regressions were found for 90-days egg production on 4-week body weight and age at sexual maturity with the significant R^2 value (0.1196). The multiple regressions of clutch size on 4 and 24-week body weight were found to be significant. R^2 value was also significant (0.0691).

In the control flock, the multiple regressions were mostly non-significant except body weight at sexual maturity on 24-week body weight and age at sexual maturity which was regressed on 16 and 24-week body weight. The coefficient of determinations were found to be significant (R^2 value 0.1355 and 0.0945, respectively).

The multiple regression of weight of first egg on 16, 20-week body weight, weight at sexual maturity and age at sexual maturity were obtained as significant which also showed significant coefficient of determination (0.7890). The significant regression was seen for 90-days egg production on weight of first egg with significant R^2 value (0.4805). It was clear from the Table that clutch size showed non-significant regression over all traits and it had non-significant value of coefficient of determination (0.0205).

The three population behaved differently at genetic level. The estimates of 50 per cent and 59 per cent level of inbreeding could not show a definite trend.

The 59 per cent inbred population did not show inbreeding depression when compared with control population. The stock with 50 per cent level of inbreeding showed marked and significant depression when compared with control population for growth and production traits. However, the body weights were less affected by inbreeding which was in agreement with Abplanalp and Woodard (1967) and Kumar (1989).

SUMMARY

SUMMARY

In present investigation the effects of inbreeding on different growth and productive traits viz., body weights from 0 to 24 week of age, weight and age at maturity, first egg weight, 90 day egg production and clutch size were studied. The performance records of 342 female birds (from 20 sires and 78 dams) with 50 per cent inbreeding and 612 female birds (from 32 sires and 151 dams) with 59 per cent inbreeding were studies with control flock of 174 female progenies (from 16 sires and 46 dams) of Babcock strain of White Leghorn. The full-sib mating were adopted in each generation to create inbred lines at Poultry Research Centre, G.B. Pant University of Agriculture & Technology, Pantnagar.

The hatch effects on various characters were tested and removed by least squares technique and the corrected data were analysed to estimate the genetic parameters.

The least squares means with their S.E., S.D. and C.V. were computed for two generations of full-sib mating (50 and 59 per cent) and control flock. The comparison of inbreds mean with control flock indicated that inbreeding has deleterious effect on body weight at 0-week (33.80 ± 0.17 g), 8-week (359.29 ± 2.00 g), 12-week (606.07 ± 3.20g), 16-week (741.06 ± 5.37 g), 20-week (920.88 ± 6.69g) of age, age at sexual maturity (201.19 ± 2.01 days), 90-days egg production (43.65 ± 0.74), and clutch size (2.10 ± 0.04) at 50 per cent level of inbreeding coefficient.

At 59 per cent, inbreeding it did affect body weight at 0-week (34.50 ± 0.14g), 12-week (633.66 ± 5.05g) of age, age at sexual maturity (190.81 ± 1.00 days) and clutch size (1.81 days).

The comparison of means at two levels of inbreeding with control population suggested decline in growth and productive traits. It was observed that 50 per cent inbreeding coefficient acted more deleteriously than 59 per cent. The homozygosity has increased to a level where amount of variation was less for growth and productive traits.

The heritability estimates of various economic traits obtained from 50 per cent inbred flock data ranged between 0.187 ± 0.127 to 0.780 ± 0.317 and 0.006 ± 0.094 to 0.693 ± 0.224 from sire and sire + dam components of variance, respectively.

The heritability ranged from 0.048 ± 0.084 to 0.574 ± 0.201 and 0.009 ± 0.066 to 0.701 ± 0.129 from sire and sire + dam component of variance, respectively in 59 per cent inbred flock.

In control flock the heritability ranged from 0.025 ± 0.181 to 0.549 ± 0.304 from sire component and 0.014 ± 0.132 to 0.899 ± 0.335 from sire + dam components of variance.

Inbreeding affected the heritability estimates for majority of the characters in 50 per cent inbred flock. The growth and production traits in 59 per cent inbred showed similar trend.

The genetic correlations among all the growth and production traits from sire components of variance and covariance were mostly non-significant in 50 per cent inbred flock except the 8-week body weight with 20 and 24-week body weight; 12-week with 16-week body weight and 16-week body weight with 24-week body weight which were positively and significantly correlated. It indicated that if birds have fast growth rate at early stage they will achieve heavy body weight at later stage of growth. It was also seen that mostly growth traits and weight at sexual maturity were correlated negatively and significantly with age at sexual maturity. It means birds with fast growth and high weight at sexual maturity exhibit reduced age at sexual maturity which is advantageous. Negative and significant correlation of ASM with 90-days egg production suggested that birds with declined ASM will achieve heavy egg weight and high egg production.

The genetic correlation among the traits in 59 per cent inbred flock from sire components of variance and covariance were found to be non-significant except 8-week with 20 and 24-week body weight, 12-week with 16-week, and 16-week with 24-week which were positively and significantly correlated while correlations with ASM were negative.

The genetic associations were mostly non-significant in control flock as per sire components of variance and covariance except 4-week body weight with 20-week and 12, 16 and 20-week with 24-week body weight. It was concluded that improvement in 4-week body weight will directly influence the later body weight of birds. The fast growing birds have early maturity and increased egg production.

In 59 per cent inbred flock some early growth traits were positively and significantly correlated with WSM.

In control flock the genetic correlations were mostly non-significant except 4-week body weight which was correlated positively and significantly with 12, 20 and 24-week body weight. The body weight at 4-week could be considered for selecting the birds for future breeding.

The phenotypic correlations were mostly significant for growth and production traits. The environmental correlations have zero to small trend.

The partial correlations showed that most of the association were non-significant in all the three flock except 0-week with 8-week, 4 with 12 and 24-week, 8-week with 12-week and 16-week with 20-week body weight which were positively and significantly correlated.

The 59 per cent inbred flock had some what better association than the 50 per cent inbred. The linear regression of weight at sexual maturity were positive and significant on monthly body weights (8-week to 24-week) with greatest contribution of 24-week body weight (R^2 = 5.16 per cent)

The age at sexual maturity had mostly negative and significant regression on monthly body weights. The 90-days egg production and clutch size had negative and significant regression on growth and other production traits in 50 per cent inbred flock.

The linear regressions were mostly significant in 59 per cent inbred flock. The age at sexual maturity had negative and significant regression on monthly body weights. It was concluded that monthly body weight was responsible for linear improvement in age at sexual maturity while weight of first egg showed the negative and significant regression over monthly body weight and WSM. This indicated that birds achieving fast growth had reduced first egg weight. The 90-days egg production and clutch size had negative and significant regression on growth and production traits.

In control flock the age at sexual maturity showed negative and significant regression on the growth traits. The clutch size showed negative and significant regression on growth and production traits. The reduction in clutch size and age at sexual maturity showed that birds will have higher egg production in a particular period.

All the three populations behaved differently at genetic level. The estimates of 50 per cent and 59 per cent level of inbreeding could not show declining trend because of increase in inbreeding coefficient.

The 59 per cent inbred population showed higher performance than the control population whereas 50 per cent inbred population showed lower performance than the control.

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APPENDICES

Appendix -I : Averages, standard error, standard deviation and coefficient of variation of growth and production traits of the uncorrected data.

Characters	Levels of inbreeding						Control		
	50% Inbred			59% Inbred					
	Means ± SE	S.D.	C.V.	Means ± SE	S.D.	C.V.	Means ± SE	S.D.	C.V.
0-WK B.W. (g)	33.63 ± 0.19	3.51	10.43	34.50 ± 0.14	3.52	10.23	35.10 ± 0.28	3.64	10.36
4-WK B.W. (g)	156.36 ± 1.29	23.84	15.25	177.13 ± 1.39	34.53	19.49	157.68 ± 2.99	39.50	25.05
8-WK B.W. (g)	361.78 ± 1.96	36.34	10.04	360.33 ± 4.04	100.12	27.79	371.55 ± 6.12	80.66	21.71
12-WK B.W. (g)	602.39 ± 3.61	66.80	11.09	633.66 ± 5.05	124.98	19.72	646.09 ± 10.37	136.88	21.19
16-WK B.W. (g)	742.31 ± 5.83	107.81	14.52	896.84 ± 4.29	106.17	11.84	842.47 ± 12.81	169.04	20.06
20-WK B.W. (g)	921.52 ± 7.26	134.31	14.57	1073.47 ± 5.03	124.38	11.59	1018.10 ± 16.38	216.02	21.22
24-WK B.W. (g)	1191.62 ± 10.89	201.40	16.90	1258.15 ± 5.40	133.63	10.62	1182.07 ± 20.62	271.98	23.00
W.S.M. (g)	1355.40 ± 14.70	271.98	20.07	1405.35 ± 5.96	147.48	10.49	1312.18 ± 32.05	422.82	32.22
A.S.M. (days)	200.48 ± 2.13	39.34	19.62	190.75 ± 1.02	25.22	13.22	176.58 ± 4.39	57.97	32.83
W.F.E. (g)	42.70 ± 0.60	9.39	22.00	40.98 ± 0.19	4.76	11.61	41.37 ± 1.01	13.36	32.28
90-days E.P. (Nos)	43.65 ± 0.74	13.73	31.45	50.50 ± 0.31	7.79	15.41	45.87 ± 1.42	18.78	40.93
C.S. (days)	2.03 ± 0.04	0.70	34.32	1.83 ± 0.02	0.40	21.93	1.59 ± 0.05	0.72	45.19

Appendix II: Least squares constants for hatch effects (h_i) of 50% Inbred, 59% Inbred and control population

(A) 50% Inbred

Generations/ hatches	Characters											
	0-WK B.W.	4-WK B.W.	8-WK B.W.	12-WK B.W.	16-WK B.W.	20-WK B.W.	24-WK B.W.	W.S.M.	A.S.M.	W.F.E.	90-day E.P.	C.S.
1.	0.00	4.550	0.00	0.00	0.013	-1.059	9.663	0.774	15.635	9.100	10.240	104.561
2.	0.00	-14.603	0.00	0.00	-0.294	-0.046	28.038	14.611	57.427	94.366	98.979	132.345
3.	0.00	-2.967	0.00	0.00	-0.017	-1.747	3.955	3.951	11.269	67.111	90.626	69.124
4.	0.00	3.527	0.00	0.00	0.035	-0.189	1.841	-14.412	-1.114	14.467	30.437	53.893
5.	0.00	6.594	0.00	0.00	0.0916	-0.452	-2.274	-10.367	-6.114	-16.894	-7.218	-4.789
6.	0.00	-13.260	0.00	0.00	-0.211	-1.537	-2.966	-12.804	-33.734	6.167	-39.886	-77.330
7.	0.00	12.873	0.00	0.00	0.0469	-0.523	-8.882	-2.835	-22.091	-25.819	-33.994	-60.495
8.	0.00	12.047	0.00	0.00	0.0364	-0.456	-5.804	-6.719	-19.492	-26.957	-14.110	-18.219
9.	0.00	-2.881	0.00	0.00	-1.384	0.759	-3.586	-9.138	-52.058	-57.675	-75.256	-41.681
10.	0.00	2.267	0.00	0.00	-0.212	0.021	-16.882	-2.713	3.453	-17.334	-20.812	-34.434
11.	0.00	-30.901	0.00	0.00	-.554	3.667	4.663	32.623	53.278	-11.247	-26.169	-96.106
12.	0.00	22.146	0.00	0.00	0.438	-0.296	-2.336	0.861	-2.197	-28.925	-24.145	-60.571
13.	0.00	11.313	0.00	0.00	0.473	2.453	8.913	3.445	-0.864	-25.175	-22.062	-76.820
14.	0.00	3.479	0.00	0.00	-0.288	-0.203	-3.996	-0.805	0.301	3.574	9.187	-34.738
15.	0.00	-14.186	0.00	0.00	-0.293	-0.389	9.655	1.528	-3.697	15.241	24.187	145.263

(B) 59% Inbred

Generation/ hatches	Characters											
	0-WK B.W.	4-WK B.W.	8-WK B.W.	12-WK B.W.	16-WK B.W.	20-WK B.W.	24-WK B.W.	W.S.M.	A.S.M.	W.F.E.	90-day E.P.	C.S.
1.	-26.143	-3.942	-1.041	-0.675	0.0245	0.00	12.946	0.00	0.00	18.730	0.00	0.00
2.	-25.209	-5.788	-0.407	0.503	-0.033	0.00	3.039	0.00	0.00	43.407	0.00	0.00
3.	49.857	6.181	0.893	-0.970	0.042	0.00	-1.415	0.00	0.00	23.959	0.00	0.00
4.	0.467	3.394	-0.163	-0.692	0.047	0.00	4.282	0.00	0.00	2.106	0.00	0.00
5.	-6.594	2.886	0.531	-2.384	0.161	0.00	-10.062	0.00	0.00	-8.790	0.00	0.00
6.	2.742	2.116	0.405	-0.301	-0.012	0.00	0.325	0.00	0.00	-19.381	0.00	0.00
7.	-0.869	0.818	1.458	3.810	-0.144	0.00	-21.726	0.00	0.00	-75.899	0.00	0.00
8.	6.684	-5.665	-1.678	0.715	-0.085	0.00	12.611	0.00	0.00	15.867	0.00	0.00

(B) 59% Inbred

Generation/ hatches	Characters											
	0-WK B.W.	4-WK B.W.	8-WK B.W.	12-WK B.W.	16-WK B.W.	20-WK B.W.	24-WK B.W.	W.S.M.	A.S.M.	W.F.E.	90-day E.P.	C.S.
1.	-26.143	-3.942	-1.041	-0.675	0.0245	0.00	12.946	0.00	0.00	18.730	0.00	0.00
2.	-25.209	-5.788	-0.407	0.503	-0.033	0.00	3.039	0.00	0.00	43.407	0.00	0.00
3.	49.857	6.181	0.893	-0.970	0.042	0.00	-1.415	0.00	0.00	23.959	0.00	0.00
4.	0.467	3.394	-0.163	-0.692	0.047	0.00	4.282	0.00	0.00	2.106	0.00	0.00
5.	-6.594	2.886	0.531	-2.384	0.161	0.00	-10.062	0.00	0.00	-8.790	0.00	0.00
6.	2.742	2.116	0.405	-0.301	-0.012	0.00	0.325	0.00	0.00	-19.381	0.00	0.00
7.	-0.869	0.818	1.458	3.810	-0.144	0.00	-21.726	0.00	0.00	-75.899	0.00	0.00
8.	6.684	-5.665	-1.678	0.715	-0.085	0.00	12.611	0.00	0.00	15.867	0.00	0.00

(C) Control population

Generation/ hatches	Characters											
	0-WK B.W.	4-WK B.W.	8-WK B.W.	12-WK B.W.	16-WK B.W.	20-WK B.W.	24-WK B.W.	W.S.M.	A.S.M.	W.F.E.	90-day E.P.	C.S.
1.	149.360	16.906	0.00	0.00	0.162	-2.877	47.255	49.759	103.602	93.822	114.343	143.974
2.	108.503	7.449	0.00	0.00	0.375	-0.544	28.655	35.140	103.507	145.822	185.581	159.852
3.	202.431	12.758	0.00	0.00	0.118	-2.782	24.346	26.033	48.388	120.703	181.176	177.233
4.	189.186	20.712	0.00	0.00	0.192	-1.254	10.075	-1.660	60.298	82.924	127.589	136.643
5.	152.268	24.064	0.00	0.00	0.675	-1.393	-12.556	-66.937	-30.215	10.671	36.403	36.129
6.	14.693	34.417	0.00	0.00	0.068	-0.100	-31.455	-36.129	-109.508	-114.177	-147.434	-135.385
7.	98.026	3.223	0.00	0.00	-0.064	-0.711	-24.844	13.176	59.102	27.489	24.510	78.781
8.	-318.839	-26.471	0.00	0.00	-0.414	2.566	-29.011	-32.795	-137.286	-167.510	-220.767	-374.274
9.	-375.003	-38.845	0.00	0.00	-0.637	3.061	-2.556	-25.118	-136.579	-125.692	-183.596	-232.052
10.	-208.640	-41.026	0.00	0.00	-0.312	0.538	-21.511	-0.573	18.397	-77.510	-136.323	-22.052
11.	-012.187	-13.188	0.00	0.00	-0.163	-3.498	12.601	39.103	-057.087	3.457	18.515	31.175

CURRICULUM VITA

The author of the thesis, Pramod Kumar Sharma, was born on 1st February, 1971 at village Rajpur in Etah District of Uttar Pradesh. He passed Highly School and Intermediate examinations in 1986 and 1988, respectively. Thereafter, in 1988, he joined the Narian College, Agra University, Agra and got the degree of B.Sc. Ag. (Honours). He joined the College of P.G.S., G.B. Pant University of Agriculture & Technology, Pantnagar in 1993 and got the degree of M.Sc. Ag. (Animal Breeding) in the year of 1996. In September 1996 he was admitted to Ph.D. degree with major in Animal Breeding and minor in statistics.

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