GENETIC AND PHENOTYPIC RELATIONSHIPS AMONG BODY SIZE, BODY CONDITION AND EGG PRODUCTION IN CHICKENS

by

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DISSERTATION
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CERTIFICATE -I

This is to certify that this dissertation entitled "Genetic and phenotypic relationship among body size, body condition and egg production of chickens" submitted for the degree of Doctor of Philosophy in the subject of Animal Breeding of the Punjab Agricultural University, is a bonafide research work carried out by M. Prakash Babu under my supervision and that no part of this dissertation has been submitted for any other degree.

The assistance and help received during the course of investigation have been fully acknowledged.

Major Adviser 10/1/78

CERTIFICATE -II

This is to certify that the dissertation entitled "Genetic and phenotypic relationships among body size, body condition and egg production of chickens" submitted by M.Prakash Babu to the Punjab Agricultural University in partial fulfilment of the requirements for the degree of Doctor of Philosophy in the subject of Animal Breeding has been approved by the student's Advisory Committee after an oral examination on the same, in collaboration with an External E aminer.

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TO MY PARENTS

C O N T E N T S

Chapter I

INTRODUCTION

Body weight in egg-type chickens is important because of its influence on feed efficiency, egg size and egg production. Birds with small body are preferred because they require less feed for body maintenance. However, reducing body weight below a certain limit may not be desirable from the standpoint of egg production and egg size.

Nordskog and Briggs (1968) made a useful distinction between body-size (bone-framework) and body-condition (fleshing) as two components constituting body weight. They have shown that fleshing or condition was economically important in terms of laying house performance and the variation in condition is mostly determined by husbandry practices.

The two components of body weight are reported to have different genetic constitution and also different relationship with egg production. The genetics of body-size, and body-condition and their relationship with egg production and other economic characters are not very well known. The present investigation is, therefore, conducted to study (a) the criteria of measuring body-condition and body-size (b) genetic, phenotypic and environmental correlations among body weight, body-size, body-condition, egg production and egg weight, (c) inheritance of these traits and (d) optimum body weight for egg production and egg size. Based on these data, an attempt has been made to develop a selection index for maximizing the genetic gains for economic merit.

REVIEW OF LITERATURE

Body weight and feed efficiency

Feed cost accounts for about two-third of the total cost of egg production. The feed consumed by the layers is used for maintenance, growth to a certain age and egg production. A major portion of the feed consumed by the layers is used for body maintenance. The large birds would use relatively more of the feed for maintenance than the smaller birds.

Joshi et al. (1949) in a study involving New Hampshire laying pullets observed that when these birds were laying at the rate of about 72 percent, 71 percent of the feed consumed was used for maintenance, 2 percent for increase in body weight and 27 percent for production of eggs.

Byerly (1941) has shown that the annual feed requirement for maintenance varied from 21.3 kg for birds weighing 1.4 kg to 37 kg for 3.2 kg birds. In addition, 6.45 kg of feed was required above that consumed for maintenance, for every 100 eggs produced.

Kleiber (1932) reported that the maintenance requirements increased with the 0.75 power of body weight. Brody et al. (1938) pointed out that for larger birds to be as efficient as the smaller birds, both laying at the same rate, the former must produce larger eggs to offset the higher maintenance cost. He concluded that if maintenance costs increase with 0.75 power of body weight, egg size also must increase with the same power for equal efficiency.

Egg size however, seems to increase only with 0.15 power of body weight. Hence, small birds are more efficient than the larger birds not only because they have lower body maintenance requirements but also because their egg size relative to body weight is greater.

Body weight and reproductive performance

Doran and Quisenberry (1971) divided 5180 Leghorn pullets into three weight classes and subsequently monitored reproductive performance until 50 percent production was obtained. Egg size and production was maximum for heavier birds and intermediate for the medium weight birds. Heavy and medium-weight birds reached 50% egg production earlier than the light-weight birds.

Dickerson and Hughes (1964), while reviewing the reproductive performance in several commercial field tests, reported that for each 45 grams below optimum body weight, egg production declined 1.0 to 1.5 percent and sexual maturity was delayed by three to four days.

Reinhart and Jerome (1970) examined the relationship between body weight and egg production in Leghorn lines selected for both increased egg numbers as well as bidirectionally for small and large body size. The large-body lines averaged 4.6 percent higher egg production than the control lines over the entire laying period.

Results of Random Sample Egg Laying Tests in USA and Canada showed that the White Leghorn entries which were intermediate in body weight produced the highest income (Nordskog, 1960).

Both positive and negative correlations between body weight and egg production have been reported. Within lines, very small birds tend to lay less eggs than the larger birds, but extremely large birds also lay fewer eggs (Hogsett and Nordskog, 1958).

Optimum body weight in relation to egg production and egg weight

Du Plessis and Erasmus (1972) conducted investigation to establish the ideal body weight in relation to egg production and egg size.

In case of White Leghorn a quadratic regression equation was obtained between total egg production and weight at sexual maturity and also between total egg production and mature body weight. For the production of standard-sized eggs (56 grams and above) the same relationship was obtained. Egg production declined very sharply when the pullets weighed 2.04 kg or more. The decline was 14 egg for every 0.23 kg increase in body weight. If egg weight is considered, pullets weighing 1.36 kg at sexual maturity produced only 162 eggs out of the total of 212 eggs weighing 56.75 grams or more. For every extra 0.45 kg in body weight there was an increase of 25 eggs weighing more than 56.75 g per bird. This increase in the production of standard-sized eggs continued until the hen reached an average body weight of 2.04 kg. Birds weighing more than 2.04 kg at sexual maturity laid fewer standard-sized eggs. The relationship between egg production, egg weight and mature body weight followed the same pattern as in the previous case. The only difference was that the increase and decrease was sharper in production. The ideal mature body weight of White Leghorn pullets was 2.04 kg.

Maximum performance is obtained when husbandry practices permit the flock to reach its optimum for body weight. Theoretically each strain would have a different optimum for each environment. A diet well balanced for all the nutrients is an important component of the environment. The practices that causes body weight to deviate from optimum norm would lower the egg production.

Kurdjeekov (1967) observed that each breed has an optimum body weight till which production was positively correlated with size and after which the correlation turned negative.

Components of body weight

The weight of chickens depends upon (1) the size of its skeleton (2) the amount of organs, muscles, skin and feathers supported by that skeleton and (3) the amount of stored-fat.

The second and third of these variables, particularly the last, may change considerably with the environmental conditions but the skeleton is very little affected after maturity (Hutt, 1949).

Nordskog and Briggs (1968) examined the relationship between egg production and body weight based on the data of the Iowa Multiple Unit Poultry Test. They assumed that strain differences on the same farm were genetic while the farm differences with samples of the same strains were environmental. On an environmental scale, lowering body weight by 0.1 kg from an overall mean of 1.5 kg decreased hen-housed egg production by 18 eggs and increased age at sexual maturity by 14 days. However, on the genetic scale, lowering body weight by 0.1 kg increased hen-housed egg production by 12 eggs and decreased age at maturity by 4 days. The authors suggested that body weight is determined by skeletal size on a genetic scale and condition or fleshing on an environmental scale.

When body weight is recorded, no distinction is usually made between body-size (bone-framework) and body-condition (fleshing). Morris _et al._ (1966) reported that the correlation between shank weight and total skeletal weight was 0.703. Shank length should therefore, be a better single measure of size than body weight. The ratio of body weight to shank length might then be used as a criterion for body-condition. Flock differences in body weight/shank length ratio, largely reflect differences in management and feeding practices (Nordskog and Briggs, 1968).

Body-size (bone-framework) and egg production

Latimer (1924) found that 11 percent of the mature body weight of White Leghorn males and 8 percent of the body weight of their females consisted of skeleton. Schneider and Dunn (1924) in a study of outbred White Leghorns noted that increase in bone length ceased at an early age (about 160 days) and remained constant during rest of the life. They pointed out that the variability of bone measurements was only one-third to one sixth as great as the variability in body weight.

Several attempts have been made to find correlation between skeleton measurements and egg production but most of these have not revealed significant relationships. Waters (1927) was unable to predict egg production from skeletal dimensions based on data of White Leghorn pullets measured for width of cranium, length of beak, and length of keel.

Cleven, er and Hall (1934) in a study involving 262 White Leghorn pullets, found curvi-linear relationship between skeletal dimensions and egg production which, they concluded, could be used in the selection of birds for egg production.

Miller and Carver (1934) found no relation between skeletal dimensions and egg production of White Leghorn hens. In this connection it is interesting to consider the work of Sweet <u>et al.</u> (1928) who compared the skeletal structure of the beef and dairy cows. They found that the two types differed greatly in external form but in weight and size of the internal organs the differences were not large enough to cause significant differences in function. In skeletal structure the two breeds were generally similar. This would indicate that both breeds had a similar origin and the evolution of the two breeds, which has been accomplished through breeding and selection has not materially affected the skeletal structure but has brought about marked changes in function. Differences in type may be attributed to extreme fleshing in one group and udder development and lack of fleshing in the other group. The greatest difference between the beef and dairy cows seems to be in regard to physiological characters of milk and flesh production.

Jull (1932) applies the conclusions of Sweet <u>et al.</u> (1928) to the fowl, by observing that for the domestic fowl, the available evidence todate shows that the flesh and egg production are inherited largely independently of the skeletal structure.

Quisenberry et al. (1941) concluded that studies on skeletal dimensions should not only include lengths of bones but diameter as well. Bone area was calculated by multiplying circumference with length of the bone. This was a crude measure of surface area of bone, but when it was correlated with body weight higher correlation coefficients were obtained than with either diameter or length alone.

Heritabilities

Heritability estimates of various traits along with their unweighted averages are presented in tables 1 to 3.

Body weight: The heritabilities of body weight reported in literature are summarized in table 1. The unweighted average being 0.454 by the method of intra-sire regression of daughter on dam whereas it is being 0.454 and 0.51 from sire component and dam component of variance respectively. These reports from literature show the trait to be moderate to highly heritable.

Egg weight: The heritability estimates reported by different workers for egg weight are presented in table 2. Most of the estimates lie in the range of 0.50 to 0.81. The unweighted average of estimates from sire and dam component of variance is 0.475 and 0.476 respectively. The heritability of egg weight is thus in general moderate to very high.

Table 1. Heritability estimates of body weight reported in literature

Breed	Sire component	Dam component	Sire+dam component	Intrasire regression of daughter on dam	Reference
1	2	3	4	5	6
-	0.42	-	-	-	Lerner and Hazel (1947)
White Leghorn	0.17	-	0.472	0.796	Lerner and Cruden (1951)
Inbred, non-inbred lines of nine breeds	-	-	0.31	0.18±0.15	Wyatt (1954)
Rhode Island Red	0.85	-	0.71	0.72±0.11	Peeler *et al.* (1955)
New Hampshire	0.46	0.385	0.42	0.365	Goodman and Godfrey (1956)
Silvar Okalabars	0.45	0.675	0.565	0.44	-do-
Combination of seven light and heavy breeds	0.81	0.39	0.60	0.36±0.11	Hogsett and Nordskog (1956)
New Hampshire	0.73	0.27	0.50	-	Jerome *et al.* (1956)
White Leghorn, Rhode Island Red and Barred Plymouth Rock	-	-	0.43	-	Yamada (1958)
	0.28±0.18	0.75±0.21	0.48±0.099	-	Friars *et al.* (1962)

contd.

Contd. Table 1

1	2	3	4	5	6
White Leghorn	0.52±0.32	-	-	-	Hussain and Singh (1964)
Mating of eight meat type lines					
Production line	0.42±0.10	-	-	-	Kinney and Shoffner (1965)
Meat line	0.29±0.08	-	-	-	-do-
White Leghorn	-	-	0.87±0.01	-	Chhabra and Desai (1966)
White Leghorn	0.63±0.12	0.54±0.07	-	-	Clayton and Robertson (1966)
White Leghorn	-	-	0.66±0.25	-	Hill *et al*. (1966)
Light Sussex	0.70±0.21	0.47±0.12	0.59±0.10	-	Jaffe (1966)
Rhode Island Red	0.37±0.13	0.86±0.12	0.62±0.07	-	Jaffe (1966)
Leghorn	-	-	0.641	-	Nordskog *et al*. (1967)
Fayoumi	-	-	0.53	-	-do-
New Hampshire and White Leghorn	0.68±0.08	-	-	-	Kinney and Lowe (1968)
--	0.44±0.15	-	-	-	Craig *et al*. (1969)
New Hampshire	0.34	-	-	-	Chung *et al*. (1970)

contd.

Contd. table 1

1	2	3	4	5	6
White Leghorn	0.53±0.04	-	-	-	Sinha and Garewal (1970)
White Leghorn	0.67±0.29	0.79±0.19	0.74±0.17	-	Hussaini and Das (1971)
White Leghorn	0.15	-	-	-	Mohapatra and Ahuja (1971)
White Leghorn	0.31±0.19	0.42±0.08	0.36±0.10	-	Krishna and Chaudhry (1972)
White Leghorn	0.33±0.00	-	-	-	Nanda *et al.* (1973)
White Leghorns and Fayoumi	0.40±0.03	-	-	0.39±0.02	Nordskog *et al.* (1974)
Unweighted average	0.464	0.51	0.541	0.454	

Table 2. Heritability estimates of egg weight reported in literature

Breed	Sire component	Dam component	Sire+dam component	Intra-sire regression of daughter on dam	Reference
1	2	3	4	5	6
White Leghorn	0.481	-	0.361	0.608	Lerner and Cruden(1951)
-	0.53	-	0.50	0.64	Blow and Glazener(1954)
White Leghorn	-	-	0.34	0.60	King and Henderson(1954)
Combination of seven light and heavy breeds	-	-	0.68	0.43	Hogsett and Nordskog (1956)
White Leghorn	-	-	0.49	-	Abplanalp(1957)
White Leghorn	0.81	0.58	0.69	-	Hicks(1958)
New Hampshire	0.51	0.42	0.47	-	Hicks(1958)
Combination of seven light and heavy breeds	-	-	0.50	0.89	Hogsett and Nordskog(1958)
Barred Plymouth Rock, White Leghorn, Rhode Island Red	-	-	0.49	-	Yamada <u>et al.</u>(1958)
White Leghorn	-	-	0.71	-	Hale (1961)

contd.

Contd.

Table 2

1	2	3	4	5	6
-	0.70±0.29	0.80±0.16	0.75±0.12	-	Waring *et al.*(1962)
White Leghorn	0.80±0.37	-	-	-	Hussain and Singh(1964)
White Leghorn	0.51±0.11	0.52±0.09	-	-	Clayton and Robertson (1966)
White Leghorn	-	-	0.62±0.28	-	Hills *et al.*(1966)
Light Sussex	0.72±0.22	0.72±0.13	0.72±0.09	-	Jaffe (1966)
Rhode Island Red	0.41±0.13	0.60±0.11	0.50±0.07	-	Jaffe (1966)
White Leghorn	0.73	-	-	-	Kumar and Kapri(1966)
White Leghorn	-	-	0.21±0.07	-	Saeki *et al.*(1966)
Fayoumi	0.310	0.264	0.287	-	Amer (1967)
White Leghorn	0.46±0.23	0.63±0.25	0.54±0.20	-	Malik and Singh(1967)
Regional Red Controls	0.72±0.09	-	-	-	Kinney and Lowe(1968)
-	0.22±0.19	-	-	-	Craig *et al.*(1969)
New Hampshire	0.36	-	-	-	Chung *et al.*(1970)

contd.

Contd. table 2

1	2	3	4	5	6
White Leghorn	0.65	-	0.31	-	Mohapatra and Ahuja (1971)
White Leghorn	1.23	-	-	-	Mohapatra(1972)
Australorp	0.36	-	-	-	Mohapatra(1972)
White Leghorn	0.79±0.05	-	-	-	Nanda *et al.*(1973)
Unweighted average	0.475	0.476	0.537	0.572	

Table 3. Heritability estimates of egg production reported in literature

Breed	Sire component	Dam component	Sire+dam component	Intrasire regression of daughter on dam	Reference
1	2	3	4	5	6
White Leghorn	0.25	0.35	0.30	-	Lerner and Cruden (1948)
White Leghorn	0.19	0.36	0.27	0.19	King and Henderson (1954)
Rhode Island Red	-	-	0.252	-	Maddison(1954)
Inbred and non-inbred lines of nine breeds	-	-	0.41	0.11 ± 0.13	Wyatt(1954)
White Leghorn, Rhode Island Red and Barred Plymouth Rock	-	-	0.31	-	Yamada(1955)
New Hampshire	0.31	0.19	0.25	-	Jerome *et al.*(1956)
White Leghorn	-	-	0.26	-	Abplanalp(1957)
White Leghorn	0.162	0.124	0.143	-	Oliver *et al.*(1957)
White Leghorn	-	-	0.13	-	Hicks(1958)
New Hampshire	-	-	0.25	-	Hicks(1958)
Combination of seven light and heavy breeds	0.17 ± 0.09	0.29 ± 0.088	0.23 ± 0.062	0.07	Hogsett and Nordskog (1958)

contd.

Contd.
Table 3

1	2	3	4	5	6
White Leghorn	0.2 ± 0.26	-	-	-	Hussain and Singh (1964)
Cornell Randombred Control	0.10-0.20	0.30-0.50	-	-	VanVleck and Doolittle(1964)
White Leghorn	0.065 ± 0.068	-	-	0.17 ± 0.17	Amer(1965)
White Rock x Rhode Island Red X Red Cornish	0.13	-	-	0.23	Kinney and Shoffner(1965)
White Leghorn	0.23 ± 0.07	0.40 ± 0.08	-	-	Shibata(1965)
White Leghorn St.2	0.14 ± 0.05	0.18 ± 0.06	0.16 ± 0.04	-	Clayton and Robertson(1966)
St.5	0.15 ± 0.06	0.23 ± 0.06	0.19 ± 0.04	-	-do-
White Leghorn Strain B	0.72 ± 0.23	0.47 ± 0.10	0.60 ± 0.10	-	Jaffe(1966)
Fayoumi	0.157	0.123	-	-	Amer(1967)
White Leghorn	0.16 ± 0.13	0.45 ± 0.20	0.31 ± 0.21	-	Malik and Singh (1967)
White Leghorn	0.09 ± 0.03	0.15 ± 0.07	0.12 ± 0.02	0.19 ± 0.07	Jain et al.(1968)
White Leghorn	0.10	0.24	0.17	-	Saadeh et al.(1968)

contd.

Contd. table 3

1	2	3	4	5	6
White Leghorn	0.13 ± 0.004	0.21 ± 0.011	0.173 ± 0.004	-	Acharya *et al.* (1969)
White Leghorn	0.23	-	-	-	Bohren *et al.* (1970)
New Hampshire	0.50	-	-	-	Chung *et al.* (1970)
White Leghorn	0.44	0.67	0.42	0.283	Mohapatra and Srivastava (1971)
White Leghorn	0.20 ± 0.12	0.24 ± 0.20	0.23 ± 0.03	-	Dhaliwal and Acharya (1972)
White Leghorn	0.38	-	-	-	Mohapatra (1972)
Australorp	0.42	-	-	-	Mohapatra (1972)
White Leghorn	0.12 ± 0.12	-	-	-	Sandhu and Dev (1972)
Unweighted average	0.228	0.303	0.270	0.180	

Egg number: The estimates reported by different workers for part year egg number are summarized in table 3. The unweighted average of estimates of part-year egg number based on sire and dam component of variance is 0.22 to 0.303 respectively. This indicates that the heritability of egg number is in general low.

Genetic, environmental and phenotypic correlations

Egg number and egg weight: Genetic, environmental and phenotypic correlations between egg number and egg weight reported in literature are given in table 4. Most of the genetic correlations range between -0.10 and -0.45. The unweighted average of genetic, environmental and phenotypic correlations being -0.262, 0.089 and -0.178 respectively.

Egg number and body weight: Correlations between egg number and body weight reported in literature are summarized in table 5. The genetic correlations fall in the range between -0.54 reported by Ragab and El-Hossori (1969) to 0.92 reported by Mohapatra and Ahuja (1971). The unweighted average of genetic, environmental and phenotypic correlations are -0.078, -0.22 and -0.028 respectively.

Egg weight and body weight: Genetic, environmental and phenotypic correlations between egg weight and body weight reported in literature are set out in table 6. Genetic correlations between egg weight and body weight are positive

Table-4. Genetic, environmental and phenotypic correlations between egg number and egg weight reported in literature

Breed	Genetic	Environmental	Phenotypic	Reference
Brown Leghorn	-0.20	-	-	Blyth(1952)
Inbred and non-inbred lines of nine breeds	-0.43	-	-	Wyatt(1953)
Combination of seven light and heavy breeds	0.10	-	-0.06	Hogsett and Nordskog(1956)
New Hampshire	-0.24	-0.10	-0.02	Jerome et al.(1956)
White Leghorn	-0.38	0.12	-	Abplanalp(1957)
Commercial poultry flocks New Hampshire	-0.351	0.206	0.013	Hicks(1958)
White Leghorn	0.190	-0.087	0.052	Hicks (1958)
Light breeds	-0.42	-	0.06	Hogsett and Nordskog (1958)
Sussex	-0.32	0.12	-0.05	Waring et al.(1962)
White Leghorn	0.15±0.08	-	-0.08±0.09	Hussain and Singh(1964)
White Leghorn Strain E	-0.15	-	-0.02	Jaffe(1966)
Strain B	0.04	-	-0.04	Jaffe(1966)
Leghorn	-0.15±0.20	-	0.00±0.02	Nordskog and Festing (1967)
White Leghorn	-	-	-0.17±0.13	Aggarwal(1970)
White Leghorn	-0.88	0.28	-0.228	Mohapatra and Ahuja (1971)
White Leghorn	-0.18	-	-	Kolstad (1972)
White Leghorn	-0.69	-	-0.34	Mohapatra(1972)
Australorp	-0.56	-	-0.71	Mohapatra(1972)
White Leghorn	-	-	-0.17	Reddy et al.(1972)
White Leghorn	0.22±0.11	-	-0.226	Nanda et al.(1973)
White Leghorn Fayoumi	-0.31±0.12	-	-	Nordskog et al.(1974)
Unweighted average	-0.262	.089	-0.178	

Table-5. Genetic, environmental and phenotypic correlations between egg number and body weight reported in literature

Breed	Genetic	Environmental	Phenotypic	Reference
Brown Leghorn	-0.05	-	-	Blyth(1952)
Inbred and non-inbred lines of nine breeds	-0.31	-	-	Wyatt(1954)
White Léghorn, Rhode Island Red and Barred Plymouth Rock	0.173	-	-	Yamada (1955)
Combination of seven light and heavy breeds	0.29	-	-	Hogsett and Nordskog (1958)
New Hampshire	-0.42	-0.02	-0.06	Jerome *et al.*(1956)
White Leghorn	-0.102	-	0.133	Hussain and Singh (1964)
White Plymouth Rock	-0.14	-0.29	-0.24	Ideta and Siegel(1966)
White Leghorn Strain B	-0.28	-	-0.01	Jaffe (1966)
Strain E	-0.08	-	0.03	Jaffe (1966)
Fayoumi	-0.54	-	-	Ragab and El-Hossori (1969)
White Leghorn	0.92	-0.352	-	Mohapatra and Ahuja (1971)
White Leghorn	-	-	-0.06	Reddy *et al.*(1972)
White Leghorn	0.47±0.06	-	0.232	Nanda *et al.*(1973)
Unweighted average	-0.0781	-0.221	-0.0287	

Table 6. Genetic, environmental and phenotypic correlations between egg weight and body weight reported in literature

Breed	Genetic	Environmental	Phenotypic	Reference
Brown Leghorn	0.66	-	-	Blyth (1952)
	0.31	-	-	Wyatt (1953)
Combination of seven light and heavy breeds	0.56	-	-	Hogsett and Nordskog (1956)
New Hampshire	0.20	0.10	0.09	Jerome *et al.* (1956)
Combination of New Hampshire and White Leghorn	0.11	0.28	0.20	Hicks (1958)
Seven light breeds	0.61	-	0.37	Hogsett and Nordskog (1958)
White Leghorn	0.87	-	0.616	Hussain and Singh (1964)
White Leghorn	0.65±0.11	-	-	Shibata(1965)
White Plymouth Rock	0.23	0.88	0.58	Ideta and Siegel (1966)
Light Sussex	0.32	-	0.25	Jeffe(1966)
Rhode Island Red	0.42	-	0.27	Jaffe (1966)
Quasi Control				
Strain I	0.31	-	-	Festing and Nordskog (1967)
Strain II	0.58	-	-	
Strain III	0.30	-	-	
Strain IV	0.68	-	-	
White Leghorn	1.17	-	-0.12	Mohapatra and Ahuja (1971)

contd.

Contd. table 6

Breed	Genetic	Environ-mental	Pheno-typic	Reference
White Leghorn	-	-	0.26	Reddy *et al.* (1972)
White Leghorn	0.36±0.04	--	0.552	Nanda *et al.* (1973)
White Leghorn and Fayoumi	0.41±0.06	-	-	Nordskog *et al.* (1974)
Unweighted average	0.446	0.42	0.307	

and range from 0.11 reported by Hicks (1958) to 1.17 reported by Mohapatra and Ahuja (1971). The unweighted average of genetic, environmental and phenotypic correlation being 0.446, 0.42 and 0.307 respectively.

Chapter III

MATERIAL AND METHODS

History of the flock

The data used in the present investigations pertained to two purebred strains viz. Punjab-White Leghorn-1 (Pb-1) and Punjab-White Leghorn-2 (Pb-2). Pb-1 was developed from a reputed commercial stock imported from USA. The first pedigreed generation of this strain was raised during 1971-72. This strain has undergone selection, since then on the basis of Osborn's index for three generations upto 1973-74. Although, the main emphasis was to select for egg production to 40 weeks of age, some attention was also given to egg weight using independent culling levels. Pb-2 was developed from Mychix strain which was initially developed by the Karnataka State Animal Husbandry Department from Mount Hope strain of USA., brought from the Central Hatchery, Chenganur (Kerala) in the year 1968. Fifty male and 500 female day-old chicks of the Mychix strain, hatched on 16th April in 1973 were received from Karnataka State Animal Husbandry Department, Bangalore. The first pedigreed generation of Pb-2 was raised during 1974-75.

Mating design

The fourth and fifth pedigreed generations during 1974-75 and 1975-76 were considered for this investigation. In the first generation, 603 birds of Pb-1 obtained in seven weekly hatches and 415 birds of Pb-2 obtained in six weekly hatches were included. Similarly, during the second generation, data on 780 birds of Pb-1 and 515 birds of Pb-2 were used. The progeny of the two strains Pb-1 and Pb-2 were obtained in five and six weekly hatches respectively during the second generation. Progeny were obtained by mating 30 sires to 270 dams in Pb-1 and 20 sires to 180 dams in Pb-2 for both the generations.

Management

All the pullets were given chick ration containing 22 percent protein upto 8 weeks of age and 18 percent protein thereafter. The birds were vaccinated against Ranikhet at day-old stage and against Ranikhet and Fowl pox at 8-10 weeks of age. The day-old chicks were wing-banded. All the chicks were pedigreed both by sire and dam. Leg-banding was done at about 20 weeks of age.

The following observations were recorded on each pullet.

Body weight: Body weight of all pullets were recorded at 20, 40 and 72 weeks of age. It was measured to the nearest of 10 grams.

Shank length: Shank length of each pullet was measured in centimeters at 20 and 40 weeks of age with the help of a scale of one millimeter divisions.

Egg production: Egg production of each pullet was recorded to forty weeks of age and also to 72 weeks of age through daily trapnesting.

Egg weight: Average egg weight of each pullet was measured by recording the weights of 3-4 eggs from each pullet during 36-40 weeks of age.

Statistical analysis

The data of each strain were analysed separately generation-wise. The data were corrected for hatch effects using the following model.

$$Y_{ij} = \mu + h_i + e_{ij}$$

where:

Y_{ij} = the measurement on j^{th} bird of the i^{th} hatch

μ = the overall population mean when equal frequencies exist among classes

h_i = effect of the i^{th} hatch

i = 1, 2 ...., H

e_{ij} = random effect peculiar to j^{th} bird of i^{th} hatch and is assumed to be independent and normally distributed i.e. NID $(0, \sigma_e^2)$

Heritability estimates

The model describing the sources of variation in the population was assumed to be

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

where:

Y_{ijk} is the measurement corrected for hatch effect on k^{th} progeny of the j^{th} dam mated to the i^{th} sire

u is the overall mean of the population

s_i is effect of the i^{th} sire ($i = 1, \ldots, s$)

d_{ij} is effect of the j^{th} dam mated to the i^{th} sire ($j = 1, \ldots, n_i$)

e_{ijk} is the random environmental plus genetic segregati[on] effect on k^{th} progeny of the j^{th} dam mated to i^{th} s[ire]

Analysis of variance

Source	d.f.	S.S.	M.S.S.	E.M.S.
Among sires	S-1	$\sum_i \frac{Y_{i..}^2}{n_{i.}}$	MS_S	$\sigma_e^2 + k_2\sigma_d^2 + k_3$
Among dams: sires	D-S	$\sum\sum_{ij} \frac{Y_{ij.}^2}{n_{ij}} - \sum_i \frac{Y_{i..}^2}{n_{i.}}$	MS_D	$\sigma_e^2 + k_1\sigma_d^2$
Among progeny: dams:sires	N-D	$\sum\sum\sum_{ijk} Y_{ijk}^2 - \sum\sum_{ij} \frac{Y_{ij.}^2}{n_{ij}}$	MS_E	σ_e^2
Total	N-1	$\sum\sum\sum_{ijk} Y_{ijk}^2 - \frac{Y_{...}^2}{N}$		

where:

N = total number of progeny

S = number of sires

D = number of dams

σ_e^2 = error variance component

σ_d^2 = component of variance due to dams

σ_s^2 = component of variance due to sires

k values were computed as under:

$$k_1 = \frac{1}{D-S}\left[N - \sum_i \frac{\sum_j n_{ij}^2}{n_{i.}}\right]$$

$$k_2 = \frac{1}{S-1}\left[\sum_i \frac{\sum_j n_{ij}^2}{n_{i.}} - \frac{\sum\sum_{ij} n_{ij}^2}{N}\right]$$

$$k_3 = \frac{1}{S-1}\left[N - \frac{\sum_i n_{i.}^2}{N}\right]$$

Different components of variance were calculated as:

$$\hat{\sigma}_e^2 = MS_E$$

$$\hat{\sigma}_d^2 = \frac{MS_D - MS_E}{k_1}$$

$$\hat{\sigma}_s^2 = \frac{MS_S - MS_E - \frac{k_2}{k_1}\,(MS_D - MS_E)}{k_3}$$

$$\hat{\sigma}_p^2 = \hat{\sigma}_s^2 + \hat{\sigma}_d^2 + \hat{\sigma}_e^2$$

Heritability estimates were obtained by the following formulae:

Heritability estimate from sire component:

$$h_s^2 = \frac{4\,\hat{\sigma}_s^2}{\hat{\sigma}_p^2}$$

Heritability estimate from dam component:

$$h_d^2 = \frac{4\,\hat{\sigma}_d^2}{4\,\hat{\sigma}_p^2}$$

Heritability estimates from sire plus dam components:

$$h_{(s+d)}^2 = \frac{2\,(\hat{\sigma}_s^2 + \hat{\sigma}_d^2)}{\hat{\sigma}_p^2}$$

Standard errors of heritability estimates were calculated according to Dickerson (1960):

$$\text{S.E.}(h_s^2) = 4\sqrt{\frac{\frac{2}{k_3^2}\left[\frac{MS_S^2}{S-1} + \frac{MS_D^2}{D-S}\right]}{1\hat{\sigma}_p^2}}$$

$$\text{S.E.}(h_d^2) = 4\sqrt{\frac{\frac{2}{k_1^2}\left[\frac{MS_D^2}{D-S} + \frac{MS_E^2}{N-D}\right]}{\hat{\sigma}_p^2}}$$

$$\text{S.E.}(h_{s+d}^2) = 2\sqrt{\frac{V(\hat{\sigma}_s^2) + V(\hat{\sigma}_d^2) + 2\text{Cov}\,\hat{\sigma}_s^2\,\hat{\sigma}_d^2}{\hat{\sigma}_p^2}}$$

where:

$$V(\sigma_s^2) = \frac{2}{k_3^2}\left[\frac{MS_S^2}{S-1} + \frac{MS_D^2}{D-S}\right]$$

$$V(\sigma_d^2) = \frac{2}{k_1^2}\left[\frac{MS_D^2}{D-S} + \frac{MS_E^2}{N-D}\right]$$

$$Cov(\sigma_s^2, \sigma_d^2) = \frac{k_2}{k_3}\left[V(\sigma_d^2) - \frac{2\ MS_E^2}{k_1^2(N-D)}\right]$$

Correlations

Genetic correlations between two traits X and Y were estimated through variance-covariance analysis of half and full-sibs, as shown in table 8.

Table 8

Variance-covariance analysis for estimating correlations

Source	d.f.	SS_Y	SS_X	SCP_{XY}
Among sires	S-1	SY_S	SX_S	$SCP(XY)_S$
Among dams: sires	D-S	SY_D	SX_D	$SCP(XY)_D$
Among progenies: dams: sires	N-D	SY_E	SX_E	$SCP(XY)_E$
Total	N-1	SY_T	SX_T	$SCP(XY)_T$

Expectations of mean squares and cross-products in the above table are as under:

Source	$E(MS_Y)$	$E(MS_X)$	$E(MSCP_{XY})$
Among sires	$\sigma^2_{e_y}+k_2\sigma^2_{d_y}+k_3\sigma^2_{s_y}$	$\sigma^2_{e_x}+k_2\sigma^2_{d_x}+k_3\sigma^2_{s_x}$	$\sigma e_{xy}+k_2\sigma d_{xy}+k_3\sigma s_{xy}$
Among dams: sires	$\sigma^2_{e_y}+k_1\sigma^2_{d_y}$	$\sigma^2_{e_x}+k_1\sigma^2_{d_x}$	$\sigma_{e_{xy}}+k_1\sigma_{d_{xy}}$
Among progenies: dams:sires	$\sigma^2_{e_y}$	$\sigma^2_{e_x}$	$\sigma^2_{e_{xy}}$

Genetic correlations were estimated from sire component of variance and covariance

$$r_{G(S)_{XY}} = \frac{\sigma s_{xy}}{\sqrt{\sigma^2_{s_x} \cdot \sigma^2_{s_y}}}$$

Phenotypic correlations were estimated by the following formula:

$$r_{P_{(XY)}} = \frac{\sigma e_{xy}+\sigma s_{xy}+\sigma d_{xy}}{\sqrt{(\sigma^2_{ex}+\sigma^2_{s_x}+\sigma^2_{d_x})(\sigma^2_{e_y}+\sigma^2_{s_y}+\sigma^2_{d_y})}}$$

Environmental correlations were estimated from the sire components:

$$r_{E(S)_{XY}} = \frac{\sigma e_{xy} - 2\sigma s_{xy}}{\sqrt{(\sigma e_x^2 - 2\sigma_{s_x}^2)(\sigma_{e_y}^2 - 2\sigma_{s_y}^2)}}$$

Standard errors of genetic correlations were calculated by the formula (Robertson, 1959).

$$S.E.r_{G_{XY}} = \frac{1 - r^2_{G_{XY}}}{\sqrt{2}} \sqrt{\frac{(S.E.h_x^2)(S.E.h_y^2)}{h_x^2 \cdot h_y^2}}$$

Relative efficiency of different criterion of selection

The relative efficiency of different criterion of selection namely, selection based on egg number alone, egg weight alone, body weight alone, index I (linear combination of egg number to 40 weeks, egg weight during 36-40 weeks of age and body weight at 40 weeks), index II (linear combination of egg number to 40 weeks, egg weight during 36-40 weeks, body size at 40 weeks and body condition at 40 weeks), index III (linear combination of egg number to 40 weeks, egg weight during 36-40 weeks and body size at 40 weeks), index IV (linear combination of egg number to 40 weeks, egg weight during 36-40 weeks and body condition at 40 weeks) and index V (linear combination, egg number and egg weight) were compared. The selection indices, their efficiency (r_{HI}), expected genetic change in each trait and the net economic return were calculated according to Hogsett and Nordskog (1958).

Economic weights:

The economic weights were estimated from the data of Fifth Random Sample Laying Test conducted by Govt.of India at Hessarghatta, Bangalore. In this test, the entries were classified into Leghorn-type and heavy-type entries. Only Leghorn-type entries were considered for the estimation of economic weights.

Hen-day production:

The entries were arranged in descending order on the basis of hen-day egg production and were divided into upper and lower groups. The average egg production of upper group was 225.1 and the net income from the group was Rs. 9.77. The average egg production of lower group was 199.9 and the net income of the group was Rs. 6.31. The production of upper group was 25.20 eggs more than that of the lower group and the net income was more by Rs.3.46 per hen. So, for every one egg increase, the net income incre ses by Rs.0.1373.

Egg weight:

The entries were arranged in descending order on the basis of egg weight and were divided into upper and lower groups. The average egg weight of upper group was 53.8 grams and the net income from the group was Rs. 8.20. The average egg weight of the lower group was 49.9 grams and the net income from the group was Rs. 7.88. The upper group egg weight was

3.9 grams more than the lower group and the net income was more by Rs. 0.32. So, for one gram increase in egg weight, the net income increases by Rs.0.0821.

Body weight:

Similarly the economic weight was calculated for body weight. For one gram increase in body weight the net income decreases by Rs 0.0018.

Since the bone and meat are sold together, body size- and body-condition were given the same economic weight as the total body weight.

Table 9

The economic weights for egg number, egg weight, body weight, body-size and body-condition

Trait	Unit	Economic weight	Relative economic weight
Egg number (x_1)	1 egg	+0.1373	76.2777
Egg weight (x_2)	1 g	+0.0821	45.6111
Body weight(x_3)	1 g	-0.0018	-1.0000
Body-size (x_4)	1 g	-0.0018	-1.0000
Body-condition (x_5)	1 g	-0.0018	-1.0000

The following optima were determined for Pb-1 and Pb-2 separately.

1. 20-week body weight in relation to egg weight during 36-40 weeks of age.
2. 40-week body weight in relation to egg weight during 36-40 weeks of age.
3. 20-week body weight in relation to egg production to 40 weeks of age.
4. 40-week body weight in relation to egg production to 40 weeks of age.
5. 20-week body weight in relation to egg mass to 40 weeks of age (average egg weight during 36-40 weeks of age multiplied by egg number to 40 weeks of age).
6. Body weight at 40 weeks in relation to egg mass to 40 weeks of age.

Body weight was treated as independent variable and egg production, egg size and egg mass were treated as dependent variables. Linear, quadratic and cubic equations were fitted (Snedecor and Cochran, 1967).

Net economic return:

Increase of one gram in egg weight results in 220 g increase in egg mass per pullet, under the assumption that annual egg production is 220 eggs. This is equal to four eggs weighing 55g and in monetary terms equal to Rs.1.40 at the rate of Rs.0.35 per egg. Tt is considered that 100 g increase in mature body weight will fetch Rs.0.60 at the rate of Rs.6.00 per kg live weight. But to sustain 100 grams extra body weight the bird will require 1.5 kg of extra feed upto 500 days of age. (This figure is derived from RSL1 data by regression analysis) At the rate of Rs.1.00 per kg of feed the net loss therefore will be Rs.0.90 per 100 g increase in body weight. It is assumed that increase of one egg to 40 weeks of age would result in increase of 3 eggs in annual egg production and results in economic gain of Rs.1.05, at the rate of Rs.0.35 per egg.

Chapter IV

RESULTS AND DISCUSSION

Body-size (bone-framework) and body-condition (fleshing)

In order to test the reliability of criteria for body-size and body-condition suggested in the literature or possibly to find other body measurements or functions of body measurements as the criteria of body-size and body-condition, 100 pullets were slaughtered at 40 weeks of age and another 284 hens at the completion of annual egg production. Before slaughtering, body weight, shank length, shank circumference and keel length were measured on each bird.

Birds were killed without the loss of blood by twisting the neck. After mechanical defeathering, the birds were transferred to autoclave pressure cooker in batches of ten. After cooking for an hour under 5-pound pressure, skeleton was mannually separated from the flesh and cleaned. Fat was not extracted from the skeleton. Weight of air dried skeleton was noted. The skeleton weight thus measured was taken as the observed body-size. Body weight minus skeleton weight was taken as the observed body-condition. The statistics of the measured traits are given in table 10.

Table-10. Mean, standard error (S.E.), standard deviation (S.D.) ahd coefficient of variation (C.V.) of traits before slaughter

Trait	Mean	S.E.	S.D.	Coefficient of variation
Body weight (g)	1544.63	11.900	197.112	12.700
Skeleton weight(g)	93.09	0.927	14.491	15.500
Shank length(cm)	8.08	0.022	0.376	4.600
Shank circumference(cm)	3.31	0.013	0.228	6.900
Keel length(cm)	9.91	0.035	0.594	5.900

6 percent of the body weight of females consisted of skeleton similar report was made by Latimer (1924). Skeleton weight had higher variability than body weight. But the variability in shank length, shank circumference and keel length was only one third as great as the variability in body weight.

Table 11

Correlation coefficients of different measures with body-condition

Criteria of measurement	Correlation-coefficient with body-condition
$\frac{\text{Body weight}}{\text{Shank length}}$	0.908**
$\frac{\text{Body weight}}{\text{Product of shank length and shank circumference}}$	0.696**
$\sqrt[3]{\frac{\text{Body weight}}{\text{Product of shank length and shank circumference}}}$	-0.117

**Significant at P <0.01

From the results in table-11 it can be concluded that body weight/shank length is a reliable index of body-condition

Table-12. Correlation coefficient between the observed skeleton weight (body-size) and some indicator traits

Skeleton weight and	r
1. Shank length	0.389**
2. Keel length	0.390**
3. Shank circumference	0.325**
4. Product of shank length and shank circumference	0.440**
Shank length and	
1. Shank circumference	0.564**
2. Keel length	0.363**
Keel length and	
1. Product of shank length and shank circumference	0.532**
2. Shank circumference	0.674**

**Significant at $P<0.01$

Multiple regression with skeleton weight as dependent variable and shank length, circumference and keel length as the independent variables yielded multiple correlation of 0.223. Multiple regression with skeleton weight as the dependent variable and keel length and product of shank length and shank circumference as independent variables yielded multiple correlation of 0.210.

Criteria for body-size (bone-framework)

The correlation coefficients between observed skeleton weight (body-size) and certain indicator traits like shank length, keel length and product of shank length and shank circumference are given in table-12. The correlations are low. The highest correlation coefficient obtained is with the product of shank length and circumference, which is 0.440. But the ratio, body weight/shank length is a reliable criterion for body-condition as the correlation coefficient between the observed body-condition and body weight/shank length is 0.908.

Body weight-body-condition= body-size

As body weight/shank length is a good criterion for body-condition, body weight-(body weight/shank length) is expected to be a good criterion for body-size, so the correlation coefficient between the observed skeleton weight and body weight-body weight/shank length was calculated. It worked out to 0.755. From this it can be concluded that reliable criterion for body size is body weight- (body weight/ shank length).

Means

Mean, standard error and coefficient of variation for various characters in two generations of the two White Leghorn strains are given in table 13.

The average 20-week body weight ranged between 1077.3 and 1170.3 g. Pb-1 was heavier than Pb-2 in both the generations. For both the strains, birds at 20-weeks of age were heavier in the 1975-76 generation. The average 40-week body weight ranged between 1500.2 g and 1605.3 g. Pb-2 was heavier than Pb-1 during 1974-75, whereas the latter was heavier during 1975-76. The average 72-week body weight ranged between 1530.9 and 1577.9 g. In both the generations of the two strains the 72-week body weight was lower than the 40-week body weight. Thus the chickens attain mature body weight by 40 weeks of age. Due to physiological phenomena of ageing they loose body weight with further increase in their age.

The average 20-week shank length ranged between 7.517 and 8.403 cm. The average shank length at 40 weeks of age ranged between 7.660 to 8.503 cm.

The coefficient of variation of body-size at different ages is more than the coefficient of variation of body weight at different ages. Body-condition at different ages had higher coefficient of variation than both the body-size or body weight. This may be due to the fact that the variation

Table-13. Mean, standard error and coefficient of variation of different traits

Sl No.	Trait	Generation	No. of observation	Strain	Mean	S.E.	C.V.
1	2	3	4	5	6	7	8
1	20-week body weight(g)	1974-75	603	Pb-1	1135.965	4.51	9.75
		1975-76	780	Pb-1	1170.325	3.89	9.27
		1974-75	415	Pb-2	1077.299	4.80	9.09
		1975-76	515	Pb-2	1117.449	4.12	8.36
2	40-week body weight (g)	1974-75	603	Pb-1	1550.188	7.38	11.69
		1975-76	780	Pb-1	1605.263	6.33	11.00
		1974-75	415	Pb-2	1600.113	9.17	11.67
		1975-76	515	Pb-2	1587.904	6.77	9.68
3	72-week body weight(g)	1974-75	603	Pb-1	1520.112	5.11	10.21
		1975-76	780	Pb-1	1577.870	6.33	11.21
		1974-75	415	Pb-2	1525.211	6.11	9.25
		1975-76	515	Pb-2	1530.865	7.99	11.85
4	20-week shank length(cm)	1974-75	603	Pb-1	7.517	0.02	6.83
		1975-76	780	Pb-1	8.403	0.02	6.09
		1974-75	415	Pb-2	7.630	0.03	6.87
		1975-76	515	Pb-2	7.804	0.07	20.44

contd.

Contd. table 13

1	2	3	4	5	6	7	8
5	40-week shank length(cm)	1974-75	603	Pb-1	7.660	0.03	9.93
		1975-76	780	Pb-1	8.503	0.02	5.69
		1974-75	415	Pb-2	7.725	0.03	7.62
		1975-76	515	Pb-2	8.408	0.02	4.32
6	20-week body-size (g)	1974-75	603	Pb-1	979.357	6.91	17.31
		1975-76	780	Pb-1	1031.741	13.77	10.20
		1974-75	415	Pb-2	992.405	56.05	12.11
		1975-76	515	Pb-2	984.531	12.75	8.64
7	40-week body-size(g)	1974-75	603	Pb-1	1346.165	14.20	25.91
		1975-76	780	Pb-1	1412.174	5.16	19.99
		1974-75	415	Pb-2	1392.881	8.30	12.13
		1975-76	515	Pb-2	1372.152	7.92	13.10
8	72-week body-size(g)	1974-75	603	Pb-1	1379.451	6.81	12.71
		1975-76	780	Pb-1	1389.222	5.78	11.62
		1974-75	415	Pb-2	1309.211	9.71	16.11
		1975-76	515	Pb-2	1323.534	9.16	15.71
9	20-week body-condition(g)	1974-75	603	Pb-1	156.596	5.62	48.05
		1975-76	780	Pb-1	138.573	1.14	22.95
		1974-75	415	Pb-2	84.896	6.03	24.50
		1975-76	515	Pb-2	132.913	0.44	7.44
10	40-week body-condition (g)	1974-75	603	Pb-1	204.008	12.39	49.15
		1975-76	780	Pb-1	193.061	2.35	33.75
		1974-75	415	Pb-2	207.222	1.09	10.73
		1975-76	515	Pb-2	215.729	6.34	36.65

contd.

Contd. table 13

1	2	3	4	5	6	7	8
11	72-week body-condition	1974-75	603	Pb-1	177.124	1.61	17.12
		1975-76	780	Pb-1	188.673	1.11	16.43
		1974-75	415	Pb-2	200.112	5.11	34.11
		1975-76	515	Pb-2	207.332	6.74	33.81
12	Egg weight(g)	1974-75	603	Pb-1	53.163	0.16	9.75
		1975-76	780	Pb-1	54.016	0.12	5.97
		1974-75	415	Pb-2	51.929	0.17	6.60
		1975-76	515	Pb-2	53.457	0.14	6.10
13	Egg number to 40 weeks	1974-75	603	Pb-1	75.926	0.71	22.94
		1975-76	780	Pb-1	85.986	0.51	16.56
		1974-75	415	Pb-2	75.044	0.85	23.10
		1975-76	515	Pb-2	82.651	0.75	20.47
14	Egg number to 72 weeks	1974-75	603	Pb-1	215.113	1.51	14.56
		1975-76	780	Pb-1	230.820	1.31	15.88
		1974-75	415	Pb-2	210.120	1.22	17.11
		1975-76	515	Pb-2	219.800	1.64	16.96

in body-condition is mostly determined by husbandry practices and environment.

Egg weight at 36-40 weeks of age ranged between 51.93 and 54.02 g. Pb-1 had higher egg weight than Pb-2 in both the generations. Egg weight during the 1975-76 generation was heavier than in the 1974-75 generation. This could be due to selection for egg weight practised in 1974-75.

Egg number to 40-weeks ranged between 75.044 and 85.986. Pb-1 laid more eggs than Pb-2 in both the generations.

Egg number to 72-weeks ranged between 210.1 and 230.8 Pb-1 laid more eggs in both the generations. Higher egg production in the 1975-76 generation could be due to selection for egg number practised in 1974-75.

Heritabilities

Strain-wise, generation-wise and also the pooled estimates of heritability calculated from the sire component, the dam component and the sire plus dam component of variance are presented in table-14.

Body weight

Heritability estimates from the sire component of variance averaged over generations for Pb-1 and Pb-2 were .592 and .317 respectively for 20-week weight, .430 and .433 for 40-week weight, .552 and .275 for 72-week body weight.

Table-14. Heritability estimates of traits

Sl No.	Traits	Generations	Strain	h^2_S	h^2_D	h^2_{S+D}
1	2	3	4	5	6	7
1	20-week body weight	1974-75	Pb-1	0.544±0.216	0.392±0.158	0.468±.143
		1975-76	Pb-1	0.646±.227	0.641±.152	0.644±.143
		Av.of two generations		.592	.519	.556
		1974-75	Pb-2	0.582±.289	0.756±.229	0.669±.199
		1975-76	Pb-2	0.238±.156	0.572±.197	0.405±.138
		Av.of two generations		.317	.649	.491
		Overall average		.436	.564	.527
2	40-week body weight	1974-75	Pb-1	0.388±.197	0.796±.202	0.592±.156
		1975-76	Pb-1	0.472±.193	0.888±.176	0.680±.140
		Av.of two generations		.430	.848	.641
		1974-75	Pb-2	0.573±.256	0.253±.174	0.413±.164
		1975-76	Pb-2	0.357±.191	0.546±.190	0.451±.146
		Av.of two generations		.433	.386	.434
		Overall average		.432	.611	.542
3	72-week body weight	1974-75	Pb-1	0.512±.198	0.621±.212	0.562±.220
		1975-76	Pb-1	0.604±.222	0.779±.164	0.691±.145
		Av.of two generations		.552	.720	.651
		1974-75	Pb-2	0.321±.131	0.512±.211	0.455±.162
		1975-76	Pb-2	0.213±.152	0.652±.205	0.433±.142
		Av.of two generations		.275	.583	.442
		Overall average		.361	.658	.533

contd.

table 14

1	2	3	4	5	6	7
4	20-week body-size	1974-75	Pb-1	0.370 $\pm$ .207	0.103 $\pm$ .228	0.211 $\pm$ .171
		1975-76	Pb-1	0.628 $\pm$ .221	0.601 $\pm$ .149	0.614 $\pm$ .140
		Av.of two generations		.490	.451	.454
		1974-75	Pb-2	0.300 $\pm$ .097	0.165 $\pm$ .212	0.231 $\pm$ .277
		1975-76	Pb-2	0.242 $\pm$ .158	0.592 $\pm$ .198	0.417 $\pm$ .140
		Av.of two generations		.284	.391	.366
		Overall average		.330	.425	.414
5	40-week body-size	1974-75	Pb-1	0.185 $\pm$ .168	0.121 $\pm$ .250	0.151 $\pm$ .172
		1975-76	Pb-1	0.714 $\pm$ .254	0.908 $\pm$ .170	0.811 $\pm$ .160
		Av.of two generations		.345	.663	.505
		1974-75	Pb-2	0.566 $\pm$ .255	0.262 $\pm$ .176	0.414 $\pm$ .164
		1975-76	Pb-2	0.217 $\pm$ .123	0.962 $\pm$ .153	0.525 $\pm$ .211
		Av.of two generations		.282	.658	.454
		Overall average		.306	.660	.467
6	72-week body-size	1974-75	Pb-1	0.512 $\pm$ .212	0.620 $\pm$ .201	0.565 $\pm$ .192
		1975-76	Pb-1	0.603 $\pm$ .221	0.773 $\pm$ .163	0.688 $\pm$ .145
		Av.of two generations		.550	.712	.642
		1974-75	Pb-2	0.351 $\pm$ .120	0.412 $\pm$ .165	0.378 $\pm$ .131
		1975-76	Pb-2	0.151 $\pm$ .108	0.149 $\pm$ .160	0.150 $\pm$ .106
		Av.of two generations		.238	.275	.239
		Overall average		.305	.472	.374

contd.

Contd.table 14

1	2	3	4	5	6	7
7	20-week body-condition	1974-75	Pb-1	.063±.143	.131±.263	.092±.174
		1975-76	Pb-1	.010±.065	.512±.162	.261±.098
		Av.of two generations		.018	.407	.170
		1974-75	Pb-2	-.311	.168±.373	.686±.229
		1975-76	Pb-2	.245±.148	.374±.177	.309±.126
		Av.of two generations		.245	.336	.412
		Overall average		.131	.377	.280
8	40-week body condition	1974-75	Pb-1	-.242	.142±.111	.696±.178
		1975-76	Pb-1	.121±.053	.542±.166	.247±.098
		Av.of two generations		.121	.340	.452
		1974-75	Pb-2	.500±.224	.086±.160	.293±.146
		1975-76	Pb-2	.069±.074	-.030±.121	.195±.091
		Av.of two generations		.108	.086	.244
		Overall average		.114	.213	.269
9	72-week body-condition	1974-75	Pb-1	-.224	.154±.126	.660±.184
		1975-75	Pb-1	.151±.096	.420±.150	.286±.098
		Av.of two generations		.151	.287	.473
		1974-75	Pb-2	.030±.084	.093±.182	.062±.114
		1975-76	Pb-2	.056±.070	-.031±.147	.012±.091
		Av.of two generations		.043	.093	.037
		Overall average		.112	.190	.255

contd.

Cntd.
Table 14

1	2	3	4	5	6	7
10	Egg weight	1974-75	Pb-1	.543±.188	.241±.112	.351±.114
		1975-76	Pb-1	.716±.243	.711±.155	.713±.152
		Av.of two generations		.607	.397	.532
		1974-75	Pb-2	.698±.313	.570±.204	.634±.198
		1975-76	Pb-2	.884±.342	.303±.146	.592±.191
		Av.of two generations		.782	.393	.613
		Overall average		.658	.396	.572
11	Egg number to 40 weeks	1974-75	Pb-1	.380±.151	-.017	0.181±.106
		1975-76	Pb-1	.249±.123	.503±.154	.376±.107
		Av.of two generations		.312	.503	.278
		1974-75	Pb-2	.259±.152	.095±.172	.177±.126
		1975-76	Pb-2	.436±.204	.322±.165	.379±.140
		Av.of two generations		.322	.212	.278
		Overall average		.316	.357	.278
12	Egg number to 72 weeks	1974-75	Pb-1	.152±.042	.412±.212	.272±.132
		1975-76	Pb-1	.178±.099	.330±.143	.254±.095
		Av.of two generations		.165	.355	.263
		1974-75	Pb-2	.253±.121	.165±.112	.212±.165
		1975-76	Pb-2	.433±.193	.118±.146	.276±.128
		Av.of two generations		.302	.147	.244
		Overall average		.233	.222	.253

Heritability estimates from the dam component of variance averaged over generations for Pb-1 and Pb-2 were .519 and .649 for 20-week body weight, .848 and .386 for 40-week body weight, and 720 and .583 for 72-week body weight.

Heritability estimates from the sire component of variance pooled over generations and strains for 20-, 40-and 72-week body weight were .436, .432 and .361 respectively. The estimates from the dam component were .564, .611 and .658.

Heritability estimates from the sire component of variance were higher than those from the dam component of variance for 20-week body weight in Pb-1 whereas the reverse was true for the heritability estimates for 40 and 72-week body weight. Heritability estimates from the dam component of variance were higher for 20 and 72-week body weight and the reverse was true for 40-week body weight in Pb-2. Higher estimates from the sire component of variance were attributed to sex-linked effects. Maternal effects and or dominance effects were attributed to higher heritability estimates from the dam component.

Heritability estimates from the sire component decreased with the increase of age, whereas the estimates from the dam component increased with the increase of age of the birds. The magnitude of heritability estimates were higher for Pb-1 than for Pb-2, except for heritability estimates of 20-week body weight from the dam component of variance.

Heritability estimates of body weight at different ages range from medium to high. Mass selection is sufficient to bring about change in body weight.

The heritability estimates of body weight obtained in this study were in reasonable agreement with the findings of Hazel and Lamoreux (1947), Yamada (1955), Goodman and Godfrey (1956) and Friars et al. (1962)

Body-size

Heritability estimates from the sire component of variance pooled over generations for Pb-1 and Pb-2 were .490 and .330 for 20-week body-size, .345 and .306 for 40-week body-size and .550 and .305 for 72-week body-size. The estimates from dam component of variance were .451 and .425 for 20-week body-size, .663 and .658 for 40-week body-size and .712 and .275 for 72-week body-size.

The heritability estimates from sire component of variance pooled over generations and strains for 20-, 40- and 72-week body-size were .330, .306 and .305. The estimates from dam component of variance were .425, .660 and .472. Thus the body-size was found to be of medium heritability in these two populations.

Heritability estimates from the dam component of variance were higher than those obtained from the sire component except for heritability of 20-week body weight in Pb-1. With the increase of the age of birds there was decline in magnitude of heritability from the sire component, whereas there is no definite trend for the estimates from the dam component. Higher magnitude of heritability for Pb-1 was observed.

Body-condition

The heritability estimates from the sire component of variance pooled over generations for Pb-1 and Pb-2 were .018 and .245 for 20-week body-condition, .121 and .108 for 40-week body-condition and .151 and .112 for 72-week body-condition. The estimates from the dam component of variance were .407 and .366 for 20-week body-condition, .340 and .086 for 40-week body-condition and .287 and .093 for 72-week body-condition.

The heritability estimates from the sire component of variance pooled over strains and generations for 20-, 40- and 72-week body-condition were .131, .114 and .112. The estimates from the dam component of variance were .377, .213 and .190.

Body-condition was lowly heritable in both the populations. The estimates from the dam component of variance were higher than the estimates from the sire component of variance. It indicates possible inclusion of dominance and or maternal effects in the dam component of variance. With the increase of age there was decline in the magnitude of heritability.

Egg weight

Heritability estimates from the sire component of variance pooled over generations for Pb-1 and Pb-2 were .607 and .782. The estimates from the dam component of variance were .397 and .393.

Heritability estimates pooled over generation and strains from the sire component of variance was .658 and from the dam component of variance, .396. The heritability estimates from the sire component of variance were higher than those obtained from the dam component of variance for both the strains and in both the generations. Similar results were obtained by Olsen and Knox (1940), Ghigi (1948), Lerner and Cruden (1951), Osborne (1953) and Hicks (1958). Their conclusion, that sex-linked genes are involved in the inheritance of egg weight is substantiated by the results of the present studies.

Egg number

Heritability estimates from the sire component of variance pooled over generations for Pb-1 and Pb-2 were .312 and .322 for egg number to 40-weeks and .165 and .302 for egg number to 72+weeks. The estimates from the dam component of variance were .503 and .212 for egg number to 40 weeks and .355 and .147 for egg number to 72 weeks.

The heritability estimates from the sire component of variance pooled over strains and generations for egg number to 40 weeks were .316 and .233 for egg number to 72 weeks. The estimates from the dam component of variance were .357 and .222.

Similar reports were made by Premnarain *et al.* (1973) Hussain and Singh (1964), Gruhn and Wendt (1963) and Jerome *et al.* (1956). Results indicate decline in heritability of egg number to 72 weeks when compared to heritability estimates of egg number to 40 weeks of age. The same sort of trend was found by Lerner and Cruden (1948) and King and Henderson (1954). They suggested that this decline in heritability could be due to the accumulation of environmentally caused variability.

Phenotypic, genetic and environmental correlations

Phenotypic, genetic and environmental correlations were estimated from the sire component of variance and covariance. The estimates are given in tables 15 to 21.

Body weight at 20 , 40 and 72 weeks of age

Phenotypic correlations between body weight at different ages were high and positive. The values ranged from .559 to .656 (tables 16 to 19) for 20-and 40-week body weight, .531 to .648 (tables 16 and 18) for 20- and 72-week body weight and .640 and .698 (tables 15 to 18) for 40- and 72-week body weight. Averaged over generations and strains, the phenotypic correlations between body weights at 20 and 40, 20 and 72 and 40 and 72 weeks were .620, .589 and .670 respectively (table 21). High positive correlation between body weight at different ages suggest that birds which are heavier at 20 weeks also tend to be heavier at 40 and 72 weeks of age.

Genetic correlations between body weight at different ages were also high and positive. The estimates ranged from .749 to .896 (tables 15 and 19) for 20 and 40 week body weight, .731 to .985 (tables 16 and 19) for 20 and 72-week body weight and .836 to .973 (tables 15 and 18) for 40 and 72-week body weight. Averaged over generations and strains, the genetic correlations between body weight at 20 and 40, 20 and 72 and 40 and 72 weeks were .882, .818 and .917 respectively (table 21).

Environmental correlations between body weight at different ages fluctuated considerably ranging from -.037 to .559 (tables 16 and 19) for 20 and 40-week body weight, 0.045 to .423 (tables 15 and 19) for 20 and 72-week body weight and .136 to .584 (tables 16 and 18) for 40 and 72-week body weight. The environmental correlations, pooled over generations and strains, were .312, .234 and .360 between body weights at 20 and 40 weeks, 20 and 72 weeks and 40 and 72 weeks respectively (table 21).

Increase of body weight at 20 weeks of age would increase body weight at 40 and 72 weeks of age. Body weight at different ages were affected by environmental factors in the same direction. Heavier birds at 20 weeks of age would also be heavier at 40 and 72 weeks of age. Similar reports were given by Singh (1977) and Chaudhuri (1976).

Body weight and egg production

Phenotypic correlations between body weight at different ages and egg production to 40 weeks and 72 weeks of age were low. The values ranged from .113 to .204 (tables 15 to 18) for 20-week body weight and egg production to 40 weeks of age, .099 to .124 (tables 15 and 18) for 20-week body weight and egg production to 72-weeks of age, -0.091 to .112 (tables 16 and 17) for 40-week body weight and egg production to 40 weeks of age, -.004 to .079 (tables 15 and 18) for 40-week body weight and egg production to 72 weeks of age and .030 to .107 (tables 15 and 19) for 72-week body weight and egg production to 72 weeks of age. Averaged over generations and strains the phenotypic correlation between 20-week body weight and egg production to 40-weeks of age, 20-week body weight and egg production to 72 weeks, 40-week body weight and egg production to 72 weeks and 72-week body weight and egg production to 72 weeks of age were .171, .112, .012, .037 and .059 respectively (table 21). Similar reports were given by Hussain and Singh (1964) and Mohapatra and Ahuja (1971).

		1	2	3	4	5	6	7	8	9	10	11
1.	20-wk. body wt.		.896 ±.063	.828 ±.302	.957 ±.028	.875 ±.100	.800 ±.115	-.471 ±.522	-.620 ±.630	.288 ±.393	.178 ±.259	.078 ±.280
2.	40-wk body wt.	.426 (.644)		.973 ±.025	.894 ±.076	1.107 -.109	1.078 ±.077	-.531 ±.544	-1.106	.514 ±.211	.391 ±.252	-.069 ±.317
3.	72-wk body wt.	.045 (.648)	.136 (.640)		.825 ±.112	.686 ±.211	.896 ±.110	.583 ±.471	.155 ±.334	.737 ±.523	.267 ±.135	.145 ±.211
4	20-wk. body-size	.413 (.587)	.109 (.397)	.032 (.625)		.976 ±.112	.905 ±.105	.310 ±.212	.211 ±.145	.181 ±.112	.158 ±.111	.150 ±.122
5	40-wk body-size	.060 (.285)	.344 (.491)	.171 (.725)	.568 (.683)		.807 ±.024	-.831 ±.313	.354 ±.312	.254 ±.211	.401 ±.333	.200 ±.408
6	72-wk. body-size	.062 (.653)	.001 (.585)	.967 (.987)	.125 (.719)	.141 (.719)		.400 ±.212	.623 ±.211	.411 ±.112	.211 ±.112	-.236 ±.141
7	20-wk body-condition	.276 (.082)	.187 (.029)	.019 (.147)	-.762 (-.758)	-.557 (-.611)	-.152 (.035)		1.371	1.033	.329 ±.152	.254 ±.134
8	40-wk body-condition	.158 (.057)	.160 (.034)	.044 (.133)	-.542 (-.546)	-.872 (-.854)	.174 (-.004)	.131 (.719)		.160 ±.145	.321 ±.211	0.291 ±.383
9	72-wk.body-condition	-.009 (.288)	.547 (.602)	.464 (.559)	-.291 (.101)	.196 (.385)	.224 (.420)	.613 (.653)	.783 (.775)		.011 ±.131	.401 ±.211
10	Egg weight	.190 (.150)	.331 (.283)	.184 (.278)	.065 (.098)	.101 (.144)	.170 (.289)	.065 (.002)	.065 (.004)	.154 (.061)		-.557 ±.181
11	Egg no. to 40 wks	.176 (.113)	.001 (-.040)	.073 (-.043)	.040 (.033)	-.095 (-.059)	.088 (.053)	.082 (.051)	.099 (.044)	-.018 (.027)	.029 (-.193)	
12	Egg no. to 72 wks	.183 (.124)	.091 (-.004)	.097 (.030)	.175 (.111)	.172 (-.004)	.117 (.028)	.009 (.058)	-.031 (.002)	-.024 (.023)	.012 (-.112)	.462 (.550)

*Above diagonal; **below diagonal; ***below diagonal in parenthesis

		2	3	4	5	6	7	8	9	10	11	12
1. 20-wk body wt.		1.015	.985 ±.007	1.002	.997 ±.012	.991 ±.005	1.325	.392 ±.379	.825 ±.107	.207 ±.236	-.014 ±.295	0.043 ±.313
2. 40-wk body wt.	-.037 (.559)		1.023	1.056	1.008	1.042	.322 ±.997	-.002 ±.483	.714 ±.177	.294 ±.243	-.309 ±.288	-.252 ±.316
3. 72-wk body wt	.046 (.648)	.136 (.640)		.973 ±.013	.969 ±.015	.992 ±.001	1.595	.513 ±.338	.923 ±.051	.269 ±.234	-.113 ±.298	-.021 ±.320
4. 20-wk body-size	.895 (.313)	-.392 (.398)	.032 (.625)		1.009	.980 ±.010	.325 ±.145	.285 ±.153	.240 ±.116	.251 ±.231	-.078 ±.294	.011 ±.314
5. 40-wk body-size	-.040 (.374)	.883 (.937)	.171 (.725)	-.250 (.391)		.987 ±.007	.490 ±.788	.128 ±.444	.211 ±.174	.351 ±.218	-.350 ±.260	-.258 ±.234
6. 72-wk body-size	.062 (.281)	.001 (.585)	.967 (.989)	.125 (.664)	.141 (.718)		1.565	.525 ±.331	.314 ±.163	.287 ±.231	-.162 ±.293	-.053 ±.319
7. 20-wk body condition	.212 (.252)	.769 (.593)	.019 (.147)	-.245 (-.040)	.443 (.309)	-.152 (.035)		1.109	1.569	.614 ±.211	0.344	.540 ±.122
8. 40-wk body condition	-.040 (.073)	.838 (.637)	.044 (.133)	-.459 (-.202)	.485 (.327)	.174 (-.004)	.917 (.920)		.272 ±.557	.329 ±.396	.467 ±.405	.186 ±.545
9. 72-wk body condition	-.009 (.061)	.547 (.602)	.464 (.559)	-.2[illegible] (.101)	.196 (.385)	.224 (.420)	.613 (.653)	.783 (.775)		.092 ±.328	.303 ±.360	.175 ±.408
10 Egg weight	.330 (.312)	.298 (.309)	.184 (.278)	.246 (.313)	.334 (.374)	.170 (.289)	.155 (.035)	.141 (.014)	.154 (.061)		.570 ±.197	-.375 ±.267
11 Egg no to 40 wks	.345 (.164)	.078 (-.091)	.073 (-.043)	.325 (.137)	.145 (-.115)	.088 -.063	.037 (.108)	-.028 (.011)	-.018 (.027)	-.094 (-.218)		.921 ±.056
12 Egg no. to 72 wks	.187 (.124)	.091 (-.004)	.097 (.030)	.175 (.111)	.172 (-.004)	.117 (.028)	.009 (.058)	-.031 (.002)	-.024 (.023)	.012 (-.112)	.462 (.550)	

*Above diagonal; **below diagonal;*** below diagonal in parenthesis

	1	2	3	4	5	6	7	8	9	10	11	12
1. 20-wk. body wt.		.955	.906	.979	.936	.895	.854	-.114	.556	.247	.032	.047
2. 40-wk body weight	.194 (.601)		.998	.975	1.057	1.060	-.104	-.212	.614	.342	-.182	-.282
3. 72-wk. body weight	.045 (.648)	.136 (.640)		.899	.827	.994	1.089	.334	.830	.268	.129	.066
4. 20-wk. body size	.654 (.450)	-.141 (.398)	-.032 (.625)		.992	.942	.317	.248	.210	.204	.036	.157
5. 40-wk. body size	.010 (.329)	.613 (.714)	.175 (.725)	.159 (.632)		.897	-.170	.241	.232	.376	.075	.070
6. 72-wk. body size	.062 (.474)	.001 (.585)	.967 (987)	.125 (.666)	.141 (.719)		.400	.574	.362	.243	-.139	.051
7. 20-wk. body condition	.244 (.167)	.478 (.331)	.019 (.147)	-.503 (.399)	-.057 (-.151)	-.152 (.035)		1.371	1.033	.471	.493	.540
8 40-wk body condition	.059 (.065)	.499 (.335)	.044 (.133)	-.500 (-.374)	-.193 (-.263)	.174 (-.004)	.524 (.819)		.216	.325	.379	.230
9 72-wk body condition	-.009 (.174)	.547 (.602)	.464 (.559)	-.291 (.101)	.196 (.385)	.224 (.420)	.613 (.653)	.783 (.775)		.051	.352	.178
10 Egg wt.	.260 (.231)	.314 (.296)	.184 (-.278)	.155 (.205)	.217 (.259)	.170 (.289)	.110 (.018)	.103 (.009)	.154 (.061)		-.563	-.295
11 Egg no. to 40 wks	.260 (.138)	.039 (-.065)	.073 (-.043)	.182 (.585)	.025 (-.087)	.088 (-.053)	.059 (.079)	.035 (.027)	-.018 (.027)	-.032 (-.205)		.866
12 Egg no. to 72 wks	.183 (.124)	.091 (-.004)	.097 (.030)	.175 (.111)	.172 (-.004)	.117 (.028)	.009 (.058)	-.031 (.002)	-.024 (.023)	.012 (-.112)	.462 (.550)	

*Above diagonal; **below diagonal; *** below diagonal in parenthesis

	1	2	3	4	5	6	7	8	9	10	11
1. 20-wk body weight		.870 ±.081	.731 ±.226	.209 ±.272	.874 ±.079	.773 ±.195	-.088 ±.276	.797 ±.122	-.033 ±.637	.033 ±.334	.105 ±.254
2. 40-wk body wt.	.318 (.622)		.836 ±.132	-.043 ±.270	1.000	.689 ±.230	.145 ±.258	.942 ±.036	.389 ±.489	.205 ±.304	-.211 ±.362
3. 72-wk body wt.	.423 (.531)	.584 (.698)		.735 ±.223	.735 ±.223	.795 ±.167	.908 ±.094	.6[illegible]2 ±.297	.321 ±.553	.296 ±.608	.262 ±.336
4. 20-wk body size	-.001 (.048)	.038 (.004)	.429 (.530)		.650 ±.270	.768 ±.198	.322 ±.154	.226 ±.200	.188 ±.137	.240 ±.270	.038 ±.156
5. 40-wk body size	.306 (.617)	.995 (.997)	.326 (.454)	.039 (.002)		.832 ±.140	.152 ±.259	.328 ±.144	.220 ±.198	.131 ±.306	.009 ±.363
6. 72-wk body size	.271 (.358)	.308 (.430)	.637 (.699)	.280 (.366)	.819 (.825)		.691 ±.243	-.118 ±.607	.243 ±.152	.464 ±.292	.143 ±.140
7. 20-wk body condition	.060 (.039)	-.019 (.050)	.298 (.397)	-.998 (-.996)	-.021 (.051)	.152 (.238)		.268 ±.263	.450 ±.598	.214 ±.264	.341 ±.267
8 40-wk body condition	.298 (.538)	.733 (.825)	.113 (.180)	.024 (.051)	.662 (.781)	-.687 (-.570)	-.006 (.030)		1.002	.341 ±.281	.015 ±.363
9 72-wk body condition	.075 (.144)	.187 (.243)	.182 (.236)	.070 (.141)	-.719 (-.582)	-.642 (-.530)	.988 (.148)	.102 (.989)		.422 ±.402	.017 ±.539
10 Egg wt.	.507 (.217)	.449 (.369)	.466 (.537)	.020 (.026)	.459 (.367)	.449 (.079)	.050 (.054)	.223 (.312)	.109 (.099)		-.222 ±.345
11 Egg no, to 40 wks	.053 (.204)	.177 (.067)	-.094 (.174)	-.097 (.010)	.187 (.076)	-.131 (.034)	.100 (.004)	.049 (.018)	.073 (.080)	.076 (-.107)	
12 Egg no to 72 wks	.001 (.099)	-.025 (.079)	-.045 (.107)	-.004 (.100)	-.104 (.028)	-.116 (.042)	.041 (.080)	.096 (.050)	.102 (.047)	-.166 (-.086)	.545 (.619)

*Above diagonal; **below diagonal; ***below diagonal in parenthesis

	1	2	3	4	5	6	7	8	9	10	11
1.20-wk body weight		.749 ±.184	.731 ±.226	.998 ±.002	.843 ±.126	.773 ±.195	.846 ±.126	.023 ±.330	-.033 ±.637	.079 ±.354	.048 ±.254
2.40-wk body wt.	.559) (.656)		.836 ±.132	.771 ±.170	.914 ±.065	.689 ±.230	.441 ±.324	.454 ±.424	.339 ±.489	.068 ±.321	-.254 ±.271
3.72-wk body wt. .	.423 (.531)	.584 (.698)		.735 ±.225	.795 ±.167	.903 ±.094	.602 ±.297	.321 ±.535	.296 ±.608	.262 ±.347	-.13[illegible] ±.256
4.20-wk body size	.997 (.998)	.446 (.663)	.429 (.537)		.855 ±.637	.768 ±.198	.316 ±.146	.245 ±.164	.216 ±.137	.109 ±.352	.094 ±.053
5.40-wk body size	.335 (.442)	.222 (.639)	.326 (.454)	.342 (.451)		.832 ±.140	.587 ±.273	.352 ±.152	.220 ±.198	.256 ±.312	.012 ±.271
6.72-wk body size	.271 (.368)	.167 (.430)	.637 (.699)	.280 (.366)	.319 (.825)		.691 ±.243	-.118 ±.607	.243 ±.152	.464 ±.292	.043 ±.140
7.20-wk body condition	.861 (.858)	.561 (.491)	.298 (.397)	.827 (.827)	.221 (.297)	.152 (.238)		.451 ±.353	.550 ±.598	.134 ±.336	.439 ±.303
8.40-wk body condition	.081 (.153)	.536 (.273)	.113 (.180)	.075 (.297)	-.704 (-.565)	-.687 (-.570)	.051 (.157)		1.002	.448 ±.362	.062 ±.497
9.72-wk body condition	.075 (.144)	.308 (.243)	.182 (.236)	.070 (.238)	-.719 (-.582)	-.642 (-.530)	.469 (.148)	.988 (.989)		.422 ±.402	.017 ±.539
10.Egg wt.	.338 (.217)	.522 (.248)	.466 (.174)	.323 (.223)	.465 (. 126)	.449 (.079)	.366 (.145)	-.106 (.112)	.109 (.099)		-.351 ±.264
11.Egg no.to 40 wks	.111 (.204)	-.023 (.112)	-.094 (.107)	.107 (.202)	-.087 (.024)	-.131 (.034)	.126 (.190)	.079 (.091)	.073 (.080)	.014 (-.161)	
12.Egg no.to 72 wks	.001 (.099)	-.025 (.079)	-.045 (.088)	-.004 (.100)	-.104 (.028)	-.116 (.042)	.041 (.080)	.096 (.050)	.102 (.047)	-.166 (.086)	.545 (.619)

*Above diagonal; **below diagonal; ***below diagonal in parenthesis

	1	2	3	4	5	6	7	8	9	10	11	12
1. 20-wk body weight		.809	.731	.603	.858	.773	.379	.410	-.033	.118	.076	.103
2. 40-wk body wt.	.438 (.639)		.836	.364	.957	.689	.293	.698	.389	.137	-.232	-.342
3. 72-wk body weight	.423 (.531)	.584 (.698)		.735	.795	.903	.602	.321	.296	.262	-.157	-.126
4. 20-wk body size	.498 (.423)	.242 (.333)	.429 (.537)		.402	.768	.310	.235	.202	.174	.066	.009
5. 40-wk body size	.320 (.400)	.608 (.818)	.326 (.454)	.190 (.226)		.832	.369	.340	.220	.223	.001	.094
6. 72-wk body size	.271 (.358)	.247 (.430)	.637 (.699)	.280 (.366)	.819 (.825)		.691	-.118	.243	.464	.093	.077
7. 20-wk body condition	.460 (.448)	.271 (.270)	.298 (.397)	.085 (.084)	.100 (.174)	.152 (.238)		.359	.500	.189	.39	.287
8. 40-wk body condition	.189 (.691)	.634 (.549)	.113 (.180)	.049 (.174)	.021 (.100)	-.687 (-.570)	.022 (.093)		1.002	.394	.038	.126
9. 72-wk body condition	.075 (.144)	.308 (.243)	.182 (.236)	.070 (.238)	-.719 (-.582)	-.642 (-.530)	.469 (.148)	.988 (.989)		.422	.017	.227
10. Egg weight	.422 (.232)	.485 (.258)	.466 (.335)	.171 (.124)	.412 (.246)	.449 (.079)	.208 (.099)	.164 (.212)	.109 (.099)		-.286	-.027
11. Egg no. to 40 wks	.082 (.204)	.077 (.289)	-.094 (.174)	.147 (.139)	-.109 (.049)	-.015 (.019)	.113 (.097)	.064 (.054)	.073 (.080)	.045 (-.134)		.777
12. Egg no. to 72 wks	.001 (.039)	-.025 (.079)	-.045 (.088)	-.054 (.064)	-.110 (.035)	-.047 (.061)	.041 (.080)	.096 (.050)	.102 (.047)	-.083 (.043)	.545 (.619)	

*Above diagonal; **below diagonal; ***below diagonal in parenthesis

	1	2	3	4	5	6	7	8	9	10	11	12
1. 20-wk body weight		.882	.818	.791	.897	.616	.616	.262	.261	.182	.054	.075
2. 40-wk body wt.	.312 (.620)		.917	.669	1.007	.874	.094	.243	.501	.239	-.207	-.312
3. 72-wk body wt.	.234 (.589)	.360 (.670)		.817	.811	.948	.840	.327	.563	.265	-.143	-.096
4. 20-wk body size	.576 (.486)	.050 (.365)	.194 (.467)		.697	.855	.318	.241	.226	.189	.051	.083
5. 40-wk body size	.165 (.364)	.610 (.761)	.200 (.589)	.174 (.429)		.864	.099	.290	.226	.299	.037	.082
6. 72-wk body size	.166 (.416)	.124 (.507)	.802 (.843)	.202 (.516)	.480 (.772)		.545	.228	.302	.356	-.053	.064
7. 20-wk body condition	.352 (.307)	.374 (.290)	.158 (.272)	-.294 (.241)	.021 (.011)	.076 (.131)	.	.840	.766	.330	.444	.413
8. 40-wk body condition	.124 (.378)	.566 (.442)	.078 (.156)	-.225 (-.100)	-.107 (-.081)	-.256 (-.283)	.273 (.461)		.609	.359	.208	.178
9. 72-wk body condition	.032 (.159)	.427 (.322)	.323 (.397)	-.110 (.169)	-.261 (-.098)	-.211 (-.055)	.541 (.400)	.885 (.882)		.236	.184	.202
10. Egg wt.	.341 (.231)	.399 (.277)	.325 (.311)	.163 (.164)	.314 (.252)	.309 (.179)	.159 (.058)	.133 (.110)	.131 (.080)		-.424	-.161
11. Egg no. to 40 wks	.171 (.171)	.058 (.012)	-.010 (.065)	-.164 (.362)	-.042 (-.068)	.036 (-.016)	.086 (.088)	.049 (.040)	.027 (.053)	.006 (-.169)		.821
12. Egg no. to 72 wks	.092 (.112)	.033 (.037)	.026 (.059)	.060 (.087)	.031 (.016)	.045 (.044)	.025 (.069)	.032 (.024)	.039 (.035)	.030 (-.034)	.503 (.584)	

** Above diagonal; ** below diagonal; *** below diagonal in parenthesis

Genetic correlations between body weight at different ages and egg production to 40 weeks and 72 weeks were variable. The genetic correlation between 20 week body weight and egg production to 40 and 72 weeks were low. Whereas at other ages the genetic correlations were low and negative (mainly) in these populations. Values ranged from -.014 to .105 (tables 16 and 18) for 20-week body weight and egg production to 40 weeks of age, .043 to .112 (tables 16 and 19) for 20-week body weight and egg production to 72 weeks of age. -.069 to -.309 (tables 16 and 15) for 40-week body weight and egg production to 40 weeks of age, -.252 to -.373 (tables 16 and 18) for 40-week body weight and egg production to 40 weeks of age, -.069 to .373 (tables 15 and 18) for 40-week body weight and egg production to 72 weeks of age, and -.021 to .141 (tables 16 and 19) for 72-week body weight and egg production to 72 weeks of age. Average over generations and strains the genetic correlations between 20-week body weight and egg production to 40 weeks, 20-week body weight and egg production to 72 weeks, 40-week body weight and egg production to 40 weeks, 40-week body weight and egg production to 72 weeks and 72-week body weight and egg production to 72 weeks were .054, .075, -.207. -.312 and -0.96 respectively (table 21).

Similar results were reported by Yamada (1955), Hussain and Singh (1964) and Prakashbabu (1973).

Environmental correlations between body weight at different ages and egg production were in general low. The values ranged from .053 to .345 (tables 18 and 16) for 20-week body weight and egg production to 40 weeks .001 to .183 (tables 15 and 18) for 20-week body weight and egg production to 72 weeks of age, -0.231 to .177 (tables 19 and 18) for 40-week body weight and egg production to 40 weeks of age, -.025 to .091 (tables 18 and 15) for 40-week body weight and egg production to 40 week of age, -.025 to .091 (tables 18 and 15) for 40-week body weight and egg production to 72 weeks of age and -.045 to .097 (tables 18 and 15) for 72-week body weight and egg production to 72 weeks of age. Averaged over generations and strains the environmental correlations between 20-week body weight and egg production to 40 weeks of age, 20-week body weight and egg production to 72 weeks, 40-week body weight and egg production to 40 weeks of age, 40-week body weight and egg production to 72 weeks of age, 72-week body weight and egg production to 72-weeks of age were .171, .092, .058, .033 and .026 respectively(table 21)

The genetic correlation between body weight and egg number indicate that an increase in egg number would also bring about a small increase in 20-week body weight but decrease in 40-week body weight.

Body weight and egg weight

Phenotypic correlations between body weight at different ages and egg weight were medium and positive. The estimates ranged from .150 to .312 (tables 15 and 16) for 20-week body weight and egg weight during 36 to 40 weeks of age and .248 to .369 (tables 19 and 18) for 40-week body weight and and egg weight Averaged over generations and strains, the phenotypic correlations between 20-week body weight and egg weight and 40-week body weight and egg weight were .231 and .277. Similar reports were made by Reddy et al. (1972) and Prakashbabu (1973).

Genetic correlations between body weight at different ages and egg weight were positive and ranged from .039 to .207 (tables 18 and 16) for 20-week body weight and egg weight, .068 to .391 (tables 19 and 15) for 40-week body weight and egg weight. Averaged over generations and strains the genetic correlations between 20-week body weight and egg weight and 40-week body weight and egg weight were .182 and .239 respectively. Similar reports were made by Knox (1934), Jerome et al. (1956) Clayton and Robertson (1966) and Prakashbabu (1973).

Environmental correlations between body weight at different ages and egg weight were medium and positive. The estimates ranged from .190 to .507 (tables 15 and 18) for 20-week body weight and egg weight, .298 to .522 (tables 16 and 19) for 40-week body weight and egg weight. Averaged over generations and strains, the environmental correlations between 20-week body weight and egg weight and 40-week body weight and egg weight were .341 and .399 respectively (table 21). Similar reports were given by Chaudhury et al.(1976) and Singh (1977).

The positive genetic correlation between body weight and egg weight indicate that an increase in egg weight would also bring about increase in body weight. The positive phenotypic correlation indicate that heavier birds would lay heavier eggs. Environmental factors would influence body weight and egg weight in the same direction.

Body weight and body-size

Phenotypic correlations between body weight and body-size at different ages were high and positive. The values ranged from .048 to .998 (tables 18 and 19) for 20-week body weight and 20-week body-size, .285 to .617 (tables 15 and 18) for 20-week body weight (tables 16 and 15) and 40-week body-size, .289 to .653 for 20 week body weight and 72-week body-size, .491 to .997 (tables 15 and 18) for 40-week body weight and 40-week body size, .430 to .585 (tables 18 and 15) for 40-week body weight and 40-week body-size, and .699 to .987 (tables 18 and 15) for 72-week body weight and 72-week body-size. Averaged over generations and strains, the phenotypic correlations between 20-week body weight and 20-week body-size, 20-week body weight and 40-week body size, 20-week body weight and

72-week body-size, 40-week body weight and 40-week body-size, 40-week body weight and 72-week body-size, and 72-week body weight and 72-week body-size were .486, .306, .416, .761, .507, and .843 respectively (table 21).

The genetic correlations between body weight and body-size at different ages were high and positive. The values ranged from .209 to .998 (tables 18 and 19) for 20-week body weight and 20-week body size, .843 to .997 (tables 19 and 16) for 20-week body weight and 40-week body size, 0.773 to .991 (tables 18 and 16) for 20-week body weight and 72 week body size, .914 to 1.008 (tables 19 and 16) for 40-week body weight and 40-week body size, .689 to 1.042 (tables 18 and 16) for 40-week body weight and 72-week body size, and .896 to .992 (tables 15 and 16) for 72-week body weight and 72-week body size. Averaged over generations and strains, the genetic correlations between 20-week body weight and 20-week body size, 20-week body weight and 40-week body size, 20-week body weight and 40-week body size, 20-week body weight and 72-week body size, 40-week body weight and 40-week body size, 40-week body weight and 72-week body size, and 72-week body weight and 72-week body size were .791, .897, 616, 1.007, .874 and .948 (tables 21) respectively.

Environmental correlations between body weight and body size at different ages were highly variable. The values ranged from -.001 to .997 (tables 18 and 19) for 20-week body weight and 20-week body size, -.040 to .335 (tables 16 and 19) for 20-week body weight and 40-week body-size, .062 to .271 (tables 18 and 15) for 20-week body weight and 72-week-body size, .222 to .995 (tables 19 and 18) for 40-week body weight and 40-week body size, .001 to .308 (tables 16 and 18) for 40-week body weight and 72-week body-size and .637 to .967 (tables 18 and 15) for 72-week body weight and 72-week body size. Averaged over generations and strains, the environmental correlations between 20-week body weight and 20-week body size, 20-week body weight and 40-week body size, 20-week body weight and 72-week body size, 40-week body weight and 40-week body size, 40-week body weight and 72-week body size and 72-week body weight and 72-week body size were .576, .165, .166, .610, .124 and .802 respectively.

Increase in body weight would also bring about increase in body-size. Heavier birds would also have heavier body-size Managemental conditions would influence both the traits in the same direction. The genetic, phenotypic and environmental correlations between body weight and body-size were not available in the literature.

Body weight and body condition

Phenotypic correlations between body weight and body condition at different ages were positive. The estimates ranged from .039 to .858 (tables 18 and 19) for 20week body weight and 20-week body condition, 0.057 to .538 (tables 18 and 15) for 20-week body weight and 40-week body condition, .061 to .288

(tables 16 and 15) for 20-week body weight and 72-week body condition, .034 to .825 (tables 18 and 15) for 40-week body weight and 40-week body condition, .243 to .602 (tables 18 and 15) for 40-week body weight and 72-week body condition, .236 to .559 (tables 18 and 15) for 72-week body weight and 72-week body condition. Averaged over generations and strains, the phenotypic correlation between 20-week body weight and 20-week body condition, 20-week body weight and 40-week body condition, 20-week body weight and 72-week body condition, 40-week body weight and 72-week body condition and 72-week body weight and 72-week body condition were .307, .378, .159, .442, .322 and .397 respectively (table-21).

Genetic correlations between body weight and body condition at different ages were variable. The values ranged from .471 to .846 (tables 18 and 19) for 20-week body weight and 20-week body condition, .620 to .797 (tables 15 and 18) for 20-week body weight and 40-week body condition, -.033 to .825 (tables 15 and 18) for 20-week body weight and 40-week body condition, -.033 to .825 (tables 18 and 16) for 20-week body weight and 72-week body condition, .454 to .942 (tables 18 and 19) for 40-week body weight and 40-week body condition, .296 to .923 (tables 18 and 16) for 72-week body weight and 72-week body condition and .389 to .714 (tables 18 and 16) for 40-week body weight and 72-week body condition. Averaged over generations and strains, the genetic correlations were .616, .262,

.261, .243, .501 and .563 for 20-week body weight and 20-week body condition, 20-week body weight and 40-week body condition, 20-week body weight and 72-week body condition, 40-week body weight and 72-week body condition, 40-week body weight and 72-week body condition and 72-week body weight and 72-week body condition$ respectively (table-21).

Estimates of environmental correlations between body weight at different ages and body condition were variable.
The values ranged from .060 to .861 (tables 18 and 19) for 20-week body weight and 20-week body condition, -.040 to .298 (tables 16 and 18) for 20-week body weight and 40-week body condition, -.009 to .075 (tables 15 and 18) for 20-week body weight, and 72-week body condition, .160 to .838 (tables 15 and 16) for 40-week body weight and 40-week body condition, .187 to .547 (tables 18 and 15) for 40-week body weight and 72-week body condition and .182 to .464 (tables 18 and 15) for 72-week body weight and 72-week body condition. Averaged over generations and strains the environmental correlations between 20-week body weight and 20-week body condition, 20-week body weight and 40 week body condition, 20-week body weight and 72-week body condition, 40-week body weight and 40-week body condition, 40-week body weight and 72-week body conditions and 72-week body weight and 72-week body condition were .352, .124, 0.032, .566, .427 and .323 respectively (table 21).

Environmental conditions would influence body weight and body-condition in the same direction. Increase of body weight would also increase the body condition. The genetic, phenotypic and environmental correlations between body weight and body-condition were not available in the literature.

Body size at different ages

The phenotypic correlations between body-size at different ages were high and positive. The values ranged from .002 to .683 (tables 18 and 15) for body-size at 20 and 40 weeks of age .366 to .719 (tables 18 and 15) for body size at 20 and 72 weeks and .719 to .825 (tables 15 and 18) for body size at 40 and 72 weeks. Averaged over generations and strains, the phenotypic correlations of 20-week body size with the body size at 40 and 72 weeks were .429 and .516. The average phenotypic correlation between the 40-week and 72-week body size was .772 (table 21).

The genetic correlations between body size at different ages were high and positive. The values ranged from .650 to .976 (tables 18 and 15) for 20-week body size and 40-week body-size, .768 to .980 (tables 18 and 16) for 20-week body-size and 40-week body-size, and .832 to .987 (tables 18 and 16) for 40-week body-size and 72-week body-size. Averaged over generations and strains the genetic correlations between 20-week and 40-week body size, 20-week and 72-week body size and 40-week and 72-week body size were .697, .855 and .864(table 21).

The environmental correlations between body-size at different ages were low and positive. The values ranged from .250 to .568 (tables 16 and 15) for 20-week and 40-week body-size, .125 to .280 (tables 15 and 18) for 20-week and 72-week body-size, and .141 to .819 (tables 16 and 18) for 40-week and 72-week body-size. Averaged over generations and strains, the environmental correlations for body size at 20 and 40 weeks, 20 and 72 weeks and 40 and 72 weeks were .174, .202 and .480 respectively (table 21).

Body-size and egg weight

Phenotypic correlations between body-size at different ages and egg weight were positive and low. The values ranged from .026 to .313 (tables 18 and 16) for 20-week body-size and egg weight .126 to .374 (tables 19 and 16) for 40-week body-size and egg weight. The values averaged over generations and strains between 20-week body size and egg weight and 40-week body-size and egg weight were .164 and .252 (tables 21).

The genetic correlations between body-size at different ages and egg weight were low. ~~and negative.~~ The values ranged from .109 to .251 (tables 19 and 16) for 20-week body-size and egg weight, .191 to .401 (tables 18 and 15) for 40-week body-size and egg weight. The genetic correlations averaged over generations and strains between 20-week body-size and egg weight and 40-week body-size and egg weight were .189 and .299 (table 21).

Environmental correlations between body-size at different ages and egg weight were low and positive. The values ranged from .020 to .323 (tables 18 and 19) for 20-week body-size and egg weight and .101 to .465 (tables 15 and 19) for 20-week body size and egg weight. The environmental correlations averaged over generations and strains between 20-week body-size and egg weight and 40-week body size and egg weight were .171 and .412 (table 21).

With the increase of egg weight, the body-size would also increase and both the traits were influenced by the environment in the same way.

Body-size and egg production

Phenotypic correlations between body-size and egg production were low. The estimates ranged from .010 to .202 (tables 18 and 19) for 20-week body-size and egg production to 40 weeks of age, .100 to .111 (tables 19 and 17) for 20 week body size and egg production to 72 weeks -.115 to .076 (tables 16 and 18) for 40-week body-size and egg production to this age, -.004 to .028 (tables 15 and 18) for 40-week body-size and egg production to 72 weeks of age and .028 to .042 (tables 15 and 18) for 72-week body-size and egg production to this age. Averaged over generations and strains, the phenotypic correlation between 20-week body-size and egg production to 40 weeks, 20-week body-size and egg production to 72 weeks, 40-week .

body-size and egg production to this age, 40-week body-size and egg production to 72 weeks and 72-week body-size and egg production to this age were .139, .064, -.049, .035 and .061 respectively.

Genetic correlations between body-size and egg production were low. The values ranged from -.078 to .150 (tables 16 and 15) for 20-week body-size and egg production to 40 weeks, -.001 to .225 (tables 18 and 15) for 20-week body-size and egg production 72 weeks, -.350 to .200 (tables 16 and 15) for 40-week body-size and egg production to this age, -.258, to .399 (tables 16 and 15) for 40 weeks body size and egg production to 72 weeks and -.053 to ~~.099~~ .122 (table 16 and 18) for 72 weeks body size and egg production to 72 weeks. Averaged over generations and strains, the genetic correlations between 20-week body-size and egg production to 40 weeks, 20 week body-size and egg production to 72 weeks, 40-week body size and egg production to this age, 40-week body size and egg production to 72 weeks and 72-week body size and egg production to this age were .051, .083, .037 .082 and .064 respectively (table 21).

Environmental correlations between body-size and egg production were low and variable. The values ranged from -.037 to .325 (tables 18 and 16) for 20-week body-size and egg production to 40 weeks, -.004 to .175 (tables 18 and 15) for 20-week body-size and egg production to 72 weeks, -.095 to

.187 for 40-week body-size and egg production to this age, -.104 to .172 (tables 18 and 15) for 40-week body-size and egg -.115 to .117 (tables 19 and 15) for 72-week body-size and egg production to 72 weeks and/duction to this age. Averaged over generations and strains the environmental correlations between 20-week body-size and egg production to 40 weeks, 20-week body-size and egg production to 72 weeks, 40-week body-size and egg production to 40 weeks, 40-week body-size and egg production to 72 weeks and 72-week body size and egg production to this age were .164, .060, -.042, .031 and .045 respectively.

The genetic, phenotypic and environmental correlations between body-size and egg production were low. Egg production seems to be largely independent of body-size.

Body-size and body-condition

Phenotypic correlations between body-size and body-condition were highly variable. The values ranged from -.996 to .827 (tables 18 and 19) for 20-week body-size and 20-week body-condition, -.546 to .297 (tables 15 and 18) for 20-week body-size and 40-week body-condition, .101 to .238 (tables 15 and 19) for 20-week body-size and 72-week body-condition, -.582 to .385 (tables 18 and 15) for 40-week body size and 72-week body-condition and -.530 to .420 (tables 18 and 15) for 72-week body-size and 72-week body-condition. Averaged over generations and strains, the phenotypic correlations between 20-week body-size and 20-week body-condition , 20-week body-size and 40-week body-condition, 20-week body-size and 72-week body-condition, 40-week body-size and 40-week body-condition, 40-week body size and 72-week body condition and 72-week body size and 72 week body condition were .241, -.100, .169, -.081, [illegible] and -.055 respectively (table 21).

Genetic correlations between body-size and body-condition were low and positive. The values ranged from .310 to .325 (tables 15 and 16) for 20-week body size and 20-week body condition, .211 to .285 (tables 15 and 16) for 20-week body-size and 40-week body condition, .181 to .240 (tables 15 and 16) for 20-week body-size and 72-week body-condition, .128 to .354 (tables 16 and 15) for 40-week body-size and 40-week body-condition, .211 to .254 (tables 16 and 15) for 40-week body-size and 72-week body condition .243 to .254 (tables 18 and 15) for 72-week body size and 72-week body-condition. Averaged over generations and strains, the genetic correlations between 20-week body-size and 20-week body-condition, 20-week body-size and 40-week body-condition, 20-week body-size and 72-week body-conditions, 40-week body-size and 40-week body-conditions, 40-week body-size and 72-week body-condition, and 72-week body-size and 72-week body-condition were .318, .241, .226, .290, .226 and .302 respectively (table 21).

Environmental correlations between body-size and body-condition were variable. The values ranged from -.998 to .827 (tables 18 and 19) for 20-week body-size and 20-week body condition .024 to -.542 (tables 18 and 15) for 20 week body size and 40-week body-condition, .070 to -.291 (tables 18 and 1[illegible]) for 20-week body-size and 72-week body-condition, -.872 to .612 (tables 15 and 18) for 40-week body-size and 40-week body-condition, -.719 and .196 (tables 18 and 15) for 40-week body-size and 72-week body-condition and -.642 to .224 (tables 18 and 16) for 72-week body-size and 72-week body-condition. Averaged over generations and strains, the environmental correlations between 20-week body-size and 20-week body-condition, 20-week body-size and 40-week body-condition, 20-week body-size and 72-week body-condition, 40-week body-size and 40-week body-condition, 40-week body-size and 72-week body-condition and 72-week body-size and 72-week body-condition were -.294, -.225, -.110, -.107, -.261 and .211 respectively (table 21).

Body-condition at different ages

Phenotypic correlation between body-condition at different ages were high and positive. These estimates ranged from .030 to .920 (tables 18 and 16) for 20-week and 40-week body-condition .148 to .653 (tables 19 and 15) for 20-week and 72-week body condition and .775 to .983 (tables 15 and 18) for 40-week and 72-week body-condition. Averaged over generations and strains, the phenotypic correlations between 20-week and 40-week body-condition, 20-week and 72-week body-condition, and 40-week and 72-week body-condition were .461, .400 and .882 respectively (table 21).

Genetic correlations between body condition at different ages were high and positive, the values ranging from .268 to 1.377 (tables 18 and 15) for 20-week body-condition and 40-week body-condition, .450 to 1.569 for 20-week and 72 week body condition and .160 to 1.002 (tables 15 and 18) for 40-week and 72-week body condition. Averaged over generations and strains, the genetic correlations between 20 and 40-week body-condition, 20-week and 72-week body-condition and 40-week and 72-week body-condition were .840, .766 and .609 respectively (table 21).

Environmental correlations between body-condition at different ages were variable. The values varied from -.006 to .917 (tables 18 and 16) for 20-week and 40-week body-condition, .469 to .988 (tables 19 and 18) for 20-week and 72-week body condition and .102 to .989 (tables 18 and 19) for 40-week body-condition and 72-week body-condition. Averaged over generations and strains the environmental correlations between 20-week and 40-week body-condition, 20-week and 72-week body condition and 40-week and 72-week body condition were .273, .541 and .885 respectively (table 21).

Body-condition and egg weight

Phenotypic correlations between body-condition and egg weight were low and positive. The values ranged from .002 to .145 (tables 15 and 19) for 20-week body condition and egg weight and .004 to .312 (tables 15 and 18) for 40-week body-condition and egg weight. Averaged over generations and strains, the phenotypic correlations between 20-week body-condition and egg weight and 40-week body-condition and egg weight were .058 and .110 (table 21).

Genetic correlations between body-condition and egg weights were low and positive. The values ranged from .134 to .614 (tables 19 and 16) for 20-week body-condition and egg weight, .321 to .448 (tables 15 and 18) for 40-week body-condition and egg weight. Averaged over generations and strains the genetic correlations between 20 week body condition and egg weight and 40-week body condition and egg weight were .330 and .359 respectively (table 21).

Environmental correlations between body condition and egg weight were low. The estimates ranged from .050 to .366 for 20-week body-condition and egg weight (tables 18 and 19) and -.106 to .223 (table 19 and 18) for 40-week body-condition and egg weight. Averaged over generations and strains, the environmental correlations between 20-week body-condition and egg weight and 40-week body-condition and egg weight were .159 and .133 respectively (table 21). Improvement in egg weight would also cause increase of body-condition as a result of correlated response. Both the traits are influenced by the environment in the same direction.

Body-condition and egg production

Phenotypic correlations between body-condition and egg production were low and positive. Values ranged from .004 to .190 (tables 18 and 19) for 20-week body-condition and egg production to 40 weeks, .058 to .080 (tables 15 and 18) for 20-week body condition and egg production to 72 weeks, .011 to .091 (tables 16 and 19) for 40-week body condition and egg production to the same age, .002 to .050 (tables 15 and 18) for 40-week body-condition and egg production to 72 weeks and .023 to .047 (tables 15 and 18) for 72-week body-condition and egg production, to this age. Averaged over generations and strains, the phenotypic correlations between 20-week body-condition and egg production to 40 weeks, 20-week body-condition and egg production to 72 weeks, 40-week body-condition and egg production to same age, 40-week body condition and egg production to 72 weeks and 72-week body-condition and egg production to same age were .088, .069, .040, .024 and .035 respectively (table 21).

Genetic correlations between body-condition and egg production were positive. The values ranged from .254 to .439 (tables 15 and 19) for 20-week body-condition and egg production to 40 weeks, .287 to .540 (tables 18 and 15) for 20-week body-condition and egg production to 72 weeks, .015 to .467 (tables 18 and 16) for 40-week body-condition and egg production to the same age, .126 to .274 (tables 19 and 15) for 40-week body condition and egg production to 72 weeks and .175 to .227

(tables 18 and 19) for 72-week body-condition and egg production to the same age. Averaged over generations and strains, the genetic correlation between 20-week body-condition and egg production to 40 weeks, 20-week body-condition and egg production to 72 weeks, 40-week body condition and egg production to the same age, 40-week body condition and egg production to 72 weeks and 72-week body-condition and 72-week egg production were .444, .413, .208, .178 and .202 respectively (table 21).

Environmental correlations between body-condition and egg production were low. The estimates ranged from .037 to .126 (tables 16 and 19) for 20-week body condition and egg production to 40 weeks, .009 to .041 (tables 15 and 18) for 20-week body-condition and egg production to 72 weeks, -.029 to .099 (tables 16 and 15) for 40-week body-condition and egg production to the same age, -.031 to .096 (tables 15 and 18) for 40-week body-condition and egg production to 72 weeks and -.024 to .102 (tables 15 and 18) for 72-week body condition and egg production to the same age. Averaged over generations and strains, the environmental correlations between 20-week body condition and egg production to 40-weeks, 20-week body-condition and egg production to 72 weeks, 40-week body-condition and egg production to the same age and 72-week body-condition and egg production to 72 weeks were .036, .025, .049, .032 and .039 respectively (table 21).

Reports were not available in the literature about genetic, phenotypic and environmental correlations between body-condition and egg production. With the increase of egg production, body-condition also would increase.

Optimum body weight for egg weight, egg production and egg mass:

20-week body weight and egg weight

Linear, quadratic and cubic equations of egg weight (g) during 36-40 weeks of age on body weight (g) at 20 weeks of age in Pb-1 and Pb-2 are presented in tables 22 and 23 respectively. In Pb-1 the quadratic equation was significant and had higher multiple correlation coefficient than either the linear or cubic equations in both the generations. So the quadratic equation explains the relationship between 20-week body weight and egg weight better. Using this equation for 1975-76 generation, the predicted values of egg weight for the corresponding value of 20-week body weight were obtained (table 34). A graph was also drawn with these values and is shown in figure 1. In Pb-1 with the increase of 20-week body weight, there was increase of egg weight during 36-40 weeks of age, almost linearly upto 1200 grams. After that, the increase in egg weight was 0.5 g or less for increase of every 100 g in body weight. Considering the economic returns from the increase in egg weight and the feed required to sustain the

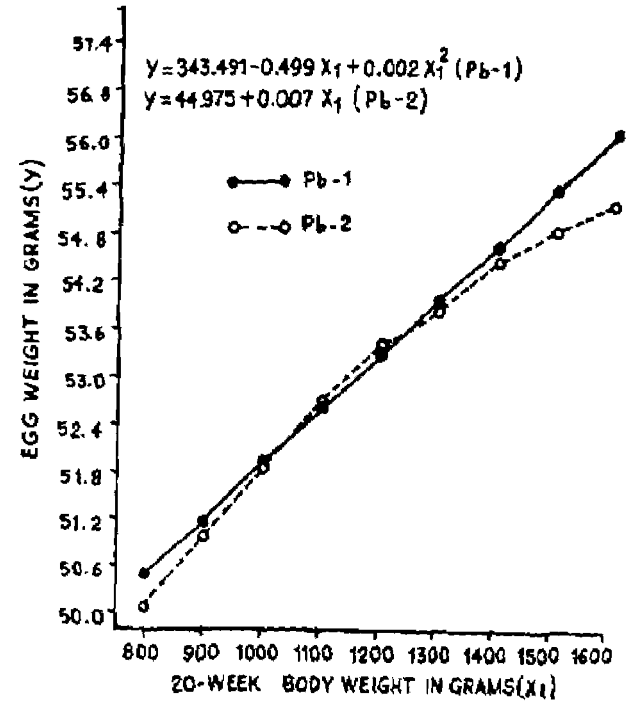

FIG.1. THE RELATIONSHIP BETWEEN EGG WEIGHT AND BODY WEIGHT AT 20 WEEKS IN Pb-1 AND Pb-2

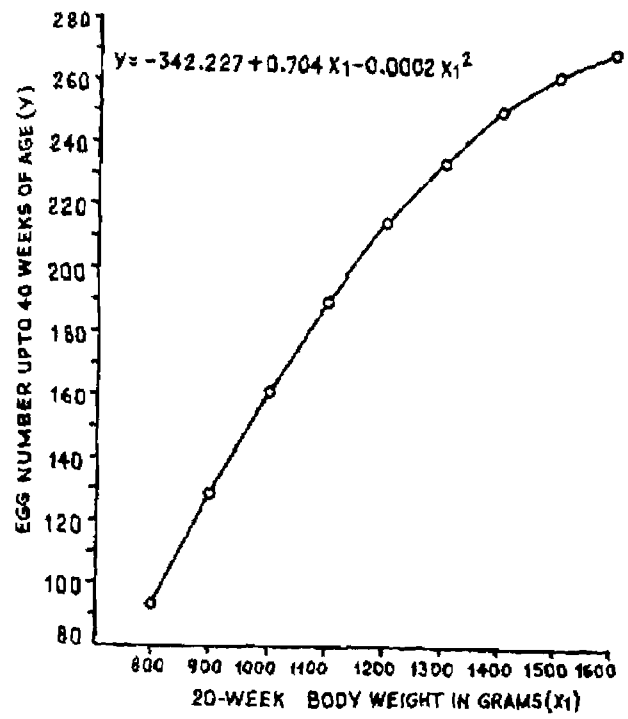

FIG.3. THE RELATIONSHIP BETWEEN EGG NUMBER TO 40 WEEKS AND BODY WEIGHT AT 20 WEEKS IN Pb-1

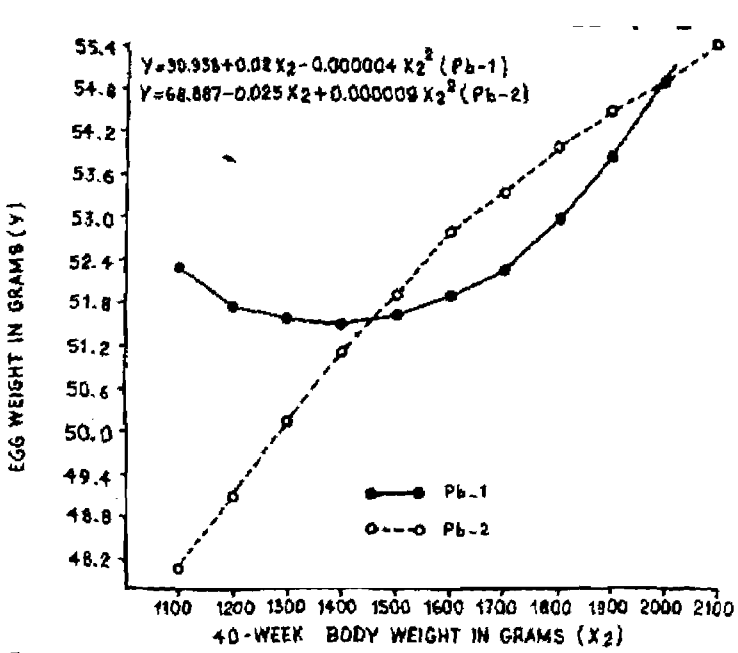

FIG.2. THE RELATIONSHIP BETWEEN EGG WEIGHT AND BODY WEIGHT AT 40 WEEKS IN Pb-1 AND Pb-2

extra body weight, 1100 to 1200 grams was the optimum 20-week body weight for maximum egg weight. Because the loss for every 100 g increase in body weight was Rs. 0.90 after giving the allowance for the economic ~~term~~ return from the sale of 100 g body weight in the market. One gram increase in egg weight would fetch Rs. 0.50 per pullet per year after giving allowance for maintenance cost and market return for body weight.

In Pb-2, the relationship between egg weight and body weight at 20 weeks seems to be linear (Fig.1). For every 100 g increase in body weight, egg weight increased by 0.7 g and it would result in net economic returns of 8 paisa after giving allowance for feed required for maintaining extra 100 g and the return in the market from the sale of 100 g. So in Pb-2 optimum 20-week body weight for maximum egg weight cannot be pointed out specifically, but higher 20-week body weight would result in higher, egg weight and economic return.

40-week body weight and egg weight

In Pb-1 the relationship between 40-week body weight and egg weight was quadratic (table 24 and figure 2). With the increase of body weight, the egg weight increased almost linearly till the body weight reached 1600 g. With further increase in body weight, egg weight increased by 0.6 g or less for every 100 g increase (table 35). 0.6 gram increase in egg weight per 100 g body weight would result in loss of 6 paisa in net economic return. So the gain in egg weight for every 100 grams should not be less than 0.7 grams.

The optimum 40-week body weight for maximum economic return from egg weight was 1600 grams in Pb-1.

In Pb-2 the relationship between 40-week body weight and egg weight was quadratic (table 25 and figure 2). Quite surprisingly the egg weight declined with the increase of 40-week body weight till about 1400 grams and after 1500 grams the egg weight increased with the increase of 40-week body weight. After 1500 grams even though there was increase in egg weight, with the increase of body weight, it would not result in extra economic return. It was not possible to draw conclusions about optimum body weight for maximum egg weight in this strain.

20-week body weight and egg number to 40-weeks,

In Pb-1 the relationship between body weight at 20-weeks and egg number to 40 weeks was quadratic (table 26 and figure 3). With the increase of body weight at 20 weeks, the egg number would increase almost linearly till the body weight was about 1200 grams. Thereafter, the rate of increase in egg number declined with the increased of body weight. But, the increase in body weight continues to give more net economic return. The optimum 20-week body weight for maximum net economic return through increased egg number cannot be pointed out as there was continued net economic return with the increase of body weight.

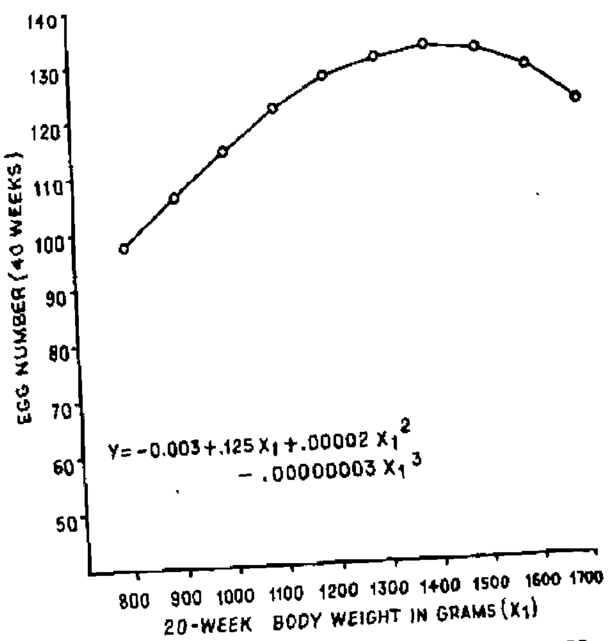

FIG.4. THE RELATIONSHIP BETWEEN EGG NUMBER TO 40 WEEKS AND 20 WEEKS BODY WEIGHT IN Pb-2

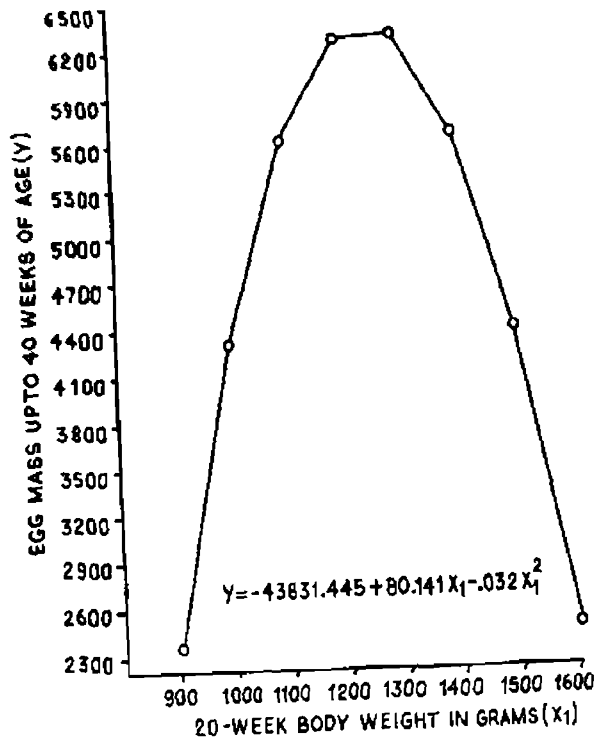

FIG.6. THE RELATIONSHIP BETWEEN EGG MASS TO 40 WEEKS AND BODY WEIGHT AT 20 WEEKS IN Pb-1

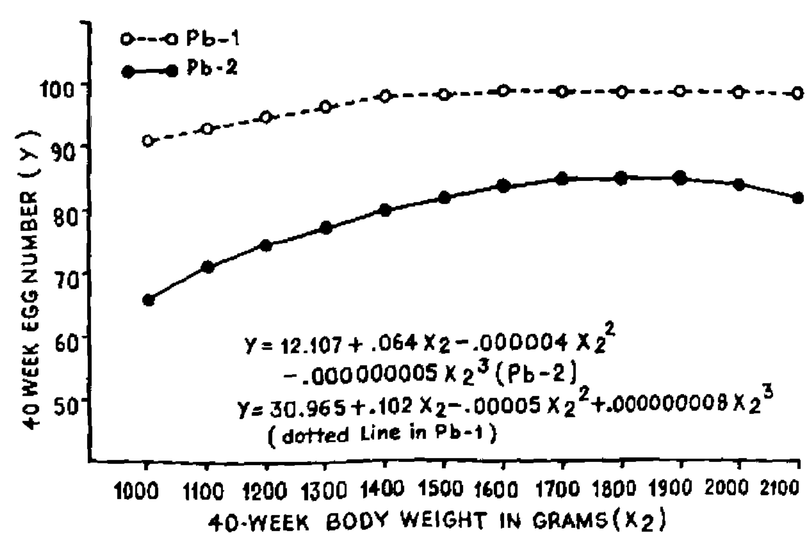

FIG.5. THE RELATIONSHIP BETWEEN EGG NUMBER TO 40 WEEKS AND BODY WEIGHT AT 40 WEEKS

In Pb-2 the relationship between body weight at 20 weeks and egg number was cubic (figure 4 and table 27). Egg number increased almost linearly till 1200 grams. Egg production declined sharply after the 20-week body weight reached 1500 grams. The pullets with 20-week body weight of 1300 to 1500 grams produced maximum number of eggs in this strain. But considering net economic returns 1200 to 1300 grams was optimum 20-week body weight for this strain.

40-week body weight and egg number

In Pb-1 the relationship between body weight at 40 weeks and egg number to 40 weeks was cubic (table-28 and figure 5). The egg number to 40 weeks was expected to increase till the body weight reached 1400 grams. After that the increase in egg number with increase in body weight was small. Birds of 1400 to 1600 grams would give maximum number of eggs. Considering the net economic return, 1300-1400 grams was the optimum 40 week body weight.

In Pb-2 the relationship between body weight at 40-weeks and egg number was cubic (table 29 and figure 5). The egg number to 40 weeks increased till the body weight at 40 weeks reached 1600 grams. Thereafter, with the increase of body weight the increase in egg number was more. Birds of 1600-1800 grams produced maximum number of eggs. Considering the net economic returns, 1600-1700 grams was the optimum 40-week body weight for maximum net economic return through egg number.

20-week body weight and egg mass:

The relationship between body weight at 20 weeks and egg mass to 40 weeks of age was quadratic in Pb-1 (table-30 and figure-6). With the increase in body weight at 20 weeks, the egg mass to 40 weeks increased till the body weight reaches 1200 g. Egg mass to 40 weeks declined sharply as soon as 20-week body weight exceeds 1300 g. Birds weighing 1200-1300 g at 20 weeks were expected to yield maximum egg mass to 40 weeks (table 34). Considering the net economic return the optimum 20-week body weight for egg mass yield appears to be 1200 g in Pb-1.

In Pb-2, the relationship between 20-week body weight and egg mass to 40-weeks of age was cubic (table 31 and figure 8) There was almost linear increase in egg mass, with the increase in body weight till the body weight reached 1200 g. Thereafter the rate of increase in egg mass declined. Even when net economic return was considered higher 20-week body weight yielded higher egg mass yield. There seems to be a close relationship between 20-week body weight and egg mass in Pb-2.

40-week body weight and egg mass to 40 weeks:

The relationship between 40-week body weight and egg mass to 40 weeks was cubic in Pb-1 (table 32 and figure 8).

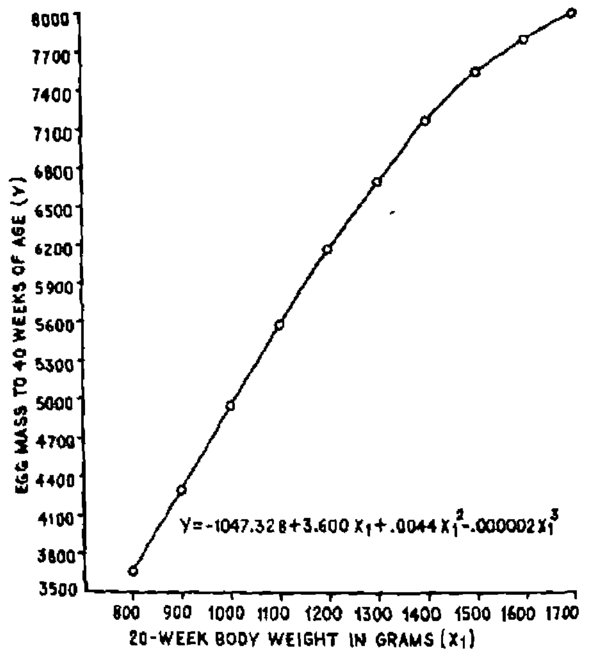

FIG.7_THE RELATIONSHIP BETWEEN EGG MASS TO 40WEEKS AND 20WEEKS BODY WEIGHT IN Pb-2

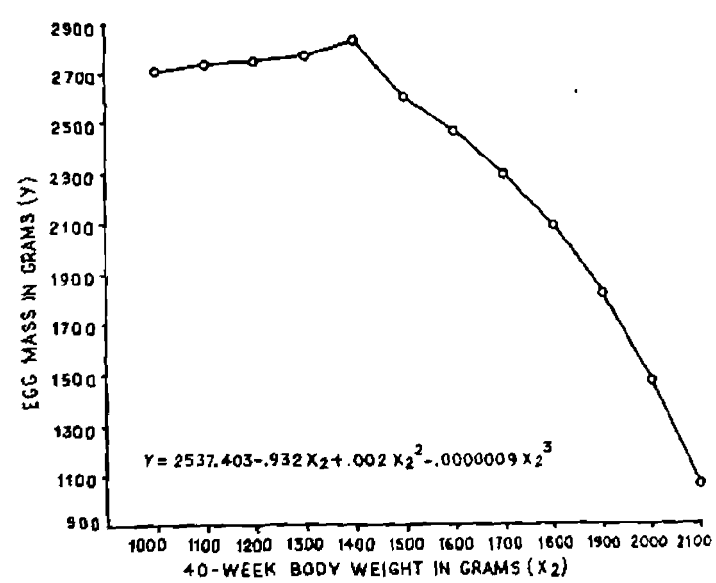

FIG.8_THE RELATIONSHIP BETWEEN 40 WEEK BODY WEIGHT AND EGG MASS TO 40 WEEKS IN Pb-1

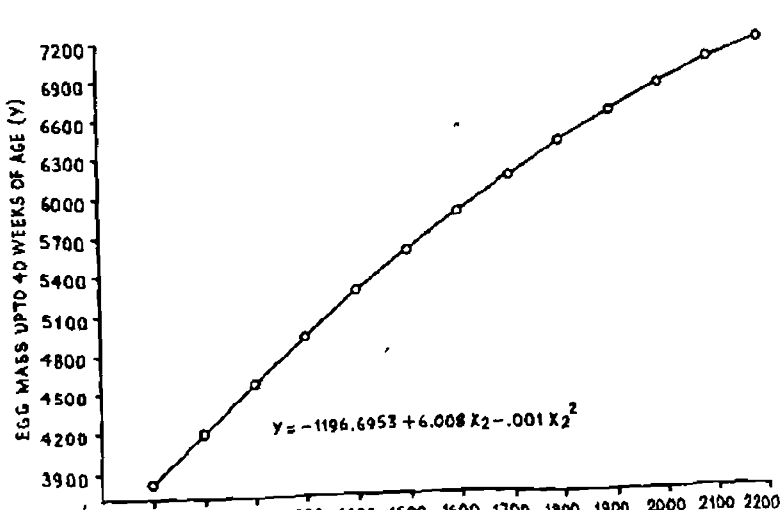

FIG.9_THE RELATIONSHIP BETWEEN BODY WEIGHT AT 40 WEEKS AND EGG MASS TO 40 WEEKS OF AGE IN Pb-2

With the increase of 40-week body weight the egg mass to 40-weeks increased till the body weight was about 1400 g. When the 40-week body weight was more than 1400 g the decline in egg mass was very sharp. Birds which were 1300-1400 g at 40 weeks produced maximum egg mass (table 35).

In Pb-2 the relationship between body weight at 40-weeks and egg mass to 40 weeks was quadratic (table 33 and figure 9). With the increase of 40-week body weight, the egg mass to 40-weeks also increased. Even after considering the net economic returns in Pb-2, higher the 40-week body weight, higher would be the egg mass output.

Table-22. Linear, quadratic and cubic equations of egg weight (36-40 weeks) on 20-week body weight (g) in Pb-1

Equation	Generation	a	b	c	d	F	R
Linear (a+bx)	1975-76	43.149	.009	-	-	84.24	.10
	1974-75	47.007	.005	-	-	13.86	.02
Quadratic ($a+bx+cx^2$)	1975-76	343.491	-0.499	.0002	-	157.11	.29
	1974-75	310.211	-0.331	.0002	-	112.45	.20
Cubic ($a+bx+cx^2$ +dx3)	1975-76	-49.537	.199	-.00001	.0000002	1.65	.01
	1974-75	-60.476	.172	-.000002	-.00000003	6.73	.03

Table-23. Linear, quadratic and cubic equations of egg weight (g) during 36-40 weeks of age on body weight (g) at 20 weeks in Pb-2.

Equation	Generation	a	b	c	d	F	R
Linear ($a+bx$)	1975-76	44.975	.007	-	-	25.50**	0.05
	1974-75	39.774	.011	-	-	48.86**	0.11
Quadratic ($a+bx+cx^2$)	1975-76	-15.800	.117	-.00004	-	4.85*	0.02
	1974-75	-10.89	.104	-.00004	-	21.25	0.09
Cubic ($a+bx+cx^2+dx^3$)	1975-76	31.649	.039	-.00002	.000000006	6.13**	0.03
	1974-75	37.780	.020	-.00001	.000000005	15.99	0.10

(*=$P<0.05$; **=$P<0.01$)

Table-24. Linear, quadratic and cubic equations of egg weight (g) during 36-40 weeks of age on 40-week body weight (g) in Pb-1

Equation	Generation	a	b	c	d	F	R
Linear ($a+bx$)	1975-76	44.969	.005	-	-	81.98**	0.10
	1974-75	43.478	.006	-	-	52.26**	0.08
Quadratic ($a+bx+cx^2$)	1975-76	30.938	.002	-.000004	-	65.36	0.14
	1974-75	46.494	.002	.000001	-	26.65**	0.08
Cubic ($a+bx+cx^2+dx^3$)	1975-76	33.663	.016	-.000002	-.0000000002	43.60**	0.14
	1974-75	46.917	-.006	.00001	.000000002	19.34**	0.09

(*=P<0.05; **=P<0.01)

Table-25. Linear, quadratic and cubic equations of egg weight (g) during 36-40 weeks of age on 40-week body weight (g) in PD-2

Equation	Generation	a	b	c	d	F	R
Linear (a+bx)	1975-76	45.036	.005	-	-	34.22**	0.06
	1974-75	41.081	.006	-	-	65.79**	0.14
Quadratic ($a+bx+cx^2$)	1975-76	68.887	-.025	.000009	-	20.64**	0.07
	1974-75	52.027	-.008	.000005	-	42.30**	0.17
Cubic ($a+bx+cx^2+dx^3$)	1975-76	66.301	-.027	0.00001	-.000000002	14.34	0.08
	1974-75	52.067	-.010	0.000007	-.0000000007	28.19	0.17

(* = P< 0.05; ** P<0.01)

Table-26. Linear, quadratic and cubic equations of egg number to 40-weeks on 20-week body weight (g) in Pb-1

Equation	Generation	a	b	c	d	F	R
Linear ($a+bx$)	1975-76	60.647	.021	-	-	21.80**	0.03
	1974-75	55.683	.0178	-	-	7.83**	0.01
Quadratic ($a+bx+cx^2$)	1975-76	342.227	.704	-.0002	-	18.04**	0.04
	1974-75	382.121	.911	-.0003	-	19.12	0.05
Cubic ($a+bx+cx^2+dx^3$)	1975-76	71.566	-.032	.00006	-.00000002	7.67**	0.03
	1974-75	-60.476	.172	-.000002	-.00000003	6.78	0.03

(*=$p<0.05$; **$p<0.01$)

Table-27. Linear, quadratic and cubic equations of egg number to 40 weeks on body weight (g) at 20 weeks of age in Po-2

Equation	Generation	a	b	c	d	F	R
Linear $(a+bx)$	1975-76	41.666	.036	-	-	21.95**	0.04
	1974-75	42.278	.030	-	-	12.63**	0.03
Quadratic $(a+bx+cx^2)$	1975-76	230.467	-.304	.0001	-	8.11**	0.03
	1974-75	386.876	-.605	.0002	-	1.63	0.01
Cubic $(a+bx+cx^2+dx^3)$	1975-76	-.003	.125	.00002	-.00000003	8.79**	0.05
	1974-75	-41.052	.131	.00002	--0000004	5.80**	0.04

(**= P<0.01)

Table-28. Linear, quadratic and cubic equations of egg number to 4.-weeks on body weight (g) at 40 weeks of age in Do-1

Equation	Generation	a	b	c	d	F	R
Linear ($a+bx$)	1975-76	97.679	-.007	-	-	6.41*	0.01
	1974-75	81.860	-.0038	-	-	0.96	0.001
Quadratic ($a+bx+cx^2$)	1975-76	113.534	-.024	.000004	-	4.46*	0.01
	1974-75	60.195	.025	-.000009	-	1.78	.01
Cubic ($a+bx+cx^2+dx^3$)	1975-76	30.965	.102	-.00005	.000000008	5.50**	0.02
	1974-75	62.058	-.011	.00003	.00000001	.250	0.01

(* = $P<0.05$; ** = $P<0.01$).

Table-29. Linear, quadratic and cubic equations of egg number to 40-weeks of age on 40-week body weight (g) in Pb-2

Equation	Generation	a	b	c	d	F	R
Linear (a+bx)	1975-76	63.402	.012	-	-	6.30**	0.01
	1974-75	64.377	.006	-	-	2.13	0.01
Quadratic $(a+bx+cx^2)$	1975-76	17.692	.070	-.00001	-	3.48*	0.01
	1974-75	37.548	.043	-.000001	-	2.67	0.01
Cubic $(a+bx+cx^2+dx^3)$	1975-76	12.107	.064	-0.00004	-0.000000005	2.47	0.01
	1974-75	38.135	.014	0.00002	-0.00000001	2.15	0.02

(*=$P<0.05$; **=$P<0.01$)

Table-30. Linear, quadratic and cubic equations of egg mass to 40-weeks of age on 20-week body weight (g) in Rb-1

Equation	Generation	a	b	c	d	F	R
Linear $(a+bx)$	1975-76	2303.433	.019	-	-	68.71**	0.08
	1974-75	2404.625	.014	-	-	18.10	0.03
Quadratic $(a+bx+cx^2)$	1975-76	-43831.445	80.141	-.032	-	75.21**	0.16
	1974-75	-41121.131	75.221	-.027	-	48.11	0.08
Cubic $(a+bx+cx^2+dx^3)$	1975-76	6399.363	-.092	.010	-.000003	22.22**	.08
	1974-75	-7339.237	.074	.002	-.000003	11.79**	.06

(* = P < 0.01) (** = < 0.01)

Table-31. Linear, quadratic and cubic equations of egg mass to 40-weeks of age on 20-week body weight (g) in Po-2

Equation	Generation	a	b	c	d	F	R
Linear ($a+bx$)	1975-76	1485.044	2.617	-	-	40.61**	0.07
	1974-75	1322.347	2.385	-	-	29.26**	0.07
Quadratic ($a+bx+cx^2$)	1975-76	20120.251	-31.080	.015	-	10.14**	0.04
	1974-75	26016.777	-43.178	.020	-	5.38**	0.03
Cubic ($a+bx+cx^2+dx^3$)	1975-76	-1047.328	3.600	.044	-.000002	14.81**	0.08
	1974-75	-1200.222	3.712	.004	-.000002	10.87**	0.07

(**=P <0.01)

Table-32. Linear, quadratic and cubic equations of egg mass to 40 weeks of age on body weight (g) at 40 weeks of age in Pb-1

Equation	Generation	a	b	c	d	F	R
Linear (a+bx)	1975-76	4490.875	.089	-	-	0.34	0.001
	1974-75	3567.148	.294	-	-	2.01	0.001
Quadratic ($a+bx+cx^2$)	1975-76	4164.921	.444	-.00009	-	0.35	0.001
	1974-75	2397.436	.013	-.0005	-	2.36	0.01
Cubic ($a+bx+cx^2+dx^3$)	1975-76	3011.064	.022	-.0009	.0000001	0.41	0.00
	1974-75	2537.403	-.932	.002	-.0000009	4.43*	0.02

(*=P <0.05)

Table-33. Linear, quadratic and cubic equations of egg mass to 40-weeks of age on 40-week body weight (g) in Pb-2

Equation	Generation	a	b	c	d	F	R^2
Linear (a+bx)	1975-76	2649.830	1.108	-	-	18.93**	0.04
	1974-75	2555.264	.835	-	-	12.43**	0.03
Quadratic ($a+bx+cx^2$)	1975-76	-1196.6953	6.008	-.001	-	10.58**	0.04
	1974-75	1719.108	1.997	-.0003	-	6.79**	0,03
Cubic ($a+bx+cx^2+dx^3$)	1975-76	-1825.726	5.370	.00001	--0.0000005	7.47**	0.04
	1974-75	1747.464	.594	.001	-0.0000005	4,85**	0.03

(**= $P < 0.01$)

Table-3... The relationship between 20-week body weight, egg weight during 36-40 weeks of age, egg number to 40 weeks and egg mass to 40-weeks of age in the two White Leghorn strains

20-week body wt(g)	Pb-1			Pb-2		
	Egg weight(g)	Egg number	Egg mass(g)	Egg weight(g)	Egg number	Egg mass(g)
800	50.124	92.973	2200.125	50.575	97.437	3674.672
900	51.031	123.373	2375.455	51.275	106.827	4298.672
1000	51.912	161.773	4309.655	51.975	114.997	4952.672
1100	52.671	190.173	5603.655	52.675	121.767	5574.672
1200	53.412	214.573	6257.755	53.375	126.957	6152.672
1300	53.912	234.973	6271.855	54.075	130.387	6674.572
1400	54.511	251.373	5645.955	54.775	131.877	7128.672
1500	54.911	263.773	4380.055	55.475	131.247	7502.672
1600	55.231	272.173	2474.155	56.175	128.317	7784.672

Table-35. The relationship between 40-week body weight, egg weight during 36-40 weeks of age, egg number to 40 weeks and egg mass to 40 weeks of age in the two White Leghorn strains

40-week body weight(g)	PD-1			PD-2		
	Egg weight(g)	Egg number	Egg mass(g)	Egg weight(g)	Egg number	Egg mass(g)
1100	48.098	93.313	2734.503	52.277	71.012	4202.1047
1200	49.178	95.189	2743.803	51.847	74.507	4572.9047
1300	50.178	96.641	2768.503	51.597	77.562	4923.7047
1400	51.098	97.717	2783.003	51.527	80.147	5254.5047
1500	51.938	98.465	2601.903	51.637	82.232	5565.3047
1600	52.698	98.933	2479.831	51.927	83.787	5856.1047
1700	53.378	99.169	2311.303	52.397	84.787	6126.9047
1800	53.978	99.221	2091.003	53.047	85.187	6377.7047
1900	54.498	99.137	1813.503	53.877	84.972	6608.5047
2000	54.938	98.965	1473.403	54.887	84.107	6819.3047
2100	55.298	98.753	1065.303	56.077	82.562	7010.1047

Relative efficiency of different criteria of selection

Table 36 gives the expected genetic gain in egg number to 40 weeks of age, egg weight (grams) during 36-40 weeks of age and body weight (grams) at 40 weeks of age when selection is based on different criteria, viz., egg number alone, egg weight alone, body weight alone, index I based on a linear combination of egg number, egg weight and body weight, index II based on a linear combination of egg number, egg weight, body-size and body-condition, index III based on linear combination of egg number and egg weight, index IV based on linear combination of egg */and body size and Index V based on linear combination of egg number, egg number, egg weight*/ and body-condition. Pooled estimates of ~~egg wt.~~ variances and covariances were used.

Table-36. Relative efficiency of different criteria of selection with selection intensity of one phenotypic standard deviation

Criteria of selection	Expected genetic change at 40 weeks of age: Egg number	Egg weight(g)	Body weight(g)	Net genetic worth	Relative efficiency
Egg no. to 40 weeks of age	5.214	-0.208	-4.218	392.439	0.944
Egg weight(g)	-2.096	2.289	14.633	-70.106	-0.169
Body weight at 40 weeks(g)	-0.528	0.150	75.432	-108.865	-0.238
Index I	5.607	-1.096	-36.211	414.320	1.000
Index II	5.798	-1.363	-2.087	381.932	0.920
Index III	5.878	-1.186	-40.311	394.288	0.948
Index IV	5.511	-1.112	-38.211	376.911	0.901
Index V	5.421	-1.011	-35.321	370.112	0.881

Selection based on egg number:

With selection differential of one standard deviation for egg number, the expected genetic increase in this trait is 5.214 eggs. With this selection intensity in egg number, the egg weight during 36-40 weeks is expected to decline by 0.208 g as a correlated response and similarly body weight at 40 weeks decline by 4.218 g.

Selection based on egg weight:

The expected genetic change with selection intensity of one phenotypic standard deviation in egg weight is 2.289 g. As a correlated response to this selection for egg weight, egg number to 40 weeks is expected to go down by 2.096 eggs while the body weight at 40 weeks is expected to increase by 14.633 g.

Selection based on body weight:

With selection differential of one standard deviation for body weight at 40 weeks, the expected genetic increase in this trait is 75.432 g. As a correlated response to this selection egg number is expected to decline by 0.528 eggs and egg weight is expected to increase by 0.150 g.

Selection based on index:

Index I is $21.910X_1-17.881X_2-0.613X_3$. Its R_{IH} value is 0.572. The index II is $19.9116X_1-39.3399X_2+0.086X_4+0.294X_5$. Its R_{IH} value is 0.0576. With selection differential of one standard deviation based on index of egg number, egg weight and body weight (index I), the expected genetic change in egg number, egg weight and body weight are 5.607 eggs, -1.096 g and -36.211 g respectively. With selection index based on egg number, egg weight, body-size and body-condition (index II), the expected genetic change in egg number, egg weight and body weight are 5.798 eggs, -1.363 g and -2.087 g respectively. Index based on egg number and egg weight (index III) is $20.966X_1-22.922X_2$. Its R_{IH} value is 0.5280. Increase in egg number is 5.878 and change in egg weight is -1.186 g. Expected genetic change through index IV and index V were presented in table 36.

Relative efficiencies:

When equal selection intensities (one phenotypic standard deviation) are practised for egg number, egg weight, body weight, index I (linear combination of egg number, egg weight and body weight), index II(linear combination of egg number, egg weight, body-size and body-condition), index III, index IV and index V the expected increase in the net genetic worth are 392.439, -70.106, -108.865, 414.320, 381.932, 394.288, 376.911 and 370.112 units respectively. Thus index I is expected to yield the best results. As compared to index I, the relative efficiency of selection based on egg number alone and index III would be about 5.6 percent less. Selection based on index II is expected to be about 8.0 percent less efficient than Index I Selection for egg weight or body weight alone is expected to cause a negative change in the economic merit of the birds.

SUMMARY AND CONCLUSIONS

Investigations were conducted to determine suitable criteria of measuring body-size (bone-framework) and body-condition (fleshing); to study the genetic, phenotypic and environmental correlations among different economic traits and inheritance of these traits and to find out optimum body weight for egg production, egg weight and egg mass in two White Leghorn populations, Pb-1 and Pb-2 maintained at P.A.U. Ludhiana. Based on these data selection indexes were constructed for maximizing the genetic gains for economic mert. During the first generation a total of 1018 birds consisting of 603 of the pb-1 and 415 of the Pb-2 which survived to 72 weeks were included in the study. Pb-1 was obtained in eight weekly hatches and Pb-2 was obtained in six weekly hatches. In the second generation, Pb-1 was obtained in five weekly hatches and Pb-2 in six weekly hatches. A total of 1295 birds consisting of 780 of Pb-1 and 515 of Pb-2 were included in the second generation. Progeny were obtained by mating 30 sires to 270 dams in Pb-1 and 20 sires to 180 dams in Pb-2, in both the generations.

The average 20-, 40- and 72-week body weight, pooled over generations, was 1153.1, 1577.7 and 1573.9 g respectively in Pb-1 and 1097.3, 1594.0 and 1528.0 g respectively in Pb-2. Thus the pullets of Pb-1 were heavier than those of Pb-2 at 20 and 72 weeks of age. At 40 weeks Pb-2 was slightly heavier than Pb-1. Pullets of both Pb-1 and Pb-2 birds became lighter at 72 weeks when compared to weight at 40 weeks.

Average egg weight during 36-40 weeks of age pooled over generations was 53.58 g in Pb-1 and 52.69 g in Pb-2. Thus birds of Pb-1 laid eggs which were heavier by about one gram than the eggs of Pb-2.

Average egg number to 40 weeks of age was 80.95 in Pb-1 and 78.84 in Pb-2. Average egg number to 72 weeks was 222.9 in Pb-1 and 214.9 in Pb-2. Thus the pullets of Pb-1 had higher egg production tha Pb-2.

The average heritabilities (from the sire component of variance pooled over generations and strains) of body weight at 20 , 40 and 72 weeks of age were .436, .432 and 0.361 respectively. The heritability estimates for body-size at 20 , 40 and 72 weeks of age were .330, .306 and .305 respectively. Heritabilities for body-condition at 20 , 40 and 72 weeks of age were .131, .114 and .112 respectively. The estimate for egg weight was .658. The heritability estimates for egg number to 40 weeks of age and to 72 weeks of age were .316 and .233 respectively. Thus body weight and body-size had medium heritable estimates. Body-condition was lowly heritable. The heritability of egg number was medium to low. Egg weight was highly heritable.

The average phenotypic, genetic and environmental correlations between 20-and 40-week body weight were .620, .882 and .312 respectively. The corresponding values for 20-and 72-week body weight were .589, .818 and .234 and for 40-week and 72-week body weight were .670, .917 and .360. The phenotypic, genetic and environmental correlations were .171, .054 and .171 between 20-week body weight and egg number to 40 weeks, .037, -.312 and .033 between 20-week body weight and egg number to 72 weeks, .012, -.207 and .058 between 40-week body weight and egg number to 40-weeks, .037, -.312 and .033 between 40-week body weight and egg number to 72 weeks and .059, -.096 and .026 between 72-week body weight and egg number to 72-weeks of age. Phenotypic, genetic and environmental correlations in respect of body weight and egg weight were .231, .182 and .341 between 20-week body weight and egg weight and .277, .239 and .399 between 40-week body weight and egg weight. The correspon-ding values of the three kinds of correlations were .486, .791 and .576 between 20-week body weight and 20-week body-size, .364, .897 and .165 between 20-week body weight and 40-week body size and .761, 1.007 and .610 between 40-week body weight and 40-week body-size. The phenotypic, genetic and environmental correlations were .307, .616, and .352 between 20-week body weight and 20-week body-condition and .442, .243 and .566 between 40-week body condition and 40-week body weight. The corresponding values in respect of body-size and body-condition were .241, .318 and -.294 between 20-week body-size and 20-week body-condition, -.081, .290 and -.107 between

40-week body-size and 40-week body-condition and -.055, .302 and -.211 between 72-week body-size and 72-week body-condition. The phenotypic, genetic and environmental correlations between body-size and egg production were .362, .051 and .164 for 20 weeks body-size and egg production to 40 weeks, .087, .083 and .060 between 20-week body size and egg number to 72 weeks, -.068, .037 and -.042 between 40-week body-size and egg production to 40 weeks, .016, .082 and .031 between 40-week body-size and egg production to 72 weeks and .044, .064 and .045 between 72-week body-size and egg production to 72 weeks. The corresponding values for body size and egg weight were .164, .189 and .163 between 20-week body-size and egg weight and .252, .299 and .314 between 40-week body size and egg weight. The phenotypic, genetic and environmental correlations were .088, .444 and .086 for 20-week body condition and egg number to 40 weeks, .069, .413 and .025 for 20-week body-condition and egg number to 72 weeks, .040, .208 and .049 for 40-week body condition and egg production to 40 weeks, .024, .178 and .032 for 40-week body-condition and egg number to 72 weeks and .035, .202 and .039 for 72-week body-condition and egg number to 72 weeks. The corresponding values were .058, .330 and .159 between 20-week body-condition and egg weight and .110, .359 and .133 between 40-week body-condition and egg weight.

In Pb-1 the relationship between 20-week body weight and egg weight (36-40 weeks), 20-week body weight and egg number to 40 weeks, 20-week body and egg mass to 40 weeks and 40-week body weight and egg weight was quadratic whereas the relationship between 40-week body weight and egg number to the same age and 40 week body weight and egg mass to 40 weeks was cubic. In Pb-1 1100 to 1200 g was the optimum 20-week body weight in terms of net economic return for egg weight and egg mass. But increase in 20-week body weight continued to give extra economic return through increased egg number. 1300 to 1400 g was the optimum 40-week body weight for egg number and egg mass interms of net economic return. Whereas 1600 g was the optimum body weight for egg weight in terms of net economic return.

In Pb-2 the relationship between 20-week body weight and egg weight was linear, quadratic between, 40-week body weight and egg weight and 40-week body weight and egg mass. But cubic between 20-week body weight and egg number, 20-week body weight and egg mass and 40-week body weight and egg mass. Increase in 20-week body weight, increased the net economic returns by the increase of egg weight and egg mass. 1200 to 1300 g was the optimum 20-week body weight for egg number to 40 weeks when net economic returns were considered. 1600-1700 g was the optimum 40-week body weight for egg number to 40-week when economic returns were considered. Whereas increase in 40-week body weight produced increase in egg mass and economic returns.

Relative economic weights gave maximum weightage to egg production, followed by egg weight. Body weight got negative weightage. Index I (linear combination of egg production, egg weight and body weight), gave maximum net economic returns, followed by index III(linear combination of egg production and egg weight), selection based on egg production alone and index II (linear combination of egg production, egg weight, body-size and body-condition). Selection based on egg weight alone or body-weight alone yielded negative net economic return.

Body weight/shank length was better criteria for measuring body-condition. Body weight-body weight/shank length was reliable index for body-size. The heritability of body-size was medium and body-condition was lowly heritable. Dividing the total body weight into two components namely body-size and body-condition and including them in an index does not improve the efficiency of the index in terms of net economic returns. So dividing the body weight into two components does not give any extra advantage. Strain differences were evident in optimum body weight for egg weight, egg production and egg mass. In Pb-2 there was close relationship between body weight and egg weight, body weight and egg production and body weight and egg mass.

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