PATTERN OF DEVELOPMENT OF SHANK LENGTH IN CHICKEN

BY
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THESIS

Submitted in partial fulfilment of the
requirements for the degree of

Master of Science (Agricultural Statistics)

Faculty of Agriculture
Kerala Agricultural University

Department of Statistics

COLLEGE OF VETERINARY & ANIMAL SCIENCES

Mannutby, Trichur.

1982

DECLARATION

I hereby declare that this thesis entitled "PATTERN OF DEVELOPMENT OF SHANK LENGTH IN CHICKEN" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

Mannuthy,
25-9-1982.

INDIRABAI, T.K.

CERTIFICATE

Certified that this thesis entitled "PATTERN OF DEVELOPMENT OF SHANK LENGTH IN CHICKEN" is a record of research work done independantly by Smt. Indirabai, T.K., under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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ACKNOWLEDGEMENTS

I am deeply indebted to Dr. P.U.Surendran, Professor and Head, Department of Statistics and the Chairman of the Advisory Committee for his inspiring guidance, generous help and co-operation in the organisation of this thesis.

I am extremely grateful to Dr. A.Ramakrishnan, Professor, Department of Poultry Science, Dr.B.R.Krishnan Nair, Associate Professor, Department of Animal Breeding and Genetics, Shri. K.L.Sunny, Assistant Professor, Department of Statistics for their valuable assistance and encouragement, at various stages in the preparation of this thesis, as Members of the Advisory Committee.

My thanks are due to Dr. G.Reghunathan Nair, Associate Professor and other members of the staff of the Department of Poultry Science for their unstinted co-operation, help and guidance in conducting the experiment and collecting the data.

I am thankful to Shri. V.K.Gopinathan Unnithan, Associate Professor, Department of Agricultural Statistics for the help rendered by him in the analysis of data.

With immense pleasure I express my gratitude and thanks to my colleagues and friends for their valuable assistance in taking the biometrical observations.

My sincere thanks are due to Shri. V.S.Skandakumar for putting the manuscript into neat type.

I place on record my sincere gratitude to the Dean, College of Veterinary and Animal Sciences for his permission to undertake this study.

I am indebted to Kerala Agricultural University for granting study leave to enable me to pursue this work.

(INDIRABAI, T.K.)

CONTENTS

INTRODUCTION

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Population explosion coupled with insufficient production and poor distribution of food are among the worlds acute problems. In many highly populated, poorly developed countries most children suffer from malnutrition in their early years. Besides causing high rate of mortality this has an adverse effect on the health of the people. Instances are many. It is reported that in one South American country 92 children out of every 1000 born die before they attain one year of age, another 12.4 per 1000 die before their fourth birthday, and among those that survive many are mentally retarded. Partly this mental retardation is due to severe protein deficiency during childhood.

The food supply in these over populated areas consists mostly of starchy grains, which supply enough energy for life processes, but lack the protein necessary for growth and repair of body tissues. High quality protein is necessary for the proper growth and good health of animals and man. Animal proteins provide a good balance of aminoacids. Animal products such as meat, milk and eggs serve as a major source of high quality protein for human beings.

According to the recommendations of Nutrition Advisory Committee of India, the per capita daily requirement of meat is 81 gms. Instead, only 4 gms. are the per capita availability per day which is evidently far below the requirement. Our major sources of meat proteins are cattle, goat, pigs, fish and poultry. Poultry meat contributes about 13% of the total meat production in India.

Until 1930's chicken meat was largely derived from old hens which had completed their life or from surplus cockerels from egg producting breed such as White Leghorns or dual purpose breeds such as New Hampshire, Sussex, which were especially grown for the meat traits. From 1930's in America and much later in the United Kingdom special strains of hybrids were developed for meat and broiler production, other than those developed for egg production. Broiler chicks were developed first as pure breeds and more recently as two and three way cross hybrids. The relatively high efficiency of these hybrids especially for meat production has severely depressed the economic value of the carcass of laying hen.

With the commercialisation of every aspect of poultry production, rearing of surplus cockerels, particularly of the egg type breed is no more an economical proposition. The place of these breeds has however been taken by young tender chicken, specially produced for meat purpose, which is commonly known as 'broilers'. Such a step, in addition to filling the gap in the production of table chickens has met the increasing demand for high quality, tender poultry meat. The production of broilers for this purpose has now become a specialised branch of poultry industry and is developing with speed along with the egg production activities. The production of chickens of meat type has become a commercial enterprise and every person engaged in this job has always tried to increase the efficiency for operations and effect economy in expenditure in order to increase his income.

The broilers have unique fleshing qualities. They should put on maximum weight gain with minimum of food consumption. They should possess a high proportion of edible flesh to bone and waste in order to ensure maximum yield to the consumer. They should have rapid feathering so that there is a minimum number of pin feathers in the dressed carcass. These are the favourable qualities of broilers which attract the breeders for broiler breeding. Those which grow faster are preferred to others. The faster the birds grow, the earlier will be the output of meat (food) from them and more crops can be raised during a given period of time. Therefore faster growth would result in increased output of meat.

It is an accepted fact that growth rate is of great practical importance in livestock industry, especially in poultry farming. It is an important factor in determining the optimum period, at which maximum gain can be effectively achieved. Usual measure of growth that we employ to study the pattern of growth is the body weight because it is convenient to obtain. Schneider and Dunn (1924) observed that variability in skeletal growth is relatively much less than the variability in body weight during the growing period. Selection for faster rate of growth would be more accurate if based on some skeletal measurements in live birds. Shank length has now been considered as an index of body weight during most of the growing period. Lerner (1939) tried to predict the body weight from the live shank length and reported that in early stages, the body weight and shank length are more closely related than in mature birds. Studies conducted by Knox and Marsden (1944), Asmundson (1945), Bryant and Stephenson (1945), Abplanalp and Kosin (1952), Rizak and Ibiary (1960), Collins et al. (1964) and Chhabra and Desai (1966) working with chicken and turkey have reported that body weight and shank length are highly associated traits.

Unni et al. (1977) studied phenotypic correlation between body weight and shank length and fitted regression equations for predicting body weight from shank length. All these reports indicate that long legged birds yield more weight and consequently more meat.

The pattern of development of shank length expressed as a function of age would help predict shank length during any period covered by the study. The study would also help to understand how the shank length at an earlier age would influence shank length and hence the body weight at a later period. A natural corollary of this is that the shank length at a specified age can be made a basis for selection of birds which would attain a specified body weight at a later period. Obviously, this procedure helps to cull birds at an early age based on shank length which would result in economic advantage to the farmer. Studies concerning the shank length are few in general and fewer still in the case of broiler birds. It was therefore felt necessary to examine the pattern of development of shank length of the two breeds of broiler birds, viz. White Cornish (WC) and White Plymouth Rock (WR), maintained in the University Poultry Farm and hence the present study was taken up.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Production of High Yielding seeds, fertiliser and water inputs in modern agriculture have brought about the Green Revolution in India. After achieving self sufficiency in food grains, it is, therefore, appropriate to plan and develop potentials for better protective foods such as eggs, poultry, milk and milk products. At present the supply of animal protein is very meagre and the average Indian diet is highly deficient in it. Accelerating the production of eggs and poultry meat is a practical way to help meet the nutritional needs of the people.

Poultry with a size of about 139 million (1972 Census) and producing 10,000 million eggs annually is today a commercially viable enterprise contributing more than Rs. 400 crores to the Gross National Product. The estimated poultry population in 1978 was 148 millions. In Kerala the size of the poultry population increased from 12.207 millions in 1972 to 13.399 millions in 1977 (Bullettin, A.H. 1980). The egg production in the State in 1979-80 was 948 millions and it is well known that poultry meat and egg are popular in the State.

The increased interest in the poultry meat production has resulted in the increased interest in the broiler breeds.

Broilers were introduced on commercial scale in India in early sixties of this century. According to a survey conducted by M/s. Progressive Agro Industrial Consultants, New Delhi on behalf of the Central Agricultural Ministry, the production of broilers in 1975-76 was around 12 millions. The important breeds of broiler chicken in the State and the Nation are Cornish, White Plymouth Rock and New Hampshire.

Cornish breed has a peculiar type of body conformation: the legs are short, the body is broad, and the breast is very wide and muscular. There are several varieties among them but commonly the White Cornish, Light Cornish and Red Cornish with light red feathers are commercially utilised. The White Plymouth Rock has a single comb, yellow skin and lays brown eggs. It has the quality of rapid growth and excellent feed conversion. Its feather colour is recessive white. New Hampshire was developed from Rhode Island Red. Formerly it was known for its egg production. But later on it became famous as a bird with excellent meat quality.

The body weight, which is the first measurable character of an animal has an economic importance, since it provides a basic background for future performance. Body weight is the usual measure of growth that we employ to study the pattern of development of growth. As it is observed that selection for faster rate of growth would be more accurate if based on some skeletal measurements, shank length has now been used to study the pattern of development of growth.

As early as 1939, Lerner tried to predict the body weight from the live shank length and reported a correlation estimate of 0.659 ± 0.032 and also found that in early stages, the body weight and shank length are more closely related than in mature birds.

Chhabra _et al_. (1972), on conducting experiments on 609 chicks at 10 weeks of age involving White Plymouth Rock, White Cornish and New Hampshire breeds and their crosses observed that birds with longer live shanks yield heavier live body weight, eviscerated weight and eviscerated percentage of live weight. The correlation of live shank length with live body weight and eviscerated weight were 0.3064 to 0.9582 and 0.2806 to 0.8614 respectively. These estimates were found to be highly significant in the case of all the genetic groups.

While studying the relationship between shank length and body weight in crosses of meat breeds of fowl, Tesovsky _et al_. (1974) found that the live shank length is highly correlated with body weight.

Sexual dimorphism in shank length in broiler breeds of poultry has been reported by Ulaganathan and Kosala Raman (1975), who found that males had larger shank length and higher body weight at 10 weeks of age.

Pati *et al*. (1975) reported on the few effects which influenced body weight and shank length at 10 weeks of age along with other traits in broiler chicken.

Siddappa (1976) in a study on White Cornish unsexed birds obtained the mean body weight of 40.05 ± 3.96 g at day old, 331.63 ± 54.93 g at 4th week and 944.89 ± 154.53 g at 8 week age.

Studies on the sexual dimorphism in shank length and its relationship with body weight in broiler breeds of poultry were conducted by Unni *et al*. (1977). Shank length and body weight of 489 broiler chicks belonging to White Cornish and White Plymouth Rock breeds were recorded at 10 weeks of age. Difference between the sexes was highly significant for both the traits studied. The phenotypic correlation coefficients between shank length and body weight at 10 weeks were 0.91, 0.86, 0.51 and 0.93 for White Cornish male, White Cornish female, White Plymouth Rock male and White Plymouth Rock female respectively. All these correlation coefficients were highly significant. The regression equations fitted for predicting the body weight from shank length were

$$y = 205.3x - 762.1$$

$$y = 138.39x - 96.21$$

$$y = 23.54x + 824.69$$

$$y = 75.89x + 268.77$$

In a study of relationship between shank length and body weight at different stages of growth in crossbred chicken of White Leghorn and Rhode Island Red, Verma et al. (1977) observed that body weight and shank length are highly correlated at all ages in male. But, in female the correlation coefficient was non significant at day old but later on it was found to be highly significant. The regression equations obtained were

$y = 25.00 + 6.38x$ at day old

$y = -27.50 + 42.37x$ at 4th week

$y = -219.33 + 107.34x$ at 8th week

$y = -261.56 + 127.98x$ at 12th week for male

and

$y = 37.92 + 0.76x$ at day old

$y = -74.16 + 56.43x$ at 4th week

$y = -147.76 + 91.61x$ at 8th week

$y = -528.03 + 170.19x$ at 12th week for female.

The regression coefficients for the male and female were all positive and went on increasing with the advancing stages of growth showing greater dependence of body weight on shank length.

Lustinecova et al. (1977) conducted experiments to study the differences in skeletal conformation in hens of egg producing and meat producing types. Keel, Pelvis and leg skeletal measurements were obtained on 20 White Plymouth Rock and 30 White Leghorn hens culled at the end of their egg production life. The measurements for White Plymouth Rock were 33.0% larger than those for White Leghorns.

Hejja and Szabo (1977) collected data on 240 males and 250 females of geese. Correlations of body weights at 1, 28 and 56 days of age with the respective weights of leg and breast are tabulated. All these correlations were found to be positive.

Thiagarajan (1977) observed that at 14 weeks of age fast feathering White Rock fowls weighed 68.6 g more than slow feathering birds, and the feed conversion ratio of the former was slightly better than that of the latter, but the difference between the groups were not significant.

Prathap Kumar (1978) working on a strain of White Plymouth Rock breed reported the mean body weight in grammes at 0th, 4th and 8th week of age as 41.06 $\pm$ 0.13, 333.96 $\pm$ 2.06 and 1015.66 $\pm$ 5.21 respectively.

Growth patterns, heritability and product moment correlations were studied for body weight, shank length, breast meat and thigh meat at different weeks of age in Japanese quail by

D.P.Singh (1978). The genetic, phenotypic and environmental correlations between body weight and shank length and body weight and breast meat were estimated at different weeks of age. Only sire component of variance was used to estimate the genetic effect.

Growth pattern was found to be mostly linear for body weight although other patterns of growth were found. Similar to other species, the growth curve for body weight was found to be sigmoid in shape. The male and female grew equally upto 4th week of age but after four weeks the growth rate was found to be more in female than in male, and it remained high upto the end of the experiment. The growth pattern for shank length, breast meat and thigh meat followed the same pattern as that of the body weight in either sex. The heritability estimate for shank length ranged from 0.19 ± 0.23 to 0.73 ± 0.33 from 5th to 8th week of age. Body weight and shank length were assumed to be moderate to highly heritable characters in quails.

Phenotypic correlation between some important economic traits of White Cornish chickens were studied by Singh and Singh (1979) and they found that eight week body weight averaged 563.04 g, 10 week body weight averaged 799.93 g, age at sexual maturity averaged 202.18 days and body weight at maturity averaged 2067.03 g. The eight week body weight was highly significantly correlated with 10 week body weight (0.96). Age at sexual maturity was significantly correlated with body weight at sexual maturity (0.18).

Renchi P. George *et al*. (1979) studied the relationship between shank length and body weight at 12 weeks of age in Desi ducks. The means of shank length was 6.44 ± 0.04 cm, 6.15 ± 0.02 cm and 6.20 ± 0.03 cm respectively in male, female and all ducks ignoring sex. The body weight was 1668.90 ± 10.995 g for male, 1466.40 ± 13.00 g for female and 1567.65 ± 11.12 g for all ducks ignoring sex. Highly significant difference between sex for body weight and shank length at 12 weeks indicated sexual dimorphism for these traits. The correlation between shank length and body weight at 12 weeks in Desi ducks was 0.26, 0.32 and 0.44 respectively for males, females and ignoring sex. All these correlations were highly significant. The regression equations fitted to predict body weight at 12 weeks from shank length are

$y = 72.48x + 1202.16$ for male

$y = 255.02x - 103.24$ for female

$y = 190.58x + 364.74$ for all ducks

Studies conducted by Sharma *et al*. (1980) with about 4000 chicks belonging to four broiler populations - two from Rocks and two from Cornish - revealed that in the day old and the eight week old broiler traits such as body weight, breast angle and shank length were positively correlated among themselves and this was consistent for all the four populations studied.

Twelve three-way crosses involving Rhode Island Red, Australorp, White Plymouth Rock and White Cornish breeds were studied for body weight at one day and 2,4,6,8 and 10 weeks of age by Varma *et al*. (1980). Significant difference occurred between crosses for the various traits. The amount of additive genetic variation in body weight at 6,8 and 10 weeks of age differed significantly among the crosses. Non additive effects were significant only at the end of two weeks.

Cook (1963) reported that shank length was not appreciably correlated with body weight.

Pande *et al*. (1972) observed that body weight at market-age (8 to 10 weeks) is the most important character of economic importance in White Cornish chicken.

The inheritance of eight week body weight in different crosses of broiler breeds were studied by Prasad *et al*. (1979). Economically eighth week body weight is the most important character in broiler chicken. Estimates of heritability of body weight at the eighth week reported by Dubovik (1979) in WC, WPR and WC x WPR were 0.48, 0.36, 0.35 for male and 0.35, 0.29 and 0.29 for female respectively. The heritability provides a measure of additive genetic variability by which it is possible to know the scope of changing population mean by selection.

Jaap *et al*. (1938) proposed a method for measuring breast width in terms of shank length. They proposed that the ratio of shank length to the cube root of body weight estimate breast width.

In attempting to interpret experimental results based on the measurements taken during the early period of growth of chicken, numerous practices and methods have been developed. Brody (1945) defined growth as a relatively irreversable time change in the measured dimension. Websters dictionary defines rate as a quantity or degree of a thing measured per unit of something else. Both Webster and Oxford dictionaries define growth as "increase, or is grown or is growing". Gould defines growth as the augmentation of body infancy and adult age. Hamond (1955) observed that rate at which an animal grows is of greater importance for the livestock as only few animals live long enough to reach the mature weight. If weight is the criterion used, the rate of growth is defined as the change in weight per unit of time (Snedecor, 1946).

Growth rate can best be expressed as regression coefficient. According to Mather (1946) the regression coefficient is the coefficient representing the rate of change of the dependent variable on the independent variable. Similarly, a growth curve is referred as a regression (Snedecor, 1946), a descriptive connotation of the mathematical term function. The growth constant 'b' is the part of the straight line formula

$$y = a + bx$$

where a is the intercept, b the slope, y the dependent and x, the independent variable.

Although linear regression is adequate for many situations, more complex functional relations are warranted by others. Jacob (1981) found that curvilinear relations give good fit to the data on body weight of domestic fowl upto 24 weeks of age. Some of the most commonly used non-linear relations are

Exponential growth curve - $y = ae^{bx}$

Modified Exponential curve - $y = k + ab^{x}$

Gomperts curve - $y = ab^{c^{x}}$ and

Logistic curve - $y = \frac{1}{a + bc^{x}}$

The curves other than straight lines can be easily transformed into linear form through the substitution of variables (Crumpler and Yoe, 1940).

Pillai *et al.* (1969) while studying growth rate of chickens from six different crosses found that the simple exponential function $W = Ae^{kt}$ yielded a very good fit.

Zelanka (1970) studied the growth of chicken during the early period of the post embryonal life. He used the exponential function $W = ae^{kt}$ (Brody) and the power function $y = at^{b}$ (Roberts) to calculate growth from 2 to 22 days of age in 40 cockrels (Experiment 1) and 90 chicks of both sexes (Experiment 2). Growth was divided into two periods; period 1, which ended at 14 days of age, was markedly different from period 2 regardless of the function used. In period 1 in both experiments, and in period 2 of the second experiment, no significant difference in the accuracy of calculation was observed between the two functions. In period 2 of the second experiment the power function was more accurate.

Tanabe and Saeki (1965) constructed growth curves for chicks of White Cornish, White Rock, New Hampshire and White Leghorn breeds from two to fifteen weeks of age and found that growth rate was defined by the equation of the type

$$\log y = \log a + b \log x$$

where y is body weight, x is the age, a and b are constants.

Log x and log y were highly correlated. The constant 'a' differed among breeds but not between sexes, 'b' was higher in male than in female.

Susaki (1966) constructed growth curves from data on body weight of three crosses of broiler breeds upto 10 weeks of age. Curves of the type

$$y = ax^b$$

$$y = a + bx + cx^2$$

$$y = a + bx + c \log x$$

gave a satisfactory fit to the data.

Wishart (1938) constructed the parabolic growth curve

$$y = a_0 + a_1x + a_2x^2$$

In this relation the growth rate was affected only by the changes in the coefficient of linear and quandratic terms and hence comparison of groups should be based on a_1 and a_2 values of the groups.

The advantage in describing growth in terms of a curve is that it helps prediction. Further the inherent property of the curve would give a measure of the rate of growth which eventually helps comparison of the rates of growth between groups.

MATERIALS AND METHODS

MATERIALS AND METHODS

A total number of 200 day old broiler chicks of White Plymouth Rock and White Cornish breeds obtained from Kerala Agricultural University Poultry Farm, Mannuthy formed the material for the study. The chicks were serially numbered and wing banded for identification.

The chicks were placed in electrically operated, thermostatistically controlled battery type brooders. Broiler starter diets were fed throughout the experiment. Feed and water were provided ad libitum throughout the experimental period. All birds were maintained under identical environmental conditions. Normal management practices were followed for the whole period of study. After four weeks the chicks were moved to deep litter houses. Adequate floor space and water space were provided.

The shank length in centimeters and body weight in grams were recorded on all days during the first week. Thereafter they were measured at weekly intervals. The measurements were taken until the chicks attained an age of eight weeks. Shank length measurements were taken from the right shank of the chicks. The measurements were taken from the exterior of the hock joint to a point between the sole pad and outer toe of the birds. These measurements were taken by the same person during the entire period of the experiment.

At the end of the experiment, the above measurements pertaining to 38 males and 61 females of White Cornish group and 35 males and 32 females of White Plymouth Rock group were available. The remaining birds died during the course of the experiment. From the available birds the first 30 birds of each group were utilised for this study.

Any organism follows its own growth pattern. Statistical models are the tools in analysing and understanding such growth patterns.

For examining the relationship between body weight and shank length one of the technique used is the coefficient of correlation. Whenever this is significant it indicates a possible linear relation and hence linear regression of the type.

(3.1) $y = a + bx$

was found out in necessary cases. Even when there is significant correlation between shank length and body weight within genetic groups the magnitude of this correlation may vary between groups. In order to test this chi-square test was employed.

Let r_i be the observed correlation between shank length and body weight

If $z_i = \frac{1}{2} \log_e \frac{1 + r_i}{1 - r_i}$ it is approximately normal with variance $\frac{1}{n_i - 3}$ where n_i is the number of pairs based on which r_i has been computed. The value of i varies from 1 to k where k is the number of observations in a group.

If

$$z = \frac{\sum (n_i - 3) z}{\sum (n_i - 3)},$$

$(n_i - 3)(z_i - z)^2$ is a chi-square with (k - 1) degrees of freedom. In case the chi-square is not significant, the correlation coefficients are homogeneous and their common value can be obtained by solving the equation

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

Linear regression can also be used to examine the relation between age and shank length. It also gives chance to predict the shank length for a given age. In order to test the significance of the regression coefficients, linear regression equations were fitted for each bird. As the regression coefficient is a measure of rate of growth the overall difference in the rate of growth of shank length can be ascertained by analysing the values of the regression coefficients of different groups as a one way classification.

The high correlation between shank length and body weight suggest that significant difference in shank length will imply significant difference in body weight. However, this can be checked by forming weekly analysis of variance tables for both shank length and body weight. Each character was analysed as one way classification.

Most of the living organisms have a sigmoid growth curve. It is therefore desirable to try curves which conform to this pattern to describe the pattern of development of shank length. The simplest of these curves is given by the exponential function which symbolically is

$$(3.2)\quad y = ae^{bx}$$

where y represents shank length at the age x and a and b are constants to be determined. For fitting this curve the method of least squares was used.

When growth curves are fitted the rate of growth at a particular period can be taken as the ratio of the magnitude of shank length at that period to the magnitude of shank length in the previous period minus 1. In the case of exponential the rate of growth therefore is

$$(3.3)\quad \frac{ae^{b(x+1)}}{ae^{bx}} - 1$$

which is the same as $e^{b} - 1$. This shows that the rate of growth depends only on the values of b and the growth rates will be equal if the 'b' values are equal. This gives a method for examing the equality of the rates of growth of the birds of the four genetic groups. It is enough if the 'b' values of the four groups are analysed as one way classification.

Modified exponential which has got a functional form,

(3.4) $y = k + ab^x$

can also be used to represent the growth of an organism. The constants to be determined in this case are k, a and b. To determine this curve the y values are first divided into three mutually exclusive groups. If the sum of the y values of the three groups in the chronological order are s_1, s_2 and s_3, the estimates of k, b and a are

$$k = \frac{s_1 \, s_3 - s_2^2}{3(s_1 - 2s_2 + s_3)}$$

$$b = \left(\frac{s_2 - s_3}{s_1 - s_2}\right)^{\frac{1}{3}} \quad \text{and}$$

$$a = \frac{(s_1 - s_2) \quad (1-b)}{b \; (1-b^3)^2}$$

The rate of growth in this case is

(3.5) $$\frac{k + ab^{x+1}}{k + ab^x} - 1$$

which is the same as

$$ab^x \, (b - 1) \div (k + ab^x)$$

The growth rates will not differ significantly when the 'b' values do not differ significantly.

Another curve used to represent the data on shank length is Gomperts curve which has got the form

(3.6) $y = ab^{c^x}$

Logarithmically this curve can be written in the form

$$\log y = \log a + (\log b)\, c^x,$$

i.e., $Y = A + B\, c^x$

where $Y = \log y$

$A = \log a$ and

$B = \log b.$

This is the equation similar to the modified exponential. The logarithms of the y values were computed first and using these values the values of A, B and C were calculated as in the case of modified exponential. The values of a, b and c in the form considered were given by

a = Antilog A

b = Antilog B

c = same as in the modified exponential.

The rate of growth in this case is

(3.7) $(ab^{c^{(x+1)}} \div ab^{c^x}) - 1$

which is the same as $b^c - 1$.

The growth rate depends on the value of b^c. The growth rates are equal if the values of b^c are not significantly different. That is if the values of clogb are not significantly different the growth rates are equal.

Logistic curve which also describes growth in its simplest form is

(3.8.) $\frac{1}{y} = a + bc^x$

It is merely a modified exponential in terms of the reciprocals of the y values. The rate of growth in this case is

(3.9) $\frac{a + bc^x}{a + bc^{x+1}} - 1$

(1e) $\frac{bc^x (1-b)}{a + bc^{x+1}}$

The rate of growth depends both on b and c.

Rao (1958) suggested a method for comparing rates of growth. This in fact is a covariance analysis. The concomitant variable is the initial shank length of the birds. For successive periods we calculate the increase in shank length. Let y_i be the increase in shank length of a bird in a group at time i, g_i is the mean value of y_i for the group. Compute the regression of y_i on g_i for each bird in every genetic group in the form

(3.10) $y_i = b\, g_i$

The method of least squares then gives

$$b = \frac{\Sigma y_i g_i}{\Sigma g_i^2}$$

It is evident that if these coefficients are equal the rates of growth of the different groups also will be equal. But these b values may be influenced by the initial value. Therefore we perform a covariance analysis in which the initial shank length is the concomitant variable and b, the corresponding value for the bird.

A number of methods have been enumerated for representing the pattern of growth of shank length and also for testing the difference in the rates of growth of the same. If all of them lead to the same result any one of the methods will be appropriate for the future analysis of the available data. If there is a discripancy the methods are to be scrutinised for their appropriateness for any given situation.

RESULTS

RESULTS

4.1. Shank Length.

The groups of birds considered in this study were as mentioned earlier, White Cornish male (WC male), White Cornish female (WC female), White Plymouth Rock male (WR male) and White Plymouth Rock female (WR female).

The average shank lengths of the four groups of birds at the end of every week and at day old along with their standard errors are given in Table 1.

At day old the WC male had the highest average shank length of 2.47 cm. It was followed by WC female with an average shank length of 2.46 cm. The least average shank of 2.42 cm was observed in WR male. Further, the average shank length of WR female was 2.44 cm. The analysis of variance table of the shank length at day old given in Table 3 indicated that there was no significant difference in shank length between the four groups.

The order in the mean shank length as observed at day ol was disturbed during the first week. At the end of this wee the maximum average shank length was 2.7 cm for WC male whic was closely followed by WR male with an average of 2.697 cm The average for the other two groups were 2.68 cm for WC female and 2.69 cm for WR female. The analysis of varianc of shank length at the end of one week given in Table 4 revealed no significant difference in average shank length between the four groups.

At the end of the second week WR male attained the highest average shank length of 3.01 cms. WC males were relegated into the second place with an average of 2.997 cm. These were followed by WR female with an average of 2.943 cm and WC female with an average of 2.923 cm. The difference between these averages were, however, found to be insignificant in their analysis given in Table 5.

The picture emerged at the end of the third week is the same as at the end of the second week with regard to the order of magnitude of the four groups. The average shank length was 3.387 for WC male, 3.287 for WC female, 3.503 for WR male and 3.323 for WR female. In the analysis of the shank lengths at the end of third week no significant difference was observed (Table 6). The average increase in the shank length from day old till the end of the third week was 0.92 cm for WC male, 0.827 cm for WC female, 1.08 cm for WR male and 0.88 cm for WR female.

Significant difference in the average shank length was observed in the analysis of shank lengths of the four groups at the end of the fourth week (Table 7). WR male differed significantly from both WR female and WO female. All other pairs did not show any significant difference. The mean shank lengths of the four groups were 4.09 cm for WO male, 3.993 cm for WO female, 4.297 cm for WR male and 4 cm for WR female. The order of magnitude of these averages were the same as in the third week. It is interesting to note that this order was maintained till the end of eighth week.

Just as in the previous weeks, the shank length of each bird continued to increase during fifth week. The average shank lengths at the end of this week were 4.913 cm, 4.68 cm, 5.293 cm and 4.8 cm respectively for WO male, WO female, WR male and WR female. The analysis of variance of the shank lengths at the end of the fifth week is given in Table 8. There was significant difference between the groups. The WR males were found to differ significantly from WR female, WO male and WO female. All the other pairs were homogeneous.

The pattern of difference observed in the average shank length at the end of the sixth week was similar to those observed at the end of the fifth week. The WR male differed significantly from all the other groups. The average shank lengths were 5.827 cm, 5.52 cm, 6.353 cm and 5.65 cm for WO male, WO female, WR male and WR female respectively. The analysis of variance is given in Table 9.

A change in the pattern of difference in the mean values therefore exhibited the extreme average body weights. The relevant information from day old till the end of eight weeks is contained in Table 2 along with standard errors. In the analysis of the body weight exhibited in Table 12 significant difference in body weight was found. WR female had the lowest average body weight which differed from the average body weights of the other three groups which were homogeneous.

On scrutiny of the body weights during the first seven days it was found that there was a drop in body weight in the case of some birds compared with the first day weight. More than 9 gms of average increase was found from the day old to the end of the first week. The average body weights at the end of the first week were 48.5 g for WC male, 48 g for WC female, 53 g for WR male and 48.53 g for WR female. The highest average body weight was found for WR male and the lowest for WC female. Table 13 gives the analysis of variance of the body weight at the end of the first week. Significant difference between the mean body weights was observed. The WR male, which had the highest mean body weight differed significantly from the other three wheih were homogeneous.

Compared with the growth of body weight during the first week more than three fold increase in the average body weight of the four groups of the birds was discernible during the second week. The average body weights of WC male, WC female, WR male and WR female were 75.6 g, 77.03 g, 89.4 g and 76.57 g respectively. There was significant difference between the four groups, as indicated by the analysis of variance of body weights, at the end of two weeks given in Table 14. As during the first week, except for WR male, the other three groups were homogeneous each of which differed in mean body weight from the mean body weight of WR male.

An interesting feature emerged at the end of the second week and continued till the end of the fifth week was that the average body weight of White Rock male was significantly higher than the average body weights of the other three groups which were homogeneous.

Steady increase in body weight could be observed in subsequent weeks. On an average there was an increase of 44.23 g from the second to the third week, 83.69 g from the third to the fourth and 113.91 g from the fourth to the fifth week. The average body weights of the four groups were in the range of 116.3 to 143.67 g during the third week, 182.13 to 249.93 g in the fourth week and 274.47 to 400.97 g in the fifth week. The relevant analyses are given in Tables 15, 16 and 17.

A common feature, different from what was observed in third, fourth and fifth weeks, prevailed at the end of the sixth, seventh and eighth weeks. WR male had the highest average body weight. It was followed by WC male. Next in order of magnitude were the body weights of WR female and WC female. There was no significant difference between the two female groups in body weight. However, the males of the two genetic groups significantly differed. The WC male had an average body weight which did not differ significantly from the WR female. The average increase in body weight recorded at the end of the sixth, seventh and eighth weeks were respectively 132.34 g, 141.66 g and 163.33 g. There was accelerated growth from day old till the end of the eighth week.

4.3. Correlations.

Development of shank length at a stage may be influenced by its magnitude at an earlier period. This could be ascertained by computing the correlation between the magnitudes at all stages, that is, by serial correlations.

In the case of WC male significant correlation between the shank lengths at day old and one week age was observed (Table 21). However there was no correlation between shanks at day old and at the end of the subsequent weeks.

Highly significant correlation ($P < 0.01$) was found between the shank lengths at one week age and at the end of subsequent weeks. The same feature continued to exist between shank lengths at the end of any two weeks. The highest correlation observed between week-end shank lengths was 0.9132 and the least 0.5225. The correlation was found to show a tendency to decrease as the interval increased.

Serial correlation between shank lengths of WC female at the end of different weeks are given in Table 22. The day old and weekly shank lengths were significantly correlated except at the fourth week and the day old shank length explained only 16% of the variation in the shank length at eight weeks. The rest of the correlations were all significant as in the case of WC male. The correlation between week-end shank length ranged from 0.6418 to 0.9372. The influence of shank length at a previous period on a subsequent period declined as the length of the interval increased.

In WR male no significant correlation existed between the day old and weekly shank lengths. Unlike in other groups the shank lengths at the end of the first and eighth weeks were not significantly correlated. The rest of the weekly shank lengths had highly significant correlations. The relevant information is contained in Table 23. The magnitude of the correlations showed a declining tendency as the interval increased.

The day old shank length had no significant influence on the subsequent shank lengths in the case of WR female. However, all week-end shank lengths were highly significantly correlated. The declining tendency of the correlations as the interval between shank length measurements increased was evident in this case also.

In all the four cases the significant correlations observed were all positive.

The coefficient of correlation computed between body weight and shank length at the end of different weeks are presented in Table 25.

At day old the coefficient of correlation was found to be least (0.01) in the case of WR male and this was not significant. The maximum correlation of 0.49 was obtained in WC female and this was highly significant. In WC male this correlation was 0.10 which was not significant. It was 0.48 for WR female which was highly significant.

The same order in the value of correlation coefficients was found at the end of one week. The coefficients of correlation were 0.81, 0.82, 0.52 and 0.73 for WC male, WC female, WR male and WR female respectively. All the correlation coefficients were different from zero ($P \angle 0.01$).

The WR female had the least coefficient of correlation (0.71) by the end of two weeks. The correlation coefficients were 0.94 for WC male, 0.89 for WC female and 0.74 for WR male and the four were highly significantly different from zero ($P < 0.01$).

The correlation between body weight and shank length recorded further increase at the end of the third week and continued to be highly significant. Its values were 0.94, 0.92, 0.90 and 0.86 respectively for WC male, WC female, WR male and WR female.

Significantly high correlation existed in the succeeding weeks also. At the end of the eighth week its range was from 0.85 to 0.94. The highest correlation was for WC female and the least for WR female. The coefficient of correlation for WC male was 0.89 and for WR male it was 0.86.

An important point to be noted here is that the coefficient of correlation between body weight and shank length was more in WC group than in WR group during the entire period of study. Further, except for the second, third and fifth weeks the coefficient of correlation was maximum for WC female. At the end of the second, third and fifth weeks the correlation was maximum for WC male. Though the correlation between body weight and shank length was less in WR male than in WR female at the beginning of the experiment, it began to increase steadily and at the end of the experiment its value was found to be the least for WR female.

For all the four groups the least correlation was observed at day old. The highest correlation of 0.96 was for WC male at the end of five weeks. At the same time WC female caught up with their male counterparts with a correlation of 0.95. The highest correlation in WR male was 0.90 and it was observed at the end of three weeks. Almost the same high level was found in WR female with a correlation of 0.88 at the end of six weeks.

Eventhough significant correlation was observed within each genetic groups, in testing for their homogeneity, it was found that only WR female had homogeneous correlation between body weight and shank length, during the first eight weeks. Estimate of the common value of this correlation was 0.7908.

In the other groups the onset of homogeneous correlation was examined. When day old values were removed the correlations became homogeneous in WC male and WC female with their estimates as 0.919 and 0.925 respectively. However, in the case of WR male homogeneity was found only after deleting the values upto the first week and the common correlation between body weight and shank length was estimated as 0.901.

Correlation coefficients were computed between body weight and shank length of individual birds. For each bird the correlation coefficient was found to be extremely high. All of them were nearly equal to unity, the maximum being 0.999

and the minimum 0.975 (Table 26). Eventhough very high correlation was observed for each bird, the chi-square analysis showed that the coefficients of correlation of WR male were heterogeneous while they were homogeneous within each of the remaining three groups. The common value of the correlation was 0.9943 for WO male, 0.9930 for WO female and 0.9941 for WR female.

As is evident from Table 27, pretty high correlation coefficients were observed between shank length and age within each group. Their range was 0.952 to 0.996 for WO male. The corresponding ranges for WO female, WR male and WR female were 0.959 to 0.993, 0.912 to 0.993 and 0.955 to 0.99 respectively. The average value of the correlation was 0.971 for WO male, 0.976 for WO female, 0.974 for WR male and 0.975 for WR female.

4.4. Functional Relations.

Since there is high correlation between shank length (x) and body weight (y) the latter can be predicted in terms of the former. Hence linear prediction equations of the form $y = a + bx$ were fitted. The values of the y intercept (a) and regression coefficients (b) are presented in Table 28.

Analysis of variance (Table 29) of the regression coefficients (linear growth rates) of the four groups indicated no significant difference between the rates of growth of the four groups.

Shank length was found to increase with age and therefore linear prediction equations were fitted for predicting shank length (y) using age (x) for each bird. The values of 'a' and 'b' are given in Table 30.

The analysis of variance of linear growth rate was given in Table 31. No significant difference was observed in the rates of growth of the males of the two genetic groups. Also WC male did not differ significantly from the females of the two groups. The two female groups also were identical with regard to their growth rates. Heterogeneity in the rates of growth was observed between WR male and WR female, and WR male and WC female.

The bird wise correlation between observed and expected shank lengths at different ages were very high, the least value being 0.9504 (Table 32).

The values of 'b' when exponential curve was fitted to the shank length of WC male ranged from 0.1291 to 0.168. The corresponding ranges for WC female, WR male and WR female were respectively 0.1234 to 0.1626, 0.1453 to 0.1834 and 0.1162 to 0.1594 (Table 32). Analysis of variance of the 'b' values (Table 33) showed lack of homogeneity between the rates of growth. However no significant difference was observed in the rates of growth of the two female genetic groups. Also no significant difference between WC male and WR female was seen. All other pairs differed significantly. The average value of 'b' was highest for WR male followed by WC male. WC female had the least average value of 'b'.

Using the exponential relation expected shank lengths at different ages were computed. For each bird the observed and expected values were highly correlated, the least being 0.9473. The relevant information is given in Table 34.

Modified exponential fitted to the shank length in the form of $y = k + ab^x$ is presented in Tables 36, 37, 38 and 39. The smallest 'b' values of the modified exponential fitted to eight weeks shank length of the four groups were 1.0292, 1.0552, 1.04 and 0.9609 respectively for WC male, WC female, WR male and WR female. The maximum values were 1.4783, 1.3326, 1.4973 and 1.3427 respectively. The analysis of variance of the 'b' values (Table 40) showed no significant difference between the rates of growth of the four groups.

Gomperts curve of the form $y = ab^{c^x}$ was also fitted to the shank length of each bird. The values of a, b and c for the four groups were presented in Tables 41, 42, 43 and 44. The analysis of variance of 'b^c' associated with four groups is given in table 45. It was found that the rates of growth of the four groups as measured by Gomperts form of growth were homogeneous.

Logistic curve was fitted to shank lengths of each bird for eight weeks. The form of the curve was

$$\frac{1}{y} = a + bc^x$$

The parameters a, b, c for the four groups are given in Tables 46, 47, 48 and 49.

The growth parameter 'b' of shank length, as recommended by Rao (1958) was estimated for each bird. The estimated values are presented in Table 50. The analysis of covariance of 'b' values taking initial shank length of the birds as concomitant variable is presented in Table 51. The initial shank length had no significant influence on the 'b' values which themselves were homogeneous.

Using Rao's method the growth parameter 'b' was estimated for body weight also. As each of the 'b' values was very large, to reduce them to manageable size, each was divided by 10^5, and the resulting 'b' values are given in Table 52. The analysis of covariance of 'b' values (Table 53) taking initial body weight as concomitant variable indicated significant difference between the groups. WR male differed significantly from the rest of the groups which were homogeneous. The average 'b' values were 25.764, 18.895, 43.9937 and 22.9846 respectively for WC male, WC female, WR male and WR female.

Table 1. Initial (day old) and week end mean shank length of the birds for eight weeks.

Period	Group			
	WG male	WG female	WR male	WR female
Day old	2.467±0.054	2.460±0.080	2.423±0.076	2.443 ±0.067
1	2.700±0.086	2.680±0.095	2.697±0.095	2.690±0.108
2	2.997±0.209	2.923±0.184	3.010±0.185	2.943±0.148
3	3.387±0.375	3.287±0.311	3.503±0.297	3.323±0.287
4	4.090±0.529	3.993±0.360	4.297±0.412	4.000±0.380
5	4.913±0.600	4.680±0.404	5.293±0.509	4.800±0.471
6	5.827±0.619	5.520±0.579	6.353±0.571	5.650±0.585
7	6.783±0.618	6.283±0.559	7.307±0.629	6.540±0.570
8	7.653±0.591	7.130±0.675	8.340±0.659	7.360±0.552

Table 2. Initial (day old) and week-end mean body weight of the birds for eight weeks.

Period	Group			
	WC male	WC female	WR male	WR female
Initial	39.867± 2.825	40.933± 3.151	41.100± 1.886	38.267± 3.151
1	48.500± 7.736	48.000± 5.434	53.000± 6.947	48.533± 9.619
2	75.600± 21.022	77.033± 15.793	89.400± 19.651	76.567± 16.288
3	118.800± 36.210	116.733± 26.233	143.667± 33.583	116.300± 30.380
4	200.000± 69.880	182.133± 48.175	249.933± 58.220	198.233± 51.456
5	309.333± 90.594	274.467± 64.555	400.967± 95.894	301.133± 72.250
6	436.233±115.958	371.633± 93.656	585.500±127.731	421.900± 90.570
7	583.167±147.539	505.367±126.616	783.133±180.530	550.267±113.246
8	744.833±176.854	648.200±165.689	970.267±240.639	711.933±120.247

Table 3. Analysis of variance of initial shank length of four groups of chicks.

Source	df	SS	MSS	F
Between groups	3	0.0337	0.0112	2.22
Within groups	116	0.5960	0.0051	1.00

Table 4. Analysis of variance of shank length at the end of first week.

Source	df	SS	MSS	F
Between groups	3	0.0070	0.0023	0.245
Within groups	116	1.1090	0.0095	

Table 5. Analysis of variance of shank length at the end of two weeks.

Source	df	SS	MS	F
Between groups	3	0.1557	0.0519	1.5043
Within groups	116	4.0041	0.0345	

Table 6. Analysis of variance of shank length at the end of three weeks.

Source	df	SS	MS	F
Between groups	3	0.8123	0.2708	2.5679
Within groups	116	12.2328	0.1055	

Table 7. Analysis of variance of fourth week shank length.

Source	df	SS	MSS	F
Between groups	3	1.9804	0.6601	3.5262*
Within groups	116	21.7153	0.1872	

* Indicates significance at 5% level.

C.D. for comparison between groups = 0.2212.

Table 8. Analysis of variance of fifth week shank length.

Source	df	SS	MSS	F
Between groups	3	6.3424	2.1141	8.1375**
Within groups	116	30.1414	0.25981	

** Indicates significance at 1% level.

C.D. for comparison = 0.2606.

Table 9. Analysis of variance of sixth week shank length.

Source	df	SS	MSS	F
Between groups	3	12.0649	4.0216	11.2273**
Within groups	116	41.5564	0.3582	

C.D. for comparison = 0.306

Table 10. Analysis of variance of seventh week shank length.

Source	df	SS	MSS	F
Between groups	3	17.13	5.71	15.6224**
Within groups	116	42.3941	0.3655	

C.D. for comparison = 0.3091.

Table 11. Analysis of variance of eighth week shank length.

Source	df	SS	MSS	F
Between groups	3	24.8162	8.2721	20.724**
Within groups	116	46.3017	0.3992	

C.D. for comparison = 0.3231.

Table 12. Analysis of variance of initial (day old) body weight.

Source	df	SS	MSS	F
Between groups	3	152.89	50.9639	6.28**
Within groups	116	941.9	8.1198	

C.D. for comparison between groups = 1.457.

Table 13. Analysis of variance of body weight at the end of first week.

Source	df	SS	MSS	F
Between groups	3	493.025	164.34	2.761*
Within groups	116	6904.5	59.52	

C.D. for comparison between groups = 2.761.

Table 14. Analysis of variance of body weight at the end of two weeks.

Source	df	SS	MSS	F
Between groups	3	3834.57	1278.19	3.68*
Within groups	116	40284.2	347.28	

C.D. for comparison between groups = 9.53.

Table 15. Analysis of variance of body weight at the end of three weeks.

Source	df	SS	MSS	F
Between groups	3	15775.50	5258.5	5.02**
Within groups	116	121504.8	1047.46	

C.D. for comparison = 16.55.

Table 16. Analysis of variance of body weight at the end of four weeks.

Source	df	SS	MSS	F
Between groups	3	77584.63	25861.54	7.55**
Within groups	116	397240.0	3424.48	

C.D. for comparison = 29.92.

Table 17. Analysis of variance of body weight at the end of five weeks.

Source	df	SS	MSS	F
Between groups	3	272697.35	90899.12	14.075**
Within groups	116	749168.0	6458.34	

C.D. for comparison = 41.09.

Table 18. Analysis of variance of body weight at the end of six weeks.

Source	df	SS	MSS	F
Between groups	3	762673.47	254224.5	21.03**
Within groups	116	1402073.0	12086.84	

C.D. for comparison = 56.22.

Table 19. Analysis of variance of body weight at the end of seven weeks.

Source	df	SS	MSS	F
Between groups	3	1353893.50	451297.83	20.97**
Within groups	116	2496448.0	21521.10	

C.D. for comparison = 73.01.

Table 20. Analysis of variance of body weight at the end of eight weeks.

Source	df	SS	MSS	F
Between groups	3	1768241.89	589413.96	17.38**
Within groups	116	3932895.0	33904.27	

C.D. for comparison = 94.13.

Table 21. Serial correlation between shank lengths of WC male at the end of different weeks.

	Day old	1	2	3	4	5	6	7	8
Day old	1	.4345*	.0792	.0110	.0352	.0409	.1671	.2311	.1504
1		1	.6893**	.6231**	.6037**	.5778**	.5223**	.5550**	.5336**
2			1	.8890**	.8777**	.9134**	.7099**	.7904**	.7412**
3				1	.9109**	.8367**	.7175**	.7467**	.7587**
4					1	.8904**	.7550**	.7859**	.7592**
5						1	.8872**	.8709**	.9132**
6							1	.8658**	.8807**
7								1	.9032**
8									1

Table 22. Serial correlation between shank lengths of VC female at the end of different weeks.

	Day old	1	2	3	4	5	6	7	8
Day old	1	.5995**	.4715**	.4346*	.3028	.4294*	.4493*	.4326*	.4040*
1		1	.7559**	.7630**	.6418**	.7496**	.7508**	.6818**	.6546**
2			1	.8695**	.6563**	.7610**	.6818**	.6725**	.6173**
3				1	.7583**	.8247**	.8025**	.7989**	.6902**
4					1	.8810**	.7835**	.7393**	.6750**
5						1	.9335**	.9091**	.8769**
6							1	.9372**	.8708**
7								1	.8900**
8									1

Table 23. Serial correlation between shank lengths of WR male at the end of different weeks.

	Day old	1	2	3	4	5	6	7	8
Day old	1	-.2880	.0470	-.1030	-.1570	-.2450	-.0133	-.0033	.0480
1		1	.6043**	.5882**	.5375**	.4760**	.5453**	.4813*	.2880
2			1	.8274**	.7227**	.6496**	.5116**	.5246**	.4261*
3				1	.8881**	.7950**	.6311**	.5925**	.5262**
4					1	.8613**	.7479**	.6823**	.6574**
5						1	.8728**	.7852**	.7536**
6							1	.9185**	.9300**
7								1	.9309**
8									1

Table 24. Serial correlation between shank lengths of WR female at the end of different weeks.

	Day old	1	2	3	4	5	6	7	8
Day old	1	.2925	.1816	.0516	.0263	-.0848	-.0470	.0421	-.0344
1		1	.7622**	.8063**	.7823**	.7565**	.7819**	.6922**	.5606**
2			1	.8176**	.7600**	.7716**	.7474**	.7604**	.6845**
3				1	.8759**	.8377**	.7773**	.6873**	.5971**
4					1	.8872**	.8109**	.7647**	.6322**
5						1	.8809**	.8086**	.6911**
6							1	.9309**	.8515**
7								1	.9078**
8									1

Table 25. Correlation between body weight and shank length at the end of different weeks.

Period	Groups			
	WO male	WO female	WR male	WR female
Day old	0.1024	0.4919**	0.0070	0.4899**
1	0.8050**	0.8842**	0.5212**	0.7270**
2	0.9400**	0.8896**	0.7435**	0.7065**
3	0.9353**	0.9150**	0.9025**	0.8559**
4	0.9265**	0.9444**	0.8842**	0.8540**
5	0.9645**	0.9539**	0.8358**	0.8537**
6	0.9242**	0.9344**	0.8822**	0.8674**
7	0.8980**	0.9385**	0.8529**	0.7554**
8	0.8851**	0.9449**	0.8561**	0.8352**
Chisquare for testing homogeneity of correlation coefficients within each group.	62.5323**	38.5102**	50.2974**	15.1791

Table 26. Correlation between body weight and shank length of individual birds.

Birds	Group			
	WC Male	WC Female	WR Male	WR Female
1	0.9862	0.9900	0.9921	0.9960
2	0.9978	0.9856	0.9801	0.9839
3	0.9945	0.9948	0.9866	0.9906
4	0.9868	0.9900	0.9748	0.9968
5	0.9906	0.9907	0.9831	0.9934
6	0.9764	0.9896	0.9896	0.9769
7	0.9970	0.9807	0.9878	0.9893
8	0.9934	0.9882	0.9934	0.9955
9	0.9967	0.9863	0.9845	0.9918
10	0.9886	0.9930	0.9916	0.9846
11	0.9915	0.9899	0.9944	0.9948
12	0.9902	0.9963	0.9973	0.9938
13	0.9971	0.9983	0.9959	0.9938
14	0.9964	0.9984	0.9920	0.9982
15	0.9967	0.9918	0.9939	0.9931
16	0.9943	0.9956	0.9919	0.9962
17	0.9976	0.9874	0.9969	0.9973
18	0.9928	0.9945	0.9947	0.9924
19	0.9965	0.9923	0.9825	0.9887
20	0.9972	0.9958	0.9989	0.9801

(Contd...)

Table 26. (Contd......)

Birds	Group			
	WC Male	WC Female	WR Male	WR Female
21	0.9956	0.9930	0.9987	0.9915
22	0.9982	0.9968	0.9845	0.9961
23	0.9894	0.9944	0.9944	0.9980
24	0.9982	0.9961	0.9991	0.9951
25	0.9956	0.9946	0.9952	0.9976
26	0.9933	0.9982	0.9972	0.9976
27	0.9942	0.9906	0.9981	0.9926
28	0.9947	0.9960	0.9965	0.9962
29	0.9894	0.9935	0.9969	0.9949
30	0.9971	0.9907	0.9973	0.9924
Chisquare for testing homogeneity of correlation coefficients.	38.3772	29.4218	62.7166**	31.5166

Table 27. Correlation between shank length and age of individual birds.

Birds	Group			
	WG Male	WG Female	WR Male	WR Female
1	0.9834	0.9833	0.9665	0.9553
2	0.9963	0.9938	0.9923	0.9722
3	0.9819	0.9857	0.9920	0.9556
4	0.9657	0.9608	0.9870	0.9736
5	0.9657	0.9676	0.9767	0.9648
6	0.9948	0.9860	0.9754	0.9878
7	0.9524	0.9836	0.9744	0.9739
8	0.9785	0.9717	0.9713	0.9644
9	0.9704	0.9788	0.9968	0.9843
10	0.9848	0.9693	0.9848	0.9769
11	0.9639	0.9889	0.9834	0.9876
12	0.9729	0.9795	0.9625	0.9812
13	0.9540	0.9891	0.9687	0.9730
14	0.9674	0.9788	0.9822	0.9641
15	0.9676	0.9772	0.9770	0.9745
16	0.9577	0.9779	0.9781	0.9753
17	0.9634	0.9791	0.9623	0.9664
18	0.9529	0.9875	0.9743	0.9899
19	0.9606	0.9753	0.9392	0.9712
20	0.9911	0.9672	0.9778	0.9760

(Contd...)

Table 27. Contd...

Birds	Group			
	WC Male	WC Female	WR Male	WR Female
21	0.9620	0.9685	0.9115	0.9828
22	0.9842	0.9711	0.9806	0.9843
23	0.9864	0.9680	0.9783	0.9738
24	0.9476	0.9781	0.9632	0.9683
25	0.9517	0.9749	0.9803	0.9791
26	0.9745	0.9584	0.9720	0.9738
27	0.9603	0.9721	0.9771	0.9827
28	0.9731	0.9645	0.9790	0.9729
29	0.9915	0.9676	0.9795	0.9627
30	0.9863	0.9658	0.9934	0.9905

Table 28. Linear prediction equation for predicting body weight using shank length at different weeks in the form $y = a + bx$.

Period	GROUP							
	WC Male		WC Female		WR Male		WR Female	
	a	b	a	b	a	b	a	b
Day old	39.87	0.0019	40.93	0.0125	41.10	0.0003	38.27	0.0103
1	48.50	0.0089	48.00	0.0143	53.00	0.0071	48.53	0.0081
2	75.60	0.0093	77.03	0.0104	89.40	0.0070	76.57	0.0064
3	118.80	0.0097	116.73	0.0108	143.67	0.0080	116.30	0.0081
4	200.00	0.0070	182.13	0.0071	249.93	0.0063	198.23	0.0063
5	309.33	0.0064	274.47	0.0060	400.97	0.0050	301.13	0.0056
6	436.23	0.0049	371.63	0.0058	585.50	0.0039	421.90	0.0056
7	593.17	0.0038	505.37	0.0041	783.13	0.0030	550.27	0.0038
8	744.83	0.0030	648.20	0.0038	970.27	0.0023	711.93	0.0038

Table 29. Analysis of variance of linear growth rates of the four groups of birds.

Source	df	SS	MSS	F
Between groups	3	32777.89	1923.59	2.279
Within groups	32	27007.11	843.97	

Table 30. Linear prediction equations of the form $y = a+bx$ for predicting shank length of different birds using age.

Birds	Group							
	WC Male		WC Female		WR Male		WR Female	
	a	b	a	b	a	b	a	b
1	1.2333	0.7067	1.2444	0.7400	0.6444	0.9000	1.4889	0.4400
2	1.2806	0.8350	1.4583	0.6750	0.9528	0.9117	1.3889	0.5000
3	1.2972	0.6117	1.4778	0.5800	0.8361	0.9617	1.1694	0.6217
4	1.3611	0.5633	1.1472	0.6083	1.2194	0.7450	1.1806	0.6150
5	1.3611	0.5633	1.1222	0.6667	0.9694	0.7417	1.3972	0.4917
6	1.3417	0.7983	1.4944	0.5167	0.7528	0.8117	1.4750	0.6250
7	1.2444	0.5600	1.3833	0.7033	0.8389	0.7767	1.1556	0.6333
8	1.1778	0.6600	0.9417	0.7517	0.6528	0.8517	1.0417	0.6533
9	1.0639	0.7250	1.0972	0.6450	1.3222	0.7533	1.1583	0.6683
10	1.2444	0.6733	1.3339	0.5100	0.9222	0.8267	1.3417	0.5383
11	0.9778	0.7200	1.2694	0.7350	0.9917	0.7883	1.2389	0.6967
12	1.3472	0.6150	1.4917	0.5217	1.1444	0.6267	1.4917	0.5217
13	1.3555	0.5400	1.6028	0.4817	0.8250	0.8083	0.9861	0.6917

(Contd..)

Table 30. Continued.

Birds	WC Male		WC Female		WR Male		WR Female	
	a	b	a	b	a	b	a	b
14	1.3278	0.5900	1.3222	0.5933	1.0472	0.7550	1.1833	0.6233
15	1.2417	0.6450	1.3444	0.5467	1.1944	0.6833	1.2722	0.6233
16	0.9861	0.6383	1.4417	0.5050	0.9528	0.8183	1.1306	0.7117
17	1.0222	0.7067	1.4222	0.5867	1.0167	0.6700	0.9500	0.7167
18	1.3361	0.5217	1.2472	0.7217	0.9806	0.7083	1.2333	0.7200
19	1.0417	0.6783	1.3444	0.6133	1.1000	0.6733	1.2972	0.5450
20	1.4417	0.8117	1.1278	0.6767	0.8861	0.7950	1.1033	0.6783
21	0.9889	0.7200	1.4778	0.4867	0.7750	0.8250	1.3750	0.6517
22	1.0139	0.7550	1.3861	0.5517	0.8111	0.8133	1.1472	0.7283
23	1.1083	0.7183	1.2722	0.6033	1.2000	0.6583	1.0972	0.7250
24	1.0778	0.6333	1.1333	0.6600	0.9889	0.7200	1.3250	0.6283
25	1.2111	0.6000	1.5806	0.4983	0.9833	0.8233	1.1139	0.6960

(Contd...)

Table 30. Continued.

Birds	WC Male		WC Female		WR Male		WR Female	
	a	b	a	b	a	b	a	b
26	1.2611	0.6567	1.3444	0.5200	0.7399	0.8433	1.0083	0.7250
27	1.1917	0.6083	1.3583	0.6417	0.9167	0.8567	1.2972	0.6650
28	0.9639	0.7383	1.4444	0.5533	1.3111	0.6667	1.2583	0.6217
29	1.4056	0.6167	1.2056	0.5633	1.1917	0.5950	1.3361	0.6617
30	1.0333	0.8400	1.4111	0.5267	1.3861	0.6517	1.4861	0.7317

Table 31. Analysis of variance table of linear growth rates of four groups of birds.

Source	df	SS	MSS	F
Between groups	3	0.2601	0.0867	3.7371*
Within groups	116	2.6957	0.0232	

C.D. for comparison between treatments = 0.0778.

Table 32. Correlation between observed and expected shank lengths of four groups of chicks for eight weeks of age when linear equation was fitted.

Birds	Group			
	WC Male	WC Female	WR Male	WR Female
1	0.9835	0.9494	0.9597	0.9549
2	0.9963	0.9130	0.9926	0.9724
3	0.9860	0.9853	0.9909	0.9561
4	0.9652	0.9684	0.9861	0.9993
5	0.9759	0.9694	0.9776	0.9683
6	0.9949	0.9859	0.9739	0.9878
7	0.9531	0.9825	0.9706	0.9738
8	0.9786	0.9727	0.9672	0.9639
9	0.9705	0.9770	0.9959	0.9843
10	0.9830	0.9693	0.9848	0.9681
11	0.9076	0.9872	0.9797	0.9823
12	0.9728	0.9846	0.9630	0.9813
13	0.9546	0.9868	0.9655	0.9731
14	0.9674	0.9776	0.9783	0.8767
15	0.9675	0.9790	0.9786	0.9743
16	0.9578	0.9741	0.9825	0.9817
17	0.9637	0.9813	0.9598	0.9474
18	0.9533	0.9905	0.9756	0.9881
19	0.9606	0.9784	0.9384	0.9543
20	0.9910	0.9897	0.9809	0.9782

(Contd....)

Table 32. Continued.

Birds	Group			
	WG Male	WG Female	WR Male	WR Female
21	0.9619	0.9742	0.9680	0.9746
22	0.9844	0.9654	0.9806	0.9813
23	0.9864	0.9789	0.9801	0.9901
24	0.9476	0.9739	0.9741	0.9784
25	0.9518	0.9584	0.9803	0.9741
26	0.9749	0.9692	0.9720	0.9823
27	0.9605	0.9576	0.8908	0.9714
28	0.9731	0.9646	0.9775	0.9912
29	0.9915	0.8504	0.9781	0.9710
30	0.9863	0.9765	0.9924	0.9847

Table 33. Growth pattern of the shank length of different groups of birds in the exponential form $y = ae^{bx}$.

Birds	WC Male		WC Female		WR Male		WR Female	
	a	b	a	b	a	b	a	b
1	2.0588	0.1525	2.1209	0.1537	1.8874	0.1787	1.9659	0.1162
2	2.1958	0.1647	2.1545	0.1475	2.0461	0.1779	1.9287	0.1288
3	1.9883	0.1432	2.0954	0.1352	2.0260	0.1834	1.9482	0.1429
4	2.0000	0.1347	1.8549	0.1473	2.0870	0.1564	1.9034	0.1463
5	2.0013	0.1422	1.9478	0.1499	1.9024	0.1622	1.9448	0.1258
6	2.2013	0.1604	2.0242	0.1290	1.8241	0.1737	2.1454	0.1397
7	1.9271	0.1351	2.1683	0.1484	1.8485	0.1685	1.9181	0.1477
8	1.9628	0.1499	1.9062	0.1626	1.8185	0.1774	1.8754	0.1515
9	1.9820	0.1557	1.8722	0.1519	2.1211	0.1588	1.9395	0.1528
10	2.0000	0.1518	1.9064	0.1307	1.8635	0.1754	2.0300	0.1306
11	1.9050	0.1580	2.0937	0.1559	1.9597	0.1664	2.0185	0.1543

Group

(Contd.....)

Table 33. Continued.

Birds	Group							
	WC Male		WC Female		WR Male		WR Female	
	a	b	a	b	a	b	a	b
12	2.0556	0.1599	2.0411	0.1284	1.9208	0.1453	2.0400	0.1285
13	1.9913	0.1302	2.0578	0.1234	1.9060	0.1682	1.8547	0.1583
14	2.0158	0.1448	1.9923	0.1401	1.9646	0.1622	1.9463	0.1440
15	2.0281	0.1355	1.9416	0.1358	2.0059	0.1511	2.0035	0.1429
16	1.8114	0.1510	1.9580	0.1297	1.9919	0.1672	2.0060	0.1538
17	1.9327	0.1548	2.0676	0.1364	1.8732	0.1529	1.8765	0.1590
18	1.9497	0.1291	2.0623	0.1554	1.7872	0.1632	2.0491	0.1558
19	1.9106	0.1521	2.0517	0.1399	1.9941	0.1457	1.9191	0.1353
20	2.0590	0.1672	1.9720	0.1500	1.8959	0.1675	1.9321	0.1532
21	1.8978	0.1588	2.0039	0.1232	1.9782	0.1717	2.1084	0.1457
22	1.9334	0.1637	2.0201	0.1326	1.8497	0.1739	1.9851	0.1594
23	1.9491	0.1594	1.9788	0.1409	1.9728	0.1486	1.9894	0.1563
24	1.8910	0.1461	1.9213	0.1517	1.9151	0.1574	2.0548	0.1414

(Contd.....)

Table 33. Continued.

Birds	Group							
	WC Male		WC Female		WR Male		WR Female	
	a	b	a	b	a	b	a	b
25	1.9469	0.1401	2.0910	0.1208	1.9389	0.1703	1.9751	0.1529
26	2.0319	0.1464	1.9454	0.1295	1.8689	0.1745	1.9220	0.1590
27	1.9307	0.1428	2.0416	0.1484	1.9259	0.1744	2.0564	0.1475
28	1.8968	0.1617	2.0271	0.1328	2.0008	0.1416	1.9937	0.1428
29	2.0534	0.1430	1.8699	0.1396	1.8807	0.1450	1.9881	0.1342
30	2.0596	0.1880	1.9825	0.1300	2.0678	0.1476	2.1920	0.1550

Table 34. Analysis of variance of the exponential growth rates (b) of shank length in the four groups of birds.

Source	df	SS	MSS	F
Between groups	3	0.0092	0.003052	23.51**
Within groups	116	0.0151	0.000129	

C.D. for comparison between groups = 0.0058.

Table 35. Correlation between observed and expected shank lengths of four groups of chicks when exponential equation was fitted.

Birds	Group			
	WC Male	WC Female	WR Male	WR Female
1	0.9800	0.9851	0.9661	0.9553
2	0.9964	0.9938	0.9350	0.9473
3	0.9819	0.9863	0.9923	0.9552
4	0.9856	0.9685	0.9869	0.9735
5	0.9756	0.9675	0.9766	0.9843
6	0.9948	0.9860	0.9755	0.9878
7	0.9524	0.9837	0.9750	0.9738
8	0.9785	0.9717	0.9714	0.9728
9	0.9705	0.9787	0.9913	0.9843
10	0.9785	0.9693	0.9852	0.9686
11	0.9617	0.9888	0.9828	0.9878
12	0.9699	0.9718	0.9629	0.9789
13	0.9540	0.9643	0.9692	0.9712
14	0.9674	0.9782	0.9821	0.9847
15	0.9676	0.9814	0.9771	0.9642
16	0.9573	0.9576	0.9781	0.9682
17	0.9635	0.9782	0.9667	0.9761
18	0.9530	0.9880	0.9759	0.9747

(Contd...)

Table 35. Continued.

	Group			
Birds	WC Male	WC Female	WR Male	WR Female
19	0.9609	0.9913	0.9793	0.9561
20	0.9910	0.9747	0.9791	0.9681
21	0.9620	0.9684	0.9712	0.9713
22	0.9842	0.9458	0.9778	0.9814
23	0.9864	0.9881	0.9782	0.9643
24	0.9476	0.9658	0.9741	0.9804
25	0.9786	0.9715	0.9632	0.9518
26	0.9754	0.9936	0.9716	0.9744
27	0.9817	0.9782	0.9770	0.9602
28	0.9913	0.9643	0.9790	0.9728
29	0.9748	0.9884	0.9796	0.9916
30	0.9846	0.9849	0.9934	0.9785

Table 36. Continued.

Birds	k	a	b
19	1.9105	0.3952	1.3649
20	-7.1756	8.7065	1.0696
21	1.7434	0.5255	1.3512
22	-0.1167	2.0289	1.1735
23	-1.0556	2.9010	1.1348
24	2.2161	0.2037	1.4536
25	2.3115	0.1691	1.4783
26	1.6806	0.6619	1.2869
27	1.9081	0.4107	1.3400
28	1.1326	0.9573	1.2552
29	-1.8176	3.6789	1.1063
30	-0.6162	2.5962	1.1596

Table 37. Growth pattern of shank length of the WC Female birds in the modified exponential form $y = k + ab^x$

Birds	k	a	b
1	0.1032	2.0212	1.1715
2	-2.3352	4.2676	1.1024
3	0.2197	1.9000	1.1539
4	1.3000	0.7635	1.2599
5	1.4634	0.7517	1.2706
6	0.2316	1.8107	1.1481
7	0.6061	1.6257	1.1905
8	0.9135	1.2285	1.2371
9	0.7292	1.2450	1.2078
10	1.5958	0.5668	1.2737
11	-2.8667	4.6915	1.1006
12	0.6095	1.5028	1.1655
13	-5.0190	6.8366	1.0552
14	0.7943	1.2649	1.1993
15	0.7413	1.2814	1.1877
16	0.9611	1.1130	1.1948
17	1.3406	0.9280	1.2309
18	-1.6174	3.4580	1.1235

(Contd....)

Table 37. Continued.

Birds	k	a	b
19	1.1312	1.0937	1.2153
20	1.8020	0.5171	1.3240
21	1.9186	0.4052	1.3121
22	1.5990	0.6538	1.2662
23	1.8750	0.4568	1.3263
24	0.4822	1.5062	1.1892
25	1.4679	0.8098	1.2251
26	1.7755	0.4809	1.2951
27	1.3325	0.8954	1.2549
28	1.6629	0.6284	1.2725
29	1.8350	0.4010	1.3326
30	1.8880	0.4440	1.3087

Table 38. Growth pattern of shank length of WR Male birds in the modified exponential form $y = k + ab^x$

Birds	k	a	b
1	1.5721	0.6545	1.3327
2	-4.9879	6.5590	1.0929
3	-4.4013	5.9956	1.1019
4	-0.4774	2.5041	1.1519
5	0.5910	1.4013	1.2098
6	0.5039	1.3842	1.2224
7	0.5675	1.3458	1.2209
8	1.1182	0.9056	1.2805
9	-14.2000	15.7715	1.0400
10	-0.9927	2.6979	1.1554
11	-0.3222	2.2158	1.1696
12	1.7956	0.4610	1.3300
13	1.4272	0.7614	1.2954
14	-0.6517	2.4998	1.1540
15	0.7480	1.3486	1.2063
16	0.7372	1.3842	1.2225
17	1.6493	0.5324	1.3195
18	0.4848	1.3660	1.2075

(Contd.....)

Table 38. Continued.

Birds	k	a	b
19	2.4040	0.1674	1.4973
20	0.4992	1.4555	1.2129
21	1.2778	0.8428	1.2856
22	0.3258	1.5906	1.2061
23	0.4182	1.1958	1.2132
24	1.9184	0.4273	1.3596
25	0.1479	1.7899	1.1956
26	1.4853	0.7084	1.3114
27	0.4104	1.5481	1.2172
28	1.0645	1.0937	1.2153
29	1.1838	0.8907	1.2368
30	-6.9867	8.6709	1.0583

Table 39. Growth pattern of shank length of WR Female birds in the modified exponential form $y = k + ab^x$.

Birds	k	a	b
1	2.0156	0.2997	1.3372
2	0.9551	1.0981	1.1927
3	1.7705	0.5071	1.3132
4	1.3991	0.7362	1.2655
5	1.6000	0.5984	1.2599
6	0.2083	2.1012	1.1531
7	1.3667	0.7841	1.2599
8	1.7826	0.4655	1.3335
9	-0.9383	2.0001	1.1633
10	1.1543	1.0208	1.2099
11	-1.1855	3.0551	1.1298
12	-0.4074	2.0538	1.1380
13	1.1658	0.8954	1.2549
14	1.8104	0.4756	1.3244
15	1.4333	0.7841	1.2599
16	1.1927	0.9908	1.2454
17	1.7753	0.4805	1.3427
18	-1.1014	3.0262	1.1326

(Contd....)

Table 39. Continued.

Birds	k	a	b
19	1.4323	0.7099	1.2535
20	0.7111	1.3314	1.2050
21	0.8122	1.4290	1.1929
22	-1.4927	3.3208	1.1255
23	1.4553	0.7056	1.2791
24	1.8926	0.5101	1.3172
25	1.2992	0.8954	1.2549
26	1.4750	0.7216	1.2392
27	0.6573	1.4591	1.1961
28	1.5299	0.7106	1.2711
29	1.9500	0.4153	1.3262
30	23.8708	-22.7366	0.9609

Table 40. Analysis of variance of growth rates (b) of shank length in the four groups of birds based on modified exponential.

Source	df	SS	MSS	F
Between groups	3	0.0157	0.00524	0.2835
Within groups	116	2.1423	0.01847	

Table 41. Growth pattern of shank length of WC Male in the Gomperts form $y = ab^{c^x}$

Birds	a	b	c
1	1.3490	0.0002	0.9812
2	28.3500	0.0650	0.9074
3	0.0693	29.7700	1.0363
4	0.5968	3.6500	1.0742
5	0.7909	2.7810	1.0931
6	18.020	0.0978	0.8809
7	1.8870	8.7600	1.2285
8	0.3473	6.1190	1.0624
9	0.7230	3.0630	1.0924
10	26.510	0.0663	0.9194
11	9.9790	1.7580	1.1491
12	0.7158	3.1420	1.0844
13	1.7310	1.3530	1.1888
14	0.4693	4.6470	1.0693
15	1.4650	1.5930	1.1508
16	1.5460	1.4090	1.1921
17	1.3740	2.1420	1.1200
18	1.6420	1.3850	1.1807

(Contd....)

Table 41. Continued.

Birds	a	b	c
19	1.5360	1.4810	1.1793
20	34.2200	0.0508	0.9164
21	1.4590	1.5600	1.1701
22	3×10^{8}	7427×10^{4}	1.0087
23	63080	3×10^{-5}	0.9836
24	2.0520	4.7790	1.2786
25	2.1340	3.9220	1.2926
26	6.1190	1.9390	1.1266
27	1.4880	1.5300	1.1630
28	0.6024	3.4970	1.0882
29	210.1000	91×10^{-6}	0.9634
30	6066×10^{6}	3×10^{-10}	9.9202

Table 42. Growth pattern of shank length of WC Female in the Gomperts form $y = ab^{c^x}$.

Birds	a	b	c
1	23×10^{-9}	9198×10^{3}	1.0092
2	101.5000	0.0196	0.9529
3	0.0011	2024	1.0165
4	0.1998	2.4340	1.1051
5	0.3080	2.2430	1.1124
6	0.0014	1445	1.0165
7	0.0284	78.8700	1.0302
8	0.2139	9.5350	1.0567
9	0.1380	14.3500	1.0465
10	7.6930	1.7580	1.1306
11	127.7000	0.0152	0.9538
12	0.0595	35.6300	1.0311
13	29.2200	0.0649	0.9404
14	0.1327	15.5200	1.0432
15	0.2411	8.4870	1.0510
16	0.5028	4.1620	1.0678
17	0.7936	2.8590	1.0881
18	679.4000	0.0028	0.9687

(Contd......)

Table 42. Continued.

Birds	a	b	c
19	0.4064	5.4460	1.0621
20	1.2970	1.7600	1.1429
21	1.5400	1.4860	1.1568
22	2.7850	2.0200	1.1147
23	1.5390	1.5040	1.1671
24	0.0541	37.2700	1.0357
25	0.4311	5.0010	1.0597
26	1.3940	1.6030	1.1439
27	0.7190	3.0950	1.0904
28	8.9480	1.8360	1.1259
29	1.5220	1.4540	1.1732
30	1.5260	1.5120	1.1560

Table 43. Growth pattern of shank length of WR Male in the Gomperts form $y = ab^{c^x}$.

Birds	a	b	c
1	0.7794	2.2580	1.1271
2	20.9800	0.0761	0.8786
3	63.5700	0.0278	0.9295
4	18.3700	0.0959	0.8897
5	0.1173	17.2600	1.0463
6	0.0778	24.8000	1.0448
7	0.0636	30.4700	1.0416
8	0.4170	4.8280	1.0801
9	18.8200	0.0922	0.8895
10	467400	38×10^{-7}	0.9848
11	32×10^{-12}	7261×10^{14}	1.0040
12	1.3680	1.6290	1.1535
13	0.1353	2.6570	1.1076
14	1999×10^{4}	9×10^{-8}	0.9893
15	0.1389	15.1900	1.0458
16	0.1761	12.1300	1.0529
17	6.3750	1.7990	1.1417
18	0.0549	34.3000	1.0389

(Contd...)

Table 43. Continued.

Birds	a	b	c
19	2.1680	4.5170	1.2346
20	0.0313	63.2800	1.0349
21	0.6287	3.3570	1.0944
22	0.0303	64.4800	1.0355
23	0.2717	7.7870	1.0563
24	1.5900	1.4640	1.1841
25	199×10^{-9}	9806×10^{3}	1.0102
26	0.1062	2.6910	1.1092
27	0.0542	37.0300	1.0413
28	0.3856	5.5780	1.0624
29	0.5670	3.6350	1.0790
30	27.3200	0.0665	0.9217

Table 44. Growth pattern of shank length of WR Females in the Gompertz form $y = ab^{c^x}$.

Birds	a	b	c
1	1.7910	1.2790	1.1968
2	0.4545	4.5530	1.0636
3	9.5740	1.7880	1.1353
4	0.4190	2.3260	1.1083
5	3.4690	1.9240	1.1145
6	3094×10^{22}	41×10^{-18}	0.9998
7	0.6656	3.1830	1.0869
8	1.3970	1.5860	1.1603
9	26×10^{-9}	748×10^{5}	1.0082
10	0.5061	4.2810	1.0671
11	27540	209×10^{-7}	0.9823
12	9×10^{-10}	2207×10^{6}	1.0059
13	0.4804	4.2620	1.0772
14	1.4190	1.5970	1.1562
15	0.7934	2.7700	1.0941
16	0.4688	4.6900	1.0731
17	1.2990	1.7070	1.1528
18	10990	18×10^{-5}	0.9802

Table 44. Continued.

Birds	a	b	c
19	0.1644	2.1790	1.1080
20	0.1780	11.6100	1.0498
21	0.1363	16.4300	1.0421
22	17520	1101×10^{-7}	0.9809
23	0.1731	2.6510	1.1032
24	1.6000	1.4980	1.1702
25	0.6552	3.3360	1.0866
26	0.1645	2.5960	1.1055
27	0.0690	30.8000	1.0372
28	0.6445	2.3210	1.1069
29	1.7010	1.3860	1.1827
30	11.9200	0.1312	0.8355

Table 45. Analysis of variance of 'clogb' in the Grompertz equation.

Source	df	SS	MSS	F
Between groups	3	1567.2739	522.4246	0.8287
Within groups	116	73131.4827	630.4438	

Table 46. Growth pattern of shank length of WC Male in the logistic from $\frac{1}{y} = a + bc^{x}$.

Birds	a	b	c
1	0.1789	0.4730	0.8479
2	0.6814	0.4507	0.7692
3	-0.8693	0.5733	0.8992
4	-0.5439	0.9999	0.9587
5	-0.6759	1.1304	0.9624
6	0.8320	0.4483	0.7521
7	0.6764	-0.2467	1.0935
8	-0.2417	0.7118	0.9287
9	-0.4491	0.9018	0.9487
10	0.7321	0.4685	0.7990
11	-3.8252	4.2819	0.9905
12	-0.4231	0.8697	0.9506
13	0.9090	-0.4786	1.0552
14	-0.2291	0.6900	0.9292
15	3.4280	-2.9950	1.0109
16	1.3081	-0.8445	1.0392
17	-1.1493	1.6041	0.9737
18	1.2713	-0.8245	1.0359

(Contd....)

Table 4b, Continued.

Birds	a	b	c
19	1.6958	-1.2519	1.0270
20	0.6046	0.4814	0.7823
21	1.4199	-0.9812	1.0335
22	-0.3565	0.5418	0.8678
23	0.8374	0.5113	0.8530
24	0.5659	-0.1466	1.1360
25	0.5521	-0.1383	1.1387
26	-3.4563	3.8896	0.9057
27	2.3363	-1.8908	1.0176
28	-0.3677	0.8423	0.9396
29	0.4050	0.4696	0.8375
30	-0.6240	0.4903	0.8491

Table 47. Growth pattern of shank length of WC Females in the logistic form $\frac{1}{y} = a + bc^x$.

Birds	a	b	c
1	-0.2192	0.4868	0.8697
2	0.5030	0.4467	0.8206
3	-0.0510	0.5165	0.8949
4	-1.1817	1.6635	0.9737
5	-1.7440	2.1942	0.9819
6	-0.6486	0.5477	0.9020
7	-0.6136	0.5123	0.8890
8	-0.3337	0.7920	0.9379
9	-0.1546	0.6574	0.9108
10	3.7665	-0.3302	1.0104
11	0.3841	0.4615	0.8254
12	-0.1101	0.5806	0.9150
13	0.7720	0.4369	0.8368
14	-0.1207	0.6055	0.9086
15	-0.2424	0.7278	0.9319
16	-0.5485	1.0234	0.9581
17	-0.7377	1.1781	0.9666
18	0.2884	0.4775	0.8323

(Contd.....)

Table 47. Continued.

Birds	a	b	c
19	-0.2229	0.6767	0.9308
20	-4.9128	5.5562	0.9929
21	1.7173	-1.2740	1.0236
22	-2.2009	2.6497	0.9861
23	1.3719	-0.9375	1.0328
24	-0.1248	0.6166	0.9055
25	-0.5910	1.0364	0.9636
26	2.4131	-1.9623	1.0163
27	-0.4590	0.9092	0.9501
28	15.7733	-15.337	1.0022
29	1.2749	-0.8190	1.0379
30	1.0384	-0.6063	1.0452

Table 48. Growth pattern of shank length of WR Male in the logistic form $\frac{1}{y} = a + bc^x$.

Birds	a	b	c
1	-0.7289	1.1863	0.9593
2	0.5271	0.4885	0.7785
3	0.4613	0.4918	0.7825
4	-0.1642	0.4806	0.8560
5	-0.1560	0.6449	0.9081
6	-0.1378	0.4491	0.8969
7	-0.1064	0.6189	0.8903
8	-0.2283	0.7273	0.9151
9	0. 8583	0.4641	0.7554
10	-0.5469	0.5440	0.8413
11	-0.3009	0.5321	0.8629
12	1. 4140	-3.9619	1.0090
13	-0.5748	1.0359	0.9536
14	-0.2249	0.5135	0.8488
15	-0.1418	0.6135	0.9099
16	-0.1634	0.6270	0.9094
17	-7.8753	8.3402	0.9952
18	-0.1220	0.6480	0.8973

(Contd....)

Table 48. Continued.

Birds	a	b	c
19	0.5907	-0.1868	1.1130
20	-0.9083	0.5921	0.8871
21	-0.3673	0.8427	0.9364
22	-0.9904	0.6076	0.8867
23	-0.1900	0.6628	0.9209
24	1.2265	-0.7946	1.0394
25	-0.1643	0.5268	0.8529
26	-0.4451	0.9176	0.9429
27	-0.9144	0.5854	0.8833
28	-0.2268	0.6936	0.9294
29	-0.8850	0.8763	0.9441
30	0.7387	0.4560	0.7992

Table 49. Growth pattern of shank length of WR Female in the logistic form $\frac{1}{y} = a + bc^x$

Birds	a	b	c
1	0.7367	-0.2980	1.0768
2	-0.4427	0.9228	0.9528
3	-3.0696	3.5212	0.9893
4	-1.2612	1.7305	0.9756
5	-3.4906	3.9528	0.9910
6	0.7035	0.4698	0.8674
7	-0.3595	0.8370	0.9416
8	1.8743	-1.0442	1.0309
9	-0.3570	0.5425	0.8749
10	-0.3221	0.7834	0.9438
11	0.2145	0.4990	0.8539
12	-0.2953	0.5143	0.8910
13	-0.2844	0.7757	0.9303
14	2.4893	-2.0453	1.0165
15	0.1471	0.6276	0.4244
16	-0.2469	0.7071	0.9282
17	4.7714	-4.3245	1.0085
18	0.6447	0.4780	0.7941

(Contd....)

Table 49. Continued.

Birds	a	b	c
19	-1.9392	2.4126	0.9837
20	-0.1876	0.6688	0.9185
21	-0.1254	0.5743	0.9122
22	0.0001	0.5049	0.8527
23	-0.7139	1.0208	0.9552
24	1.5646	-1.1501	1.0270
25	-0.4082	0.8649	0.9458
26	-0.5302	0.9975	0.9519
27	-0.1006	0.5695	0.9010
28	-0.8590	1.3167	0.9685
29	0.8541	-0.4247	1.0600
30	0.1016	0.4704	0.7199

Table 50. Initial shank length yo and b values of the four groups of birds by Rao's method.

WC Male		WC Female		WR Male		WR Female	
b	yo	b	yo	b	yo	b	yo
125.45	2.5	116.6	2.6	180.36	2.5	81.34	2.4
133.33	2.5	94.78	2.4	169.44	2.4	84.62	2.4
108.04	2.4	93.31	2.5	182.35	2.4	114.96	2.5
104.26	2.5	99.01	2.4	145.26	2.5	101.91	2.4
109.14	2.5	113.69	2.5	152.98	2.4	88.95	2.4
129.67	2.5	80.48	2.4	165.55	2.4	100.63	2.5
110.06	2.5	102.75	2.6	163.14	2.4	110.12	2.3
118.86	2.4	127.66	2.4	172.91	2.4	116.69	2.4
135.32	2.5	105.05	2.3	138.81	2.4	109.07	2.4
118.40	2.4	79.50	2.4	161.25	2.3	93.16	2.5
128.24	2.5	114.76	2.5	157.68	2.4	108.38	2.4
108.31	2.5	88.38	2.4	135.08	2.5	88.14	2.5
107.08	2.5	75.43	2.4	170.00	2.5	121.71	2.3
116.04	2.5	92.77	2.5	154.82	2.4	110.55	2.5
107.16	2.5	85.56	2.4	142.99	2.5	104.74	2.5
120.85	2.4	74.59	2.4	168.82	2.5	121.97	2.5
132.28	2.5	93.34	2.5	143.64	2.5	122.13	2.4
103.87	2.4	107.37	2.5	144.86	2.3	115.57	2.4

(Contd....)

Table 50. Continued.

WC Male b	ye	WC Female b	ye	WR Male b	ye	WR Female b	ye
124.69	2.5	102.56	2.5	151.33	2.6	93.65	2.4
126.54	2.5	110.84	2.5	159.50	2.4	118.20	2.4
126.40	2.5	79.43	2.4	166.03	2.5	108.42	2.5
128.85	2.4	89.99	2.5	160.92	2.3	111.56	2.4
125.41	2.3	95.03	2.5	155.23	2.4	118.31	2.5
118.81	2.5	105.08	2.4	146.70	2.5	102.78	2.6
109.43	2.5	79.22	2.5	162.72	2.4	119.50	2.5
115.97	2.5	93.98	2.4	173.41	2.3	122.20	2.8
111.53	2.4	105.92	2.6	165.78	2.5	106.13	2.5
129.63	2.5	94.98	2.6	119.75	2.4	104.79	2.5
100.55	2.4	92.07	2.3	118.90	2.3	99.57	2.5
142.39	2.5	84.79	2.5	117.86	2.4	101.76	2.4

Table 51. Analysis of covariance of initial shank length and b values of shank length by Rao's method.

Source	df	SS(x)	SP(xy)	SS(y)	Deviation	df	MSS	F
Between groups	3	57598.60	-32.52	0.0337				
Within groups	116	21447.57	12.89	0.5860	0.5783	115	.0050	
Total (Treatment + Error)	119	79046.16	-19.63	0.6197		118		1.92
Treatment Adjusted					0.0288	3	.0096	

Table 52. Initial body weight yo and b values of the four groups of birds by Rao's method.

Birds	Group							
	WC Male		WC Female		WR Male		WR Female	
	yo	b	yo	b	y0	b	yo	b
1	39	33.176	40	28.545	42	59.521	34	16.871
2	42	45.433	44	24.394	44	64.742	40	16.488
3	40	21.530	44	18.562	44	67.530	43	28.952
4	38	21.670	38	18.188	41	57.662	38	16.955
5	42	22.963	42	23.175	37	50.789	35	16.036
6	40	41.577	39	16.270	42	57.372	41	28.720
7	37	21.934	44	27.770	41	49.930	33	24.084
8	40	24.316	42	30.018	40	61.820	36	27.882
9	44	29.772	40	22.346	43	52.887	42	28.729
10	40	27.926	41	15.082	44	49.552	43	24.196
11	39	30.206	40	26.347	41	44.849	41	25.604
12	47	24.998	41	11.879	40	30.187	41	15.566
13	41	19.099	40	10.256	44	51.825	34	28.320
14	40	21.603	42	15.348	40	37.659	41	24.418
15	43	20.464	35	14.687	38	36.642	39	22.884
16	35	32.579	39	10.261	41	48.985	40	23.832
17	38	26.258	47	17.995	40	40.763	34	25.306
18	43	21.091	41	22.882	40	41.515	41	24.971

(Contd....)

Table 52. Continued.

Birds	Group							
	WC Male		WC Female		WR Male		WR Female	
	yo	b	yo	b	yo	b	yo	b
19	45	26.038	44	22.736	40	40.489	34	20.523
20	38	26.086	45	22.038	39	34.651	35	28.946
21	39	26.824	34	13.831	44	43.821	39	23.349
22	40	26.416	42	16.196	40	43.076	38	19.990
23	38	25.900	37	17.503	41	32.023	35	25.050
24	35	20.332	42	19.874	39	32.254	40	20.664
25	42	18.890	37	13.628	44	41.082	42	26.989
26	38	20.248	40	15.304	40	43.657	40	23.782
27	40	19.575	42	21.084	42	38.453	41	21.159
28	34	26.958	41	20.311	42	21.750	33	18.575
29	40	19.450	37	16.654	39	21.908	37	18.964
30	39	29.607	40	13.675	41	22.417	38	21.732

Table 53. Analysis of covariance of initial body weight yo and b values by Rao's Method.

Source	df	SS(x)	SP(xy)	SS(y)	Deviation	df	MSS	F
Between groups	3	11063.21	615.22	140.22				
Within groups	116	6844.66	540.61	890.70	848.0008	115	7.3739	
Total (Treatment + Error)	119	17907.86	1155.83	1030.93	956.3257	118		2.967*
Treatment Adjusted					65.6257	3	21.8746	

DISCUSSION

DISCUSSION

The earlier workers such as Lerner (1939), Chhabra *et al.* (1972), Tesovsky *et al.* (1974), Unni *et al.* (1977), Verma *et al.* (1977), Renuchi P. George *et al.* (1979) confined their studies to shank lengths and body weights at different periods and the correlation between them. But in the present investigation the pattern of development of shank length in chicken was given prime importance, in addition to investigation on the above aspects.

The average shank lengths of the day old chicks were 2.47 cm, 2.46 cm, 2.42 cm and 2.44 cm for WC male, WC female, WR male and WR female respectively. In the case of a cross between White Leghorn and Rhode Island Red, Verma *et al.* (1977) observed that the mean shank length of the day old chicks were 2.40 cm for male and 2.39 cm for female. The average shank length of the broilers in the present study were higher than the mean shank length of the above crossbred birds. In all the genetic and sex groups considered in the study there was no significant difference in the shank length and hence when day old the shank lengths of the genetic groups can be considered homogeneous.

During the first seven days, the daily increase in shank length was observed in all the four groups. Range of increase was 0.02 to 0.06 cm for WC male, 0.01 to 0.06 cm for WC female, 0.01 to 0.08 cm for WR male and 0.02 to 0.06 cm for WR female. The average daily increase was 0.035 cm for WC male, 0.034 cm for WC female, 0.037 cm for WR male and 0.036 cm for WR female.

The average shank lengths of the four groups at the end of the fourth and eighth weeks also were comparatively higher than the mean shank length reported by Verma et al. (1977) in crossbreds.

Analysis of variance of shank lengths upto the end of the third week showed no significant difference between the average shank lengths of the four groups at the end of the different weeks. Significant difference was observed by the end of the fourth week and it persisted till the end of the experiment. At the end of the fourth week the mean shank length of WR male differed significantly from those of the females of the two genetic groups. The pattern of difference observed at the end of fifth and sixth weeks was the same. In both cases WR male was found to differ significantly from all the other three groups which were homogeneous. At the end of the seventh and eighth weeks significant difference was observed between WC male and WC female as also between WR male and WR female. This finding is in agreement with the findings of Ulaganathan and Kosala Raman (1975) and Unni *et al*. (1977) who observed that the difference between the sexes for shank length was significant. Also there was significant difference in two genetic group means (t = 0.32 at df 116) and this is in agreement with the findings of Ulaganathan and Kosala Raman.

Homogeneity in shank length between groups existed only during the first three weeks. Thereafter WR males diverged from the other three with a higher shank length. By the end of eight weeks the two genetic groups differed in shank length and there was also difference between sexes in shank length within each genetic group.

Apparently the pattern of growth of shank of the four groups did not differ during the first three weeks. Thereafter WR male had a lead over the rest. Analysis at the end of the eighth week clearly showed difference in growth rates between sexes within genetic groups as also the difference in growth rate between genetic groups. WRgenetic group had a higher growth rate than the WC.

At day old the mean body weight was 39.87 g for WC male, 40.93 for WC female, 41.1 g for WR male and 38.27 g for WR female. Also the mean body weight was 40.4 g for WC breed and 39.69 g for WR breed. These figures were comparatively less than the average body weights of the two groups reported by Siddappa (1976) and Pratap Kumar (1978). Siddappa observed a mean body weight of 42.03 g in WC breed and Pratap Kumar observed a mean body weight of 41.06 g in WR breed. However, the smaller initial body weight in WR than in WC observed by these authors was in agreement with what is observed in the present investigation.

Daily uniform increase in mean body weight was observed during the first seven days in WR male and WR female. In WC male the body weight remained stagnant during the second day and later on it began to pick up. In WC female a depression in the mean body weight took place during the second day and later on it increased. The average daily increase in the mean body weights were 1.23 g, 1.01 g, 1.7 g and 1.47 g respectively for WC male, WC female, WR male and WR female.

Throughout the experiment WR male dominated the other three in body weight. The order of magnitude of body weight was not the same for the other three groups till the end of the third week. After that a trend is found to set in. WC male had the second highest body weight followed by WR female. WC female had the least body weight. This difference continued to exist till the end of the investigation. A definite divergence in growth rate took place at least by the end of the fourth week which continued till the end of the eighth week.

Significant difference could be observed in the body weights of four groups from the beginning of the study. The average body weight of WR male was significantly higher than the average body weights of the other three groups at the end of second, third, fourth and fifth weeks. However, the pattern of increase in body weight was the same as that in shank length at the end of the seventh and eighth weeks. That is, significant difference could be observed between body weights of different sexes as also between the breeds (t = 94.15 at df 116). These are in agreement with the results reported by Ulaganathan and Kosala Raman (1975) and Unni et al. (1977).

The significant correlations obtained between shank length and body weight at the end of eight weeks were 0.89, 0.94, 0.86 and 0.84 for WC male, WC female, WR male and WR female respectively. The corresponding correlations obtained by Unni et al. (1977) were 0.91 for WC male, 0.86 for WC female, 0.51 for WR male and 0.93 for WR female and these were broadly in agreement with the findings of the study. Further these are in agreement with the significant correlation of 0.3664 to 0.9582 in White Plymouth Rock, White Cornish and New Hampshire breeds reported by Chhabra et al. (1972).

The shank length-body weight correlation for (WC, WR) male at fourth and eighth week age were (0.93, 0.88) and (0.89, 0.86). These are in contrast with the correlations 0.6452 and 0.7953 observed by Verma et al. (1977) in the crossbred. The shank length-body weight correlation for (WC, WR) female observed at the fourth and eighth weeks were (0.94, 0.85) and (0.94, 0.83). These also are in contrast with the correlations 0.479 and 0.6806 between these characters estimated by Verma et al. (1977).

Though Verma et al. (1977) observed significant correlation between shank length and body weight in day old male chicks and only non significant correlation between shank length and body weight in day old female chicks, in the present study the correlation between body weight and shank length was found to be non significant in male and significant in female at the same period.

High correlation was found between shank length and body weight in all weeks except at day old. This was in agreement with the corresponding results obtained in geese by Hejja and Szabo (1977) and in Japanese quail by Singh (1978).

Correlation between body weight and shank length of each bird was pretty high and was significant for all the four groups studied (Table 26). So shank length can be made a criterion for selection of broiler birds for attaining highest body weight during a pre-assigned period. In short, shank length serves as a reliable index of body weight during most of the growing periods. This result agrees with the findings of Lerner (1937) and Jaap (1938). However, we find from the serial correlations given in Tables 21,22, 23 and 24 that day old shank length is uncorrelated with the same at the end of different weeks for all but WC female. The shank lengths at one week and at subsequent periods till the end of the eighth week are highly significantly correlated. Coupling these information with the high correlation between the body weight and shank length observed in each bird of the genetic groups, it can be inferred that the shank length at one week age can be used for selecting the birds for body weight. It is desirable to maintain birds with longer shank lengths at the end of first week to obtain ~~higher~~ birds with higher body weight. Such birds are expected to give higher body weight at the end of the eighth week under identical managemental practices. In general, serial correlation shows a tendency to decline when the interval between determinations increased.

The correlation between body weight and shank length was in the range 0.9764 to 0.9982 for WC male, 0.9807 to 0.9984 for WC female, 0.9748 to 0.9991 for WR male and 0.9769 to 0.9982 for WR female. The average correlation was

0.9943 for WC male, 0.9930 for WC female, 0.9961 for WR male and 0.9941 for WR female.

Shank length was found to increase with age. Between age and shank length the average correlation was found to be 0.971 for WC male, 0.976 for WC female, 0.974 for WR male and 0.975 for WR female. The mean weekly increase in the shank length was 0.65 for WC male, 0.58 for WC female, 0.74 for WR male and 0.61 for WR female. Thus WR male had an edge over the rest in the rate of increase of shank length.

As high correlation was observed between body weight and shank length linear prediction equations were fitted. Same type of relations were fitted by Unni et al. (1977), Verma et al. (1977) and Renchi P. George et al. (1979).

Linear prediction equations were also fitted for predicting shank length using age. Significant difference was observed between the rates of growth (b values) of WR male and WR female as also between WR male and WC female (Table 29. These findings agree with the analysis of variance of shank length and body weight at the end of eight weeks. In the analysis of variance two more pairs were found to be heterogeneous, viz. WC male, WR male and WC male, WC female. While analysing the rates of growth as measured by linear equation these significant differences were masked.

This shows that rate of growth as measured by linear regression is not true representive of its value. The average linear regression equations fitted were

$y = 1.2330 + 0.6683x$ for WC male,

$y = 1.3309 + 0.5991x$ for WC female,

$y = 0.9718 + 0.7715x$ for WR male and

$y = 1.2409 + 0.6386x$ for WR female.

Highly significant correlation tending to unity was obtained between the observed and expected shank lengths at different ages thereby showing that the linear function gives a good fit to shank length as function of age.

Analysis of rate of growth (Table 33) based on exponential relation between shank length and age for eight weeks give the very same result that we obtained when the analysis of shank length (Table 11) and analysis of body weight (Table 20) at the end of eight weeks were performed. The average exponential equations are

$y = 1.9856 + 0.1494\ e^{x}$ for WC male,

$y = 2.0054 + 0.1400\ e^{x}$ for WC female,

$y = 1.9341 + 0.1636\ e^{x}$ for WR male and

$y = 1.9836 + 0.1453\ e^{x}$ for WR female.

The analysis of variance of the rates of growth revealed that no significant difference existed between the growth rates of WC male and WR female; as also between the rates of growth of the females of the two groups. Rest of the comparisons between groups were significant.

The correlation between the observed and expected shank lengths of each bird was very high, approaching unity in all cases. Hence the exponential curve gives a very good fit to the shank lengths for eight weeks. This is in agreement with the findings of Suzuki (1966), Pillai et al. (1969), Solanka (1970) and Jacob Thomas (1981) in the body weights of chicken.

Modified exponential fitted to the shank length gives a poor fit as the analysis of variance of the rates of growth showed no significant difference between the groups.

The analysis of variance of the 'b^{c}' values associated with the rates of growth when Gomperts curve was fitted also showed no significant difference between the groups. As such Gomperts curve also should not be recommended for expressing shank length as a function of age in eight weeks.

The analysis of covariance of the 'b' values of shank length by Rao's (1958) method taking initial shank length of the birds as concomitant variable showed that the four groups are homogeneous. This is in variance of the results we obtained in the analysis of the eighth week shank length as also of body weight. The method recommended by Rao (1958) for analysing the rates of growth does not suit the present context.

The analysis of covariance of 'b' values of body weight (Rao's method) taking initial body weight as concomitant variable revealed significant difference between the groups. But the pattern of difference was not in agreement with the results obtained in the analysis of variance of eighth week body weight.

Therefore it can be concluded that expressing shank length as an exponential function of age gives the best possible representation. The linear form also gives a good fit. But the rate of growth as measured by the linear is not completely representative.

SUMMARY

SUMMARY

In order to examine the pattern of development of shank length in chicken an investigation was conducted in Kerala Agricultural University Poultry Farm with 200 day old unsexed chicks of WC and WR breeds under identical management practices. Body weight in g and shank length in cm of each bird were recorded at weekly intervals for eight weeks. In addition to this, body weight and shank length were recorded during the first seven days. At the end of the eighth week measurements on the first 30 males and females each of the two genetic groups were utilised for the study.

The average shank length of the day old chicks were 2.47 cm for WC male, 2.46 cm for WC female, 2.42 cm for WR male and 2.44 cm for WR female. There was no significant difference in the day old shank length of the four groups.

Steady increase was observed in the shank lengths during the subsequent weeks. The pattern of growth was uniform upto the end of third week. Significant difference in the mean shank length occured from the fourth week onwards. At the end of the experiment it was observed that the difference between sexes as also between breeds in shank length was significant.

Heterogenity in the pattern of growth of body weight was observed from the beginning of the study. WR genetic group had a higher growth than the WC group throughout the experiment. Significant difference in growth rates was observed between the two sexes, with male found dominating the female.

At the end of eight weeks identical results were obtained from the analyses of variance of shank length and body weight. There was no significant difference between the pairs WC male, WR female and WC female, WR female. All the other pairs were significantly different.

Pretty high correlation, approaching unity, was obtained between body weight and shank length of each bird. All these correlations were highly significant. From practical point of view these correlations imply that for obtaining highest body weight at a particular period it is desirable to select birds with the longest shank. However the shank length at day old was uncorrelated with the same at the end of different weeks. So selection based on day old shank length will not be as accurate as the selection based on shank length at a later period. From the highly significant correlation obtained between the shank length at the end of first week and at subsequent periods, it is desirable to maintain birds with longer shank lengths at the end of first week.

Shank length was found to increase with age. The mean weekly increase for WC male was 0.65 cm. The corresponding increments for WC female, WR male and WR female were 0.58 cm, 0.74cm and 0.61 cm respectively. Significantly high correlation was obtained between shank length and age. This led to fitting linear prediction equations of the form $y = a + bx$. The average 'b' values for WC male, WC female, WR male and WR female were 0.6693, 0.5991, 0.7715 and 0.6383 respectively. The correlation between the observed and expected shank length was significantly high, indicating that the linear function gives a good fit to shank length as a function of age. The analysis of variance of the 'b' values revealed that the rates of growth of two pairs, WR male and WR female, and WR male and WC female were heterogeneous. In the analysis of shank length at the end of eight weeks in addition to the above pairs, the pairs WC male, WR male and WC male, WC female also were heterogeneous. The descripancy in the result revealed by the analysis of the rates of growth of linear regression shows that rate of growth measured by linear regression is not a true representative of its value.

Exponential of the form $y = ae^{bx}$ fitted to the shank lengths was found to give good fit to the data. The analysis of variance of the rates of growth gave the same result as the analysis of variance of the shank length and body weight at the end of eight weeks. The correlation between the observed and expected shank lengths also was very high.

Modified exponential, Gomperts and Logistic curves fitted showed a different pattern of growth in the shank lengths of the four groups. So they are expected to give a poor fit to the data.

Analysis of shank length and body weight by the method suggested by Rao (1958) revealed unsuitability of that for the comparison of growth rates in the present study.

In short, shank length as linear and exponential functions of age in weeks give good fit. However the best form of representation is exponential.

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PATTERN OF DEVELOPMENT OF SHANK LENGTH IN CHICKEN

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ABSTRACT OF A THESIS

Submitted in partial fulfilment of the requirements for the degree of

Master of Science (Agricultural Statistics)

Faculty of Agriculture

Kerala Agricultural University

Department of Statistics

COLLEGE OF VETERINARY & ANIMAL SCIENCES

Mannutby, Trichur.

1982

ABSTRACT

Shank length and body weight measurements on 30 male and 30 female chicks from each of White Cornish (WC) and White Plymouth Rock (WR) breed were utilised to study the pattern of development of shank length in chicken. The birds were reared for eight weeks in Kerala Agricultural University Poultry Farm under uniform management.

Upto the end of three weeks uniformity could be seen in the pattern of growth of shank length of the four groups. Thereafter WR male had a lead over the rest. The growth pattern of body weight was not uniform in the groups from the beginning. At the end of eight weeks the growth pattern was found to differ between sexes and breeds. Uniformity in growth rates was found in females of the two genetic groups as also between WC male and WR female. All the other pairs were heterogeneous.

High correlation between body weight and shank length revealed that longer shank length can be made a criterion for selection for higher body weight. Shank length at the end of the first week was found to be most suitable for this purpose.

Shank length has high positive correlation with age.

The method of comparison of growth rates recommended by Rao (1958) was found unsuitable for the present study.

Among the functional forms examined Modified Exponential, Gomperts and Logistic were found to be unsuitable for expressing shank length as a function of age.

Most suitable patterns for expressing shank as a function of age in weeks were found to be linear and exponential. Among these two exponential turned out to be better than the other.