COMPARATIVE STUDY OF GROWTH PATTERN IN DUCKS - A STATISTICAL APPROACH

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "COMPARATIVE STUDY OF GROWTH PATTERN IN DUCKS - A STATISTICAL APPROACH" is a bonafide record of research work done by me during the course of research work and 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,
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(VISHNU NAMBOODIRI M)

CERTIFICATE

Certified that this thesis entitled "COMPARATIVE STUDY OF GROWTH PATTERN IN DUCKS - A STATISTICAL APPROACH" is a record of research work done independently by Sri.Vishnu Namboodiri,N under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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(Vishnu Namboodiri,M)

Dedicated to my

beloved parents

CONTENTS

Introduction

INTRODUCTION

The agro-climatic conditions form a natural gift to Kerala State which is ideal for Duck farming. Duck farming in Kerala is found to be a remunerative enterprise because ducks require no elaborate housing, necessitate only low capital investment, bring quick returns from outlay and well distributed turn over throughout the first year of production as well as in subsequent years.

According to 1972 livestock census, 9.01 million ducks, about 6.5 per cent of the total poultry population are concentrated mostly in the Eastern and Southern States (Indian Poultry Industry Year Book, 1986). West Bengal is having the first place in duck farming followed by Assam, Tamil Nadu, Andhra Pradesh, Bihar, Kerala, Orissa, Jammu and Kashmir and Tripura. Kerala is having a duck population of 3.6 millions and a total egg production of 36.348 millions. The duck population increased to 53 millions in 1984.

The duck is the second contributor of eggs to the Indian market next to the chicken, thus contributing a major share to the Gross National Product. The age old belief coupled with the gross anatomy of ducks suitable for swimming, has perhaps pushed the Duck farmers to locate themselves around coastal areas of our country so that they could exploit the natural surroundings of water and marshy lands to the advantage of duck farming.

So far we have put comparatively less importance in duck improvement programme in an intensified scale as we have done so far the chicken breeding project. So adequate research and attention is needed to improve the present situation.

Study of body weight and its growth rate under various time periods is an important aspect in the case of birds especially those having economic importance such as chicken and ducks. Body weight being one of the most important economic character of ducks, its study will have significant implications in the case of rearing of ducks. It is this character which is most concerned to the farmers point of view also to get the maximum return. In order to study the increase in body weight and also the growth rates in ducks, mathematical growth models are to be fitted. To find the optimum economic body weight these models can be made use of. The various models prevalent in studying the growth rates of birds are exponential, modified exponential, Gompertz, Logistic, Von-Bertalanffy, second degree curve etc.

If a functional relationship between body weight and age is available, then it will be easy to find the optimum age to attain the maximum body weight. By doing so, it will be always possible to have a useful future planning for the industry of rearing ducks as a whole.

So far very little work has been done in the study of growth pattern and to find the optimum body weight in the case of ducks. The few references available are that of Kamar <u>et al</u>.(1971), Majna <u>et al</u>.(1973), George <u>et al</u>.(1980) and(1981), Easwaran <u>et al</u>. (1984) and Hamid <u>et al</u>. (1983).

George <u>et al</u>. (1980) studied only Desi ducks whereas Easwaran <u>et al</u>. (1984) studied both Desi and Khaki Campbell ducks. Both these authors have not made their study through functional relationship. No mathematical relationship suitable to model the increase in body weight over a period of time in the case of ducks have been worked out so far.

No serious statistical analysis has been done so far in the case of White Pekin ducks. Hence a study on the increase of body weight of Desi as well as White Pekin ducks using mathematical models is a necessity for the present time. Based on such a study only, a suitable mathematical model can be identified for predicting the optimum body weight in the growth span of ducks.

It is also very essential to have a comparative study of the two prominant genetic groups viz. Desi and White Pekin in the growth pattern by considering the difference in growth rates as well as growth parameters. Normally it is believed that the growth pattern of the different genetic groups are differing between groups. Sometimes the sex of the birds also will have a significant role in deciding the growth pattern. All these points necessitates a detailed study of the growth pattern of the major genetic groups of ducks namely Desi and White Pekin.

With this in view a study has been initiated using day old straight run ducklings of Desi as well as White Pekin reared in Kerala Agricultural University Duck Farm, Mannuthy. Through the data generated a comparative study of growth pattern in ducks are done with the following objectives.

i) To examine the pattern of growth in two breeds of ducks ie. Desi and White Pekin in University Duck Farm, Mannuthy.

ii) To compare them (a) between genetic group (b) between males and females in each genetic group (c) between males of the genetic group (d) between females of the genetic group.

iii) To fit appropriate growth curves for prediction of body weight at different stages of growth.

The data are being categorised into six groups namely Desi males, Desi females, WP males, WP females, Desi ducks irrespective of sex and WP ducks irrespective of sex.

To meet the first objective, the six different growth curves viz. exponential, modified exponential, Gompertz, Logistic, Von-Bertalanffy and second degree are fitted and the detailed investigation of the curves are made. To meet the second objective the growth rates of the fitted curves are to be analysed for the six groups. The third objective can be met by choosing the most suitable growth curve on the basis of coefficient of determination (r^2) and standard error of the estimate (s) and based on the most appropriate growth curve the prediction of the body weight can be done.

The appropriate growth curves can also be obtained through graphical approach. Hence a study of the most promising growth curves along with the actual data plotted in the same graph paper for each of the six groups can also be investigated.

Review of Literature

REVIEW OF LITERATURE

The literature abounds with the study of growth mainly in cattle, sheep, pigs, goats and poultry. Comparatively less work was done on this aspect in ducks. In general growth is measured in terms of body weight. Reasons for the examination of growth in terms of body weight are many.

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. It can be measured with reasonable accuracy and it indicate the duck's ability to grow and survive. Wide variation in it may provide opportunity for early selection of ducks for better performance at later stages.

Growth models that relate animals weight as a function of age are of value not only to nutritionists, but also to geneticists, physiologists, economists, statisticians and managers. Typically, growth models relate the average weight of animals of one breed of a species as a function of age. From such a model, one could determine, the expected average weight of a group of animals of the same breed at any given age, within the limits of the model.

Wishart (1938) while studying the growth rate of bacon pig, fitted a second degree parabola for the figures of each pig. The method of orthogonal polynomial fitted was that of Aitken (1933). The Aitken polynomial fitted was

$$W = a_0 + a_1 (2x - 16) + a_2 \frac{(6x (x-1)}{1.2} - 45x + 120$$

where 'x' is the age in weeks and 'w' is the weight in (lb).

Brant (1951) studied the early growth of domestic fowl and reported that the equation of the type,

$$y = ae^{bx} + c$$ gave excellent fit

where y = body weight in grams

x = the age in weeks

a, b, c are constants.

In this equation 'b' describes the rate of growth of the fowl from the end of first week to the end of 12th week. He also reported that the value of 'b' is highly significant between hatches and also between sexes.

Gilbreath and Upp (1952) have studied the growth pattern of Cornish fowl and reported that the body weight and shank length are the best measurements for mass and skeletal development. He also obsrved that there exists significant variability in body weight within both sexes at the third week of age and also the variation due to sex were apparent.

Ash and Nothers (1964) conducted studies in White Pekin market ducklings and observed that males are heavier (0.05 lb) than females by the end of 9 weeks. The food conversion rate is less in females than in males. They also reported that the females should be marketed earlier than males ie. at the age of seven weeks.

Roberts (1964) while studying the rate of early growth in two lines of White Leghorn chicken observed that the graph for the males and females of the two lines approaches to linearity upto 7 to 8 weeks of age. He fitted a power function of the form

$$y = at^b$$

where

y = body weight at time 't'

a = body weight at time 'o'

b = growth rate of the individual

Mahelka (1965) opined that the growth rate of White Pekin ducklings is maximum at 30-50 days of age and the fattening finish at the age of 60-65 days.

Susaki and Hamakawa, (1965) constructed growth curves from data on body weight of three broiler breeds and three crosses upto ten weeks of age. Curves of the type

$y = ax^b$

$y = a + bx + cx^2$

$y = a + bx + c (\log x)$ gave satisfactory fit to the data.

Bozko and Rubin (1966) while studying the duration of rearing ducklings for meat, observed that ducklings were slaughtered at 45, 50 or 54 days of age. At these three ages the average carcase without intestine was 1486, 1664 and 1780 g respectively.

There are two very different kinds of comparisons of growth of organisms.

Intraspecific and inter specific. The basic assumptions underlying both types of comparison is that each species has a characteristic and inherent pattern of growth. In the Intraspecific, we seek to discern variation in the inherent growth pattern which might be used. On the other hand, with interspecific comparisons we may examine the inherent pattern of growth curve as a part of reproductive strategy. The rate constants of equation which can be fitted to growth curves are powerful and fruitful tools for making interspecific comparisons of growth (Ricklefs, 1967).

Laird and Howard (1967) have studied the growth pattern of inbred mice and their F_1 hybrids and fitted a form of the Gompertz equation

$$W = Wo \, e^{\frac{Ao}{\alpha}(1 - e^{-\alpha t})}$$

where 'W' is the weight at time 't', 'wo' is the initial weight for the period of study and Ao and α are constants. 'At' is the initial specific growth rate and α measures the rate of exponential decay of 'Ao'. They also opined that when animals as distantly related as cows, mice and chicken are compared with respect to their growth curves, it becomes evident that the growth curves are imposable. Species differences are apparent only in the scale differences in the time and weight axes.

Tallis (1968) suggested that growth and development can be regarded as a stochastic process in continuous time. Moreover in some situation of primary production, certain growth patterns may be more economical or otherwise more desirable than others.

Ricklefs (1968) while studying the pattern of growth in 105 species of birds opined that growth parameters are found to exhibit as much as 20 percentage variation within a species with respect to geographic locality and time of nesting season. Growth patterns are correlated with other parameters of life history to evaluate the extent of diversity in the course of growth. Low rate of growth and prolonged growth periods occur primarily in species large for their families and on oceanic species. The shape of the growth curve is not related to the mode of development. He also observed that the weight specific growth rate as measured by the constants of fitted growth curves are most highly correlated with the adult body size of the species and the brood size. He fitted the growth curves such as logistic, Gompertz and Von-Bertalanffy.

Pillai *et al.* (1969) while studying the growth rate of chickens from six different crosses found that the simple exponential function.

$W = A\ e^{kt}$ yielded a very good fit. Zelenka (1970) while studying growth of chicken during the early period of post embryonal life used exponential function

$W = a\ e^{kt}$ and the power function

$Y = at^{b}$

to calculate growth from 2 to 22 days of age in 40 Cockerels and 90 chicks of both sexes. Growth was divided into 2 periods. The first period ended at 14 days of age. It was markedly different from period two regardless of the function used. In the first experiments and in the second period of the second experiment, no significant difference was found in the accuracy of the calculation between two functions. In the second period of the experiment the power function was more accurate.

Liljedhl (1970) used a mathematical function

$$y = (A + B e^{\lambda x})/(1 + c e^{\lambda x})$$

to give information about the growth of broiler chicken. Where 'y' is the body weight and 'x' is age. All the four parameters A, B, C and λ are significantly different from zero. For one of the forms in which the time difference between the early and late hatch of chicken tested was so large that they represented two different stages of genetic improvement. Statistically significant differences between two hatches were found in all four parameters. By making second derivative of the body weight function equal to zero. Some important growth characteristics such as Co-ordinates of maximum growth rate, the corresponding inflexion weight and proportion of body weight at slaughter (56 days) attained at the point of inflexion (growth rate maximum) were derived. Among other things it was found that growth rate increased upto a maximum of 29 g to 45 g per day more in males than in female and it decreased subsequently. The maximum occured between 36 and 48 days; later in males than in females.

Kamar **et al.** (1971) studied the effect of crossing in the growth of ducks of Pekin, Khaki Campbell, Pekin x Khaki Campbell, Khaki Campbell x Pekin found that for the four groups body weight averaged 45.8, 35.8, 37.5 and 45.4 g at hatching, 462.3, 266.5, 326.4 and 425.7 g at 4th week 1935, 1366, 1771 and 1971g at 12th week and 2205, 1591, 1855 and

1954 g at 24th week of age. The differences between pure breds cross breds and between the two cross breds were not significant except that between crossbreds at 4th week. In all groups maximum weight gain occured between 4th and 8th week.

Ricklefs (1973) analysed the growth curves of 81 species of birds and found that the Gompertz equation gave excellent fit to most of the species. Also among species with similar modes of development growth rate decreases with increasing body weight in an allometric manner, with slopes of -0.26 to -0.42 depending on the group. Among those species that can walk at an early age but acquire flight relatively late, the rate of growth depends on primarily the relative size of the musculature of the lower extremities.

Majna et al.(1973) compared the growth intensity in three type of meat-type ducks ie. Pekin, Pekin x Aylesbury and Pekin x White Campbell x Wild ducks and observed that the body weight averaged 60.3, 47.2 and 39.9 g at hatching, 1041, 817 and 577 g (C.V. 13.4, 26.9 and 25.8 per cent respectively) at 28 days and 2512, 2254 and 1654 g (C.V. 6.8, 13.1 and 11.1 per cent respectively) at 53 days of age.

A thorough review of Gompertz equation and other models was presented by Buffington (1973). The Gompertz growth model was fitted to data of mean weight as well as the data for the curve forming 95 per cent confidence limit of the mean weight.

The Gompertz equation provided an excellent fit in Buffington's experiment. The form considered was

$$W = A\,e^{-Be^{-ct}}$$

where

W = Weight in kg at time 't'

t = age in days

Parameters A, B, C were interpreted as

A = asymptotic weight approached ie. weight in kg at time $t = \infty$

$A\,e^{-b}$ = Weight in kg at time $t = 0$

C = Rate of exponential decay of specific growth rate per days.

The values of A, B and C in the Gompertz equation which gave best fit, were found out by the author for mean weights of entire flock, weight of all males and for the weights of females. The Gompertz equation was also fitted to the two curves forming confidence limits to the mean weights.

Gibes (1975) compared the growth rates of Pekin domestic ducklings and wild mallards and observed that in the Pekin, weight gain and increases in linear measurements were more rapid than in the mallards. In both, weight gain fastest at 4 week of age. After 5 weeks of age growth rate declined in both wild and domestic ducks.

A functional relation between body weight and age if it could be established with the desired closeness is useful for planning and future analysis (Surendran and Rajagopalan, 1975). The growth in body weight of domestic fowl has two phases, viz. self accelerating phase and self limiting phase and the rate of growth in these phases need not be similar.

Hussain (1976) studied the growth rate of White Leghorn Light Sussex and their reciprocal crosses under two environments and measured the rate of growth by means of linear and quadratic regression coefficients calculated by the method of orthogonal polynomials.

George et al. (1980) have studied the growth pattern of Desi ducks and have observed that the body weight at 7th, 8th, 9th and 10th weeks of age were 1033, 1139, 1201 and 1254 g respectively. The average daily gains are 20.2, 19.6, 18.4 and 17.3 g respectively. The average hatch weight was 42 g. Also they have opined that even though they attain satisfactory market weight at 7 weeks of age, it is uneconomical to raise them for meat production.

Ren-yu-Tzeng and Becker (1981) have studied the growth patterns of body weight and abdominal fat weights in male broiler chickens and found that the Gompertz curve gave excellent fit to the live weight data as also the abdominal fat weight. The equation considered was of the Laird (1967) from which applies the birth weight rather than mature weight.

$$Wt = Wo\ e^{L/K(1 - e^{-kt})}$$

where 'wt' is the weight of the broiler or its part at time 't'. The absolute growth rate

$$\frac{dw}{dt} = L.\ Wt.\ e^{-kt}$$

The co-ordinates (Wi, ti) of the point of inflexion and the asymptote A are

$$ti = 1/k \log^{(L/K)}$$

$$Wi = Wo\ e^{(L/K)-1},\quad A = Wo\ e^{(L/K)}$$

A = Upper asymptotic weight as age 't' approaches infinity. It is an estimate of mature weight. Wo = Lower asymptotic weight as age 't' tends to zero. It is the estimate of hatch weight or initial weight of animals. L = the slope of the growth curve when t = 0 or the initial specific growth rate.

K = the rate of exponential decay of the initial specific growth rate L, which measures the rate of decline in the growth rate. Wi = Weight at age 'i' the age at which the growth rate is maximum. This occurs when the growth rate per day changes an increasing to a decreasing function of age. The initial weight specific parameter (Wo) used in Gompertz equation is best suited to the special case of broiler chicken which have a short growth period and are marketed before maturity. Hence only Gompertz model was used to mathematically describe the live weight, carcass weight and abdominal fat weight percentage measured on a weekly basis.

The other forms of the non linear curves considered was the Logistic curve

$$Wt = A(1+e^{-kt})^{-M}$$

and Von Bertalanffy

$$Wt = A(1 - Be^{-kt})^{3}$$

where A, B, K and M are [illegible] parameters.

Renchi et al. (1981) have studied the growth pattern of Desi ducks to 12 weeks of age with an objective to assess their meat production potential. They observed that irrespective of age and housing system, male ducklings had significantly higher body weight than females. The pattern of growth of Desi ducklings till 12 weeks of age showed that the gain in weight was uniformly fast till around 11th week of age and thereafter the decline phase started. The mean body weight at 12th week of age was 1443 g.

Jacob Thomas and Surendran (1983) have studied the growth pattern of domestic fowls upto 12 weeks of age and observed that the modified exponential and exponential curves are best suited to predict the body weight for 12 weeks data.

Sharma et al.(1984) conducted studies on phenotypic correlation of external body measurements with egg production and body weight in White Pekin ducklings and reported that body weight is significantly correlated with all body measurements (0.27-0.99) and egg weight (0.39-0.67) at most ages. Generally egg production was significantly correlated with body measurement from 40 - 48 weeks of age and with egg weight from 22 to 30 (0.48 - 0.88) and 40 - 48 weeks of age (0.66 - 0.79)

Easwaran et al. (1984) reported that irrespective of sex, the pattern of growth both in Khaki Campbell and Desi ducklings showed a linear increase from day old to the age of 18th week. The increased rate of growth in both genetic group was observed upto 11th week of age and thereafter the rate of growth was comparatively less. Statistical analysis of the data indicated that the rate of growth of Desi males, Desi females, Khaki Campbell females and males were in descending order of magnitude. There were no significant correlations between hatch weight and weight of 8th and 10th week in both genetic groups. The analysis of body weight between the two groups and between the two sexes indicate that there was significant difference between genetic group and between sexes in respect of body weight.

Kanoun (1984) reported that the early body weight is always better than shank length at the same ages as a predictor of final weight in broiler chickens.

Jacob Thomas and Surendran (1984) studied the growth pattern of domestic fowls of two genetic groups and observed that males in each genetic groups had a higher mean body weight than females. Also 24 weeks completely covers the growth period of both groups. The exponential and Gompertz curve were found suitable for fitting 24 weeks body weight data.

Pierce and Nordskog (1985) analysed the body weight and shank length at 20 weeks of age and fitted an exponential equation of the type

$$y = \alpha x^{\beta}$$

where y = shank length and 'x' is the body weight at 20 weeks of age. α and β are growth constants.

Sahoo *et al.*(1985) have conducted experiments in Khaki Campbell ducklings reported that there is a significant difference ($P<0.01$) in the mean weekly body weight as well as live weight gain between weeks of age. Females were having higher growth rate than males. Further the weekly average live weight appeared to be more than double that of the preceeding week upto 3rd week and more than one half in the 4th week of age. The increase was moderate from 5th to 12th week and low from 13th to 16th week.

Indirabai *et al.*(1985) reported that in broiler chickens, the pattern of growth was well established by using a linear function of age and body weight.

Grossman *et al.*(1985) used Logistic growth curve to explain the pattern of growth in chicken. The logistic curve used was chosen from among growth formulae that express rate of gain as a functions of initial body weight, final body weight and growth rate constant. The logistic function expresses rate of gain ($\frac{dw}{dt}$) proportional to growth rate constant 'k' weight at a given time (x), Wx and relative weight yet to be gained ($\frac{W\infty - Wx}{W\infty}$)

This can be written as

$$\frac{dw}{dt} = KWx \quad (W\infty - Wx)/W\infty$$

for which we obtain upon integration from 0 to t

$$Wt = \frac{W\infty}{1 + (\frac{W\infty}{Wo} - 1)\, e^{-kt}}$$

where Wo and $W\infty$ are initial and maximum weights. Weight at the inflexion point is

$Wt^* = W\infty/2$ where 't*' is the time to the point of inflexion. The age at the point of inflexion

$$t^* = \frac{Ln (W\infty - Wo) - Ln (Wo)}{k}$$

Grossmen and Bohran (1985) studied the inheritance of parameters of the Logistic curve and observed that growth rate constant and age at inflexion point are having low heritability in each sex and line.

Campbell et al. (1985) reported that the body weight averaged 2.55 and 2.14 kg in the case of males and females of White Pekin ducks at 8th week of age. The daily gain was 41.9 and 40.7 g respectively.

Sharma et al. (1986) reported that the body weight at 10, 12 and 14 weeks of age averaged 1186.0±23.0, 1376.04±22.0 and 1514±18.0 g respectively in the case of Khaki Campbell ducks. Also the optimum marketing age is calculated as 10 weeks of age.

Anthony et al. (1986) have studied the growth curves of Japanese quails as modified by divergent selection of 4 week body weight of two weight selected lines and reported that the Gompertz curve is best for describing the growth of both the lines. The logistic curve best fit the growth pattern of the low weight category. Also he observed that the pattern of growth of both the sexes are identical.

Simmons *et al.* (1987) fitted a regression equation of the form

$W = 49.89 + 7.89\ D + 0.81\ D^2$ to explain the body weight at a particular time in the brooding period where
W = Individual broiler weight in grams and D = day of the brooding period.

Ibe and Wakalor (1987) fitted an allometric growth curve of the form

$y = \alpha W^{\beta}$ in broiler chickens

where

W = Body weight

y = linear structural body parameters

Buzzard *et al.* (1988) have studied the growth pattern of Desi and Khaki Campbell ducks under rural condition and observed that there is no significant difference between growth rate of Desi and Khaki Campbell ducks. The difference if any is due to non genetic influences like poor nutrition, management etc.

Harpal Singh *et al*. (1988) while studying the inheritance of body weight in guinea fowl observed that phenotypic correlations of the body weight with shank length, keel length and breast angle at various ages were all positive and observed high values excepting with weight at hatching. This indicates that the body weight at any age (except day old) may be considered for evaluating growth upto 20 weeks of age.

Hamid *et al*. (1988) have compared the performance of growing ducklings of Khaki Campbell, Indian Runner and Indigeneous under farm conditions. The average final body weight and body weight gain were found highest in ducklings of Khaki Campbell (1788.44 g and 1744.11 g) followed by Indian Runner (1743.28 and 1702.47 g) and Indigeneous ducks (1703.89 and 1668 g) respectively. The growth rate was significantly better in Khaki Campbell ducklings (82.218) as compared to that of Indian Runner (85.138) and Indigeneous ducklings (83.48) were significant ($P<0.01$) difference was found between them.

Materials and Methods

MATERIALS AND METHODS

This study was initiated using day-old straight run ducklings of Desi eighty one in number and that of White Pekin seventy two in numbers, from Kerala Agricultural University Duck Farm, Mannuthy. The ducklings were hatched on May 31, 1988 and June 6, 1988. They were serially numbered and wing banded for identification.

On the day of hatching the ducklings were placed in electrically operated, thermostatically controlled battery type brooders. They were allocated to different compartments of the brooder at random. A commercial all-mash starter ration was fed *ad libitum*, while the ducklings were brooded in the batteries. Fresh water was made available at all times.

After a few weeks, the ducklings were moved to deep litter houses/pens. They were housed in two adjacent sections of a brooder house divided into sections. Adequate floor area and water space were made available. Necessary warmth was provided by Infra-red bulbs for four weeks. At this stage the ducklings were fairly well feathered and due to temperate weather only moderate brooder heat was required.

All the ducklings were fed on the same feed formula and the management practices were identical.

The weight of each duckling was recorded on all days during the first seven days. Thereafter it was taken at weekly intervals. The weighing was continued until the ducks attained an age of 12 weeks. At the end of the experiment weights were available on 14 males and 25 females of Desi group and 26 males and 26 females of white pekin group. The remaining ducklings either died during the course of the experiment or the data on them were not available for recording body weight.

The data so gathered were used for the comparison of the rates of growth of:

i) between genetic groups
ii) between males and females of each genetic group
iii) between males of the genetic groups
iv) between females of the genetic groups
v) to fit appropriate functions of growth to predict body weight at different ages.

The data corresponding to each duckling was plotted on a graph paper to ascertain the pattern of growth at different time points.

Measuring body weights along y-axis and age along the x-axis, the graph of growth of each duckling was drawn separately. The graph indicated a sigmoid curve in general. The choice of an appropriate curve to depict the growth pattern in any situation is not easy. As the pattern of growth approximated a sigmoid curve the following mathematical models were tried.

3.1. Growth Curve Models

Six mathematical models viz. the exponential, the modified exponential, the Gompertz, the Logistic, the Von-Bertalanffy and second degree curve were examined to find out the best fit for a representative curve for both the genetic groups.

3.1.1. Exponential function

The form of the function considered was

$y = a\,e^{bx}$ where 'y' is the body weight at age 'x' and 'a' and 'b' are constants. The constants 'a' and 'b' are calculated using the principle of least squares.

When the growth curve is fitted, the rate of growth at a particular period can be verified as the ratio of the weight during the period to the weight during the previous period minus one. In the case of exponential, the rate of growth is given approximately as

$$\left(ae^{b(x+1)} \div ae^{bx}\right) - 1$$
$$= e^{b} - 1 .$$

3.1.2. Modified Exponential function

The form of the modified exponential function considered is

$$y = k + ab^x$$

where 'k', 'a' and 'b' are constants.

For fitting this equation, the observed series is divided into three equal parts. The 'y' values for each part are summed. The constants 'a', 'b' and 'k' are determined as

$$b = \left(\frac{s_3 - s_2}{s_2 - s_1}\right)^{1/n}$$

where s_1, s_2 and s_3 are the sum of the y values of the three equal parts.

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

$$k = \frac{1}{n}\left(s_1 - \left(\frac{b^n - 1}{b - 1}\right) a\right)$$

where 'n' is the number of observations in each part.

The growth rate at a particular period is approximately given by

$$\left(ab^{(x+1)} - ab^x\right) \div \left(k + ab^x\right)$$

i.e. $ab^x\,(b-1)/(k + ab^x)$

and the growth rates are not significantly different provided that b's do not differ significantly.

3.1.3. Gompertz Curve

The Gompertz curve was fitted in the form

$$y = ab^{c^x}$$

which take the logarithmic form

$$\text{Log } y = \log a + (\log b)\, c^x = A + Bc^x$$

For fitting this curve the data is divided into three equal parts and the sum of the logarithms of the y values are found out for each part. Let 'n' be the number of observations in each part, then,

$$c = \left(\frac{s_3 - s_2}{s_2 - s_1}\right)^{1/n}$$

where s_1, s_2 and s_3 are sum of logarithms of each part

$$B = (s_2 - s_1)\frac{c - 1}{(c^n - 1)^2}$$

$$A = 1/n\left(s_1 - \frac{c^n - 1}{c - 1}\log b\right)$$

The rate of growth at a particular period can be calculated as

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

$$ab^{c^x}(b^c - 1) - 1$$

and the growth rate depends upon the values of b^c.

3.1.4. Logistic curve

The form of the curve considered

$$y = \frac{k}{1 + 10^{b+cx}}$$

where k, b and c are constants.

The curve is fitted by taking three points at equal intervals. If y_0, y_1 and y_2 are the three points at the beginning, middle and end of the data and 'n' is the number of observations between these points then

$$k = \frac{2\, y_0\, y_1\, y_2 - y_1^2\,(y_0 + y_2)}{y_0\, y_2 - y_1^2}$$

$$b = \log\left(\frac{k - y_0}{y_0}\right)$$

$$c = 1/n \left\{ \log \frac{y_0\,(k-y_1)}{y_1\,(k-y_0)} \right\}$$

and the growth rate at a particular period was given by

$$\frac{1 + 10^{b+cx}}{1 + 10^{b+c(x+1)}}$$

The growth rate at a particular period depends upon the value of b and c.

3.1.5. Von-Bertalanffy Curve

The form of the curve considered is as given by Ren-yu-Tzeng (1981).

$$Wt = A(1 - be^{-kt})^3$$

where 'A' is the mature weight, which is known and 'b' and 'k' are constants.

The curve take the logarithmic form

$$\log\left(1 - (w\,t/A)^{1/3}\right) = \log_e b - kt$$

$$y = B + Ct$$

The least square estimate of B and C are obtained as

$$C = \frac{n\Sigma ty - \Sigma t\,\Sigma y}{n\Sigma t^2 - (\Sigma t)^2}$$

$$B = \bar{y} - C\bar{t}$$

The growth rate at a particular point is given by

$$\frac{be^{-kt}(1-e^{-k})}{1 - b\,e^{-kt}}$$

which depends in the value of 'be^{-k}'. I[illegible]

[illegible], [illegible]

5.1.6. Second Degree Equation

The second degree equation considered was of the form

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

where 'a', 'b' and 'c' are constants.

The polynomial is fitted by taking x^2 as x_2 and proceeding as in the case of multiple regression. The constants are evaluated as

$$a = \frac{\sum(x-\bar{x})(y-\bar{y}) \sum(x^2-\overline{x^2})^2 - \sum(x^2-\overline{x^2})(y-\bar{y})\sum(x-\bar{x})(x^2-\overline{x^2})}{\sum(x-\bar{x})^2\sum(x^2-\overline{x^2})^2 - \left[\sum(x-\bar{x})(x^2-\overline{x^2})\right]^2}$$

$$b = \frac{\sum(x-\bar{x})^2 \sum(x^2-\overline{x^2})(y-\bar{y}) - \sum(x-\bar{x})(x^2-\overline{x^2})\sum(x-\bar{x})(y-\bar{y})}{\sum(x-\bar{x})^2\sum(x^2-\overline{x^2})^2 - \left[\sum(x-\bar{x})(x^2-\overline{x^2})\right]^2}$$

and the growth rate at a particular period is given by

$$1 + \frac{b + c(1+2x)}{a + bx + cx^2}$$

The growth rate at a particular period is dependent on 'b' and 'c' values.

3.2. Comparison of Growth Curves

In order to compare the relative efficiency of various growth curves and to select the one which best fits the observed data, two criteria ~~are~~ used, viz.

(i) Coefficient of determination (r^2) and

(ii) Standard error of the estimate (s).

3.2.1. Coefficient of determination

It is calculated as the square of the correlation coefficient between the observed and predicted values. A large value of r^2 indicates best fit of the curve.

3.2.2. Standard Error of the estimate

The standard error of the estimate measures the inadequacy of fit of the [illegible] equation or of the error which is made in the estimation or prediction of y from given values of x. The standard error of the estimate is calculated as

$$s = \sqrt{\frac{\sum (y_i - \hat{y}_i)^2}{n - 2}}$$

where $\hat{y}_i$ is the predicted values and 'n' is the number of observations. A small value of 's' indicates goodness of fit of the curve.

Rao (1958) suggested a procedure for the comparison of rates of growth between different groups.

Let y_i denote the increase in body weight at time 'i' and 'gi' is the mean of all y_i's in the experiment. Then 'gi' is the time metameter. The difference in the values of y_i are due to the time factor 'gi'. Hence we may write

$$y_i = bg_i$$

and the method of least squares leads to

$$b = \sum y_i g_i / \sum g_i^2$$

This comparison of difference in rates of growth between groups will obviously be a comparison of 'b's. The value of 'b' may be affected by initial body weight. Hence a covariance analysis of the b values taking initial values as concomitant variable can be adopted for comparing the growth rates of the groups.

Results

IV RESULTS

The present study was initiated to assess the growth pattern of two breeds of ducks ie. Desi and White Pekin and to compare the rates of growth at different ages by fitting mathematical models. The study was also aimed to find out the best suitable curve for the prediction of body weight at different ages.

4.1. Average body weights

4.1.1. Average body weight upto seven days

The average body weights of the Desi males during the first seven days were 36.6428 g, 38.3571 g, 41.2143 g, 42.5 g, 47.2143 g, 51.7143 g and 58.5 g respectively (Table 1). The corresponding figures for Desi females were 38.16 g, 40.12 g, 42.2 g, 45.32 g, 50.28 g, 55.52 g and 63.28 g respectively. Both the groups were having a consistant increase in body weight during the first seven days. The Desi females had a higher mean body weight on all the seven days. The average body weight of the White Pekin (WP) males during the first seven days were 38.6538 g, 34.3462 g, 40.0769 g, 41.1923 g, 42.4615 g, 43.5769 g and 49.1153 g respectively (Table 1). The average body weights of White

Pekin (WP) females during the first seven days were 38.3846 g, 37.6154 g, 41.3462 g, 45.8846 g, 46.0769 g, 47.1923 g and 55.3462 g respectively.

On the seventh day the females in each genetic group had a higher average body weight than males. Considering the two genetic groups irrespective of sex, the Desi ducklings have an average body weight of 61.5641 g, on the seventh day whereas the average body weight of White Pekin ducklings was 52.2308 g.

4.1.2. Average body weight upto twelve weeks

The average body weights of Desi males, Desi females, WP males and WP females for the first twelve weeks are shown in Table 2.

In twelve weeks, Desi males attained a body weight of 1291.7857 g, with a standard error of 59.7857 g. Steady increase was noted during the first twelve weeks. The Desi females had an average body weight of 1239.4 g, by the end of 12 weeks (Table 2). This was less by 52 g than the corresponding average body weight of Desi males. Also tho body weight showed a steady increase during the 12 weeks. While considering the Desi ducklings irrespective of sex, the body weight averaged 1258 g at the end of the 12th week with a standard error of 35.6814 g.

In the case of WP group, the WP females were, on an average heavier than WP males. The average body weight attained at the end of twelfth week was 1021.7308 g, with a standard error of 79.5385 g in the case of WP males and 1401.6154 g with a standard error of 73.0109 g for WP females (Table 2). Thus a WP female weighed about 380 g more than WP male at the end of twelfth week. Considering the WP group irrespective of sex, the average body weight attained at the end of 12th week was 1214.6154 g with a standard error of 58.5788 g.

4.2. Comparison of body weight at different ages

4.2.1. Initial body weight

The analysis of variance of initial body weights of the four categories of birds were given in table 3. It was found that the four groups viz. Desi males, Desi females, WP males, WP females were homogeneous.

4.2.2. Fourth week body weight

The initial homogeneity in body weights of the groups were not maintained at later stages. The analysis of variance of fourth week body weights were shown in table 4. From the analysis of variance, it was found that the three groups viz. Desi males and WP males, Desi females and WP males and WP males and WP females were not homogeneous.

The average body weight of the four groups viz. Desi males, Desi females, WP males and WP females at the end of fourth week were 289.4286 g, 345.72 g, 190.3486 g and 286.5385 g respectively.

4.2.3. Eighth week body weight

The difference between the groups was significant in the eighth week. During this week the Desi males, Desi females, WP males and WP females had an average body weight of 633.9286 g, 709.2 g, 537.8846 g and 811.7308 g respectively (table 5). The analysis of variance of body weight indicated that the three groups viz. Desi males and WP females, Desi females and WP females and WP males and WP females were heterogeneous.

4.2.4. Twelfth week body weight

The difference between the groups existed in the twelfth week also. The body weight of the four groups viz. Desi males, Desi females, WP males and WP females averaged 1291.7860 g, 1239.4 g, 1023.269 g and 1401.539 g respectively. The WP females had the highest mean body weight. From the analysis of variance it was found that the five groups viz. Desi males and WP males, Desi males and WP females, Desi females and WP males, Desi females and WP females, WP males and WP females were not homogeneous (Table 6).

From Table 2 it could be observed that the plateau in the body weights was not attained till 12th week of age. This indicates that 12 weeks do not cover the growth period of Desi as well as White Pekin ducklings.

4.3. Study through Growth Curves

To depict the pattern of growth, exponential, modified exponential, Gompertz, Logistic, Von-Bertalanffy and Second degree curves were fitted.

4.3.1. Exponential curve

The exponential curve was fitted for each of the 91 birds using their body weights for 12 weeks at weekly intervals. The exponential curve considered was of the form $y = ae^{bx}$

ie. $\log y = \log a + bx$

The values of 'a' and 'b' when the exponential was fitted was shown in tables 7 and 8. The 'b' values when exponential was fitted to Desi males and Desi females were in the range 0.2173 to 0.2916 and 0.2318 to 0.2970 respectively (Table 7). The square of the correlation coefficient (coefficient of determination) between the observed and expected body weights for Desi males and Desi females were shown in table 13. The values of 'a' and 'b' when the exponential curve was fitted to WP males and WP females were shown in table 8. The 'b' values range from 0.2121 to 0.3174 for males and 0.2213 to 0.3264 for females. The square of the correlation coefficient (coefficient of determination) between observed and expected body weights were shown in table 13.

The standard error of the estimate when the exponential curve was fitted was shown in table 15. From the table it was clear that the standard error of the estimate was having a very high value for almost all ducklings and thus indicating lack of fit for the observed data.

The analysis of variance of the 'b' values for the four groups obtained by fitting the exponential law for the 12 weeks body weights was given in table 17. There was significant difference between the four groups. The average value of 'b' was highest for WP females followed by WP males. The rate of growth was therefore highest for WP females, next higher for the WP males, third higher for the Desi males and least for Desi females.

4.3.2. Modified Exponential Curve

The form of the modified exponential function fitted to the weekly body weights of four groups of ducklings was

$$y = k + ab^x$$

The values of the constants 'k', 'a' and 'b' for Desi males, Desi females, WP males and WP females were shown in tables 9, 10, 11 and 12. The 'b' values for Desi males and Desi females ranged from 0.1009 to 1.1084 and 0.8495 to 1.1698 respectively whereas for WP males and WP females the 'b' values ranged from 1.0648 to 1.2994 and 0.9269 to 1.4917 respectively.

The square of the correlation coefficient (coefficient of determination) between observed and expected values were shown in table 14. The coefficient of determination in almost all cases was greater than 0.95 thus indicating a good fit. Also the standard error of the estimate was comparatively small (Table 16). The analysis of variance of 'b' values for the four groups obtained by fitting the modified exponential and for the 12 weeks body weight was given in table 18. There was significant difference between the four groups. The average value of 'b' was higher for WP females followed by WP males. The rate of growth was therefore highest for WP females, next higher for WP males third higher for Desi females and least for Desi males.

4.3.3. Gompertz Curve

The Gompertz curve was also fitted using 12 week body weights of each bird in the experiment. The curve was of the form $y = ab^{c^x}$

$$\text{ie. } Log\ y = \log a + c^x (\log b)$$

The values of 'a', 'b' and 'c' for the four groups were given in tables 19, 20, 21 and 22. The square of the correlation coefficient (coefficient of determination) between the observed and expected values were shown in table 27. In all the cases the value of r^2 was greater than 0.92. Also the standard error of the estimate when the curve was fitted to the four groups was shown in table 29.

The rate of growth when the Gompertz curve was fitted was depending upon the values of 'b^c'. So analysis of variance of 'b^c' was carried out and was shown in table 31. From the analysis of variance it was found that the four groups were significantly different in respect of rate of growth. The rate of growth was maximum for Desi females followed by Desi males and least for WP males.

4.3.4. Logistic curve

The Logistic curve was also fitted to the data on body weight upto 12 weeks for each bird of the four groups. The curve fitted was of the form

$$y = \frac{k}{1 + 10^{b+cx}}$$

The values of 'k', 'b' and 'c' when the curve was fitted to the four groups viz. Desi males, Desi females, WP males and WP females were shown in tables 23, 24, 25 and 26. The curve fitting was a failure for two ducklings of the WP female group.

The square of the correlation coefficient (coefficient of determination) between the observed and expected body weights were shown in table 28. The standard error of the estimate when the curve was fitted to the four groups were shown in table 30.

4.3.5. Von-Bertalanffy curve

The form of the curve fitted as given by Ren-yu-Tzeng (1981) was

$$W_t = A(1 - be^{-kt})^3$$

where A is the mature weight, which was known and 'b' and 'k' were constants.

The values of A were estimated from the mature birds of the Kerala Agricultural University Duck Farm, Mannuthy and were 2000 g, 1750 g, 3500 g and 3300 g for Desi males, Desi females, WP males and WP females respectively. The values of the constants 'b' and 'k' when the curve was fitted to Desi males, Desi females, WP males and WP females were shown in tables 32 and 33. The coefficient of determination of body weights when the curve was fitted to the four groups were shown in tables 40 and 41. In almost all the cases the coefficient of determination was around 0.95 and in no case it was less than 0.88. The standard error of the estimate was also small for almost all birds (Table 38).

The growth rate of the fitted Von-Bertalanffy curve was depending upon the values of be^{-k}. Thus analysis of variance of be^{-k} values was carried out to test the significance of the four groups. From the analysis of variance it was found that the four groups were significantly different in respect of growth. The growth rate was highest for WP males, next higher for WP females, next higher for Desi males and least for Desi females.

4.3.6. Second Degree Equation

The second degree equation fitted was of the form

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

The values of 'a', 'b' and 'c' were shown in tables 34, 35, 36 and 37 for the four groups. The coefficient of determination of body weights were shown in table 41. Also the standard error of the estimate was calculated for the four groups and were shown in table 39.

4.4. Comparison of Growth Curves

In order to compare the efficiency of the various curves fitted and to judge the best suitable curve to depict the pattern of growth, the growth curves were fitted to the average body weights of the four groups of ducklings and also the average weight of the two groups irrespective of sex. The coefficient of determination (r^2) and the standard error of the estimate (s) were used as the tools to find out the adequacy of fit of these curves.

The parameters, coefficient of determination (r^2) and standard error of the estimate (s) of the six growth curves viz. the exponential, the modified exponential, the Gompertz, the Logistic, the Von-Bertalanffy and second degree curves fitted to the average body weights of six groups of ducklings were shown in tables 43 to 48.

4.4.1. Comparison based on coefficient of determination

The curves having highest value of coefficient of determination was taken as the best curve to depict the pattern of growth. The coefficient of determination when six curves viz. the exponential, the modified exponential, the Gompertz, the Logistic, the Von-Bertalanffy and second degree fitted to the six groups of ducklings were 0.9311, 0.9931, 0.9934, 0.9435, 0.9750 and 0.9688 respectively for Desi males, 0.8752, 0.9844, 0.9933, 0.9470, 0.9758 and 0.9357 respectively for Desi females, 0.9426, 0.9954, 0.9924, 0.9937, 0.9924 and 0.9927 respectively for WP males, 0.8954, 0.9953, 0.9953, 0.9922, 0.9967 and 0.9825 respectively for WP females, 0.8973, 0.9881, 0.9934, 0.9450, 0.9747 and 0.9258 respectively for Desi ducklings irrespective of sex and 0.9202, 0.9967, 0.9949, 0.9938, 0.9962 and 0.9895 respectively for WP ducklings irrespective of sex.

From the above values it was found that for Desi males and Desi females the Gompertz curve gave best fit with $r^2 = 0.9934$ and 0.9933 respectively. The fitted equations were written as

$$y = 1140.9350\ (0.0256)^{0.7840^x} \text{ for Desi males}$$

$$y = 1039.9080\ (0.0256)^{0.7407^x} \text{ for Desi females}$$

For Desi ducklings irrespective of sex, the Gompertz curve gave best fit with $r^2 = 0.9934$. The fitted equation was written as

$$y = 1063.5950\ (0.0259)^{0.7555^x}$$

In the case of WP males and WP ducklings irrespective of sex, the modified exponential curve gave best fit with $r^2 = 0.9954$ and 0.9967 respectively. The fitted equations were written as

$$y = -248.7951 + 261.4310\ (1.1473)^x \text{ for WP males and}$$

$$y = -420.5439 + 420.7679\ (1.1259)^x \text{ for WP ducklings}$$

irrespective of sex.

The Von-Bertalanffy curve gave best fit to the WP female ducklings. The value of r^2 was 0.9967 in that case. The fitted equation was

$$y_t = 3300\ \left(1 - 0.8161 \exp\ (-0.9916\ t)\right)^3 \text{ for WP females}$$

4.4.2. Comparison based on standard error of the estimate (s)

The standard error of the estimate (s) when the six growth curves viz. the exponential, the modified exponential, the Gompertz, the logistic, the Von-Bertalanffy and the second degree fitted to the average body weight of the six groups of ducklings were shown in tables 43 to 48.

While comparing the growth curves of the six groups based on standard error, same result was obtained as in the case of comparison using r^2 values. The standard error of the estimate when the Gompertz curve was fitted to Desi males, Desi females and Desi ducklings irrespective of sex were 27.1346, 28.1021 and 27.4707 respectively. Also the values of 's' when the modified exponential was fitted to WP males and WP ducklings irrespective of sex were 21.8033 and 22.2852 respectively. In the case of WP females the Von-Bertalanffy curve had a standard error of 28.9758.

4.5. Rao's Method

By the method of Rao (1958) the growth parameter 'b' was estimated for each bird. Each of these values was enormously large, numbering into thousands. To reduce this to a manageable size, each was divided by 10000. The resulting values of 'b' were presented in tables 49 and 50.

The growth parameter had a mean value of 29.7571 for Desi males, 49.9364 for Desi females, 28.3723 for WP males and 91.0782 for WP females.

The analysis of covariance of 'b' values taking initial body weight as concomitant variable was presented in table 51. The initial body weight had significant relation with the 'b' values. It was also found that the rate of growths of all the four groups were distinct. The growth rate was highest for WP females next higher for Desi females, next higher for Desi males and least for WP females.

The graphs of the growth curves which gave best fit to the six groups of ducklings were drawn and were given in Figures 1-6. The graphs were drawn by taking the number of weeks on x-axis and the mean weekly body weight on y-axis. For Desi males, Desi females, Desi ducklings irrespective of sex, WP males, WP ducklings irrespective of sex, Gompertz and modified exponential curves were drawn whereas for WP females Gompertz and Von-Bertalanffy curves were drawn along with the curves of the observed values for the sake of comparison.

Fig.1. GOMPERTZ AND MODIFIED EXPONENTIAL CURVES FITTED TO DESI MALES

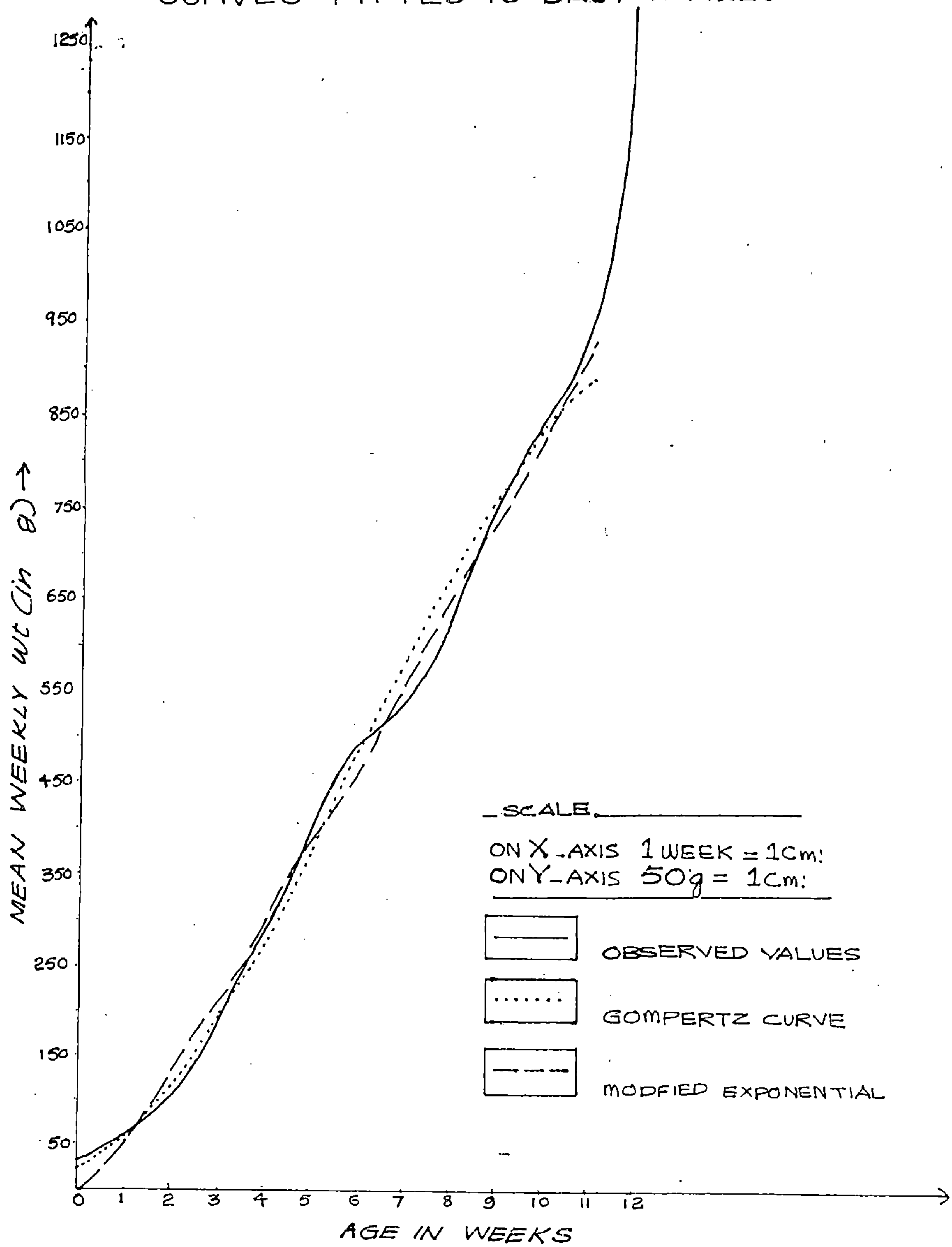


FIG. 2. GOMPERTZ AND MODIFIED EXPONENTIAL CURVES FITTED TO DESI FEMALES

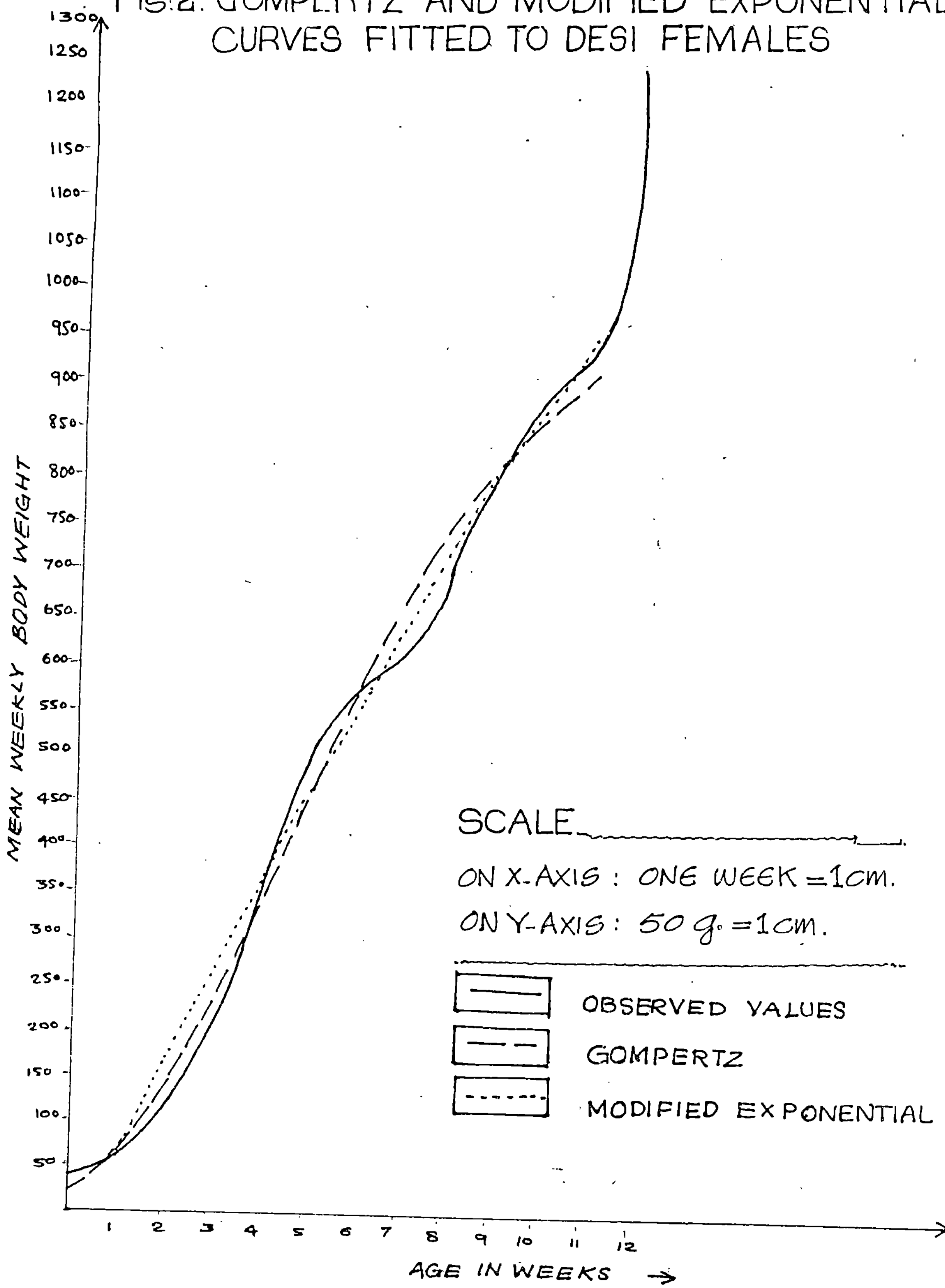
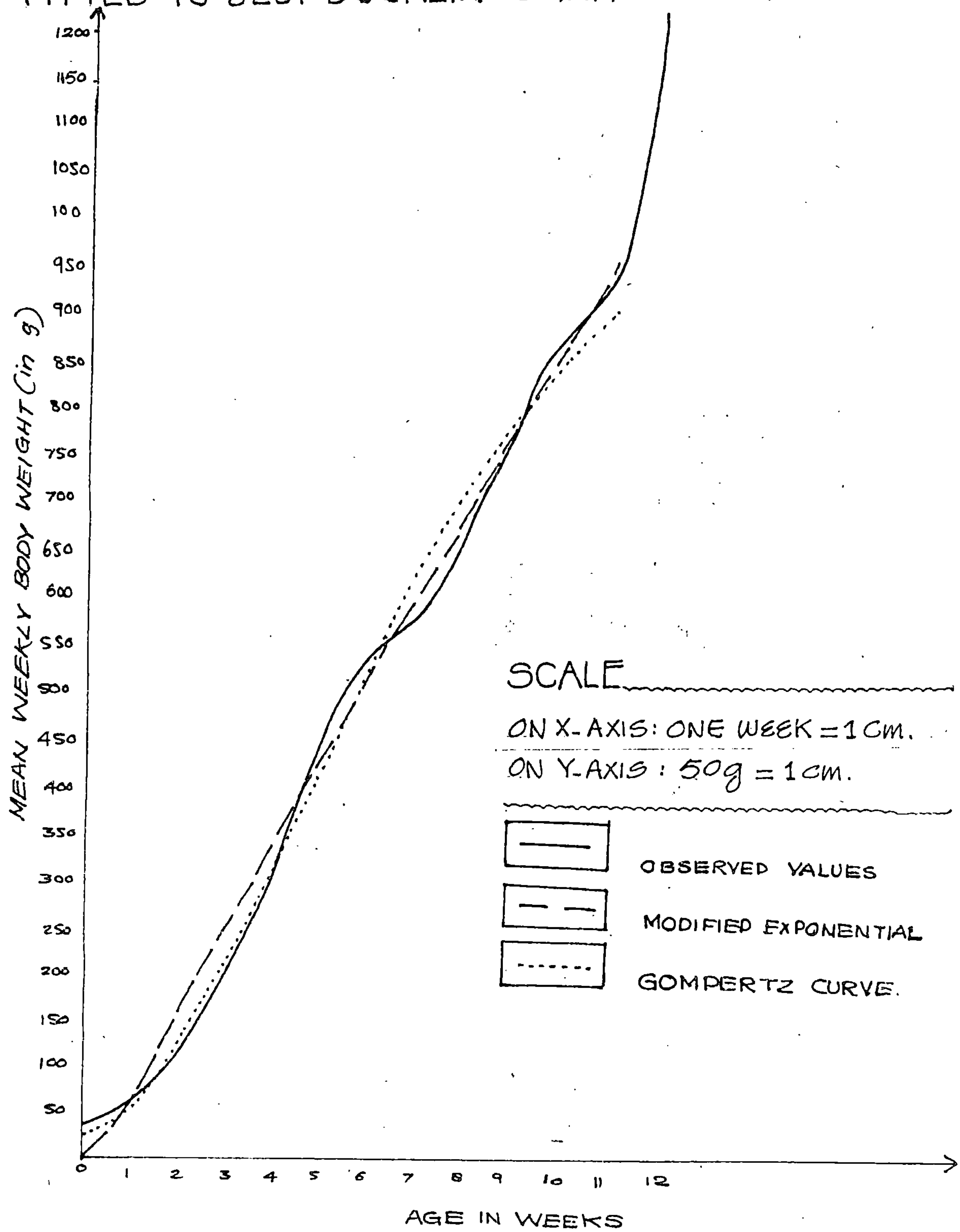


Fig.3 GOMPERTZ AND MODIFIED EXPONENTIAL CURVES FITTED TO DESI DUCKLINGS IRRESPECTIVE OF SEX



170172

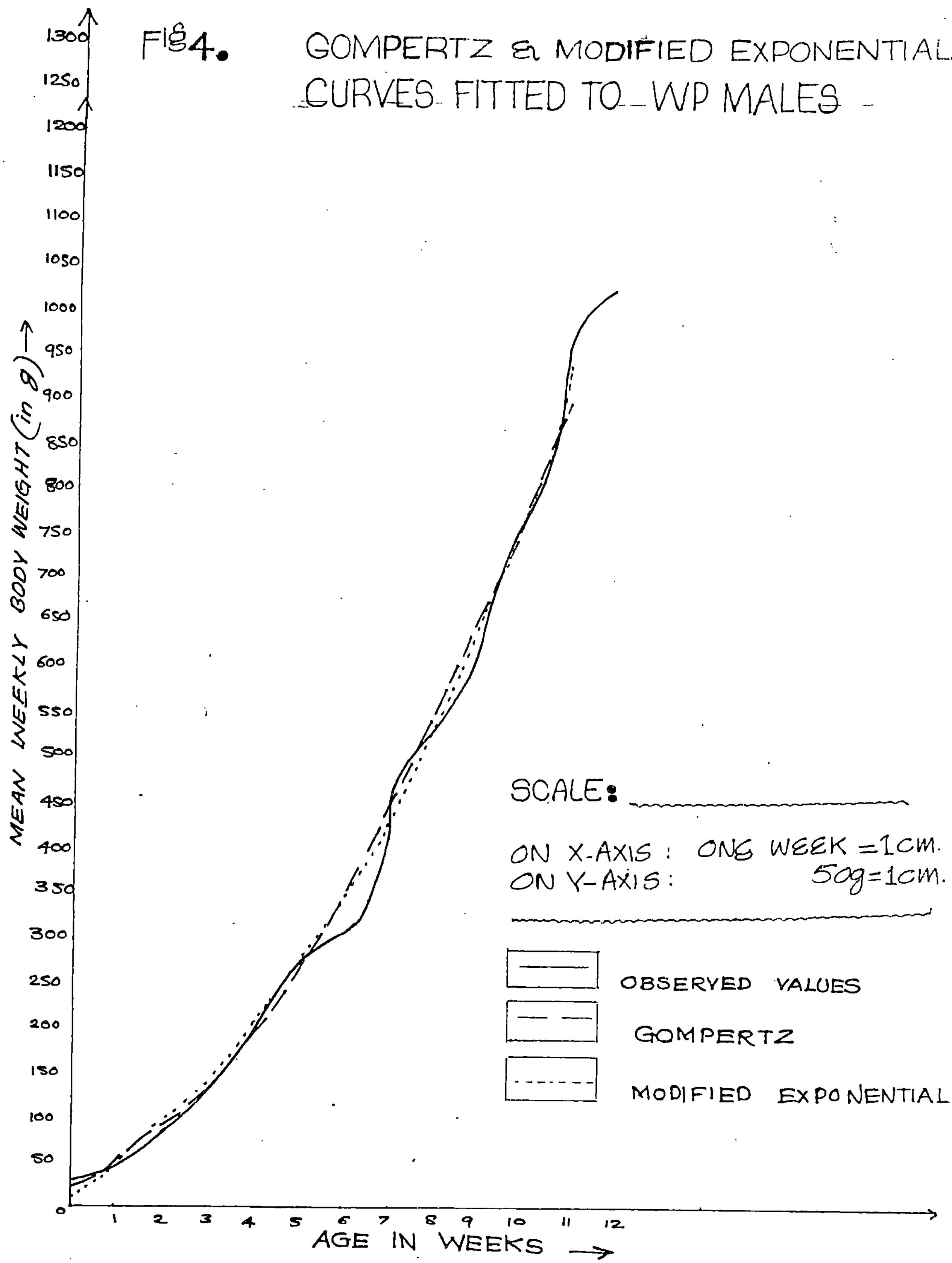


Fig 4.
GOMPERTZ & MODIFIED EXPONENTIAL CURVES FITTED TO WP MALES
MEAN WEEKLY BODY WEIGHT (in g)
1300
1250
1200
1150
1100
1050
1000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
1 2 3 4 5 6 7 8 9 10 11 12
AGE IN WEEKS
SCALE:
ON X-AXIS : ONE WEEK = 1CM.
ON Y-AXIS : 50g = 1CM.
OBSERVED VALUES
GOMPERTZ
MODIFIED EXPONENTIAL

VON_BERTALANFFY AND GOMPERTZ
Fig: 5. CURVES FITTED TO WP FEMALES

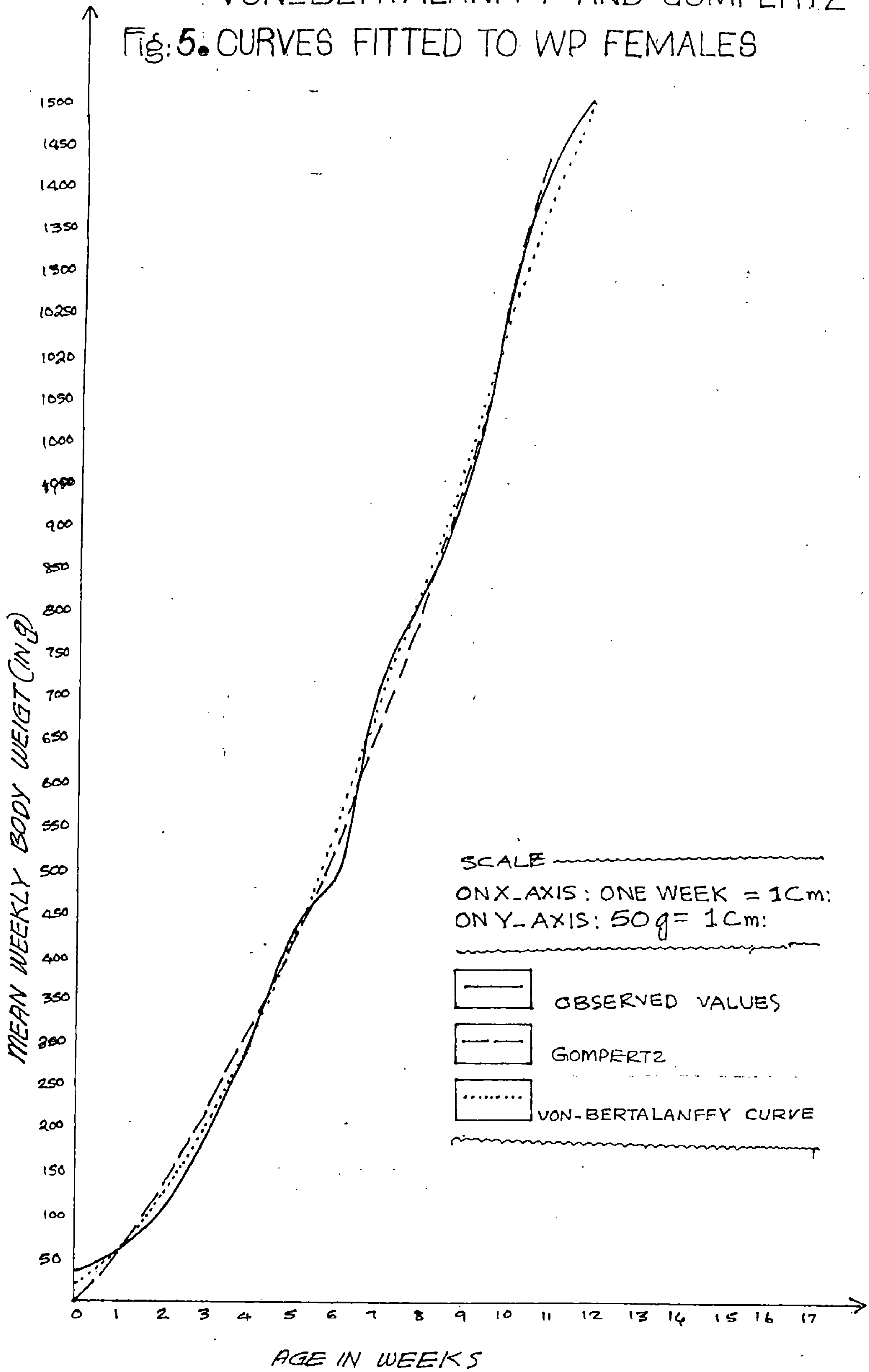


FIG_6. GOMPERTZ AND MODIFIED EXPONENTIAL CURVES FITTED TO WP DUCKLINGS IRRESPECTIVE OF SEX

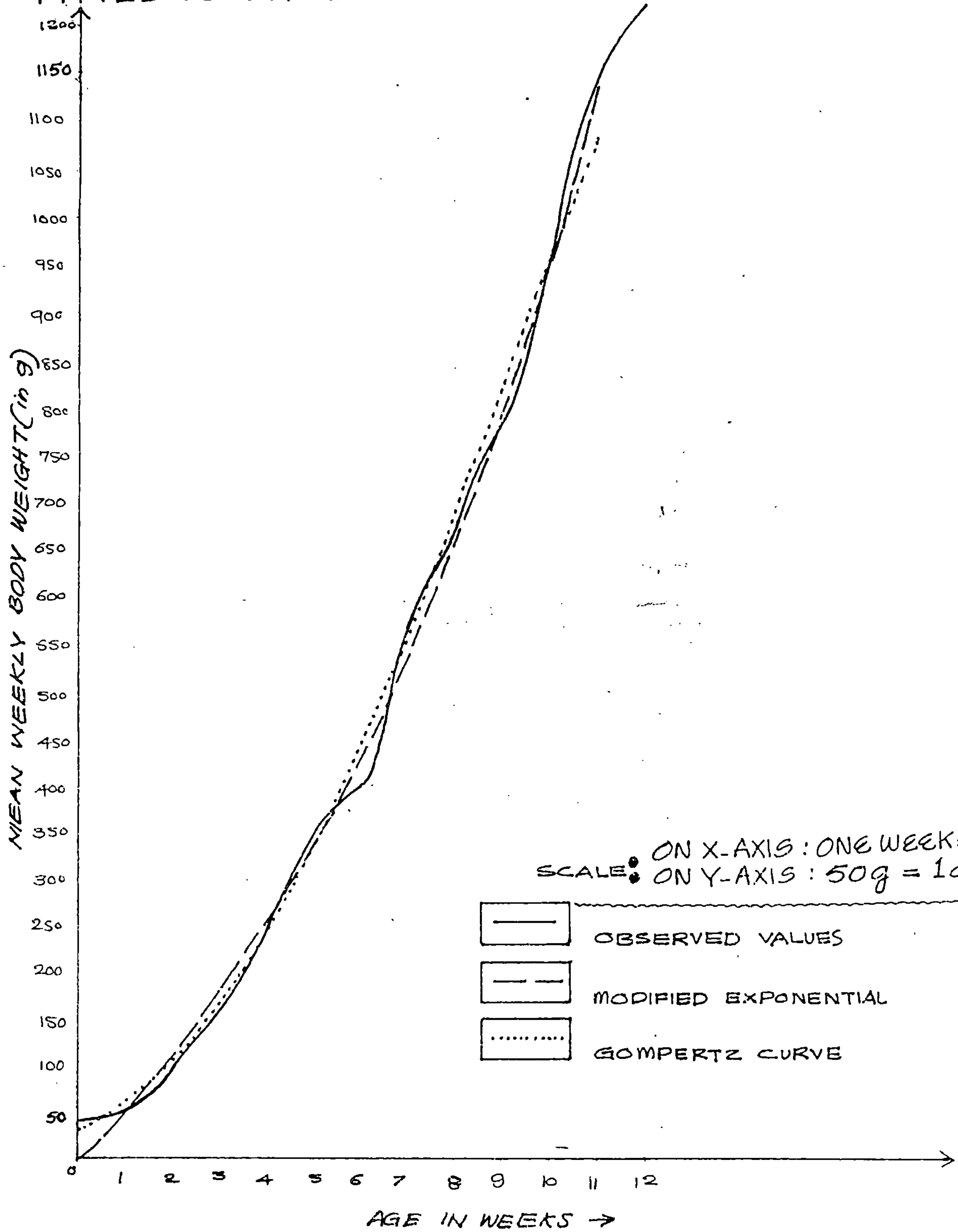


Table 1

Means and standard errors of body weight (in *g*) of six groups of ducklings from the first seven days

Days	Desi males	Desi females	WP males	WP females	Desi ducklings irrespective of sex	WP ducklings irrespective of sex
1.	36.6428±0.5704	38.16±0.6026	38.6538±0.5318	38.3846±0.6565	37.6153±0.3739	38.4423±0.2308
2.	38.5751±0.4873	40.12±0.5206	34.3462±0.5112	37.6154±0.7423	39.4872±0.3971	37.4807±0.4466
3.	41.2143±0.5155	42.20±0.9715	40.0769±0.7882	41.3462±0.9097	41.8462±0.4132	40.7115±0.6025
4.	42.5000±0.6934	45.32±0.8539	41.1923±1.7169	45.8846±0.9928	44.3077±0.6343	44.2884±0.6867
5.	47.2143±0.7857	50.28±1.1966	42.4615±0.9385	46.0769±1.0840	49.1795±0.8440	44.2692±0.7536
6.	51.7143±1.0865	55.52±1.5249	43.5769±1.1055	47.1923±1.2000	54.1538±1.0833	45.3846±0.8465
7.	58.5000±2.3008	63.28±1.8371	49.1153±1.6261	55.3462±1.8245	61.5641±1.4679	52.2308±1.2862

Table 2

Means and standard errors of body weights (in g) of six groups of ducklings upto 12 weeks of age

Weeks	Desi male	Desi female	WP males	WP females	Desi ducklings irrespective of sex	WP ducklings irrespective of sex
0.	36.6428±0.5704	38.16±0.6026	38.6538±0.5318	38.3846±0.6565	37.6153±0.3739	38.4423±0.2308
1.	58.5000±2.3008	63.28±1.8371	49.1153±1.6261	55.3462±1.8245	61.5641±1.4679	52.2308±1.2862
2.	108.3591±5.7880	118.08±6.4057	84.2692±4.2148	105.0769±5.5824	114.5897.4.6151	74.6731±3.7569
3.	190.4785±12.2795	210.80±15.0442	134.1538±9.6694	188.5769±13.8538	203.4872±10.6142	161.3654±9.1912
4.	289.4285±21.1864	345.60±26.7933	202.6923±15.6217	293.8461±25.4454	325.4359±19.4049	245.4807±16.6825
5.	412.2142±30.9867	495.20±36.8022	277.8462±24.3026	431.0385±38.2648	465.4103±26.6075	354.4423±24.8731
6.	491.07±35.2196	573.00±42.6947	309.1923±26.8709	492.3077±40.7528	543.5897±30.5518	400.7500±27.3568
7.	536.0700±33.2874	609.80±39.1977	468.4651±31.0443	706.1530±58.7461	583.3333±28.1254	568.4615±39.8507
8.	633.8800±38.4135	709.00±44.4700	537.8846±44.4047	811.7308±62.4173	682.0513±31.8745	674.8077±42.4943
9.	757.8500±45.8085	813.00±44.4259	637.3076±52.9834	935.5769±60.8904	793.2051±32.7900	786.4422±45.0875
10.	839.2857±56.3175	892.40±44.0673	781.7307±59.1510	1145.7692±63.7451	873.3333±34.5368	963.7500±50.0313
11.	931.7857±48.8623	928.80±41.2667	964.2307±71.4727	1309.6154±66.9822	929.8718±31.3482	1136.9231±54.1892
12.	1291.7857±59.7857	1239.40±45.0836	1021.7308±79.5385	1401.6154±73.0109	1258.2051±35.6814	1214.6154±58.5788

Table 3

Analysis of variance of Initial body weight of four groups of ducklings

Source	d.f.	MSS	F
Between groups	3	13.2708	1.7746 N.S
Within groups	87	7.4783	

Mean Table

Groups	Mean body weights (in g)
Desi males	36.6429
Desi females	38.1600
WP males	38.6539
WP females	38.3846

Table 4

Analysis of variance of the fourth week body weight of four groups of ducklings

Source	d.f.	MSS	F
Between groups	3	105836.3	7.7891**
Within groups	87	13587.69	

** Indicates significance at 1% level

CD for the comparison between

Groups	Desi males	Desi females	WP males	WP females	Mean body weights
Desi males		77.3159	76.7803	76.7803	289.4286^{a}
Desi females			64.8783	64.8783	345.7200^{ab}
WP males				64.2390	190.3846^{c}
WP females					286.5385^{ab}

Table 5

Analysis of variance of eighth week body weights of four groups of ducklings

Source	d.f.	MSS	F
Between groups	3	342317.4	5.6529**
Within groups	87	60555.63	

** Indicates significance at 1% level

CD for the comparison between

Groups	Desi males	Desi females	WP males	WP females	Mean body weight
Desi males		163.22	162.0893	162.0893	633.9286[a]
Desi females			136.9631	136.9631	709.2000[ab]
WP males				135.6137	537.8846[a]
WP females					811.7308[b]

Table 6

Analysis of variance of Twelfth week body weight of four groups of ducklings

Source	d.f.	MSS	F
Between groups	3	643840	5.9571**
Within groups	87	108079.8	

** Indicates significance at 1% level

CD for the comparison between

Groups	Desi males	Desi females	WP males	WP females	Mean body weight
Desi males		218.0562	216.5457	216.5457	1291.7860^{a}
Desi females			182.9779	182.9779	1239.4000^{ab}
WP males				181.1751	1023.2690
WP females					1401.5390^{ab}

Table 7

Parameters of Growth curves of individual Desi males and females in the exponential form $y = ae^{bx}$ for 12 weeks.

No.	Desi males		Desi females	
	a	b	a	b
1.	54.5831	0.2688	48.9232	0.2730
2.	70.3613	0.2501	51.5375	0.2748
3.	90.5578	0.2755	54.5585	0.2699
4.	54.9537	0.2600	104.1730	0.2779
5.	68.5717	0.2736	93.8811	0.2664
6.	56.5986	0.2815	66.5596	0.2699
7.	59.0975	0.2173	76.2667	0.2830
8.	67.9917	0.2842	59.3970	0.2549
9.	63.8296	0.2725	105.0115	0.2565
10.	64.1811	0.2916	88.2889	0.2517
11.	68.3721	0.2597	60.4557	0.2484
12.	56.6524	0.2868	61.8598	0.2490
13.	62.9901	0.2798	78.6505	0.2528
14.	74.4097	0.2838	88.2764	0.2671
15.			74.8556	0.2669
16.			86.9000	0.2651
17.			68.4296	0.2576
18.			61.8598	0.2490
19.			65.9328	0.2460
20.			46.1975	0.2716
21.			94.1292	0.2676
22.			68.8876	0.2783
23.			62.1555	0.2318
24.			101.0114	0.2687
25.			74.3119	0.2970

Table 8

Parameters of Growth curve of individual WP males and females in the exponential form $y = ae^{bx}$ for 18 weeks

No.	WP males		WP females	
	a	b	a	b
1.	55.2209	0.2685	98.7715	0.3018
2.	57.2555	0.2975	74.0686	0.2867
3.	39.0279	0.2389	76.6957	0.3064
4.	38.6062	0.2530	67.5347	0.2913
5.	44.9767	0.2395	68.8996	0.2933
6.	37.6153	0.3055	56.0609	0.3182
7.	41.8776	0.2896	38.8558	0.2213
8.	53.0331	0.2121	71.6056	0.3090
9.	72.5166	0.2985	33.0459	0.2924
10.	53.2369	0.3174	55.2485	0.3123
11.	75.2868	0.3128	52.4013	0.3137
12.	49.8250	0.2878	37.6861	0.2917
13.	50.4950	0.2983	74.9376	0.2882
14.	36.2166	0.2683	77.3631	0.3071
15.	62.2426	0.2680	45.9631	0.2823
16.	62.4041	0.3157	58.4116	0.3018
17.	41.4809	0.2864	66.0550	0.3065
18.	39.6483	0.2303	56.6183	0.3075
19.	59.9992	0.2746	82.6316	0.2957
20.	61.8331	0.2844	63.6944	0.3239
21.	53.8412	0.2782	37.5218	0.2786
22.	39.2025	0.2364	72.8669	0.2826
23.	43.8582	0.2476	51.0882	0.2593
24.	45.5084	0.2259	74.9715	0.3128
25.	51.9175	0.2786	40.2124	0.2899
26.	44.4918	0.2727	64.6653	0.3264

Table 9

Parameters of the Growth curve of individual Desi males for twelve weeks in the Modified exponential form $y = K + ab^x$

No.	K	a	b
1.	-392.0433	406.1595	1.1044
2.	-9877.6210	9878.2890	1.0071
3.	5746.3250	-5806.3130	0.9762
4.	3590.3250	-3623.3320	0.9801
5.	-1534.9570	1524.8220	1.0486
6.	-439.1822	450.5016	1.1084
7.	-5727.0140	5754.3000	1.0069
8.	2812.8910	-2887.3240	0.9578
9.	4549.8770	-4599.6580	0.9794
10.	-10366.0300	10316.9400	0.1009
11.	-464.6250	491.9454	1.0995
12.	-887.0508	874.5153	1.0711
13.	-2432.5390	2404.6210	1.0327
14.	2344.4660	-2440.0290	0.9408

Table 10

Parameters of the Growth curve fitted to individual Desi females for Twelve weeks in the modified exponential form $y = K + ab^x$

No.	K	a	b
1.	-558.5598	553.6031	1.0823
2.	-840.6453	829.3912	1.0639
3.	-905.2712	891.9890	1.0624
4.	2132.7340	-2306.9820	0.8964
5.	1637.6540	-1764.3110	0.8917
6.	6110.8640	-6150.3480	0.9852
7.	2636.6980	-2731.3190	0.9467
8.	-474.7256	483.0128	1.0817
9.	1535.5630	-1648.5870	0.8802
10.	1081.3970	-1199.2430	0.8495
11.	-586.5211	603.0282	1.0742
12.	3311.5790	-3362.9260	0.9669
13.	1300.5010	-1375.2660	0.9035
14.	1428.8160	-1569.8710	0.8763
15.	2033.4950	-2105.7770	0.9402
16.	1947.5850	-2033.6130	0.9256
17.	-18175.0000	18160.3100	1.0042
18.	21045.3100	-21059.0100	0.9967
19.	-188.7025	234.4906	1.1435
20.	-145.4605	166.5296	1-1698
21.	1411.9450	-1585.1430	0.8565
22.	2280.4340	-2384.3600	0.9423
23.	3017.2980	-3019.4300	0.9804
24.	1817.6090	-1964.6060	0.8902
25.	2436.2780	-2583.8120	0.9309

Table 11

Parameters of Growth curves of individual WP males for Twelve weeks in the modified exponential form $y = K + ab^x$

No.	K	a	b
1.	-191.2503	216.6875	1-1634
2.	-243.3244	256.7155	1.1766
3.	-4.8607	40.2958	1.2772
4.	-35.5510	64.3779	1.2347
5.	-36.1510	72.5710	1.2230
6.	-35.7852	61.9823	1.2994
7.	-68.8115	93.0530	1.2444
8.	-198.0000	232.7391	1.1018
9.	-797.7798	789.9142	1.1021
10.	-737.5383	704.1233	1.1023
11.	-1848.6250	1786.5450	1.0648
12.	-117.1871	143.1103	1.2122
13.	-88.2222	118.8996	1.2463
14.	-73.8608	93.9470	1.2043
15.	-50.8763	103.7014	1.2542
16.	-486.7515	475.3893	1.1434
17.	-53.4252	77.9632	1.2627
18.	-76.5992	102.0791	1.1656
19.	-357.5332	372.2158	1.1265
20.	-589.0046	581.2256	1.1042
21.	-162.4009	188.1907	1.1815
22.	-51.3113	78.4831	1.1999
23.	-111.4810	136.9683	1.1639
24.	-20.1248	62.5030	1.2204
25.	-194.9116	216.0299	1.1645
26.	-135.1566	151.8551	1.1806

Table 12

Parameters of Growth curve of individual WP females for twelve weeks in the modified exponential form $y = K + ab^x$

No.	K	a	b
1.	3348.6320	-3567.4810	0.9269
2.	-519.8471	526.5580	1.1262
3.	-4529.5790	4187.4470	1.0309
4.	-1274.8580	1246.3370	1.0675
5.	-2818.8020	2774.2820	1.0358
6.	-308.9548	302.4160	1.1829
7.	-7089.7500	7093.2680	1.0044
8.	-3078.2490	3007.6290	1.0403
9.	-30.2008	54.7745	1.2828
10.	-218.0434	228.4734	1.2004
11.	38.6679	13.7284	1.4917
12.	-1721.7510	1692.8840	1.0557
13.	89042.7800	-89152.7400	0.9983
14.	-33.7802	72.10839	1.2740
15.	-582.0154	568.4683	1.1137
16.	-859.5871	830.0349	1.0989
17.	-575.8060	556.9786	1.1183
18.	-1663.3790	1634.1790	1.0647
19.	-699.2376	662.2980	1.1261
20.	10.4005	29.4673	1.3608
21.	-528.3008	536.1495	1.1188
22.	-123.7935	152.1503	1.1797
23.	-2829.6760	2758.6790	1.0453
24.	-14.2673	48.3706	1.3231
25.	-873.4829	833.9853	1.1105
26.	-154.2535	168.8789	1.2305

Table 13

Square of the correlation coefficient (coefficient of determination) between observed and expected values of four groups of ducklings for 12 weeks when the exponential curve was fitted

No.	Desi males	Desi females	WP males	WP females
1.	0.9234	0.9701	0.9478	0.6627
2.	0.9232	0.9530	0.9323	0.9208
3.	0.8643	0.9279	0.9067	0.8238
4.	0.9092	0.7429	0.9732	0.8463
5.	0.9300	0.8325	0.9609	0.8707
6.	0.9610	0.9223	0.9624	0.8583
7.	0.9349	0.8236	0.9552	0.9192
8.	0.8984	0.9555	0.9699	0.7757
9.	0.9030	0.8447	0.8939	0.9595
10.	0.9025	0.8304	0.9028	0.9350
11.	0.9761	0.9418	0.8506	0.9195
12.	0.9395	0.8779	0.9588	0.9506
13.	0.9140	0.8397	0.9423	0.8544
14.	0.8721	0.8227	0.9503	0.7794
15.		0.8308	0.8842	0.9727
16.		0.8322	0.9368	0.9252
17.		0.9224	0.9510	0.8998
18.		0.9464	0.9599	0.8869
19.		0.9764	0.9457	0.8819
20.		0.9711	0.9160	0.8858
21.		0.7881	0.9500	0.9701
22.		0.7216	0.8988	0.9487
23.		0.9211	0.9539	0.9503
24.		0.7533	0.9854	0.8670
25.		0.7902	0.9594	0.9319
26.			0.9547	0.8739

Table 14

Square of the correlation coefficient (coefficient of determination) between observed and expected values of four groups of ducklings for 12 weeks when the Modified Exponential curve was fitted

No.	Desi males	Desi females	WP males	WP females
1.	0.9957	0.9869	0.9929	0.9612
2.	0.9904	0.9899	0.9945	0.9941
3.	0.9841	0.9891	0.9524	0.9895
4.	0.9722	0.9702	0.9951	0.9913
5.	0.9875	0.9682	0.9948	0.9901
6.	0.9865	0.9884	0.9943	0.9456
7.	0.9759	0.9763	0.9986	0.9857
8.	0.9812	0.9866	0.9893	0.9809
9.	0.9723	0.9769	0.9955	0.9964
10.	0.9904	0.9628	0.9938	0.9975
11.	0.9905	0.9735	0.9826	0.9760
12.	0.9898	0.9855	0.9979	0.9887
13.	0.9896	0.9703	0.9909	0.9783
14.	0.9772	0.9604	0.9958	0.9978
15.		0.9761	0.9445	0.9764
16.		0.9837	0.9952	0.9945
17.		0.9918	0.9951	0.9951
18.		0.9845	0.9893	0.9953
19.		0.9923	0.9925	0.9880
20.		0.9878	0.9942	0.9968
21.		0.9567	0.9984	0.9968
22.		0.9659	0.9583	0.9906
23.		0.9897	0.9913	0.9896
24.		0.9714	0.9940	0.9893
25.		0.9678	0.9956	0.9951
26.			0.9950	0.9924

Table 15

Standard error of the estimate of four groups of ducklings for 12 weeks when the exponential curve was fitted

No.	Desi males	Desi females	WP males	WP females
1.	98.5579	97.3482	128.1779	738.2389
2.	157.8335	126.7156	221.9775	268.0571
3.	362.4103	151.3184	67.7167	491.9807
4.	144.2763	527.6917	46.3851	333.1532
5.	207.9927	354.6538	52.8992	335.5516
6.	142.3911	194.5812	107.4686	348.4846
7.	66.5077	361.7240	112.3169	56.4306
8.	273.6176	85.6839	44.5449	507.5307
9.	208.7477	337.1795	351.3475	80.7107
10.	279.9694	265.3236	321.4297	249.9538
11.	111.8191	109.1757	493.5063	250.8320
12.	183.9359	247.3216	132.9264	91.9032
13.	221.3500	238.0670	173.3942	350.5814
14.	322.8684	338.6707	75.9780	534.8020
15.		281.5413	167.6454	87.5657
16.		322.1044	320.1162	247.9210
17.		171.6540	101.7525	345.1275
18.		116.0585	45.0130	305.8254
19.		85.6030	162.1071	408.2155
20.		88.2425	222.6149	429.9344
21.		387.8068	142.1857	58.6997
22.		351.9081	69.1970	222.0333
23.		105.3775	67,4551	97.2454
24.		446.3034	28.2984	481.6258
25.		447.0422	130.3733	114.9141
26.			101.7889	478.3837

Table 16

Standard error of the estimate of four groups of ducklings for 12 weeks when the modified exponential curve was fitted

No.	Desi males	Desi females	WP males	WP females
1.	18.2185	30.4226	26.4551	136.4647
2.	27.1256	28.0169	32.6753	37.7139
3.	58.6002	30.3380	41.3756	58.8133
4.	41.3381	95.8134	14.0417	42.2136
5.	40.2187	77.1836	15.1105	44.9906
6.	37.7551	34.5197	26.5713	128.6262
7.	24.7434	65.2936	12.0183	14.6216
8.	51.4266	26.2863	15.7923	77.6459
9.	54.1654	64.7349	34.9470	16.2045
10.	38.3068	65.9206	36.6974	25.1071
11.	30.2779	40.3504	80.6435	56.4476
12.	34.6250	43.0165	16.8720	50.4060
13.	36.0982	54.6841	39.4070	85.5196
14.	61.8967	81.9154	14.0496	15.3389
15.		55.1780	104.4698	72.9477
16.		51.4836	38.0831	38.4604
17.		26.8172	22.2584	32.4638
18.		30.8574	15.8117	38.0725
19.		23.9254	30.2865	66.8313
20.		29.0205	30.3503	15.4287
21.		92.3186	14.0276	25.5305
22.		72.5760	35.0428	25.9756
23.		20.7367	19.5890	60.6894
24.		82.4109	13.8267	35.0933
25.		84.1882	21.6686	43.2315
26.			19.7193	44.0663

Table 17

Analysis of variance of 'b' values (growth rate) when the exponential curve was fitted for 12 weeks

Source	d.f.	MSS	F
Between groups	3	0.00501	10.1811**
Within groups	87	0.00049	

** Indicates significance at 1% level

CD for the comparison between

Groups	Desi males	Desi females	WP males	WP females	Mean 'b' values
Desi males		0.0147	0.0146	0.0146	0.2704^{a}
Desi females			0.0123	0.0123	0.2638^{ab}
WP males				0.0122	0.2726^{ab}
WP females					0.2962

Table 18

Analysis of variance of 'b' values (growth rate) when the modified exponential was fitted for twelve weeks

Source	d.f.	MSS	F
Between groups	3	0.2896	16.4474**
Within groups	87	0.0176	

** Indicates significance at 1% level

CD for the comparison between

Groups	Desi males	Desi females	WP males	WP females	Mean 'b' values
Desi males		0.0880	0.0874	0.0874	0.9581[a]
Desi females			0.0739	0.0739	0.9737[a]
WP males				0.0731	1.1853[b]
WP females					1.1388[b]

Table 19

Parameters of Growth curve of individual Desi males for twelve weeks in the Gompertz form $y = ab^{c^x}$

No.	a	b	c
1.	1583.3970	0.0219	0.8571
2.	972.2749	0.3502	0.7856
3.	1420.8500	0.0222	0.7432
4.	812.8108	0.0287	0.7723
5.	1341.5430	0.0242	0.7995
6.	1662.4150	0.0199	0.8437
7.	672.4063	0.0596	0.8301
8.	1097.2400	0.0197	0.7313
9.	1025.7740	0.0240	0.7609
10.	1280.3660	0.0187	0.7661
11.	1495.871	0.0276	0.8411
12.	1404.5340	0.0197	0.8145
13.	1253.1440	0.0214	0.7880
14.	1167.7370	0.0191	0.7209

Table 20

Parameters of Growth curve fitted to individual Desi females for twelve weeks in the Gompertz form $y = ab^{c^x}$

No.	a	b	c
1.	1218.3760	0.0221	0.8345
2.	1220.1700	0.0224	0.8261
3.	1214.9390	0.0223	0.8192
4.	1484.1600	0.0165	0.6869
5.	1161.4110	0.0212	0.6872
6.	1030.9790	0.0262	0.7639
7.	1230.7040	0.0186	0.7259
8.	1245.5170	0.0258	0.8544
9.	1164.7500	0.0267	0.6908
10.	899.8826	0.0268	0.6725
11.	1237.2890	0.0296	0.8445
12.	1105.8220	0.0264	0.7511
13.	890.9308	0.0280	0.7088
14.	1088.2020	0.0263	0.6825
15.	1032.4900	0.0299	0.7251
16.	1138.4620	0.0232	0.7142
17.	1030.8240	0.0307	0.7842
18.	857.9836	0.0356	0.7895
19.	2293.2550	0.0295	0.8880
20.	2604.9570	0.0122	0.8908
21.	1136.2840	0.0184	0.6630
22.	1128.0780	0.0184	0.6630
23.	708.6017	0.0423	0.7848
24.	1131.1990	0.0194	0.6879
25.	1335.6380	0.0134	0.7080

Table 21

Parameters of Growth curve of individual WP males for twelve weeks in the Gompertz form $y = ab^{c^x}$

No.	a	b	c
1.	2874.3640	0.0131	0.8877
2.	3815.5480	0.0092	0.8781
3.	1.7014E + 38	5.8775	0.9982
4.	34674.5800	9.3808	0.9519
5.	15115.1900	0.0025	0.9452
6.	196535.3000	0.00016	0.9543
7.	17628.2600	0.0018	0.9327
8.	1134.5520	0.0347	0.8864
9.	2290.8860	0.0152	0.8216
10.	2013.6900	0.0114	0.8159
11.	2232.5360	0.0124	0.7879
12.	5794.5990	0.0061	0.9068
13.	15311.6600	0.0024	0.9243
14.	4520.3500	0.0059	0.9168
15.	14840.3200	0.0034	0.9317
16.	2690.1610	0.0112	0.8330
17.	32299.7400	0.0010	0.9413
18.	2370.8370	0.0127	0.9149
19.	1921.7020	0.0182	0.8523
20.	1922.0350	0.0164	0.8354
21.	3406.5630	0.0106	0.8897
22.	10294.6900	0.0030	0.9409
23.	2876.5370	0.0115	0.9099
24.	40991.7400	0.0010	0.9593
25.	2507.4430	0.0134	0.8771
26.	2940.5840	0.0099	0.8931

Note: E + 38 $= 10^{38}$

Table 22

Parameters of Growth curves of individual WP females for Twelve weeks in the Gompertz form $y = ab^{c^x}$

No.	a	b	c
1.	1898.5290	0.0114	0.7022
2.	2648.7460	0.0155	0.8475
3.	1945.6530	0.0139	0.7732
4.	1761.1860	0.0163	0.8026
5.	1576.4220	0.0171	0.7824
6.	6313.9900	0.0051	0.8848
7.	486.5866	0.0459	0.8186
8.	1942.9730	0.0127	0.7756
9.	1513668.0000	1.9124 E-5	0.9672
10.	5204.5930	0.0066	0.8846
11.	3. 3.0162	14.8605	1.0748
12.	1825.0160	0.0178	0.8001
13.	1839.7160	0.0131	0.7556
14.	98469.3400	0.00039	0.9531
15.	2098.5060	0.0143	0.8335
16.	2258.7680	0.0132	0.8186
17.	2287.0180	0.0119	0.8333
18.	2060.0000	0.0166	0.7930
19.	3073.8210	0.0095	0.8315
20.	2.3563 E-9	1.5980 E+10	1.0115
21.	2278.5850	0.0175	0.8418
22.	3724.4660	0.0099	0.9063
23.	2069.5650	0.01310	0.7790
24.	1.1062 E+17	3.3487	0.9910
25.	2659.9050	0.01009	0.8128
26.	9962.4490	0.0035	0.9066

Note: E±n = $10^{\pm n}$, 'n' is any number.

Table 23

Parameters of Growth curves for individual Desi males for 12 weeks in the Logistic form

$$y = \frac{k}{1 + 10^{b+cx}}$$

No.	k	b	c
1.	1656.7930	1.6413	-0.1728
2.	1232.1170	1.5470	-0.2088
3.	1649.0870	1.6513	-0.2568
4.	1056.1380	1.4523	-0.2004
5.	1433.3090	1.5768	-0.2220
6.	1224.1410	1.6471	-0.1902
7.	938.4976	1.4249	-0.1792
8.	1552.2920	1.6004	-0.2333
9.	1263.1780	1.4853	-0.2369
10.	1582.8100	1.6456	-0.2336
11.	1672.1800	1.6107	-0.1847
12.	1660.7040	1.6304	-0.2001
13.	1417.2860	1.5717	-0.2180
14.	1547.9450	1.6619	-0.2631

Table 24

Parameters of Growth curve fitted to individual Desi females for 12 weeks in the Logistic form

$$y = \frac{k}{1 + 10^{b+cx}}$$

No.	k	b	c
1.	1384.2600	1.5154	-0.1769
2.	1370.9850	1.5692	-0.1895
3.	1158.3830	1.4579	-0.1953
4.	1669.0620	1.6098	-0.2956
5.	1485.6360	1.5693	-0.2649
6.	1427.3560	1.5997	-0.2241
7.	1457.4760	1.6351	-0.2678
8.	1355.9290	1.5172	-0.1618
9.	1623.3650	1.5865	-0.2623
10.	1396.8370	1.5305	-0.2492
11.	1780.4240	1.6614	-0.1474
12.	1314.9440	1.5034	-0.2323
13.	1189.6490	1.4815	-0.2409
14.	1475.5690	1.5549	-0.2635
15.	1214.3670	1.5276	-0.2553
16.	1378.9740	1.5476	-0.2569
17.	1232.9350	1.5095	-0.2165
18.	1126.1850	1.4338	-0.1944
19.	1535.3300	1.5615	-0.1636
20.	1342.1040	1.5852	-0.1709
21.	1506.1060	1.5754	-0.2774
22.	1029.0600	1.4533	-0.2921
23.	917.5786	1.3645	-0.1907
24.	1505.5060	1.5752	-0.2863
25.	1586.7840	1.6102	-0.2696

Table 25

Parameters of Growth curve of individual WP males for 12 weeks in the Logistic form

$$y = k/1 + 10^{b+cx}$$

No.	k	b	c
1.	1155.7940	1.4686	-0.1867
2.	1813.2780	1.6695	-0.1822
3.	1642.5570	1.6496	-0.1076
4.	3076.1330	1.8914	-0.1107
5.	1437.7320	1.5216	-0.1178
6.	2927.4120	1.8810	-0.1399
7.	1702.1640	1.6298	-0.1486
8.	940.5587	1.3412	-0.1306
9.	1748.7610	1.6774	-0.2232
10.	1655.2150	1.6784	-0.2274
11.	2075.6280	1.7066	-0.2284
12.	1750.2090	1.6309	-0.1604
13.	1916.8840	1.7059	-0.1674
14.	1151.5800	1.5302	-0.1395
15.	1555.4450	1.5359	-0.1599
16.	2152.9660	1.7228	-0.2050
17.	2136.6630	1.7195	-0.1367
18.	859.6698	1.3595	-0.1252
19.	1402.6960	1.5553	-0.1836
20.	1494.0140	1.5179	-0.1893
21.	1476.0930	1.5664	-0.1681
22.	824.2018	1.3279	-0.1227
23.	1010.1100	1.4079	-0.1387
24.	1527.0380	1.5703	-0.1151
25.	1473.8700	1.6014	-0.1699
26.	1452.2910	1.5261	-0.1427

Table 26

Parameters of Growth curve of individual WP females for 12 weeks in the Logistic form

$$y = k/1 + 10^{b+cx}$$

No.	K	b	c
1.	1782.9670	1.6620	-0.2955
2.	1706.0930	1.5573	-0.2058
3.	1738.9210	1.6749	-0.2523
4.	1387.3740	1.5745	-0.2289
5.	1522.9070	1.5919	-0.2240
6.	18736.3300	2.6697	-0.1369
7.	484.2730	1.1802	-0.1663
8.	1583.9770	1.6588	-0.2474
9.	1594.8530	1.6490	-0.1422
10.	2034.4260	1.6978	-0.1866
11.	2013.5230	1.6716	-0.1781
12.	1515.7660	1.6139	-0.2282
13.	1699.8540	1.6408	-0.2598
14.	2239.7310	1.7630	-0.1443
15.	1647.9280	1.6270	-0.2077
16.	1824.0820	1.6494	-0.2145
17.	1526.4940	1.5930	-0.2113
18.	1841.8180	1.6764	-0.2355
19.	2211.1980	1.7458	-0.2109
20.	1829.6450	1.5789	-0.1936
21.	1277.7130	1.4906	-0.1503
22.	1997.2720	1.7123	-0.2431
23.	1840.9670	1.6762	-0.1420
24.	2039.8180	1.7216	-0.2303

Table 27

Square of the Correlation coefficient (coefficient of determination) between observed and expected values for the four groups of ducklings for 12 weeks when the Gompertz curve was fitted

No.	Desi males	Desi females	WP males	WP females
1.	0.9950	0.9841	0.9878	0.9899
2.	0.9897	0.9948	0.9967	0.9884
3.	0.9835	0.9942	0.9483	0.9940
4.	0.9824	0.9928	0.9941	0.9968
5.	0.9835	0.9789	0.9899	0.9903
6.	0.9858	0.9931	0.9932	0.9515
7.	0.9755	0.9913	0.9991	0.9934
8.	0.9853	0.9935	0.9899	0.9910
9.	0.9781	0.9935	0.9907	0.9967
10.	0.9961	0.9933	0.9972	0.9964
11.	0.9783	0.9765	0.9914	0.9962
12.	0.9955	0.9926	0.9939	0.9708
13.	0.9934	0.9866	0.9911	0.9914
14.	0.9870	0.9844	0.9945	0.9932
15.		0.9867	0.9205	0.9967
16.		0.9939	0.9950	0.9935
17.		0.9936	0.9950	0.9935
18.		0.9865	0.9895	0.9945
19.		0.9926	0.9826	0.9884
20.		0.9900	0.9972	0.9941
21.		0.9854	0.9965	0.9969
22.		0.9867	0.9602	0.9910
23.		0.9944	0.9884	0.9904
24.		0.9941	0.9898	0.9910
25.		0.9946	0.9877	0.9880
26.			0.9964	0.9954

Table 28

Square of the Correlation coefficient (coefficient of determination) between observed and expected values for the four groups of ducklings for 12 weeks when the Logistic curve was fitted

No.	Desi males	Desi females	WP males	WP females
1.	0.9605	0.9540	0.9787	0.9824
2.	0.9349	0.9559	0.9953	0.9840
3.	0.9460	0.9774	0.9433	0.9851
4.	0.9418	0.9615	0.9862	0.9929
5.	0.9563	0.9318	0.9819	0.9814
6.	0.9455	0.9224	0.9867	0.8747
7.	0.8853	0.9518	0.9957	0.9868
8.	0.9217	0.9541	0.9832	0.9868
9.	0.9306	0.9150	0.9867	0.9932
10.	0.9467	0.8826	0.9833	0.9962
11.	0.9504	0.9536	0.9815	0.9961
12.	0.9397	0.9565	0.9949	-
13.	0.9564	0.9253	0.9894	0.9846
14.	0.9287	0.9199	0.9911	0.9854
15.		0.9521	0.9055	0.9938
16.		0.9500	0.9865	0.9687
17.		0.9451	0.9854	0.9900
18.		0.9466	0.9913	0.9913
19.		0.9746	0.9861	0.9813
20.		0.9810	0.9925	0.9897
21.		0.9224	0.9971	-
22.		0.9826	0.9564	0.9863
23.		0.9404	0.9889	0.9924
24.		0.9592	0.9919	0.9780
25.		0.9573	0.9925	0.9786
26.			0.9960	0.9906

Table 29

Standard error of the estimate of four groups of ducklings for 12 weeks when Gompertz curve was fitted

No.	Desi males	Desi females	WP males	WP females
1.	20.5000	34.6566	35.3088	69.5503
2.	27.7823	21.2251	24.7033	54.0075
3.	58.9723	22.2188	48.0421	45.6809
4.	33.2187	46.2425	15.9761	25.1255
5.	46.5611	62.1188	22.4342	45.2558
6.	38.9715	26.8557	29.0741	122.9137
7.	25.2118	39.1713	9.4767	10.4514
8.	45.4248	18.3067	15.1405	52.9070
9.	48.7904	34.1853	51.4087	15.6391
10.	24.5468	28.1475	24.8154	32.8951
11.	46.0422	37.7311	56.0084	30.8409
12.	22.6933	30.5269	36.3090	63.1022
13.	28.2328	36.1564	39.0283	43.9022
14.	47.2123	50.9320	16.5612	48.5945
15.		40.4789	131.7605	19.9648
16.		30.8988	71.5177	94.3692
17.		23.5103	23.8405	43.9266
18.		30.1828	15.6182	35.5860
19.		23.2882	47.1263	60.5248
20.		25.8176	20.5742	46.8733
21.		52.7629	20.2515	16.1995
22.		45.1175	34.3538	43.1089
23.		15.0310	23.9014	26.6374
24.		36.8273	19.2303	57.8975
25.		36.0143	37.3745	39.4397
26.			16.3883	43.4247

Table 30

Standard error of the estimate of four groups of ducklings for 12 weeks when Logistic curve was fitted

No.	Desi males	Desi females	WP males	WP females
1.	111.3193	123.9161	59.4623	107.3325
2.	136.1116	123.3398	44.4710	76.7426
3.	187.4925	84.7647	65.7497	90.9440
4.	111.6436	173.7145	40.0598	49.0502
5.	146.7061	189.0500	43.1021	83.7864
6.	159.2067	194.0107	63.3964	304.4880
7.	123.6882	173.5760	34.8999	22.5468
8.	212.1824	97.1557	28.9272	85.1701
9.	185.4460	243.6428	79.0117	33.4726
10.	187.1648	239.1490	110.1262	38.5894
11.	140.6159	80.5690	114.4779	49.8655
12.	176.3228	138.5192	35.0269	-
13.	144.8660	158.9094	62.5501	76.8052
14.	222.8417	215.0948	32.8021	88.9610
15.		137.2909	156.1724	43.5170
16.		158.2458	87.9088	100.0714
17.		141.1186	63.6398	70.1682
18.		120.6435	18.7446	48.8805
19.		78.4596	51.5083	105.3158
20.		66.0029	48.2486	79.9245
21.		216.5470	26.2941	-
22.		64.3456	48.5725	84.9031
23.		98.9025	28.8092	32.1123
24.		159.1714	21.4539	132.6992
25.		182.1046	36.0139	77.8224
26.			22.2273	78.8113

Table 31

Analysis of variance of rates of growth based on Gompertz Curve for twelve weeks

Source	d.f.	MSS	F
Between groups	3	0.0105	33.3234**
Within groups	85	0.000315	

** Indicates significance at 1% level

CD for the Comparison between

Groups	Desi males	Desi females	WP males	WP females	Mean b^c values
Desi males		0.0118	0.0117	0.0119	0.0512[a]
Desi females			0.0099	0.0101	0.0619[a]
WP males				0.0099	0.0166
WP females					0.0270

Table 32

Parameters of the Growth curve of individual Desi males and Desi females in the Von-Bertalanffy form $y_t = A(1-be^{-kt})^3$ for 12 weeks. A = 2000 (desi males) and A = 1750 (Desi females)

No.	Desi males		Desi females	
	b	k	b	k
1.	0.8149	0.1107	0.8251	0.1185
2.	0.7422	0.1022	0.8204	0.1233
3.	0.7836	0.1694	0.7918	0.1177
4.	0.7653	0.0932	0.8457	0.2549
5.	0.7941	0.1314	0.7579	0.1800
6.	0.8414	0.1300	0.7992	0.1424
7.	0.7372	0.0690	0.7934	0.1760
8.	0.7980	0.1490	0.7905	0.1021
9.	0.7768	0.1185	0.7797	0.1953
10.	0.8228	0.1478	0.7324	0.1423
11.	0.7995	0.1217	0.7640	0.1052
12.	0.8378	0.1333	0.7566	0.1439
13.	0.7966	0.1279	0.7161	0.1246
14.	0.7907	0.1513	0.7567	0.1705
15.			0.7367	0.1374
16.			0.7407	0.1594
17.			0.7594	0.1234
18.			0.7589	0.1062
19.			0.7756	0.1147
20.			0.8200	0.1108
21.			0.7478	0.1812
22.			0.7336	0.1384
23.			0.7254	0.0866
24.			0.7430	0.1962
25.			0.8518	0.2093

Table 33

Parameters of the Growth curve of individual WP males and females in the Von-Bertalanffy form $y_t = A(1-be^{-kt})^3$ for 12 weeks A = 3500 for WP males and A = 3300 for WP females

No.	WP males		WP females	
	b	k	b	k
1.	0.8076	0.0708	0.7445	0.1297
2.	0.8325	0.0919	0.8102	0.1039
3.	0.8123	0.0467	0.7982	0.1179
4.	0.8252	0.0530	0.7908	0.0947
5.	0.8085	0.0515	0.7926	0.0980
6.	0.8700	0.0796	0.8576	0.1135
7.	0.8443	0.0730	0.7931	0.0397
8.	0.7794	0.0435	0.7941	0.1125
9.	0.8698	0.1046	0.8575	0.0685
10.	0.8400	0.0991	0.8641	0.1092
11.	0.8205	0.1207	0.8670	0.1068
12.	0.8358	0.0796	0.8786	0.0803
13.	0.8457	0.0874	0.7844	0.0996
14.	0.8301	0.0560	0.7894	0.1175
15.	0.8195	0.0809	0.8407	0.0774
16.	0.8557	0.1142	0.8359	0.1007
17.	0.8471	0.0721	0.8298	0.1178
18.	0.8069	0.0437	0.8293	0.0999
19.	0.8042	0.0773	0.7973	0.1166
20.	0.8068	0.0844	0.8663	0.1297
21.	0.8171	0.0755	0.8531	0.0690
22.	0.8082	0.0452	0.8087	0.0997
23.	0.8093	0.0529	0.8058	0.0658
24.	0.8029	0.0468	0.8232	0.1267
25.	0.8188	0.0741	0.8522	0.0761
26.	0.8222	0.0647	0.8670	0.1068

Table 34

Parameters of Growth curve of individual Desi males for 12 weeks in the second Degree form $y = a + bx + cx^2$

No.	a	b	c
1.	0.8686	7.0105	7.4844
2.	44.0884	2.9556	7.7867
3.	104.9614	1.7308	12.0146
4.	40.0444	2.5599	6.6027
5.	44.3701	4.8057	9.2821
6.	4.9795	7.8337	8.5958
7.	11.7808	3.2193	5.2135
8.	64.4771	3.6109	9.9356
9.	53.9251	3.1848	8.4778
10.	59.5819	4.3741	9.9942
11.	5.3186	7.3956	8.6277
12.	21.6792	6.6284	8.8049
13.	49.9709	4.0949	8.9261
14.	86.0084	2.3871	10.6642

Table 35

Parameters of Growth curve of individual Desi females for 12 weeks in the second Degree form $y = a + bx + cx^2$

No.	a	b	c
1.	3.4511	6.3621	6.9521
2.	15.4356	5.6523	7.2838
3.	34.6129	3.8267	7.1916
4.	186.4081	-4.0454	13.6265
5.	119.6994	-0.4575	11.3932
6.	43.4650	4.2602	8.7410
7.	109.0615	0.3636	10.6535
8.	8.7448	5.0135	6.2173
9.	117.1518	-5.2947	11.8495
10.	92.9246	0.1194	9.6410
11.	22.5525	4.1179	6.7763
12.	78.7073	1.5674	9.3300
13.	85.9695	-0.0355	8.6156
14.	114.3776	-0.3996	10.8342
15.	94.6983	-0.0499	9.1459
16.	110.6044	-0.4176	10.4380
17.	47.7033	3.0659	8.0334
18.	29.1383	3.6309	6.8877
19.	9.3072	5.7917	7.3773
20.	1.9904	6.0754	6.4850
21.	136.9730	-1.9070	11.4863
22.	127.1529	-2.6583	9.0221
23.	36.6579	1.8147	5.9060
24.	165.2602	-3.6119	12.2575
25.	132.0714	-0.4670	11.6162

Table 36

Parameters of Growth curves of individual WP males for 12 weeks in the second Degree form $y = a + bx + cx^2$

No.	a	b	c
1.	18.6544	5.4116	7.3560
2.	25.3292	7.6159	9.7318
3.	15.1224	2.4491	4.0729
4.	-3.0659	4.7363	4.7284
5.	2.0260	4.2488	4.8558
6.	-20.7173	9.5305	7.4076
7.	-0.7358	7.0874	6.9227
8.	14.7522	2.3467	4.4157
9.	67.4316	5.8981	11.9728
10.	48.5949	6.4820	10.4672
11.	103.5230	4.8506	13.8352
12.	1.4400	7.9226	8.0466
13.	4.5655	8.6763	8.8921
14.	6.4271	4.2103	4.9108
15.	-8.0898	9.1119	8.7036
16.	25.5354	10.4206	12.4158
17.	-7.1744	7.5260	6.7927
18.	9.9256	2.5579	3.8653
19.	25.7084	5.7313	8.3427
20.	45.9426	4.9695	9.1710
21.	16.0964	6.2223	7.8176
22.	17.9471	2.0420	3.8176
23.	10.6684	3.6504	4.9517
24.	-2.7583	4.1209	4.4391
25.	11.1539	6.4176	7.6114
26.	11.7722	5.0190	6.2099

Table 37

Parameters of Growth curves of individual WP females for 12 weeks in the second Degree form $y = a + bx + cx^2$

No.	a	b	c
1.	243.6704	-6.4176	15.5336
2.	46.9421	6.9481	11.2659
3.	121.2518	2.3526	13.1142
4.	86.4897	2.4556	10.2448
5.	81.8292	3.2368	10.7089
6.	48.5370	7.7378	11.4207
7.	23.7218	0.7837	3.3638
8.	132.1704	0.7857	12.3915
9.	-10.1313	6.8017	5.7557
10.	11.4725	10.2967	10.8703
11.	14.0066	9.7847	10.4596
12.	-49.7233	11.7562	7.1622
13.	91.5810	2.7048	11.0853
14.	146.3456	0.2148	13.1350
15.	-13.9206	8.4920	7.2948
16.	26.2637	8.0879	10.3088
17.	58.8063	6.7652	11.7889
18.	53.4186	5.7023	10.1874
19.	90.2777	4.8432	13.1609
20.	61.2678	8.5235	13.2934
21.	-26.4236	8.3796	6.0414
22.	32.7223	7.6294	10.8316
23.	13.4395	4.8462	6.3481
24.	98.2732	5.1883	13.7935
25.	-6.1114	7.5619	6.8102
26.	75.3681	7.4451	13.5869

Table 38

Standard error of the estimate of four groups of ducklings for 12 weeks when Von-Bertalanffy curve was fitted

No.	Desi males	Desi females	WP males	WP females
1.	54.3845	82.4783	41.5534	151.9284
2.	81.0735	76.8700	46.2477	58.7313
3.	34,1241	42,4986	34,1774	46.5413
4.	41.6917	71.1304	36.2313	38.1277
5.	43.9294	77.9678	39.5570	36.7014
6.	99.2789	92.7408	81.8121	112.6618
7.	62.6298	69.3139	47.8963	16.7444
8.	24.1394	70.6180	21.5932	79.0825
9.	93.5323	106.3366	43.5004	50.3449
10.	72.6336	108.2121	32.8981	81.0524
11.	138.7769	67.1124	60.8273	75.7618
12.	80.7506	54.9543	59.8362	128.2972
13.	92.0996	73.1120	71.7822	45.4008
14.	34.4608	92.6436	29.1528	77.6266
15.		57.5570	156.3444	71.5681
16.		59.6896	88.4910	84.1459
17.		60.7360	62.2111	41.6778
18.		56.8521	18.3462	37.3695
19.		76.3880	42.8416	40.7188
20.		66.3788	21.8524	66.8421
21.		94.9525	37.7180	78.1929
22.		70.3537	36.0743	59.4753
23.		45.4411	28.7905	36.2975
24.		67.6327	34,7701	49.1031
25.		76.0423	45.4333	69.2226
26.			26.1862	50.5703

Table 39

Standard error of the estimate of four groups of ducklings for 12 weeks when second Degree Equation was fitted

No.	Desi males	Desi females	WP males	WP females
1.	75.5315	65.4986	59.0605	326.4560
2.	110.1429	69.2575	60.9739	88.5094
3.	173.3137	67.8161	49.8949	163.0248
4.	87.3331	267.6602	38.2391	121.0899
5.	95.9545	195.7322	50.3829	117.3133
6.	89.7634	111.1614	56.7970	125.9985
7.	90.0698	166.4069	35.1866	49.4475
8.	130.3472	71.0195	60.9854	182.2231
9.	107.1617	210.7106	103.6819	35.2626
10.	111.2460	185.0927	65.6569	46.8981
11.	95.6630	85.2042	146.3636	54.4541
12.	94.5610	132.8923	45.8542	102.7817
13.	97.0890	153.3225	55.6542	133.3686
14.	148.0969	192.5473	35.9254	196.4481
15.		150.1649	148.8638	49.9130
16.		175.2676	59.2823	80.7242
17.		102.8613	48.5230	83.9104
18.		83.4260	41.6548	79.1684
19.		79.2926	66.3074	132.6140
20.		50.4508	72.6976	89.1204
21.		220.8937	48.7046	59.2064
22.		177.0052	53.6709	73.6139
23.		90.4218	46.5974	52.3097
24.		243.0420	48.3253	134.0320
25.		189.7166	49.9431	57.1433
26.			38.1043	99.1878

Table 40

Square of the correlation coefficient (coefficient of determination) between observed and expected values of four groups of ducklings for 12 weeks when the Von-Bertalanffy curve was fitted

No.	Desi males	Desi females	WP males	WP females
1.	0.9771	0.9427	0.9867	0.9532
2.	0.9747	0.9533	0.9922	0.9888
3.	0.9680	0.9842	0.9674	0.9943
4.	0.9708	0.9858	0.9788	0.9937
5.	0.9647	0.9733	0.9718	0.9946
6.	0.9459	0.9466	0.9657	0.9659
7.	0.9730	0.9784	0.9854	0.9858
8.	0.9820	0.9432	0.9855	0.9818
9.	0.9753	0.9570	0.9943	0.9787
10.	0.9826	0.9276	0.9963	0.9824
11.	0.9672	0.9513	0.9917	0.9843
12.	0.9639	0.9813	0.9813	0.9176
13.	0.9590	0.9580	0.9784	0.9921
14.	0.9817	0.9595	0.9868	0.9842
15.		9780	0.8836	0.9692
16.		0.9813	0.9816	0.9746
17.		0.9700	0.9742	0.9952
18.		0.9650	0.9890	0.9948
19.		0.9484	0.9886	0.9955
20.		0.9584	0.9976	0.9914
21.		0.9608	0.9913	0.9520
22.		0.9686	0.9594	0.9874
23.		0.9650	0.9851	0.9866
24.		0.9820	0.9730	0.9945
25.		0.9798	0.9862	0.9690
26.			0.9937	0.9950

Table 41

Square of the Correlation Coefficient (Coefficient of determination) between observed and expected values of four groups of ducklings for 12 weeks when the second degree curve was fitted

No.	Desi males	Desi females	WP males	WP females
1.	0.9743	0.9776	0.9890	0.8163
2.	0.9522	0.9769	0.9949	0.9860
3.	0.9375	0.9805	0.9589	0.9454
4.	0.9500	0.8482	0.9896	0.9536
5.	0.9768	0.9019	0.9807	0.9635
6.	0.9688	0.9549	0.9812	0.9572
7.	0.9244	0.9141	0.9943	0.9568
8.	0.9481	0.9662	0.9817	0.9178
9.	0.9536	0.8972	0.9802	0.9888
10.	0.9637	0.8713	0.9889	0.9950
11.	0.9739	0.9629	0.9618	0.9913
12.	0.9654	0.9408	0.9935	0.9382
13.	0.9686	0.8940	0.9888	0.9532
14.	0.9389	0.8889	0.9899	0.9145
15.		0.9086	0.9024	0.9879
16.		0.9063	0.9955	0.9819
17.		0.9609	0.9848	0.9863
18.		0.9697	0.9878	0.9814
19.		0.9831	0.9902	0.9723
20.		0.9882	0.9862	0.9852
21.		0.9629	0.9957	0.9702
22.		0.8440	0.9477	0.9947
23.		0.9452	0.9864	0.9894
24.		0.8476	0.9882	0.9699
25.		0.8989	0.9945	0.9771
26.			0.9965	0.9829

Table 42

Analysis of variance of rates of growth based on Von Bertlanffy Equation for twelve weeks

Source	d.f.	MSS	F
Between groups	3	0.0478	50.9171**
Within groups	87	0.00092	

** Indicates significance at 1% level

CD for the comparison between

Groups	Desi males	Desi females	WP males	WP females	Mean be^{-k} value
Desi males		0.0201	0.0199	0.0199	0.6997
Desi females			0.0169	0.0169	0.6675
WP males				0.0167	0.7647
WP females					0.7459

Table 43

Parameters, Coefficient of determination (r^2) and standard error of the estimate (s) of the Growth curve fitted to the average body weight upto 12 weeks in the exponential form $y = ae^{bx}$

No.	Genetic group	a	b	r^2	s	Fitted Equation
1.	Desi males	65.8189	0.2713	0.9311	192.2346	$y = 65.8189 \exp (0.2713\ x)$
2.	Desi females	74.9940	0.2643	0.8752	244.8711	$y = 74.9940 \exp (0.2643\ x)$
3.	WP males	51.3660	0.2779	0.9426	142.0726	$y = 51.3660 \exp (0.2779\ x)$
4.	WP females	62.7081	0.2983	0.8954	295.5382	$y = 62.7081 \exp (0.2983\ x)$
5.	Desi ducks	71.6246	0.2668	0.8973	226.4729	$y = 71.6246 \exp (0.2668\ x)$
6.	Pekin ducks	57.1734	0.2891	0.9202	213.8537	$y = 57.1734 \exp (0.2891\ x)$

Table 44

Parameters, Coefficient of determination (r^2) and standard error of the estimate (s) of the Growth curve fitted to the average body weight upto 12 weeks in the modified exponential form $y = k + ab^x$

No.	Genetic group	k	a	b	r^2	s	Fitted Equation
1.	Desi males	-4428.3080	4406.7500	1.0179	0.9931	27.2762	$y = -4428.3080+4406.7500(1.1079)^x$
2.	Desi females	2426.4740	-2485.2600	0.9540	0.9844	43.3115	$y = 2426.4740-2485.2600\ (0.9540)^x$
3.	WP males	-248.7951	261.4310	1.1473	0.9954	21.8033	$y = -248.7951+261.4310\ (1.1473)^x$
4.	WP females	-695.5954	679.1788	1.1038	0.9953	31.3015	$y = -695.5954+679.1778\ (1.1038)^x$
5.	Desi ducks	4117.8960	-4162.5340	0.9758	0.9881	37.0013	$y = 4117.8960-4162.5320(0.9758)^x$
6.	Pekin ducks	-420.5439	420.7679	1.1259	0.9967	22.2852	$y = -420.5439+420.7679\ (1.1259)^x$

Table 45

Parameters, Coefficient of determination (r^2) and standard error of estimate (s) of the growth curve fitted to average body weight upto 12 weeks of Six groups of ducklings when Gompertz curve was fitted $y = ab^{c^x}$

No.	Genetic group	a	b	c	r^2	s	Fitted equation
1.	Desi males	1140.9350	0.0256	0.7840	0.9934	27.1346	$y = 1140.9350(0.0256)^{0.7840^x}$
2.	Desi females	1039.9080	0.0256	0.7407	0.9933	28.1024	$y = 1039.9080(0.0256)^{0.7407^x}$
3.	WP males	2307.8780	0.0138	0.8719	0.9924	28.9761	$y = 2307.8780(0.0138)^{0.8719^x}$
4.	WP females	2114.5660	0.0143	0.8272	0.9953	32.4552	$y = 2114.5660(0.0143)^{0.8272^x}$
5.	Desi ducks	1063.5950	0.0259	0.7555	0.9934	27.4707	$y = 1063.5950(0.0259)^{0.755^x}$
6.	Pekin ducks	2131.1280	0.1459	0.8476	0.9949	28.5039	$y = 2131.1280(0.1459)^{0.8476^x}$

Table 46

Parameters, Coefficient of determination (r^2) and standard error of the estimate (s) of the growth curve fitted to average body weight upto 12 weeks of six groups of ducklings in the Logistic form $y = \frac{k}{1 + 10^{b+cx}}$

No.	Genetic group	k	b	c	r^2	s	Fitted Equation
1.	Desi males	1412.8690	1.5747	-0.2169	0.9435	162.3944	$1412.8690/1+10^{1.5747-0.2169x}$
2.	Desi females	1299.7010	1.5193	0.2360	0.9470	153.2978	$1299.7010/1+10^{1.5193+0.2360x}$
3.	WP males	1371.5140	1.5376	-0.1669	0.9937	32.2365	$1371.5140/1+10^{1.5376-0.1669x}$
4.	WP females	1569.8190	1.6009	-0.2101	0.9922	51.1721	$1569.8190/1+10^{1.6009-0.2101x}$
5.	Desi ducks	1335.3320	1.5390	-0.2293	0.9450	158.0741	$1335.3320/1+10^{1.5390-0.2293x}$
6.	Pekin ducks	1438.7870	1.5605	-0.1912	0.9938	37.3429	$1438.7870/1+10^{1.5605-0.1912x}$

Table 47

Parameters, Coefficient of determination (r^2) and standard error of the estimate (s) of the Growth curve fitted to the average body weight upto 12 weeks in the Von-Bertalanffy form $y_t = A(1-be^{-kt})^3$

No.	Genetic group	b	k	r^2	s	Fitted Equation
1.	Desi males (A = 2000)	0.7858	0.1229	0.9750	62.6304	$y_t = 2000(1-0.7858\ \exp(-0.1229\ t))^3$
2.	Desi females (A = 1750)	0.7548	0.1400	0.9758	61.0716	$y_t = 1750(1-0.7548\ \exp(-0.1400t))^3$
3.	WP males (A = 3500)	0.8166	0.0727	0.9924	32.7318	$y_t = 3500(1-0.8166\ \exp(-0.0727\ t))^3$
4.	WP females (A = 3300)	0.8161	0.9916	0.9967	28.9756	$y_t = 3300(1-0.8161\ \exp(-0.9916t))^3$
5.	Desi ducks (A = 2000)	0.7605	0.1218	0.9747	62.5480	$y_t = 2000(1-0.7605\ \exp(-0.1218t))^3$
6.	Pekin ducks (A = 3500)	0.8158	0.0837	0.9962	27.7071	$y_t = 3500(1-0.8158\ \exp(-0.0837t))^3$

Table 48

Parameters, Coefficient of determination (r^2) and standard error of the estimate(s) of the growth curve fitted to the average body weight upto 12 weeks in the second degree form $y = a + bx + cx^2$

No.	Genetic group	a	b	c	r^2	s	Fitted equation
1.	Desi males	42.3207	4.4099	8.7428	0.9688	99.1225	$y = 42.3207+4.4099x+8.7428x^2$
2.	Desi females	77.0358	1.4926	9.1056	0.9357	133.2131	$y = 77.0358 + 1.4926x + 9.1056x^2$
3.	WP males	20.4062	5.4388	7.3927	0.9927	50.2407	$y = 20.4062+5.4388x + 7.3907x^2$
4.	WP females	56.7821	5.4172	10.3907	0.9825	82.9949	$y = 56.7821+5.4172x + 10.3907x^2$
5.	Desi ducks	64.5940	2.5386	8.9749	0.9258	119.8454	$y = 64.5940+2.5386x + 8.9749x^2$
6.	Pekin ducks	37.2087	5.5456	8.8897	0.9895	62.6464	$y = 37.2087+5.5456x + 8.8897x^2$

Table 49

Initial body weights (y_0) and 'b' values of Desi males and females by Rao's Method

No.	Desi males		Desi females	
	y_0	b	y_0	b
1.	37	28.6606	41	42.5676
2.	34	26.2629	36	44.8483
3.	36	32.4553	39	36.1854
4.	36	19.8882	40	57.5847
5.	37	28.6999	39	47.6965
6.	38	35.5934	35	52.6878
7.	34	19.5195	33	54.5785
8.	38	33.3988	40	41.6078
9.	40	26.3333	41	59.0886
10.	35	34.5357	40	59.1596
11.	40	31.4726	38	38.8841
12.	38	37.2155	40	43.5874
13.	37	29.7353	38	44.1581
14.	33	32.8098	40	55.3456
15.			35	44.1938
16.			38	46.2308
17.			37	41.1020
18.			40	34.9971
19.			41	39.3190
20.			34	37.1976
21.			39	58.1677
22.			35	29.1131
23.			38	31.4725
24.			39	52.5086
25.			38	56.4377

Table 50

Initial body weights (y_0) and 'b' values of WP males and females by Rao's Method

No.	WP males		WP females	
	y_0	b	y_0	b
1.	38	27.6569	38	62.0844
2.	38	37.5028	46	52.2269
3.	36	13.6291	36	60.6972
4.	39	18.8139	36	44.6451
5.	42	18.4368	38	50.5135
6.	38	35.7455	40	72.2034
7.	39	28.7355	30	12.9531
8.	41	12.5673	34	57.3173
9.	36	42.9014	35	30.9718
10.	34	36.9730	40	59.6710
11.	40	42.7112	42	56.5258
12.	40	33.5953	37	43.8288
13.	37	38.9261	36	52.1445
14.	33	19.0586	38	59.4676
15.	44	45.1920	38	40.5790
16.	40	50.3719	38	57.4716
17.	40	28.1126	40	59.1871
18.	36	12.0517	38	50.2868
19.	38	32.2240	38	61.2953
20.	44	31.1623	39	71.8568
21.	39	29.6141	40	34.1920
22.	37	13.9307	47	50.6504
23.	38	18.5596	40	31.3727
24.	40	16.1452	38	67.5662
25.	36	30.4285	38	37.1140
26.	42	23.0309	38	67.5279

Table 51

Analysis of Covariance of Initial body weight (y_0) and 'b' values by Rao's Method

Source	d.f	SS(x)	SP(xy)	SS(y)	Adjusted d.f.	Adjusted MSS	F
Between groups	3	39.8125	136.8125	9427.453	3	3063.431	
Within groups	87	650.6094	614.4375	10369.81	86	113.8318	26.912**
Total	90	690.4219	751.25	19797.27	89		

** Indicates significance at 1% level

CD for the comparison between

Groups	Desi males	Desi females	WP males	WP females	Mean 'b' values	Adjusted values $y_{10} - (x_{10} - X_{00})$
Desi males		7.0776	7.0286	7.0286	29.7571	31.1634
Desi females			5.9384	5.9384	45.9364	45.9098
WP males				5.8798	28.3723	27.8794
WP females					51.7062	51.4675

Regression estimate (b) $= 614.4375/650.6094 = 0.9444$

To test 'b'

$$F(1,86) = \frac{(614.4375)^2/650.6094}{113.8318} = 5.0977^*$$

Discussion

V. DISCUSSION

The results of the present investigation "Comparative study of growth pattern in ducks - A statistical approach" were given in Chapter IV. On the basis of these results the following discussions, conclusions and recommendations are made.

Based on the results of mean body weights and standard errors of the six groups of ducklings for the first seven days, it could be observed that the initial body weight was slightly higher for White Pekin (WP) males followed by Desi males. The standard error was least for WP males followed by Desi males. The initial mean body weight of Desi males and females were 36.6428 g and 38.16 g which were less than the 42.64 g and 43.33 g reported by Easwaran <u>et al</u>. (1984). The mean initial body weight of Desi duckling irrespective of sex was 37.6153 g which was also less than the mean body weight of 42 g reported by George <u>et al</u>. (1980). The mean initial body weight of WP duckling irrespective of sex was 38.4423 g which was also not in agreement with the findings of Kamar <u>et al</u>. (1971) and Majna <u>et al</u>. (1973).

The initial increase in body weight of the WP males were not maintained on the 7th day. On the seventh day, Desi females showed the highest mean body weight (63.28 g). While considering the ducklings irrespective of sex, Desi ducklings were on an average heavier than the WP ducklings, but the standard error was high for Desi ducklings compared to WP ducklings on the seventh day. While considering sex also Desi males and females were on an average heavier than WP males and females.

In the case of WP ducklings, there was a drop in the body weight on the second day. The decrease was noticed in the case of males and females also.

Based on the mean and standard errors of body weight of six groups of ducklings on weekly basis upto 12 weeks of age, it could be observed that on the 4th week, the body weight averaged 289.4285 g with a standard error of 21.1864 g in the case of Desi males and 345.6 g with a standard error of 26.7933 g for Desi females. These were not in agreement with the findings of Easwaran et al. (1984) The 8th and 12th week body weight was also less than the body weight reported by Easwaran et al. (1984). While considering the Desi duckling irrespective of sex the body weight averaged 1258.2051 g which was less than the mean body weight reported by Renchi *et al.* (1981). On the 12th week, Desi males were heavier than the Desi females.

In the case of WP males and females the mean body weight at 4th week were less than the mean body weight of the Desi males and females of the same age. But on the 8th week WP males showed an average body weight which was less than that of Desi males whereas WP females were heavier than that of Desi females. Same was the case on the 12th week. On the 12th week WP females were heavier than WP males.

While considering the WP duckling irrespective of sex, the 4th week body weight averaged 245.4807 g which was less than the mean body weight of 325.4359 g in the case of Desi ducklings and also the findings of Kamar *et al.* (1971) and Majna *et al.* (1973). On the 8th week Desi ducklings were on an average heavier than WP ducklings. The 8th week body weight was also not in agreement with the findings of Kamar *et al.* (1971) and Majna *et al.* (1973). On the 12th week, of Desi ducklings were heavier then the WP ducklings. The standard error was small for Desi ducklings compared to WP ducklings.

The analysis of variance of the initial body weight, body weightes at 4th, 8th and 12th week revealed that there was no significant difference in initial body weight of the four groups viz. Desi males, Desi females, WP males and WP females. But the 4th, 8th and 12th week body weights were significantly different for the four groups. The significance at the 4th week was due to the higher average body weight of Desi females whereas on the 8th and 12th week the significance was due to the higher average body weight of WP females compared to the other three groups. A plateau in body weight was not observed in the case of Desi and White Pekin groups on the 12th week of age. This indicate that the first 12 weeks do not cover the entire growth period of these two genetic groups.

From the exponential growth curve fitted to the four groups of ducklings viz. Desi males, Desi females, WP males and WP females on individual basis showed that the coefficient of determination was fairly large whereas the standard error of the estimate was higher for almost all ducklings. This indicates the lack of fit of the curve to the observed values. Based on the fitting of the same curve on the average basis, WP males showed higher value of r^2 (0.9426) and a high value of 'a' (142.0726). From the analysis of variance of the growth rate of the exponential curve, it was found that the four groups were significantly different in respect of growth. The growth rate was higher for WP females followed by WP males and least for Desi females.

The modified exponential fitted to the four groups of ducklings on the individual basis revealed that the coefficient of determination was very high for almost all ducklings and the standard error of the estimate (s) was comparatively less and thus indicating goodness of fit to the observed data. When the curve was fitted to the six groups viz. Desi males, Desi females, WP males, WP females, Desi ducklings irrespective of sex and WP ducklings irrespective of sex on an average basis observed that the coefficient of determination (r^2) was highest for WP ducklings irrespective of sex (r^2 = 0.9967) followed by WP males (r^2 = 0.9954). The standard error was least for WP males (s = 21.8033) followed by WP ducklings irrespective of sex (s = 22.2852). The analysis of variance of the growth rate revealed that WP males had a higher growth rate than WP females. This was just reverse of the findings on the basis of the exponential curve. The rate of growth was least for Desi males.

The Gompertz curve fitted to the four groups of ducklings on the individual basis showed that for almost all ducklings of the four groups, the coefficient of determination (r^2) was of the highest order and the standard error of the estimate was least. This indicates the goodness of fit of the curve. On the average basis, the curve showed a high value of r^2 (0.9953) for WP females followed by WP ducklings irrespective of sex (r^2 = 0.9949). The standard error of the estimate was least for Desi males (s = 27.1346) followed by Desi ducklings irrespective of sex (s = 27.4707). The analysis of variance of the growth rate on the basis of Gompertz curve revealed that there was significant difference between the growth rate of the four groups of ducklings. The rate of growth was maximum for Desi females and least for WP males.

Based on the Logistic curve fitted to the four groups of ducklings on the individual basis showed a large value of coefficient of determination (r^2) but the standard error of the estimate was high for almost all ducklings. This indicates that curve is a poor fit to the observed data. When the curve was fitted to the six groups on the average basis, the coefficient of determination (r^2) was high for WP males and WP ducklings irrespective of sex. The standard error was also least for these two groups.

The Von-Bertalanffy curve was also fitted to the body weight of the individual ducklings of the four groups. The coefficient of determination in this case was large for almost all ducklings and the standard error of the estimate was also small, and thus indicating goodness of fit to the observed values. When the curve was fitted to the average body weight of the six groups of ducklings, WP females showed a large value of coefficient of determination (r^2 = 0.9967) followed by WP ducklings irrespective of sex (r^2 = 0.9962). The standard error of the estimate was least for WP duckling irrespective of sex followed by WP females. The analysis of variance of the growth rate showed that the four groups were significantly different in respect of growth. WP males had a higher rate of growth followed by WP females. The rate of growth was least in the case of Desi females.

Based on the second degree equation fitted to the four groups of ducklings on individual basis the coefficient of determination was higher for all groups whereas the standard error of the estimate was very high for almost all ducklings. This indicates lack of fit of the equation to the observed data. When the curve was fitted on the average basis, WP males showed the highest value of r^2 (r = 0.9927) with least standard error (s = 50.2407).

Based on the analysis of the growth parameter estimate (b) as explained by Rao (1958) and by initial body weight (y_0) as concomitant variable it was found that there was significant relationship between initial body weight and the 'b' values. The analysis of covariance was conducted and was given in Table 51. It was found that the four groups were highly significantly different and the WP females had the maximum 'b' value followed by Desi females.

From the six curves viz. the exponential, modified exponential, Gompertz, Logistic, Von-Bertalanffy and second degree fitted to the six groups of ducklings on individual and average basis, it was found that the Gompertz, modified exponential and Von-Bertalanffy curves gave best fit to the six groups. The Gompertz curve gave best fit to Desi males, Desi females and Desi ducklings irrespective of sex whereas the modified exponential gave best fit to WP males and WP ducklings irrespective of sex. The Von-Bertalanffy curve gave best to WP females. The forms of the best fitted equations were given in Table 44, 45 and 47 along with the coefficient of determination and standard error of the estimate.

The graph of the two best fitted curves Gompertz and modified exponential were plotted along with observed values for five groups of ducklings except WP females and were shown in Figures 1, 2, 3, 5 and 6. For WP females Gompertz and Von-Bertalanffy curve were plotted along with observed values and were shown in Fig.4. The graphical representation also confirms the appropriateness of these curves viz. Gompertz,modified exponential and Von-Bertalanffy.

Among the three curves viz. Gompertz, modified exponential and Von-Bertalanffy, the Gompertz curve was consistently superior when the six groups were considered. Hence the general conclusion one can make is that the model suitable for fitting the trend of body weight in the case of ducklings irrespective of breed and sex, Gompertz is the best. The second best curve is the modified exponential.

The main recommendation of the study is that the Gompertz form is the best curve to fit the growth of body weight in ducklings in general. This is in agreement with the findings of Ricklefs (1973) for birds in general. Buffington (1973) and Ren-yu-Tzeng and Becker (1981) also suggested Gompertz curve for fitting the body weight data in broiler chicken.

Summary

SUMMARY

With a view to compare the rates of growth of two breeds of ducklings ie. Desi and White Pekin (WP) and to find out a suitable mathematical model to predict the body weight at different stages of growth, an experiment was initiated on May 31st, 1988. It consisted of 91 day old ducklings of which 14 were Desi males, 25 Desi females, 26 WP males and 26 WP females. Body weights of these ducklings were recorded for 12 weeks at weekly intervals along with daily weights for seven days. The ducklings were hatched and reared at Kerala Agricultural University Duck Farm, Mannuthy under same feed formula and identical management practices.

The initial body weights were 36.6328 g, 38.16 g, 38.6538 g, 38.3846 g. 37.6153 g and 38.4423 g respectively for Desi males, Desi females, WP males, WP females, Desi ducklings irrespective of sex and WP ducklings irrespective of sex. WP males showed a high initial body weight followed by WP females. Desi males showed the least initial body weight. While considering the two groups irrespective of sex, WP ducklings showed a higher mean initial body weight than the Desi ducklings.

Steady increase in body weight was noticed during the first 12 weeks. At the end of 12th week the mean body weights of the six groups viz. Desi males, Desi females, WP males, WP females, Desi ducklings irrespective of sex and WP ducklings irrespective of sex were 1291.7857 g, 1239.4 g, 1021.7308 g, 1401.6154 g, 1258.2051 g and 1214.6154 g respectively. In the case of WP ducklings, females were on an average heavier than males in all the 12 weeks whereas in the case of Desi ducklings, females maintained their high body weight upto 10th week of age. While considering irrespective of sex, Desi ducklings were on an average heavier than WP ducklings at 12th week of age.

The analysis of variance of the initial body weight and body weight at 4th, 8th and 12th weeks showed that there exist no significant difference in initial body weight. The difference in body weight between groups started from 4th week onwards. On the 4th, 8th and 12th weeks non-significant difference in body weight was obtained for males and females of Desi group whereas in WP group it was significant.

To depict the pattern of growth and to predict body weight at different ages, exponential, modified exponential, Gompertz, Logistic, Von-Bertalanffy and second degree curves were tried.

Among the above six curves fitted, Gompertz, modified exponential and Von-Bertalanffy gave best fit to the data on individual and on average basis. The graphical representation of the fitted curves also confirms the appropriateness of these curves. The Gompertz curve gave best fit to the Desi males, Desi females and Desi ducklings irrespective of sex. The analysis of variance of the growth rate (b^c) when the Gompertz curve was fitted showed significant difference between groups. The modified exponential gave best fit to WP males and WP ducklings irrespective of sex. The analysis of variance of the growth rate (b) showed significant difference between groups. The Von-Bertalanffy curve gave best fit to WP females. The analysis of variance of the growth rate (be^{-k}) showed significant difference between groups.

By the method of Rao (1958) the growth rate estimate (b) were calculated for each group. The 'b' values had significant relationship with the initial body weight (y_0). Hence the analysis of covariance of 'b' values taking initial body weight (y_0) as concomitant variable was conducted. The four groups were significantly different and the WP female showed the maximum growth rate.

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COMPARATIVE STUDY OF GROWTH PATTERN IN DUCKS - A STATISTICAL APPROACH

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ABSTRACT OF A THESIS

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ABSTRACT

An investigation based on 14 Desi males, 25 Desi females, 26 White Pekin (WP) males and 26 WP females belonged to the Kerala Agricultural University Duck Farm, Mannuthy was undertaken (i) to examine the pattern of growth in the two breeds of ducks (ii) to compare the rates of growth between and within each genetic groups and (iii) to fit appropriate growth curves for prediction of body weight at different stages of growth.

The ducklings were reared under uniform feed formula and identical management practices. The initial mean body weights of the six groups of ducklings viz. Desi males, Desi females, WP males, WP females, Desi ducklings irrespective of sex and WP ducklings irrespective of sex were 36.6428 g, 38.16 g, 38.6538 g, 38.3486 g, 37.6153 g and 38.4423 g respectively. Females in each genetic groups had a higher mean body weight than males except 11th and 12th week in the case of Desi ducklings. On the 12th week the body weight averaged 1291.7857 g, 1239.4 g, 1021.7308 g, 1401.6154 g, 1258.2051 g and 1214 g for Desi males, Desi females, WP males, WP females, Desi ducklings irrespective of sex and WP ducklings irrespective of sex respectively.

The initial body weight was non significant for all the four groups whereas the 4th, 8th and 12th week body weights showed significant difference between groups.

It could be observed that a plateau in body weight was not attained on the 12th week of age for Desi and White Pekin ducklings.

Gompertz ($y = ab^{c^x}$), modified exponential ($y = k+ab^x$) and Von-Bertalanffy ($y_t = A(1-be^{-kt})^3$ were found suitable for fitting body weights for the first 12 weeks. The first two gave good fit to almost all birds on individual and average basis.

When the growth rates of the fitted curves were compared, Gompertz curve showed significant difference between groups. The maximum growth rate was noticed in Desi females. Based on modified exponential and Von-Bertalanffy the rate of growth was significant and maximum growth was noticed for WP males. By the method of Rao (1958) the initial body weight had significant relation with the growth rate (b). The rate of growth was maximum for WP females followed by Desi females. The graphs of the best fitted curves - Gompertz, modified exponential and Von-Bertalanffy were drawn for all the six groups along with the observed values and that also confirms the above findings.