DEVELOPMENT OF A SUITABLE MODEL FOR ASCERTAINING THE GROWTH AND EGG PRODUCTION IN QUAILS

By

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THESIS

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requirement for the degree of

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1991

DECLARATION

I hereby declare that this thesis entitled **"Development of a suitable model for ascertaining the growth and egg production in quails"** 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.

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CERTIFICATE

Certified that this thesis entitled **"Development of a suitable model for ascertaining the growth and egg production in quails"** is a record of research work done independently by **Mr. John Thomas M.** 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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JOHN THOMAS, M.

Dedicated to my father

CONTENTS

Introduction

INTRODUCTION

Coturnix Japanese quail belongs to the class Aves, family Phasianidae and genus coturnix and is named Coturnix coturnix Japonica. The Bobwhite quails belong to a different family. Coturnix were either domesticated in Japan about the 11th century or brought to Japan from China about that time. The male of this species is lighter than female and is identified by the cinnamon coloured feathers on the upper throat and lower breast region. The female is similar to male in colouration except that the feathers on the throat and upper breast are long, pointed and much lighter in cinnamon. Japanese quails are prolific layers and have showed that under tropical conditions quails mature by about 7 to 8 weeks of age and reach peak production by about 10 weeks. Under favourable environments (temperature, humidity, day light) they produce for long periods and averaging 250 eggs per year. The weight of egg is approximately 10 g (6.7 to 13.8 g). The eggs are multicoloured ranging from dark brown-blue and white to buff each heavily mottled with black, brown and blue. Adult males weigh about 151 g (116 to 190 g) and females weigh about 166 g (130 to 200 g) at 10th week of maturity.

Quails in general are easy to rear needing comparatively smaller area for its rearing. Feeding is also very easy and less costly. It is generally disease free in comparison to poultry as a whole. Normally one quail egg cost about 50 paise in market. Quail egg and meat are considered to be of high medicinal value and hence it is more dear among the common people. By taking all these points into account it is very much economically viable for a lower middle class family to rear about 50 quails in their limited resources.

Very few studies were undertaken in the past with regards to body weight and egg production models in quails. The only available reference in literature at present are Laird (1965), Marks (1978), Ricklefs (1979), Kozaczynski (1985), Ricklefs (1985), Anthony *et al.* (1986). Laird (1965) has fitted only a Gompertz curve for the growth pattern which he has not compared with any other model. Except Ricklefs (1979, 1985) none of them contributed much towards the development of suitable models for ascertaining the growth in quails. Since Ricklefs (1979) fitted logistic form for growth of Japanese quail and Ricklefs (1985) fitted Gompertz form, it was worth investigating the exact model for ascertaining the growth in quails. With regard to egg production models in quails no reference was available and hence it was also worth developing a suitable model for this purpose.

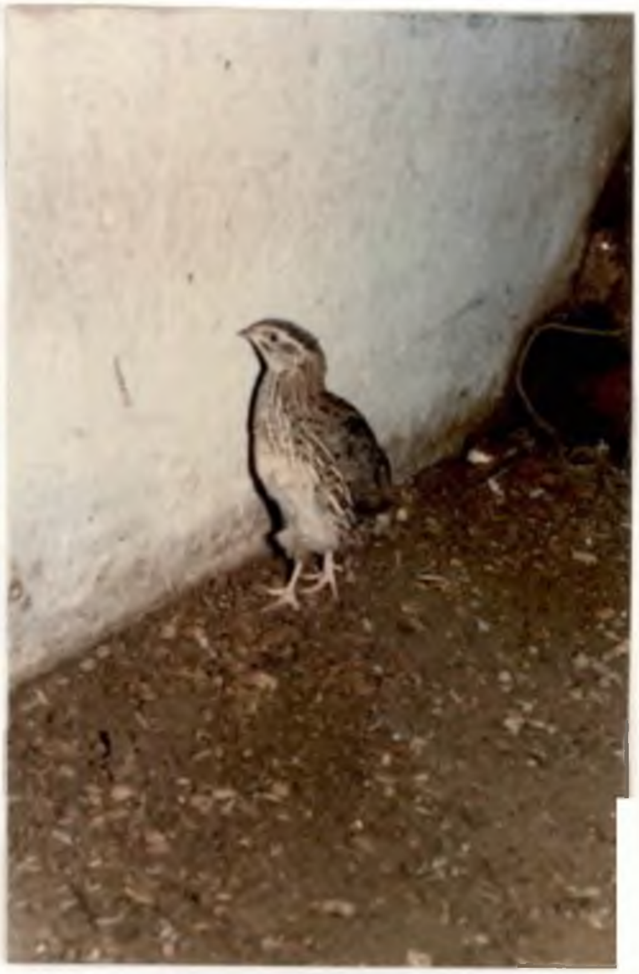
A study of growth curve may indicate the earliest age at which reliable prediction of adult weight may be made. Similarly the egg production also can be predicted through suitable mathematical models. Under this situation it was thought useful to develop suitable models for ascertaining growth and egg production in quails with the following objectives.

1. To find a suitable relationship between age and body weights.
2. To investigate the trend of egg production in quails through suitable mathematical models.
3. To study the impact of climatic elements (temperature, humidity) on egg prduction in quails.

With this study in view an experiment has been conducted on Japanese quails. Under this experiment 150 day old birds of same breed were hatched at the Kerala Agricultural University Poultry Farm. The birds were kept under homogenous conditions and were fed as per the package of practices recommended by KAU. Weekly body weights, daily egg production and daily climatological parameters were observed. This data has been used for development of suitable models.

Male

Female



Quail eggs

Review of Literature

REVIEW OF LITERATURE

2.1 Growth studies

Growth curves reflect the life time inter relationship between an individual's inherent impulse to grow and mature in all body parts and environment in which these impulses are expressed. Knowledge of growth curves is important to all biologists regardless of specialisation, who are concerned with the effects of their research and recommendations on life time production efficiency. Development of the theory and techniques for fitting growth curves may be traced both through time and scientific disciplines. In particular the theory and methodology of fitting growth curves owes much to the mathematicians, demographers and economists. A review of growth curve analyses in the chicks, ducks, quails and other avian species are presented here.

2.1.1 Growth studies (General)

Gompertz (1825) (See Winsor, 1932) developed a model $W_t = W_\infty \exp[-(\text{In}W_\infty - \ln w_{t'}) \exp(-k(t-t')]$ which is obtained by integrating the differential equation in terms of natural logarithm with respect to t

$$dW_t/dt = kW_t(\ln W_\infty - W_t)$$

where, W_∞ = maximum weight, W_t = weight at time t,

k = proportionality of growth rate constant

Ludwig (1929) pointed out that most of the equation representing growth can be reduced to four types. With k standing for a constant, t for time, W for body weight, A_t for time at completion of growth and A_w for final weight, these four types can be expressed as follows:

$\phi = k(A_t - t)$ when rate of growth is considered proportional to the time remaining for completion of growth.

$\phi = k(A_w - w)$ when rate of growth is proportional to the weight to be gained.

$\phi = (k/t)$ when rate of growth is inversely proportional to the elapsed time.

$\phi = (k/w)$ when rate of growth is inversely proportional to the weight already attained.

Bertalanffy (1938, 1949, 1957) outlined a general theory of organic growth. Bertalanffy's differential equation is given by

$dw/dt = aw^m - bw$; a, b, m are constants.

Integrating, the function yielded the following growth curves

$$W = \left(\frac{a}{b} - \left(\frac{a}{b} - W_o^{1-m} \right) \exp(-b(1-m)t) \right)^{1/1-m}$$

where, W_o is weight at time $t = 0$.

when $m = 0$,

$$W = \frac{a}{b} - \left(\frac{a}{b} - w_o \right) \exp(-bt)$$

which is monomolecular or modified exponential.

when $m = 2$,

$$W = 1/\left(\frac{a}{b} - \left(\frac{a}{b} - w_o \right) \exp(-bt) \right)$$

which is autocatalytic or logistic curve.

when $m = 1$,

the original differential equation gives

$W = w_o \exp[(a-b)t]$ which is exponential.

Under certain important assumption on constants and letting $m \rightarrow 1$, this differential equation tends to Gompertz equation of the form

$$W \rightarrow A \exp[B \exp(kt)]$$

where, $A \rightarrow (a/b)^{1/1-m}$, $B = \log(A/w_o)$, $K \rightarrow b(m-1)$

Medawar (1940) pointed out that a growth curve would be of little interest to biologists if data representation were, its only function. The value of a growth curve lies in its potential for bringing out relationship which are not obvious from the data alone. This potential depends upon the correlation of the magnitude of growth curve parameters with significant experimental or biological conditions.

Brody (1945) defined two independent growth curves. One is based on the tendency for instantaneous rate of gain, prior to puberty or the point of inflection to be proportional to growth already made and is described by the differential equation

$$dW_x/dx = kW_x \quad \text{-----------------} \quad (2.1.1)$$

where, k = proportionality or growth rate constant

W_x = weight of animal at time x

Rearranging equation (2.1.1) and then integrating with respect to x from t' to t he obtained

$$W_t = W_o \exp(kt)$$

where, W_o is initial body weight

Following puberty the rate of gain tends to be proportional to the gain yet to be made and is described by the second equation

$$dW_x/dx = -k'(w_\infty - w_x) \qquad \text{-----------} \; (2.1.2)$$

where, k' = growth rate constant and W_∞ = maximum weight.

Rearranging equation (2.1.2) and integrating with respect to x from t' to t_o he obtained

$$W_t = W_\infty - (w_\infty - w_o)\exp(-k't)$$

when $t' = 0$

where, t' is the initial time.

In 1838, Verhulst (See Allee *et al.*, 1949) developed an equation to describe population growth and termed the function for this S-shaped curve the logistic function.

The equation for rate of gain, from which the logistic function was derived is,

$$dW_x/dx = kW_x(W_\infty - W_x)/W_\infty \qquad \text{------------} \; (2.1.3)$$

which indicates that the instantaneous rate of gain is a function of growth already made and potential for growth.

Rearranging equation (2.1.3) and then integrating, using partial fractions between t' and t with respect to x, we obtain

$$W_t = W_\infty(1+((w_\infty/W_{t'})-1)\exp(-k(t-t')))^{-1} \qquad \text{-------} \; (2.1.4)$$

Equation (2.1.4) relates weight at a given time to a function of initial and final weights, growth rate constant and time.

Richards (1959) used an extended form of Von Bertalanffy's growth function

$$W = \left(\frac{\eta}{k} - \left(\frac{\eta}{k} - w_o^{1-m} \right) \exp(-(1-m)kt) \right)^{1/1-m} \qquad (2.1.5)$$

(which is sigmoid) to plant data for supplying an empirical fit. Here W_o = weight at $t = 0$; η (eta), k (kappa) are proportionality constants of anabolism and catabolism.

m = slope of Von Bertalanffy's relation.

Equation (2.1.5) can be abbreviated as

$$W^{1-m} = A^{1-m} - \beta \exp(-k't) \qquad \text{-------} \ (2.1.6)$$

where, $A^{1-m} = \eta/k$; $\beta = (\eta/k) - w_o^{1-m}$; $k' = (1-m)\,k$ are constants.

Therefore,

$$W^{1-m} = A^{1-m}\,(1-b\exp(-kt)) \text{ when } m < 1 \qquad \text{-------} \ (2.1.7)$$

$$= A^{1-m}\,(1+b\exp(-kt)) \text{ when } m > 1 \qquad \text{-------} \ (2.1.8)$$

where, $b = \pm \beta A^{m-1}$

when $m = 0$, equation (2.1.7) reduces to monomolecular form $W = A(1-b\exp(-kt))$ and when $m = 2$ equation (2.1.8) reduces to the autocatalytic form $W = A(1+b\exp(-kt))^{-1}$

When $m = 1$ equation (2.1.6) is insoluble.

When m lies between 0 and 1 the curves are transitional in form between the monomolecular and Gompertz and when m lies between 1 and 2 the curve lie between Gompertz and autocatalytic. It was derived that as $m \to 1$ equation (2.1.5) represents the Gompertz equation

$$W = A\exp(-b\exp(-kt))$$

where, W = size at time t, A = ultimate limiting value,

k = constant of catabolism (kappa)

The absolute growth rate for (2.1.5) is given by

$$kW((A/W)^{1-m} - 1)/(1-m) \qquad \text{-----------} \quad (2.1.9)$$

when $m = 0$, (2.1.9) reduces to the growth rate of monomolecular function $k(A-W)$ and when $m = 2$ equation (2.1.9) reduces to growth rate of autocatalytic function $kW(A-W)/A$

Equation (2.1.9) becomes $kW\log_e(A/W)$ which is growth rate of Gompertz function. Here k is the "rate constant" which determines the spread of curve along time axis.

Nelder (1961) developed a logistic function

$$W_t = W_\infty(1+ ((W_\infty /W_{t'})^{1/\theta}-1) \exp(-k(t-t')/\theta))^{-\theta}$$

by integrating the differential equation

$$dW_x/dx = kW_x(1-(W_t/W_\infty)^{1/\theta} \qquad \text{------------} \ (2.1.10)$$

which is a generalization of logistic function given in differential equation form

$$dW_x/dx = kW_x \ (1-(W_x/W_\infty)) \qquad \text{------------} \ (2.1.11)$$

suggested by Verhulst (1838) (see Allee *et al.* 1949)

Here W_∞ = maximum weight, W_x = weight of animal at time x

An advantage of Nelder's (1961) generalized logistic function is that when $u = 1/\theta \# 1$, the curve is asymmetrical and is more flexible.

Nelder (1962) (on reparameterization of Nelder (1961)) developed a logistic model of the type

$W_t = W(1+((W_\infty /W_{t'})^u-1) \exp(-uk(t-t')))^{-1/u}$ which is obtained by integrating the differential equation $dW_x/dx = kW_x(1-(W_t/W)^u)$ between t' and t with reference to x and letting $u = 1/\theta$

Fabens (1965) gave properties and fitting of the Bertalanffy growth curve. He also developed a weight-growth curve,

$$W = (a\ (1-b\ \exp(-kt)))^3$$

to recapture data as well as conventional age-size data. A computer programme is also presented to fit the curve,

where $a = q\eta/\varkappa$, $b = 1-\varkappa c/q\eta$, $k = \varkappa/3$

η = anobolic constant, $\varkappa$ = catabolic constant,
q = constant characteristic of taxon,
W = weight of animal
$c = a(1-b)$

The weight growth curve has an inflection point at $W = 8a^3/27$.

Bhattacharya (1966) generalized the growth function suggested by Von Bertalanffy as

$$y = (\alpha + \beta\gamma^t)^\delta$$

where, α, β, γ and δ are parameters.

The equation reduces to modified exponential when $\delta = 1$, logistic equation when $\delta = -1$, Gompertz equation when $\delta \to \infty$

Laird *et al.* (1968) used a growth equation of the Gompertz type

$$W = W_o \exp\left(\frac{A_o}{\alpha} (1-\exp(-\alpha t))\right); \quad A = A_o \exp(-\alpha t)$$

where, W = weight (or size in any other volumetric terms) at time t, W_o = initial weight at the start of the period of observation; A_o and A are specific growth rates at the starting time and at time t respectively, α = rate of exponential decay of A_o for representing the growth of individual parts of organism and of the whole organism.

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

Turner *et al.* (1976) introduced a general theory of growth which gave the following growth rate equation,

$$X = (\beta / k^n)\, x^{1-np}\, (k^n - x^n)^{1+p}$$

where, x = size of the system at time t, k = size at $t = \infty$ and β, n, p are parameters determining the particular characteristic of given curve.

Pruitt and Turner (1978), Turner and Pruitt (1978) have proved that general theory of growth is useful in numerical analysis of many and diverse biological and biochemical processes. The range of applicability of the theory is illustrated by the fact that it yields

1. the logistic curve $(1+\exp(-\beta(t-\tau)))^{-1}$ with point of inflection 1/2

2. the Gompertz $\exp(-\exp(-\beta-(t-\tau)))$ with point of inflection 1/e

3. Bertalanffy-Richards function

   $(1+\exp(-n\beta(t-\tau))^{-1/n}$

with point of inflection $(1+n)^{-1/n}$.

Here τ is constant of integration and is growth curve parameter.

Pruitt *et al.* (1979) developed the generic growth curve $(1+(1+np\beta(t-\tau))^{-1/p}))^{-1/n}$ whose point of inflection is given by $((1-np)/(1+n))^{1/n}$

where n and p are shape parameters, β is maximum specific growth rate, τ is the constant of integration and reported that the analysis of growth in terms of the generic growth curve can be a powerful technique leading to relationships which may not be apparent from the growth data alone.

2.1.2 Growth studies in chicks

Lerner (1939) observed that the curve form $W = bt^a$ is not entirely satisfactory for representing the growth of a chick but has been very widely used with many excellent results for limited portions of growth curve.

Here W = weight at time t, a and b are constants.

The first derivative of this equation is

$$dW/dt = u = ab\ t^{(a-1)}$$

Sang (1962) used the logistic function,

$$W_t = A/(1 + \exp(c-kt))$$

to analyse mean growth rate of selected lines of Brown Leghorns and found no sizeable differences among growth rates (k values) for six lines of chickens.

Roberts (1964) used a special case of the polynomial, a simple power function in time, to fit a linear portion of the early growth curve from hatching to seven weeks of age. He estimated the exponent of a function in the form

$$W_x = ax^k$$

Where W_x = weight at time x, a = initial weight, k = early growth rate. The method was to take ratios of consecutive weights and solve for weekly k's in each individual using the equation

$$k = \log (w_2/w_1)/\log (x_2/x_1)$$

Average values for k in four different lines, over the seven weeks showed significant differences between lines and sexes when data were subjected to an analysis of variance.

Tanabe and Sacki (1964) working with pure and crossbred chicken from hatching to ten weeks of age, used the time function

$$W_x = ax^k$$

to estimate the values of k (early growth rate for each sex based on the log transformed function

$$\log W_x = \log a + k \log x$$

Here W_x = weight at time x, a = initial weight. In both the pure and crossbred lines, males and higher k value than females of same breed.

Krause *et al.* (1967) fitted the logistic function

$$W_t = \beta(1 + \alpha \exp(- \gamma t)^{-1}$$

to juvenile body weights of Athens-Canadian randombred chickens taken at 4 day intervals from 20 to 140 days of age.

Here $\beta = w_\infty$ = maximum weight, $\alpha = (w_\infty / w_{t'})-1$, $w_{t'}$ = weight at initial time t', $\gamma = k$ = proportionality or growth rate constant.

Pillai *et al.* (1969) while studying growth rate of chickens from six different crosses found that simple exponential function w = A exp(kt) yielded a very good fit. Here A, k are constant, w is the weight at time 't'.

Lilljedhl (1970) used a mathematical function of the logistic type

$$Y = (A + B \exp(KX))/(1 + C \exp(KX))$$

to give information about the growth of broiler chickens.

Here y = body weight, X = age.

All the four parameters A, B, c and K were 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 difference 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 growth rates maximum, the corresponding inflection weight and proportion of body weight at slaughter (56 days) attained at the point of inflection (growth rate maximum) were derived. Also it was found that growth rate increased upto maximum of 29 g to 45 g per day - more in males than in females and it decreased subsequently. The maximum occurred between 36 and 48 days later in males than in females.

Zelenka (1970) while studying growth of chicken during the early period of post embryonal life used exponential function.

$$w = a \exp(kt)$$

where, w = weight at time t; a, k are constants and the power function $y = at^b$ to calculate growth from 2 to 22 days of age in 40 cockerals and 90 chicks of both sexes.

Tzeng and Becker (1981) used Gompertz model (Laird, 1965)

$$W_t = w_o \exp(\frac{L}{k} (1-\exp(-kt)))$$

in their study related to growth and found that it gave excellent fit to the live weight data as also the abdominal fat weight. Here W_t = weight of the broiler or its part at time 't', dw/dt = $L.w_t \exp(-kt)$ = absolute growth rate. Other forms of non linear curves considered were logistic curve,

$$W_t = A (1 + \exp(-kt))^{-m} \text{ and}$$

Von Bertalanffy

$$W_t = A (1-B \exp(-kt))^3$$

where, A, B, K and m are parameters.

Grossman and Bohren (1982) in their study of "Comparison of proposed growth curve functions in chicken" contradicted the claim that growth in chicken is best described by any one of the growth functions but rather that under some set of environmental conditions one function should be able to describe accurately growth in chickens.

By describing overall body growth as a function of its components one should be able to have a better understanding of the growth characteristics and their relationships and be able to develop breeding plans to select for desirable aspects of the growth curve.

Jacob and Surendran (1984) observed that curves of the form

$$y = a \exp(bx) \text{ (exponential)}$$

$$y = ab^{c^{x}} \text{ (Gompertz)}$$

were suitable in fitting body weights for 24 weeks.
where 'y' is body weight at age x.

Grossman *et al.* (1985) used the logistic function model

$$W_t = W_\infty(1 + (\frac{W_\infty}{W_o} - 1) \exp(-kt))^{-1}$$

for comparative purposes in two populations of chickens from hatching through 45 week of age. Here W_t = weight at time t, k = growth rate constant, w_o = initial weight, w_∞ = maximum weight.

Grossman and Bohran (1985) used the logistic function

$$W_t = (1 + \exp(-a(t-\mu)/\sigma))^{-1}$$

where W_t = weight at time 't',

to determine whether two parameters of logistic growth function, growth rate constant

$$K = \frac{a}{\sigma} \quad \text{where, } a = \pi / \sqrt{2}$$

and age at inflection point (μ) were inherited traits in chickens.

Knizetova *et al.* (1985) expressed the growth of chickens with widely different genetic growth abilities by means of four parameters Richards function (Richards, 1959)

$$Y_t = A\ (1 \pm b \exp(-kt))^{-1/n})\ n > -1;\ n \neq 0;\ A,\ k > 0$$
$$Y_t = A\ (1 + b \exp(-kt))^{-1/n} \text{ for } n > 0$$
$$Y_t = A\ (1 - b \exp(-kt))^{-1/n} \text{ for } n < 0$$

The parameters estimated using the generalized least squares method are the following.

Y_t = body weight (grams) at age t (days)

A = asymptotic value of size as $t \rightarrow \infty$; generally interpreted as average size at maturity independent of short term fluctuation of size in response to extraneous environmental effects.

b = integration constant, time scale parameter of no specific biological significance.

k = rate at which logarithmic function of degree of maturity in body weight changes linearly per unit of time (maturity index), this rate estimates the maturation rate of curve (i.e. the relative rate at which A is reached).

n = shape parameter determining the position of the inflection point of the curve. In the original Richards function, it was designed as m (m = n+1) and by other authors as (M = -1/n), and established the degree of maturity in body weight at the point of inflection.

Tierce and Nordzkog (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, x = body weight at 20 weeks of age, α, β are growth constants.

Indirabai *et al.* (1985) reported that growth curves of the form

Y = a + bx (linear), y = a exp(bx) (exponential) were suitable for predicting the pattern of growth in broiler chicken.

Here y is body weight at age x.

Ibe and Nwakalor (1987) fitted an allometric growth curve of the form $y = \alpha W^{\beta}$ in broiler chicken, where w = body weight, y = linear structural body parameters.

Grossman and Koops (1988) examined the growth of chickens with the help of multiphasic growth function based on a sum of logistic functions to describe mean body weight gain curves for four lines of chickens and to estimate number of phases and values of parameters within each phase. The function is of the form

$$Y_t = \sum_{i=1}^{n} (a_i\ (1 + \tan h\ (b_i\ (t-c_i))))$$

with first derivative at age t as

$$Y_{t'} = \sum_{i=1}^{n} (a_i b_i\ (1-\tan h^2\ (b_i(t-c_i))))$$

where y_t = mean weight (grams) at age t, n = number of phases, tan h = hyperbolic tangent, a_i = half asymptotic weight, b_i = growth rate relative to a_i (week^{-1}), c_i = age at maximum gain (weeks).

Study revealed that a diphasic function is appropriate to fit weight gain data for male and female chickens.

2.1.3 Growth studies in ducks

Susaki and Hamakawa (1965) while studying the growth of broiler ducks 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.

2.1.4 Growth studies in quails

Laird (1965) fitted the Gompertz equation to growth curves of several varieties of domestic chicken, turkey, goose, duck and quail.

Marks (1978) utilized four quail lines (P, T, S and C which is maintained as a non selected control) to investigate growth patterns in quail. Body weight measurements suggested that the growth of all lines was best approximated by the logistic growth curve model

$$y = A/(1 + \exp(-k(x-T_i)))$$

where, y = weight at age x, k = constant proportional to overall growth rate, T_i = age at inflection, A = asymptotic weight

Ricklefs (1979) studied the patterns of growth development in Japanese quail, Common turn and the Starling. It was observed that the growth rate varied inversely with functional maturity. The starling grows 4 times and the Turn two and a half time more rapidly than quail. Growth rate of each species was determined by fitting the growth curve by a logistic equation.

$$W(t) = A/(1 + \exp(-k(t-t_i)))$$

where W(t) = weight at age t, A = asymtote or weight plateau of growth curve, k = growth rate constant, t_i = age at inflection point of growth curve (the point of maximum growth rate).

Ino *et al.* (1985) observed that at 2, 4, 6, 8, 10 and 12 week of age, the body weight of unspecified number of Japanese quails averaged 35.4, 75.3, 94.0, 96.7, 100.6 and 102.0 g respectively in male V/s 36.1, 77.9, 109.0, 118.6, 122.3 and 125.5 g in females. Age at sexual maturity averaged 35.9 and 44.8 days in male and female respectively.

Kozaczynski (1985) used the data obtained from 129 males and 151 females Hungarians, 68 males and 101 females Pharroh x Hungarian, 26 males and 33 females PAN, 92 males and 120 females BEK Japanese quails.

For the 4 breed types the body weight at 12 week of age averaged 152.4, 151.1, 151.9 and 147.9 g for males and 187.8, 181.5, 181.8 and 181.0 g for females respectively. Growth rate was highest from 7 to 21 days of age and lowest from 70 to 84 days. Correlation between body weight at various ages were mostly significant and ranged from 0.19 to 0.95. Hungarian quails matured earlier than the other 3 types.

Ricklefs (1985) observed that growth curves of selected and unselected lines of broilers and Japanese quail show that the chicks respond to selection for 8 weeks or 4 week body mass respectively, by increasing the exponential growth rate during the first 2 weeks after hatching. The Gompertz equation used was of the form

$$M(t) = A \exp(-\log(A/I) \exp(-kt))$$

Here, $M(t)$ = Mass (g) at age t, A = mass plateau in grams (Asymptote), k = rate of attainment of asymptote (unit = 1/time), I = initial mass at age zero.

$$\log M(t) = \log A - \log(A/I) \exp(-kt)$$

$$\begin{aligned}\frac{d}{dt}(\log M(t)) &= \log(A/I)\, K \exp(-kt) \\ &= k \log(A/M) = k(\log A - \log M)\end{aligned}$$

Anthony *et al.* (1986) have studied the growth curves of Japanese quails as modified by divergent solution 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 fits the growth pattern of the low weight category. Also he observed that the pattern of growth of both the sexes were identical.

Sreenivasaih *et al.* (1987a) reported an initial average body weight of 100 Japanese quails (Monsoon hatch-August) as 5.74 g and the birds attained an average body weight of 117.27 g at 88 days (12.57 weeks) of age. The initial average body weight of 60 Japanese quails (WInter hatch-November) was 6.02 g and the birds attained an average body weight of 126.74 g at 88 days (12.57 weeks) of age.

2.2 Egg production studies

Mathematical models play a dominant role in poultry egg production. Models relating to egg production over time help in the prediction of egg production in certain time intervals or total egg production during any period. Also, from such models one can determine optimum time interval at which production is maximum.

Earlier workers (McNally, 1971; Timmermans, 1973) while trying to fit mathematical models for egg production employed the same models that were found to fit milk-yield at different lactation. One of the reasons for this is that milk yield and egg production both reach a peak and then onwards start declining.

A brief review of the works conducted are presented here.

Brody *et al.* (1923) employed the exponential curve

$$Y = a \exp(-bt)$$

to describe average lactation course of a large number of cows of different breeds.

Here y = average weekly or fortnightly milk yield, t = time, a, b are constants. They observed that the equation failed to fit the data remarkably well.

Sikka (1950) made an attempt to see whether the parabolic exponential equation

$$y = a \exp (bt + ct^2)$$

would represent the lactation curve better. Here y = average weekly or fortnightly milk yield, and a, b, c are constants.

Narain (1962) studied three day egg laying of *Drosophila melanogaster* at various intervals throughout the life time. It was described that the decline in egg production of *D. milanogaster* from Nai-Basti (in India) by the model

$$N(t) = 66.56 \exp(-0.029\ t)$$

where $N(t)$ is daily egg production corresponding to day of egg laying.

Wood (1967) fitted a gamma type function

$$y = at^{b} \exp(-ct)$$

to the lactation yield. The function accounted for 89.7 per cent of total variation in log daily yield. The function accounted for 89.7 per cent of total variation in log daily yield.

Tonkinson *et al.* (1969 b) suggested to use principal component analysis technique for the evaluation of egg production curves. The technique requires the computation of characteristic roots and vectors from the matrix of corrected sum of squares and cross products originating from the data matrix. The technique partitions the total variations of egg production curves with sets of independent derived responses. These responses are analysed by conventional ANOVA techniques for estimates of treatment, replicate and interaction effects. The curves can be reconstructed based upon the derived responses for visual interpretation of the analysis of variance results.

McMillan *et al.* (1970 a) used the mathematical model

$$N(T) = M(1-\exp(-\xi(T-T_{o}))) \exp(-\alpha T)$$

to estimate the daily egg production of a Drosophila female whose production curve closely related to the curve of laying hens.

Here N(T) = number of egg laid in period T, M = the potential maximum egg production per period, T_o = the initial period of egg laying, ξ = the rate of increase in egg laying, α = rate of decrease in egg laying.

McMillan *et al.* (1970 b) calculated parameters of egg production model

$$N(t) = M(1-\exp(-\xi(t-t_o)))\exp(-\alpha t)$$

(McMillan *et al.* 1970 a)

of *Drosophilla melanogaster* From the model he also derived maximum egg production rate, time of this maximum, total egg production over 4-day intervals and total potential life time egg production. A feature of this model is that the parameters and derivations can be calculated withiout measuring daily egg productions throughout the entire life time of females.

McNally (1971) suggested that Wood model (1967)

$$y_t = at^b \exp(-ct)$$

where y_t = average daily yielded in the i^{th} week,

and a, b and c are constants

which has been found to fit lactation data in cattle can be taken as a basis of mathematical model for poultry egg production. He opined that the variation of number of eggs produced by a group of hens with time over a laying year has the same general form as that of milk yield over a lactation.

The addition of an extra term proportional to the square root of time to Wood model improved the fit giving multiple correlation ranging from 0.936 to 0.994. Hence Wood model may be written as

$$Y_t = at^b \exp(-ct + dt^{1/2})$$

The modified model was found to fit better than the Wood model with the highest values of R^2 ranging from 93.6 to 99.4 per cent.

Gavora *et al.* (1971) verified that the egg production curve developed for egg production in *D. melanogaster* (McMillan, 1970) can be used for avian species also.

$$N(t) = M(1-\exp(-\xi(t-t_o)))\ \exp\ (-\alpha t)$$

where $N(t)$ = number of egg laid on day t; M = potential maximum daily egg production, t_o = initial day of egg laying, ξ = rate of increase in egg laying; and α = rate of decrease in egg laying.

The model was fitted for weekly, fortnightly and monthly time scale and also for all individuals as well as groups of hens.

Timmermans (1973) used a mathematical model of egg production as suggested by McMillan (1970) and Gavora (1971) to a strain of white Leghorn bird (WB) and a strain composed of medium heavy breeds (MB). Both strains selected in a constant environment. It was found that the function of McMillan fits in a high degree to the observed data. The prediction of the production has been investigated on hen housed basis. Later he proposed to use in further investigations the hen day data instead of hen housed data.

Schaeffer *et al.* (1977) compared three methods 1. non linear method, 2. multiplicative method, 3. regression methiod to predict the 305 day milk and fat yields of Canadian Holstein and Jersey cattle.

The study found that the non linear method which consists of a non linear model

$$y_{ij} = A \exp(-\beta (i-t_o))(1-\exp(-B\ (i-t_o)))/B \exp(\epsilon_{ij})$$

was at least as accurate as either the multiplicative or regression methods because it requires only less computer storage for parameter estimates than other methods and could be implemented easily into a milk recording programme. Here y_{ij} = amount of milk given on the ith day of lactation of jth cow, t_o = "lag time" parameter and may indicate when a cow's udder begins to lactate prior to calving, B = slope of the lactation curve during the increasing production stage, A = peak production, β = slope during the decline in production after the peak, ϵ_{ij} = residual effect which was splitted into $\exp(\epsilon_{ij}) = \exp(n \sin(ip)) \exp(e_{ij})$ where i sin (ip) = period effect in a particular set of records.

p is 2π divided by the length of the period which could differ among lactation groups.

Ramachandra *et al.* (1979) fitted four models including the one suggested by McNally (1971) to identify the one which best fits the data and explain the minimum variation in egg production due to variation in the egg laying period in white cornish hens. The models are

1. $\mu y.t = \alpha + \beta t + t^2$
2. $\mu y.t = \alpha + \beta \log t + \gamma (\log t)^2$
3. $\mu y.t = \alpha t \exp(-rt)$
4. $\mu y.t = \alpha t \exp(-\gamma t + \delta\sqrt{t})$

In all the models $\mu y.t$ represents the true (but unknown) average weekly egg production during laying period t. Under customary assumptions of the least square method $\mu y.t$ is measured as y_t with a random error component which has zero expectation and constant variance.

The sample estimates of the unknown parameters in the case of each model were obtained by the application of the principle of least squares.

It was found that model 4 fitted to the sample data is an excellent one.

Adams and Bell (1980) used two equations

$$y = (1.0/(0.01 + ar^{x-b})) - c(x-d)$$

where x = age of flock, y = per cent hen day production, a, b, c, d and r are constants, and

$$y = a + br^{x}$$

where x = age of flock, y = weight per egg, a, b, r are constants for predicting egg production and egg size as function of age.

Congleton *et al.* (1981) observed that prediction of laying hens using incomplete gamma curves

$$y = An^{b} \exp(-cn)$$

is highly biased during most of the laying cycle. Here y = predicted production for the n^th^ week of laying, A, b, c are parameters (specifying per cent production for each week in laying) which can be estimated by multiple linear expression.

An equation with an additional parameter (d)

$$\hat{y} = An^{b} \exp(-cn + d\sqrt{n})$$

was also investigated and found that it did not improve the fit of the model.

McMillan (1981) derived an egg production model

$$y_t = A(\exp(-k_2 t) - \exp(-k_1 t))$$

where k_1 and k_2 are instantaneous rates of increase and decrease in egg production, respectively and A is the maximum potential egg production.

Gavora *et al.* (1982) fitted exponential models of McMillan *et al.* (1970 a, b)

$$N_p = a\,(1-\exp(-c(t-d)))\,\exp(-bt)$$

Wood (1967), $N_p = f\,t^g \exp(-ht)$ and a linear regression,

$$N_p = m - kt$$

to the results for individual hens, as well as to the mean results of groups of hens.

In all the three models, N_p = the number of eggs laid in 28 day period p, t = age of the birds in the middle of the 28 day period in days that is t = (age at first egg 14 + 28 p) and a, b, c, d, f, g, h, k and m are model parameters. The models were fitted to the data by the International Mathematics and Statistics Library Routine ZXSSQ. Overall the McMillan model gave the best results with mean R^2 of 0.71 from fitting it to the results of 223 individuals with sixteen 28 day periods each and R^2 of 0.97 from fitting it to the period means for groups. The respective R^2 values were 0.68 and 0.95 for the wood model and 0.60 and 0.90 for the linear regression.

McMillan *et al.* (1986) compared three mathematical models of production curves with respect to their ability to predict 50 week egg production from actual egg production record lengths of 16, 20 and 24 weeks.

1. Wood (1967) model $y = f\, t^{g} \exp(-ht)$
where f, g, h are constants.

2. Compartmental model $y = a\,(1-\exp(-c(t-d)))\,\exp(-bt)$
where a, b, c, d are parameters which take different interpretations depending on the particular situations to which model is applied.

3. Regression model $y = m-kt$
y = average total group egg production over time t, m and k are constants.

The study reported that when the model is intended only to predict full record egg production from past record, the linear model is better due to its simplicity and lower costs of fit. When the model is intended to serve several purposes, the compartmental model is preferable by virtue of the biological interpretation of its constants.

Johari *et al.* (1986) fitted McMillan model (1970 b) to annual egg production curves of white Leghiorn strain crosses to study their biological and statistical significance. The R^2 values were ranging from 80.31 to 97.87 per cent.

Johari *et al.* (1987) compared the fitting of five mathematical models.

Exponential (Brody *et al.* 1983) $y = a\ \exp(-bt)$

Parabolic exponential (Sikka, 1950) $y_t = a\ \exp(bt + ct^2)$

Gamma type function (Wood, 1967) $y_t = at^b\ \exp(-ct)$

Gamma type function (McNally, 1971) $y_t = at^b\ \exp(-ct + dt^{1/2})$

Inverse polynomial (Nelder, 1966) $y = t(a + bt + ct^2)^{-1}$

in the study on white leghorn strain cross entries.

The fitted models were compared using coefficients of determination (R^2). In all the models a, b, c, d are constants. The study revealed that Nelder's inverse polynomial is the ideal one for hen housed egg production in layer type chickens. In this model 'a' is the rising extreme of the curve (depicting peak production) 'b' is the slope of curve (depicting the rate of increase of production) and 'c' is the decending phase (rate of decline of production).

Sreenivasaiah *et al.* (1987) reported an average egg weight of Japanese quails as 9.47 ± 0.06 of g (Monsoon - August) 10.15 ± 0.05 g (Winter - November).

Cason and Britton (1988) used weekly egg production data from six first cycle and 13 molted commercial layer flocks to compare three non linear egg production models.

1. Compartmental or McMillan model

$P = a \exp(-bt)\ (1-\exp(-c(t-d)))$

2. Adams-Bell model

$P = 0.07\ (1/(.01 + ar^{t-b}) - c\ (t-d))$

3. Compartmental type model based on a logistic growth curve

$P = a \exp(-bt)(1/(1 + \exp(c + dt)))$

where p = egg production in time period t,

t = age of flock in weeks, and a, b, c, d, r are constants

Based on the comparisons the Adams Bell model was superior ($R^2 = .9938$) to compartmental (McMillan model) ($R^2 = .9523$) in terms of goodness of fit or predictive ability for egg production in first cycle flocks and is as good as the compartmental model in molted flocks, for either hen housed or hen day egg production data.

The logistic model ($R^2 = .9930$) was superior to compartmental model ($R^2 = .9423$) in terms of goodness of fit and predictive ability only for first cycle flocks. Here R^2 is the mean coefficient of determination.

Predictions of total production based on 24 week of data were significantly more accurate for the Adams-Bell and logistic models than for compartmental model in terms of error or percentage error in first cycle flocks, with no difference in molted flocks.

Yang *et al.* (1989) derived a new model (called as modified compartmental model)

$$y(t) = a \exp(-bt) (1+ \exp(-c(t-d)))^{-1} \text{ ---------(2.2.1)}$$

for poultry egg production which not only has theoretical advantages over the compartmental model

$$y (t) = m (1-\exp(-p(t-q)) (\exp(-nt) \text{ ---------(2.2.2)}$$

and wood model

$$y (t) = f^{t} g \exp(-ht) \text{ ---------(2.2.3)}$$

but also appears better in respect of its goodness of fit to the data and its ability to predict.

In model (2.2.1) the parameters are 'a' = a scale parameter, b = rate of decrease in laying ability, c = reciprocal indicator of the variation in sexual maturity, d = mean age of sexual maturity of hens and ae^{-bt} = exponential decay function.

In model (2.2.2) m, n, p and q are a scale parameters a measure of persistency of egg production, rate of sexual maturity and age at first egg respectively.

In model (2.2.3) f, g and h are parameters without reasonable interpretation.

Several criteria of goodness of fit, for different models including R^2 and errors of estimated annual egg numbers and estimated peaks of egg production curves are presented.

Results showed that modified compartmental model had higher R^2, smaller errors of annual egg numbers and greater agreement of estimated peaks with actual peaks than the other two models.

Narayanankutty *et al.* (1989) in their study observed that for 40 eggs from 12 week old quails and 40 from 24 week old quails weight averaged 8.56 ± 0.10 and 9.95 ± 0.13 g respectively.

2.3. Climatological studies

Yeates *et al.* (1941) and Rao *et al.* (1966), found detrimental efforts of high temperature on egg production in chicken.

Zannelli (1963) reported that higher weight gains was observed under low temperature regions.

Rao *et al.* (1966) reported that relative humidity had no effect on egg production in chicken.

Wilson *et al.* (1971) reported that 6 month old female Japanese quails kept in hot environment showed a higher egg production than those kept in cold environment.

Sreenivasaiah and Joshi (1987) observed that in Japanese quails mean temperature (°C) and vapour pressure (mm of Hg) during the production period of two seasons (Monsoon - August, Winter - November) of hatch differed significantly. Egg production and egg weight of winter hatched birds were significantly higher than the monsoon hatched birds.

Regression analysis indicated that regardless of season of hatch age had profound effect on both egg production and egg weight of monsoon hatched birds. Egg weight of winter hatched birds was greatly influenced by egg production. Definite detrimental effects due to high temperature and vapour pressure on egg production and egg weight were observed among monsoon hatched birds. Winter hatching was preferable and it was thought that values of climatic elements during production period of winter hatched birds were optimum for species. Both temperature and vapour pressure were found to influence egg production and egg weight. Also it was observed that relative humidity had no effect on egg production in quails.

Materials and Methods

MATERIALS AND METHODS

3.1 Materials

The study was initiated using day old straight run birds of Japanese quails (*Coturnix coturnix japonica*), one hundred and fifty in number from Kerala Agricultural University Poultry Farm, Mannuthy. The quails were hatched on 1st February, 1989. They were serially numbered and wing banded.

On the day of hatching, the quails were placed in electrically operated thermostatically controlled battery type brooders. They were allocated to different compartments of the brooder at random. About thirty of chicks were allotted to each section of battery brooder. Commercial all-mash starter ration was fed *ad libitum* while the chicks were brooded in the batteries. Fresh water was made available at all time.

After few weeks the quails were divided into males and females and moved to individual cages. Necessary warmth was provided by infra-red bulbs. At this stage the birds were fairly well feathered and due to temperate weather only moderate heat was required. All the birds were fed on same feed formula and all management practices were identical.

3.2 Methods

The body weight of each bird was recorded at weekly intervals until the birds attained an age of 12 weeks. At the end of 12th week weights were available on fifty eight (58) males and forty five (45) females. The weighing was stopped when females started laying. The weight of the birds were also recorded at 27th and 35th experimental week.

The data so gathered were used for fitting appropriate functions of growth.

The choice of the appropriate curve to depict the growth pattern in any situation is not easy. On visual observation of data the pattern of growth appropriated to sigmoid curve upto 12th week. The following functions were considered.

(i) Linear $W_t = a + bt$ (3.2.1)
(ii) Quadratic $W_t = a + b_1 t + b_2 t^2$ (3.2.2)
(iii) Exponential $W_t = a \exp(bt)$ (3.2.3)
(iv) Von Bertalanffy $W_t = a[1-b \exp(kt)]^3$ (3.2.4)
(v) Modified exponential $W_t = k + ab^t$ (3.2.5)
(vi) Logistic $W_t = a/[1+b \exp(-kt)]$ (3.2.6)
(vii) Gompertz $W_t = a \exp[-b \exp(-kt)]$ (3.2.7)

Where a, b, b_1, b_2 and k are constants and W_t is the body weight at time t. The parameters of equations (3.2.1) to (3.2.4) were estimated using method of least squares and the parameters of equations (3.2.5) to (3.2.7) are estimated by method of partial sums (Nair, 1954).

The estimates of parameters and other related parameters are given as follows.

3.2.1 Linear

$$W_t = a + bt$$

The estimates of parameters are given as

$$b = (N\Sigma tW_t - \Sigma t\Sigma W_t)/(N\Sigma t^2 - (\Sigma t)^2$$

$$a = \bar{W} - b\,\bar{t}$$

Growth rate (GR) of an organism at any instant of time (t) is defined as "the increase in organism material (body weight) of organism per unit of time".

$$\text{i.e. } GR = dW_t/dt = b$$

3.2.2 Quadratic

$$W_t = a + b_1t + b_2t^2$$

where, $a = D_1/D$, $b_1 = D_2/D$, $b_2 = D_3/D$

$$D_1 = \begin{vmatrix} \Sigma W_t & \Sigma t & \Sigma t^2 \\ \Sigma tW_t & \Sigma t^2 & \Sigma t^3 \\ \Sigma t^2W_t & \Sigma t^3 & \Sigma t^4 \end{vmatrix} \qquad D_2 = \begin{vmatrix} n & \Sigma W_t & \Sigma t^2 \\ \Sigma t & \Sigma tW_t & \Sigma t^3 \\ \Sigma t^2 & \Sigma t^2W_t & \Sigma t^4 \end{vmatrix}$$

$$D_3 = \begin{vmatrix} n & \Sigma t & \Sigma W_t \\ \Sigma t & \Sigma t^2 & \Sigma tW_t \\ \Sigma t^2 & \Sigma t^3 & \Sigma t^2W_t \end{vmatrix} \qquad D = \begin{vmatrix} n & \Sigma t & \Sigma t^2 \\ \Sigma t & \Sigma t^2 & \Sigma t^3 \\ \Sigma t^2 & \Sigma t^3 & \Sigma t^4 \end{vmatrix}$$

$$\text{Growth rate (GR)} = b_1 + 2b_2t$$

3.2.3 Exponential

$$W_t = a \exp(bt)$$

where the constants a and b are estimated as $\hat{a} = \exp(A)$

$$A = \bar{Z}_t - B\bar{t},\ Z_t = \log W_t$$

$$\hat{b} = B = (n \sum t Z_t - \sum t \sum Z_t)/[n \sum t^2 - (\sum t)^2]$$

When the curve is fitted the rate of growth at a particular period can be verified as the ratio of weight during the period to the weight during previous period minus one. In the case of exponential, the rate of growth is approximately given as exp(b) -1.

3.2.4 Von Bertalanffy

$$W_t = a[1-b \exp(kt)]^3$$

where 'a' is mature body weight which is known; b and k are constants.

$$(W_t/a)^{1/3} = 1-b \exp(kt)$$

$$b \exp(kt) = 1-(W_t/a)^{1/3}$$

$$\log b + kt = \log [1-(W_t/a)^{1/3}]$$

$$B + kt = Z_t$$

where $Z_t = \log [1-(W_t/a)^{1/3}]$

$$B = (\sum Z_t \sum t^2 - \sum t \sum Z_t)/(n \sum t^2 - \bar{Z}t)^2),\ \hat{b} = \exp(B)$$

$$\hat{K} = (n \sum Z_t t - \sum t \sum Z_t)/(n \sum t^2 - (\sum t)^2)$$

The growth rate at a particular point is approximately given by

$$b \exp(kt)\ [1-\exp(K)]/(1-b \exp(kt)]$$

which depends on the value of $b \exp(K)$.

3.2.5 Modified exponential

$$W_t = K + ab^t$$

where the constants a, b, and K are estimated as

$$\hat{b} = [(S_3 - S_2)/(S_2 - S_1)]^{1/n}$$

$$\hat{a} = (S_2 - S_1)\ (\hat{b} - 1)/(\hat{b}^n - 1)^2$$

$$\hat{k} = [S_1 - \hat{a}\ (\hat{b}^n - 1)/(\hat{b}-1)]/n$$

Here S_1, S_2, S_3 are the sum of the W_t values of three equal parts obtained from partial sums and 'n' is the number of observations in each part.

The growth rate at a particular period is approximately given by

$$(ab^{t+1} - ab^t)/(K + ab^t)$$

$$\approx ab^t\ (b-1)/(K + ab^t)$$

3.2.6 Logistic

$$W_t = a/(1 + b\ \exp(-kt)$$

which can be written as $Z_t = A + BC^t$

where, $C = \exp(-K)$, $A = 1/a$, $B = b/a$, $Z_t = 1/W_t$

The estimates of parameters are given by,

$$\hat{K} = \log\ (1/C) \text{ where } C =((S_3 - S_2)/(S_2 - S_1))^{1-n}$$

$$\hat{a} = 1/A \text{ where } A = (S_1 -(S_2 - S_1)/(c^n-1)/n$$

$$\hat{b} = a.B \text{ where } B = (S_2 - S_1)(C-1)/(C(c^n-1)^2)$$

$$S_1 = \sum_{t=0}^{3} Z_t, \quad S_2 = \sum_{t=4}^{7} Z_t, \quad S_3 = \sum_{t=8}^{11} Z_t$$

The growth rate at a particular period is given by

$$\frac{1 + b\ \exp(-kt)}{1 + b\ \exp[-kt(t + 1)]} - 1$$

3.2.7 Gompertz

$$W_t = a\ \exp[-b\ \exp(-kt)]$$

which can be written in the form

$$Z_t = A + BC^t$$

where, $A = \log a$, $B = -b$, $C = \exp(-k)$, and $Z_t = \log W_t$

The estimates of parameters are given by

$$\hat{a} = \exp(A) \text{ where } A = (S_1 - (S_2 - S_1)/(C^n - 1))/n$$

$$\hat{b} = -B \text{ where } B = (S_2 - S_1)\ (C-1)/(C^n - 1)^2$$

$$\hat{K} = \log_e (1/C) \text{ where } C = ((S_3 - S_2)/(S_2 - S_1))^{1/n}$$

$$S_1 = \sum_{t=0}^{3} Z_t, \quad S_2 = \sum_{t=4}^{7} Z_t, \quad S_3 = \sum_{t=8}^{11} Z_t$$

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

$$\frac{a \exp(-b \exp(-k(t+1)))}{a \exp(-b \exp(-kt))} - 1$$

3.3 Comparison of growth curves

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

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

(ii) Standard error of the estimate(s)

3.3.1 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.

3.3.2 Standard error of the estimate

The standard error of the estimate measures the inadequacy of fit of the 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

$$S = \sqrt{\Sigma(y_i - \hat{y}_i)^2/(n-2)}$$

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

3.3.3 Comparison of rates of growth

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

Let Y_t denote the increase in body weight at time t and g_t is the mean of all y_t's in the experiment. Then g_t is the time metameter. The difference in the values of y_t are due to the time factor (g_t), hence we may write

$$Y_t = bg_t$$

and the method of least squares leads to

$$b = (\sum y_t g_t)/(\sum g_t^2)$$

Thus obviously, comparison of difference in rates of growth between groups will be a comparison of b's. The 'b' values 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.

3.4 Egg production

Daily egg production of quails were recorded from the end of March 1989 till the end of experiment. The data was converted to weekly, fortnightly, hen housed and hen day egg production basis.

McNally (1971) and Timmermans (1973) observed that the profile of egg production in poultry bears much resemblance to that one of the milk yield in dairy cattle. Hence the following milk production curves can be used to predict the egg production in quails.

(i) Linear $Y_t = a + bt$ (3.5.1)

(ii) Exponential (Brody, 1923) $Y_t = a \exp(-bt)$ (3.5.2)

(iii) Parabolic exponential (Sikka, 1950) $Y_t = a \exp(bt + Ct^2)$ (3.5.3)

(iv) Inverse polynomial (Nelder, 1966) $Y_t = t\ (a + bt + Ct^2)^{-1}$ (3.5.4)

(v) Gamma function (Wood, 1967) $Y_t = at^b \exp(-ct)$ (3.5.5)

(vi) Gamm type function (McNally, 1971) $Y_t = at^b \exp(-ct + dt^{1/2})$ (3.5.6)

(vii) Quadratic function (Ramachandra *et al.*, 1979) $Y_t = a + bt + ct^2$ (3.5.7)

(viii) Quadratic function in log scale (Ramachandra *et al.*,1979) $Y_t = a + b(\log_e t) + c(\log_e t)^2$ (3.5.8)

(ix) Quadratic-cum-log (Malhotra *et al.*,1980) $Y_t = a + bt + ct^2 + d(\log_e t)$ (3.5.9)

(x) Emperical $Y_t = t/(a \exp(bt))$ (3.5.10)

(xi) Linear hyperbolic (Bianchini-Sobrinho *et al.*, 1986) $Y_t = a + bt + c/t$ (3.5.11)

Where Y_t is the egg production in time scale (weekly, fortnightly, monthly hen housed, monthly hen day); a, b, c, d are parameters.

For estimating the parameters of the above curves the following method suggested by Kendall *et al.* (1983) was used.

Let the linear model be

$$\underline{Y} = \underset{\sim}{X}\,\underline{B} + \underline{U}$$

where,

$\underline{Y}$ = n x 1 vector of egg production

$\underset{\sim}{X}$ = n x k matrix of known coefficients

$\underline{B}$ = k x 1 vector of regression coefficients

$\underline{U}$ = n x 1 vector of error random variables with means and dispersion matrix $E(\underline{U}) = 0$

$$V(\underline{U}) = \sigma^2 \underset{\sim}{I}$$

The vector of least square estimators of $\underline{B}$ is given by

$$\underline{B} = (\underset{\sim}{X}'\underset{\sim}{X})^{-1} \underset{\sim}{X}'\underline{Y}$$

and its dispersion matrix is given by

$$V(\underline{B}) = \sigma^2 (\underset{\sim}{X}'\underset{\sim}{X})^{-1}$$

Unbiased estimator of σ^2 is S^2

$$\text{Where, } (n-k)\, S^2 = (\underline{Y} - \underset{\sim}{X}\underline{B})'\, (\underline{Y} - \underset{\sim}{X}\underline{B})$$

$$= \underline{Y}'\, \underline{Y} - \underline{B}'\, \underset{\sim}{X}'\, \underline{Y}$$

3.5 Comparison of production curves

In order to compare the relative efficiency of various egg production curves and to select the one which best fit the observed data the following criteria are used.

3.5.1 Coefficient of determination

(As described in section 3.3.1)

3.5.2 Standard error of estimate

(As described in section 3.3.2)

3.5.3 Furnival index (I)

Furnival (1961) constructed an index (I) of fit as

$$I = \left(\prod_{i=1}^{n} f'(y_i) \right)^{-1/n} . s$$

where, $f'(y_i)$ is the derivative of some function of $f(y)$ of the dependent variable Y with respect to y; n is the number of data points, s is the root mean square residual obtained from fitted regression.

A large value of I indicates a poor fit and vice versa.

3.6 Climatological studies

Weekly egg production of thirty two (32) female Japanese quails hatched on first February 1989 and climatological parameters under which they were reared such as daily temperature and humidity (which was converted to weekly basis) were measured and utilised for this study. The birds started egg production from tenth week onwards and it was recorded daily up to the 34th week. The egg production in any week depends on the previous two to three week climatological parameters. In order to correlate the effect of climatological parameters on egg production the previous three week average of those parameters were considered in correspondence with the present week's egg production, i.e. average of sixth, seventh and eighth week climatological parameters were used to correlate with the nineth week egg production; average of seventh, eighth, nineth week climatological parameters were used to correlate the tenth week production etc.

In order to find a suitable relationship of temperature and humidity with that of weekly egg production, a multiple linear repression equation was fitted.

Results

RESULTS

The present investigation was undertaken mainly for the development of mathematical models for ascertaining growth and egg production in Japanese quails. Various mathematical models (described in sections 3.2, 3.4) were fitted to choose the best one for this purpose. The results obtained were presented in this chapter.

4.1 Average body weights

The average body weights along with standard error for male, female and birds irrespective of sex were presented in Table 1. The body weights varied from 7.1172 g for first week to 157.6552 g during twelveth week in the case of males; 7.1622 g to 179.2000 g in the case of females; 7.1369 g to 167.0680 g in the case of birds irrespective of sex.

A graph with age (number of weeks) on X-axis and mean body weight of Japanese quails on Y-axis (Fig.1) was plotted.

Analysis of variance was conducted to test whether the difference in body weights of male and female Japanese quails were significant or not (Table 2.)

4.2 Growth study through mathematical models

The mathematical models utilised were described in section 3.2. The models were fitted for fifty eight (58) male and forty five (45) female Japanese quails using their body weights for first twelve weeks. The parameters of the fitted mathematical models namely linear, quadratic, exponential, Von Bertalanffy, modified exponential, logistic and Gompertz were presented in Table 3 to Table 9 for males and females along with the values of coefficient of determination r^2 and standard error of estiamte(s).

Models described in section 3.2 were also fitted for males, females and birds irrespective of sex using their average body weights over twelve weeks. The parameters of the fitted models were presented in Table 10 to 16 along with r^2 and s values.

4.3 Rao's method

By the method of Rao (1958) the growth parameter 'b' was estimated for each of the 58 male and 45 female Japanese quails and were presented in Table 17. The growth parameter had a mean value of 0.009250 and 0.009741 for male and female Japanese quails respectively.

Analysis of covariance of 'b' values, taking initial body weight as concomitant variable was presented in Table 18.

4.4 Egg production study

Daily egg production data of thirty two (32) female Japanese quails reared for thirty four (34) weeks beginning from first February 1989 to 30th September 1989 were utilised for the study. The birds started egg laying around 10th week onwards. The data was coverted to total number of eggs produced on weekly, fortnightly and mean weekly egg production per bird basis (Table 19). Figure 6 and 7 shows the nature of weekly and fortnightly egg production. Hen housed and hen day egg production were worked out and presented in Table 20. A combined graph of hen housed and hen day egg production (y-axis) over various months (x-axis) were shown in Fig.8.

Study was mainly conducted through mathematical models described in section 3.4. The models were fitted for four catagories namely total number of eggs produced on weekly, fortnightly and hen housed and hen day egg production data.

For comparison of fitted equations the coefficient of determination (r^2), standard error of estimate(2) and Furnival index (I) were worked out.

In the case of r^2 value, it was assumed a linear trend of the variables. Hence the comparision under non linear models r^2 values will not be adequate. Therefore Furnival index (I) was taken as best criteria for comparison.

The parameters of the fitted mathematical models for the four categories (weekly, fortnightly, hen housed and hen day) were presented in Table 21 to 24 along with r^2, s and I values.

4.5 Climatological studies

Under this study the data on temperature and humidity were collected upto 34 weeks. Data were converted to weekly basis in order to match with weekly egg production data. As mentioned in section 3.6 the climatological data of previous three weeks were correlated with present weeks average egg production per bird.

A multiple linear regression equation was fitted by taking previous three weeks average temperature (Z_1) and previous three weeks average humidity (Z_2) as explanatory variables and present weekly average egg production per bird (Y) as dependent variable (Table 25). The fitted equation was as given.

$$Y = -41.7275 + 0.7687^{**}\ Z_1 + 0.3150^{**}\ Z_2 \text{ with } r^2 = 0.7654$$

The ANOVA of fitted regression equation was given in Table 26.

Table 1. Mean and standard error of body weights (in g) of Japanese quails

Week	Male	Female	Irrespective of sex
1	7.1172 ± 0.1591	7.1622 ± 0.1813	7.1369 ± 0.1698
2	22.2362 ± 2.1702	22.5978 ± 1.6934	22.3942 ± 1.9796
3	46.6207 ± 9.6479	47.1556 ± 9.3662	46.8544 ± 9.4831
4	74.7241 ± 13.4540	76.8445 ± 13.4400	75.6505 ± 13.4235
5	95.5172 ± 14.1089	97.5111 ± 12.9275	96.3884 ± 13.5764
6	121.0690 ± 14.9536	123.3778 ± 12.2980	122.0777 ± 13.8392
7	131.4828 ± 13.8136	131.0222 ± 10.6141	131.2816 ± 12.4613
8	140.6552 ± 12.1591	142.4444 ± 9.7318	141.4369 ± 11.1476
9	147.2414 ± 12.6426	154.5333 ± 14.2217	150.4272 ± 13.7540
10	151.5862 ± 14.8573	166.8445 ± 15.7450	158.2524 ± 20.1326
11	152.1724 ± 15.0708	174.2667 ± 15.7803	161.8252 ± 18.8578
12	157.6552 ± 14.5199	179.2000 ± 19.8055	167.0680 ± 20.0584
27	172.4310 ± 23.9862	194.0000 ± 17.7508	181.8544 ± 23.9376
35	179.4483 ± 22.1567	192.4839 ± 19.1841	185.1456 ± 21.8023

Table 2. Mean sum of squares (M.S.S.) of body weights of Japanese quails over different weeks of age

Source	DF	M.S.S. over various weeks							
		1	2	3	4	5	6	7	8
Between sexes	1	0.0480	3.3010	7.2500	113.9370	100.6880	135.1250	5.3750	81.1250
Within sexes	101	0.0290	3.9070	90.7480	180.8470	185.1460	192.0820	156.7670	124.6960

Source	DF	M.S.S. over various weeks					
		9	10	11	12	27	35
Between sexes	1	1347.5000**	5899.5000**	12369.7500**	11762.2500**	11788.616**	4309.316**
Within sexes	101	178.3140	232.5740	236.6630	289.8640	461.9624	437.3812

** Significant at 1 per cent level

Table 3. Fitting of linear form W_t = a + bt using twelve weeks body weights of Japanese quails

Sl. No.	Male				Female			
	a	b	r^2	s	a	b	r^2	s
1.	12.1030	14.1406	0.8846	19.3184	8.9940	15.3266	0.9188	17.2295
2.	11.1030	13.1406	0.9083	15.7899	8.0849	17.5434	0.9487	15.4337
3.	28.0243	13.3476	0.8463	21.5140	13.8425	14.0678	0.9112	16.6119
4.	7.9303	13.9248	0.9211	15.4079	5.7576	16.4168	0.9487	14.4324
5.	7.0212	13.8339	0.9327	14.0563	-1.5848	17.0297	0.9787	9.5069
6.	4.3909	18.6437	0.9384	18.0709	7.3303	15.7556	0.9460	14.2361
7.	23.5727	12.6927	0.8081	23.3900	1.4515	15.9164	0.9497	13.8561
8.	16.2121	14.7238	0.8726	21.2791	9.1818	16.0105	0.8836	21.9778
9.	1.3333	15.1154	0.9484	13.3230	9.2001	13.0692	0.9440	12.0345
10.	21.8970	12.6287	0.8270	21.8438	25.8000	12.4000	0.7598	26.3621
11.	24.5637	12.9364	0.8338	21.8431	13.6485	14.6797	0.9059	17.8960
12.	17.0121	14.1622	0.8485	22.6296	14.9378	14.9032	0.8639	22.3741
13.	17.4227	13.3927	0.8523	21.0875	2.8061	17.0350	0.9287	17.8547
14.	-0.3757	14.9860	0.9475	13.3351	6.7394	14.5119	0.9099	17.2722
15.	3.6485	13.7566	0.9327	13.9753	8.5151	16.3182	0.9150	18.8107
16.	1.3455	14.2392	0.9282	14.9790	5.8182	17.2203	0.9669	12.0407
17.	5.0727	14.8965	0.9003	18.7514	4.4848	14.7587	0.9321	15.0685
18.	9.0121	16.3930	0.8977	20.9276	-0.9333	19.1923	0.9717	12.3791
19.	16.2727	14.8427	0.8789	20.8392	-0.5697	17.5209	0.9647	12.6716
20.	10.5151	14.8566	0.8964	19.0997	19.4848	15.7741	0.8945	20.4844
21.	19.7576	13.9476	0.8447	22.7197	-8.9940	15.1350	0.9830	7.5259
22.	15.3636	13.0594	0.8578	20.1091	7.0667	15.9462	0.9266	16.9687
23.	18.4000	14.9615	0.8667	22.1884	7.4606	16.6035	0.9430	15.4341
24.	11.8243	15.1014	0.8954	19.5168	1.8000	15.3154	0.9685	12.0464
25.	19.9091	13.2217	0.8268	22.8860	10.5575	15.8399	0.9178	17.9220
26.	13.3333	13.3615	0.8995	16.8888	12.3819	16.7336	0.8920	22.0164
27.	18.6666	13.2077	0.8573	20.3765	5.0485	14.8874	0.9317	15.2428
28.	5.6424	15.2678	0.9251	16.4291	1.2879	17.0955	0.9576	13.6083
29.	11.4303	15.6595	0.8926	20.5456	10.0758	17.1025	0.8949	22.1602
30.	13.3151	13.7490	0.9025	17.0910	11.6758	16.2717	0.8976	19.5079

Contd

Table 3. (Contd.)

Sl. No.	Male				Female			
	a	b	r^2	s	a	b	r^2	s
31.	15.5272	14.2804	0.8703	20.8435	8.4848	15.3818	0.9270	16.3277
32.	15.2000	14.2999	0.8654	21.3244	4.2970	17.0825	0.9539	14.2027
33.	-1.8303	12.9713	0.9749	7.8735	0.9334	17.5231	0.9674	12.1574
34.	18.1091	14.2371	0.8593	21.7902	6.9757	15.6602	0.9601	12.0676
35.	-4.5878	18.7545	0.9748	11.4115	5.8848	15.6741	0.9521	13.2966
36.	15.7152	16.1951	0.8640	24.2994	-11.3151	15.7203	0.9663	11.1080
37.	17.2879	12.8647	0.8600	19.6251	-2.7001	17.4500	0.9598	13.5112
38.	14.0697	13.3906	0.9057	16.3390	4.7545	17.9955	0.9453	16.3749
39.	2.2364	12.8098	0.9563	10.3523	-5.2819	18.9549	0.9627	14.1172
40.	24.6224	11.9678	0.8164	21.4640	9.4151	16.1297	0.9381	15.6691
41.	19.3090	15.5832	0.8543	24.3349	2.4454	13.8430	0.9050	16.9568
42.	18.5940	11.6573	0.8205	20.6215	4.6303	16.1517	0.9526	13.6298
43.	13.9879	14.0839	0.9041	17.3484	6.7212	17.4531	0.9269	18.5402
44.	7.2999	16.6039	0.9100	19.7503	-11.8604	18.1119	0.9907	6.6338
45.	2.8151	12.8836	0.9658	9.1738	-14.9212	19.3776	0.9907	7.1181
46.	-1.2485	16.9280	0.9445	15.5160				
47.	22.4182	12.8510	0.8181	22.9119				
48.	13.1455	14.2776	0.8704	20.8310				
49.	6.2667	16.7462	0.9204	18.6188				
50.	16.8728	15.3965	0.8853	20.9548				
51.	3.6303	13.7671	0.9494	12.0218				
52.	-1.1575	14.4524	0.9273	15.3079				
53.	8.4182	13.7049	0.8825	18.9088				
54.	19.2364	12.6559	0.8485	20.2226				
55.	0.1152	13.8797	0.9269	14.7359				
56.	12.9576	13.3706	0.8795	18.7137				
57.	1.6849	11.6434	0.9535	9.7236				
58	7.8970	14.6364	0.9254	15.7180				

Table 4. Fitting of quadratic form $W_t = a + b_1t + b_2t^2$ using twelve weeks body weights of Japanese quails

Sl. No.	Male					Female				
	a	b_1	b_2	r^2	s	a	b_1	b_2	r^2	s
1.	-35.2687	34.4426	-1.5617	0.9853	7.2787	-28.5590	31.4207	-1.2380	0.9748	10.1265
2.	-28.7687	30.2284	-1.3144	0.9931	4.5600	-28.0590	33.0335	-1.1916	0.9895	7.3560
3.	-31.8770	36.4481	-1.7770	0.9862	6.7838	-23.7406	30.1748	-1.2390	0.9771	8.8861
4.	-29.4067	29.9264	-1.2309	0.9883	6.2527	-24.2731	29.2871	-0.9900	0.9809	9.2780
5.	-26.7250	28.2966	-1.1125	0.9870	5.9986	-20.6795	25.2131	-0.6295	0.9912	6.4544
6.	-39.6434	37.5155	-1.4517	0.9915	7.0936	-23.2342	28.8547	-1.0076	0.9821	8.6381
7.	-34.3250	37.5060	-1.9087	0.9787	8.2224	-30.0978	29.4376	-1.0401	0.9875	7.2731
8.	-37.8409	37.8894	-1.7820	0.9918	5.6754	-40.6589	37.3709	-1.6431	0.9704	11.6760
9.	-27.7500	27.5797	-0.9588	0.9841	7.8036	-21.1406	26.0723	-1.0002	0.9956	3.6429
10.	-33.8223	36.5083	-1.8369	0.9903	5.4576	-39.7455	40.4909	-2.1608	0.9752	8.9300
11.	-30.4588	36.5174	-1.8139	0.9868	6.4952	-29.2001	33.0434	-1.4126	0.9841	7.7420
12.	-39.8366	38.5259	-1.8741	0.9872	6.9370	-39.6795	38.3106	-1.8006	0.9815	8.6856
13.	-34.7705	35.7612	-1.7207	0.9835	7.4187	-37.9816	34.5154	-1.3446	0.9827	9.2776
14.	-28.2998	26.9535	-0.9206	0.9809	8.4799	-34.5638	32.2132	-1.3616	0.9846	7.5178
15.	-29.8364	28.1072	-1.1039	0.9887	6.0242	-38.2045	36.3409	-1.5402	0.9911	6.4315
16.	-32.5181	28.7521	-1.1164	0.9814	8.0297	-21.5229	28.9378	-0.9013	0.9916	6.3850
17.	-37.8818	33.3055	-1.4161	0.9762	9.6593	-31.0683	29.9957	-1.1721	0.9869	6.9684
18.	-42.7000	38.5554	-1.7048	0.9883	7.4585	-23.1229	28.7021	-0.7315	0.9849	9.5344
19.	-34.0682	36.4173	-1.6596	0.9814	8.6069	-30.2593	30.2451	-0.9788	0.9928	6.0279
20.	-29.9774	32.2105	-1.3349	0.9639	11.8769	-25.0683	34.8683	-1.4688	0.9669	12.0957
21.	-36.2501	37.9508	-1.8464	0.9828	7.9328	-14.4413	17.4695	-0.1796	0.9843	7.6249
22.	-34.6591	34.4977	-1.6491	0.9854	6.7828	-31.0776	32.2937	-1.2575	0.9804	9.2427
23.	-37.2592	38.8154	-1.8349	0.9884	6.9080	-25.4413	30.7043	-1.0847	0.9806	9.4972
24.	-36.8046	35.9423	-1.6031	0.9896	6.4875	-26.2684	21.3447	-0.9253	0.9912	5.8533
25.	-37.8407	37.9716	-1.9038	0.9868	6.6673	-34.0411	34.9536	-1.4703	0.9916	6.0256
26.	-27.9319	31.0466	-1.3604	0.9865	6.5171	-42.7770	40.3731	-1.8184	0.9903	6.9434
27.	-31.2045	35.0096	-1.6771	0.9863	6.6515	-29.5042	29.6957	-1.1391	0.9826	8.1077
28.	-34.3047	32.5880	-1.3169	0.9893	6.5351	-29.1248	30.1294	-1.0026	0.9883	7.5287
29.	-37.0321	36.4291	-1.5977	0.9793	9.5128	-41.2611	39.1040	-1.6924	0.9767	10.9945
30.	-29.5414	32.1160	-1.4128	0.9914	5.3415	-34.6159	35.1110	-1.5261	0.9812	8.8013

Contd.

Table 4. (Contd.)

Sl. No.	Male					Female				
	a	b_1	b_2	r^2	s	a	b_1	b_2	r^2	s
31.	-37.1774	36.8681	-1.7375	0.9906	5.9180	-27.8184	30.9404	-1.1968	0.9793	9.1543
32.	-37.7769	37.0044	-1.7465	0.9859	7.2745	-21.6727	28.2124	-0.8561	0.9763	10.7439
33.	-17.5046	19.6888	-0.5167	0.9893	5.4108	-21.2637	27.0360	-0.7318	0.9832	9.2091
34.	-36.7317	37.7402	-1.8079	0.9886	6.5452	-19.2819	26.9134	-0.8656	0.9875	7.1192
35.	-30.2772	29.7642	-0.8469	0.9933	6.1906	-24.8272	28.8364	-1.0125	0.9892	6.6648
36.	-45.2769	42.3346	-2.0107	0.9883	7.5168	-23.1634	20.7981	-0.3906	0.9718	10.6992
37.	-32.1704	34.0611	-1.6305	0.9890	5.8039	-30.5297	29.3770	-0.9175	0.9845	8.8322
38.	-25.8430	30.4960	-1.3158	0.9873	6.3145	-34.4389	34.7926	-1.2921	0.9908	7.0955
39.	-21.7182	23.0760	-0.7897	0.9902	5.1569	-33.6573	31.1157	-0.9354	0.9845	9.5738
40.	-29.282	35.0783	-1.7778	0.9845	6.5747	-22.3846	29.7581	-1.0483	0.9751	10.4790
41.	-40.3272	41.1416	-1.9660	0.9812	9.2075	-31.3389	28.3220	-1.1138	0.9597	11.6412
42.	-29.2090	32.1443	-1.5759	0.9604	10.2078	-18.1046	25.8952	-0.7495	0.9717	11.0948
43.	-28.3451	32.2266	-1.3956	0.9869	6.7508	-26.1728	31.5506	-1.0844	0.9603	14.4064
44.	-40.4842	37.0828	-1.5753	0.9864	8.0873	-17.6181	20.5794	-0.1898	0.9917	6.5991
45.	-18.3936	21.9730	-0.6992	0.9923	4.5822	-22.1180	22.4619	-0.2373	0.9920	6.9242
46.	-35.7859	31.7298	-1.1386	0.9844	8.6746					
47.	-35.3769	37.6204	-1.9053	0.9860	6.7026					
48.	-38.3770	36.3587	-1.6985	0.9854	7.3690					
49.	-38.6042	35.9766	-1.4793	0.9875	7.7893					
50.	-33.9225	37.1659	-1.6746	0.9831	8.4877					
51.	-24.2408	25.7119	-0.9188	0.9889	5.9484					
52.	-32.6046	27.9297	-1.0367	0.9718	10.0489					
53.	-36.3547	32.8932	-1.4760	0.9781	8.6126					
54.	-31.7182	34.4936	-1.6798	0.9880	5.9943					
55.	-31.5819	27.4641	-1.0450	0.9760	8.9075					
56.	-31.7090	32.5134	-1.4725	0.9791	8.2193					
57.	-17.3910	19.8187	-0.6289	0.9795	6.8117					
58.	-30.2998	31.0064	-1.2592	0.9893	6.2734					

Table 5. Fitting of exponential form W_t = a exp (bt) using twelve weeks body weights of Japanese quails

Sl. No.	Male				Female			
	a	exp(b)	r^2	s	a	exp(b)	r^2	s
1.	18.6083	1.2504	0.6260	52.3858	18.5951	1.2574	0.6916	52.3038
2.	18.0813	1.2440	0.6639	45.5260	19.4494	1.2684	0.7357	58.9079
3.	21.0599	1.2375	0.5919	53.9838	19.3081	1.2468	0.6969	48.5182
4.	17.3570	1.2532	0.6840	47.0061	18.1009	1.2669	0.7515	52.4613
5.	17.0077	1.2541	0.7067	45.2047	16.9860	1.2728	0.8019	48.0468
6.	18.3764	1.2812	0.6892	66.8291	18.3391	1.2613	0.7466	50.4252
7.	20.7171	1.2356	0.5462	54.4006	16.2102	1.2733	0.7257	51.4704
8.	20.3614	1.2475	0.6059	57.0104	18.8951	1.2608	0.6193	59.6094
9.	16.5810	1.2624	0.7257	46.4843	17.9044	1.2423	0.7342	40.5268
10.	21.0496	1.2309	0.5658	51.4690	22.0419	1.2263	0.4856	55.4780
11.	22.1088	1.2299	0.5818	52.7820	19.6843	1.2492	0.6744	52.0692
12.	19.9029	1.2467	0.5761	56.8957	19.1449	1.2563	0.5975	59.2909
13.	19.4909	1.2433	0.5913	52.9997	17.6269	1.2724	0.6795	58.5227
14.	15.4677	1.2686	0.7280	46.0798	16.7217	1.2624	0.6574	51.4847
15.	15.3594	1.2632	0.6917	45.6180	18.7422	1.2642	0.6584	58.9429
16.	14.7895	1.2701	0.6814	47.6338	19.4832	1.2632	0.7784	52.4081
17.	15.9056	1.2709	0.6418	54.2924	16.3689	1.2650	0.6958	49.4599
18.	17.9022	1.2718	0.6262	63.2113	18.2429	1.2807	0.7987	56.9942
19.	20.5943	1.2470	0.6301	55.8939	17.1711	1.2766	0.7471	54.8400
20.	18.8433	1.2530	0.6723	51.6142	22.1127	1.2478	0.6782	57.8483
21.	20.3256	1.2451	0.5836	56.8721	12.8356	1.2846	0.8459	36.8402
22.	18.8204	1.2427	0.5959	50.5028	17.7309	1.2674	0.7002	55.0064
23.	20.7950	1.2489	0.6068	59.1939	18.5973	1.2666	0.7407	54.6617
24.	19.0667	1.2551	0.6368	55.8689	16.4780	1.2660	0.7468	46.9878
25.	20.5753	1.2369	0.5567	54.0915	19.0171	1.2605	0.6711	56.9433
26.	19.0710	1.2413	0.6652	46.6798	19.5356	1.2657	0.6200	65.3159
27.	20.6730	1.2361	0.6079	51.2181	17.2060	1.2598	0.6971	49.0024
28.	17.0109	1.2657	0.6755	53.1318	17.3909	1.2733	0.7403	54.2308
29.	18.4408	1.2642	0.6398	59.3534	19.1383	1.2690	0.6357	64.9277
30.	18.9738	1.2457	0.6602	49.0949	19.1871	1.2555	0.6454	55.8726

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Table 5. (Contd.)

Sl. No.	Male				Female			
	a	exp(b)	r^2	s	a	exp(b)	r^2	s
31.	19.4966	1.2491	0.6045	55.5889	17.8601	1.2630	0.7044	52.7448
32.	18.6062	1.2555	0.5978	57.2052	18.6890	1.2661	0.7676	52.2408
33.	13.4374	1.2658	0.7951	35.1019	17.8025	1.2730	0.7902	51.7521
34.	19.4266	1.2522	0.5918	58.1758	18.9281	1.2556	0.7762	46.8500
35.	15.9855	1.2927	0.7659	59.0629	18.3825	1.2586	0.7445	48.9226
36.	19.2399	1.2670	0.5811	67.9310	12.6966	1.2885	0.7795	41.9944
37.	19.5613	1.2379	0.6048	49.4563	16.4697	1.2793	0.7426	54.0776
38.	19.3353	1.2406	0.6758	46.4911	18.5644	1.2750	0.7126	61.5585
39.	15.0793	1.2538	0.7495	37.2738	16.2829	1.2905	0.7451	59.9064
40.	21.7750	1.2234	0.5666	49.0667	19.3650	1.2589	0.7438	52.1628
41.	21.2913	1.2515	0.5906	63.2767	15.3883	1.2615	0.6653	45.9360
42.	19.3210	1.2293	0.5806	45.5530	17.8463	1.2653	0.7838	48.3728
43.	19.6009	1.2449	0.6704	49.7207	18.7307	1.2711	0.7191	59.0194
44.	18.0937	1.2701	0.6495	61.0716	15.0095	1.2871	0.8409	44.7818
45.	15.8084	1.2489	0.7761	35.5877	14.4959	1.2994	0.8309	50.2210
46.	15.7104	1.2834	0.7055	56.5855				
47.	20.8017	1.2351	0.5518	54.0037				
48.	18.3704	1.2546	0.6035	55.5098				
49.	18.1195	1.2701	0.6643	60.1168				
50.	19.9951	1.2565	0.6362	59.9892				
51.	15.7974	1.2594	0.7364	42.6064				
52.	14.3508	1.2730	0.6826	47.2688				
53.	16.5308	1.2583	0.6193	50.8118				
54.	19.5489	1.2384	0.5896	50.5878				
55.	14.1945	1.2705	0.6841	45.5747				
56.	18.7336	1.2433	0.6343	48.3947				
57.	14.4528	1.2453	0.7627	31.5465				
58.	18.1124	1.2537	0.6887	49.0423				

Table 6. Fitting of Von-Bertalanffy from $W_t = a\ [1-b\ \exp(kt)]^3$ using twelve weeks body weights of Japanese quails

Sl. No.	Male (a = 210 g)				Female (a = 230 g)			
	b	k	r^2	s	b	k	r^2	s
1.	0.6408	-0.1831	0.9441	13.7832	0.6879	-0.1843	0.9542	12.9738
2.	0.6369	-0.1643	0.9509	11.7185	0.7812	-0.2386	0.9845	8.5417
3.	0.5754	-0.1751	0.9156	16.2999	0.6357	-0.1625	0.9404	13.7063
4.	0.6694	-0.1771	0.9625	10.8239	0.7449	-0.2063	0.9725	10.6347
5.	0.6778	-0.1757	0.9676	9.9103	0.8090	-0.2145	0.9895	6.7366
6.	1.0482	-0.3473	0.9966	4.3183	0.7115	-0.1919	0.9702	10.6442
7.	0.5540	-0.1620	0.8775	19.0038	0.7343	-0.1867	0.9783	9.2312
8.	0.6298	-0.2006	0.9494	13.9593	0.6816	-0.1940	0.9416	15.7477
9.	0.7391	-0.1984	0.9830	7.8234	0.6467	-0.1442	0.9626	9.9326
10.	0.5607	-0.1596	0.8936	17.4203	0.5445	-0.1398	0.8196	22.9441
11.	0.5551	-0.1685	0.9043	16.9174	0.6392	-0.1713	0.9463	13.6855
12.	0.6094	-0.1871	0.9255	16.3635	0.6256	-0.1735	0.9215	17.2914
13.	0.5987	-0.1719	0.9157	16.2273	0.7415	-0.2085	0.9757	10.7214
14.	0.7485	-0.1937	0.9795	8.5130	0.6719	-0.1636	0.9464	13.4739
15.	0.6966	-0.1716	0.9666	10.0045	0.6896	-0.1971	0.9687	11.8086
16.	0.7179	-0.1789	0.9653	10.5893	0.7805	-0.2278	0.9866	8.7840
17.	0.7022	-0.1937	0.9526	13.2450	0.6925	-0.1674	0.9623	11.3534
18.	0.7253	-0.2367	0.9742	11.2970	1.3003	-0.3528	0.9698	18.0415
19.	0.6373	-0.2046	0.9496	13.9069	0.7984	-0.2213	0.9935	5.5094
20.	0.6867	-0.2038	0.9467	13.8003	0.6457	-0.2022	0.9427	15.2226
21.	0.5936	-0.1851	0.9197	16.7332	0.8103	-0.1734	0.9836	7.4176
22.	0.6046	-0.1639	0.9148	15.8026	0.7071	-0.1926	0.9630	12.1684
23.	0.6271	-0.2092	0.9487	14.4187	0.7464	-0.2134	0.9715	10.9862
24.	0.6678	-0.2056	0.9620	12.2443	0.7218	-0.1767	0.9821	8.0268
25.	0.5794	-0.1703	0.8998	17.7348	0.6746	-0.1904	0.9659	11.8295
26.	0.6280	-0.1700	0.9450	12.6784	0.6778	-0.2099	0.9614	13.6960
27.	0.5853	-0.1702	0.9191	15.6414	0.6939	0.1713	0.9631	11.2776
28.	0.7138	-0.2043	0.9755	9.7315	0.7703	-0.2125	0.9865	7.7652
29.	0.6948	-0.2213	0.9598	12.9903	0.7073	-0.2191	0.9585	14.2337
30.	0.6340	-0.1774	0.9527	12.1551	0.6571	-0.1808	0.9460	14.3384

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Table 6. (Contd.)

Sl. No.	Male (a = 210 g)				Female (a = 230 g)			
	b	k	r^2	s	b	k	r^2	s
31.	0.6234	-0.1888	0.9406	14.5642	0.6873	-0.1824	0.9583	12.4632
32.	0.6279	-0.1892	0.9347	15.2810	0.7867	-0.2244	0.9709	11.3698
33.	0.7336	-0.1581	0.9841	6.3162	0.8283	-0.2322	0.9784	10.0605
34.	0.6123	-0.1908	0.9331	15.4928	0.7128	-0.1903	0.9781	9.0214
35.	1.2237	-0.3506	0.9896	8.9333	0.7092	-0.1873	0.9787	8.9344
36.	0.6778	-0.2408	0.9612	14.0067	0.8154	-0.1772	0.9830	7.9689
37.	0.5927	-0.1617	0.9159	15.4530	0.8031	-0.2166	0.9871	7.7156
38.	0.6268	-0.1718	0.9496	12.1137	0.7941	-0.2408	0.9884	7.6628
39.	0.6948	-0.1553	0.9757	7.8093	0.9019	-0.2564	0.9900	7.3125
40.	0.5419	-0.1498	0.8765	17.8171	0.7158	-0.2030	0.9632	12.1426
41.	0.6382	-0.2282	0.9488	15.2913	0.6960	-0.1536	0.9311	14.4841
42.	0.5738	-0.1420	0.8635	18.0756	0.7615	-0.2046	0.9636	12.1104
43.	0.6405	-0.1863	0.9555	12.0456	0.7807	-0.2352	0.9544	14.6611
44.	0.7502	-0.2425	0.9792	10.1079	0.9174	-0.2311	0.9894	7.3058
45.	0.6931	-0.1573	0.9819	6.7420	1.0377	-0.2670	0.9896	8.1224
46.	0.8286	-0.2425	0.9895	7.0487				
47.	0.5620	-0.1646	0.8892	18.2026				
48.	0.6365	-0.1863	0.9364	15.0076				
49.	0.7642	-0.2462	0.9843	8.8511				
50.	0.6665	-0.2237	0.9588	12.9626				
51.	0.7027	-0.1734	0.9750	8.5524				
52.	0.7363	-0.1812	0.9638	10.9674				
53.	0.6576	-0.1721	0.9327	14.5268				
54.	0.5819	-0.1596	0.9057	16.1697				
55.	0.7195	-0.1713	0.9601	11.0457				
56.	0.6248	-0.1687	0.9299	14.4928				
57.	0.6864	-0.1374	0.9663	8.8203				
58.	0.6849	-0.1923	0.9715	9.9683				

Table 7. Fitting of modified exponential form $W_t = k + ab^t$ using twelve weeks body weights of Japanese quails

Sl. No.	Male					Female				
	k	a	b	r^2	s	k	a	b	r^2	s
1.	163.9384	-245.0447	0.7521	0.9565	12.3864	200.9154	-245.1225	0.8366	0.9708	10.334
2.	165.3366	-215.8630	0.8052	0.9810	7.4207	226.1211	-282.1480	0.8327	0.9877	7.704
3.	159.8471	-241.6212	0.7212	0.9766	8.7057	173.3957	-228.8422	0.7918	0.9780	8.400
4.	167.7558	-229.2746	0.7948	0.9721	9.5396	210.0499	-262.0112	0.8346	0.9776	9.609
5.	170.6955	-223.6132	0.8117	0.9782	8.1923	266.6588	-301.7841	0.8948	0.9880	7.146
6.	225.6341	-304.7634	0.8108	0.9782	11.3062	212.4865	-255.0987	0.8489	0.9823	8.207
7.	150.5409	-249.2208	0.6839	0.9588	11.3223	198.8199	-261.1647	0.8280	0.9752	10.275
8.	177.8341	-253.6819	0.7646	0.9724	10.3710	213.3607	-267.4097	0.8356	0.9562	13.717
9.	230.7521	-266.5086	0.8846	0.9785	8.7578	165.0680	-209.8250	0.8164	0.9885	5.626
10.	147.0304	-261.4604	0.6656	0.9465	13.3823	157.7321	-231.4638	0.7316	0.9404	13.391
11.	156.3837	-239.9615	0.7081	0.9773	8.4033	173.8451	-246.6636	0.7667	0.9742	9.741
12.	166.1128	-259.1395	0.7300	0.9572	12.7911	167.9366	-284.7830	0.7061	0.9440	15.749
13.	157.1927	-241.4964	0.7282	0.9609	11.3147	227.8141	-285.5292	0.8478	0.9732	11.380
14.	195.7738	-246.9884	0.8476	0.9692	10.5027	168.9433	-242.5633	0.7795	0.9615	11.753
15.	174.6588	-225.9999	0.8288	0.9772	8.4693	194.5022	-271.6741	0.7895	0.9730	11.155
16.	177.3641	-234.0547	0.8265	0.9658	10.6913	283.5470	-311.4117	0.8982	0.9928	5.623
17.	165.2859	-263.4979	0.7487	0.9373	16.0256	178.1192	-241.5617	0.8069	0.9715	10.161
18.	187.1813	-285.4888	0.7574	0.9616	13.7961	300.0216	-338.6324	0.8942	0.9842	9.270
19.	172.9213	-270.0449	0.7326	0.9574	13.4977	260.1619	-303.5030	0.8816	0.9895	7.072
20.	171.9506	-250.8732	0.7636	0.9454	14.2928	210.5899	-252.5438	0.8234	0.9754	9.894
21.	158.8989	-285.4201	0.6728	0.9446	15.1265	274.9760	-305.4132	0.9205	0.9765	8.877
22.	148.5922	-249.4521	0.7023	0.9418	13.9106	190.9590	-262.9399	0.7967	0.9704	11.293
23.	173.4858	-273.2112	0.7216	0.9675	11.7267	215.7255	-266.6726	0.8365	0.9806	9.099
24.	176.1137	-261.9190	0.7587	0.9659	11.9466	204.0956	-250.1310	0.8525	0.9841	7.593
25.	157.1719	-246.0018	0.7185	0.9556	12.1497	195.6006	-255.1274	0.8069	0.9837	8.057
26.	160.5914	-227.1659	0.7693	0.9738	9.1244	203.2485	-278.3002	0.7900	0.9763	10.630
27.	154.0206	-251.9375	0.7009	0.9635	11.2577	212.9009	-249.7476	0.8668	0.9764	9.019
28.	187.5848	-249.0773	0.8130	0.9756	9.6615	296.0054	-323.4373	0.9090	0.9857	7.904
29.	178.0179	-275.6724	0.7439	0.9568	13.8691	218.0186	-282.6589	0.8188	0.9687	12.363
30.	166.2498	-227.3428	0.7794	0.9803	7.8729	212.9579	-256.4950	0.8467	0.9730	10.222

Contd

Table 7. (Contd.)

Sl. No.	Male					Female				
	k	a	b	r^2	s	k	a	b	r^2	s
31.	166.8358	-253.6160	0.7398	0.9655	11.3732	209.9149	-247.3254	0.8523	0.9797	8.6113
32.	165.1522	-258.3229	0.7305	0.9619	12.0600	277.1983	-305.4186	0.8974	0.9771	10.0037
33.	205.5454	-233.7702	0.8962	0.9860	5.9429	276.8853	-310.3356	0.8948	0.9830	8.8016
34.	167.3957	-253.4505	0.7336	0.9730	9.9598	225.0890	-257.4897	0.8696	0.9883	6.5315
35.	273.3392	-320.4421	0.8827	0.9892	7.4939	229.6618	-265.2423	0.8726	0.9880	6.7279
36.	188.9175	-285.9516	0.7461	0.9679	12.422	359.7891	-389.3833	0.9415	0.9699	10.5803
37.	148.8030	-242.4947	0.7065	0.9576	11.6661	310.7318	-346.4321	0.9119	0.9820	9.3285
38.	171.2174	-216.9931	0.8077	0.9842	6.7630	235.7042	-291.6541	0.8435	0.9867	8.1902
39.	174.7937	-213.3276	0.8559	0.9825	6.8333	276.7466	-332.1031	0.8796	0.9794	10.9740
40.	143.9125	-238.9098	0.6778	0.9660	9.8901	220.2350	-259.5834	0.8514	0.9783	9.2791
41.	180.2350	-289.7511	0.7155	0.9578	14.0100	175.2133	-228.8705	0.8292	0.9443	13.2978
42.	131.1208	-268.3412	0.6225	0.8936	17.8562	227.1223	-260.4118	0.8694	0.9717	10.5774
43.	168.0497	-231.2896	0.7726	0.9767	8.6608	308.6038	-332.1158	0.9090	0.9587	13.9283
44.	198.4853	-279.3443	0.7921	0.9699	12.1818	955.1025	-975.2821	0.9785	0.9916	6.4043
45.	189.2563	-218.9779	0.8762	0.9885	5.394	485.2807	-518.2831	0.9487	0.9898	7.5135
46.	206.7318	-276.0309	0.8256	0.9682	12.1911					
47.	153.3342	-246.7610	0.7003	0.9613	11.1568					
48.	162.4482	-264.3253	0.7237	0.9501	14.1011					
49.	204.0732	-272.3026	0.8099	0.9727	11.1508					
50.	182.0986	-260.9365	0.7564	0.9777	9.4760					
51.	177.8614	-222.1326	0.8390	0.9813	7.4297					
52.	190.2545	-239.0581	0.8512	0.9587	11.7102					
53.	155.3202	-238.1950	0.7506	0.9431	13.7223					
54.	151.6216	-224.6323	0.7329	0.9730	8.7740					
55.	164.9066	-229.6761	0.8087	0.9512	12.599					
56.	151.1785	-245.8327	0.7186	0.9402	14.1243					
57.	175.5328	-201.3312	0.8830	0.9739	7.3288					
58.	182.0564	-242.539	0.8094	0.9765	9.3833					

Table 8. Fitting of logistic form $W_t = a/1+b \exp(-kt)$ using twelve weeks body weights of Japanese quails

Sl. No.	Male					Female				
	a	b	k	r^2	s	a	b	k	r^2	s
1.	152.5710	38.8391	0.8162	0.9917	6.4079	163.7900	38.4549	0.7658	0.9555	14.1010
2.	144.6990	33.7999	0.7619	0.9888	6.9623	185.3642	46.6043	0.8088	0.9586	15.6354
3.	152.1891	43.3044	0.9037	0.9742	10.7228	153.4382	39.2967	0.8245	0.9552	13.1737
4.	148.6116	36.0033	0.7704	0.9926	5.7522	170.5569	41.9428	0.7885	0.9501	15.2617
5.	147.1801	35.1431	0.7568	0.9872	7.0510	174.7130	38.3427	0.7111	0.9616	13.5972
6.	193.1123	51.5837	0.8250	0.9851	10.2302	167.6904	40.0934	0.7664	0.9527	14.8025
7.	145.9866	45.6057	0.9513	0.9755	9.7540	164.3494	41.4814	0.7698	0.9848	8.1877
8.	163.4043	41.9336	0.8407	0.9858	8.8767	174.2610	40.6608	0.7670	0.9710	12.1802
9.	162.1092	33.4109	0.6765	0.9920	6.4594	141.3042	31.8986	0.7478	0.9825	7.8714
10.	143.4711	42.6213	0.9423	0.9911	6.2749	147.7484	40.1381	0.8968	0.9458	13.8536
11.	150.0159	42.4876	0.9195	0.9721	10.9997	158.8080	40.4362	0.8374	0.9765	10.1852
12.	156.8975	42.6880	0.8754	0.9886	7.3226	160.7172	48.0852	0.9147	0.9918	6.2218
13.	148.9376	40.3527	0.8628	0.9819	8.6864	180.4389	41.0787	0.7462	0.9898	7.9240
14.	155.6389	34.3841	0.7017	0.9926	5.3995	152.4851	38.7752	0.7891	0.9943	5.0401
15.	145.3980	35.1438	0.7382	0.9931	5.0736	173.0641	43.8345	0.8140	0.9939	6.4892
16.	148.1724	36.1794	0.7338	0.9955	4.0477	185.3612	39.9989	0.7321	0.9500	17.0383
17.	153.2709	43.7801	0.8403	0.9964	3.6507	154.1474	38.7047	0.7737	0.9908	6.1210
18.	172.3861	49.3458	0.8662	0.9943	5.8306	196.6278	43.5528	0.7426	0.9414	19.0055
19.	162.7998	44.6126	0.8839	0.9829	9.0639	182.7520	39.6691	0.7194	0.9813	10.3071
20.	156.2952	40.3950	0.8332	0.9674	11.3178	178.1444	42.5364	0.8221	0.9216	20.5125
21.	154.3252	49.4482	0.9680	0.9912	6.4013	150.3265	34.1394	0.6559	0.9567	12.0654
22.	142.8177	40.3136	0.8786	0.9926	5.4400	167.0787	44.6193	0.8236	0.9727	11.1325
23.	164.7700	45.8276	0.9039	0.9861	8.5766	174.9730	43.9420	0.7982	0.9490	15.9868
24.	162.2651	41.7339	0.8399	0.9914	6.5969	159.8176	36.0041	0.7203	0.9874	7.4966
25.	149.4700	39.9554	0.8826	0.9801	8.8259	170.1170	41.8489	0.7960	0.9814	10.3575
26.	146.7926	35.3372	0.8078	0.9848	7.6555	180.8682	47.7206	0.8361	0.9836	10.4336
27.	147.9313	41.4027	0.9143	0.9861	7.4762	160.0292	34.9574	0.7105	0.9776	9.9324
28.	161.0933	39.5184	0.7682	0.9925	6.3009	182.7188	37.5701	0.6864	0.9751	12.1881
29.	165.5757	48.4897	0.8857	0.9825	8.9757	184.4013	46.2166	0.8109	0.9690	13.4583
30.	150.6449	37.0269	0.8005	0.9851	8.3204	170.4015	38.9918	0.7632	0.9638	13.4687

Contd.

Table 8. (Contd.)

Sl. No.	Male					Female				
	a	b	k	r^2	s	a	b	k	r^2	s
31.	156.6387	42.5693	0.8612	0.9906	7.0740	165.4490	39.0798	0.7589	0.9525	14.6862
32.	155.9276	46.2486	0.8868	0.9877	7.6311	180.1149	39.0989	0.7311	0.9335	18.5582
33.	135.3267	30.3695	0.6587	0.9754	8.0874	181.3279	40.2197	0.7326	0.9394	17.7085
34.	157.9105	47.0649	0.8974	0.9795	9.9371	167.0109	35.7250	0.7319	0.9512	14.9132
35.	189.3867	45.9464	0.7392	0.9751	12.1992	168.8429	36.0780	0.7227	0.9694	12.1634
36.	176.0976	53.7911	0.9041	0.9826	10.2178	164.4605	32.1779	0.5881	0.9948	4.5155
37.	142.7670	39.0415	0.8815	0.9911	6.0080	185.1556	38.3856	0.6846	0.9797	10.7926
38.	149.5566	33.7501	0.7666	0.9729	10.5430	188.4689	44.2608	0.7780	0.9735	12.7843
39.	136.2337	29.4012	0.6829	0.9932	4.6018	193.5117	44.5576	0.7389	0.9756	12.0826
40.	139.9199	41.2120	0.9386	0.9796	8.6642	172.4566	39.4060	0.7753	0.9327	17.8678
41.	171.6660	48.9980	0.9173	0.9826	9.8546	144.5802	32.7734	0.7193	0.9728	9.1852
42.	128.6274	41.4450	0.9866	0.9827	6.5552	166.9997	38.6369	0.7454	0.9289	17.9847
43.	153.2663	36.9524	0.8068	0.9781	9.8691	189.5505	42.6814	0.7320	0.9151	22.2938
44.	175.5572	44.7244	0.8180	0.9902	7.4456	188.7253	35.8378	0.6188	0.9778	10.8188
45.	138.6245	26.7885	0.6486	0.9877	6.2181	195.4401	39.6018	0.6436	0.9821	10.1162
46.	171.9819	43.3034	0.7638	0.9943	5.3873					
47.	147.4760	43.2312	0.9199	0.9787	9.2910					
48.	153.9172	44.8359	0.8859	0.9954	4.6554					
49.	176.3955	42.9709	0.7785	0.9911	7.6518					
50.	168.1246	48.3309	0.8870	0.9680	12.8064					
51.	144.7622	33.3731	0.7191	0.9848	7.2827					
52.	150.4717	34.0455	0.6833	0.9962	3.9147					
53.	144.5246	38.1363	0.8059	0.9926	5.2550					
54.	143.4013	39.4547	0.8665	0.9758	9.6590					
55.	142.4020	35.4530	0.7357	0.9982	2.3833					
56.	143.7593	37.6537	0.8505	0.9908	5.7188					
57.	126.3302	23.9437	0.6091	0.9920	4.5280					
56.	157.3121	36.5884	0.7695	0.9896	6.9291					

Table 9. Fitting of Gompertz form W_t = a exp [-b exp (-kt)] using twelve weeks body weights of Japanese quail

Sl. No.	Male					Female				
	a	b	k	r^2	s	a	b	k	r^2	s
1.	156.7725	5.0220	0.4791	0.9916	5.2678	174.0030	4.4575	0.4007	0.9730	10.0737
2.	151.1534	4.4686	0.4222	0.9955	3.5494	196.0003	4.7875	0.4175	0.9842	8.7551
3.	154.7829	5.2278	0.5387	0.9938	4.4351	159.3442	4.7277	0.4571	0.9783	8.3106
4.	154.8572	4.7179	0.4331	0.9959	3.5211	180.9313	4.7314	0.4137	0.9747	10.2040
5.	154.3868	4.5942	0.4173	0.9949	3.8900	194.1329	4.3251	0.3424	0.9846	8.1388
6.	202.4648	5.2242	0.4376	0.9963	4.4566	179.1029	4.4819	0.3926	0.9768	9.5061
7.	147.5777	5.6822	0.5902	0.9919	4.8655	173.8830	4.9408	0.4119	0.9935	5.0179
8.	168.1596	4.9769	0.4785	0.9940	4.6586	185.1077	4.6249	0.4007	0.9730	10.6568
9.	178.7962	4.2030	0.3353	0.9921	5.2585	148.5159	4.3203	0.4099	0.9957	3.3772
10.	144.8657	5.6998	0.5991	0.9953	3.6592	151.1450	5.0486	0.5311	0.9581	11.0913
11.	152.2191	5.2015	0.5547	0.9936	4.4179	163.6813	4.9713	0.4791	0.9901	5.8350
12.	160.0794	5.3741	0.5223	0.9930	4.8802	163.2631	5.9143	0.5570	0.9937	4.9750
13.	151.9056	5.2097	0.5185	0.9902	5.4603	193.0185	4.7335	0.3866	0.9920	6.0315
14.	166.9628	4.5895	0.3746	0.9928	4.9826	158.0163	5.0511	0.4531	0.9950	4.1554
15.	153.5956	4.7144	0.4036	0.9977	2.5847	179.8029	5.0615	0.4508	0.9990	2.0808
16.	156.6605	4.8405	0.4032	0.9947	4.1344	204.6063	4.1839	0.3450	0.9812	9.5574
17.	157.3094	5.7227	0.4999	0.9920	5.6730	161.3918	4.9111	0.4286	0.9958	3.7646
18.	177.0876	5.6613	0.4982	0.9992	2.0955	216.9755	4.5170	0.3561	0.9727	12.3112
19.	166.2762	5.3631	0.5201	0.9880	6.5981	200.0941	4.5189	0.3560	0.9952	4.7782
20.	161.6566	5.0708	0.4801	0.9724	9.8965	186.5089	4.5082	0.4311	0.9597	13.2714
21.	155.9701	6.1175	0.6050	0.9960	3.7744	171.6447	4.4302	0.3178	0.9768	8.8390
22.	145.0535	5.4805	0.5448	0.9914	5.0559	174.0158	5.1470	0.4538	0.9861	7.4082
23.	167.7151	5.5239	0.5395	0.9980	2.7080	185.3796	4.7352	0.4143	0.9754	10.2703
24.	166.8214	5.2282	0.4873	0.9965	3.6075	171.8083	4.4771	0.3748	0.9957	3.8838
25.	152.2062	5.2704	0.5355	0.9878	6.1036	177.8424	4.7487	0.4308	0.9947	4.7283
26.	151.3085	4.7912	0.4684	0.9929	4.4841	187.6526	5.1104	0.4577	0.9944	5.0912
27.	150.0545	5.4897	0.5632	0.9968	3.0670	173.4582	4.2738	0.3605	0.9850	7.2439
28.	169.1582	4.8172	0.4194	0.9971	3.2465	204.8346	4.1934	0.3234	0.9875	7.7286
29.	169.6218	5.6519	0.5165	0.9909	6.0286	193.5603	4.9767	0.4310	0.9808	9.5715
30.	155.8200	4.6911	0.4540	0.9956	3.7292	181.0871	4.4847	0.3945	0.9774	9.4816

Contd.

Table 9. (Contd.)

Sl. No.	Male					Female				
	a	b	k	r^2	s	a	b	k	r^2	s
31.	160.1809	5.2446	0.5071	0.9968	3.3076	176.3127	4.4848	0.3919	0.9763	9.5574
32.	159.0620	5.5511	0.5262	0.9957	3.8149	199.1793	4.2359	0.3489	0.9654	12.5675
33.	150.1221	4.2419	0.3320	0.9899	5.0056	200.2744	4.3847	0.3527	0.9716	11.5022
34.	161.0165	5.4534	0.5274	0.9958	3.8129	180.9018	4.1817	0.3663	0.9785	9.0938
35.	207.9940	4.7461	0.3612	0.9929	6.1260	183.2219	4.2544	0.3611	0.9870	7.1370
36.	180.1215	5.7087	0.5188	0.9958	4.3037	195.3182	4.2907	0.2755	0.9887	6.4459
37.	144.9853	5.3604	0.5448	0.9965	3.1733	208.2546	4.4067	0.3253	0.9888	7.3534
38.	156.1814	4.3610	0.4221	0.9876	6.1229	200.5710	4.7938	0.4021	0.9914	6.5949
39.	146.4951	4.2989	0.3649	0.9976	2.4517	211.4276	4.8930	0.3677	0.9894	7.6041
40.	141.3684	5.4142	0.5905	0.9953	3.4448	183.9129	4.4695	0.3984	0.9657	11.8911
41.	174.6436	5.6516	0.5468	0.9920	5.7268	153.4808	4.6819	0.3985	0.9715	9.3145
42.	129.6722	6.3541	0.6635	0.9741	8.0884	181.2520	4.3246	0.3727	0.9589	12.9123
43.	158.3134	4.6927	0.4611	0.9907	5.5262	210.8006	4.2564	0.3399	0.9478	16.2553
44.	182.3380	5.2599	0.4557	0.9963	4.0778	234.6334	4.1579	0.2616	0.9934	5.6635
45.	151.5491	3.9899	0.3367	0.9951	3.4884	232.5885	4.4501	0.2888	0.9952	5.1286
46.	182.0225	5.0885	0.4110	0.9966	3.9775					
47.	149.5542	5.4500	0.5631	0.9913	5.0249					
48.	156.8388	5.6686	0.5329	0.9966	3.5834					
49.	185.1975	4.8652	0.4206	0.9948	4.8067					
50.	172.4804	5.2958	0.5048	0.9896	6.4176					
51.	154.2059	4.4497	0.3861	0.9934	4.3798					
52.	162.2282	4.5628	0.3635	0.9880	6.2778					
53.	148.5103	5.2240	0.4814	0.9891	5.9308					
54.	146.2260	5.0748	0.5176	0.9916	4.8664					
55.	149.4904	4.9931	0.4172	0.9921	5.0622					
56.	146.574	5.2999	0.5229	0.9882	5.9668					
57.	139.4108	3.8540	0.3173	0.9892	4.7057					
58.	164.7302	4.6989	0.4235	0.9953	4.0006					

Fitting of models using average body weights of Japanese quails over twelve weeks

Table 10. Linear $W_t = a + bt$

Sex	a	b	r^2	s
Male	11.5402	14.2256	0.9039	17.5456
Female	5.1070	16.1753	0.9538	13.4568
Irrespective of sex	8.7296	15.0774	0.9295	15.6984

Table 11. Quadratic $W_t = a + b_1t + b_2t^2$

Sex	a	b_1	b_2	r^2	s
Male	-32.7088	33.1894	-1.4588	0.9926	5.1460
Female	-28.3067	30.4955	-1.1015	0.9951	4.6110
Irrespective of sex	-20.7853	32.0124	-1.3027	0.9943	4.7077

Table 12. Exponential $W_t = a \exp(bt)$

Sex	a	exp(b)	r^2	s
Male	18.4335	1.2520	0.6534	51.3204
Female	17.9536	1.2655	0.7336	52.3387
Irrespective of sex	18.2102	1.2581	0.6916	51.7545

Table 13. Von-Bertalanffy $W_t = a\,[1-b \exp(kt)]^3$

Sex	b	k	r^2	s
Male (a = 210 g)	0.6515	-0.1854	0.9580	11.9131
Female (a = 230 g)	0.7221	-0.1954	0.9851	7.8073
Irrespective of sex (a = 220 g)	0.6813	-0.1880	0.9724	10.0626

Table 14. Modified exponential $W_t = k + ab^t$

Sex	k	a	b	r^2	s
Male	168.6513	-240.1105	0.7718	0.9754	9.3476
Female	219.5777	-265.1914	0.8532	0.9921	5.7300
Irrespective of sex	187.1863	-245.3882	0.8106	0.9858	7.3496

Table 15. Logistic a/1+b exp(-kt)

Sex	a	b	k	r^2	s
Male	153.7328	39.1829	0.8161	0.9918	6.4281
Female	171.6814	39.2857	0.7496	0.9778	10.7745
Irrespective of sex	161.5433	39.0390	0.7829	0.9863	8.3039

Table 16. Gompertz $W_t = a \exp[-b \exp(-kt)]$

Sex	a	b	k	r^2	s
Male	158.6057	4.9667	0.4677	0.9991	1.6903
Female	183.8152	4.5238	0.3846	0.9949	4.6230
Irrespective of sex	169.1025	4.7301	0.4267	0.9982	2.6054

Table 17. Initial body weights (W_0) and 'b' values of male and female Japanese quails for Rao's method

Sl. No.	Male		Female	
	W_0	b	W_0	b
1.	7.0	0.009532	7.0	0.009383
2.	7.0	0.008268	7.0	0.010811
3.	7.0	0.009923	7.0	0.009777
4.	6.9	0.009056	7.2	0.010352
5.	6.9	0.008853	6.9	0.009385
6.	6.9	0.010741	6.9	0.010228
7.	6.9	0.009980	6.9	0.009567
8.	7.0	0.010210	7.0	0.010455
9.	7.0	0.008240	7.0	0.008020
10.	7.0	0.009208	7.2	0.009408
11.	7.0	0.009595	7.2	0.010195
12.	7.2	0.010136	7.2	0.010521
13.	7.2	0.009998	7.2	0.010385
14.	7.2	0.008936	7.2	0.009359
15.	7.2	0.008137	7.0	0.010283
16.	7.2	0.008195	7.0	0.010525
17.	7.2	0.009277	7.0	0.009125
18.	7.2	0.010391	7.4	0.011679
19.	7.0	0.010215	7.4	0.010113
20.	7.0	0.009807	7.4	0.011260
21.	7.0	0.010021	7.0	0.007931
22.	7.0	0.009146	7.0	0.010455
23.	7.4	0.010568	7.0	0.010825
24.	7.4	0.009834	7.0	0.009019
25.	7.4	0.009552	7.0	0.010535
26.	7.4	0.009063	7.0	0.011331
27.	7.4	0.009406	7.0	0.008658
28.	7.0	0.009573	7.3	0.010202
29.	7.0	0.010816	7.3	0.011204

Contd.

Table 17. (Contd.)

Sl. No.	Male		Female	
	W_0	b	W_0	b
30.	7.0	0.009374	7.3	0.010065
31.	7.0	0.010039	7.2	0.010431
32.	7.0	0.010150	7.2	0.010385
33.	7.0	0.007082	7.2	0.010676
34.	7.0	0.010326	7.2	0.009972
35.	7.0	0.010861	7.2	0.009921
36.	7.0	0.011209	7.2	0.007862
37.	7.3	0.009264	7.5	0.010127
38.	7.3	0.009258	7.5	0.011036
39.	7.2	0.007353	7.5	0.010767
40.	7.2	0.009300	7.5	0.010512
41.	7.2	0.011744	7.5	0.008152
42.	7.2	0.008783	7.0	0.010316
43.	7.2	0.009587	7.2	0.011618
44.	7.5	0.010677	7.2	0.009040
45.	7.5	0.007571	7.2	0.010074
46.	7.0	0.009984		
47.	7.0	0.009986		
48.	7.0	0.009821		
49	7.0	0.010506		
50.	7.0	0.010801		
51.	7.0	0.008665		
52.	7.0	0.007907		
53.	7.2	0.009109		
54.	7.2	0.009312		
55.	7.2	0.007680		
56.	7.2	0.009384		
57.	7.2	0.006609		
58.	7.2	0.009038		

Table 18. Analysis of covariance of initial body weights (W_0) and 'b' values by Rao's method

Source	D.F.	SS(X)	SS(Y)	SP(XY)	ADJ D.F	ADJ M.S.S	F	Mean of 'b' values	ADJ Values $W_{io}-(X_{io}-6.241748)$
Between groups	1	579.6616	0.001085	0.794905	1	7.586867E-06	9.318347**	0.009539	0.009250
Within group	101	2.75	0.000082	0.000902	100	8.141859E-07		0.0100432	0.000741
Total	102	582.4116	0.001176	0.795807	101				

Regression estimate = 0.000328

$$\text{To test 'b'} = \frac{[SP(XY)]^2}{SS(X)} / \text{ ADJ M.S.E.}$$

$$= 0.3631 < 1 \text{ (not significant)}$$

Table 19. Total weekly fortnightly and mean weekly egg production per bird of Japanese quails

Weeks	Total weekly egg production	Total fortnightly egg production	Mean weekly egg production
1	23		0.7188
2	69	92	2.1563
3	119		3.7188
4	134	253	4.1875
5	153		4.7813
6	147	300	4.5938
7	138		4.3125
8	178	316	5.5625
9	196		6.1250
10	180	376	5.6250
11	185		5.7813
12	166	351	5.1875
13	170		5.3125
14	168	338	5.2500
15	141		4.4063
16	121	262	3.7813
17	117		3.6563
18	154	271	4.8125
19	158		4.9375
20	168	326	5.2500
21	179		5.5938
22	180	359	5.6250
23	164		5.1250
24	145	309	4.5313
25	146		4.5625
26	139	285	4.3438

Table 20. Hen housed and hen day egg production of Japanese quails during the period 1.1.1989 to 30.9.1989

Months	Number of layers at the beginning of month	Number of days in each month	Total hen days	Total number of eggs produced	Hen housed egg production	Number of birds expired	Number of days absent by dead birds during the month	Hen days of survivors	Hen day egg production
(1)	(2)	(3)	(4) (=2x3)	(5)	(6) $\frac{(5)}{(4)} \times 100$	(7)	(8)	(9) (4)-(8)	(10) $\frac{(5)}{(9)} \times 100$
February	62	28	1736	0	0	0	--	1736	0
March	62	31	1922	38	1.9771	0	--	1922	1.9771
April	62	30	1860	885	47.5806	0	--	1860	47.5806
May	62	31	1922	1304	67.8460	3	41	1881	69.3248
June	59	30	1770	1294	73.1073	3	12	1758	73.6064
July	56	31	1736	976	56.2212	5	29	1707	57.1763
August	51	31	1581	1003	63.4409	8	195	1386	72.3665
September	43	30	1290	722	55.9690	2	41	1249	57.8063

Table 21. Fitting of mathematical models for weekly egg production of Japanese quails

Models	a	b	c	d	r^2	s	I
Linear	121.4000	1.9419	--	--	0.1601	34.7162	34.7162
Exponential	101.1137	0.0237	--	--	0.1264	38.1350	12228.2900
Parabolic exponential	57.0929	0.1462	-4.5362	--	0.4850	0.3165	101.4965
Inverse polynomial	0.0205	0.0032	0.0001	--	0.9213	0.0145	280.6831
Gamma function	35.5322	1.0571	-0.0833	--	0.8223	0.1860	59.6288
Gamma type function	1049.1900	3.6236	0.2729	-4.0810	0.9223	0.1258	40.3254
Quadratic function	69.0193	13.1663	-0.4157	--	0.4889	27.6640	27.6640
Quadratic function log scale	13.4228	124.6064	-25.6003	--	0.7471	19.4584	19.4584
Quadratic-cum-log	31.6676	-17.2984	0.2521	122.8046	0.7602	19.3758	19.3758
Emperical	0.0266	-0.0775	--	--	0.6480	23.4910	7532.5820
Linear hyperbolic	192.6841	-1.3239	-183.4538	--	0.7194	20.4970	20.4970

Table 22. Fitting of mathematical models for fortnightly egg production of Japanese quails

Models	a	b	c	d	r^2	s	I
Linear	241.1923	7.7198	--	--	0.1749	68.1949	68.1949
Exponential	210.2932	0.0420	--	--	0.1426	73.1730	47549.3000
Parabolic exponential	119.7881	0.2671	-0.0161	--	0.5443	0.2650	172.2323
Inverse polynomial	0.0063	0.0013	0.0001	--	0.9374	0.0034	269.1243
Gamma function	129.8996	1.1039	-0.1627	--	0.8166	0.1681	109.2483
Gamma type function	90987.1600	4.8825	0.7049	-7.5894	0.9240	0.1141	74.1584
Quadratic function	126.0351	53.7827	-3.2902	--	0.5245	54.2986	54.2986
Quadratic function log scale	97.1038	268.8874	-75.5807	--	0.8018	35.0586	35.0586
Quadratic-cum-log	195.6462	-107.5919	3.3230	370.8704	0.8190	35.3130	35.3130
Emperical	0.0074	-0.1435	--	--	0.6793	43.3137	28146.1400
Linear hyperbolic	450.5895	-10.0145	348.5215	--	0.8052	34.7535	34.7535

Table 23. Fitting of mathematical models for hen housed egg production of Japanese quails

Models	a	b	c	d	r^2	s	I
Linear	26.2958	6.5026	--	--	0.3500	20.9682	20.9882
Exponential	8.3317	0.3720	--	--	0.1428	38.8248	3298.7340
Parabolic exponential	0.6035	2.1221	-0.2188	--	0.7807	0.7445	63.2596
Inverse polynomial	0.6405	-0.2770	0.0302	--	0.6786	0.1150	156.6152
Gamm function	8.4609	5.2193	-1.2209	--	0.9371	0.3987	33.8736
Gamma type function	1.109345E+19	25.4443	5.7197	-48.8799	0.9963	0.1123	9.5416
Quadratic function	-27.2613	42.2073	-4.4631	--	0.8448	11.4576	11.4576
Quadratic function log scale	1.2589	96.6707	-35.3734	--	0.9571	6.0220	6.0220
Quadratic-cum-log	50.4287	-51.2273	1.9775	137.3186	0.9609	6.6385	6.6385
Emperical	0.1197	0.0668	--	--	0.2687	30.4821	2589.9000
Linear hyperbolic	127.2179	-7.7595	-118.4475	--	0.9533	6.2830	6.2830

Table 24. Fitting of mathematical models for hen day egg production of Japanese quails

Models	a	b	c	d	r^2	s	I
Linear	24.9896	7.3183	--	--	0.4022	21.1125	21.1125
Exponential	8.1594	0.3847	--	--	0.1748	40.4675	3542.5890
Parabolic exponential	0.5927	2.1329	-0.2185	--	0.7884	0.7398	64.7593
Inverse polynomial	0.6414	-0.2772	0.0301	--	0.6838	0.1146	165.6879
Gamm function	8.2854	5.1986	-1.2019	--	0.9378	0.4011	35.1081
Gamma type function	4.855436E+18	25.0332	5.6049	-47.9365	0.9934	0.1505	13.1725
Quadratic function	-28.5834	43.0336	-4.4644	--	0.8513	11.7737	11.7737
Quadratic function log scale	1.2386	95.4551	-33.5394	--	0.9382	7.5873	7.5873
Quadratic-cum-log	42.7397	-42.7434	1.4483	126.064	0.9401	8.6287	8.6287
Emperical	0.1222	0.0795	--	--	0.3046	31.5089	2758.3370
Linear hyperbolic	124.5305	-6.7486	-116.8264	--	0.9346	7.8062	7.8062

Table 25. Weekly mean temperature and humidity with weekly average egg production per bird

Average weekly egg production Y	Previous three weeks average	
	Temperature Z_1	Humidity Z_2
0.72	29.00	65.80
2.16	29.00	68.80
3.72	29.70	69.90
4.19	29.90	70.70
4.78	29.80	74.40
4.59	30.00	75.90
4.31	30.00	75.70
5.56	30.20	75.50
6.13	29.60	77.10
5.63	29.10	79.00
5.78	28.50	80.10
5.19	27.50	82.50
5.31	26.80	84.00
5.25	26.00	85.90
4.41	26.30	84.50
3.78	26.60	82.30
3.66	27.00	80.70
4.81	26.50	81.80
4.94	26.10	84.00
5.25	25.70	84.40
5.59	25.90	83.70
5.63	26.00	84.80
5.13	26.20	84.10
4.53	26.60	84.00
4.56	26.90	81.80
4.34	26.60	82.60

Table 26. ANOVA

Source	DF	M.S.S.
Regression	2	12.8714**
Error	23	0.3430

FIG.1 AGE v/s MEAN BODY WEIGHT OF QUAILS

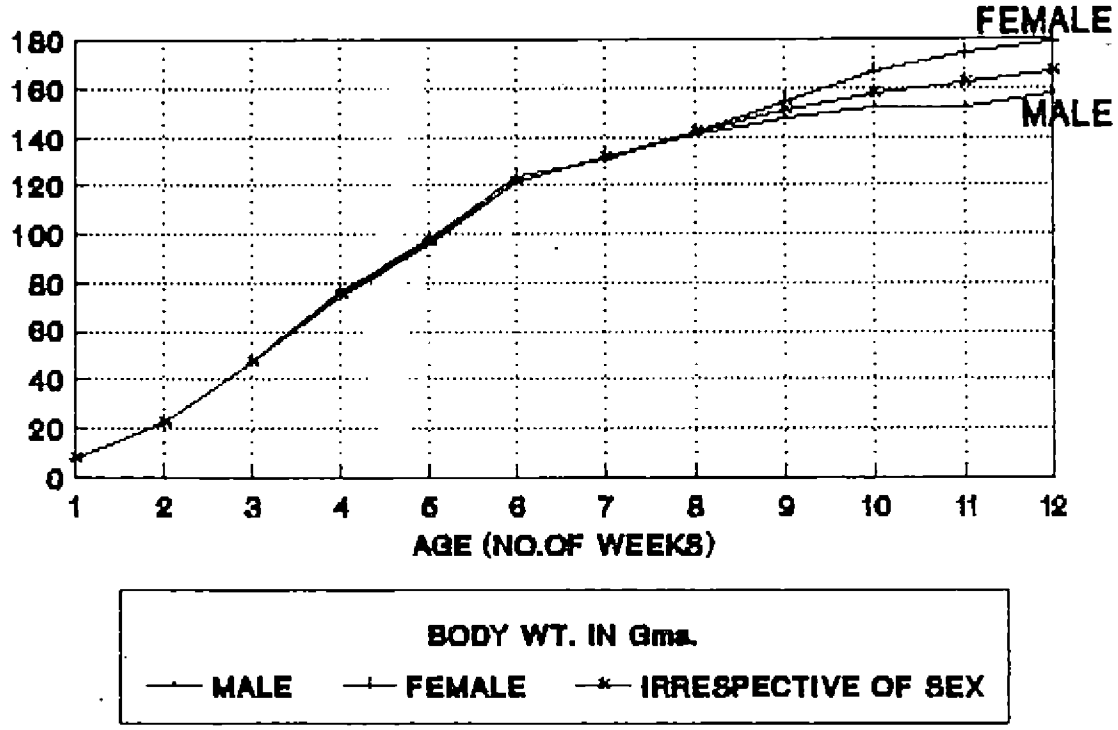


FIG.2 GOMPERTZ CURVE FITTED TO JAPANESE QUAILS (MALE) USING AVERAGE WEEKLY BODY WEIGHT

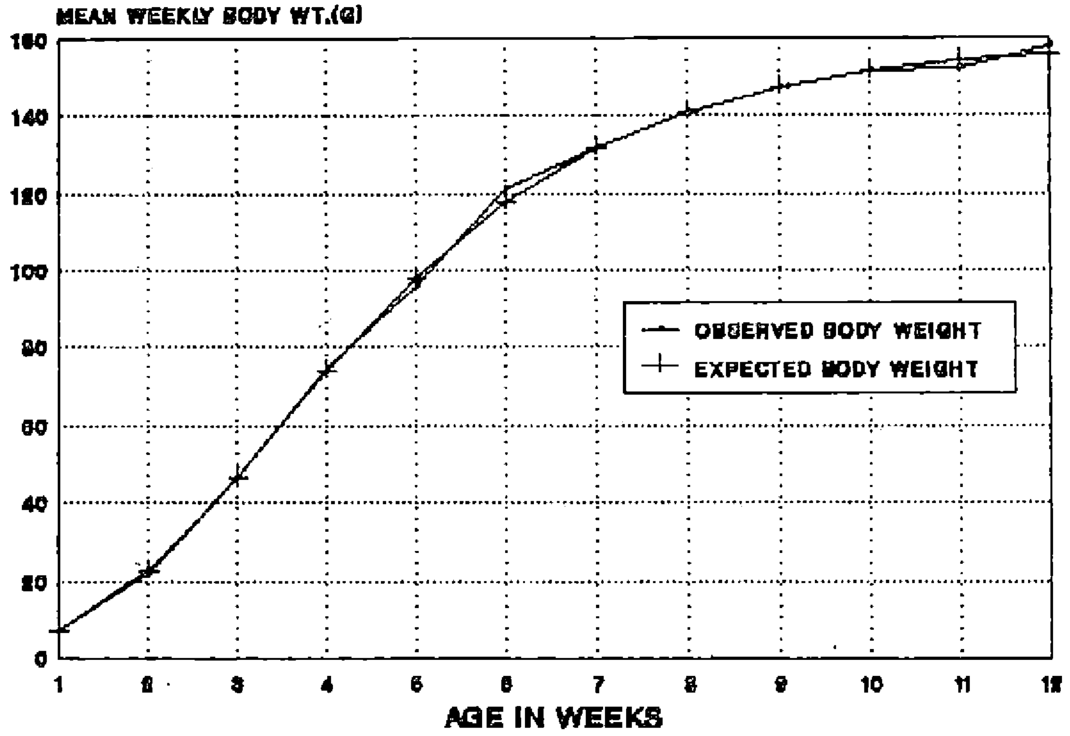


FIG.3 QUADRATIC CURVE FITTED TO JAP.QUAILS (FEMALE)USING AV.WEEKLY BODY WEIGHT

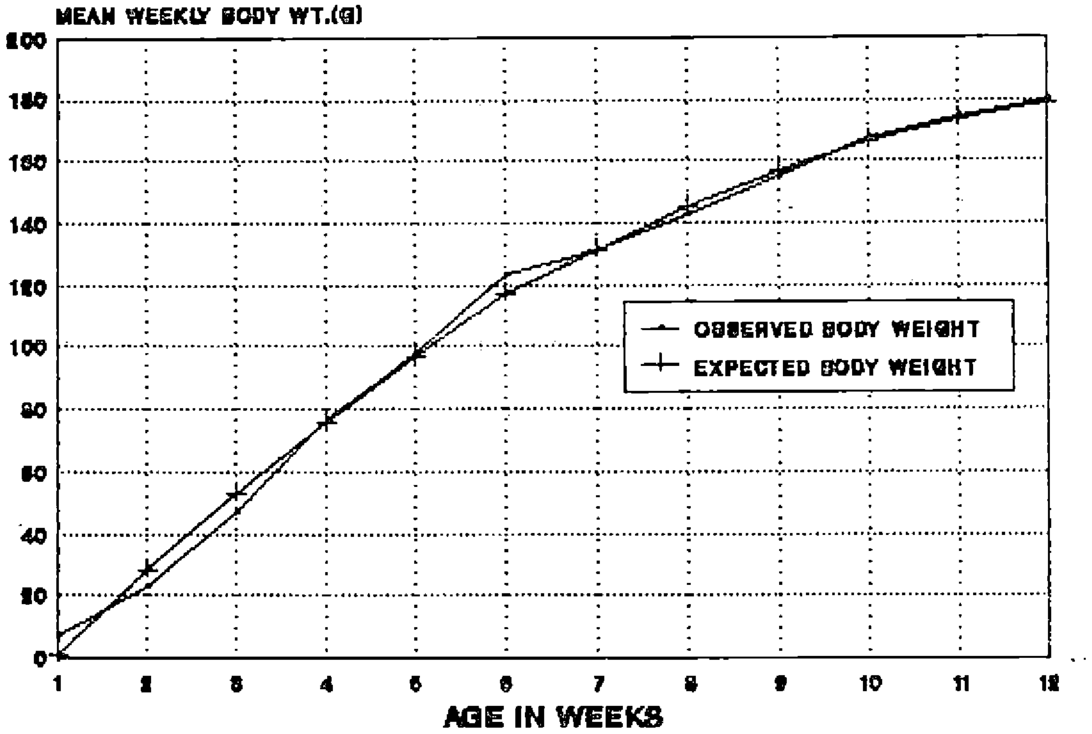


FIG.4 **GOMPERTZ CURVE FITTED TO JAPANESE QUAILS (FEMALE)USING AV.WEEKLY BODY WEIGHT**

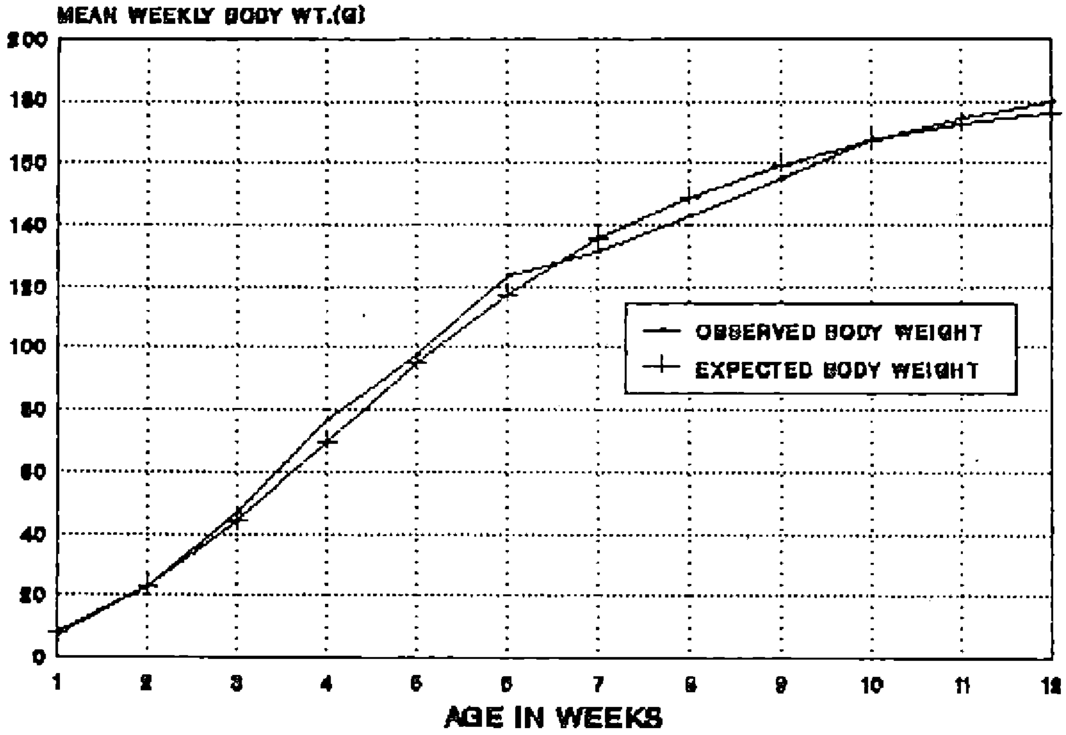


FIG.5 **GOMPERTZ CURVE FITTED TO JAPANESE QUAILS**
USING AVERAGE WEEKLY BODY WEIGHT
(IRRESPECTIVE OF SEX)

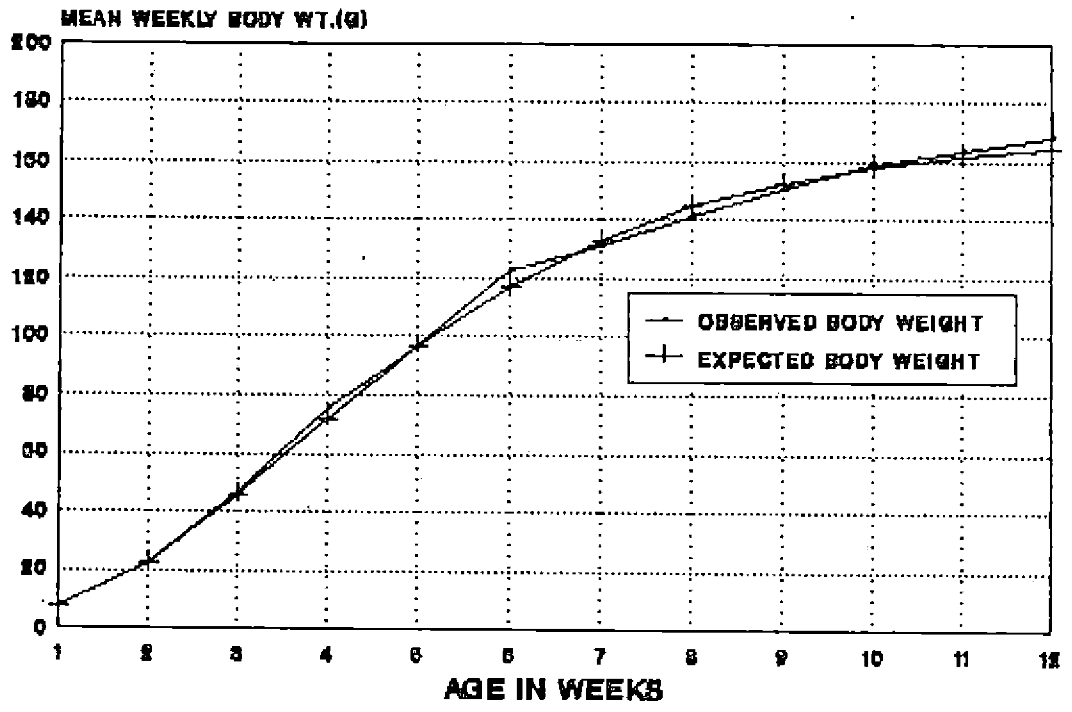


FIG. 6 WEEKLY EGG PRODUCTION OF JAPANESE QUAILS
(COTURNIX COTURNIX JAPONICA)

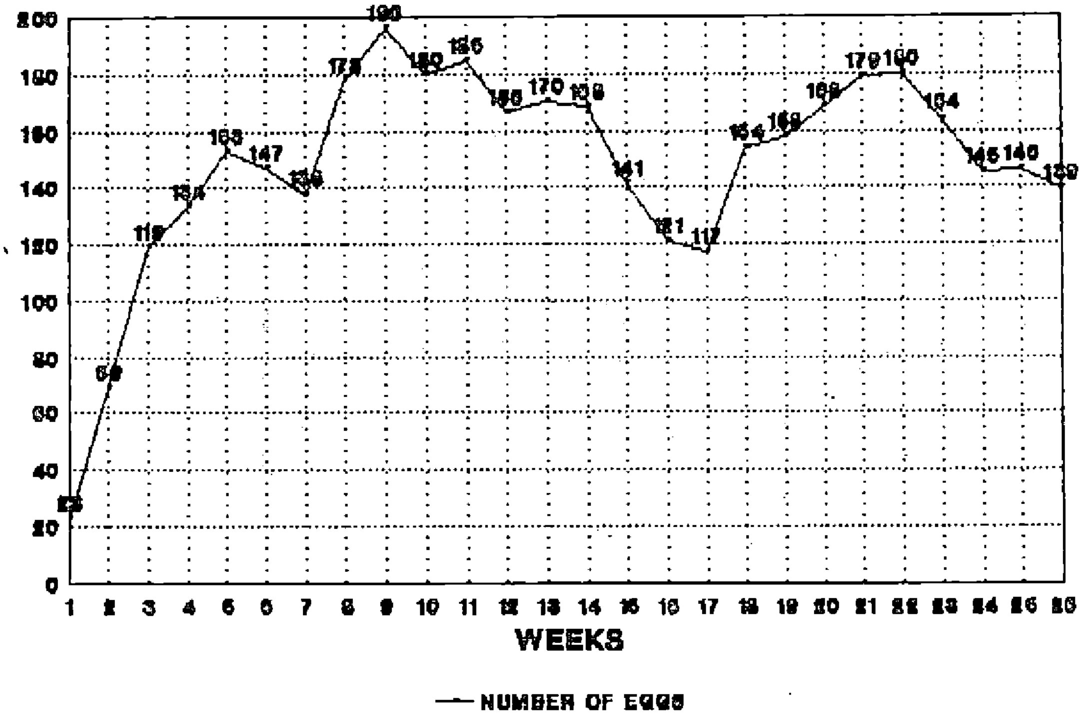


FIG. 7 FORTNIGHTLY EGG PRODUCTION OF JAPANESE QUAILS
(COTURNIX COTURNIX JAPONICA)

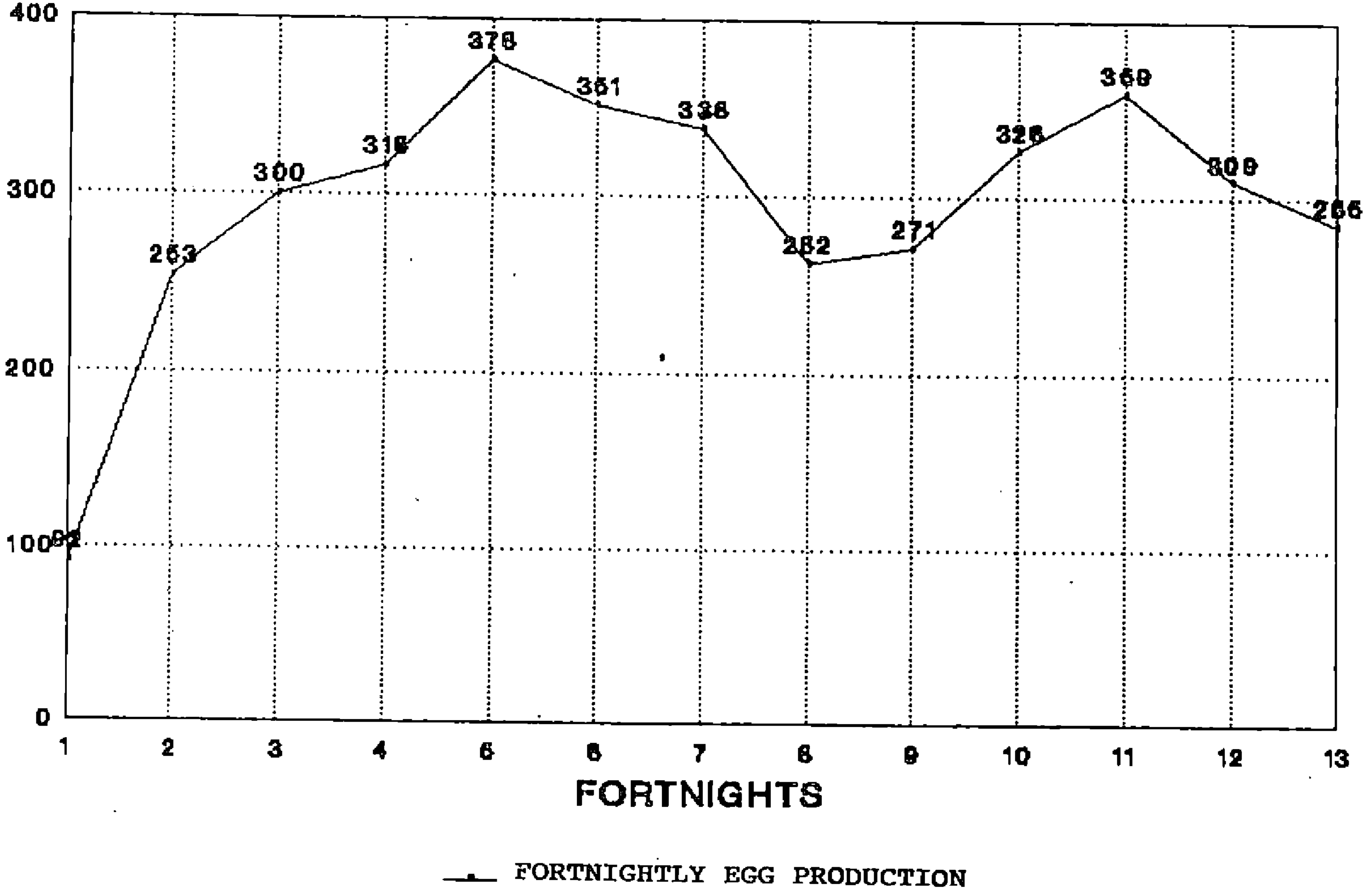
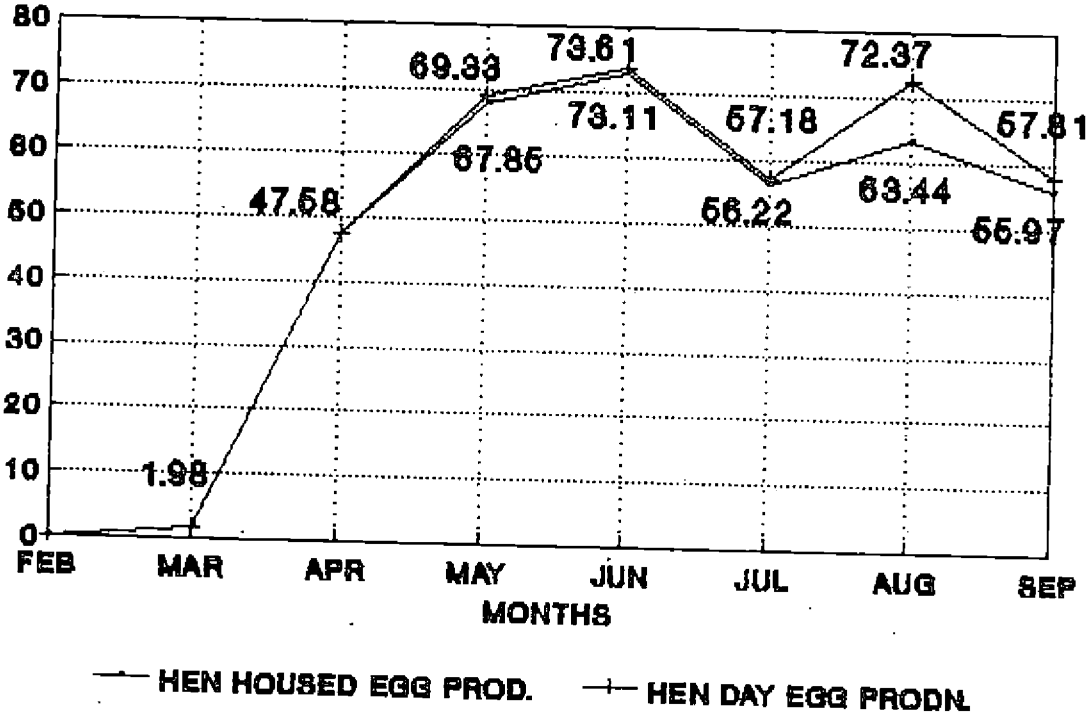


FIG.8 HEN HOUSED & HEN DAY EGG PRODN.
JAP.QUAILS(COTURNIX COTURNIX JAPONICA)



COMBINED DATA FOR 1.2.'89 TO 30.9.'89

FIG.9 **EXPECTED WEEKLY EGG PRODN.OBTAINED FROM QUADRATIC-CUM-LOG & QUADRATIC FNJN LOG SCALE ALONG WITH OBSERVED EGG PRODN.**

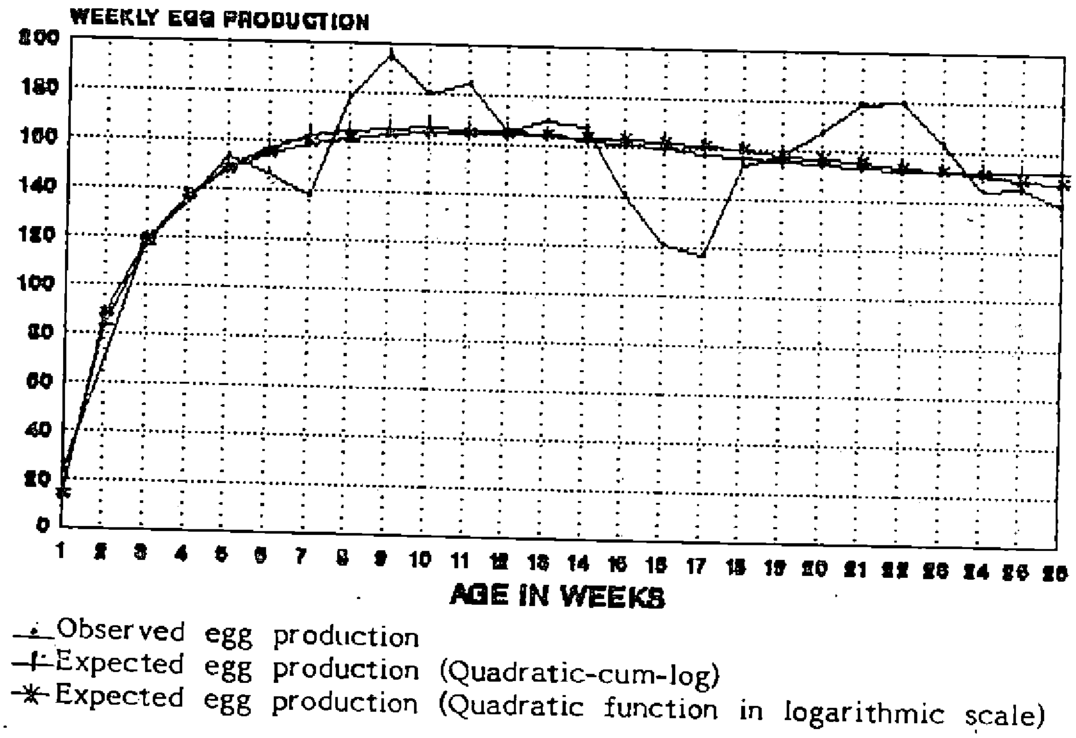


FIG.10 **EXPECTED FORTNIGHTLY EGG PRODN.OBTAINED FROM LINEAR HYPERBOLIC FN.& QUADRATIC FN. IN LOG SCALE WITH OBSERVED EGG PRODN**

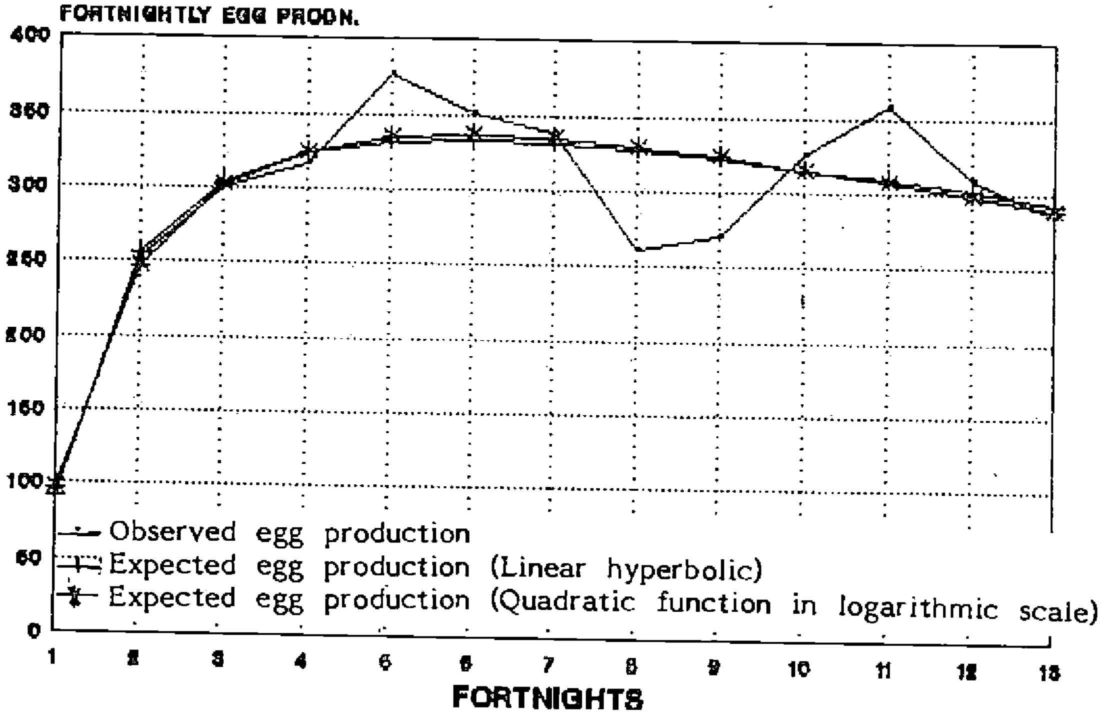


FIG.11 QUADRATIC FUNCTION IN LOG SCALE FITTED TO THE MONTHLY HEN HOUSED EGG PRODN. OF JAPANESE QUAILS

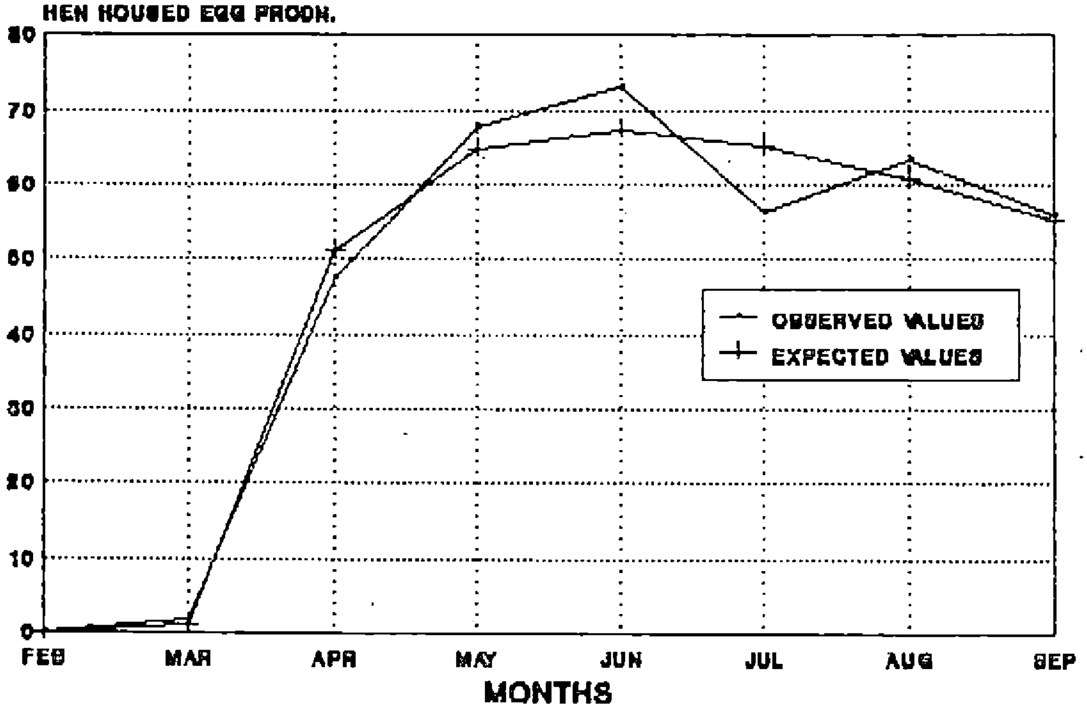
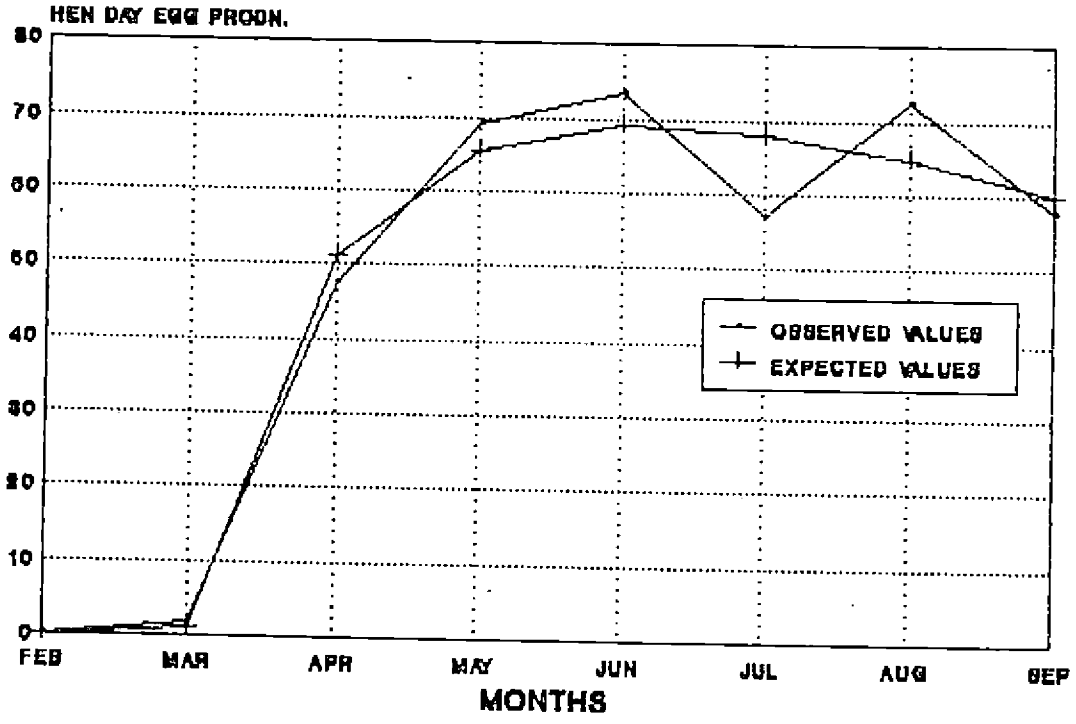


FIG.12 **QUADRATIC FUNCTION IN LOG SCALE FITTED TO THE MONTHLY HEN DAY EGG PRODN. OF JAPANESE QUAILS**



Discussion

DISCUSSION

The results of the present investigations were already given in chapter 4. Most of the results obtained were having a reasonable comparison with the results obtained by other research workers in this field with few exception.

In the case of egg production in quails practically no work have been done. Hence could not have a comparative study of this aspect. The discussion of the result obtained were given in this chapter.

5.1 Growth study

The average hatching weight of one hundred and three (103) Japanese quails (58 males and 45 females) were found to be 7.1369 ± 0.1698 g. This was slightly higher than the average hatching weight (6.50 g) given by Ricklefs (1979) but falls in the range of 5.12 - 8.05 g for Japanese quails as hatching weight given by Ricklefs (1979). The average hatching weight in the present study was also higher than the average hatching weight given by Sreenivasaiah *et al.* (1987 a) who reported an average initial body weight as 5.74 g (Monsoon hatch - August) and 6.02 g (Winter hatch - November).

It was observed that the average hatching weight for males and females were found to be 7.1172 ± 0.1591 g and 7.1622 ± 0.1813 g respectively and females weighed more.

The body weight steadily increased for males, females and birds irrespective of sex (Table 1) upto 12th week. In all the cases females exceeded males with respect to body weights. The same phenomenon was observed by Ino *et al.* (1985) for males and females eventhough the body weights were not in agreement with the present study.

The average body weight during the 12th weeks were found to be 157.6552 ± 14.5199 g and 179.2000 ± 19.8055 g for males and females respectively. This was found to be in agreement with the results obtained by Kozaczynski (1985).

Analysis of variance (Table 2) showed that there was no significant difference in body weights between males and females upto 8th week. But from 9th week to 12th week there was significant difference in body weights between male and female Japanese quails. Fig.1 further substantiate the claim.

In order to study the trend in body weights further body weights were taken at 27th and 35th week for males and females.

During the 27th week the average body weights again shown an increasing trend with females weighing more (194 g) than males (172.4310 g) and the analysis of variance have shown that there was significant difference in body weights between males and females.

At the 35th week there was a slight decline in average body weights for females (192.4839 g) while the average body weights for males (179.4483 g) again shown an increasing trend and the analysis of variance again showed that there was significant difference in body weights between males and females. The average body weights for birds irrespective of sex were also worked out for 27th and 35th week and it was found to be 181.8544 ± 23.9376 g and 185.1456 ± 21.8023 g respectively. In general it could be concluded that the body weights of quails showed an increasing trend even upto 35th week.

Various mathematical models were fitted and Gompertz curve has emerged as best one for ascertaining growth in quails over twelve weeks having higher 'r^2' values and lower 's' values. This was found to be in agreement with the curve suggested by Laird (1965) and Ricklefs (1985).

It was observed that for the development of suitable models for ascertaining growth in quails using average body weights over twelve weeks, Gompertz curve emerged as the best one followed by quadratic and logistic in the case of males and birds irrespective of sex while quadratic curve (Fig.3) emerged as best one followed by Gompertz and modified exponential in the case of females.

In general Gompertz curve was found to be most suitable for the development of models for ascertaining growth in Japanese quails having highest 'r^2' and lowest 's' values. Fig.2, 4, 5 showing observed and expected body weights over twelve weeks further substantiate the claim.

The Gompertz form fitted to the average body weights over twelve weeks were of the form.

$$W_t = 158.6057 \exp(-4.9667 \exp(-0.4677\ t)) \quad \text{(Male)}$$

$$r^2 = 0.9991, \ s = 1.6903$$

$$W_t = 183.8152 \exp(-4.5238 \exp(-0.3846\ t)) \quad \text{(Female)}$$

$$r^2 = 0.9949, \ s = 4.6230$$

$$W_t = 169.1025 \exp(-4.7301 \exp(-0.4267\ t))$$

$$r^2 = 0.9982, \ s = 2.6054 \quad \text{(Birds irrespective of sex)}$$

Rao's method have shown that the initial body weight had no significant effect on growth rate of Japanese quails.

5.2 Egg production study

The average age at sexual maturity for 32 female Japanese quails was approximately 9 to 10 weeks or 69.41 ± 9.18 days. This was found to be higher than the reported age at sexual maturity by Ino *et al.* (1985) as 35.9 days for males and 44.8 days for females.

The average weight of egg was found to be 12.20 ± 1.05 g which was also found to be higher than the reported egg weight by Sreenivasaiah *et al.* (1987b) and Narayanankutty *et al.* (1989).

With regard to egg production study scientists fitted a number of mathematical models in chicken, ducks, turkey, goose, turn, starling etc.

Still none of these scientists have developed a suitable model for ascertaining the egg production in Japanese quails which was evident from the available literature.

In the present study a number of mathematical models tried in milk production in cattle were used to predict the egg production in quails. The comparisons were made on the value of Furnival index (I).

It was observed that for predicting weekly egg production quadratic-cum-log function and quadratic function in log scale emerged as first and second best having respective I values 19.3758, 19.4584 and r^2 values 0.7602, 0.7471 (Table 21). It is evident that there is not much difference between respective I values and r^2 values. Figure 9 further shows that there is not much variation between expected egg productions in comparison with observed egg production in the case of these two curves.

With regard to prediction of fortnightly egg production linear hyperbolic function and quadratic function in logarithmic scale emerged as first and second best having respective I values 34.7535 and 35.0586 and r^2 values 0.8052 and 0.8018 (Table 22). Figure 10 further shows that there is not much variation between expected egg production in comparison with observed egg production of these two curves.

It was observed that hen housed and hen day egg production were highest in the month of June (73.1073% and 73.6064% respectively) followed by August (Table 20).

In the case of prediction of hen housed and hen day egg production, quadratic function in logarithmic scale has emerged as best one having least I values and comparatively good r^2 values (Tables 23 & 24 for hen housed and hen day egg production respectively). Figure 11 and 12 (for hen housed and hen day egg production respectively) between observed and expected egg production shows a good fit for quadratic function in logarithmic scale.

In general, quadratic function in logarithmic scale can be considered as suitable model for ascertaining egg production in quails with regard to weekly, fortnightly, hen housed and hen day egg production. The form of the fitted quadratic function in logarithmic scale was

$$Y = 13.4228 + 124.6064(\log_e t) - 25.60003(\log_e t)^2$$

$I = 19.4584$, $r^2 = 0.7471$, $s = 19.4584$ (weekly)

$$Y = 97.1038 + 268.8874(\log_e t) - 75.5807(\log_e t)^2$$

$I = 35.0586$, $r^2 = 0.8018$, $s = 35.0586$ (Fortnightly)

$$Y = 1.2589 + 96.6707(\log_e t) - 35.3734(\log_e t)^2$$

$I = 6.0220$, $r^2 = 0.9571$, $s = 6.0220$ (Hen housed)

$$Y = 1.2386 + 95.4551(\log_e t) - 33.5394(\log_e t)^2$$

$I = 7.5873$, $r^2 = 0.9382$, $s = 7.5873$ (Hen day)

5.3 Climatological studies

The average weekly temperature and average weekly humidity under which the experiment was conducted were found to be 27.8 ± 1.6°C and 79.4 ± 5.7% respectively.

(i.e. 26.2°C to 29.4°C - temperature
73.7% to 85.1% - humidity)

The multiple linear regression equation fitted by taking previous three weeks temperature (Z_1) and previous three weeks average humidity (Z_2) and the present weekly average egg production per bird (Table 25) showed an r^2 value of 76.5% which gives good fit. The analysis of variance of this regression equation (Table 26) showed a highly significant value for regression equation. Further analysis of the coefficients of equation showed highly significant values of coefficients of Z_1 and Z_2 which indicated that the average temperature and humidity were contributing factors for the egg production in quails.

It was evident from the study of previous workers (Wilson *et al.*, 1971; Sreenivasaiah and Joshi, 1987 a,b) that temperature was having significant effect on production. Accordingly multiple regression equation was fitted by taking average temperature and humidity of the previous three weeks as explanatory variable and the present weekly average egg production per bird as dependent variable.

Summary

SUMMARY

With a view to develop suitable models for ascertaining growth and egg production in quails an experiment was initiated on first February, 1989 at the Kerala Agricultural University Poultry Farm, Mannuthy. One hundred and fifty (150) day old quails have been used in this experiment. Forty seven (47) birds died during the period of twelve weeks due to some reason or other. The data on the remaining birds consisting of 58 males and 45 females were considered for the present study.

The body weights of these birds were recorded continuously upto 12 weeks. The initial average body weights were 7.1172 ± 0.1591 g, 7.1622 ± 0.1813 g and 7.1369 ± 0.1698 g for males, females and birds irrespective of sex respectively.

At the 12th week the average body weights of males and females were 157.6552 ± 14.5199 g and 179.2500 ± 19.8055 g respectively.

Since the body weights have shown an increasing trend (Fig.1) for males and females and females had begun egg production (females started egg production from around 10th week onwards and they have to be kept undisturbed for uninterrupted egg production) body weights were not taken upto 26th

week. Further body weights were taken only at 27th and 35th week to ascertain the trend by which time the males and females had reached an average body weights of

172.43 g; 194.00 g (27th week)

179.45 g; 192.00 g (35th week) respectively which again showed an increasing trend with a slight decline in the case of average body weights of females.

Analysis of variance was conducted for the body weights of 58 males and 45 females birds which showed that there was significant difference in body weights between males and females from 9 to 12 weeks as well as on 27th and 35th weeks.

Mathematical models such as linear, quadratic, exponential, Von-Bertalanffy, modified exponential, logistic and Gompertz were fitted and were compared using coefficient of determination (r^2) and standard error of estimate(s) values. By comparison Gompertz curve $W_t = a \exp[-b \exp(-kt)]$ was chosen as the best one for ascertaining growth in Japanese quails from 1 to 12 week. It was also concluded that Gompertz curve of the following forms were most suitable for ascertaining growth in Japanese quails using average body weights over 12 weeks. The forms were

$$W_t = 158.6057 \exp[-4.9667 \exp(-0.4677\ t)] \text{ (Male)}$$

$$W_t = 183.8152 \exp[-4.5238 \exp(-0.3846\ t)] \text{ (Female)}$$

$$W_t = 169.1025 \exp[-4.7301 \exp(-0.4267\ t)] \text{ (Birds irrespective of sex)}$$

Figures of Gompertz curves showing observed and expected body weights were also drawn to support the claim.

Rao's method was tried and it was observed that initial body weight had no significant effect on growth rate of Japanese quails.

Mathematical models such as linear, exponential, parabolic exponential, inverse polynomial, Gamma function, Gamma type function, quadratic function, quadratic function in logarithmic scale, quadratic-cum-log function, emperical and linear hyperbolic functions were tried for predicting egg production. The fitted models were compared using Furnival index (I). The r^2 and s values were used only as a second criteria for comparison. Before fitting, the egg production data was converted to weekly and fortnightly basis. Hen housed and hen day egg production were also computed. The models were fitted to weekly, fortnightly, hen housed and hen day egg production data. It was concluded that quadratic function in logarithmic scale was mot suitable for ascertaining egg production in quails. The forms of the models were

$$Y = 13.4228 + 124.6064 (\log_e t) -25.6003 (\log_e t)^2 \quad \text{(weekly)}$$

$$Y = 97.1038 + 268.8874 (\log_e t) -75.5807 (\log_e t)^2 \quad \text{(fortnight)}$$

$$Y = 1.2589 + 96.6707 (\log_e t) -35.3734 (\log_e t)^2 \quad \text{(hen housed)}$$

$$Y = 1.2386 + 95.4551 (\log_e t) -35.5394 (\log_e t)^2 \quad \text{(hen day)}$$

Figures of quadratic function in logarithmic scale showing observed and expected egg production were also drawn to support the claim.

Climatological parameters (temperature and humidity) recorded daily from the beginning of the experiment till the end, was utilised to study the impact of these parameters on egg production. The parameters were converted to weekly basis. As the present average weekly egg production per bird is correlated with the previous three weeks climatological parameters, a multiple linear regression equation of the form

$$Y = -41.7275 + 0.7687^{**} Z_1 + 0.3150^{**} Z_2 \text{ with } r^2 = 0.7654$$

was fitted with average weekly egg production per bird (Y) as dependent variable and weekly average temperature (Z_1) and weekly average humidity (Z_2) as explanatory variable. It was found that the weekly average temperature and weekly average humidity have significant effect on the average egg production.

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* Originals not seen

DEVELOPMENT OF A SUITABLE MODEL FOR ASCERTAINING THE GROWTH AND EGG PRODUCTION IN QUAILS

By

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ABSTRACT OF A THESIS

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ABSTRACT

An investigation was carried out into the growth and egg production aspect of Japanese quails at the Kerala Agricultural University Poultry Farm, Mannuthy on 1st February, 1989 with the following objectives.

1. to find a suitable relationship between age and body weight.
2. to investigate the trend of egg production in quails through suitable mathematical models.
3. to study the impact of climate parameters (temperature, humidity) on egg production in quails.

The birds were reared under uniform feed formula and identical management practices (recommended by Kerala Agricultural University Package of Practices). The investigation mainly depended on data consisting of weekly body weights of individual birds, daily egg production of birds (beginning from age at sexual maturity) and daily climatological parameters (temperature and humidity) from beginning till the end of experiment of 30th September, 1989.

Mathematical models such as linear, quadratic, exponential, Von-Bertalanffy, modified exponential, logistic and Gompertz were fitted for the purpose using body weights of

individual birds as well as average body weights over twelve weeks and the fitted models were compared using coefficient of determination (r^2) and standard error of estimate(s).

Mathematical models such as linear, exponential, parabolic exponential, inverse polynomial, Gamma function, Gamma-type function, quadratic function, quadratic function in logarithmic scale, quadratic-cum-log, emperical and linear hyperbolic functions were fitted for the development of suitable models for ascertaining egg production using total weekly, fortnightly egg production, hen housed and hen day egg production and fitted models were compared using Furnival index, r^2 and s.

Multiple linear regression equation was fitted using average weekly egg production per bird as dependent variable and weekly temperature and humidity as explanatory variable to study the impact of climatological parameters on egg production in quails.

The investigation has the following, salient features.

(i) The hatching weight of Japanese quails were 7.1369 g.

(ii) The females weighed more than the males during the entire period of experiment and the body weights have shown an increasing trend. At the end of 12th week the average body weights of males and females were 157.6552 g and 179.2500 g respectively.

(iii) Rao's method justified that initial body weights had no significant effect on growth rate.

(iv) Gompertz curve $W_t = a \exp[-b \exp(-kt)]$ was most suitable for ascertaining growth in quails on individual basis as well as on the basis of average body weights over twelve weeks.

(v) Average age at sexual maturity (females) was found to be approximately 10 weeks and on an average the eggs weighed 12.20 g.

(vi) Quadratic function in logarithmic scale $W_t = a + b(\log_e t) + c(\log_e t)^2$ was most suitable for ascertaining egg production in quails (weekly, fortnightly, hen housed and hen day production basis).

(vii) Climatic parameters had significant impact on egg production in quails.