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## GROWTH RATES OF BODY WEIGHT AND LINEAR MEASUREMENTS IN JAPANESE QUAIL

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### ABSTRACT

*A total of 60 Japanese quails were used to study the relationship between early body weight growth rates (0-3 weeks) and growth parameters (absolute values and rates) measured in a six week period from hatch. A rule based system was used to classify quails into high (H), low (L) and medium (M) body weight growth rate groups. Birds which were one standard deviation above the overall group body weight growth rate mean were tagged as high, those that were one standard deviation below the overall group mean as low, while all remaining birds were tagged as medium. The body weight, linear measurements (body length, body girth, wing length, and shank length) and the associated growth rates were compared between high, medium and low.*

*Body weight and all linear measurements except the shank length showed significant ( $P < 0.05$ ) differences between sexes (females > males) across high, low and medium groups and within sexes across weeks of rearing (wks1-wks6). The low group was significantly lower than the medium and high groups for all the measurement taken while the high weight group was significantly ( $P < 0.05$ ) higher in all measurements taken. As expected, female birds were larger than their male counterparts in all the three groups. Growth rates of body weight also showed significant differences ( $P < 0.05$ ) among groups. Other linear measurements showed no significant differences ( $P > 0.05$ ) and all measurements increased with increase in the bird age. The early growth rate (1-3 weeks) of all the body measurements were significantly ( $P < 0.05$ ) higher than the late growth rate (3-6 weeks) except the body girth which showed no significant difference. Birds selected for high growth rates remain the largest birds at the end of the experiment, while those selected for low growth rate remains the smallest. The results indicate that most development in the Japanese quail takes place within implication of the results are fully discussed.*

**Keywords:** Growth rate, Body weight, linear measurements, Japanese quail.

## INTRODUCTION

In Nigeria, poultry keeping has become one of the most popular enterprises adopted by small and medium scale farmers in both rural and urban areas (Geidamet *et al.*, 2006). It is one of the main sources of animal protein for the teeming Nigerian population thus making significant contribution to human nutrition and economic development. The poultry groups have been reported to constitute more than 57% of the total livestock production in Nigeria, (Alabi and Osifor, 2004). The population has been put at 114.3 million comprising 82.4 million chickens and 31.9 million other poultry which include pigeons, ducks, guinea fowls and turkeys (RIMS, 1992). The recent increase in the cost of feed, inadequate supply of day old chicks, prevalence of diseases, high cost of drugs and biologicals among others have placed the production and consumption of these birds beyond the reach of most Nigerians. Thus, with a population of over 140 million, Nigeria is still grossly under provided with animal protein which is an essential food component as the demand for animal protein far exceeds the supply (Anaekwe, 2011).

Protein supplied from animal products

was estimated to be just 3.0g/caput/day in 1993 with a projection of 5.32g/caput/day made for the year 2010 (Shaibet *et al.*, 1997) which is far short of the 35g recommended by FAO (1993). This calls for a search for alternative cheaper source of poultry birds that will be within the reach of the common man. Hence, the subsequent introduction of the Japanese quail birds (Musa *et al.* 2008).

Japanese quail is the smallest farmed avian species for egg and meat production (Minvielle, 1998). Its marked advantages over other poultry birds such as its small body size, fast growth rate, early sexual maturity, high rate of lay, short incubation period and highly disease resistance have made it to assume a worldwide importance not only as a good source of animal protein but also as a laboratory animal.

Growth has been defined as an increase in mass of an organism with time and represents the visible result of a complex and interrelated series of metabolic and developmental events (Reddish, 2004). Growth determines not only the size of the animal but also its shape and forms and as long as an animal grows at the same rate along its dimension, bodily proportion

remains unchanged (Emmerson, 1997).

Body weight has been regarded as a function of frame work or size of the animal and its condition (Dalton, 1981). It is a measure of the body mass, which is a composite of each contributing tissue especially fat, muscle and bone. Growth rate of an organism is a complete coordinated growth of all parts of the body (Ricklefs, 1973). It is thus associated with body weight, linear measurements and carcass yield.

Live body weight, body conformation and yield are important factors to poultry breeders, consumers and processors (Adeniji and Ayorinde, 1990). Several researchers have reported selection for body weight in Japanese quails based on absolute body weight at different ages (Darden and Marks, 1988; Marks, 1990; Marks, 1993; Aggrey *et al.*, 2003 and Ojo *et al.*, 2011). There is however a dearth of records on selection based on early growth rates and its effect on matured body weight and conformation in the Japanese quail. Establishment of relationships between body parameters, body weight and growth rate in the Japanese quails can help in organizing a breeding program that will result in genetic improvement,

yielding optimum and good conformation of birds of maximum economic returns. Also the reliable early prediction of future and lifetime performance remains a valid preoccupation of genetics in livestock production and can contribute to optimization, breeding and management practices for optimal profitability. This study therefore examined the effectiveness of early growth rate in determining body weight and conformation at a later age in the Japanese quail.

## MATERIALS AND METHODS

The experiment was conducted at the Poultry Pavilion of the Animal Production Department, Faculty of Agriculture, and University of Ilorin. All experiments were carried out in accordance with Institutional guidelines on the care and use of animals for scientific studies, and in compliance with generally accepted rules of best practice worldwide.

### *Origin and Management of Experimental Birds*

Sixty (60) day old Japanese quail of mixed sex (yielding an expected ratio of 30-females and 30 males) obtained from eggs collected from a random bred population that has been

maintained in the department for three generations (Ojo *et al.*, 2011). These birds were initially maintained at the National Veterinary Research Institute (NVRI) station Vom, Jos Plateau State Nigeria from fertile eggs brought in from the Republic of Benin in 1992 with the help of the Nigerian Directorate for Food Road and Rural Infrastructure (DFFRI) and have been maintained for more than a decade (Musa *et al.*, 2008).

Birds were wing tagged from day-old and kept in brooding pen where heat was provided and all necessary medications administered. Feed and water were supplied *ad-libitum* throughout the 6 weeks period of the experiment.

#### *Data Collection*

**Body Weight (BW):** Body Weight in gram (g) units recorder to two decimal places, was taken by use of a sensitive weighing scale (Scout II brand)

**Body Length (BL):** Body Length, was taken as the nostril to pygostyle distance measured in centimeter (cm) units when a tape measure is stretched from a bird's nasal opening, along its gently stretched neck, and along its back, to the tip of its pygostyle.

**Body Girth (BG):** Body Length, was taken as the distance in centimeter (cm) units covered when a tape measure is looped round the region of the breast, taking care to run the tape under (rather than over) the Wing.

**Shank Length (SL):** The Shank Length was taken as the distance in centimeters (cm) between the foot pad and the hock joint, measured by use of a set of Vernier callipers.

**Wing Length (WL):** Wing Length was taken as the distance from the humerus-coracoid junction to the distal tip of the phalange digits, and was measured in centimeter (cm) units by use of a tape measure.

#### *Identification of Valuable Markers and Classification of Quails*

Weekly body weight and body conformation (as defined by linear body part measurement) was taken in each member of a cohort of 60 Japanese quail from hatch to 6 weeks of age. Growth rates (body weight growth potential) between 1 and 3 weeks (Early Growth Rate), and between 3 and 5 weeks age (Late Growth Rate) were calculated from the primary data on weekly body weight by use of the formula of Maciejowski and Zeiba (1982).

$$I = [(T2 - T1) / (T2 + T1)/2] \times 100$$

Where:

I= Growth rate per unit period (%).

T1= Average initial reading for the stated period (g or cm).

T2= Average final reading for the stated period (g or cm).

A rule- based system was used to classify quail based on 0-3 week body weight growth potential as follows; every bird exhibiting a body weight growth potential that was one standard deviation ( $+1$  SD) above the group mean was assigned to a "high growth rate group" (H); birds that exhibited a growth potential that was at least one standard deviation ( $-1$  SD) below the group mean were assigned to the "Low Growth Rate Group" (L), and all remaining birds were assigned as the "Medium Growth Rate" (M).

#### *Statistical Analysis*

All data collected were subjected to analysis of variance (ANOVA) using SPSS (version 17) to obtain the variance component and analysed using Completely Randomized Design (Steel and Torrie, 1980). Significantly different means ( $P < 0.05$ ) were further separated by use of the Duncan's Multiple Range procedure option in SPSS 17 (SPSS IBM).

## RESULTS

The means of body weight and linear measurements at different ages in Japanese quails selected for early growth rates is shown on Table 1.

**Body weight:** When separated by sex and weight class, the result of body weight from week 1 to week 6 showed the Low females were significantly ( $P < 0.05$ ) lower than the Medium and the High weight class throughout the experimental period while the High weight class was also significantly ( $P < 0.05$ ) higher than the Medium and the Low weight classes. Values for body weight in the female quail ranged from 11.50-87.38g, 13.80-120.80g and 15.25-137.10g in the low, medium and the high weight class respectively. High females were 49.72g and 16.3g heavier than the Low and Medium females respectively. Similarly for the male weight classes, weeks 1 and 2 showed that low males were not different ( $P > 0.05$ ) from the medium but the High class were significantly heavier ( $P < 0.05$ ). From week 3 upward however, the low males were constantly lower ( $P < 0.05$ ) than the medium except in week 6. The Medium males were not different from the High males except in weeks 2 and 3 where the High males were significantly ( $P < 0.05$ ) higher than the

Medium. Values obtained ranged from 12.57-86.29g, 12.78-103.00g and 14.57-112.00g for the Low, Medium and the High weight males respectively. When pairwise comparison was done within sex and weight classes, body weight means showed significant ( $P < 0.05$ ) differences with differences increasing with increase in weeks of rearing for all weight classes. At all the evaluation dates, ignoring weight classes, sexual dimorphism was observed in body weight and was clearly significant at fifth week of age (85.38g and 80.52g for female and male quails respectively). Average body weight of Japanese quails of both sexes and groups combined were increasing significantly ( $P < 0.05$ ) in successive weeks of life and ranged from 13.41g (1<sup>st</sup> week) to 108.55g (6<sup>th</sup> week).

**Body Length:** the result on body length when separated by sex and weight classes at week one showed the Low females were not significantly different from the Medium female but the Medium female were significantly lower than the High females. Week two to week six however showed the Low females to be significantly ( $P < 0.05$ ) lower than the Medium females while the Medium females were not significantly different from

the High females until the sixth week of age. Values obtained for body length varied from 9.05-15.53cm, 9.95-16.07cm and 8.80-17.1cm for the low females, medium females and the high females respectively. For the male weight classes, at week one Low males were not significantly ( $P > 0.05$ ) different from the Medium males and the Medium were not different from the High males. Significant differences ( $P < 0.05$ ) were however observed between the weight classes from weeks two upward between the Low and the Medium weight classes with the Low males being significantly lower than the Medium males. Medium males were also significantly lower ( $P < 0.05$ ) than the High males in weeks two and three but showed no significant differences in weeks four to week six. Values for body length in the male weight classes ranged from 7.41-14.93cm, 7.81-16.07cm and 8.04-16.46cm for Low, Medium and High males respectively. When weight classes were ignored, and sexes compared, the males were not different from the females significantly at any age examined. Comparison of group performance between successive weeks showed that body length means were significantly ( $P < 0.05$ ) different in all cases with values increasing with increase in weeks of rearing for all groups.

**Body Girth:** for body girth, when separated by sex and weight class, at week one, there was no significant difference ( $P < 0.05$ ) between the three classes. Week two also showed that Medium females did not have significantly larger body girth than the Low female but they were significantly lower than the High females. From week three upward however, the Low females were constantly significantly lower ( $P < 0.05$ ) than the Medium females (with the exception of week 6) while there were no significant differences between the Medium and the High females except at week 6. Values obtained for body girth ranges from 6.7-12.31cm, 6.9-13.16cm and 6.98-14.4cm for the Low, Medium and High females respectively. For the males, body girth showed no significant differences between the Low and the Medium class weight except at week five when the Low males were significantly Lower ( $P < 0.05$ ). Likewise, the Medium males were not significantly different ( $P < 0.05$ ) from the High males throughout the period of rearing. Values for body girth in males ranged from 6.4-12.66cm, 6.39-13.6cm and 6.87-13.51cm from week 1 to week 6 for the Low, Medium and High males respectively. Comparison of the performance of each group between successive weeks showed that body

girth increased significantly from week to week in all groups examined except for weeks 2 and 3 in the Low male group. At all the evaluation dates, ignoring weight classes, significant differences were not observed between the males and the females throughout the period of rearing. When all birds were considered, irrespective of sex and weight class, body girth values ranged from 6.72cm in week one and 13.28cm in week six.

**Wing Length:** the result of wing length among the female weight class groups showed that between weight classes, the High females had significantly ( $P < 0.05$ ) longer wings than the Low females except at weeks 1, 5 and 6. Though the High weight class wing length was also longer than that of the Medium weight class, the difference was however not significant ( $P > 0.05$ ). The Medium weight class was also not significantly different ( $P > 0.05$ ) from the low weight class except at weeks three and four where the Medium class were significantly higher than the Low class weight in wing length. Likewise in the males, wing length was significantly ( $P < 0.05$ ) higher at weeks 3, 4 and 5 in the High class compared with the Low class but was the same throughout the period of rearing between the High and the Medium weight classes.

When performance within each group was compared between successive weeks, wing length increased significantly ( $P < 0.05$ ) in successive weeks of life for all weight classes except in the Low females where the increment was not great enough to be significant. Values obtained for wing length ranged from 3.4-8.65cm, 3.66-8.39cm, 3.95-8.92cm, 4.13-9.18cm, 4.09-9.24cm and 4.09-8.86cm in weeks one and six for Low female, Low male, Medium female, Medium male, High female and the High male groups respectively. When all birds were grouped by sex, ignoring weight class, no significant differences were observed between sexes at all the evaluation dates. Female quails however had a longer wing length (8.93cm) compared with the males (8.84cm) at the end of the sixth week. When performance within each group was compared, between successive weeks of rearing all group showed significant week to week increase ( $P < 0.05$ ) except in the Low females where there were no significant differences. Wing length ranged between 3.89cm at week one and 8.89cm at six week of age irrespective of sex and weight class.

**Shank length:** the result on shank length showed that there were no significant differences ( $P > 0.05$ ) in

shank length values among the weight classes for the females and the males. When weight classes were ignored and sexes were compared, the females tend to have a longer shank length than the males though the differences were not significant ( $P < 0.05$ ) when all birds were sorted by sex only. Values obtained for shank length ranged between 1.68cm-3.12cm for week 1 and week 6 in males and 1.81-3.14cm for week 1 and week six in the females.

Generally, selection for early body weight rate (0-3 weeks) caused the H group to be significantly larger for all body measurements while the L group was significantly smaller for all measurements taken at each age point examined (week 1-6). At the end of the sixth week, the High group was 37.21g larger than the Low group in BW, and 1.55cm, 1.52cm and 0.53cm larger than Low group for BL, BG and WL respectively.

### **Growth Rate of Body weight and Linear Measurements**

Table 2 shows the growth rates of body weight and other linear body measurements of Japanese quails at different ages of rearing. Significant differences ( $P < 0.05$ ) were only observed in body weight rates between weeks two and three and

weeks five and six. The Low female weight class was significantly lower than the Medium and the High weight class groups at age 3 weeks while the Medium was not different ( $P < 0.05$ ) from the high weight class at the same age. For the males at the same age, the Medium weight class was significantly higher ( $P < 0.05$ ) in rate of change of bodyweight than the Low but not significantly different from the High group while the rate of change in bodyweight of the Low weight class was not different from the High. Shank length rates between ages 1-2 also showed significant ( $P < 0.05$ ) differences (HF > MF, LF) between groups while other measurements showed no significant differences ( $P > 0.05$ ) between groups. When performance within each group was compared between successive weeks, body weight rates and all body measurement rates decreased progressively as the birds advanced in age though the differences were not significant ( $P > 0.05$ ). Between the first (1-2) and fifth (5-6) weeks rate intervals growth rates reduced by 21.15%, 27.9% and 29.74% in L, M and H females respectively while reduction was 18.59%, 34.21% and 43.45% in L, M, and H males respectively. Likewise when all birds were separated by sexes only,

significant sexual dimorphism was observed for rate of change of bodyweight between week 5 and 6 only ( $F > M$ ) though the females still had larger rates than the males for all other measurements. When all birds were considered irrespective of bodyweight class and sex, the rate of change of bodyweight and linear body measurements showed significant reduction in successive intervals except for BG and SL rates in which changes occurred in only 2 of the intervals.

Figures 1, 2, 3, 4 and 5 showed the body weight and body measurement rates for early (1-3) and late (3-5) weeks of rearing in the Japanese quails. Early rates of all body measurements for all selected groups were significantly ( $P < 0.05$ ) higher than late rates of change of body measurements except for body girth where late rates were higher than the early rates though the differences were not significant.

The low group had a significant lower early body weight (BW) rate (Fig 1) compared to the medium and high group while the medium was not significantly different from the high group. However, the low group had a kind of compensatory growth in the late week of rearing which made them

had a higher BW rate than the other groups. Early body length (BL) rate (Fig 2) was significantly higher ( $P<0.05$ ) than the late BL rate for all the three groups, however there were no significant differences ( $P<0.05$ ) between groups in the early and the late weeks of rearing. The BL rate ranged from 35.1% in the low females and 44.4% in the high females for early growth rates while late growth rates ranged from 22.23% in the low males and 29.53% in the low females.

Body girth (BG) rate (Fig 3) showed no significant differences ( $P<0.05$ ) between early and late weeks of rearing. Likewise between groups no significant differences ( $P>0.05$ ) existed in the early and the late rates though the low males and females had the least rates (19.02% and 26.09% respectively). Wing length (WL) rate for early and late weeks of rearing are shown on fig 5. Early wing length rate was significantly higher ( $P<0.05$ ) than the late wing length rate in all the three groups. However, there were no significant differences observed among the growth rate groups within the early and the late growth rates. The low females had a higher value of 58.74% and 22.81% (sexes combined) for early and late wing length rates respectively compared to 57.11% and 18.67% in the medium

and 55.88% and 18.95% in the high group.

Figure 6 shows the early and late shank length rates for the three groups of Japanese quails selected based on early body weight rates. The early shank length rates showed significant differences between groups and sexes with the high female having the highest rate (45.84%). The early rates were not significantly different ( $P<0.05$ ) from the late rates except in the low males and the high females where significant differences were observed.

## DISCUSSIONS

The approach used for selection in this study differs from that of previous studies (Marks, 1980; Nestor *et al.*, 1982; Darden and Marks, 1988; Marks, 1993; Reddish *et al.*, 2003 and Ojo *et al.*, 2011). Most selection studies in the Japanese quail have been based on absolute body weight at a particular age which varied from study to study and not on growth rates as was done in this study. However the results obtained still follow the same trend as observed in other studies. Selection for growth rates in the high line resulted in BW at six weeks that was heavier than the medium and the low groups. Likewise for all other body measurements, selection for early growth rate resulted

in significantly higher measurements in the high group birds at six weeks of age. Though body weights of the high male and female groups reported in this study was considerably smaller than the previous cited papers; (Aggrey *et al.*, 2003; Reddish *et al.*, 2003; and Balcioglu *et al.*, 2005) in which quails were selected divergently for body weight, results of the present study were similar to those reported by Aggrey *et al.* (2003) when all selected groups were combined and birds separated by sexes. The lower body weight observed in this study compared with those reported by these authors could be as a result of differences in the sub lineage, the environmental condition under which the birds have been raised and duration over which selection and breeding had occurred. Body weight of both sexes was similar for the low group throughout the period of study. However in the high and the medium group the females became significantly heavier than the males from the fourth week of age. Several studies have shown that Japanese quail exhibit sexual dimorphism (Hyankova *et al.*, 2001; Aggrey *et al.*, 2003; Reddish *et al.*, 2003; Balcioglu, 2005). According to Oguz *et al.* (1996) females are heavier than males, and this difference becomes apparent at about the third or fourth week of age.

Similarly, the differences observed in the linear measurement was expected since growth of the various parts contribute to the overall body weight of the animal and therefore the heavier birds were expected to have higher body measurements compared to the smaller ones. This corroborates the report of Maciejowski and Zieba, 1982 that external body parts are known to be positively correlated with body weight. Though shank length and diameter are reported to be good indicators of leg development (Maciejowski and Zieba, 1982), the result showed no significant differences between groups and may suggest non proportional increase of shank length with body weight and also support the report of Adeniji and Ayorinde, (1990) that a longer shank length does not indicate plumpness. The increase in body weight and body measurements in successive weeks of life shows growth and development in the Japanese quail is proportional. Growth and development have been described as physiological features which bear both practical and economic significance for animal husbandry (Dalton, 1981). While growth is characterised by an increase in body weight, development is characterised by an alteration in the structure and shape of the body (Reddish, 2004).

The progressive decrease in growth rates of body weight and body measurements in the Japanese quails selected for early growth rate shows that most of the development takes place at the early stage of growth except for the body girth which development is higher at the latter stage of growth. Previous reports have shown higher rates of growth at an early stage of development in the Japanese quail and some other poultry species. Tulobaev *et al.* (2011) has reported an accelerated development of Japanese quails between day 1 and 14 and again between day 35 and 42. Also Kuzniacka and Adamski (2010) have reported a significant decrease in the growth rates of pheasants from the third week of life for all body measurements and this decrease continued till the end of rearing. Selection for early growth rates resulted in higher BW and body measurement rates in the high group and lower rates in the low groups. However the effect of selection between sexes was not consistent. Aggrey *et al.* (2003) had earlier reported higher growth rates in males than females in all lines of Japanese quails divergently selected for four week body weight.

Though for all measurements taken,

it seems the low growth rate observed in the low weight class at the early stage of rearing was compensated for at the latter stage as the low weight class tended to have a higher growth rate for all measurements between weeks five and six. Selection for early growth rate however resulted in higher growth rates in the high females than in the low females as well as a decline in growth rate of males selected for decreased early growth rate compared to their high counterparts. The higher early (1-3 weeks) than late (3-5 weeks) growth rates for bodyweight and all body measurements in this present study further corroborate the report of Tulobaev *et al.* (2011) who stated that Japanese quail chicks go through a period of accelerated development at an early stage of life.

## CONCLUSION

The result of this study shows that birds selected for high early growth rates remained the largest birds at the end of the experiment, while those selected for low growth rate remained the smallest. The results also indicate that most development in the Japanese quail takes place within the early age of 0-3 weeks. The analysis also proves that early growth rate is not a determinant for late growth rate

but rather for late growth weight. It is therefore possible to select birds for late bodyweight (6 weeks age) based on growth rate at an early age window. Such an approach could accelerate the efficiency of selection through more effective use of space and lower costs afforded by earlier culling. Further studies will determine the extent to which early growth rate effects on final bodyweight at 6 weeks are heritable and the effect of body weight class on relationship between traits.

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Table 1: Means of Body Weight (g) and Linear Measurements (cm)  $\pm$ SEM at Different Ages in Japanese Quails Selected for Early Growth Rates

| sn | Phenotype | G0 - LF                        | G0 - LM                         | G0 - MF                         | G0 - MM                         | G0 - HF                        | G0 - HM                         | G0 - AF                        | G0 - AM                        | G0 - A                         |
|----|-----------|--------------------------------|---------------------------------|---------------------------------|---------------------------------|--------------------------------|---------------------------------|--------------------------------|--------------------------------|--------------------------------|
| 1  | BW-wk1    | 11.50 $\pm$ 0.42 <sup>a</sup>  | 12.57 $\pm$ 0.37 <sup>ab</sup>  | 13.8 $\pm$ 0.77 <sup>bc</sup>   | 12.78 $\pm$ .64 <sup>ab</sup>   | 15.25 $\pm$ 0.75 <sup>c</sup>  | 14.57 $\pm$ 0.75 <sup>bc</sup>  | 13.54 $\pm$ 0.48               | 13.26 $\pm$ 0.39               | 13.41 $\pm$ 0.31               |
| 2  | BW-wk2    | 19.63 $\pm$ 0.98 <sup>a*</sup> | 20.57 $\pm$ 0.95 <sup>a</sup>   | 25.3 $\pm$ 1.87 <sup>bc*</sup>  | 22.78 $\pm$ 1.2 <sup>ab</sup>   | 28.13 $\pm$ 1.43 <sup>c*</sup> | 27.57 $\pm$ 1.38 <sup>c*</sup>  | 24.42 $\pm$ 1.1 <sup>*</sup>   | 23.57 $\pm$ 0.89 <sup>*</sup>  | 24.02 $\pm$ 0.71 <sup>*</sup>  |
| 3  | BW-wk3    | 28.63 $\pm$ 1.49 <sup>a*</sup> | 31 $\pm$ 1.59 <sup>a</sup>      | 42.4 $\pm$ 2.05 <sup>bc*</sup>  | 39.56 $\pm$ 1.42 <sup>bc*</sup> | 48 $\pm$ 1.87 <sup>c*</sup>    | 45.86 $\pm$ 3.06 <sup>c*</sup>  | 39.88 $\pm$ 1.88 <sup>*</sup>  | 38.87 $\pm$ 1.68 <sup>*</sup>  | 39.41 $\pm$ 1.26 <sup>*</sup>  |
| 4  | BW-wk4    | 45.25 $\pm$ 2.15 <sup>a*</sup> | 48.57 $\pm$ 3.94 <sup>a*</sup>  | 64.1 $\pm$ 2.9 <sup>bc*</sup>   | 60.56 $\pm$ 1.72 <sup>bc*</sup> | 70 $\pm$ 3.37 <sup>c*</sup>    | 66.14 $\pm$ 3.94 <sup>bc*</sup> | 60.12 $\pm$ 2.59 <sup>*</sup>  | 58.61 $\pm$ 2.29 <sup>*</sup>  | 59.41 $\pm$ 1.73 <sup>*</sup>  |
| 5  | BW-wk5    | 64.25 $\pm$ 3.66 <sup>a*</sup> | 64.29 $\pm$ 5.62 <sup>a*</sup>  | 89 $\pm$ 4.77 <sup>b*</sup>     | 82.89 $\pm$ 2.34 <sup>b*</sup>  | 102 $\pm$ 4.21 <sup>c*</sup>   | 93.71 $\pm$ 4.5 <sup>bc*</sup>  | 85.38 $\pm$ 3.86 <sup>b*</sup> | 80.52 $\pm$ 3.35 <sup>a*</sup> | 83.1 $\pm$ 2.58 <sup>*</sup>   |
| 6  | BW-wk6    | 87.38 $\pm$ 4.81 <sup>a*</sup> | 86.29 $\pm$ 7.81 <sup>a*</sup>  | 120.8 $\pm$ 8.18 <sup>cd*</sup> | 103 $\pm$ 2.55 <sup>ab*</sup>   | 137.1 $\pm$ 4.73 <sup>d*</sup> | 112 $\pm$ 2.83 <sup>bc*</sup>   | 115.54 $\pm$ 5.39 <sup>*</sup> | 100.65 $\pm$ 3.37 <sup>*</sup> | 108.55 $\pm$ 3.41 <sup>*</sup> |
| 7  | BL-wk1    | 7.40 $\pm$ 0.18                | 7.41 $\pm$ 0.26                 | 7.84 $\pm$ 0.09                 | 7.81 $\pm$ 0.22                 | 8.08 $\pm$ 0.23 <sup>b*</sup>  | 8.04 $\pm$ 0.10                 | 7.78 $\pm$ 0.11                | 7.76 $\pm$ 0.13                | 7.77 $\pm$ 0.08                |
| 8  | BL-wk2    | 9.05 $\pm$ 0.28 <sup>a*</sup>  | 9.39 $\pm$ 0.24 <sup>ab*</sup>  | 9.95 $\pm$ 0.42 <sup>bc*</sup>  | 9.92 $\pm$ 0.17 <sup>bc*</sup>  | 10.55 $\pm$ 0.17 <sup>c*</sup> | 10.13 $\pm$ 0.22 <sup>bc*</sup> | 9.86 $\pm$ 0.22 <sup>*</sup>   | 9.82 $\pm$ 0.13 <sup>*</sup>   | 9.84 $\pm$ 0.13 <sup>*</sup>   |
| 9  | BL-wk3    | 10.54 $\pm$ 0.14 <sup>a*</sup> | 11.24 $\pm$ 0.40 <sup>ab*</sup> | 12.33 $\pm$ 0.31 <sup>cd*</sup> | 11.63 $\pm$ 0.27 <sup>bc*</sup> | 12.69 $\pm$ 0.29 <sup>d*</sup> | 12.20 $\pm$ 0.33 <sup>cd*</sup> | 11.89 $\pm$ 0.24 <sup>*</sup>  | 11.69 $\pm$ 0.20 <sup>*</sup>  | 11.79 $\pm$ 0.15 <sup>*</sup>  |
| 10 | BL-wk4    | 12.35 $\pm$ 0.35 <sup>a*</sup> | 12.69 $\pm$ 0.60 <sup>ab</sup>  | 14.34 $\pm$ 0.33 <sup>c*</sup>  | 13.86 $\pm$ 0.36 <sup>bc*</sup> | 14.44 $\pm$ 0.72 <sup>c*</sup> | 14.60 $\pm$ 0.46 <sup>c*</sup>  | 13.76 $\pm$ 0.33 <sup>*</sup>  | 13.73 $\pm$ 0.30 <sup>*</sup>  | 13.74 $\pm$ 0.22 <sup>*</sup>  |
| 11 | BL-wk5    | 14.21 $\pm$ 0.33 <sup>a*</sup> | 14.06 $\pm$ 0.47 <sup>a*</sup>  | 15.51 $\pm$ 0.18 <sup>b*</sup>  | 15.30 $\pm$ 0.45 <sup>b*</sup>  | 16.33 $\pm$ 0.22 <sup>b*</sup> | 15.66 $\pm$ 0.36 <sup>b*</sup>  | 15.36 $\pm$ 0.22 <sup>*</sup>  | 15.03 $\pm$ 0.28 <sup>*</sup>  | 15.21 $\pm$ 0.17 <sup>*</sup>  |

*Growth Rates of Body Weight.....Ojo et al, (2013)*

|    |        |                            |                            |                            |                            |                           |                            |                           |                           |                           |
|----|--------|----------------------------|----------------------------|----------------------------|----------------------------|---------------------------|----------------------------|---------------------------|---------------------------|---------------------------|
| 12 | BL-wk6 | 15.53 ± 0.39 <sup>ab</sup> | 14.93 ± 0.46 <sup>a</sup>  | 16.07 ± 0.21 <sup>bc</sup> | 16.07 ± 0.19 <sup>bc</sup> | 17.10 ± 0.21 <sup>d</sup> | 16.46 ± 0.29 <sup>cd</sup> | 16.22 ± 0.20 <sup>*</sup> | 15.84 ± 0.22 <sup>*</sup> | 16.04 ± 0.15 <sup>*</sup> |
| 13 | BG-wk1 | 6.74 ± 0.16                | 6.40 ± 0.22                | 6.90 ± 0.22                | 6.39 ± 0.18                | 6.98 ± 0.25               | 6.87 ± 0.28                | 6.87 ± 0.12               | 6.54 ± 0.13               | 6.72 ± 0.09               |
| 14 | BG-wk2 | 7.34 ± 0.16 <sup>a</sup>   | 7.70 ± 0.19 <sup>ab</sup>  | 7.53 ± 0.17 <sup>ab</sup>  | 7.47 ± 0.32 <sup>ab</sup>  | 8.50 ± 0.27 <sup>c</sup>  | 8.17 ± 0.31 <sup>bc</sup>  | 7.77 ± 0.15 <sup>*</sup>  | 7.75 ± 0.17 <sup>*</sup>  | 7.76 ± 0.11 <sup>*</sup>  |
| 15 | BG-wk3 | 8.18 ± 0.27 <sup>a</sup>   | 8.34 ± 0.34 <sup>ab</sup>  | 9.54 ± 0.33 <sup>c</sup>   | 9.14 ± 0.32 <sup>abc</sup> | 9.59 ± 0.47 <sup>c</sup>  | 9.37 ± 0.33 <sup>bc</sup>  | 9.13 ± 0.24 <sup>*</sup>  | 8.97 ± 0.20 <sup>*</sup>  | 9.06 ± 0.16 <sup>*</sup>  |
| 16 | BG-wk4 | 9.29 ± 0.23 <sup>a</sup>   | 10.21 ± 0.44 <sup>ab</sup> | 11.25 ± 0.27 <sup>b</sup>  | 10.64 ± 0.39 <sup>b</sup>  | 11.53 ± 0.65 <sup>b</sup> | 11.33 ± 0.46 <sup>b</sup>  | 10.73 ± 0.3 <sup>*</sup>  | 10.72 ± 0.25 <sup>*</sup> | 10.73 ± 0.20 <sup>*</sup> |
| 17 | BG-wk5 | 11.21 ± 0.43 <sup>a</sup>  | 11.66 ± 0.50 <sup>ab</sup> | 12.46 ± 0.27 <sup>bc</sup> | 12.73 ± 0.33 <sup>c</sup>  | 13.45 ± 0.26 <sup>c</sup> | 12.90 ± 0.35 <sup>c</sup>  | 12.38 ± 0.25 <sup>*</sup> | 12.46 ± 0.24 <sup>*</sup> | 12.42 ± 0.17 <sup>*</sup> |
| 18 | BG-wk6 | 12.31 ± 0.51 <sup>a</sup>  | 12.66 ± 0.59 <sup>ab</sup> | 13.16 ± 0.27 <sup>ab</sup> | 13.60 ± 0.25 <sup>bc</sup> | 14.40 ± 0.15 <sup>c</sup> | 13.51 ± 0.20 <sup>bc</sup> | 13.28 ± 0.25 <sup>*</sup> | 13.29 ± 0.22 <sup>*</sup> | 13.28 ± 0.17 <sup>*</sup> |
| 19 | WL-wk1 | 3.40 ± 0.20                | 3.66 ± 0.12                | 3.95 ± 0.21                | 4.13 ± 0.29                | 4.09 ± 0.16               | 4.09 ± 0.26                | 3.82 ± 0.12               | 3.97 ± 0.14               | 3.89 ± 0.09               |
| 20 | WL-wk2 | 5.00 ± 0.25 <sup>a</sup>   | 5.40 ± 0.20 <sup>ab</sup>  | 5.62 ± 0.17 <sup>abc</sup> | 5.82 ± 0.23 <sup>bc</sup>  | 6.13 ± 0.14 <sup>c</sup>  | 5.91 ± 0.27 <sup>bc</sup>  | 5.58 ± 0.14 <sup>*</sup>  | 5.72 ± 0.14 <sup>*</sup>  | 5.65 ± 0.10 <sup>*</sup>  |
| 21 | WL-wk3 | 6.43 ± 0.26 <sup>a</sup>   | 6.41 ± 0.16 <sup>a</sup>   | 7.20 ± 0.23 <sup>b</sup>   | 7.24 ± 0.17 <sup>b</sup>   | 7.19 ± 0.22 <sup>b</sup>  | 7.30 ± 0.23 <sup>b</sup>   | 6.96 ± 0.15 <sup>*</sup>  | 7.01 ± 0.13 <sup>*</sup>  | 6.98 ± 0.10 <sup>*</sup>  |
| 22 | WL-wk4 | 7.19 ± 0.15 <sup>a</sup>   | 7.44 ± 0.13 <sup>a</sup>   | 8.09 ± 0.17 <sup>b</sup>   | 8.08 ± 0.17 <sup>b</sup>   | 8.19 ± 0.35 <sup>b</sup>  | 8.07 ± 0.18 <sup>b</sup>   | 7.84 ± 0.15 <sup>*</sup>  | 7.88 ± 0.11 <sup>*</sup>  | 7.86 ± 0.10 <sup>*</sup>  |
| 23 | WL-wk5 | 8.14 ± 0.10 <sup>ab</sup>  | 7.97 ± 0.18 <sup>a</sup>   | 8.67 ± 0.17 <sup>b</sup>   | 8.73 ± 0.23 <sup>b</sup>   | 8.84 ± 0.33 <sup>b</sup>  | 8.70 ± 0.25 <sup>b</sup>   | 8.56 ± 0.13 <sup>*</sup>  | 8.49 ± 0.14 <sup>*</sup>  | 8.53 ± 0.10 <sup>*</sup>  |
| 24 | WL-wk6 | 8.65 ± 0.10 <sup>ab</sup>  | 8.39 ± 0.19 <sup>a</sup>   | 8.92 ± 0.16 <sup>ab</sup>  | 9.18 ± 0.22 <sup>b</sup>   | 9.24 ± 0.26 <sup>b</sup>  | 8.86 ± 0.20 <sup>ab</sup>  | 8.93 ± 0.11 <sup>*</sup>  | 8.84 ± 0.13 <sup>*</sup>  | 8.89 ± 0.08 <sup>*</sup>  |

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|    |        |              |               |              |              |              |              |              |              |              |
|----|--------|--------------|---------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| 25 | SL-wk1 | 1.89 ± 0.07  | 1.60 ± 0.10   | 1.90 ± 0.13  | 1.67 ± 0.06  | 1.61 ± 0.10  | 1.79 ± 0.14  | 1.81 ± 0.07  | 1.68 ± 0.06  | 1.75 ± 0.04  |
| 26 | SL-wk2 | 2.14 ± 0.08* | 1.96 ± 0.11*  | 2.17 ± 0.09* | 1.92 ± 0.06* | 2.28 ± 0.10* | 2.14 ± 0.13* | 2.19 ± 0.05* | 2.00 ± 0.06* | 2.10 ± 0.04* |
| 27 | SL-wk3 | 2.35 ± 0.10* | 2.39 ± 0.05*  | 2.42 ± 0.09* | 2.37 ± 0.10* | 2.56 ± 0.09* | 2.39 ± 0.08  | 2.44 ± 0.06* | 2.38 ± 0.04* | 2.41 ± 0.04* |
| 28 | SL-wk4 | 2.61 ± 0.11* | 2.57 ± 0.080* | 2.71 ± 0.12* | 2.57 ± 0.07  | 2.88 ± 0.13* | 2.73 ± 0.15* | 2.73 ± 0.07* | 2.62 ± 0.06* | 2.68 ± 0.05* |
| 29 | SL-wk5 | 2.86 ± 0.11* | 2.80 ± 0.10*  | 2.88 ± 0.11* | 2.88 ± 0.09* | 3.01 ± 0.15* | 2.91 ± 0.13* | 2.92 ± 0.07* | 2.87 ± 0.06* | 2.89 ± 0.05* |
| 30 | SL-wk6 | 3.26 ± 0.15* | 3.04 ± 0.13*  | 3.08 ± 0.11* | 3.24 ± 0.13* | 3.10 ± 0.11  | 3.03 ± 0.13  | 3.14 ± 0.07* | 3.12 ± 0.08* | 3.13 ± 0.05* |

BW-Bodyweight; BL-Body Length; BG-Body Girth; WL- Wing Length; SL-Shank Length; LF-Low Female; LM-Low Male; MF-Medium Female; MM-Medium Male; HF-High Female; HM-High Male; AL-All Female; AM-All Male; A-All; <sup>a-e</sup> Means in the same row having different superscript differs significantly; \* - Means in the same row within the same phenotype differs significantly from the previous week

Table 2: Means of Body Weight and Linear Measurement Rates (%)  $\pm$ SEM at Different Ages in the Japanese Quail

| sn | Phenotype | G0-LF                         | G0-LM                          | G0-MF                          | G0-MM                           | G0-HF                          | G0-HM                           | G0-AF                         | G0-AM                          | G0-A                          |
|----|-----------|-------------------------------|--------------------------------|--------------------------------|---------------------------------|--------------------------------|---------------------------------|-------------------------------|--------------------------------|-------------------------------|
| 1  | BW Rate - |                               |                                |                                |                                 |                                |                                 |                               |                                |                               |
|    | Wk 1 to 2 | 51.71 $\pm$ 3.61              | 47.84 $\pm$ 3.18               | 57.40 $\pm$ 4.02               | 55.91 $\pm$ 4.46                | 59.24 $\pm$ 3.28               | 61.71 $\pm$ 1.70                | 56.22 $\pm$ 2.16              | 55.22 $\pm$ 2.29               | 55.75 $\pm$ 1.56              |
| 2  | BW Rate - |                               |                                |                                |                                 |                                |                                 |                               |                                |                               |
|    | Wk 2 to 3 | 37.17 $\pm$ 3.88 <sup>a</sup> | 40.19 $\pm$ 3.98 <sup>ab</sup> | 51.70 $\pm$ 4.08 <sup>bc</sup> | 54.30 $\pm$ 3.58 <sup>c</sup>   | 52.32 $\pm$ 4.22 <sup>c</sup>  | 49.28 $\pm$ 2.50 <sup>bc*</sup> | 47.42 $\pm$ 2.65 <sup>*</sup> | 48.48 $\pm$ 2.28               | 47.92 $\pm$ 1.75 <sup>*</sup> |
| 3  | BW Rate - |                               |                                |                                |                                 |                                |                                 |                               |                                |                               |
|    | Wk 3 to 4 | 45.11 $\pm$ 2.18              | 42.16 $\pm$ 7.41               | 40.78 $\pm$ 2.30               | 42.08 $\pm$ 2.58 <sup>*</sup>   | 37.00 $\pm$ 2.85 <sup>*</sup>  | 36.41 $\pm$ 2.48                | 40.95 $\pm$ 1.50              | 40.38 $\pm$ 2.52 <sup>*</sup>  | 40.68 $\pm$ 1.41 <sup>*</sup> |
| 4  | BW Rate - |                               |                                |                                |                                 |                                |                                 |                               |                                |                               |
|    | Wk 4 to 5 | 34.24 $\pm$ 2.98 <sup>*</sup> | 27.49 $\pm$ 1.54               | 32.11 $\pm$ 3.07               | 31.12 $\pm$ 1.8 <sup>*</sup>    | 37.37 $\pm$ 2.15               | 34.76 $\pm$ 2.06                | 34.39 $\pm$ 1.63 <sup>*</sup> | 31.12 $\pm$ 1.17 <sup>*</sup>  | 32.85 $\pm$ 1.04 <sup>*</sup> |
| 5  | BW Rate - |                               |                                |                                |                                 |                                |                                 |                               |                                |                               |
|    | Wk 5 to 6 | 30.56 $\pm$ 3.17 <sup>b</sup> | 29.25 $\pm$ 3.1 <sup>b</sup>   | 29.50 $\pm$ 3.79 <sup>b</sup>  | 21.70 $\pm$ 1.96 <sup>ab*</sup> | 29.50 $\pm$ 2.15 <sup>b*</sup> | 18.26 $\pm$ 3.37 <sup>a*</sup>  | 29.82 $\pm$ 1.81 <sup>b</sup> | 22.95 $\pm$ 1.78 <sup>a*</sup> | 26.60 $\pm$ 1.35 <sup>*</sup> |
| 6  | BL Rate - |                               |                                |                                |                                 |                                |                                 |                               |                                |                               |
|    | Wk 1 to 2 | 19.91 $\pm$ 3.53              | 23.62 $\pm$ 4.01               | 22.93 $\pm$ 4.43               | 23.95 $\pm$ 3.31                | 26.71 $\pm$ 3.49               | 22.84 $\pm$ 2.63                | 23.16 $\pm$ 2.26              | 23.51 $\pm$ 1.86               | 23.33 $\pm$ 1.47              |
| 7  | BL Rate - |                               |                                |                                |                                 |                                |                                 |                               |                                |                               |
|    | Wk 2 to 3 | 15.41 $\pm$ 3.77              | 17.78 $\pm$ 3.55               | 21.76 $\pm$ 3.30               | 15.77 $\pm$ 2.27                | 18.29 $\pm$ 1.72 <sup>*</sup>  | 18.45 $\pm$ 3.04                | 18.74 $\pm$ 1.81              | 17.20 $\pm$ 1.62 <sup>*</sup>  | 18.02 $\pm$ 1.22 <sup>*</sup> |
| 8  | BL Rate - |                               |                                |                                |                                 |                                |                                 |                               |                                |                               |
|    | Wk 3 to 4 | 15.58 $\pm$ 3.36              | 11.68 $\pm$ 5.27               | 15.09 $\pm$ 1.84               | 17.35 $\pm$ 2.84                | 12.02 $\pm$ 5.59               | 17.79 $\pm$ 4.06                | 14.30 $\pm$ 2.06              | 15.76 $\pm$ 2.27               | 14.98 $\pm$ 1.51              |
| 9  | BL Rate - |                               |                                |                                |                                 |                                |                                 |                               |                                |                               |
|    | Wk 4 to 5 | 14.09 $\pm$ 3.38              | 10.61 $\pm$ 2.21               | 8.04 $\pm$ 1.80 <sup>*</sup>   | 9.82 $\pm$ 2.63                 | 13.09 $\pm$ 6.26               | 7.11 $\pm$ 3.87                 | 11.45 $\pm$ 2.26              | 9.24 $\pm$ 1.65                | 10.41 $\pm$ 1.42              |
| 10 | BL Rate - |                               |                                |                                |                                 |                                |                                 |                               |                                |                               |
|    | Wk 5 to 6 | 8.77 $\pm$ 3.80               | 6.05 $\pm$ 2.68                | 3.53 $\pm$ 10                  | 5.17 $\pm$ 2.19                 | 4.64 $\pm$ 1.03                | 5.04 $\pm$ 1.83                 | 5.48 $\pm$ 1.29 <sup>*</sup>  | 5.40 $\pm$ 1.25                | 5.44 $\pm$ 0.89 <sup>*</sup>  |

[illegible]

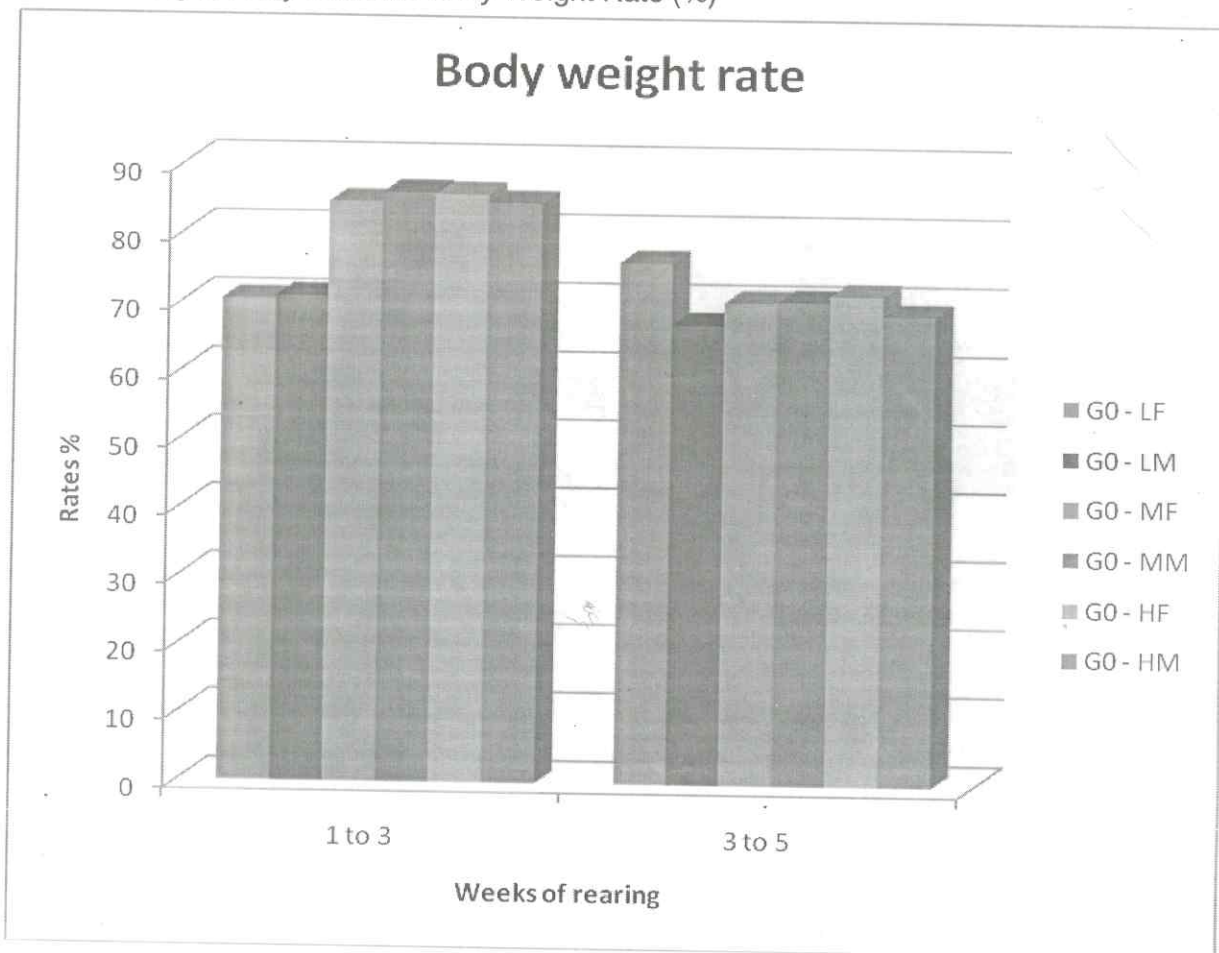
[illegible]

BW-Bodyweight; BL-Body Length; BG-Body Girth; WL- Wing Length; SL-Shank Length; LF-Low Female; LM- Low Male; MF-Medium Female; MM-Medium Male; HF-High Female; HM- High Male; AL-All Female; AM-All Male; A-All

<sup>a-c</sup> Means in the same row having different superscript differs significantly;

\* - Means in the same row within the same phenotype differs significantly from the previous week

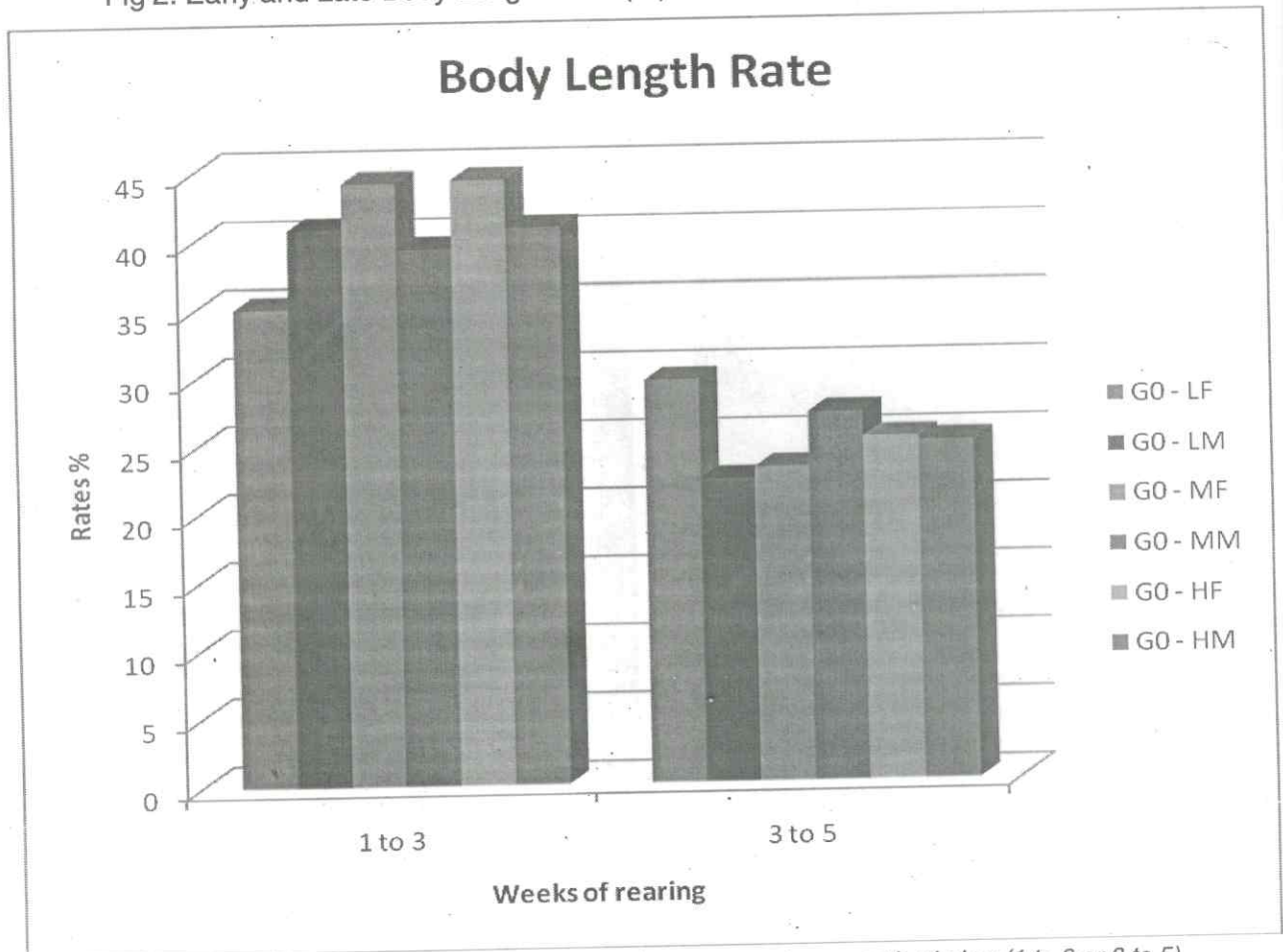
Fig 1: Early and Late Body Weight Rate (%)



*a,b,c* - Denotes significant difference in growth rate between groups in a growth window (1 to 3 or 3 to 5).

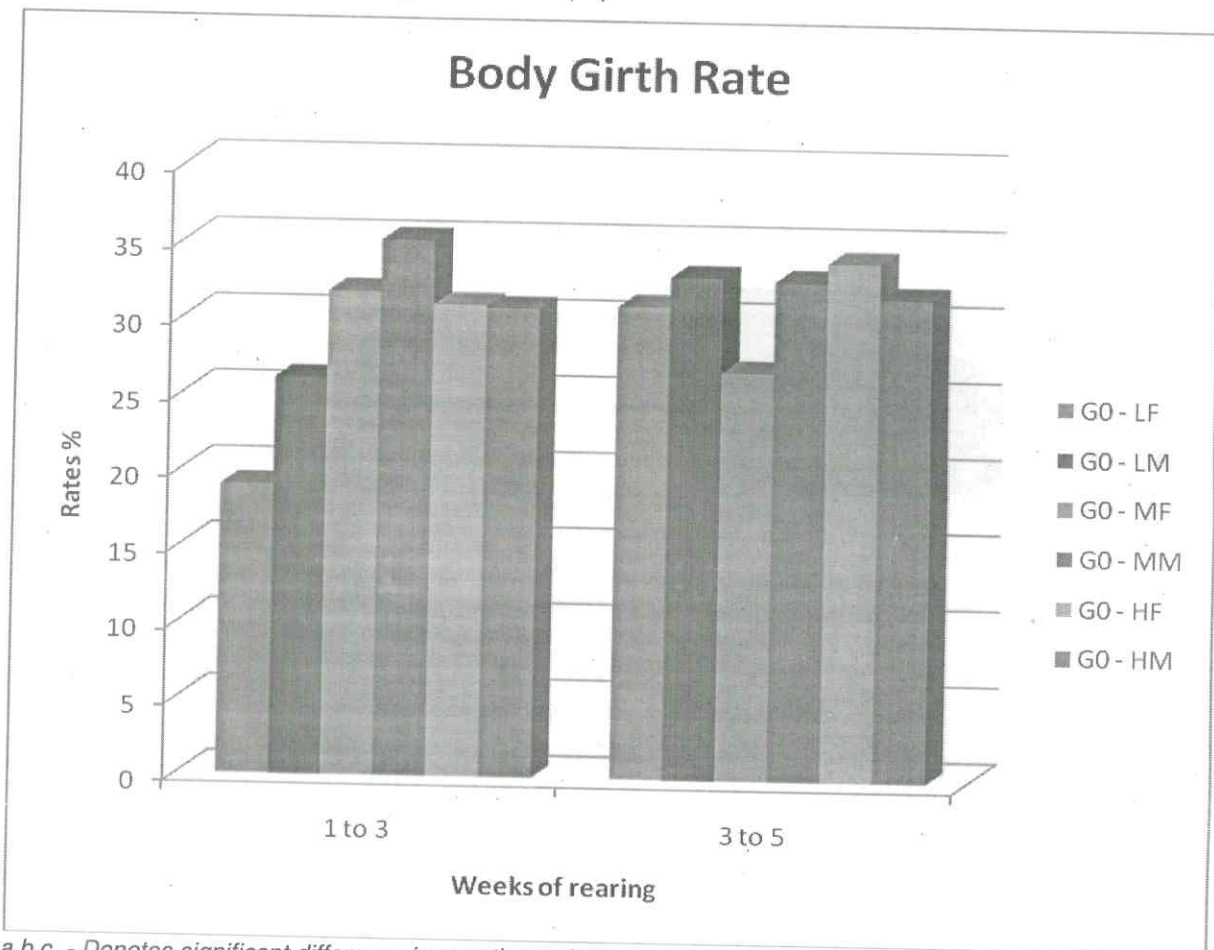
*\** - Denotes significant difference between early (1 to 3) and late (3 to 5) growth rate for each group.

Fig 2: Early and Late Body Length Rate (%)



*a,b,c* - Denotes significant difference in growth rate between groups in a growth window (1 to 3 or 3 to 5).  
*\** - Denotes significant difference between early (1 to 3) and late (3 to 5) growth rate for each group.

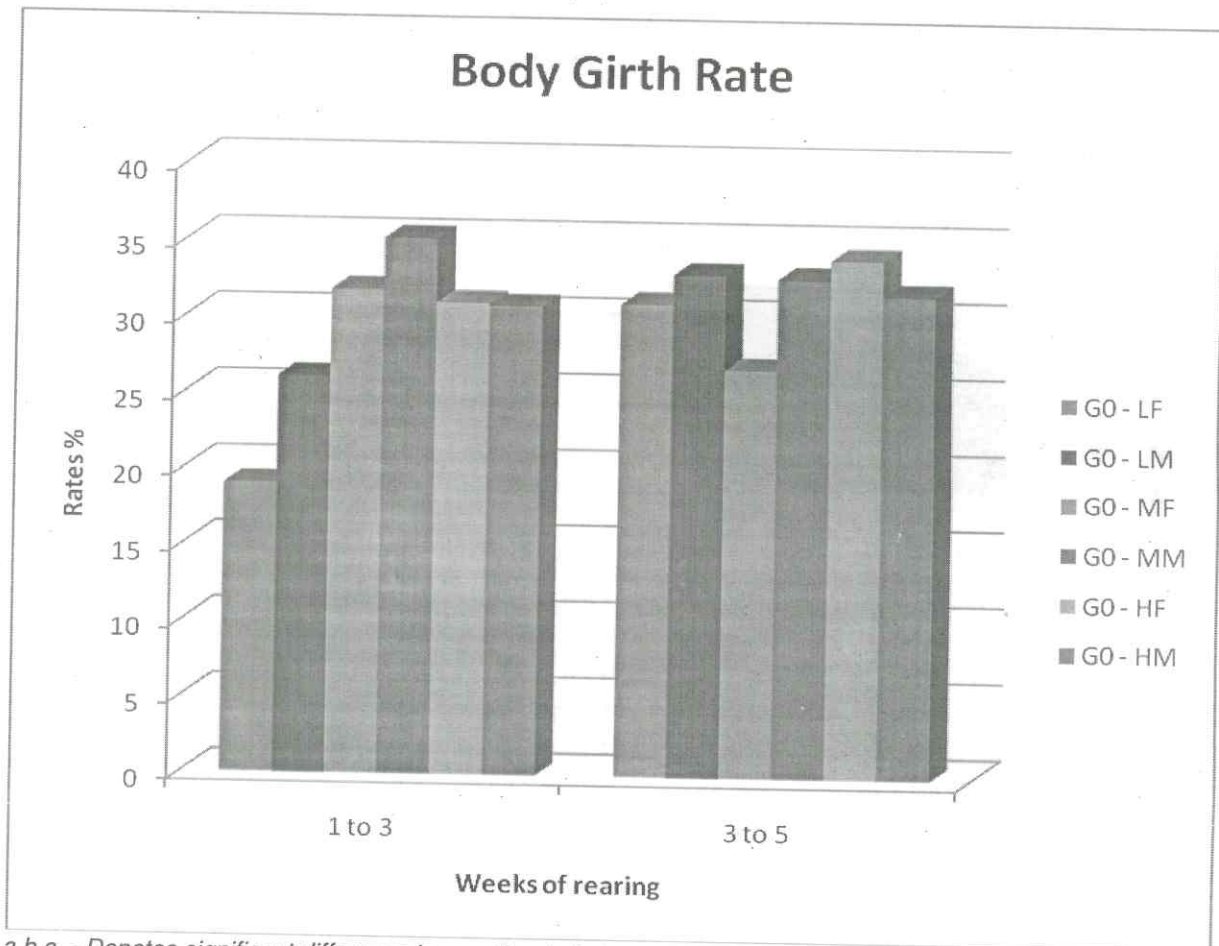
Fig 3: Early and Late Body Girth Rate (%)



a,b,c - Denotes significant difference in growth rate between groups in a growth window (1 to 3 or 3 to 5).

\* - Denotes significant difference between early (1 to 3) and late (3 to 5) growth rate for each group.

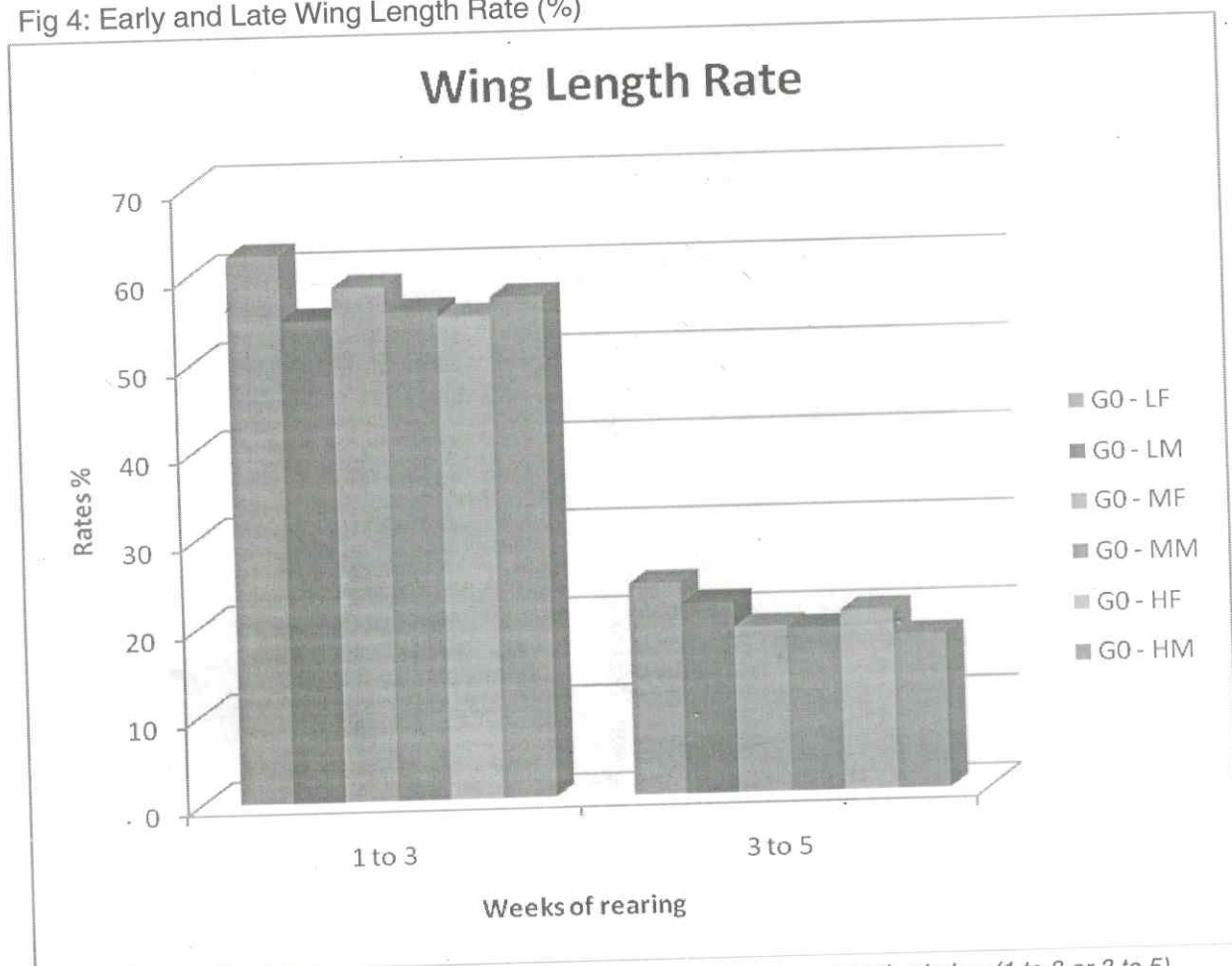
Fig 3: Early and Late Body Girth Rate (%)



*a,b,c* - Denotes significant difference in growth rate between groups in a growth window (1 to 3 or 3 to 5).

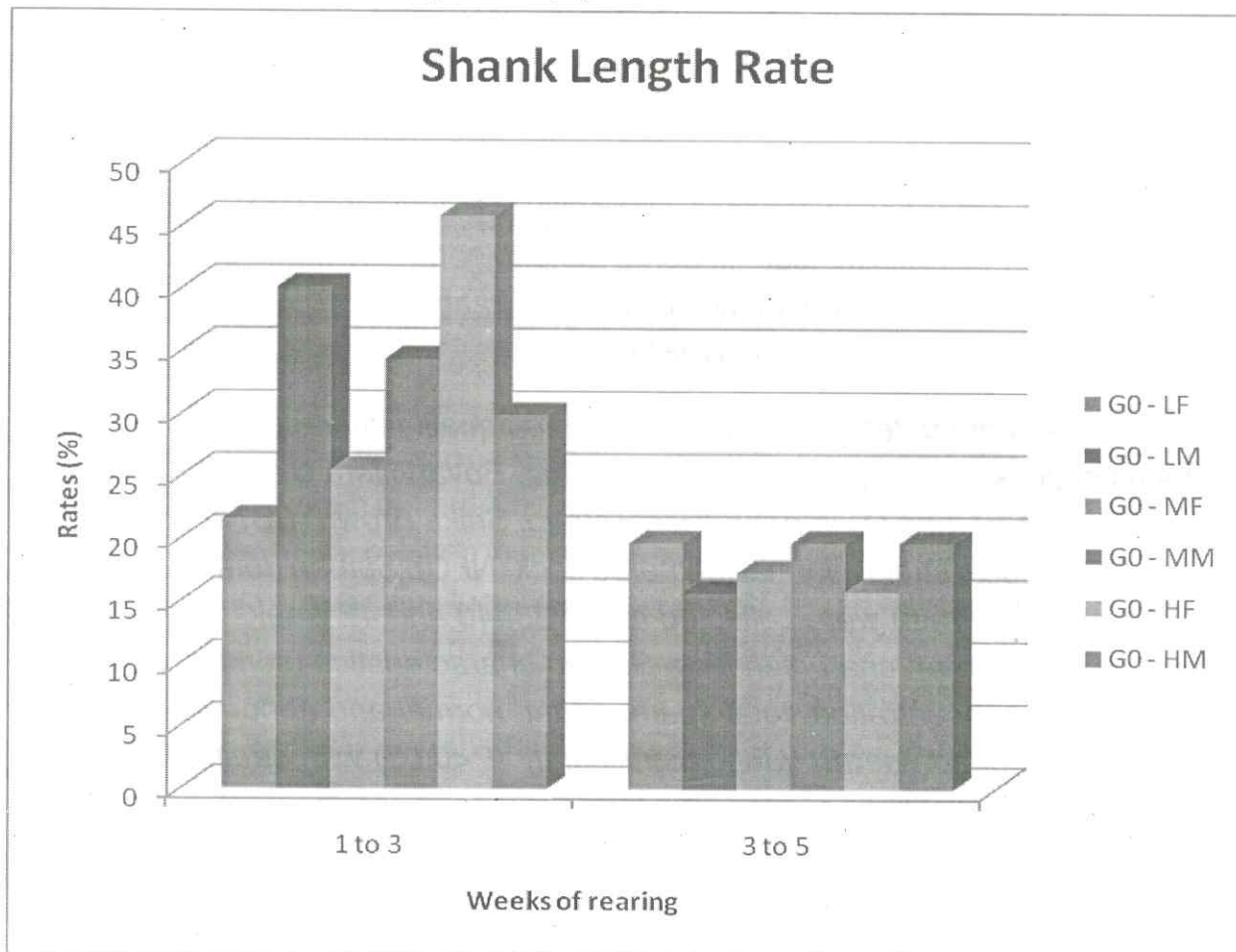
*\** - Denotes significant difference between early (1 to 3) and late (3 to 5) growth rate for each group.

Fig 4: Early and Late Wing Length Rate (%)



a,b,c - Denotes significant difference in growth rate between groups in a growth window (1 to 3 or 3 to 5).  
 \* - Denotes significant difference between early (1 to 3) and late (3 to 5) growth rate for each group.

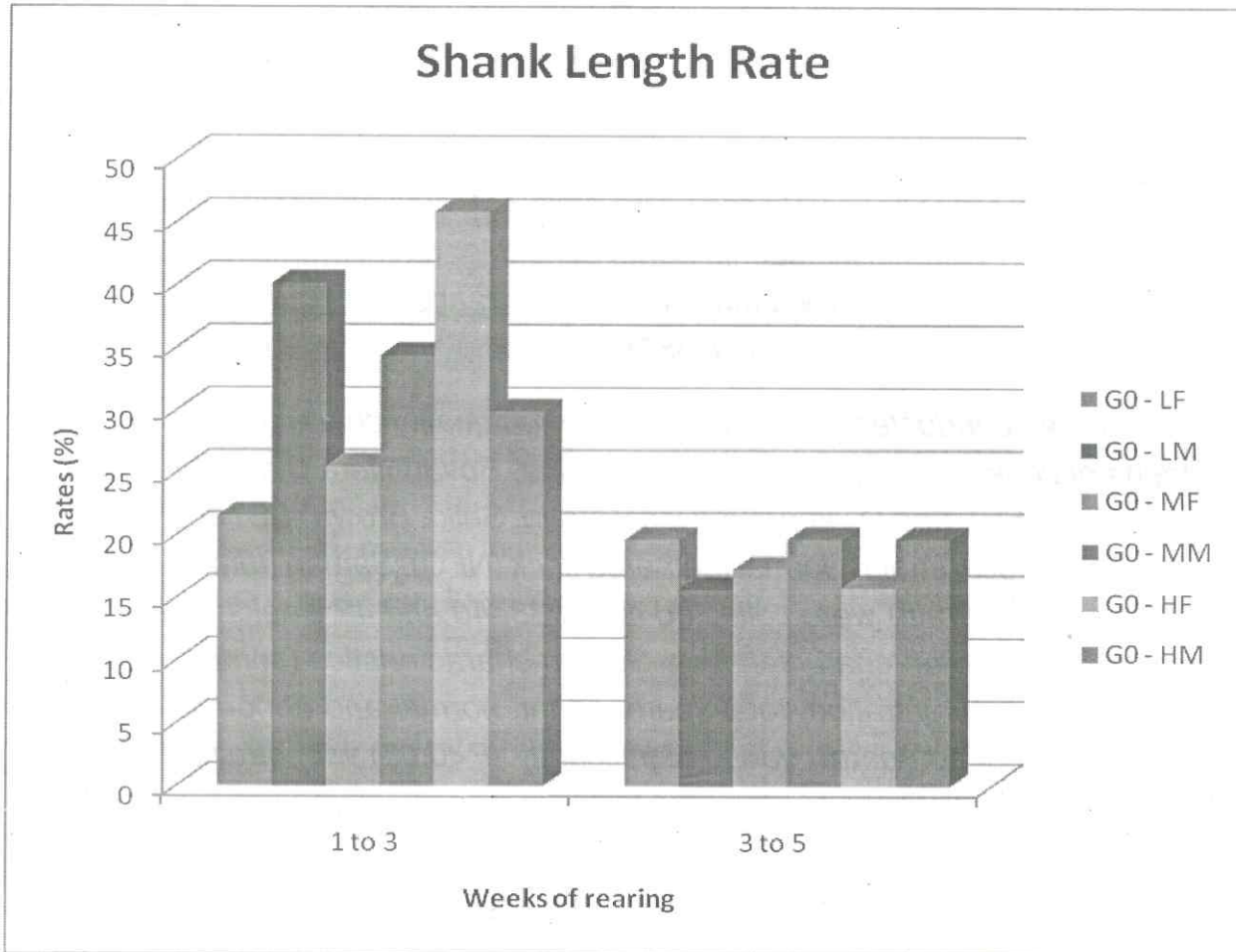
Fig 5: Early and Late Shank Length Rate (%)



*a,b,c* - Denotes significant difference in growth rate between groups in a growth window (1 to 3 or 3 to 5).

*\** - Denotes significant difference between early (1 to 3) and late (3 to 5) growth rate for each group.

Fig 5: Early and Late Shank Length Rate (%)



a,b,c - Denotes significant difference in growth rate between groups in a growth window (1 to 3 or 3 to 5).

\* - Denotes significant difference between early (1 to 3) and late (3 to 5) growth rate for each group.