# GENETIC AND PHYSIOLOGICAL EVALUATION OF HYLA RABBITS IN GUINEA SAVANNAH ZONE OF NIGERIA.

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**SEPTEMBER, 2012**

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**BY**

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**B.Sc ZOOLOGY, LASU, OJO, 2008**
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**DEPARTMENT OF ANIMAL SCIENCE,**
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## DECLARATION

I hereby declare that the work in the thesis entitled '***GENETIC AND PHYSIOLOGICAL EVALUATION OF HYLA RABBITS IN GUINEA SAVANNAH ZONE OF NIGERIA'*** has been performed by me in the Department of Animal Science under the supervision of Prof. B.I Nwagu and Dr. (Mrs). M. Orunmuyi. The information derived from literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at any University.

| _____ | _____ | _____ |
|---|---|---|
| Name of Student | Signature | Date |

## CERTIFICATION

This thesis titled ***"GENETIC AND PHYSIOLOGICAL EVALUATION OF HYLA RABBITS IN GUINEA SAVANNAH ZONE OF NIGERIA",*** by Oludayo Michael AKINSOLA meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, Zaria and is approved for its contribution to scientific knowledge and literary presentation.

| | | |
|---|---|---|
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| Dean, Postgraduate School<br>Prof. A.A. Joshua | Signature | Date |

## DEDICATION

This thesis is specially dedicated to The Almighty God, the Creator of Heaven and Earth, to my super-mum Mrs. Sherifat Akinsola, my late Father (Mr M.O. Akinsola) and to my guardian, Dr. O.T.F Abanikannda.

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## TABLE OF CONTENTS


Cover page - - - - - - - - - i

Title page - - - - - - - - - ii

Declaration - - - - - - - - - iii

Certification - - - - - - - - - iv

Dedication - - - - - - - - - v

Acknowledgment - - - - - - - - vi

Table of contents - - - - - - - - vii

List of tables - - - - - - - - - xiii

List of figures - - - - - - - - xv

List of abbreviations - - - - - - - - xvi

Abstract - - - - - - - - - xix

CHAPTER ONE

1.0 INTRODUCTION - - - - - - - 1

CHAPTER TWO

2.0 LITERATURE REVIEW - - - - - - 4

2.1 Historical Origin of Rabbits - - - - - - 4

2.2 Biological Description of Rabbits - - - - - - 4

2.3 Rabbit Breeds - - - - - - - - 5

2.3.1 New Zealand White Breed - - - - - - 5

2.3.2 Californian Breed - - - - - - - 6

2.3.3 Chinchilla Breed - - - - - - 6

2.4 Rabbit Hybrids - - - - - - - 7

2.4.1 Hyla Hybrid - - - - - - - - 7

2.4.2 Hycole Hybrid - - - - - - - 7

2.4.3 Hyplus Hybrid - - - - - - - 7

2.4.4 Non Descript Rabbits- - - - - - - 8

2.5 The Concept of Stress - - - - - - 8

2.5.1 Definition of Stress - - - - - - - 8

2.5.2 Causes and Symptons of Stress - - - - - 9

2.5.3 Mechanism of Heat Balance - - - - - - 11

2.5.3.1 Thermoregulatory Function - - - - - 11

2.5.3.2 Heat Dissipation Pathways - - - - - 12

2.5.3.3 Respiration rate - - - - - - - 12

2.5.3.4 Ear Lobe - - - - - - - - 14

2.5.3.5 Pulse Rate - - - - - - - 14

2.6 Body Temperature Changes - - - - - - 14

2.6.1 Rectal temperature- - - - - - - - 14

2.7 Adaptability Estimation - - - - - - 15

2.8 Doe Litter Traits - - - - - - - - 15

2.8.1 Litter Size - - - - - - - - 16

2.8.2 Litter Weight - - - - - - - - 16

2.9 Factors Affecting Doe Litter Traits - - - - - 16

2.9.1 Genetic and Non-Genetic Factors - - - - - 16

2.9.1.1 Parity - - - - - - - - 17

2.9.1.2 Lactation - - - - - - - 17

2.9.1.3 Pre-weaning Mortality - - - - 18

2.10 Growth Traits - - - - - - - 19

2.10.1 Pre-weaning Growth - - - - - - - 19

2.10.2 Post-weaning Growth - - - - - 19

2.11 Genetic Parameters for Growth Traits - - - - 20

2.11.1 Heritability- - - - - - - - - 20

2.11.2 Repeatability - - - - - - 21

2.11.3 Genetic and Phenotypic Correlation of Bodyweight - 22

2.12 Prediction of Bodyweight from Linear Body Measurement - 22

CHAPTER THREE

3.0 MATERIALS AND METHODS- - - - - - - - 24

**3.1** Location of the Study Area - - - - - - 24

3.2 Experimental Animals and Management - - - - - 24

3.3 Experimental Mating Plan - - - - - - 25

3.4 Data Collection - - - - - - - - - 28

3.4.1 Meteorological Data of the Rabbitry Microclimate - - - 28

3.4.2 Thermoregulatory Parameters Measurement - - - 28

3.4.3 Adaptability Estimation - - - - - - 29

3.5 Breeding data estimation - - - - - - - 29

3.5.1 Reproductive Traits - - - - - - - 29

3.5.2 Weaning Traits - - - - - - - 30

3.6 Growth Traits - - - - - - - - - 30

3.6.1 Linear Body Measurements - - - - - - 30

3.7 Statistical Analysis - - - - - 31

CHAPTER FOUR

4.0 RESULTS - - - - - - - - 36

4.1 Temperature Humidity Index - - - - - - 36

4.1.1 Thermoregulatory Response of Hyla Grand-parent and Old Non Descript Rabbits - - - - - - - - 38

4.1.2 Thermoregulatory Responses of Hyla $F_1$ Progeny and Grower Non Descript Rabbits - - - - - - - 40

4.1.2.1 Circadian Rhythm - - - - - - - 42

4.1.2.2 Sexual Dimorphism- - - - - - - - 44

4.1.2.3 Adaptability Indices - - - - - - - 46

4.3 Growth and Reproductive performance of Hyla rabbits - - - 48

4.3.1 Growth Performance of Hyla Grand-parent Rabbits - - 48

4.3.2 Growth Performance of Hyla $F_1$ Progeny Rabbits - - - 51

4.3.3 Reproductive Performance at Pre-weaning ages - - - 52

4.3.4 Parity - - - - - - - - - 54

4.4 Genetic Parameter - - - - - - - 56

4.4.1 Heritability Estimates for Pre-weaning Growth Traits - - - 56

4.4.2 Repeatability Estimates for Pre-weaning Growth Traits - - - 56

4.4.3 Genetic and Phenotypic Correlations for Pre-weaning Growth Traits- 56

4.5 Bodyweight and Linear Body Measurement - - - - 58

4.5.1 Least Square Means (± S.E) of Bodyweight and Biometric Traits - 58

4.5.2 Pairwise Phenotypic Correlations between BW and LBMs of Purebred and Crossbred Rabbits - - - - - - 60

4.5.3 Principal Component Matrix - - - - - - 62

4.5.4 Prediction of Bodyweight of Hyla Rabbits from Interdependent Body Measurements and Independent Principal Components - 64

4.5.4.1 Purebreds - - - - - - - 64

4.5.4.2 Crossbreds - - - - - - - 64

CHAPTER FIVE

5.0 DISCUSSIONS - - - - - - - - 66

5.1 Thermoregulatory Activities- - - - - - - 66

5.2 Growth Performance of Hyla Rabbits- - - - - - 68

5.2.1 Growth Performance of the Grand-Parent Hyla Rabbits- - - 68

5.2.2 Growth Performance of $F_1$ Progeny Rabbits- - - - 68

5.3 Reproductive Performance- - - - - - - 69

5.3.1 Reproductive Performance of Purebred and Crossbred Hyla Rabbits- 69

5.3.2 Effect of Parity on Reproductive Traits - - - - 71

5.4 Genetic Parameters for Pre-weaning Body weight - - - 72

5.4.1 Heritability Estimates of Preweaning Kits Weight - - - 72

5.4.2 Repeatability Estimates of Preweaning Kits Weight - - - 72

5.4.3 Estimates of Genetic and Phenotypic Correlations - - - 73

5.5 Prediction of Bodyweight from Linear Body Measurements - - 74

5.5.1 Relationship between Bodyweight and Linear Body Measurements- 74

5.5.2 Phenotypic Correlations of Body Weight and Biometric Traits- - 74

5.5.3 Principal Component Analysis - - - - - 75

5.5.4 Prediction of Bodyweight from Linear Body Measurement using

Stepwise Multiple Regression- - - - - - 76

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATION - 77

6.1 Summary - - - - - - - - 77

6.2 Conclusions - - - - - - - - - 79

6.3 Recommendations - - - - - - - - 80

REFERENCES - - - - - - - - 81

## LIST OF TABLES

Table 2.1: Physiological Body Reactions in Rabbits as Affected by Heat Stress- 13

Table 3.1: Mating Plan for Crossing of Hyla Rabbits- - - - 26

Table 3.2: Number of Kittens Obtained from each Cross- - - - 27

Table 4.1: Thermoregulatory Parameters of Grand parent and Non descript Mature rabbits as Affected by Breed during the Hot and Cool Periods- - - - - - 39

Table 4.2: Thermoregulatory Parameters of $F_1$ progeny Hyla and Grower Non Descript Rabbits as affected by Breed during the Hot and Cool Periods - - - - - - 41

Table 4.3: Thermoregulatory Parameters as affected by Circadian Rhythm- 43

Table 4.4: Thermoregulatory Responses of Hyla $F_1$ Progeny and Non Descript Grower Rabbits as Affected by Sex- - - - - 45

Table 4.5: Adaptability Indices of Hyla and Non Descript Rabbits under Tropical Conditions - - - - - 47

Table 4.6: Least Squares Means ± s.e of Bodyweight Measurement of Grand- parent Hyla Rabbits by Breed - - - - 49

Table 4.7: Least Square Means ± s.e of Post Weaning Growth of $F_1$ progeny Hyla as Affected by Breed and Sex from 8 to 12 Weeks- - 51

Table 4.8: Least Square Means ± s.e for Reproductive and Growth Traits from Birth through 35 Days - - - - - 53

Table 4.9: Least Square Means ± s.e for Doe Traits as Affected by Different Parity in Hyla purebred and Crossbred rabbits - - 55

Table 4.10: Heritabilities and Repeatabilities, Genetic and Phenotypic of Preweaning kit weight for $F_1$ progeny purebreds - - 57

Table 4.11: Least Square Means ± s.e of Body weight and Linear Body Measurements in Hyla Rabbits - - - - - 59

Table 4.12: Phenotypic Correlations among of Bodyweight and Linear Body Measurements of Hyla Purebred and Crossbred Rabbits - 61

Table 4.13: Eigenvalues and Share of Total Variance along with Factor Loadings and Communalities of the Body Measurements of Purebred and Crossbred Hyla Rabbits - - - - - 63

Table 4.14: Stepwise Multiple Regression of Body weight on Original Body Measurements and on their Principal Components Factor Scores of Purebred and Crossbred Hyla Rabbits - - - 65

## LIST OF FIGURE

Figure 1: Monthly Temperature Humidity Index inside the Rabbitry during the Experiment - - - - - - - - 37

## LIST OF ABBREVIATIONS

**ANOVA**- Analysis of variance

**ARD**- Average relative deviation

**B.p.m** – Beats per minute

**Br.p.m** – Breadth per minute

**BL**- Body length

**BW**- Body-weigth

**CORR-** Correlation

**EL**- Ear length

**GL**- Gestation length

**GLM-** General linear model

**GND-** Grower non descript

$\mathbf{h^2_s}$- Heritability due to sire variance

**HCAW-** Hyla Californian White

**HG**-Heart girth

**HNZW**- Hyla New Zealand White

**HR**- Heart rate

**HW**- Height at withers

**IKW** – Individual kit weight

**KMO**- Kaiser–Meyer–Olkin

**LBL**- Length of back leg

**LBMs**- Linear body measurements

**LFL**- Length of front leg

**LHPSI**- Livestock and poultry heat stress indices

**LOS-** Level of significance

**LSB** – Litter size at birth

**LSMLMW** - Mixed model Least Square Maximum Likelihood and Mean Weight

**LWW** – Litter weight at weaning

**NCP**- New Zealand California parent

**NTS- Nose to shoulder**

$^{o}$**C** – Degree Celsius

**OND**- Old non descript

**PCA**- Principal Component Analysis

**PDIFF**- Pair-wise difference

**PWM**- Pre-weaning mortality

**R**- Repeatability

$\mathbf{R^2}$= Coefficient of determination

**REG**- Regression

**REML**- Restricted Maximum Likelihood

**RR**- Respiratory rate

**RT**- Rectal temperature

**SAS** - Statistical Analysis Software

**SPSS**- Superior Performing Statistical Software

**TC**- Thigh circumference

**THI**- Temperature Humidity Index

**TL**- Tail length

## ABSTRACT

106 grand-parent Hyla rabbits of New Zealand (NZW) and California (CAW) breeds were imported from France consisting of 22 bucks of 11 NZW line (HYLA.GPC) and 11 CAW line (HYLA.MAX) and 84 does of NZW line (HYLA.NG). They were mated naturally to produce two genetic groups consisting of 205 and 192 kits for Hyla purebred and crossbred respectively. 20 non-descript rabbits consisting of 12 old and 8 grower rabbits were used as control for the physiological evaluation. Adaptability index were found to be proportionately moderate in Hyla New Zealand grand-parent (HNZW), Hyla California grand-parent (HCAW) and old non-descript (OND) (0.37, 0.36 and 0.39) respectively. However values obtained for the $F_1$ progeny lines and grower non-descript were 0.34, 0.33 and 0.35 for Hyla New Zealand (HNP), Hyla New Zealand X Californian (NCP) and grower non-descript (GND). Genetic groups for both grand-parent and its $F_1$ progeny rabbits had significant ($P < 0.05$) influence on body-weights at all ages. Reproductive traits such as litter size at birth (LSB) to litter size at 35 (LS35), litter weight at birth (LWB) to litter weight at 35 (LW35) were significantly ($P < 0.05$) higher for purebred than the crossbred Hyla rabbits. Individual kit weights were significantly ($P < 0.05$) higher for crossbred than the purebred rabbits at pre and postweaning ages. Estimates of heritability (0.39 - 1.30), repeatability (0.21 – 0.77), and phenotypic correlations (0.28 - 1.00) were moderate to high, except for genetic correlations (0.09 - 0.87) which were low to high from birth through 35 days for pre weaning kit weights. From the factor analysis, two principal components which accounted for 83.97 % of the total variance were extracted for Hyla purebred and three principal components accounted 89.88 % for Hyla crossbred rabbits. In conclusion, the average performance of the Hyla rabbits was moderate and this implied gradual

acclimatization to the tropical environment of Zaria. Heritability and repeatability estimates implied that progress will be faster through individual selection for the pre weaning traits. The adaptability index should be further investigated to include more variables and larger sample size to improve accuracy of the estimates obtained.

# CHAPTER ONE

## 1.0 INTRODUCTION

Rabbits can be considered as one of the several species quite suitable for meat production. They are characterized by quality protein (20 – 21 % CP) with high biological value amino acids, meat low in calories and fat, prolificacy, short gestation length, initial capital outlay, great genetic flexibility, highly unsaturated lipids (60 % of the total fatty acids), valuable animal model for biomedical research, low sodium and cholesterol. It is considered a delicacy for healthy food products (Dalle Zotte, 2002).

However, the most obvious limitation to rabbit production in regions with hot climate is the susceptibility of this species to heat stress. Heat stress, as indicated by elevated body temperature, occurs when environmental extremes, acute or chronic, lead to alteration in the rate of heat production and body temperature (Freeman, 1988). It occurs when animals are exposed to high ambient temperatures (30 – 39.5 $^{o}$C), high humidity (60 – 90 %), low wind speed and high direct and indirect solar radiation (Willmer *et al*., 2000).

The importation of domestic animal diversity is essential to meet future needs in Nigeria due to the quest for protein sufficiency. Also, this will be a suitable way to improve performance of our local rabbits by introducing purebred exotic rabbits with high growth and reproductive potentials. In semi-intensive and intensive systems, the rearing of more productive rabbit breeds could be a suitable path to improve the productivity and reduce the production cost. Imported populations such as Hyla rabbits are usually bigger in size, have rapid growth, great adaptability, better reproductive efficiency and disease resistance. Hamouda *et al*. (1990) reported that Hyla rabbits are productive breeds used in many crossbreeding programs for genetic improvement.

Estimation of genetic parameters are primordial to the establishment of strategies to be used in Hyla rabbit breeding programs and the evaluation of response to selection for traits and genetic associations among traits (Nizza and Moniello, 2000). Diversity that exists between Hyla breeds and our local breeds is likely to provide genetic combinations suited to a variety of environment and production systems in Nigeria. Genetic information on production traits for Hyla rabbits raised under the Guinea Savannah Zone of Nigeria is very limited. Without the knowledge of the genetics of Hyla rabbits, planned improvement of rabbit meat in Nigeria will be limited. This study is therefore designed to study the heritable characteristics favouring survival of Hyla rabbits, the capacity and process of adjustment of the animal to itself and to the physical environment in its new micro-climate.

**Hypotheses:**

This study was designed to evaluate the following hypotheses:

$H_o$: Performance of Hyla rabbits in Guinea Savannah zone are not influenced by their genetic and physiological changes in response to internal and external stimuli.

$H_a$: Performance of Hyla rabbits in Guinea Savannah zone are influenced by their genetic and physiological changes in response to internal and external stimuli.

$H_o$: Relationships involving body measurements and body weight may not be different when orthogonal conformation traits derived from the factor analysis are used instead of the intercorrelated original traits.

$H_a$: Relationships involving body measurements and body weight may be different when orthogonal conformation traits derived from the factor analysis are used instead of the intercorrelated original traits.

**Specific objectives:**

1. To estimate the adaptability of Hyla and non-descript rabbits to the guinea savannah zone of Nigeria.
2. To determine variations in growth and reproductive traits of Hyla pure and crossbred rabbits.
3. To estimate some genetic parameters for pre-weaning growth traits in Hyla purebred rabbits.
4. To predict bodyweight from biometric traits using principal component factor analysis and intercorrelated original traits.

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

## 2.1 HISTORICAL ORIGIN OF RABBITS

Domestic rabbit originated from the wild rabbit (*Oryctolagus cuniculus*). It occurred mainly in south-west Europe, but did not occur in central Europe. Some 2000 years ago the Romans kept rabbits in enclosure, 'leporaria', for their meat. This method was later used in France and England; it served to meet the desire for hunting. The first wild rabbits came to Germany around 1300 BC, and they were kept on the island of Amrum. Real domestication was completed in the Middle Ages, initially in France, by keeping them in enclosures (Oglesbee, 2006). The first books on this animal species also appeared in France. Domestic rabbit were kept in Germany from the middle of the twelfth century, i.e. after the wild form. They were still kept extensively in enclosures. Soon after the animals became domesticated, the first different colours and forms appeared. At the end of the eighteenth century there were already several breeds, including the Angora rabbit and animals with lop ears. Currently there about 80 breeds with approximately 200 colour strains, which can be divided into five groups depending on size and hair length. In addition, there are breeds which do not fit into the normal classification, as well as new breeds (Whitman 2004).

## 2.2 BIOLOGICAL DESCRIPTION OF RABBITS

Rabbit have a fairly long body. The neck is short, with long ears, a short-tail and soft hairs, varying in length. The body is divisible into four parts namely- head, neck, trunk and tail. The individual breed differs in colouring, size, form, and hair structure. Thakur *et al.* (1988) stated that rabbit belongs to the Phyllum *Chordata*, Subphyllum *Craniata*, Class *Mammalia*, Subclass *Eutheria*, Order *Lagomorpha*, Family *Leporidae*, Genus *Oryctolagus*, Species *cuniculus*. They

are social burrowing herbivores that are natural prey for majority of carnivores. As a prey species, the rabbit have evolved to be constantly vigilant, lightweight and fast-moving, with a highly efficient digestive system that enables them to spend the minimum time possible above the ground and in danger of capture. The life expectancy of the rabbit is 5 - 8 years, but some individuals live up to 10 years or more (Marai *et al.,* 2001).

## 2.3 RABBIT BREEDS

The concept of breed was first used in animal breeding in the sixteenth century, but its meaning has undergone many changes with time and is still different in the minds of different people. Among others, the following definitions have recently been used.

Encarta Encyclopedia (2011) defined breed as a population or a group of population which can be distinguished from other populations of the same species on the basis of different allele frequencies, chromosome changes or genetically determined phenotypic characteristics.

### 2.3.1 New Zealand White Breed

Sandford (1986) reported that there are about four different strains of the New Zealand breed which include; New Zealand White, New Zealand Blue, New Zealand Red and New Zealand Black, respectively. The New Zealand Red strain was first developed in California with a system of selecting similar breed to that used in France on the Burgundy Fawn Strain (Lebas, 1983). The genetic constitution of the New Zealand Red strain include the gene for the elimination of all black pigment from the Agouti colouring, thus giving it a complete extension of the yellow colour (Sandford, 1986). Thereafter, a number of modifying genes to produce the bright reddish buff colour was introduced. The New Zealand White, strain although very similar to the Red, Blue and the Black strains, differs considerably. It is heavier and larger, weighing up to 4.07 Kg

(Sandford, 1986; Lebas *et al.,* 1986). Aduku and Olukosi (1990) reported that New Zealand White breed of rabbit can reach adult weight of 4.1 to 5.4 Kg.

### 2.3.2 Californian Breed

The Californian is an American breed, which was presented for the first time in 1928 in Californian by its breeder, whose objectives was a meat animal that has a very good fur (Lebas *et al.,* 1986). According to Sandford (1986), the Californian breed was developed by crosses of New Zealand White and Himalayan with further introduction of the Chinchilla gene but the breed, according to the breeder, did not become well known in America for some 15 years after its original development. Lebas *et al.* (1986) stated that the Californian breed is today possibly the second most popular meat producing rabbit. The adult Californian weighs between 3.6 - 5.0 Kg (Lebas *et al.,* 1986; Aduku and Olukosi, 1990).

### 2.3.3 Chinchilla Breed

The Chinchilla rabbit falls under both the medium and small class breeds. The Chinchilla Giganta, also called Grand Chinchilla, weighs between 4.10 and 5 Kg, while the small weighs between 2.5 and 3.4 Kg (Lebas *et al*., 1986; Sandford, 1986; Aduku and Olukosi, 1990). Sandford (1986) reported that the intention in the production of the Chinchilla Giganta in the early 1920s by Chris Wren was to produce a large, fitness rabbit, with good meat qualities and good pelt with the Chinchilla colouring. The advantage of the small breed, according to Lebas *et al.*, (1986), is that they usually develop very quickly and make excellent mothers. They eat less than the medium and large breeds and could be crossed or used as purebred in developing countries to produce light, meaty carcass of 1 to 1.2 Kg.

## 2.4 RABBIT HYBRIDS

### 2.4.1 Hyla Hybrid

They are meat breeds with high productivity, growth rate, high disease resistant, more than 96 % survival rate of growing rabbits (Yamani, 1994). Hyla rabbits are pedigree breed, single sex consisting of line-A male, line-B female, line-C male and line-D female. The reproduction mode of grand parent is cross breeding, that is, cross-breeding of line-A male with line-B female will produce parent male (female from cross-breeding of line A and line-B will be kept as commodity rabbit), cross-breeding of line-C male with line-D female will produce parent female (male from cross-breeding will be kept as commodity rabbit). Nizza and Moniello (2000) reported that Hyla rabbits can attain a weight of 2750 g in 90 days.

### 2.4.2 Hycole Hybrid

The hycole hybrid females are characterised by high prolificacy and early maturity, while the males by fast growth but late maturity. The meat yield at 70 days is 57 to 58 %. Liveweight at 70 days is 2500 – 2550 g. The phenotype is white fur with black extremities (Grimaud, 2012).

### 2.4.3 Hyplus Hybrid

The female hyplus 19 is characterized with white fur and black extremities. The breeding age ranged between 17 – 19 weeks. Rabbits born alive per litter are 10 - 11. Live weight at 70 days ranged between 2250 – 2350 g. The male type is hyplus 40 which is characterized with white fur and black extremities. The breeding age is 20 weeks. Liveweight at 70 days ranged from 3100 – 3200 g. The carcass meat yield is 58 – 59 % (Grimaud, 2012).

### 2.4.4 Non Descript Rabbits

FAO (2008) reported that non descript rabbits are rabbits that are unimproved, multipurpose and do not fall under standard classification for breeds. They can also be regarded as mixed breeds.

## 2.5 THE CONCEPT OF STRESS

### 2.5.1 Definition of Stress

The ability of the body to maintain a stable internal environment to challenges from widely variable externals environments was first described by Bernard (1878) and later referred to as homeostasis (Dobson *et al*. 2001). He discovered that diverse detrimental (extraneous) stimuli (stressors) such as pain, hunger, thirst, severe climatic conditions, or noxious agents cause physiological changes in animals that may lead to pathological state.

Selye (1936) defined stress as a complex or general adaptation syndrome (GAS) of an organism in response to extraneous environmental factors. Since then, the understanding of stress has continued to widen. Anokhin *et al.* (1991) and von Borell (2001) defined stress as a non – specific component of physiological and pathological responses of living organisms, mainly of neuro – humoral origin, in response to environmental factors. The various definitions and the correct usage of the word ‘’ stress’’ depend upon the school of thought espoused. However in the present study, the concept of stress is examined as proposed by Selye (1976), Anokhin *et al.* (1991) and von Borell (2001). Heat stress is the state at which mechanisms activate to maintain an animal's body thermal balance, when exposed to untolerable (uncomfortable) elevated temperature.

### 2.5.2 Causes and Symptons of Stress

From the process of evolution, the higher animals have developed adaptation that counteracts many of the influences of the external environment and provides a relatively stable condition of existence for the body cells within their internal environment (homeostasis). However, through the action of extreme or extraneous environmental factors (stressors) that disagree with the normal physiological functions, the body undergoes some clinical and physiological changes in an attempt to mobilize its defence or compensatory mechanisms to combat or adapt to the stimulus (Arthington *et al.,* 2003). Typically, regardless of the animal involved or the nature of the stress factor itself, the response of an animal under stress is non – specific. This response, considered as a single type of reaction, is known as the General Adaptation Syndrome (GAS) and is divided into the following three phases (von Borell, 2001).

*The alarm reaction*: It includes the body's initial complex chain of physical and biochemical responses to stress induced by the interaction of the nervous system and a variety of different hormones, involving an increased amount of adrenal activity. The body goes on full alert. The adrenals produce extra amounts of hormones. The adrenal glands respond rigorously to an immediate stress situation. There is actually an initial hyperadrenic response to stress. After the alarm reaction is over, the body goes through a temporary recovery phase that lasts 24 – 48 hours. During this time there is less cortisol secreted, the organism is less able to respond to stress, and the mechanisms over-stimulated in the initial alarm phase by the involvement of hormones become resistant to more stimulation. In this let-down phase the animal feels more tired and restlessness, and have a desire to rest. If the stress is continued for a long period, the adrenals will finally be overtaxed to the point of depletion.

*The resistance stage*: After a period of time of continued severe stress, the adrenals which have a great capacity for increasing their size and function begin to adapt and to re-build themselves. The capacity for increased adrenal size and function is the basis for resistance stage. The prolonged alarm reaction starts as a hyperadrenia, which leads to a hypoadrenia and later progresses into another state of hyperadrenia as the resistance stage takes over. This phase of resistance can last months or even up to 15 – 20 years. The adrenal hormone cortisol is largely responsible for this stage. It stimulates the conversion of proteins, fats and carbohydrates to energy through gluconeogenesis so that the body has a large supply of energy long after glucose stores in the liver and muscles have been exhausted. Cortisol also promotes the retention of sodium to keep the blood pressure elevated and the heart contracting strongly. If the stress is prolonged and severe, it will continue beyond the resistance stage and into the third stage of GAS. The reported production of this GAS over and over, results in haemorrhage of adrenal glands, atrophied thymus glands (the chief gland in immunity), and biochemically devastated bodies of animals exposed to repeated stress.

*The exhaustion stage*: This stage of GAS is characterized by hypoadrenia to the point where the organism loses the ability to adapt to stress. The adrenal cortical enlargement of the triad of chronic stress is due to the hypertrophy of the resistance stage. However, adrenal function in the exhaustion stage is severely limited. In the exhaustion stage, there may be a total collapse of body function, or a collapse of specific organs or systems. The body has little or no ability to resist any further stress. Two major causes of exhaustion are loss of sodium ions (decreased aldosterone) and depletion of adrenal glucocorticoid hormones such as cortisol, leading to decreased gluconeogenesis, rapid hypoglycaemia and potassium retention. Simultaneously, insulin levels are still high. Body cells function less effectively in this condition as they rely

heavily on a proper amount of blood glucose and the ratio of sodium to potassium. As a result, the organism becomes weak. When energy is not available, every-requiring mechanism of the cell slows dramatically. This lack of energy, combined with the electrolyte imbalance produces a cell in crisis. The anti – stress mechanisms are lost and there is no more reserve potential for the animal to fall back on.

### 2.5.3 Mechanism of Heat Balance

Exposure to high ambient temperature induces rabbits to balance the excessive heat load by using different means to dissipate, as much as possible their latent heat. If such means fail, rabbits use strategies that include: depression in feed intake, efficiency and utilization, protein, energy and mineral metabolism balances, reactions, hormonal secretions and blood metabolites (Thwaites *et al*., 1992). Above 35 $^{o}$C, rabbits can no longer regulate their internal temperature and heat prostration sets in (Lebas *et al*., 1986).

#### *2.5.3.1 Thermoregulatory function*

The comfort zone temperature for rabbits is around 18 – 21 $^{o}$C (Marai *et al*., 2001). At either higher or lower temperatures, the animal has to expend energy to maintain its body temperature. The heat load in rabbit increases by exposure to a high environmental temperature and animals try to sustain homeothermy by using internal physiological means to help re-establish thermal balance. Rabbits use general body position, breathing rate and peripheral temperature (especially ear temperature), as three means to increase heat loss. Respiration and the ear are the most important heat dissipation pathways, since most of the sweat glands in rabbits are un-functional and perspiration (evacuation of water through the skin) is never great because of the fur.

*2.5.3.2 Heat dissipation pathways*

Body position: When the temperature is above 25 – 30 $^{o}$C, animals stretch out and erect their ears to lose as much heat as possible by radiation and convection (Lebas *et al*., 1986).

*2.5.3.3 Respiration rate*

Respiration rate can be an indicator of heat stress (Habeeb *et al*., 1992). In mammals, respiration is directed at the elimination of $CO_2$ from the tissues of the body and the provision of $O_2$ under thermo-neutral conditions, and evaporation of moisture from the respiratory tract and prevention of hypothermia under high ambient temperatures. Between 0 and 30 $^{o}$C, latent heat evacuation is only controlled by altering the breathing rate (Marai and Habeeb, 1994). Several groups found that respiration rate in rabbits increased under heat stress conditions (Table 2.1). Marai *et al*. (2005) reported respiration rate of 85 r.p.m under a mild condition and 134 r.p.m under the hot conditions. The increase in respiration rate in summer estimated by Habeeb *et al.* (1998) was 42 – 59 % higher than the winter average.

**Table 2. 1: Physiological body reactions in rabbits as affected by heat stress**

| Parameters | Winter | Summer | References |
|---|---|---|---|
| RR (r p m) | 81.9±2.1 | 127.0±1.6 | Gad (1998) |
| | 69.0 | 190 | Johnson *et al*. (1957) |
| | 98.5 | 133.0 | Marai *and Habeeb* (1994) |
| | 79.4± 1.8 | 125.2±1.7 | Gad (1998) |
| | 97.7±3.8 | 108.5±1.4 | Marai *et al*. (1996) |
| ET ($^{o}$C) | 9.6-30.2 | 37.2-39.4 | Gonzalez *et al*. (1971) |
| | 31.5±0.42 | 37.2-±0.13 | Gad (1998) |
| | 31.5±0.33 | 37.0±0.10 | Gad (1998) |
| RT ($^{o}$C) | 38.7 | 40.0 | Marai *et al*. (1994) |
| | 39.1±0.07 | 40.2±0.05 | Gad (1998) |
| | 39.0±0.05 | 40.1±0.06 | Gad (1998) |
| | 39.4±0.06 | 39.8±0.09 | Marai *et al*. (2005) |

Source: Marai *et al*., 2006. r.p.m = respiration per minute, RR- respiratory rate, ET – ear temperature, RT – rectal temperature

#### *2.5.3.4 Ear Lobe*

The ear lobe plays an important role in thermoregulation of rabbits, since its function is like that of a car radiator. The physiological role of the ear lobe is through a vasomotor mechanism that controls blood circulation from the body core to the very large meshwork of blood vessels and blood capillaries that could be dilated and constricted by a vasomotor mechanism (Marai *et al*., 2006). The ear temperature of rabbits was 15 – 28 % higher in summer than in winter, i.e. proportional to the change in ambient temperature, which increased from 18.8 $^{o}$C in winter to 30.7 $^{o}$C in summer (Table 2.1).

#### *2.5.3.5 Pulse Rate*

The pulse rate reflects primarily the homeostasis of circulation along with the general metabolic status. The rate increases on exposure to high environmental temperature (Aboul-Naga, 1987). This increases blood flow from the core to the surface to give a chance for more heat to be lost by sensible (loss by conduction, convention and radiation) and insensible (loss by diffusion water from the skin) means. Alexiev *et al*. (2004) reported breed differences to exist in the rate of cutaneous cooling. At very high temperatures, the pulse rate may decrease due to a decrease in the metabolic rate.

## 2.6 BODY TEMPERATURE CHANGES

### 2.6.1 Rectal Temperature

The rectal temperature is often used as a representative measurement of animal core temperature, for practical purposes (Nieslon, 1995). Rectal temperature increases with exposure to high environmental temperature (Tharwat *et al.,* 1994). However, Shafie *et al*. (1970) reported that the diurnal variation in body temperature varied within a very short range (0.2 – 0.3 $^{o}$C) revealing a

high efficiency of body heat regulation in rabbits. Finzi *et al*. (1994) showed that the average body temperature goes up from morning till night, while environmental air temperature goes up from morning till noon then decreases at night, indicating that body temperature is not affected instantly by changes in air temperature during the day. Particularly, the increase value in rectal temperature was estimated to be about 1.0 $^{o}$C, when the ambient temperature increased from 18.8 $^{o}$C in winter to 30.7 $^{o}$C in summer (Gad, 1998) (Table 2.1). The increase in rectal temperature of the heat stressed rabbits may be due to either poor ability of the animals to prevent the rise in rectal temperature or failure of the physiological mechanisms of animals to balance the excessive heat load caused by exposure to high ambient temperature (Habeeb *et al.,* 1992).

## 2.7 Adaptability Estimation

Adaptability is a long term genetic and physiological changes taking place in an animal in response to internal and external stimuli. Marai *et al*. (2005) reported adaptability index of rabbits to the subtropical environment of Egypt to be proportionately 0.844 and 0.876, in New Zealand White and Californian breed.

## 2.8 Doe Litter Traits

Litter traits are considered as character of the doe because there is a larger environmental component of variance associated with the doe during kindling and raising a litter to weaning (Khalil *et al*., 1986). The larger the number of young the doe kindles and weans, the greater is the profitability of the organization (Afifi and Emara, 1987). Litter traits (litter size and weight at different ages up to weaning) are usually regarded as the best estimates of number and weight of young produced by the doe since they constitute a function of all pre-weaning effects. Litter weight at weaning, as a composite trait, reflects the contribution of fertility, maternal behavior, milk production, pre-weaning growth and survival (Lukefahr and Cheeke, 1990). In some

situations, genetic improvement, through crossing in the compound trait can be more rapid than improvement through one or a combination of the contributing traits (Hohenboken, 1985).

### 2.8.1 Litter Size

Vaclavovsky *et al*. (2000) reported litter size at birth of 9.49 for Hyla rabbits which was higher than 8.50 recorded at first generation with Hyla rabbit in Tunisia (Hamouda *et al*., 1990). Chrystosome *et al*. (2011) observed litter size at birth in Hyla purelines to be 7.29 in France and 6.45 in Benin. Yamani *et al*. (1994) reported litter size at birth to be 6.1 for Hyla rabbits in Sam Elgar project in Egypt.

### 2.8.2. Litter Weight

Chrystosome *et al*. (2011) reported that kit weight at birth in Hyla pure NZW lines to be 55.6 g in France and 54.4 g in Benin. Yamani *et al*. (1994) observed kit weight at birth to be 46 g in Sam Elgar project in Egypt. Mean kit weight was reported to range from 49.0 g to 58.8 g (Afifi *et al*., 1987) and from 53.4 g to 66.1g (Lukefahr *et al*., 1984). Nizza and Moniello (2000) reported live weight of Hyla rabbits to be 2750 g at 90days which had almost the same weight with Italian hybrids. Ferraz *et al*. (1992) reported that breed of doe affected litter weight at weaning with Californian does weaning heavier litters than New Zealand White does with 3073.7 versus 2841.1g for total weaning weight and 671.11 versus 646.58 g for average weaning weights.

## 2.9 FACTORS AFFECTING DOE LITTER TRAITS

### 2.9.1 Genetic and Non-Genetic Factors

*Genetic factors*: The genetic factors affecting litter traits could be classified as genotype of both dam and fetus. This plays a vital role in determining birth weight, while the subsequent litter

weights basically depend, beside the fetus genotype, on the suckled milk from the dam (Abdel-Azeem, 2006).

*Non-genetic aspects*: The non-genetic factors affecting litter traits could be classified according to Turner and Young (1969) into: 1-External factors (e.g. year, season and month of kindling effects, feeding type, feed intake, managerial procedures, and diseases). 2- Internal maternal factors (e.g. parity, weight of doe and milk yield …etc.) 3- Interaction between all previous genetic and non-genetic factors.

2.9.1.1 *Parity*

Differences in litter traits at birth due to parity effects may be attributed to changes in the physiological efficiency of the doe such as those associated with ovulation rate, ova wastage, implantation, embryo survival rate, embryonic mortality, uterine capacity, efficiency of providing the young with nourishment and intra-uterine environment during the prenatal development as reported by Khalil *et al.,* (1988); Khalil and Afifi (2000). The change with parity may be a result for differences in age of the doe which increases as parity advances (Blasco *et al.,* 1992). However, McNitt and Moody (1990) reported that milk production increased with advances of parity, reached its maximum production at the $6^{th}$ parity after which there is some decline. They concluded that females should be discarded at the $7^{th}$ or the $8^{th}$ parity when milk production started to decline.

*2.9.1.2 Lactation*

In rabbits, early growth and survival are dependent in part on the intrinsic ability of the dam to provide an adequate maternal environment (Yahaya, 1993). The moulting stage of rabbit's life, when it should feed on milk from the doe only, is very important and will affect its future

growth, development and ability to thrive. Milk production in the rabbit reaches its peak by the 21st day of lactation (Sandford, 1986). Growth of the young up to 22 days depends on the milk consumed. Therefore maternal influence is greatest at this point (Peinado *et al*., 1988). Litter size and weight at 21 days give very good evaluation of the doe's maternal ability as the young depend solely on dam's milk of that age (Ferraz and Eler, 1994). There also exists a large variation in milk intake between litter-mates (Venge, 1963). Breed variation in milk has also been reported (Venge, 1963) and the New Zealand White females has been reported to produce less milk in their first lactation than subsequent lactations. This has been advanced as the reason for the low weaning weights observed in the litter of first parity does (Lukefahr, 1982).

#### 2.9.1.3 *Pre-weaning Mortality*

Chrystosome *et al*. (2011) reported mortality rate in lactation of Hyla rabbits to be 25 % in Benin Republic. The same authors confirmed that the high mortality rate was due to the high ambient temperature. The recorded high values for mortality rate may be attributed to the direct effect of heat stress on the sensitive offspring, in addition to a reduction of milk production (Ayyat and Marai, 1995) due to the general depression of metabolic activity in the summer (Shafie *et al*., 1994). During the postweaning phase, Habeeb *et al*. (1997) estimated the mortality rate at 18 % in the summer, while no mortality was recorded during the winter. During 4 – 5 weeks of age, mortality rate percentage was significantly lower in spring than in winter and autumn (El-Dessoki, 1991). During 5 – 9, 9 – 13 and 5 – 13 weeks of age intervals, mortality rate values were higher in summer and lower in spring than in autumn and winter (Shehata *et al*., 1998).

## 2.10 GROWTH TRAITS

### 2.10.1 Pre-Weaning Growth

Productivity of rabbit as a function of growth traits, and knowledge of these major component is essential to improve production. The young rabbit has high growth rate which starts prior to birth and continues until the animal is about ten weeks old (Lang, 1981). The weight of the fetus increases from 1g at day 16 of gestation to a birth weight of 60 g, after 31 days of pregnancy (Prudhon and Selme, 1973). After birth, the young rabbit approximately doubles its weight every week until it reaches 450 g at three weeks of age and thereafter, the rabbit begins to eat solid food. Growth rate of the kit is 10-20 g/day when milk is the sole food, and increases to 30-50 g/day between three and eight weeks of age (Rao *et al*., 1977). The growth rates under tropical conditions are much lower and are primarily attributed to poor nutrition (Rajadevan, 1984). Major environmental factors that affect prenatal growth, according to Mariana *et al.* (1988) include size, parity, nutrition and health of the mother, duration of pregnancy, litter size, position of fetus within the uterine horn, competition between one litter mate and another, relative stage of pre-implantation development of the embryo and the endometrium, placental size and ambient temperature.

### 2.10.2. Post-Weaning Growth

Post-weaning growth traits (body weight and daily gain) in rabbits are important since heavier marketable body weight controls the economics of rabbit farms. Daily gain is an expression of rabbit's growth. The economics of a given meat rabbit breed is greatly determined by its growth rate and fecundity (Afifi and Emara, 1990). Many investigators (Iraqi, 2008) demonstrated that progeny growth traits are influenced by both genetic (e.g. breed) and non genetic factors (e.g. managerial and nutritional factors as well as, year, month and/or season of kindling, year–season

of kindling, parity, litter size at birth …etc). The potential growth of an animal, its pattern of development and to some extent, its ultimate carcass composition in terms of the proportion of muscle, bone and fat are genetically predetermined (Lebas, 1969). Growth rate and development in the rabbit is breed dependent (Lukefahr *et al*., 1980), where as some rabbits reach 2 Kg at eight weeks of age (Chen *et al*., 1978) while others achieve much poorer growth (Lang, 1981). In Californian (CAL) rabbits raised in Egypt, the average body weight ranged from 395 to 667 g, from 857 to 1171 g, from 1483 to 2153 g and from 1570 to 2072 g for BW 4, 8, 12 and 14 weeks of age. For Baladi Red (BR) rabbits the means of body weight ranged from 318 to 497 g, from 590 to 921 g, from 830 to 1481g and from 1176 to 1757 g for BW 4, 8, 12 and 14 weeks of age. Yamani (1994) reported $BW_5$ and $BW_{12}$ in Hyla rabbits to be 415 and 2153 g respectively. Chrystosome *et al*. (2011) reported $BW_5$ Hyla rabbits to be 638 g. Nizza and Moniello (2000) reported $BW_5$ and $BW_{12}$ to be 717.4 and 2750 g.

## 2.11 GENETIC PARAMETERS FOR GROWTH TRAITS

### 2.11.1 Heritability

El-Deghadi (1996) reported that heritability values in general, decreased from weaning at 5 weeks with advance of age up to 12 weeks. In such situation, there is obviously a large effect of maternal genotype and/or maternal environmental effect on animal performance during earlier or post-weaning periods of growth (Khalil and Mansour, 1987 and Khalil, 1993). Such evidence of maternal effect may probably be due to the correlation between rabbit growth with litter condition (Randi and Scossiroli, 1980). Most of the literatures cited by different authors showed that estimates of heritability for body weight according to sire-component estimates (paternal half-sibs) were lower than those for dam (covariance's between maternal half-sibs), which is due to maternal effect on body weight from birth up to later ages. Ferraz and Eler (1994) using

animal model to estimate the direct and maternal heritabilities as 0.01 and 0.09; 0.04 and 0.17; 0.08 and 0.03 for body weight at weaning, 8 and 11 weeks of age, respectively. Ahmed (1997) reported heritability estimates of sire for body weight at 5, 6, 8, 10 and 12 weeks of age as 0.14, 0.17, 0.16, 0.21 and 0.20 in NZW and 0.12, 0.09, 0.11, 0.11 and 0.13 in CAL rabbits, all estimates based on Henderson method III. The same author estimated sire heritability for the same traits in the same breeds using REML method as 0.19, 0.24, 0.20, 0.24 and 0.22 in NZW, 0.14, 0.10, 0.13, 0.13 and 0.16 in CAL rabbits for body weight at 5, 6, 8, 10 and 12 weeks of age, respectively. The author concluded that estimates of heritability obtained for body weight using Henderson III method were smaller in most cases than their corresponding estimates obtained by REML method. Furthermore, Akanno and Ibe (2005) with NZW and Dutch breeds of rabbits reported that heritability estimate was 0.43 for $BW_6$ and 0.36 for $BW_{12}$. Iraqi *et al*., (2002) estimated heritability using multi-trait animal model as 0.34, 0.30 in NZW and 0.10, 0.25 in Z-line rabbits for $BW_8$ and $BW_{12}$ respectively. The authors reported that heritability estimates for $BW_{12}$ were moderate in both strains, while for $BW_8$ were low in Z - line rabbits and moderate in NZW rabbits.

### 2.11.2 Repeatability

The breeding value of individuals upon which selection can be based, particularly for traits that can be measured more than once in lifetime. Such estimates indicate the extent to which selection will influence future animal performance (Ibe, 1995). Iraqi (2008) reported 0.15 to 0.27 repeatability estimates of litter size traits in rabbits. Meanwhile most literature reported a range of 0.00 to 0.26 (Khalil 1994; Lukefahr and Hamilton 1997). Chineke *et al*. (2001) reported moderate to high repeatability for body weights and linear body measurement at all ages except for heart girth which was low (0.11). Therefore selection of sires for these traits based on a single

production record would not be efficient from a genetic standpoint and consequently assessment of several parities before selecting parents for these traits is necessary (Khalil and Mansour 1987; Khalil 1994). This implies that great reliability can be put on selection or culling of does and bucks based on 2 or more records. Ndjon and Nwakalor (1998) also obtained moderate to high pre and post weaning growth traits.

### 2.11.3 Genetic and Phenotypic Correlations of Bodyweight

All phenotypic correlations among kitten body weight at 2, 4, 6 and 8 weeks of age were positive and highly significant in rabbits (Nwagu *et al*., 2000). Elamin *et al*. (2011) reported moderate to high genetic and phenotypic correlation for both pre-weaning and post-weaning ages of Sudanese rabbits. Sri vidya Devi *et al*. (2007) observed low to high genetic and phenotypic correlations of pre-weaning body weights in Soviet chinchilla rabbits.

## 2.12 Prediction of Bodyweight from Linear Body Measurement.

The strong relationship existing between body weight and body measurements may be useful as selection criterion, since positive correlations of traits suggest that the traits are under the same gene action (Pleiotropy). Yakubu and Ayoade (2009) reported that heart girth alone explained about 83 % of the variation in bodyweight in rabbits. The combinations of heart girth and body length, thigh circumference and body length accounted for about 84 % and 73 % of the variability in rabbits bodyweight, respectively. Similar findings have been reported by other workers (Wu *et al*., 2008 and Teguia *et al*., 2008). Ibe (1989) observed that the use of body measurements to predict bodyweight should be treated with caution due to multicollinearity, which has been shown to be associated with unstable regression estimates. Correlation between principal components is zero, the selection of animals for any principal component will not cause

correlated response in terms of other principal components (Pinto *et al*., 2006). This is buttressed by the report of Yamaki *et al*. (2006) who used principal component analysis to identify independent and informative variables thereby eliminating redundant information for the purpose of reducing costs of quails' genetic programmes. Yakubu and Ayoade (2009) reported PC1 contributed to about 61 % of the total variation in bodyweight when used as a sole predictor. When both PC1 and PC2 were combined, the $R^2$ progressively improved to about 82 %.

# CHAPTER THREE

## 3.0 MATERIALS AND METHODS

### 3.1 Location of the Study Area

The study was carried out at the Rabbitry of National Animal Production Research Institute (NAPRI) Shika, Zaria, Kaduna State. The Rabbitry lies between $11^{o}$ 12' 42" N and $7^{o}$ 33' 14" E at an altitude of 691m above sea level (Ovimaps, 2012).

### 3.2 Experimental Animals and Management

The grand-parent Hyla rabbits were imported from France at ten weeks old in June 2010. The foundation population of the grand-parent Hyla stock consisted of 22 male rabbits made up of 11 NZW male line (Hyla.GPC), 11 CAW male line (Hyla.MAX) and 84 NZW female line (Hyla.NG) were used at the start of the study. A total of 397 $F_1$ parent rabbit kits were produced which consisted of 205 purebred (NZW Male x NZW Female) and 192 crossbred (CAW Male x NZW Female) Hyla rabbits. 20 local non-descript rabbits were used consisting of 12 mature rabbits at 9 month and 8 grower rabbits at 12 weeks as control for physiological evaluation.

The rabbits were fed once daily with pelletized diet containing 18 % CP, 2800 ME kcal/kg and green forages. Cages and house were cleaned daily. The rabbits were kept under similar management and environmental conditions to avoid bias. According to the breeding plan, each doe was transferred to the cage of the assigned buck to be mated and returned back to its own cage. Mating started from June through December, 2011. On the $25^{th}$ day of pregnancy, nest boxes were supplied with some straw to help the does in preparing a warm comfortable nest for receiving their litters. The mating and kindling dates were noted, litter size, litter weight and kit weight were recorded immediately kindling was discovered. Kits were handled with nylon

disposable hand gloves so as to avoid rejection of the kits by their dams. Within 12 hours after kindling, litters were checked, recorded and thereafter examined every morning to get rid of the dead kits. Identifications were done at two weeks using coloured indelible marker on the ear and at 35$^{th}$ day post-kindling. Young rabbits were sexed, tatooed, separated from their dams and transferred to standard progeny metal cages of dimension 60 x 60 x 50 cm$^3$.

### 3.3 Experimental Mating Plan

The design of the mating plan is presented in Table 3.1. Sire of each line were divided into two genotypes of similar ages. Does of New Zealand White (Hyla.NG) rabbits were mated to bucks of New Zealand White (Hyla.GPC) to obtain purebreds. Does of New Zealand White (Hyla.NG) were also mated to bucks of Californian (Hyla.MAX) to obtain crossbreds. The mating plan permitted the simultaneous production of two genetic groups. Distribution of breeding does and their sires as well as number of litters of the two genetic groups are presented in Tables 3.1 and 3.2 respectively. According to the mating plan, bucks were assigned at random to mate the does with a restriction to avoid full-sib, half-sib mating and parent-offspring mating.

**Table 3.1: Mating Plan for Crossing of Hyla Rabbits.**

| | Dam breed |
|---|---|
| Sire breeds | New Zealand White (Hyla.NG) |
| ♂NZW (Hyla.GPC) | ♂ NZW x NZW ♀ (Purebred) |
| ♂CAW (Hyla.MAX) | ♂ CAW x NZW ♀ (Crossbred) |

NZW-New Zealand White; CAW- Californian rabbits

**Table 3.2 : Number of Kittens obtained from each cross**

| Type of cross | Mating type | No. of buck | No. of dam | No.of progeny |
|---|---|---|---|---|
| Purecross | ♂NZW x ♀NZW | 11 | 27 | 205 |
| Maincross | ♂NZW x ♀CAW | 11 | 28 | 192 |

NZW-New Zealand White; CAW- Californian rabbits

## 3.4 DATA COLLECTION

### 3.4.1 Meteorological Data of the Rabbitry Microclimate.

The dry – bulb temperature and relative humidity readings of the rabbit microclimate were recorded at 08:00 h every morning and 14.00 h evening during the study period. The ambient temperature and RH were measured from the readings of wet– and dry–bulb thermometer (Cocet, Shenzhen=Guangdong, China) which was used to compute the temperature humidity index. Environmental readings such as Ambient Temperature (AT) and Relative Humidity (RH) of the rabbitry micro-climate were taken daily from February through November, 2011. Readings were estimated with the following procedures.

### 3.4.2 Thermoregulatory Parameters Measurement

A total of 106 grand-parents, 104 $F_1$ progeny of Hyla rabbits and 20 non-descript local rabbits were used for the physiological evaluation. Parameters measured were Respiratory Rate (RR), Heart Rate (HR), Rectal Temperature (RT) and Ear Temperature (ET). Measurements were taken at 08.00 to 10.00h and 14.00h to 16.00h of the day Bi-monthly measurements for hot and cool periods of the season was taken. Rectal and Ear Temperature were measured with a digital thermometer. The ear temperature was measured by placing the digital thermometer in direct contact with the central area of the auricle. RR was measured by visually counting the flank movement for one minute. HR was measured using a stethoscope. Sexual differences in thermoregulatory response were evaluated for both Hyla and non descript young rabbits.

The temperature-humidity index (THI), an indicator of thermal comfort level for animals in an enclosure was calculated according to LPHSI (1990) which was modified for rabbit by Marai *et al*. (2001) and given as:

$$THI = t - [(0.31 – 0.31 \times RH) (t – 14.4)]$$

Where RH = relative humidity /100. t = ambient temperature. The values of THI obtained for the temperate and tropical region are classified as: <27.8 $^{o}$C = absence of heat stress, 27.8 - 28.9 $^{o}$C = moderate heat stress, 28.9 – 30 $^{o}$C = severe heat stress and above 30 $^{o}$C = very severe heat stress (Marai *et al*., 2001).

### 3.4.3 Adaptability Estimation

Tolerance values of Hyla and local nondescript rabbits were estimated as deviations in their physiological studied traits due to heat stress and expressed as a proportion of normal values. Deviations in the studied traits due to heat stress (regardless of minus or plus sign) relative to normal values (those in the hot conditions) and expressed as a proportion of normal values were used to detect adaptability to hot climate conditions.

Adaptability index = 1 – average relative deviations in all the traits studied (Marai *et al*., 2001).

## 3.5 Breeding Data Estimation

The data generated for this study included 205 purebred kits (Hyla.NG X Hyla.GPC) and 192 crossbred kits (Hyla.NG X Hyla.MAX). A total of 397 offspring were born from June to January 2012. There were three parities. Litter birth and weaning traits investigated included litter size at birth and weaning (No), litter weight at birth and weaning (g), gestation length (days) and pre-weaning mortality (%).

### 3.5.1 Reproductive Traits

1. Gestation Length (GL): Taken in days as the difference between the date of kindling and the date at which successful mating occurred.

2. Litter Size at Birth (LSB): This is the number of kits the doe kindles at birth.
3. Litter Birth Weight (LBW): This is the weight of the kits at birth. Measurement was taken in grams (g), using a digital scale (Mettler Toledo, Top Pan Sensitive Balance, J. Liang Int. Ltd. U.K.
4. Pre-weaning mortality (%): Litter size at birth (alive) – litter size at weaning/ Litter size at birth (alive) x 100.

### 3.5.2 Weaning Traits

The weaning traits measured include:

1. Litter Size at weaning (LSW): Taken by actual count of weaners alive at weaning.
2. Litter Weight at weaning (LWW): Weight of litters taken in g at weaning.

## 3.6 GROWTH TRAITS

Body weight was taken by digital weighing scale (Mettler Toledo, Top Pan Sensitive Balance, J. Liang Int. Ltd. U.K.). The measurements were taken while the animals were held in a standing position. Measurement was taken in Kg for grandparent and g for the $F_1$ Hyla rabbits.

### 3.6. 1 Linear Body Measurements

Measurements were taken at eight weeks. Ten (10) biometric traits were measured on each animal. The anatomical reference points were in accordance with standard zoometrical procedures (Gueye *et al*., 1998; Teguia *et al*., 2008). The body components measured were:

Body length (BL): diagonal distance from the points of shoulder to points of hip or first thoracic vertebrae to base of tail or to hip bone. This is also described as the distance between the most

cranial palpable spinosus process of the thoracic vertebrae and either sciatic tubers or distance between the tops of the pelvic bone.

Ear length (EL): measured from the ear base to the zygomatic arch of the ear using a tailor's tape measure.

Tail length (TL): measured from the base of the tail to the tip (Coccygeal vertebrae) using a tailor's tape measure.

Heart girth (HG): This refers to the body circumference and was measured just behind the fore-legs using a tailor's tape measure.

Nose to shoulder (HS): Is the distance from nose to the point of the shoulder and was measured using a tailor's tape measure.

Shoulder to tail-drop (STT): This is the distance from the point of the shoulder to the pin bone (otherwise called Coccygeal vertebrae) and was measured using a tailor's tape measure.

Height at withers: This was taken using a graduated measuring stick.

Thigh circumference: This refers to the circumference of the thigh and was measured using a tailor's tape measure.

Length of front and back leg (LFL and LBL): This is the length of front and back legs and was measured using a tailor's tape measure.

All linear biometric traits are measured in centimeter.

### 3.7 Statistical Analysis

Growth and reproductive data were subjected to GLM procedure of Statistical Analysis Software (SAS 9.0, 1993) package. Significant differences in means were seperated using pairwise-

difference (P-DIFF SAS 9.0, 1993). The factor programme of Superior Performing Statistical Software (SPSS, 2009, version 19.0, SPSS Inc, New York) was used for the principal component modelling.

Data on bodyweight of the $F_1$ was used to estimate heritability, repeatability, genetic and phenotypic correlations at different pre-weaning ages using Harvey's (1990) LSMLMW program (Least Square Maximum Likelihood and Mean Weight Procedure).

**3.7.1** *Correlation and Regression Analysis*

The degree of association between all pairs of biometric variables was computed for the two genotypes of Hyla rabbits using linear correlation. SASCORR and SAS REG procedure of SAS 9.0 (1993) package were used.

**3.7.2** *Principal Component Analysis Procedures*

The correlation coefficients of body weight and the linear body measurements were also determined. From the correlation matrix, data for the principal component factor analysis were generated. According to Everitt *et al.* (2001), principal component analysis is a method for transforming the variables in a multivariate data set $x_1$, $x_2$, ---, xp, into new variables, $y_1$, $y_2$,---, yp which are uncorrelated with each other and account for decreasing proportions of the total variance of the original variables defined as:

$$y_1 = a_{11}\, x_1 + a_{12}\, x_2 + \text{----------} + a_{1p}\, x_p$$

$$y_2 = a_2\, x_1 + a_{22}\, x_2 + \text{----------} + a_{2p}\, x_p$$

$$y_p = a_{p1}\, x_1 + a_{p2}\, x_2 + \text{----------} + a_{pp}\, x_p$$

with the coefficients being chosen so that $y_1$, $y_2$, ------, $y_p$ account for decreasing proportions of the total variance of the original variables, $x_1$, $x_2$, ------, $x_p$.

or in matrix form:

$$Y_1 = a'x$$

The $a_{ji}$ are scaled such that $a_1'a_1=1$. $Y_1$ accounts for the maximum variability of the p variables of any linear combinations. The variance of $Y_1$ is $\lambda_1$. The next, principal component $Y_1$ is formed such that its variance, $\lambda_2$ is the maximum amount of the remaining variance and that it is orthogonal to the first principal component. That is,

$$a_i'a_2 = 0$$

Components are extracted until some stopping criteria is encountered or until p components are formed. The weights used to create the principal components are the eigenvectors of the characteristics equation:

$$(R- \lambda_1 I)a = 0$$

Where R is the correlation matrix. The $\lambda_1$ are the eigenvalues, the variances of the components. The eigenvalues are obtained by solving $(R- \lambda_1 I)a = 0$ for $\lambda_1$.

During the evaluation, factors were rotated with varimax rotation of Kaiser. The aim of the Varimax rotation is to maximize the sum of variances of $a_{ij}^2$ quadratic weight. Anti-image correlations, Kaiser – Meyer Olkin measures of sampling adequacy and Barlett's Test of Sphericity were computed to test the validity of the factor analysis of the data sets. The appropriateness of the factor analysis was further tested using communualities and ratio of cases to variables.

The stepwise variable selection multiple regression procedure was used to obtain models for predicting body weight from body measurements (a) and from established principal components (b).

$$BW = a + B_i x_i + \text{---------} Bk x k \text{----------(a)}$$

$$BW = a + B_iPC_i + \text{-------- } BkPCk \text{ ---------- (b)}$$

where; BW is the body weight, a is the regression intercept, $B_1$ is the i-th partial regression coefficient of the ith linear body measurement, $X_i$ represents independent variables (i.e body measurements) or $PC_i$ represents the i-th principal component and k represents infinity.

*Physiological Parameter Estimates*

$Y_{ijkl} = \mu + B_i + S_J + C_K + e_{ijk}$

Where:

$Y_{ijkl}$ = observation on the $i^{th}$ animals

$\mu$ = overall population mean;

$B_i$ = effect of the $i_{th}$ breed

$S_J$ = fixed effect of the $j_{th}$ sex

$C_K$ = fixed effect of the $k_{th}$ circadian rhythm

$e_{ijk}$ = random effect associated with the record of the $i^{th}$ animal group

*Genetic Parameter Estimates*

The design of the experiment is of Nested type (Henderson, 1963), in which a sire was mated to several dams with each mating producing several offspring. The model equation for the trial was a one way nested classification based on sires within lines as shown below:

$Y_{ijkl} = \mu + S_i + e_{ijk}$

Where:

$Y_{ijkl}$ = observation on the $i^{th}$ sire

$\mu$ = overall population mean;

$L_i$ = effect of the $i^{th}$ sire

$e_{ijk}$ = random effect associated with the record of the $i^{th}$ animal group

Where parity was found to have a significant effect, the data were transformed by adding or subtracting the Least Square constants according to Harvey (1990) method.

Heritability of pre-weaning growth at different ages due to sire model was then obtained using the standard expression given by Becker (1992) as follows:

$$h^2 = \frac{4\sigma_s^2}{\sigma_T^2}$$

$h^2$ = heritability estimate (broad sense)

$\sigma_S^2$ = variance due to sire

$\sigma_T^2$ = total variance

Repeatability estimates was obtained using the following formula:

$$R = \frac{\sigma_I^2}{\sigma_I^2 + \sigma_e^2}$$

Where $\sigma^2_I$ = fixed effect of each animal and $\sigma^2_e$ = within individual records variance.

Standard error of repeatability was expressed as stated by Becker, (1992).

$$S.E.(R) = \frac{2(1-R)^2[1+(K-1)R]^2}{K(K-1)(N-1)}$$

Where K is the number of records taken on each individual, n is the number of individuals and R is the estimated repeatability of a trait.

**Genetic and Phenotypic Correlations**

The genetic and phenotypic correlations amongst the individual kit weight at various ages (birth, 7, 14, 21, 28 and 35 days) were obtained by using the Harvey (1990) method.

# CHAPTER FOUR

## 4.0 RESULTS

## 4.1 TEMPERATURE HUMIDITY INDEX (THI)

The monthly temperature humidity index (THI) inside the rabbitry during the experimental period is shown in Figure 1. THI in the mornings averaged 24.2 $^{o}$C while the evenings THI averaged 27.8 $^{o}$C. The THI values estimated averaged 27.3 $^{o}$C during the cool period and 28.7 $^{o}$C during the hot period. Overall, the results obtained indicated that THI in the evening was higher ($P < 0.05$) by 14 % than THI in the morning. Also, THI in the hot was higher ($P < 0.05$) than THI in the cool season by 5 %.

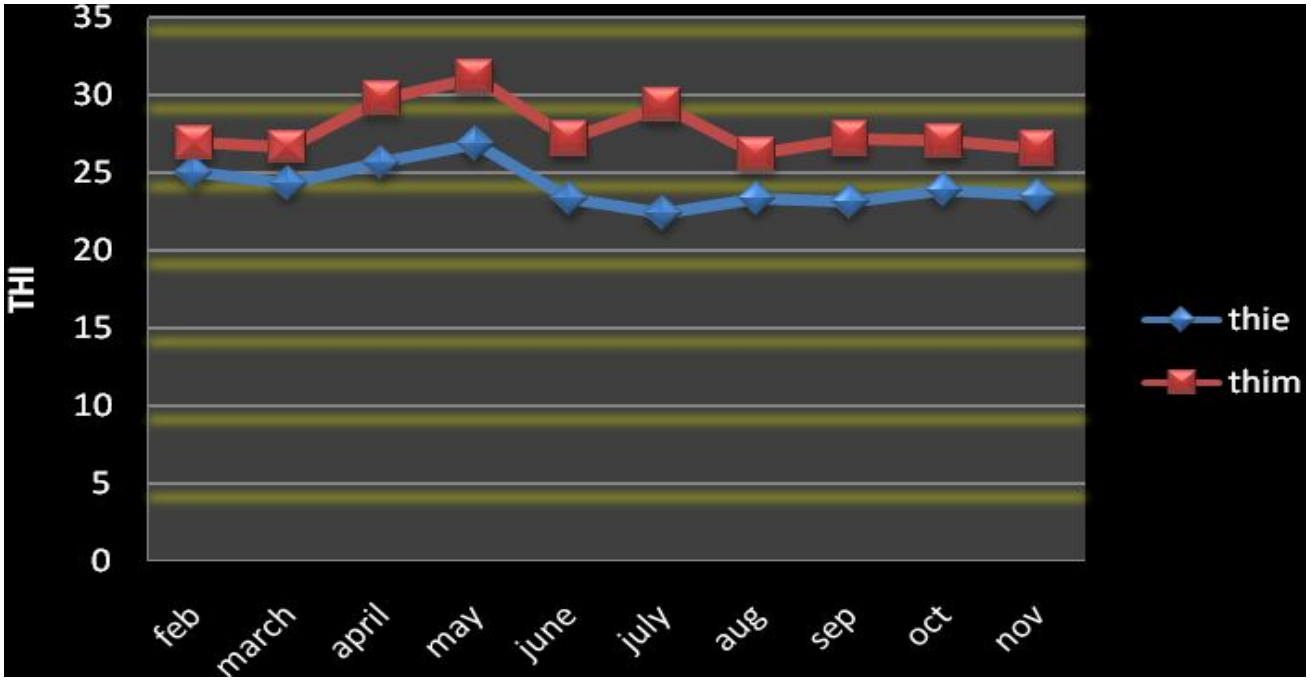



Figure 1: Monthly Temperature Humidity Index inside the Rabbitry during the Experimental Period. thie- Temperature-humidity index evening, Thim- Temperature-humidity index morning, THI-Temperature Humidity Index.

### 4.1.1 Thermoregulatory Response of Hyla Grand-Parent and Old Non Descript Rabbits

Table 4.1 shows the least squares means (± standard error) of thermoregulatory parameters measured during hot and cool periods based on grand-parent hyla and non-descript old rabbits. Breed had significant ($P < 0.05$) effect on the thermoregulatory parameters. HNZW had the highest value for respiratory rate (RR) and heart rate (HR) for both hot (137.10 ± 1.67 breadths/min and 139.21 ± 1.91 beats/min) and cool (104.90 ± 1.35 breadths/min and 114.50 ± 2.37 beats/min) periods. Hyla California (HCAW) recorded the highest value for rectal temperature (39.49 ± 0.06 and 39.27 ± 0.06 $^{o}$C) during the hot and cool periods. Old non descript (OND) recorded the least value in all the parameters for both hot and cool periods.

Table 4.1: Thermoregulatory Parameters (Means±SE) of Grand Parent and Non Descript Rabbits as Affected by Breed During the Hot and Cool Periods.

| | Hot | | | Cool | | |
|---|---|---|---|---|---|---|
| Breed | RR(br.p.m) | HR(b.p.m) | RT($^{o}$C) | RR(br.p.m) | HR(b.p.m) | RT($^{o}$C) |
| HNZW | 137.10±1.67$^{a}$ | 139.21±1.91$^{a}$ | 39.45±0.07$^{b}$ | 104.90±1.35$^{a}$ | 114.50±2.37$^{a}$ | 39.05±0.03$^{b}$ |
| HCAW | 123.60±2.61$^{b}$ | 119.48±2.43$^{b}$ | 39.49±0.06$^{a}$ | 103.80±0.90$^{b}$ | 111.50±2.20$^{b}$ | 39.27±0.06$^{a}$ |
| OND | 104.96±6.36$^{c}$ | 110.57±3.74$^{c}$ | 39.12±0.09$^{c}$ | 99.20±2.23$^{c}$ | 104.00±1.38$^{c}$ | 38.62±0.12$^{c}$ |
| SED | 1.77 | 1.35 | 0.02 | 0.04 | 0.99 | 0.03 |
| LOS | ** | ** | * | * | ** | * |

$^{abc}$Means within the same column having the same superscript are not significantly(P>0.05; 0.01) different
HNZW- Hyla New Zealand; HCAW- Hyla Californian; SED= Standard error of difference; OND- Old non-descript; RR-Respiratory rate; HR=Heart rate; RT- Rectal temperature; LOS- Level of significance. br.p.m- breadths per minute; b.p.m – beat per minutes; $^{o}$C – degree Celsius.

### 4.1.2 Thermoregulatory Responses of Hyla $F_1$ progeny and Grower Non Descript Rabbits

The least squares means (± standard error) of thermoregulatory parameters of Hyla $F_1$ progeny and grower non-descript local rabbits based on breed differences during the hot and cool periods are shown in Table 4.2. Breed had significant ($P < 0.05$) effect on respiratory rate (RR) and heart rate (HR) but rectal temperature (RT) and ear temperature (ET) were not significantly ($P > 0.05$) affected during the hot period. However, during the cool period RR, HR and ET were significantly ($P < 0.05$) affected by breed but RT was not significantly ($P > 0.05$) affected. Hyla New Zealand (HNP) recorded the highest value for RR (109.31 ± 1.48 breadths/min), RT (39.02 ± 0.09 $^{o}$C) and ET (36.88 ± 0.09 $^{o}$C) except for HR (109.75 ± 1.72 beats/min) which showed an intermediate value during the hot period. During the cool period, HNP had the highest values for RR (88.37 ± 1.38 breadths/min) and ET (35.65 ± 0.13 $^{o}$C). New Zealand x Californian crossbred (NCP) recorded the highest value for HR (105.78 ± 1.84 beats/min) and RT (39.07 ± 0.04 $^{o}$C). The least values for all the parameters studied were recorded in grower non descript (GND), except for RR (105.16±1.79 beats/min) in the hot period and HR (breadths/min) during the cool period which showed an intermediate values.

Table 4.2: Thermoregulatory Parameters (Means±S.E.) of Hyla $F_1$ Progeny and Grower Non Descript Rabbits as Affected by Breed

| | Hot | | | | Cool | | | |
|---|---|---|---|---|---|---|---|---|
| Breed | RR(br.p.m) | HR(b.p.m) | RT($^o$C) | ET ($^o$C) | RR(br.p.m) | HR(b.p.m) | RT($^o$C) | ET ($^o$C) |
| HNP | 109.31±1.48$^a$ | 109.75±1.72$^b$ | 39.02±0.09 | 36.88±0.09 | 88.37±1.38$^a$ | 100.50±1.09$^c$ | 38.95±0.05 | 35.65±0.13$^a$ |
| NCP | 105.16±1.79$^c$ | 112.88±2.81$^a$ | 38.97±0.08 | 36.87±0.16 | 87.97±2.38$^b$ | 105.78±1.84$^a$ | 39.07±0.04 | 35.16±0.18$^{ab}$ |
| GND | 107.92±2.66$^b$ | 103.08±4.65$^c$ | 38.93±0.17 | 36.73±0.25 | 79.67±2.89$^c$ | 101.67±2.99$^b$ | 38.84±0.10 | 34.61±0.37$^b$ |
| SED | 0.99 | 0.53 | 0.05 | 0.08 | 0.02 | 0.50 | 0.29 | 0.01 |
| LOS | * | * | NS | NS | * | * | NS | * |

$^{abc}$Means within the same column having the same superscript are not significantly(P>0.05) different
SED= Standard error of difference; RR-Respiratory rate; HR= Heart rate; RT- Rectal temperature; HNP= Hyla purebred, NCP = Hyla crossbred. GND-Grower non-descript, NS-non-significant, br.p.m- breadths per minute; b.p.m – beat per minutes; $^o$C – degree Celsius.

4.1.2.1 *Circadian Rhythm*

The dynamics of thermoregulatory parameters of Hyla $F_1$ progeny and grower non-descript rabbits as affected by circadian rhythm are shown in Table 4.3. Except for the heart rate (HR), all other parameters such as respiratory rate, rectal temperature and ear temperature (RR, RT and ET) were significantly ($P < 0.05$) affected by circadian rhythm. The values for RR, HR, RT and ET recorded at 14.00 h were higher than values recorded at 08.00 h of the day.

Table 4.3: Thermoregulatory Parameters as affected by Circadian Rhythm for $F_1$ Progeny and grower Non Descript Rabbits

| Genotypes | H | RR (br.p.m) | HR (b.p.m) | RT ($^oC$) | ET ($^oC$) |
|---|---|---|---|---|---|
| HNP | 8.0 | 96.33± 1.58$^b$ | 104.63±1.32 | 38.87 ± 0.06$^b$ | 36.03 ± 0.11$^b$ |
| | 16.0 | 101.33±1.71$^a$ | 105.63±1.19 | 39.10 ± 0.04$^a$ | 36.51 ± 0.11$^a$ |
| NCP | 8.0 | 94.13±2.17$^b$ | 107.63±2.89 | 38.78 ± 0.09$^b$ | 35.33 ± 0.43$^b$ |
| | 16.0 | 99 ±2.18$^a$ | 111.03±1.59 | 39.18 ± 0.04$^a$ | 36.31 ± 0.18$^a$ |
| GND | 8.0 | 90.17±4.33$^b$ | 107.17±3.25 | 38.78 ± 0.09$^b$ | 35.33 ± 0.43$^b$ |
| | 16.0 | 97.42±5.04$^a$ | 107.58±3.39 | 39.00 ±0.10$^a$ | 36.00 ± 0.35$^a$ |

$^{abc}$Means within the same column having the same letter are not significantly($P>0.05$) different. GND – Grower non descript rabbits. RR-Respiratory rate; HR= Heart rate; RT- Rectal temperature; ET- Ear temperature,. HNP= Hyla purebred; NCP = Hyla crossbred; br.p.m- breadths per minute; b.p.m – beat per minutes; $^oC$ – degree Celsius. H- Hour

4.1.2.2 *Sexual Dimorphism*

The effect of sex on thermoregulatory parameters of Hyla $F_1$ progeny are shown in Table 4.4. The heart rate (HR), rectal temperature (RT) and ear temperature (ET) were not significantly ($P > 0.05$) affected by sex. Sex had a significant ($P < 0.05$) effect only on respiratory rate (RR). The female recorded the highest RR (102.67 ± 2.03 breadths/min) while the non descript grower male had the least RR (96.54 ± 0.69 breadths/min).

Table 4.4: Thermoregulatory Responses of Hyla $F_1$ Progeny and Non Descript Grower Rabbits as Affected by Sex

| Sex | RR(br.p.m) | HR(b.p.m) | RT($^{o}$C) | ET($^{o}$C) |
|---|---|---|---|---|
| HP.Male | 98.77 ± 1.62[b] | 106.11 ± 1.33 | 39.15 ± 0.04 | 36.51 ± 0.04 |
| HP.Female | 102.67 ± 2.03[a] | 106.51 ± 1.81 | 39.08 ± 0.04 | 36.51 ± 0.12 |
| HC.Male | 98.22 ± 0.19[b] | 106.00 ± 0.29 | 39.27± 0.01 | 35.89±0.07 |
| HC. Female | 100.12 ± 0.20[a] | 105.00 ± 1.25 | 39.16±0.10 | 36.09±0.06 |
| ND. Male | 96.54 ± 0.69[bc] | 105.88 ± 2.38 | 39.00 ± 0.02 | 36.00± 0.19 |
| ND. Female | 97.88 ± 1.04[b] | 104.96 ± 1.06 | 39.12 ± 0.07 | 36.12 ± 0.20 |
| SED | 0.91 | 0.78 | 0.04 | 0.04 |

[abc]Means within the same column having the same letter are not significantly(P>0.05) different. RR-Respiration rate; HR – Heart rate; RT- Rectal temperature; ET – Ear temperature; br.p.m – breadth per minute; b.p.m – beats per minute.SED- Standard error of difference. HP – Hyla purebred, HC-Hyla crossbred, ND- Non descript

4.1.2.3 *Adaptability Indices*

The average relative deviation and adaptability values estimated for different genotype of rabbits during the adaptation study are shown in Table 4.5. The average relative values (0.63, 0.64 and 0.61) for the grand- parent Hyla and old non-descript rabbits (HNZW, HCAW and OND) were slightly lower compared to the values (0.66, 0.67 and 0.65) recorded for Hyla $F_1$ progeny and grower non-descript rabbits (HNP, NCP and GND). Similarly, adaptability estimates for the grand- parent Hyla and old non-descript rabbits (HNZW, HCAW and OND) were 0.37, 0.36 and 0.39. Estimates of adaptability for Hyla $F_1$ progeny and young grower non-descript rabbits (HNP, NCP and GND) were 0.34, 0.33 and 0.35. Adaptability was numerically higher in grand-parent Hyla rabbits and non-descript old rabbits compared to the Hyla $F_1$ progeny and grower non-descript rabbits.

Table 4.5: Adaptability Indices of Hyla and Non Descript Rabbits under Tropical Conditions

| | Genotypes | | | | | |
|---|---|---|---|---|---|---|
| ESTIMATES | HNZW | HCAW | OND | HNP | NCP | GND |
| ARD | 0.63 | 0.64 | 0.61 | 0.66 | 0.67 | 0.65 |
| Adaptability Index | 0.37 | 0.36 | 0.39 | 0.34 | 0.33 | 0.35 |

OND= Old non descript; HNP= Hyla purebred; NCP = Hyla crossbred, GND- grower non descript; Ard: Average relative deviation; HNZW- Hyla New Zealand; HCAW- Hyla Californian

## 4.3 GROWTH AND REPRODUCTIVE PERFORMANCE OF HYLA RABBITS

### 4.3.1 Growth Performance of Hyla Grand-Parent Rabbits

The effect of breed on body weight recorded at different ages in Hyla grand-parent rabbits are shown in Table 4.6. Breed effect had a significant ($P < 0.05$) effect on all the ages studied in grand-parent Hyla rabbits. The results obtained showed that average bodyweight were significantly ($P < 0.05$) higher in Hyla.MAX at age 10 through 27 weeks old compare to Hyla.GPC and Hyla.NG. However, at age 32 weeks, average bodyweight of Hyla.NG ($5.00 \pm 0.10$ Kg) was superior to the average bodyweight of the two male lines (Hyla.MAX and Hyla.GPC) which recorded values of $4.95 \pm 0.10$ and $4.65 \pm 0.08$ Kg, although no significant difference ($P > 0.05$) was observed between Hyla.NG and Hyla.MAX.

Table 4.6: Least Squares Means ± S.E of Bodyweight Measurement of Grand-Parent Hyla Rabbits by Breed

| | Age of rabbits (weeks) | | | |
|---|---|---|---|---|
| | 10 | 17 | 27 | 32 |
| Hyla.NG | 2.78± 0.03[b] | 3.59±0.03[b] | 4.51 ± 0.05[b] | 5.00±0.10[a] |
| Hyla.Max | 3.23 ±0.09[a] | 3.98±0.07[a] | 4.68±0.09[a] | 4.95±0.10[a] |
| Hyla.GPC | 2.30 ±0.04[c] | 3.25±0.06[c] | 4.07±0.07[c] | 4.61±0.08[b] |
| SED | 0.02 | 0.03 | 0.04 | 0.04 |

[abc]Means within the same column having the same superscript are not significantly(P>0.05) different
Hyla.NG- New Zealand Hyla female line; Hyla.GPC – New Zealand Hyla male line; Hyla.MAX- California Hyla male line. SED- Standard Error of Difference

### 4.3.2 Growth Performance of Hyla $F_1$ Progeny Rabbits

The effects of breed and sex on post-weaning body weight recorded at different ages (8, 10 and 12 weeks) in Hyla parent rabbits are shown in Table 4.7. Breed and sex effects were significant ($P < 0.05$) on post-weaning body weight studied ($BW_8$, $BW_{10}$ and $BW_{12}$) in Hyla rabbits. The result obtained from this study showed that Hyla crossbred rabbits were significantly ($P < 0.05$) heavier compared to purebred Hyla rabbits at all ages. Hyla crossbred male had the highest value (1314.57 ± 38.57 g) for $BW_8$ while the least value (1247 ± 42.09 g) were obtained in the female purebred Hyla rabbits. Crossbred male had the highest value (1771.52 ± 51.45 g) at ten weeks, while the male purebred showed the least value (1601.02 ± 59.91 g). Finally, at week 12, the female Hyla crossbred had the highest value (2232.88 ± 106.52 g), while the least value were observed in male purebred Hyla rabbits (1980.93 ± 95.11 g).

Table 4.7: Least Squares Means ± (S.E) of Post Weaning Growth of $F_1$ Progeny Hyla Rabbits by Breed and Sex from 8 to 12 weeks

| | Age of rabbits | | |
|---|---|---|---|
| Genotypes | 8 | 10 | 12 |
| Male (Pure) | 1297.05±37.50[a] | 1601.02±59.91[bc] | 1980.93±95.11[bc] |
| Male (Cross) | 1314.57±38.57[a] | 1771.52±51.45[a] | 2097.52±104.03[b] |
| Female (Pure) | 1247.59±42.09[c] | 1662.66±58.84[b] | 1934.83±115.55[c] |
| Female (Cross) | 1288.39±54.71[b] | 1743.67±79.78[a] | 2232.88±106.52[a] |
| SED | 10.81 | 31.25 | 17.67 |

[abc]Means within the same column having the same superscript are not significantly(P>0.05) different
Pure-Hyla.Gpc X Hyla.Ng (NZW X NZW); Cross- Hyla.Max X Hyla.Ng (NZWXCAW); SED-Standard Error of Difference

### 4.3.3 Reproductive Performance at Pre-weaning Ages

The least squares means (±) S.E for litter traits at pre-weaning ages (birth through 35 days) are shown in Table 4.8. The results showed that values obtained for litter size and weight at different ages were significantly ($P < 0.05$) higher in purebred than the crossbred Hyla rabbits. However values obtained for individual kit weight were significantly ($P < 0.05$) higher in crossbred compared to the purebred Hyla rabbits. Litter size ranged between 6.51 ± 0.47 – 3.46 ± 0.32 and 6.24 ± 0.63 – 2.79 ± 0.38 in purebred and crossbred Hyla rabbits respectively, from birth through weaning. Litter weight ranged between 331.49 ± 27.21 g – 2454.86 ± 177.85 g and 321.91 ± 36.02 g – 2168.44 ± 279.40 g in purebred and crossbred Hyla rabbits respectively, from birth through weaning. Individual kit weight ranged between 57.97 ± 1.41 g – 744.94 ± 16.64 g and 59.66 ± 0.92 g – 752.71 ± 20.23 g in purebred and crossbred Hyla rabbits respectively, from birth through weaning.

Table 4.8: Least Square Means ± S.E for Reproductive and Growth Traits from Birth to 35 days

| | NZWXNZW (Hyla purebred) | | | | | | NZWXCAW (Hyla Crossbred) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Trait | Birth | 7 | 14 | 21 | 28 | 35 | Birth | 7 | 14 | 21 | 28 | 35 |
| N | 205 | 195 | 172 | 160 | 147 | 142 | 192 | 180 | 171 | 157 | 126 | 98 |
| LS | 6.51 ±0.47[a] | 5.41 ±0.41[a] | 5.00 ±0.37[a] | 4.65 ±0.39[a] | 4.16 ±0.37[a] | 3.46 ±0.32[a] | 6.24 ±0.63[b] | 5.06 ±0.58[b] | 4.59 ±0.48[b] | 4.21 ±0.45[b] | 3.58 ±0.43[b] | 2.79 ±0.38[b] |
| LW | 331.49 ±27.21[a] | 736.11 ±55.85[a] | 1331.60 ±101.21[a] | 1943.00 ±150.31[a] | 2454.86 ±177.85[a] | 2629.70 ±201.32[a] | 321.91 ±36.02[b] | 706.74 ±72.46[b] | 1266.65 ±135.50[b] | 1876.80 ±195.4[b] | 2137.97 ±256.82[b] | 2168.44 ±279.40[b] |
| IKW | 57.97 ±1.41[b] | 138.14 ±2.12[b] | 269.25 ±5.26[b] | 420.43 ±8.17[b] | 585.50 ±11.54[b] | 744.94 ±16.64[b] | 59.66 ±0.92[a] | 139.39 ±3.20[a] | 275.25 ±4.67[a] | 429.98 ±9.57[a] | 595.63 ±14.41[a] | 752.71 ±20.23[a] |

[abc]Means betweenthe same row having the same superscript are not significantly(P>0.05) different
NZW- New Zealand; CAW-Californian; LW-Litter weight; LS-Litter size; N-Number; IKW-Individual kit weight.

### 4.3.4 Parity

The least squares means (±) S.E for doe traits as affected by different parity in Hyla purebred and crossbred was shown in Table 4.9. Litter size at birth (LSB), Litter size at 35 days (LS35), Litter weight at birth (LWB), Litter weight at 35 days (LW35) and pre-weaning mortality (PWM) were significant ($P < 0.05$) at different parity, except for gestation length (GL) which was not significant ($P > 0.05$) for Hyla purebred. Parity 3 had the highest values for LSB (8.67 ± 1.86), LS35 (4.49 ±1.22), LWB (619.67 ± 97.64 g), LW35 (4801.56 ± 1022.73 g) and GL (31.37 ± 0.80), except for PWM which recorded the highest value (75.13 ± 8.23 %) at second parity for Hyla purebred. Hyla crossbred showed significant ($P < 0.05$) different for LSB, LS35, LWB, LW35 and PWM, though non significant ($P > 0.05$) different was obtained for GL. The third parity recorded the highest value for LSB, LWB, LS35, LW35 and GL, except for PWM which showed its highest value (51.00 ± 2.26 %) at parity one.

Table 4.9: Least Squares Means (± S.E) of Doe Traits as Affected by Different Parity in Hyla Purebred and Crossbred Rabbits

| Parity | LSB | LS35 | LWB | LW35 | GL | PWM |
|---|---|---|---|---|---|---|
| Pure | | | | | | |
| 1 | 6.10 ± 0.46$^{c}$ | 3.03± 0.30$^{c}$ | 282.69 ± 24.10$^{c}$ | 2730.52± 252.49$^{c}$ | 30.57 ± 0.20 | 63.72 ± 4.96$^{b}$ |
| 2 | 7.06 ± 0.76$^{b}$ | 3.72±0.50$^{b}$ | 415.83± 40.02$^{b}$ | 3500.26± 419.20$^{b}$ | 30.97 ± 0.33 | 75.13± 8.23$^{a}$ |
| 3 | 8.67 ± 1.86$^{a}$ | 4.49±1.22$^{a}$ | 619.67± 97.64$^{a}$ | 4801.56±1022.73$^{a}$ | 31.37 ± 0.80 | 54.63± 20.08$^{c}$ |
| Cross | | | | | | |
| 1 | 5.98 ± 1.20$^{c}$ | 2.86 ± 0.40$^{c}$ | 265.26 ± 10.28$^{c}$ | 2600.29 ± 250.46$^{c}$ | 30.00 ± 0.09 | 51.00 ± 2.26$^{ab}$ |
| 2 | 6.45 ± 0.49$^{b}$ | 3.59 ± 0.12$^{b}$ | 352.28 ± 50.26$^{b}$ | 3320.12 ± 192.34$^{b}$ | 30.27 ± 0.04 | 50.00 ± 0.58$^{ab}$ |
| 3 | 8.60 ± 0.36$^{a}$ | 4.37 ± 0.06$^{a}$ | 600.46 ± 62.29$^{a}$ | 4709.20 ± 923.45$^{a}$ | 30.98 ± 0.26 | 42.00 ± 0.76$^{a}$ |

$^{abc}$Means within the same column having the same superscript are not significantly($P>0.05$) different
LSB- Litter size at birth; LWB- Litter weight at birth; GL- Gestation length; PWM- Pre-weaning mortality

## 4.4 GENETIC PARAMETER

### 4.4.1 Heritability Estimates for Pre-Weaning Growth Traits

Table 4.10 shows the genetic parameter estimates for the pre-weaning growth parameters. Moderate to high heritability estimates (0.39 ± 0.29 to 1.3 ± 0.44) were obtained from sire variance component ($h^2_S$ ± S.E) in Hyla purebred rabbits at birth through 35 days of age. The lowest $h^2_S$ value was recorded at 7 days while the highest value was recorded at 28 days.

### 4.4.2 Repeatability Estimates for Pre-Weaning Growth Traits

The estimates obtained for Hyla purebreds from birth through 35 days are given in Table 4.10. The values ranged from 0.21 ± 0.002 to 0.77 ± 0.002. Estimates at birth showed the highest value (R = 0.77 ± 0.002), while the least value was obtained at 7 days of age (R = 0.21 ± 0.002).

### 4.4.3 Genetic and Phenotypic Correlations for Pre-Weaning Growth Traits

The result of genetic and phenotypic correlations for pre-weaning growth traits from birth through 35 days obtained in this study are presented in Table 4.10. Moderate to high phenotypic correlations (0.28 and 1.00) were obtained among pre-weaning traits. Low to high genetic correlations (0.09 and 0.87) were obtained for these traits.

Table 4.10: Heritabilities and Repeatabilities (1st and 2nd column), Genetic (below diagonal), Phenotypic Correlations (above the diagonal) of pre-weaning kit weight for $F_1$ progeny purebreds

| TRAITS | R | $h^2$ | BW | IK7days | IK14days | IK21days | IK28days | IK35days |
|---|---|---|---|---|---|---|---|---|
| BW | 0.77±0.002 | 0.53±0.32 | | 0.61 | 0.60 | 0.28 | 0.40 | 0.71 |
| IK7 | 0.21±0.002 | 0.39±0.29 | 0.79 | | 0.30 | 0.36 | 0.54 | 0.71 |
| IK14 | 0.25±0.003 | 0.64±0.35 | 0.63 | 0.67 | | 0.67 | 0.63 | 0.75 |
| IK21 | 0.43±0.003 | 0.99±0.41 | 0.39 | 0.42 | 0.69 | | 1.00 | 0.96 |
| IK28 | 0.36±0.002 | 1.30±0.44 | 0.20 | 0.25 | 0.51 | 0.85 | | 0.91 |
| IK35 | 0.33±0.003 | 0.89±0.39 | 0.09 | 0.15 | 0.37 | 0.68 | 0.87 | |

R- Repeatability, $h^2$ – Heritability, BW- Birth weight IK- Individual kit weight

## 4.5 BODYWEIGHT AND LINEAR BODY MEASUREMENT

### 4.5.1 Least Squares Means (± S.E) for Bodyweight and Biometric Traits

Least Squares Means (± S.E) of body weight and linear body measurements in Hyla for both purebred and crossbred rabbits are presented in Table 4.11. Average body weight was significantly ($P < 0.05$) affected by breed. Biometric traits was not significantly ($P > 0.05$) affected by breed. Purebred Hyla rabbits however had higher values in traits such as ear length (EL), nose to shoulder (NTS), shoulder to tail drop (STT), body length (BL), body weight (BW), thigh circumference (TC) and tail length (TL) compared to crossbred rabbits. Crossbred Hyla rabbits showed higher values in traits such as height at wither (HW), length of front leg (LFL), length of back leg (LBL) and height girth (HG) compared to the purebred Hyla rabbits.

Table 4.11: Least Square Means of BW and Linear body measurements in Hyla rabbits

| Traits | Means±S.E (Hyla purebred) | Means±S.E (Crossbred) |
|---|---|---|
| BW | 1290.72±14.22[b] | 1300.52±22.21[a] |
| EL | 10.09±0.06 | 10.07±0.09 |
| NTS | 10.99±0.08 | 10.81±0.11 |
| STT | 27.83±0.17 | 27.71±0.27 |
| BL | 25.36±0.18 | 25.31±0.28 |
| TC | 7.47±0.06 | 7.47±0.10 |
| HW | 8.96±0.06 | 8.99±0.09 |
| LFL | 11.63±0.10 | 11.83±0.16 |
| LBL | 17.69±0.20 | 17.84±0.31 |
| HG | 23.69±0.18 | 23.98± 0.28 |
| TL | 7.11±0.06 | 7.10±0.09 |

[abc]Means within the same column having the same superscript are not significantly (P>0.05) different
SE- Standard Error; BW-Body-weight. EL- ear length, NTS- nose to shoulder, STT-shoulder to tail drop; BL –body length; TC- thigh circumference; HW- height at wither; LFL-length of front leg; LBL- length at back leg; HG- height at wither, TL- tail length

### 4.5.2 Pairwise Phenotypic Correlations between BW and LBMs of Purebred and Crossbred Rabbits

The result of the correlation between body weight and biometric traits are presented in Table 4.12. Phenotypic correlations between bodyweight and morphostructural traits were highly associated and positive for Hyla purebred and crossbred rabbits. The highest correlation was recorded between shoulder to tail drop (STT) – bodyweight (BW) (r = 0.96) while the lowest correlation was observed between length of front leg (LFL) – (BW) bodyweight (r = 0.60) in purebred rabbits. In the crossbred, the highest correlation was obtained between STT – BW (r = 0.94) while the lowest correlation was recorded between LFL – BW (r = 0.62).

Table 4.12: Phenotypic Correlations of Bodyweight and Linear Body Measurements of HYLA Purebred and Crossbred Rabbits

| Traits | BW | HW | BL | HG | TL | TC | LFL | LBL | STT | EL | NTS |
|---|---|---|---|---|---|---|---|---|---|---|---|
| BW | | 0.80 | 0.90 | 0.86 | 0.77 | 0.74 | 0.62 | 0.69 | 0.91 | 0.84 | 0.87 |
| HW | 0.86 | | 0.80 | 0.68 | 0.66 | 0.65 | 0.60 | 0.61 | 0.78 | 0.76 | 0.73 |
| BL | 0.89 | 0.86 | | 0.87 | 0.84 | 0.81 | 0.72 | 0.71 | 0.96 | 0.89 | 0.86 |
| HG | 0.88 | 0.76 | 0.85 | | 0.76 | 0.71 | 0.62 | 0.64 | 0.89 | 0.80 | 0.81 |
| TL | 0.79 | 0.76 | 0.85 | 0.82 | | 0.79 | 0.69 | 0.74 | 0.85 | 0.87 | 0.78 |
| TC | 0.77 | 0.76 | 0.86 | 0.79 | 0.87 | | 0.68 | 0.69 | 0.79 | 0.83 | 0.78 |
| LFL | 0.63 | 0.67 | 0.72 | 0.62 | 0.72 | 0.71 | | 0.67 | 0.69 | 0.78 | 0.68 |
| LBL | 0.71 | 0.70 | 0.73 | 0.66 | 0.73 | 0.68 | 0.71 | | 0.70 | 0.77 | 0.69 |
| STT | 0.92 | 0.84 | 0.94 | 0.89 | 0.88 | 0.85 | 0.69 | 0.73 | | 0.87 | 0.85 |
| EL | 0.84 | 0.83 | 0.89 | 0.82 | 0.88 | 0.88 | 0.79 | 0.79 | 0.89 | | 0.86 |
| NTS | 0.87 | 0.79 | 0.86 | 0.83 | 0.81 | 0.79 | 0.66 | 0.71 | 0.86 | 0.87 | |

BW-Body weight, EL-Ear length, HS- Head size, HG- Heart girth, TL – Tail length, STT- Shoulder to tail drop, LFL-Length of front leg, LBL- Length of back leg, TC- Thigh circumference, BL- Body length, HW- Heigth at wither, NTS- Nose to shoulder, LBMs- Linear body measurement. Upper matrix= Hyla purebred, Lower matrix= Hyla crossbred, Significant at $P < 0.01$ for all correlation coefficients.

### 4.5.3 Principal Component Matrix

The principal component matrix for Hyla rabbits are presented in Table 4.13. Two principal components (PC1 and PC2) were extracted for Hyla purebred which contributed to 83.97 % of the total variance. Three principal components (PC1, PC2 and PC3) were extracted for Hyla crossbred which contributed 89.88 % of the total variance.The determinants of the correlation matrix were 1.77E0.06 versus 6.45E0.07 for purebred and crossbred Hyla rabbits. The anti – image correlations computed showed that partial correlations were low, indicating that true factors existed in the data of both breeds. In the purebreds, ear length (EL), nose to shoulder (NTS), shoulder to tail drop (STT), body length (BL), height at withers (HW), heart girth (HG) and tail length (TL) were associated with the first PC while the second PC has had its highest loadings on length of front leg (LFL) and length of back leg (LBL). In their, crossbred counterpart, PC1 had its loadings for HW, BL, HG, TL, TC, STT, EL and NTS. PC2 was solely related to LFL and PC3 had its highest loadings for LBL.

Table 4.13: Eigenvalues and share of total variance along with factor loadings and communalities of the body measurements of Purebred and Crossbred Hyla rabbits

| Traits | PC1 | PC2 | PC3 | Communality |
|---|---|---|---|---|
| Purebred | | | | |
| HW | *0.779* | 0.348 | | 0.729 |
| BL | *0.833* | 0.497 | | 0.941 |
| HG | *0.845* | 0.364 | | 0.846 |
| TL | *0.638* | 0.640 | | 0.817 |
| TC | *0.593* | 0.652 | | 0.777 |
| LFL | 0.346 | *0.829* | | 0.807 |
| LBL | 0.384 | *0.802* | | 0.791 |
| STT | *0.852* | 0.462 | | 0.939 |
| EL | *0.683* | 0.668 | | 0.912 |
| NTS | *0.761* | 0.509 | | 0.837 |
| Eigen value | 7.870 | 0.527 | | |
| % of total variance | 78.70 | 5.27 | | |
| Crossbred | | | | |
| HW | 0.706 | 0.252 | 0.512 | 0.829 |
| BL | 0.810 | 0.372 | 0.357 | 0.921 |
| HG | 0.859 | 0.248 | 0.269 | 0.872 |
| TL | 0.734 | 0.505 | 0.280 | 0.873 |
| TC | 0.750 | 0.543 | 0.180 | 0.890 |
| LFL | 0.324 | 0.833 | 0.374 | 0.939 |
| LBL | 0.372 | 0.402 | 0.801 | 0.942 |
| STT | 0.837 | 0.341 | 0.345 | 0.936 |
| EL | 0.702 | 0.522 | 0.405 | 0.929 |
| NTS | 0.782 | 0.274 | 0.413 | 0.857 |
| Eigen value | 8.147 | 0.522 | 0.318 | |
| % of total variance | 81.48 | 5.22 | 3.18 | |

BW-Body weight, EL-Ear length, HS- Head size, HG- Heart girth, TL – Tail length, STT- Shoulder to tail drop, LFL-Length of front leg, LBL- Length of back leg, TC- Thigh circumference, BL- Body length and , NTS- Nose to shoulder, HW- Heigth at wither, LBMs- Linear body measurement, PC= principal component. Breed 1: Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy= 0.951; Bartlett's Test of Sphericity (chi square = 4103.19; P<0.001). Breed 2: Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy = 0.950; Bartlett's Test of Sphericity (chi square = 2848.29; P<0.001).

### 4.5.4 Prediction of Bodyweight from Interdependent Body Measurement and Independent Principal Components

Table 4.14 shows the multiple regression equation and coefficient of determination ($R^2$) of biometric measurements of Hyla purebred and crossbred rabbits. The $R^2$ values observed in this study ranged from 0.84 - 0.89 for purebred and 0.85 - 0.91 for crossbred rabbits using original measurements as explanatory variables. When orthogonal traits were used as independent variables the $R^2$ ranged from 0.72 - 0.88 for purebred and 0.66 - 0.88 for crossbred rabbits.

#### *4.5.4.1 Purebreds*

The highest value (0.89) was obtained when STT, NTS, HW, HG and LFL were combined in multiple regression equation. The least value (0.84) was recorded when STT was used as a sole predictor. When STT and NTS were combined the $R^2$ was 0.86. The highest value (0.88) from orthogonal traits as independent variables was obtained when PC1 and PC2 were combined. When PC1 was used as sole predictor the least value (0.72) was obtained for the $R^2$.

#### *4.5.4.2 Crossbreds*

The highest value (0.91) was obtained when STT, NTS, HW, HG and TL were combined in multiple regression equation. The least value (0.85) was recorded when STT was used as a sole predictor. When STT and NTS were combined the $R^2$ was 0.87. The highest value (0.88) from orthogonal traits as independent variables was obtained when PC1, PC2 and PC3 were combined. When PC1 was used as a sole predictor the least value (0.66) was obtained for the $R^2$. When PC1 and PC3 were combined the $R^2$ improved with a value of 0.84.

Table 4.14:Stepwise Multiple Regression of Body Weight on Original Body Measurements and on their Principal Components Factor Scores of Purebred and Crosssbred

| Traits | Models | $R^2$ |
|---|---|---|
| Purebred | | |
| Original body measurements as explanatory variables | | |
| STT | BW= -789.63 + 63.32STT | 0.84 |
| STT and NTS | BW= -1086.24 + 44.56STT + 74.48NTS | 0.86 |
| STT, NTS and HW | BW= -1086.79 + 37.37STT + 63.71NTS + 35.59HW | 0.88 |
| STT, NTS, HW and HG | BW= -1186.43 + 27.04STT + 55.14NTS + 38.00HW + 19.41HG | 0.88 |
| STT, NTS, HW, HG and LFL | BW= -1122.81 + 29.50STT + 93.16NTS + 40.06HW + 18.97HG – 19.63LFL | 0.89 |
| Orthogonal traits as independent Variables | | |
| PC1 | BW= 972.06 + 477.64PC1 | 0.72 |
| PC1 and PC2 | BW= 971.88 + 477.45PC1 + 226.45PC2 | 0.88 |
| | | |
| Crossbred | | |
| Original body measurements as explanatory variables | | |
| STT | BW= -887.75 + 67.21STT | 0.85 |
| STT and NTS | BW= -1177.49 + 48.36STT + 74.48NTS | 0.87 |
| STT, NTS and HW | BW= -1172.04 + 38.57STT + 59.10NTS + 48.36HW | 0.89 |
| STT, NTS, HW and TL | BW= -1231.29 + 48.84STT + 68.25NTS + 49.91HW – 47.77TL | 0.90 |
| STT, NTS, HW, TL and HG | BW= -1333.49 + 37.96STT + 53.82NTS + 51.75HW – 52.16TL + 24.05HG | 0.91 |
| STT, NTS, HW, TL, HG and TC | BW= -1300.26 + 39.40STT + 57.22NTS + 54.14HW – 38.67TL + 24.87HG – 32.77TC | 0.91 |
| Orthogonal traits as independent Variables | | |
| PC1 | BW= 975.58 + 467.01PC1 | 0.66 |
| PC1 and PC3 | BW= 975.58 + 467.01PC1 + 247.37PC3 | 0.84 |
| PC1, PC3 and PC2 | BW= 975.58 + 467.01PC1 + 247.37PC3 + 116.32PC2 | 0.88 |

BW-Body weight, EL-Ear length, HS- Head size, HG- Heart girth, TL – Tail length, STT- Shoulder to tail drop, LFL-Length of front leg, LBL- Length of back leg, TC- Thigh circumference, BL- Body length and , NTS- Nose to shoulder, HW- Heigth at wither, LBMs- Linear body measurement, PC= principal component
$R^2$= coefficient of determination.

# CHAPTER FIVE

## 5.0 DISCUSSIONS

## 5.1 THERMOREGULATORY ACTIVITIES

Temperature humidity index (THI) in the cool was averaged 27.3 $^{o}$C and 28.7 $^{o}$C during the hot period. This range exceeded some of the ranges reported in literature at similar periods (Marai *et al*., 2005). In the study conducted by Marai *et al*. (2005), a THI value of 17.3 $^{o}$C for mild period and 28.8 $^{o}$C for hot period was reported in the subtropical climate of Egypt. Adenkola *et al*. (2009) reported low THI in the morning and late evening hour, when it was very high in afternoon alongside windy and dusty conditions. THI in the cool period indicated absence of heat stress and exposure to moderate heat stress in the hot period.

The increase in thermoregulatory parameters for both cool and hot periods in grandparent and $F_1$ progeny of Hyla rabbits was in agreement with the result obtained by Farghly (2011), who observed that heat stress was apparent in the rabbits during the hot period due to failure of thermoregulatory mechanism. Marai *et al*. (2005) reported breed differences in thermoregulatory parameters during the mild and hot periods for NZW and CAL rabbits. The RT and ET values obtained are within the established normal range of 38.6 – 39.5 $^{o}$C and 24 - 30 $^{o}$C for domestic rabbits (Willmer *et al*., 2000). The RR observed for both grandparent and $F_1$ progeny Hyla rabbits were higher than the established normal range of 35 – 50 $^{o}$C and the HR was lower compared to the established value of 130 – 260 beats/min for domestic rabbits (Willmer *et al*., 2000). The observed differences could be due to stress-induced hyperthermia (Piccione *et al*., 2007). The adverse effect of the very severe heat stress conditions on the Hyla rabbits physiological background studied were similar to the results reported by many workers and

recently reviewed by Marai *et al.* (2002). The significant increase in each of the thermoregulatory parameters was similar to the results of Habeeb *et al.* (1997) and Marai *et al.* ( 2001). Rabbits use general body position, breathing rate and peripheral temperature, especially ear, as three devices to modify heat loss. However, respiration and ear are the most important dissipation pathways. Marai and Habeeb (1994) indicated that between 0 – 30 $^{o}$C, latent heat evacuation is only controlled by altering the breathing rate.

Higher values were observed for HR, RR, RT and ET for $F_1$ progeny Hyla rabbits at 14.00 h compared to 8.00 h of the day. The diurnal variations agreed with the observation made by (Piccione *et al*., 2007), who demonstrated that such a fluctuation was driven by biological clock in the hypothalamus.

Sexual differences observed in the thermoregulatory parameters showed that young does are more sensitive to environmental conditions in the tropics. This agrees with the earlier study of Massaro *et al*. (2006) who reported that sex hormone (testosterone) had effect on airway smooth muscle of the male animals which tends to suppress their respiratory activities. However, Marai *et al*. (2004) reported that young does were more sensitive to light regimes than the young bucks.

Moderate adaptability estimates was recorded in this study. This was lower than the 78.5 % reported by Marai *et al*. (2004) for young rabbit does and 81.7 % for young bucks of NZW under subtropical environment of Egypt. Marai *et al*. (2005) reported adaptability estimates of 0.82 and 0.80 for mature NZW and CAL rabbits respectively in Egypt. The moderate adaptability coefficients might be due to complexity of environmental factors in the tropics. Environmental factors contributed greatly to the alteration of the health status of the rabbits, which might have

rendered the thermoregulatory apparatus less efficient. This reflects that adaptability is a long-term process rather than the presumed short-term process by researchers.

## 5.2 GROWTH PERFORMANCE OF HYLA RABBITS

### 5.2.1 Growth Performance of the Grand-Parent Purebred Rabbits

The hybrid females were characterised by high prolificacy and early maturity, while the hybrid males by fast growth but late maturity. High bodyweight at different ages of Hyla grand parent rabbits obtained from this study agrees with some reports in literature (Chrysostome *et al*., 2011 and Hamouda *et al*., 1990). Nizza and Moniello (2000) reported that Hyla rabbits can attain a weight of 2750 g in 90days. Values of 2300 g for Hyla New Zealand White obtained fell within the range of 2500 – 2550 g established for Hycole hybrid rabbits at 70 days. Metzger *et al.* (2004) in the temperate region found similar results in bodyweight at ten weeks when comparing Pannon White and Hyplus genotypes.

### 5.2.2 Growth Performance of $F_1$ Progeny Rabbits

Post-weaning growth performance of $F_1$ Hyla rabbits were intermediate compared to the reports from temperate and tropical countries. Values obtained at different ages were lower than the average body weight range for Italian hybrids, but the average bodyweights in this study were higher than the reports by some authors on hybrid and local rabbits at different ages in the tropical countries (Akanno and Ibe, 2005; Elamin *et al*., 2011). Iraqi *et al*. (2002) reported that baladi Red (BR) rabbits the means of body weight ranged from 318 to 497 g, from 590 to 921 g, from 830 to 1481 g and from 1176 to 1757 g for BW 4, 8, 12 and 14 weeks of age. Yamani (1994) reported BW at 5 weeks and BW at twelve weeks in Hyla rabbits to be 415 and 2153 g respectively. Crossbred Hyla rabbits showed superior performance compared to the purebreds at

all the ages studied. This agrees with the report of some authors (Yamani 1994; Hamadou *et al*., 1990 and Chrysostome *et al*., 2011). The observed differences could be due to heterosis. El-Dessoki (1991) reported that crossbred rabbits mothered by NZWXCAL crosses showed heavier weight than purebred rabbits at 4, 8 and 10 weeks of age. The influence of sex on the body weight in this study are likely connected with the usual between-sex hormonal action which leads to differential growth rates. Isaac (2005) reported that sexual dimorphism in bodyweight and size are clearly widespread among many mammalian taxa, with male-biased dimorphism being the more common, but certainly not the exclusive pattern. However, Bacchi *et al*., (2010) found no sexual dimorphism in the bodyweight and morphometric characters considered in *Lama guanicoe guanicoe* in Argentina.

## 5.3 REPRODUCTIVE PERFORMANCE

### 5.3.1 Reproductive Performance of Purebred and Crossbred Hyla rabbits

Significant breed differences in litter size between Hyla purebred and crossbred rabbits were in line with the report of Shawer (1963). However, Afifi (1971) and Tag –El-Din (1979) reported non- significant breed differences in that respect. The values of litter size, litter weight and individual kit weight obtained in this study were lower than the range reported in the temperate country at pre-weaning ages, also, within the range reported in the literature for tropical country. Vaclavovsky *et al*. (2000) reported litter size of 9.49 in Hyla purebred rabbits reared in Slovenia. Chrysostome *et al*. (2011) reported values of 7.29 in France and 6.45 in Benin for Hyla purebred rabbits. Hamouda *et al*. (1990) reported litter size value of 8.50 at first generation with Hyla rabbits in Tunisia. The litter size at birth in this study were also lower than 8.3 reported as average in different rabbit breeds in Australia (Prayaga and Eady, 2002), but closer to 6.30 recorded with New Zealand White rabbits in USA (Medellin and Lukefahr, 2001). Litter size

from birth through 35 days obtained from this study were within the range reported by Kabir *et al*. (2010) for pure and crossbred rabbits in Nigeria. The weaned kits' weights were also higher than the value of litter size recorded at 35 days-old in Hyla rabbitry in Tunisia (Hamouda *et al*., 1990) and also higher than those reported by Karikari *et al*. (2011) in Ghana. Differences in litter size could be due to climatic conditions and management practice.

Hyla purebreds produced significant heavier litterweight compared to Hyla crossbred rabbits at all pre-weaning age. This agrees with the report of Hassan (1993) who observed that litter performances in NZW purebred are better than those in crossbred. This could be explained by the findings of Rao *et al*. (1977) who stated that the total weight of rabbit in a given litter increased with increased litter size. It also corroborated the earlier submissions of Ozimba and Lukefahr (1991). This difference could be due to increase in litter sizes of the Hyla purebred compared to crossbred rabbits in the study. This reflects the superiority of Hyla purebred in their postnatal maternal abilities (in terms of milk production, pre-weaning growth and survival, maternal behavior, mothering ability, etc.). The Hyla crossbred kits had significantly ($P < 0.05$) higher individual kit weight (IKW) than Hyla purebreds at all the pre-weaning ages. High body weights obtained in this study agree with earlier report in literature. The average weights of kits at birth were closer to 58.1 g and 60.2 g but lower than 62.07 g reported respectively by Prayaga and Eady (2002) in Australia and Karikari *et al*. (2011) in Ghana. However, these kits' weight were higher than the 43.7 g reported in Sudanese rabbits (Elamin *et al*., 2011). The weaned kits' weight were also higher than the value recorded in Hyla rabbitry in Tunisia (Hamouda *et al*., 1990), Egypt (Yamani, 1994) and Chrystosome *et al*. (2011) in Benin. The Hyla crossbred rabbits had heavier kit weights at weaning compared to Hyla purebreds. This might be due to heterotic effect of the crosses. This high genetic value of crossbred on bodyweight can be

exploited in commercial rabbit production. Intensive selection among the crossbreds with rigorous progeny test appears to have the potential to transform meat rabbit industry in this zone.

### 5.3.2 Effect of Parity on Reproductive Traits.

The significant ($P < 0.05$) effect of parity on LSB, LS35, LWB and LW35 revealed a consistent linear trend as ages of rabbit increases. This agrees with the report of Moura *et al*. (1991) who observed a significant ($P < 0.01$) effect of parity for most litter traits studied among different breeds of rabbits. The differences in litter size and litter weight due to parity effect may be attributed to changes in physiological efficiency of the does with advance of parity (Afifi *et al*., 1992). Furthermore, Blasco *et al*. (1992) reported that these changes may be related to ovulation rate, fetal survival, uterine capacity and intra uterine environment during the pre-natal development stage. Khalil and Soliman (1989) reported that variation in litter traits from kindling up to weaning in different parities may be associated with the differences in doe's care and ability to suckle her young till weaning. The non significant ($P > 0.05$) effect of parity on gestation length observed in this study agrees with the reports of some authors (Sedki *et al*., 2002; Nofal *et al*., 2002 and Hilmy, 1991). Gestation length numerically increased as parity increases. The high mortality rate during lactation reduced markedly the survivability of kits. The significance decrease of mortality at 3$^{rd}$ parity compared to 1$^{st}$ and 2$^{nd}$ parity was due to improvement in management practice. Mortality is reported to be obvious sign of heat stress (Yamani and Farghally, 1988). The mortality of kits during lactation was within the range of 60 % and 56 % on the average reported in Benin on Hyla rabbits (Chrysostome *et al*., 2011). The high mortality rate at different parity indicates a low lactation trait of Hyla rabbit does in the tropical climatic conditions of Nigeria.

## 5.4 GENETIC PARAMETERS FOR PRE-WEANING BODY WEIGHT

### 5.4.1 Heritability Estimates of preweaning kits weight

The moderate to high heritability estimates of preweaning bodyweight at birth through 35 days of age in Hyla purebred rabbits agree with reports in literature. This was an indication that additive gene action operates for the expression of these traits. Odubote and Somade (1992) obtained heritability estimate of 0.33 ± 0.08 for litter birth weigth in New Zealand rabbits. Elamin *et al*. 2011 and Orunmuyi *et al*. (2006) reported a moderate to high heritability which was above 1. Heritability estimate obtained in this study were similar to those reported in temperate environment (Szendro *et al*., 1988; Akanno and Ibe 2005 and Lukefahr *et al*., 1996). Iraqi (2008) reported a low heritability estimates (0.00, 0.05 and 0.07) for preweaning body weight at birth, 21 and 28 days using animal models. Khalil *et al*. (1988) reported that maternal effects resulted in high heritability estimates obtained for pre-weaning bodyweights in rabbits. Akanno and Ibe (2005) reported that moderate heritability estimate would be improved upon by combining pedigree and individual selection records. Estimates of heritability were not consistent as the age increases. Saatci *et al*. (2003) reported that heritability estimates for quail tends to increase as age increases. Differences in heritability estimates could be attributed to method of estimation, strain, environmental effects and sampling error due to small data set or sample size (Mielenz *et al*., 2006).

### 5.4.2 Repeatability Estimates of preweaning kits weight

The estimate of repeatability obtained in this study was moderate to high. This value agrees with some of the ranges reported in literature at similar ages for New Zealand rabbits (Chineke *et al* 2001; Ferraz and Eler 1994 and Akanno and Ibe 2005). Lukefahr *et al*. (1983) reported a value of 0.37 for litter birth weight. Okoro *et al*. (2007) reported estimates of repeatability of 0.34 for

litter birth weights in rabbits, which was lower than the value obtained from this study. Ndjon and Nwakalor (1998) reported moderate to high estimates of repeatability for litter weight at weaning. Moderate to high repeatability implies that great reliability can be put on selection or culling of does and bucks for Hyla purebred rabbits at preweaning ages based on two or more records.

### 5.4.3 Estimates of Genetic and Phenotypic Correlations

Low to high genetic and moderate to high phenotypic correlations were observed at all the preweaning ages studied. The implication of the present findings is that for traits with positive and high genetic correlation, selection for one trait will lead to improvement in the other. This however, is the phenomenon of correlated response. These findings corroborated with the work of Elamin (2011). Low to high genetic correlation for preweaning body weight at various age are in line with the reports of Abdullah *et al*. (2003) and Chineke and Adeyemi (2001). The moderate to high phenotypic correlations observed are consistent with the findings of Tiamiyu *et al.* (2000) and Okoro *et al*. (2008). The positive genetic and phenotypic correlations obtained in this study were in corroboration with the findings of Chineke (2000). The strong relationship existing between body-weight and body-measurements may be useful as selection criterion, since positive correlations of traits suggest that the traits are under the same gene action (Pleiotropy). This, therefore, provides a basis for the genetic manipulation and improvement of the rabbit stock.

## 5.5 PREDICTION OF BODYWEIGHT FROM LINEAR BODY MEASUREMENTS

### 5.5.1 Relationship between Bodyweight and Linear Body Measurements

Values obtained from this study agrees with earlier report in literature (Akanno and Ibe 2005; Chineke *et al*., 2001 and Kabir, 2010). The mean body weights and linear body measurements of purebred and crossbred Hyla rabbits were higher than those reported by Obasi and Ibe (2008). Non significant effect of breed on linear body measurements obtained from this study is in contrast with some report in the literatures (Kabir, 2010; Zalla *et al*., 2007 and Obasi and Ibe 2008). Oke *et al*. (2003) found significant ($P < 0.05$) breed effect on most of the parameters studied.

### 5.5.2 Phenotypic Correlations of Body Weight and Biometric Traits.

Phenotypic correlation between bodyweight and biometric traits were highly associated and positive for Hyla purebred rabbits with a range of 0.62 - 0.91 and crossbred Hyla rabbits with a range of 0.63 – 0.94. The present estimates are comparable to the range of values recorded for rabbits in earlier research (Yakubu, 2009). The positive correlations between BW and biometric traits obtained in the present study indicate that an increase in any one body measurement would result in a corresponding increase in live body weight. The strong relationship existing between BW and body measurements suggests that either or a combination of these biometric traits could be used to estimate live weight in Hyla rabbits fairly well in the situation where scales are not available. The association may also be useful as selection criterion since positive correlations of traits suggest that the traits may be under the same genetic influences.

### 5.5.3 Principal Component Analysis

The values obtained from factor analysis with varimax rotation of the intercorrelated traits in purebred and crossbreds Hyla rabbits agree with reports in literature (Yakubu and Ayoade 2009 and Moses *et al*., 2011). This was supported by Kaiser-Meyer- Olkin measure of sampling adequacy studied from the diagonal of partial correlation, revealing the proportion of the variance in the body measurements caused by the underlying factor. This was found to be sufficiently high for all the morphometric traits in both breeds (0.951 and 0.950) respectively. The overall significance of correlation matrix was tested with Barlett's Test of sphericity for body dimensions of the purebred versus crossbred rabbits (chi square = 4103.19; $P < 0.001$) and crossbred (chi square = 2848.29; $P < 0.001$) which provided enough support for the validity of the factor analysis of the data set. The communalities, which represent the proportion of the variance in the original variables that is accounted for by the factor solution, ranged from 0.73 – 0.94 for purebred and 0.83 – 0.94 for crossbred Hyla rabbits. These further lend credence to the appropriateness of the factor analysis. After varimax rotation, two factors were extracted for purebred rabbits which accounted for 83.97 % of the total variance, while three factors were extracted for crossbred rabbits which accounted for 89.88 % of the total variance. The factor pattern coefficients were used to assess the relative contributions of the various body measurements in determining the numerical value of the corresponding factor (principal component). These coefficients show the relative contribution of each trait to a particular principal component (factor) for the two breeds of Hyla rabbits. The body parts associated with PC1 are by themselves rather good estimator of general size. The present findings are in consonance with the observation of Shahin and Hassan (2000) in NZW rabbits that the first factor explained the highest percentage of total variance. Yakubu and Ayoade (2009) reported

that two principal components analysis which accounted for 90.27 % of the total variance were extracted in NZW X Chinchilla crossbred rabbits in Nigeria. The large communalities observed for the pure and crossbred Hyla rabbits indicate that a large number of variance has been accounted for by the factor solution.

### 5.5.4 Prediction of BW from LBMs using Step-wise Multiple Regression.

The values of the coefficient of determination obtained in the purebred and crossbred Hyla rabbits agree with report in literatures. Saatci and Tulku (2007) reported similar findings in Turkish geese. In their study, they concluded that regression analyses showed that easily measurable body parts (chest girth and body length) can help in the determination of body weight. The higher association of body weight with heart girth was possibly due to relatively large contribution to body weight by heart girth consisting of bones, muscles and viscera. It is in concert with the findings of Szabone (1997) and Ngapongora *et al*. (2004).

# CHAPTER SIX

## 6.0 SUMMARY, CONCLUSION AND RECOMMENDATION

### 6.1 Summary

A study was undertaken to determine the genetic and physiological evaluations of Hyla rabbits in Guinea Savannah Zone of Nigeria. It was observed that adaptability estimates ranged from 33 – 39 % for all the studied breeds. The grandparent Hyla and mature non-descript rabbits showed higher adaptability coefficients compared to the $F_1$ progeny and grower non-descript rabbits. Crossbred Hyla rabbits showed superior performance for individual kit weight compared to the purebred Hyla rabbits. Comparison of body weights among the lines of Hyla grand-parent rabbits at age 10, 17 and 27 weeks showed significant ($P < 0.05$) differences except at 32 weeks which was not statistically ($P > 0.05$) different between Hyla.GPC and Hyla.NG but both differed significantly ($P < 0.05$) from Hyla.MAX. Purebred Hyla rabbits showed superiority in LSB and LWB compared to the crossbred Hyla rabbits. Crossbred Hyla rabbits showed significant ($P < 0.05$) higher average bodyweight at 8, 10 and 12 weeks compared to the purebred Hyla rabbits. Parity had significant ($P < 0.05$) effect on LSB, LWB, LS35, LW35 and PWM. Non significant ($P > 0.05$) effect of parity was obtained for GL.

Moderate to high heritability (0.39 to 1.30) and repeatability (0.21 to 0.77) estimates of pre-weaning bodyweight from birth through 35 days of age in Hyla purebred rabbits was obtained for this study. The high correlations were indications of pleiotropic effects reflecting the effects of same set of genes for the growth traits at different pre-weaning ages.

Low to high genetic and moderate to high phenotypic correlations were observed at all the pre-weaning ages studied. Phenotypic correlations between bodyweight and biometric traits were highly associated and positive for Hyla purebred and crossbred rabbits.

The communalities, which represented the proportion of the variance in the original variables that is accounted for by the factor solution, ranged from 0.73 – 0.94 % for purebred and 0.83 - 0.94 % for crossbred Hyla rabbits. These further lend credence to the appropriateness of the factor analysis. After varimax rotation, two factors (PC1 and PC2) were extracted for purebred rabbits which accounted for 83.97 % of the total variance, while three factors (PC1, PC2 and PC3) were extracted for crossbred rabbits which accounted for 89.88 % of the total variance.

The $R^2$ values observed in this study ranged from 0.84 - 0.89 % for purebred and 0.85 - 0.91% for crossbred rabbits when original body measurements were used as explanatory variables. When orthogonal traits were used as independent variables, the $R^2$ ranged from 0.72 - 0.88 % for purebred and 0.66 - 0.88 % for crossbred Hyla rabbits.

## 6.2 CONCLUSIONS

The following conclusions were deduced from this study:

1. Adaptability estimates were moderate for all the breeds. Both the grower (35 %) and mature (39 %) non descript rabbits had higher adaptability coefficients than the grower (34 % and 33 %) and mature (37 % and 36 %) Hyla rabbits. The result also showed that grower rabbits were more sensitive to heat stress than the matured rabbits. This was an indication that exposure to high ambient temperature is the major constraint on rabbit productivity. Such changes in environmental temperature resulted in their impairment of growth and reproductive performance compared to that of their counterparts in temperate countries.

2. Crossbred Hyla rabbits had better performance than the pure bred for individual body weight; hence they will be suitable for meat production. Improvement of litter traits could be sought through pure breeding and selection as evidenced by the performance of the pure bred in this traits.

3. The genetic trends for kit weights suggested that individual selection of litters at pre-weaning ages will be more effective in the improvement of growth traits in Hyla rabbits.

4. Body measurements and principal components are good predictors of body weights in Hyla rabbits. Both could aid in selection and breeding programmes for improved productive and reproductive performance of Hyla rabbits. Multicollinearity of two or more independent body measurements could lead to unstable regression coefficients, thereby leading to erroneous inferences. Since principal component analysis corrects for multicollinearity, it serves as a better tool to predict body weight with more accuracy.

## 6.3 RECOMMENDATIONS

1. In view of the accuracy of prediction model obtained for predicting bodyweight from linear body measurements, therefore principal component factor analysis may be useful as an added tool in predicting bodyweight.

2. The adaptability index should be further investigated to include more variables, indices and larger sample size to improve accuracy of the estimates obtained.

## REFERENCES


Abdel Azeem, A.S. (2006). A study of physiological and performance aspects in four pure breeds of rabbits and their crosses. M.Sc. Thesis, Faculty of Agriculture, Fayoum University, Egypt. Pp 94.

Abdullah, A.R., Sokunbi, O.A., Omisola, O.O. and Adewunmi, M.K. (2003). Interrelationship between body weight and body linear measurements in domestic rabbits (*Oryctolagus cuniculus*). In: Nigerian Livestock: A Goldmine for Economic Growth and Food Security. Taiwo, A.A, Raji, A.M, Ogbonna, J.U and Adebowale, E.A.Obafemi Awolowo University, Ibadan, Nigeria. *Proceedings of the 28th Annual Conference of the Nigerian Society for Animal Production*, 16th – 20th March, Pp 133-136.

Aboul-Naga, A.I. (1987). The role of aldosterone in improving productivity of heat-stressed farm animals with different techniques. Ph.D. Thesis. Faculty of Agriculture, Zagazig University, Zagazig, Egypt.

Adenkola, A.Y., Ayo, J.O. and Sackey, A.K.B. (2009). Ascorbic acid-induced modulation of rectal temperature in pigs during harmattan season. *Journal of Thermal Biology*, 34 (3): 152-154.

Aduku, A.O. and Olukosi, J.O. (1990). Rabbit Management in the tropics: Production, processing, utilization, marketing, economics, research and future projects. *Living Book Series*, Abuja. Pp 43-56.

Afifi, E.A. (1971). A study of some economical and productive characters in some breeds of rabbits and their crosses. Ph.D. Thesis, Faculty of Agriculture, Ain-Shams University, Egypt.

Afifi, E.A. and Emara, M.E. (1987). Litter size in purebred and crossbred rabbits. *Journal of Applied Rabbit Research, 10(1):133-136.*

Afifi, E.A., Khalil, M.H. and Emara, M.E. (1987). Effect of maternal performance and litter preweaning traits in doe rabbits. *Journal of Animal Breeding and Genetics*. 106:358-362.

Afifi, E.A. and Emara, M.E. (1990). Analysis of litter size in rabbits in diallel crossing schemes involving four local Egyptian and exotic breeds. *Journal of Applied Rabbit Research*, 12:256-258.

Afifi, E. A., Yamani, K. A., Marai,I. F. M. and El-Maghawry, A. M. (1992). Environmental and genetic aspects of litter traits in New Zealand White and Californian rabbits under the Egyptian conditions. *Journal of AppIied. Rabbit Research*, 15:335- 351.

Ahmed, E.G.A. (1997). Productive performance of different exotic strains of rabbits. Ph.D. Thesis, Faculty of Agriculture, Suez Canal University. Ismailia, Egypt.

Akanno, E.C. and Ibe, S.N. (2005). Estimation of genetic parameters for growth traits of domestic non descript rabbits in the humid tropics. *Livestock Research for Rural Development. (LRRD)* 17 (7)://www.utafoundation.org/lrrd/1707/akan 17806.htm.

Alexiev, J., Gudev, D., Popova, S., Moneva, P. (2004). Thermoregulation in sheep. IV. Effect of heat stress on heart rate dynamics in shorn and inshorn ewes from three breeds. Zhovot-nov dni-Nauki 41 (1), 169-171.

Anohkin, B.M., Danilevsky, V.M. and Zanarim, L.G. (1991). Internal medicine of livestock. *Agropromizdat*, Moscow, Pp. 339-352 (in Russian).

Arthington, J.D., Eicher, S.D., Kunklet, W.E. and Martin, F.G. (2003). Effect of transportation and commingling on the acute–phase protein response, growth and feed intake of newly weaned beef calves. *Journal of Animal Science,* 81: 1120-1125.

Ayyat, M.S. and Marai, I.F.M., (1995). Evaluation of application of the intensive rabbit production system under the subtropical conditions of Egypt. *Journal of World Rabbit.* Science 6 (2), 213–217.

Bacchi, C.S., Lanari M.R., von Thungen J. 2010. Non-genetic factors affecting morphometric and fleece traits in guanaco (*Lama guanicoe guanicoe*). *Small Ruminant Research*, 88: 54–61.

Becker, W.A. (1992). *Manual of Quantitative Genetics* (5th Ed.). Academic Enterprise, Pullman, Washington, DC. Pp 11-13.

Bernard, C. (1878). Les phenomenes de la vie.Libraire J.B. Bailliere et Fils, Paris, France, vol. 1, Pp 879.

Blasco, A., Ounhayoun, J. and Gomez, G. (1992). Harmonization of criteria and terminology in rabbit meat research. *World Rabbit Science*. 1(1):3-10.

Cannon, W.B. (1932). In: The Wisdom of the Body. W.W. Norton, New York, Pp. 24.

Chen, C.P., Rao, D.R., Sunki, G.R. and Johnson, W.M. (1978). Effects of weaning and slaughter ages upon rabbit meat production. *Journal of Animal Science*. 63: 1581- 1586.

Chineke, C. A. (2000). Characterization of physical body traits of domestic rabbit in humid tropics. In: Animal Production in the New Millennium: Challenges and Options. Ukachukwu S.N, Ibeawuchi J.A, Ibe S.N, Ezekwe, A.G, Abasiekong, S.F. Micheal Okpara University, Umudike, Abia State. *Proceedings of 25th Annual Conference of Nigerian Society for Animal Production*, 19th – 23rd March, 25:237-239.

Chineke, C.A. and Adeyemi, A. (2001). Estimates of heritability of weaning and post weaning body measurements in domestic rabbits. In: Strategies for Poverty Alleviation: Animal

Production Option. Malau-Aduli, A.E.O and Adeyinka, I.A. Ahmadu Bello University, Zaria. *Proceedings of the 26th Annual Conference of the Nigerian Society for Animal Production*, 21st – 26th March, 26:23-24.

Chineke, C.A., Ikeobi, C.O.N. and Ologun A.G. (2001). Repeatability of body measurements in domestic rabbit. In: Strategies for Poverty Alleviation: Animal Production Option. Malam-Aduli, A.E.O and Adeyinka, I.A. Ahmadu Bello University, Zaria. *Proceedings of the 26th Annual Conference of the Nigerian Society for Animal Production*, 21st – 26th March, 26:25-26.

Chrystosome, C.A.A.M., Gbangboche, A.B. and Houangni, M.S.M. (2011). Evaluation of reproduction performance of Hyla rabbits in hot and humid region in Benin. *Research Opinion in Animal and Veterinary Science*, 1(10), 669-672.

Dalle Zotte, A. (2000). Main factors influencing the rabbit carcass and meat quality. *Proceedings of the 7th World Rabbit Congress*, Valencia, Spain, 1-32.

El-Dessoki, A.E.M. (1991). Study of the effect of some genetic and environmental factors affecting meat yield from some foreign and local breeds of rabbits and their crosses. Master of Science Thesis, Faculty of Agriculture, Mansoura University, Egypt.

Elamin, K.M., Yousif, I.A., Elkhairey, M.A. and Mekki, D.M . (2011). Heritability estimates and genetic correlations for post-weaning body weight traits in Sudanese rabbits. *Livestock Research for Rural Development* 23, (11).

El-Deghadi, A.S. (1996). Genetic and phenotypic analysis for four traits in rabbits. Master of Science Thesis, Faculty of Agriculture, Moshtohor Zagazig University, Banha Branch, Egypt.

Encarta Encyclopedia, (2011). Study tools, a Multimedia Encyclopedia, Dictionary and an Atlas. Microsoft Student with Encarta Premium, DVD.

Everitt, B. S., Landau, S. and Leese, M. (2001). *Cluster Analysis*. 4th edition. London, Arnold Publisher.

FAO (2008). Production environment descriptors for animal genetic resources. PED Worksheet. Report of FAO/WAAP Workshop, Caprarola, Italy, 6 – 8 May. 97 pp.

Farghly, M.F.A. (2011). Using light flashes programme as a tool to avoid the hot weather effect on growth performance of New Zealand White rabbits. *Egyptian Poultry Science*. 31 (11): 437-451.

Ferraz, J.B.S., Johnson, R.K. and Van Vleck, L.D. (1992). Estimation of genetic trends and genetic parameters for reproductive and growth traits of rabbits raised in subtropics with animal models. *Journal of Applied Rabbit Research,* 15: 131-142.

Ferraz, J.B.S. and Eler, J.P. (1994). Use of different animal models in prediction of genetic parameters of 23 traits of Californian and New Zealand White rabbits raised in tropics and suggestion of selection criteria. *Proceedings of the 5th World Congress. Genetics of Applied Livestock Production*, 20:348-351.

Finzi, A., Morera, P. and Kuzminsky, G. (1988). Acclimatisation and repeatability of thermotolerance parameters in rabbits. *Proceedings of the 4th Congress of the World Rabbit Science Association*. Budapest, Hungary, 419-424.

Freeman, B.M. (1988). The domestic fowl in biomedical research: physiological effects of the environment. *World Poultry Science Journal*, 44:41-40.

Fortun-Lamothe, L., Gidenne, T., Chalaye, F. and Debray, L. (2001). Feeding strategy around weaning: Effect of dietary starch/fibre ration. *Proceedings of the 9th Journees de Recherche Cunicoles*, Pais 195-198.

Gad, S.O.A. (1998). Evaluation of growth and production performance of Al-Gabli rabbits and their crosses under semi-arid conditions. M.Sc Thesis, Faculty of Agriculture, Moshtohor, Zagazig University, Banha Branch, Egypt.

Garcia, F., Blasco, A., Baselga, M. and Salvaador, A. (1980). Genetic analysis of some reproductive traits in meat rabbits. Proceedings of the 2nd World Rabbit Congress, April, Barcelona, Spain. 93 – 97.

Gonzales, R.R., Kluger, M.J. and Hardy, J.D. (1971). Partitional calorimetry of the New Zealand White rabbit at temperatures 5 - 35 $^{o}$C. *Journal of Applied Physiology*., 31: 728-734.

Grimaud (2012). *Manual of hyplus rabbits. Grimaud frères selection* (1st Ed.). La Corbiere 49450 Roussay France.

Gueye, E.F., Ndiaye, A. and Branckaert, R.D.S. (1998). Prediction of body weight on the basis of body measurements in mature indigenous chickens in Senegal. *Livestock Research for Rural Development 10: http:// www. Cipav.org.co/Irrd 10/3/sene103.htm*.

Habeeb, A. A., Marai, I. F. M. and Kamal, T. H. (1992). Heat stress. In Farm animals and the environment (ed. C. J. C. Philips and D. Piggins), CAB International, Wallingford. pp. 27-47.

Habeeb, A. A., Aboul-Naga, A. I. and Yousef, H. M. (1993). Influence of exposure to high temperature on daily gain, feed efficiency and blood components of growing male Californian rabbits. *Egyptian Journal of Rabbit Science,* 3:73-80.

Habeeb, A.A.M., El-Masry, K.A., Aboulnaga, A.I. and Kamal, T.H. (1997). The effect of hot summer climate and level of milk yield on blood biochemistry and circulating thyroid

and progesterone hormones in Friesian cows. *Arab Journal of Nuclear Sciences and Applications* 29, 161–173.

Habeeb, A.A.M., Aboul-Naga, A.I. and Khadr, A.F. (1998). Deterioration effect of summer hot climate on bunnies of acclimatized rabbits during suckling period. In: *1st International Conference on Indigenous versus Acclimatized Rabbits*, El-Arish, North Sinai, Egypt, 253–263.

Hamouda, M., Salwa, K. and El-Gaied, J. (1990). Crossing of local rabbits with the Hyla strain: growth and reproductive performance in the first generation. *Options Mediterraneennes*, Serie A, 8: 103-108.

Hassan, A.A.M. (1993). Reproductive performance for the doe rabbits. M.Sc. Thesis, Faculty of Agriculture, Moshtohor, Zagazig University., Egypt. Pp 72.

Harvey, W.R. (1990). Mixed Model Least Squares and Maximum Likelihood Computer Programme, Pp 91.

Henderson, C.R. (1963). Selection index and expected genetic advance. Statistical genetics and plant breeding. *National Academy of Science*, National Resources Council Publication,Washington. Pp 982.

Hilmy, A.F.M., (1991). Some productive aspects in rabbits. MSc. Thesis, Faculty of Agriculture, Moshtohor, Banha Branch, Zagazig University, Egypt. Pp 104.

Hohenboken, W.D. (1985). Heritability and repeatability. In: General and quantitative genetics. (Edited by Chapnes, A.B), PP 77-119, Elseviex Science Publishers BV., Amsterdam-Oxford-New York-Tokyo. (C.F. Abd El-Halim, 2005).

Ibe, S.N. (1989). Measures of size and conformation in commercial broilers. *Journal of Animal Breeding Genetics*, 106:461-469

Ibe, S.N. (1995). Repeatability of growth traits in Nigeria local chickens using early records. *Nigerian Journal of Animal Production*. 22(1):5-9.

Iraqi, M.M., Youssef, Y.M.K., El-Raffa, A.M. and Khalil, M.H. (2002). Genetic and environmental trends for post-weaning in New Zealand White and Z-line rabbits using the animal model approach. *3rd Science Conference on Rabbit Production in Hot Climate*, 8-11 Oct: 89-101.

Iraqi, M.M., Ibrahim, M.K., Hassan, N.S.H. and El-Deghadi, A.S. (2006). Evaluation of litter traits in purebred and crossbred rabbits raised under Egyptian conditions. *Livestock Research for Rural Development 18 (6). http://www.cipav.org.co/irrd12/10/iraq 20069.htm.*

Iraqi, M.M. (2008). Estimation of genetic parameters for post weaning traits of Gabali rabbits in Egypt. *Livestock Research for Rural Development, 20(5). Article http://www.cipav.org.co/irrd20/5/iraq 20069.htm.*

Isaac, J.L. (2005). Potential causes and life-history consequences of sexual size dimorphism in mammals. *Mammal Review*, 35: 101–115

Johnson, H.D., Ragasdale, A.C. and Eheng, C.S. (1957). Influence of constant environmental temperatures on growth responses and physiological reactions of rabbits and cattle. *Monthly Agricultural Experimental Station Research Bulletin*, No 648.

Kabir, M. (2010). Assessment of growth and reproductive traits in diallel crossing of three rabbit breeds. PhD Thesis, Faculty of Agriculture, Animal Science Department, Ahmadu Bello University, Zaria. pp 137.

Kabir, M., Oni, O.O, Akpa, G.N. and Adeyinka, I.A. (2006). Heritability estimates and the interrelationship of body weight and shank length in two strains of Rhode Island Chickens. *Pakistan Journal of Biological Sciences*, 9 (15): 2892-2896.

Karikari, P.K., Darkoh, G. and Deku, G. (2011). Evaluation of millet residue meal based diets as feed for the domestic rabbit *(Oryctolagus cuniculus). Research Opinions in Animal and Veterinary Sciences*, 1(3): 144-149.

Khalil, M.H. and Mansour, H. (1987). Factors affecting reproductive performance of female rabbit. *Journal of Applied Rabbit Research*. 10(3): 140-146.

Khalil, M.H. and Soliman, A.M. (1989). Genetic analysis for some reproductive traits in female rabbits. *Journal of Applied Rabbit Research*. 12:205-208.

Khalil, M.H., Afifi, E.A. and Emara, M.E. (1986). Doe litter performance at weaning for two breeds of rabbits with emphasis on sire and doe effects. *Animal Production Research Institute*, University of Agriculture, Cairo. 12-18.

Khalil, M.H., Afifi, E.A., Emara, M.E. and Owen, J.B. (1988). Genetic and phenotypic aspects of doe reproduction in four breeds of rabbit. *Journal of Agricultural Science*. 110(1):191-197.

Khalil, M.H. (1993). Diversity of repeatability between parities for litter traits and reproduvtive intervals in doe rabbits. *World Rabbit Science* 1(4): 147-154

Khalil, M. H. (1994). Lactational performance of Giza White rabbits and its relation with preweaning litter traits. *Animal Production*, 59: 141-145.

Khalil, M.H. and Afifi, E.A. (2000). Heterosis, maternal and direct additive effects for litter performance and post-weaning growth in Gabli rabbits and their crosses with New Zealand White. *7th World Rabbit Congress*, 4-7 July, Valencia, Spain.

Lang, J. (1981). The nutrition of the commercial rabbit. Part 2: Feeding and general aspects of nutrition. *Nutrition Abstract and Review, Series B*. 51(5):287-297.

Lebas, F. (1969). Milk feeding and weight gains of the rabbit before weaning. *Animal Zoo-technology* 18(2):197-208.

Lebas, F. (1983). Small- scale rabbit production: feeding and management systems. *World Animal Review.* 46:11-17.

Lebas, F., Coudert, P., Rouvier, R. and de Rochambeau, H. (1986). The Rabbit Husbandry, Health and Production. FAO, United Nations, Rome. 234-236.

LPHSI, (1990). Livestock and Poultry Heat Stress Indices, Agricultural Engineering Guide. Clemson University Press, Clemson Science, 29634, USA.

Lukefahr, S.D (1982). Evaluation of rabbit breeds and crosses for overall commercial productivity. Ph.D. Thesis, Oregon State University, Corvallis, USA.

Lukefahr, S.D. and Hamilton, H.H. (1997). Heritability and repeatability estimates of maternal performance traits in purebred and crossbred does. *World Rabbit Science*, 3(5): 99-105.

Lukefahr, S.D., Honenboken, W.D., Cheeke, P.R. and Patton, N.M. (1980). Post-weaning performance of New Zealand White purebred and Flemish Giant purebred and terminal cross litters in straight bred and crossbred rabbits. *Journal of Applied Rabbit Research*, 3(4): 13-16.

Lukefahr, S.D., Honenboken, W.D., Cheeke, P.R. and Patton, N.M. (1983). Doe reproduction and pre-weaning litter performance of straight bred and crossbred rabbit. *Journal of Animal Science*, 57 (5): 1090-1098.

Lukefahr, S.D., Honenboken, W.D., Cheeke, P.R. and Patton, N.M. (1984). Genetics effect on maternal performance and litter pre-weaning and post-weaning traits in rabbit. *Animal production*, 38:293-300.

Lukefahr, S.D. and Cheeke, P.R. (1990). Rabbit planning project strategies for developing countries. II: Research applications. *Livestock Research for Rural Development*, 2(3):35-48.

Lukefahr, S.D., Odi, H.B. and Atakora, J.K.A. (1996). Mass selection for 70-day body weight in rabbits. *Journal of Animal Science*, 74:1481-1489.

Marai, I.F.M. and Habeeb, A.A.M. (1994). Thermoregulation in rabbits. *Options Mediterraneennes*: 8, 33–41.

Marai, I. F. M., Ayyat, M. S., Gabr, H. A. and Abd El-Monem, U. M. (1996). Effect of summer heat stress and its amelioration on production performance of New Zealand White adult female and male rabbits, under Egyptian conditions. *Proceedings of the Sixth World Rabbit Congress*, Toulouse, France, vol. 2, pp. 197-208.

Marai, I.F.M., Ayyat, M.S. and Abd El-Monem, U.M. (2001). Growth performance and reproductive traits at first parity of New Zealand White female rabbits as affected by heat stress and its alleviation under Egyptian conditions. *Tropical Animal Health and Production*, 33:1-12.

Marai, I.F.M., Habeeb, A.A.M. and GAD, A.E. (2002). Rabbits' productive, reproductive and physiological performance traits as affected by heat stress: a review. *Livestock Production Science,* 78, 71-90.

Marai, I. F. M., Habeeb, A. A. M. and Gad A. E. (2004). Growth performance traits and the physiological background of young doe rabbits as affected by climatic conditions and lighting regime, under sub-tropical conditions of Egypt. *Proceedings 8th World Rabbit Congress September 7-10, Puebla*, Mexico. 4: 13-15.

Marai, I.F.M., Habeeb, A.A.M and Gad A.E. (2005). Tolerance of imported rabbits grown as meats animals to hot climate and saline drinking water in the sub-tropical environment of Egypt. *Proceedings of the British Society of Animal Science.* 81: 115-123.

Marai, I.F.M., El-Darawany, A.A., Abou-Fandoud, E.I. and Abdel-Hafez, M.A.M.(2006). Tonica dartos index as a parameter of adaptability of rams in sub-tropical conditions of Egypt. *Animal Science (Japan)* 77, 487–494.

Mariana, J.C., Hulot, F., Tomassone, R., Dervin, C. and Poujardieu, B. (1988). Estimate of the average duration of the ovarian follicle growth: A comparative study of two strains of rabbit. *Proceedings of the 4th World Rabbit Congress*. Budapest, Hungary. 1:473-485.

Massaro, D., Owen G. and Massaro G.D. **(**2006**).** Estrogen receptor regulation of pulmonary alveolar dimensions: alveolar sexual dimorphism in mice. *American Journal of Physiology, Lung Cell Molecular Physiology.* Pp 290: L866–L870.

McNiit, J.I. and Moody, G.L. (1990). Effects of month, breed and parity on doe productivity in southern Loisiana. *Journal of Animal Science*, 13:169-170.

Medellin, M.F. and Lukefahr, S.D. (2001). Breed and heterotic effects on postweaning traits in Altex and New Zealand White straightbred and crossbred rabbits. *Journal of Animal Science*, 79: 1173-1178.

Metzger, S.Z., Odermatt, M., Szendro, Z.S., Mohaupt, M., Romvári, R., Makai, A., Biróné Németh, E., Radna,i I., Sipos, L. (2004). Comparison of carcass traits and meat quality of Hyplus hybrid, purebred Pannon White rabbits and their crossbreds. *8th World Rabbit Congress, Puebla City, Mexico.* 12: 56-57.

Mielenz, N., Noor, R.R. and Schuler, L. (2006). Estimation of additive and non- additive genetic variances of bodyweight, eggweight and egg production for quails with an animal model analysis. *Arch. Tierz Dum*., 49: 300-307.

Moses, O., Yakubu, A., Peters, S.O., Ozoje, M.O., Adebambo, O.A. and Imumorin, I.G. (2011). Application of multivariate principal component analysis to morphological characterization of indigenous goats in Southern Nigeria. *Acta agriculture Slovenia*, 98:2-4.

Moura, A.S.A.A.T., Polastre, R. and Carmelo, M.J. (1991). Genetics study of individual performance from weaning to slaughter in selected rabbits. *Journal of Animal Science,* 14:228-294.

Ndjon, M.N. and Nwakalor, L.N. (1998). Estimates of genetic parameters in a mixed population of purebred and crossbred rabbits.I: Repeatability. *Proceedings of Silver Anniversary Conference of the Nigeria Society for Animal production*, Abeokuta. 24:498-499.

Ngapongora, J.M.N., Mbaga, S.H. and Mutayoba S.K. (2004). Study on the growth performance of growing native Muscovy ducks under semi and fully confined rearing systems. *www.husdyr.kvi.dk&U=w. 6:23-25*.

Nieslon, K.S. (1995). Animal Physiology. In: Nielson, Knut (Ed.), Adaptation and Environment, fourth edition. Cambridge University, Press.

Nizza, A. and Moniello, G. (2000). Meat quality and caecal content characteristics of rabbit according to dietary and botanical origin of starch. *World Rabbit Science*, Pp I. 3-9.

Nofal, R.Y., Abd El-Ghany, A.M. and Saleh, K. (2002). Best linear unbiased prediction (BLUP) on some litter traits and muscularity rate of New Zealand White rabbits under Egyptian conditions. *The 3rd Science Conference on Rabbits Production in hot climate*, 8-11 Oct. Hurghada, Egypt, Pp 127-137.

Nwagu, B.I., Iyeghe-Erakpotobor, G.T., Adeyinka, I.A., Oni, O.O., Yahaya, H.K. and Abdulmalik, M.E. (2000). Phenotypic correlation for doe performance and litter traits of purebred rabbits in Shika, Zaria. In: Animal Production in the New Millennium: Challenges and Options. Ukachukwu S.N, Ibeawuchi J.A, Ibe S.N, Ezekwe, A.G, Abasiekong, S.F. Micheal Okpara University, Umudike, Abia State. *Proceedings of the 25th Annual Conference of Nigeria Society for Animal Production*, 19th – 23rd March, 264-265.

Obasi, V.N. and Ibe, S.N. (2008). Influence of additive gene effects on body measurements in the domestic rabbit. *Nigerian Journal for Animal Production*, 35(1):1-8.

Odubote, I.K. and Somade, B.(1992). Genetics analysis of rabbit litter traits at birth and weaning. *Nigerian Journal of Animal Production*, 19:64-69.

Oglesbee, B. (2006). The 5 - Minute Veterinary Consultant: Ferret and Rabbit. Ames, I.A Blackwell, 3: 7-8.

Oke, U.K., Ibe, S.N., Onyiro, O.M. and Nwachi, C. (2003). Influence of age and sex on the productive traits of rabbits in the humid tropics. In : Nigerian Livestock: A Goldmine for Economic Growth and Food Security. Edited by Taiwo, A.A, Raji, A.M, Ogbonna, J.U and Adebowale, E.A.Obafemi Awolowo University, Ibadan, Nigeria. *Proceedings of the Annual Conference of the Nigerian Society for Animal production*, 16th – 20th March, 3: 122-124.

Okoro, V.M.O., Ogundu, U.E. and Egwuekwe, E.E. (2007). Repeatability estimates of pre-weaning litter traits and teat number in non-descript rabbits. *Tropical Journal of Animal science*, 10(1-2):1-4.

Okoro, V.M.O., Ezeokeke, C.T., Ogundu, U.E. and Chukwudum, C. (2008). Phenotypic correlation between body weight and linear body measurement in chinchilla rabbits. In: Repositioning Animal Agriculture for the Realization of National Vision 2020. Edited by Bawa, G.S., Akpa, G.N., Jokthan, G.E., Kabir, M. and Abdu, S.B. Ahmadu Bello University, Zaria. *Proceedings of the 13th Annual Conference of the Animal science Association of Nigeria*, March, 13:2-4.

Orunmuyi, M., Adeyinka, I.A, Ojo, O.A. and Adeyinka, F.D. (2006). Genetic parameters estimates for pre-weaning litter traits in rabbits, *Pakistan Journal of Biological Science* 9 (15), 2909- 2911. http://scialert.net/abstract/ doi=pjbs.2006.2909.2911

Ovimaps, (2012). Ovi location map; Ovi earth imagery date; April 3rd, 2012.

Ozimba, C.E. and Lukefahr, S.D. (1991). Comparison of rabbit types for postweaning litter growth, feed efficiency and survival performance traits. *Journal of Animal Science*, 69:3494-3500.

Peinado, E., Zamora, M., Gallego, J.A. and Sanchez, M. (1988). Growth of rabbits born in extensive conditions. *World Review of Animal production*, 24(1):15-19.

Piccione, G., Assenza, A., Fazio, F., Grasco, F. and Caola, G. (2007). Serum Concentration of calcium phosphate and 1, 25- dihydroxy vitamin $D_3$ in goats (*Capra hyrcus*): daily rhythms. *Journal of Applied Biomedical Sciences*, 5: 91-96.

Pinto, L.F.B., Dacker, I.U, De melo, C.M.R, Ledur, M.C and Coutinho, L.L. (2006). Principal components analysis applied to performance and carcass traits in the chicken. *Animal Resources*, 55: 419 – 425.

Polak, J. and Frynta, D. (2010). Patterns of sexual size dimorphism in cattle breeds support Rensch rules. Evolutionary Ecology, 24: 1255–1266.

Prayaga, K.C. and Eady, S.J. (2002). Performance of purebred and crossbred rabbits in Australia: doe reproductive and pre-weaning litter traits. *Australian Journal of Agricultural Resources,* 53:993-1001.

Prudhon, M. and Selme, M. (1973). Growth in weight of fetuses during gestation in postpartum mated and control rabbits. *Proceedings of the Conference on Poultry and Rabbit Research.* Paris. France. Pp 118-122.

Rajadevan, P. (1984). Evaluation of production and reproduction traits in rabbits. M. Phil. Thesis, postgraduate Institute of Agriculture, University of Peradeniya, Sri lanka.

Randi, E. and Scossiroli, R. E. (1980). Genetic analysis of production traits in Italian, New-Zealand White and Californian pure-breed populations. *2nd World Rabbit Congress., April (1980), Barcelona, Spain.*

Rao, D.R., Sunki, G.E., Johnson, W.M. and Chen, C.P. (1977). Postnatal growth of New-Zealand White rabbits. *Journal of Animal Science* 44:1021-1025.

Saatci, M. and Tulku. M. (2007). Zoometrical body measurements and their relation with live weight in native Turkish geese. *Turkish Journal of Veterinary Animal Science Production*. 6: 25-28.

Saatci, M.H., Aksoy, A.R. and Dewi, I.A. (2003). Application of REML procedure to estimate the genetic parameters of weekly liveweight in one-to-one sire and dam pedigree recorded Japanese quail. *Poultry Science*, 85: 185-190.

Sandford, J.C. (1986). The domestic rabbit: 3rd Edition. Granada Publishing Ltd. New York. Pp 243.

SAS. (1993). Statistical Analysis System, Computer Software, Version 9: Statistics SAS Institute Inc. Cary, NC 27513, NC 27513, USA.

Sedki, A.A., Kaiaty, A.M. and Ashour, G. (2002). Physiological performance indices of rabbits adaptability under untraditional housing conditions. *The 3rd Science Conference on Rabbit Production in hot climates, Cairo*, 8-11 Oct, 351-362.

Selye, H. (1936). A syndrome produced by diverse nocuous agents. *Nature, 138,* 32.

Selye, H. (1976). *Stress in health and disease.* Reading, MA: Butterworth's.

Shahin, K.A. and Hassan, N.S. (2000). Sources of shared variability among body shape characters at marketing age in New Zealand White and Egyptian rabbit breeds. *Annual Zootechnology, 49*:435-45.

Shafie, M.M., Kamar, G. A.R., Borady, A.H.A, Hassanien, M.M. (1970). Reproductive performance of Giza rabbit does under different natural and artificial environmental conditions. *Egyptian Journal of Animal Production*. 24, 167-174.

Shafie, M.M., Murad, H.M., El- Bedawy, T.M. and Salem, S.M. (1994). Effect of heat stress on feed intake, rumen fermentation and waterturnover in relation to heat tolerance response by sheep, *Egypt Journal of Animal Production* 31 (2), 317–327.

Shawer, M.F.K. (1963). A comparative study of production traits between Egyptian and Standard breeds of rabbits. M.Sc, Thesis, Faculty of Agriculture, Alexandria University, Egypt.

Shehata, A.S., Sarhan, M.A. and Gendy, K.M. (1998). Digestibility, thyroid function and growth performance of New Zealand White rabbits as affected by season of the year and age. *Egyptian Journal of Rabbit Science* 8 (2), 141–156.

SPSS (2009). Superior Performing Statistical Software PC version 19.0, Michigan Avenue, Chicago Illinois, USA.

Sri Vidya Devi, D., Ramesh Gupta, B., Narasimha Rao, G. and Satyanarayana, A.(2007).Genetic Study on Pre-Weaning Body Weights of Soviet Chinchilla Rabbits. *Indian Journal of Animal Research*, 41 (4): 261-265.

Swiger, L.A., Harvey, W.R., Everson, D.O. and Gergory, K.E. (1964). The variance of intraclass correlations involving groups with one observation. *Biometrics.* 20: 818-826.

Szabone, W.E. (1997). Changing of body measurements and the correlation of these with body weight from 0-16 weeks of age in geese. *Allathenyeztes es Takarmanyozas*. 46:409-414.

Szendro, Z.S., Kustos, K. and El-Din, S.S. (1988). Hair pulling of Rabbit does and its relationship with their rearing ability. *Proceedings of the 4th World Rabbit Congress*, Budapest, Hungary, 1:173-181.

Tag El-Din, T.H. (1979). A comparative study of reproductive, mortality and body weight in White Baladi and Bauscat rabbits and their crossbred. M. Sc. Thesis, Faculty of Agriculture, Zagazig University, Egypt.

Tawfeek, M.I. and El-Hindawy, M.M. (1991). Reproduction and growth performance of NZW and CAL rabbit as affected by Supplementation with lacto-sace during summer. *Egyptian Journal of Rabbit Science* 1(2): 124-135.

Teguia, A., Ngandjou, H.M., Defang, S. and Tchoumboue, T. (2008). Study of the live body weight and body characteristics of the African Muscovy Duck (*Cairina moschata*). *Tropical Animal Health Production*. 40:5-10.

Testik, A., Baselga, M., Yavuz, C. and Garcia. M.L. (1998). Growth performances of California and line V rabbits reared in Turkey. *2nd Science Conference of Rabbit Production*. *In hot climate,* Adana, Turkey, 159-162

Thakur, R.S., Puranik, P.G. and Jajurley, D.S. (1988). Study of a mammal rabbit as per latest syllabus for B.Sc. 1st year students of Nagpur and Amravit University. New Delhi, India. Pp 256.

Tharwat, E.E., Khadr, A.F., Amin, S.O., Miukawy, M.Y. and Kotby, E.A. (1994). Effect of hot environment on reproductive performance of New Zealand White rabbit. *Options Mediterraneennes*. 8, 613–618.

Thwaites, C.J., Barillse, N.B. and Kasa, W. (1992). Effects of dehydration on the heat tolerance of male and female New Zealand White rabbits. *Journal of Agricultural Science* (Cambridge), 115: 437-440.

Tiamiyu, A.K., Raji, A.M., Babatunde, B.B. and Hamzat, R.A. (2000). Interrelationships among live body measurement in medium breed rabbits. *Proceedings of the 25th Annual Conference of the Nigeria Society for Animal Production (NSAP),* (25):252-253.

Turner, H.N. and Young, S.S.Y. (1969). *Quantitative genetics in sheep breeding*. Macmillan Melbourne, Australia. (C.F. Abd El-Raouf, 1993).

Vaclavovsky, J., Kemerova, N. and Lorek, M.O. (2000). Performance traits in broiler rabbits of Hyla combinations. *Series for Animal Sciences*. 17(2):155-163.

Vargas, S., Larbi, A. and Sanchez, M. (2007). Analysis of size and conformation of native Creole goat breeds and crossbreds used in smallholder agro-silvopastoral systems in Puebla, Mexico. *Tropical Animal Health Production*, 39: 279–286.

Venge, C. (1963). Studies of the maternal influence on the growth in rabbits. *Acta. Agriculturae. Scandinavia.* 3:243.

Von Borell, E.H. (2001). The biology of stress and its application to livestock housing and transportation assessment. *Journal of Animal Science,* 79: E260 –E267.

Willmer, P., Stone, G. and Johnston J. (2000). Environmental physiology of animals. 1st ed. Blackwell Scientific Publications, Oxford. Pp 672.

Whitman, B.D. (2004). *Domestic rabbits and their histories*. Leawodd (Kansas): Leathers Publishing.

Wu, M.C., Huano, C.T., Lee, S.C. and Chang, H.L. (2008). Summer depression in litter performance in New Zealand White rabbits. *Journal of Chinese Society of Animal Science*, 27, 395-408.

Yakubu, A. (2009). Fixing collinearity instability in the estimation of body weight from morpho-biochemical traits of West African Dwarf goats. *Trakia Journal of Sciences*, 7: 61-66.

Yakubu, A. and Ayoade, J.A. (2009). Application of principal component factor analysis in quantifying size and morphological indices of domestic rabbits. *International Journal of Morphology,* Pp 27(4):1013-1017.

Yakubu, A., Ogah, D.M. and Idahor K.O. (2009). Principal component analysis of the morphostructural indices of White Fulani cattle. *Trakia Journal Science*, 7: 67-73.

Yakubu, A. and Akinyemi, M.O. (2010). An evaluation of sexual size dimorphism in Uda sheep using multifactorial discriminant analysis. *Acta Agriculturae Scandinavica* A-Animal Science, 60: 74–78.

Yahaya, H.K. (1993). Performance of New Zealand White, California and Chinchilla rabbits and their crosses in a warm tropical environment. M.Sc. Thesis. Department of Animal Sciences, Ahmadu Bello University, Zaria.

Yamaki, M., Correa, G.S.S, Silva, M.A, Barbosa, L and Torres, R.A (2006). Evaluation of quail carcasss traits using principal componenet analysis. *Proceedings of the 8th World Congress on Genetics Applied to Livestock Production*, August 13 -18, Belo Horizonte, MG, Brazil.

Yamani, K.A. and Farghally, H.M. (1988). Adaptability of rabbits to the hot climates. *Proceedings of 4th World Congress*. *World Rabbit Sciences Association*, 10-14 October, Budapest, Hungary. Pp: 65-69.

Yamani, K.A. (1994). Rabbits meat production situation in Egypt. *1st International Conference on Rabbit Production in Hot Climates*, Cairo, Egypt, 57-64.

Yamani, K.A., El-Maghawry, A.M., Tawfeek, M.I., Soliman, A.M. and Farghaly, H.M. (1994). Evaluation of the performance of three meat rabbit breeds recently introduced to Egypt. 1-Litter weight and related traits. *1st International Conference on Rabbit Production in Hot Climates,* Cairo, Egypt, 236-296.

Zalla, I.L., Hassan, W.A., Maigandi, S.A. and Daneji, A.I. (2007). Breed effect on litter traits in rabbits in semi-arid zones of Nigeria: Preliminary result. *Proceedings of the 32nd Annual Conference of the Nigeria Society for Animal Production*, Calabar, 134-137.