EVALUATION OF PERFORMANCE OF DOE GENETIC GROUPS OF THE DOMESTIC RABBIT AT THE NGONG FARMERS TRAINING CENTER, KENYA

By

DR. LAMECK M. MAMBIRI (BVM – University of Nairobi)

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University of Nairobi,
College of Agriculture and Veterinary Sciences
Faculty of Veterinary Medicine,
Department of Animal Production

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other university.

Signature..................................... Date.04/09/2013..

Dr. Lameck M. Mambiri (BVM)

This thesis has been submitted for examination with my/our approval as university supervisors

Signature..................................... Date.12/09/2013

Prof. Jacob W. Wakhungu (B.Sc., PGD, MSc., PhD)

Signature..................................... Date 16/9/13

Prof. Reuben O. Mosi (B.Sc., MSc., PhD)

Signature .... Date 17/9/13

Dr. Henry Mutembei (BVM, MSc. DSH, PGD, PhD)

DEDICATION

To my late grandfathers, Saul and Alfonse and my late maternal grandmother, Marta for their ever present interest in my academic endeavors and life. I will forever cherish your support.

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LIST OF ABBREVIATIONS

CC	Californian
CV	Coefficient of Variation
DGG	Doe Genetic Groups
FG	Flemish Giant
KNBS	Kenya National Bureau of Statistics
ILRI	International Livestock Research Institute
KW	Kenya White
LPHSI	Livestock and Poultry Heat Stress Index
LSB	Litter Size at Birth
LSW	Litter Size at Weaning
MoLD	Ministry of Livestock and Fisheries Development
NC	Crossbreed of New Zealand White and Californian
NFTC	Ngong Farmers Training Center
NK	Crossbreed of New Zealand White and Kenya White
NW	New Zealand White
PROC GLM	General Linear Models Procedure
REML	Restricted Maximum Likelihood
RH	Relative Humidity
Td	Dry Bulb Temperature
THI	Temperature Humidity Index

ABSTRACT

The domestic rabbit in Kenya is considered a non conventional livestock species despite the country having many rabbits of both local and pure exotic breeds and their crossbreeds. The Government through the Ministry of Livestock Development (MoLD) set up the National Rabbit Breeding and Multiplication Unit situated at the Ngong Farmers Training Center (NFTC) to supply farmers with breeding stock of rabbits of high genetic quality and also offer training and extension services in rabbit husbandry. However, there is little information concerning the performance of the different genetic groups of rabbits in the country. This study was therefore carried out with the aim of assessing and comparing the performance of doe genetic groups and factors (season and parity) affecting this performance of rabbits kept at the Ngong Farmers Training Center, Nairobi, Kenya. Production records (n=862) of 92 does of 6 genetic groups i.e. New Zealand White (NW), Californian (CC) ,Flemish Giant (FG), Kenya White (KW) and the crosses between NW and CC (NC) and NW and KW (NK) were used in this study. Statistical analysis using General Linear Model Procedure (GLM PROC) under Restricted maximum likelihood (REML) showed that there were significant ($p>0.05$) differences between the doe rabbit genetic groups in the open days, age at first successful mating, litter size at birth (LSB), and at weaning (LSW). The respective estimated means for gestation and weaning periods were 31.3 ± 0.05 and 35.6 ± 0.60 days while those for open days and kindling intervals

were 40.6 ±0.87 and 65.5 ± 1.30 days respectively. The highest mean age at first successful mating was recorded in the FG at 6.69 ± 0.51 months and was significantly ($p<0.05$) different from the other DGG. Reproductive longevity was highest in the KW at 32.2 ± 6.85 months followed by the NC at 27.2 ± 10.2 months and both were significantly ($p<0.05$) different from the other DGG. Season 1 had the highest kindling intervals at 71.4 ±1.09 and was significantly ($p<0.05$) different from season 2 and 3 at 64.0 ±2.37 days. The mean number of matings per conception were 1.14 ± 0.02, 1.20 ± 0.02 and 1.18 ± 0.03 in season 1, 2 and 3 of mating respectively with no significant ($p>0.05$) differences between them. Litter size at birth (LSB) ranged from 7.15 ± 0.16 to 7.55±0.16 with no significant ($p>0.05$) differences observed between the seasons. Litter size at weaning (LSW) was lowest in season 1 at 4.76±0.18 and was significantly ($p>0.05$) different from seasons 2 and 3 at 5.24±0.16 and 5.45±0.18 respectively. LSB peaked at parities 3 and 6 at 7.86±0.26 and 7.80±0.33 which were significantly ($p<0.05$) different from parities 1, 2, 4, 5, 7, 8 and 9. Parities 3 and 5 had LSW at 6.21 ± 0.31 and 5.88 ± 0.34 which were higher than and significantly ($p<0.05$) different from parities 1, 2, 4, 6, 7, 8, 9. Parities 4 and 9 had the highest open days at 49.1±2.35 and 47.7± 1.46 days and were significantly ($p<0.05$) different from parities2, 3 and 8. The kindling interval was high in parity 4, 9 and 6 at 80.5±2.38, 78.9±1.45 and 77.8±2.39 days respectively and they were significantly ($p<0.05$) different from parities 2, 3, 5 and 8.

The NZW performed better than the other DGG in terms of LSB, LSW and doe productivity (number of kits weaned per doe per year) at 33.4 while CC and NK were lowest at 26.4 and 28.5 respectively. The CC and the NK performed poorly in comparison to the other DGG. Season of mating and weaning did not adversely affect LSB and LSW whereas Parities beyond parity number 6 had reduced LSB and LSW. This indicates that any of these DGG can be successfully raised at the center all year round and only those considered genetically superior be reared beyond parity 6. Studies involving litter sizes and their weights at birth and at weaning and the weights of the does at service, kindling and weaning of the litter need to be carried out. They will give more information and fair comparisons of the DGG in terms of productivity.

CHAPTER ONE

1.0 INTRODUCTION

The domestic rabbit, a descendant of the European wild rabbit *Oryctolagus cuniculus* belongs to the order lagomorpha after it was removed from the order rodentia because of physiological and anatomical (Sardi and Cooper, 2004) differences like having two more incisor teeth than rodents. It is closely related to the hare and wombat.

Rabbits have several functions, the principle of which is meat production. Rabbit meat is a wholesome, tasty product, high in protein and low in fat, cholesterol, caloric content and sodium. The size of the carcass and the wide range in methods of preparation make it an excellent and economical meat for use during any season of the year (Mcnitt et al., 1996). Rabbit skin is important as a source of fur or in some breeds like the Angora, wool. Its economic value is enhanced by its variety in both size and color (Mcnitt et al., 1996 and lebas et al., 1997). Rabbits' droplets are a good source of manure mostly used in backyard farming (Nalugwa, 1994). In the research and pharmaceutical industry Rabbits are used in the production of e.g. Thromboplastin, a blood anticoagulant in addition to being used as laboratory animals for testing new products yet to be released for use by man or other animals (Mcnitt et al., 1996). Other roles include teaching where they are used for demonstration in learning institutions and youth programs like the 4K clubs that introduce the youth to animal husbandry of which rabbits are an integral part and on the fun part rabbits are kept as pets and displayed in rabbit shows by enthusiasts (Mcnitt et al., 1996).

Rabbits possess various attributes that are advantageous in comparison to other livestock. They can be successfully raised on diets that are low in grain and high in roughage (Mcnitt et al., 1996) without affecting their normal growth and reproductive performance hence an advantage over poultry and swine that rely on more grain therefore competing for food with man. They also convert forage into meat more efficiently than ruminants, a special attribute for developing countries, where population pressures and food shortages are greatest. In many cases, there is abundant local vegetation, which cannot be consumed directly by man but can be fed to rabbits (Nalugwa, 1994). Few does can be kept on a backyard scale whereas this is not feasible for the larger domestic herbivores like cattle which need more space and food and take longer to attain mature weight (Nalugwa, 1994). In addition, the large amount of meat produced per animal necessitates advanced storage like refrigeration.

Another characteristic of rabbits is their high reproductive performance, which has a great potential. They attain sexually mature weight at a rate 30% faster than other animals (Ajayi et al., 2005). Age and body weight determine sexual development, (Rommers et al., 2001) which is around 10 to 12 weeks in medium sized rabbits under normal body condition (Hulot et al., 1982, Deltoro and Lopez 1985). Ovulation occurs at this time and sexual precocity is well developed at four to six months in small and medium sized doe breeds like the New zealand white and five to eight months in the large breeds like Flemish giant, by which time they should have attained 80% of their adult weight (Lebas et al., 1997). Another attribute is their high reproductive performance whereby they are polytochous. They have a short gestation length i.e. 30 days and the ability to rebreed immediately after parturition resulting in a short generation interval in addition to their rapid growth rate.

Despite all the uses and its advantages over other livestock species, the rabbit industry in Kenya is still lagging behind. There is lack of information concerning rabbit breeding and production in Kenya. Also breed suitability studies in different parts of the country for different traits have not been carried out.

1.1 Justification

Kenya has many rabbits, both local, pure exotic breeds and their crossbreeds weighing over three kilograms at four months (MoLD, 2006). With the perennial food shortage in Kenya, a rapidly growing and multiplying rabbit breed under various management systems could go a long way in alleviating the problem by being a source of food and livelihood.

However, despite all the benefits of rabbit production and the government's efforts to set up demonstration multiplication centres (e.g. National rabbit breeding and multiplication unit, Ngong Farmers Training Centre), rabbit farming is neglected and left mainly in the hands of a few highly specialized small scale farmers and Institutions eg International Livestock Research Institute and 4K clubs in primary schools (MoLD, 2006). There is therefore a disjointed system in rabbit production with non-uniform and sometimes undefined breeding objectives and plans hence lack of information to improve rabbit breeding and production in the country. This study is thus designed to provide basic information for purposes of up-scaling the rabbit industry for the benefit of farmers.

1.2 Objectives

The general objective was to evaluate and compare performance of the different doe genetic groups in the domestic rabbit kept at NFTC and the factors affecting this performance

1.2.1 Specific Objectives

(i). Establish the reproductive indices of the doe in the domestic rabbit.

(ii). Compare doe genetic groups for litter traits and reproduction intervals and periods in the domestic rabbit at NFTC, Nairobi Kenya.

(iii). Determine the effects of parity and season on litter traits and doe production and reproduction at NFTC.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 I Introduction

Kenya has many rabbits, weighing over 3kg at 4 months of age. The predominant breeds include Kenya white, New Zealand white, Californian and the Flemish giant and a variety of their crossbreeds. They are principally reared for meat but also as a source of income when sold live. They produce skins and wool, manure, are used in teaching and research and as pets (Nalugwa., 1994). However, rabbit farming is considered as a sideline enterprise and it is evident at the national level where rabbits were not considered for counting during the last population census (KNBS., 2010). Among some communities, rabbit meat is considered as a boy's snack and not food for adults (Nalugwa., 1994). In recent years, the domestic rabbit has gained prominence among commercial farmers owing to its advantages over the larger domestic species. Central to this performance is the doe, whose performance determines the success of the enterprise.

Doe production (and reproduction) is affected by several factors. Of great importance in doe production is litter size which is observed both at birth and at weaning and longevity of the doe. Some of the factors reported to affect these traits are the age and weight at first service, breed (pure, cross or inbred), age/parity and management (feeding, housing, season) – environment (Lebas et al., 1997). Litter size and weights at birth and at weaning are therefore an indication of mothering ability of the doe hence its role in rabbit production (Lebas et al., 1997).

Other important traits in reproduction are the age at first service; inter estrus and kindling intervals and conception and kindling rates. The heritability of growth and carcass traits is high and rapid improvement of these traits through selection (Falconer and Mackay 1996) can be made. The heritability of litter traits and longevity are however low. Generally, there has been comparatively little genetic selection of rabbits of important commercial traits like the carcass quality. Again, there is little commercial development of high performing hybrids, use of well designed crossbreeding schemes or other techniques that are routine in other types of livestock enterprises (Mcnitt et al., 2000).

2.2 Doe performance traits

2.2.1 Litter size

The doe in rabbits is known to be polytochous and the number of kits born and raised to weaning is an indicator of doe performance (Mcnitt et al., 1996). Litter size at birth and at weaning has been the objective of selection in several studies involving rabbit populations (Baselga et al., 1992; de Rochambeau et al., 1994, 1998; Gomez et al., 1996). However, response to selection, when estimated, has been slow (de Rochambeau et al., 1994; Garcia and Baselga, 2002a, b) because of their low heritability (Baselga et al., 1992). Litter size at birth is highly dependent on ovulation rate, uterine capacity and embryonic or fetal survival in the doe (Christenson et al 2000., Blasco, 1996 and Argente et al., 2003), while litter size at weaning depends on litter size at birth, nest quality and survival rates of the litter (Lebas et al., 1997). Khalil (1993) reported LSB and LSW as 7.1 and 5.3 respectively for NW and 6.7 and 4.99 kits for the CC. Elsewhere Laxmi et al., (2009) reported 5.76 and 4 for the NW and 6.08 and 3.85 for the FG. These results and those from other studies vary from even the same genetic group

2.2.2 Reproductive Longevity

Longevity, a non-traditionally studied trait, is defined as the age at which a doe either dies or is culled from the production herd (Lukefahr and Hamilton, 2000). Long living animals able to maintain a high rate of reproductive performance during successive lactations are of great interest in animal production to reduce the replacement cost of the animals and in terms of animal welfare (Theilgaard et al., 2007). Piles et al., (2006) described reproductive longevity as the period between the age at first successful mating, assessed by pregnancy diagnosis and at first kindling to the time the doe is culled or dies or the ability of the female to delay involuntary culling. Other studies were carried out involving number of litters/ parturitions or length of life (Youssef et al., 2000 and Sanchez et al.,

2008) or number of matings or age at culling (Lukefahr and Hamilton, 2000). Breed differences in doe reproductive longevity would affect cumulative litter production and replacement costs that impact herd profitability. In meat rabbit production, the doe replacement rate is about 120% (Rafel et al., 2001) with about 50% of the dead or culled does replaced during their first 3 production cycles (Rosell, 2003) or at between 1 to 2 years to be replaced by a new generation (Piles et al., 2006). At this age, the quality of the carcass is deemed to be of good quality. The main problems associated with high replacement rate are the replacement cost of the does, the greater frequency of less mature females (young does are still growing and are less immunologically mature at parturition, showing lower litter size and more health problems), and sometimes the management and pathological problems related to introduction of animals from other farms (Piles et al., 2006). All of these considerations lead to a strong interest in increasing reproductive longevity, defined as the ability of the female to delay involuntary culling. Despite its importance, longevity has not been included in rabbit selection programs. Theilgaard et al (2007) reported the LP line of the NW to attain parities of above 25 and suggested its use in breeding programs to harness this trait.

The difficulty in improving longevity through conventional breeding methods is mainly due to its low heritability and the time needed to obtain relevant information. However, in mice, it has been shown that reproductive life and number of parities can be improved by selection on phenotypic performance (Farid et al., 2002).

2.3 Factors affecting doe performance

2.3.1 Parity

Studies concerning parity i.e. previous exposure to litter, have been carried out and they show that experience with the young may influence subsequent parental behavior and development of the litter through a process that involves learning and or hormonal priming. Wang and Novak (1994) showed that parity seems to have qualitative and quantitative influences on maternal behavior. Multiparous mothers exhibit increased maternal responsiveness to the young, and this behavior is relatively stable across the pre-weaning stages as compared to the primiparous mothers (Carlier and Noirot 1965; Bridges 1978 and Wright; Bell 1978). Litter development is also affected by the history of experience of the parent where litters from the multiparous does are usually heavier and develop faster than those from primiparous does (Wright and Bell, 1978; Myers and Master, 1983; Ostermeyer and Elwood, 1984).

2.3.2 Breed/genetic group

Several studies have shown breed or genetic group differences in doe performance in terms of age at first successful mating, longevity and litter survival rates from birth to weaning (Mcnitt and Lukefahr, 1990., Ozimba and

Lukefahr, 1991., Hamilton et al., 1997). Large breeds e.g. FG take longer to attain sexual maturity at between 6 to 8 months (Mcnitt et al., 1996 and Lebas et al., 1997) compared to small and medium sized breeds like the NW. Khalil (1993) found the NW to raise more and heavier kits from birth to weaning compared to the CC.

2.3.3 External environmental factors

There are limited genetic studies in the tropics where climate, diet management and stock sources differ markedly from the temperate countries (Mcnitt et al. 1996). Rabbit populations in tropical environments have heterogeneous history involving multiple breed introduction and crossings that might explain the higher heritabilities observed in the various doe production traits (Lebas et al., 1997).

Seasonal variation in conception rates, total litter size at birth and kits born alive were reported in the USA (Ross et al., 1961, Sittman et al., 1964). Mcnitt and Lukefahr, (1983) also noted seasonal effects on reproduction in rabbits in Oregon, USA and Malawi. Abdel-Samee (1995) and Marai et al., (2001) reported the effects of heat stress on reproductive performance of rabbits in Egypt.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 The study site

The national rabbit breeding and multiplication unit is located within the Ngong farmers training center, an agricultural training institution set up by the ministry of livestock development on the southern outskirts of Nairobi. The center produces suitable breeds for meat production, sells breeding stock to interested farmers and trains farmers and extension officers on rabbit management. It is located in an area that receives annual rainfall of between 900mm - 1400mm per year and ambient temperatures of between 10°C at night and 28°C during the day in the warm seasons.

3.2 Rabbit population

The New Zealand White (NW), Californian (CC), their crossbreed (NC), Flemish giant (FG), Improved local (NK) and Kenya white (KW) genetic groups were kept at the center between the years 1984 and 2004. The Kenya white is the most common rabbit breed in Kenya that assembled genes from the European breeds introduced in Kenya in the early 20th century (Nalugwa, 1994). It is a small breed (adults weigh about 3kg) with various colors though the most common is white.

They have black eyes and pointed ears. The bucks kept at the center during this study were CC, FG, NZW and KW genetic groups. Plates 1, 2 and 3 show Californian, Flemish giant and New Zealand white breeds.

PLATE 1. The Californians are white rabbits with black and dark brown ears, nose, feet, legs and tail. Adults weigh about four and a half and five kilograms. It is suitable for commercial rabbit meat production.

PLATE 2. The Flemish Giants vary from dark steel grey to golden brown in color. Their underside and tips of their feet are white. This is a giant breed with adults weighing over 6.5 kilograms.

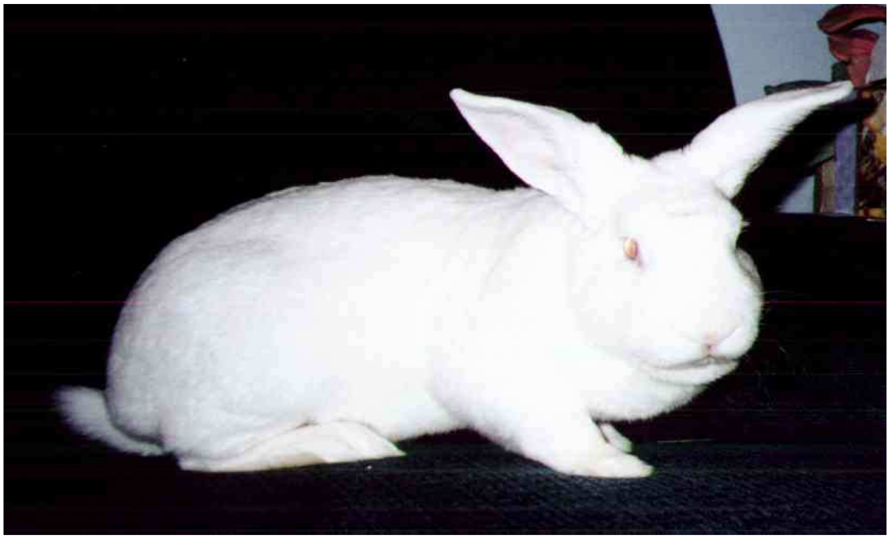

PLATE 3. The New Zealand whites are easily distinguished by their white fur and pink eyes with a relatively large and solid body. They have erect ears and adults weigh about 5 to 5.5 kilograms

Table 1 shows the number of each doe genetic group in this study

Table 1. Number of does per genetic group in the periods 1984-2004 at NFTC,Kenya.

Doe Genetic Group	Total
New Zealand white	39
Californian	19
Flemish Giant	13
Kenya white	7
New Zealand white x Californian cross	2
New Zealand white x Kenya white cross	12
Total	92

3.3 Management of the rabbits

3.3.1 Housing

The rabbits were kept indoors in a shed made of concrete floor and dwarf wooden walls. The upper half of the wall was covered with wire netting to facilitate ventilation and natural lighting whereas the roofing was done by iron sheets. Bucks were penned individually in wire cages raised above the floor and each cage was fitted with a metal feeder and semi automatic drinkers. Weaners were penned in group cages of 5 to 7 to which was provided an extra feeder. Each breeding doe was allocated a cage like the bucks´ but in addition a kindling box was attached to the cage. Grass straw lined the floors of the kindling boxes to facilitate nesting and keep the kits warm, (MoLD 2006).

3.3.2 Feeding

The does were fed on a pelleted commercial diet that is placed in metal feeders. The chemical composition of the diet is shown in Table 2. The feeders could hold up to a kilogram of feed and the does were allowed unlimited access to the feed. Occasionally, the rabbits were given a mixture of plants like Black Jack (*Bidens bidens*), Mexican marigold (*Tagetes minuta*), Pig weed (*Amaranthus spp*), Chick weed (*Stellaria media*), Kale (*Brassica oleracea*), Lucerne (*Medicago sativa*) and sweet potato vines (*Ipomoea batatas*) to supplement the concentrates. The cages were also fitted with nippled semi automatic drinkers and the does were allowed free access to clean drinking water (Nalugwa, 1994).

Table 2 shows Chemical composition of the pelleted commercial diet for rabbits at NFTC.

Table 2. Proximate composition of the commercial pelleted diet fed to the does at NFTC

Nutrient	Crude Fiber	Crude Protein	Ether Extract	Calcium	Phosphorus
% Composition	11	18	4.8	0.7	0.4

Source: MoLD (1994).

3.3.3 Reproduction management

At most 20 breeding does of different genetic groups i.e. NW, CC, FG, KW, NC and NK (Table 1) were kept at the center at any one time and were bred the whole year round. At mating the doe was taken to the buck's cage and natural service was preferred to Artificial Insemination which was only used when there were an insufficient number of bucks. Heat detection was done by checking for redness and swelling of the vulva while pregnancy diagnosis was done by abdominal palpation and those found not pregnant after 2 weeks were mated again at between 28-31 days after the initial mating. The kits were weaned at 5-6 weeks of age after which the does were mated 2 days later (Nalugwa, 1994).

3.4 Data processing and analysis

3.4.1 Doe records.

Doe information obtained from the record cards were entered into an Ms excel worksheet. It included; Doe identity, her sire and dam, parity number, date of service, buck used in that service, date of kindling, kits born alive, kits born dead, number of kits weaned and date of weaning.

There were six doe genetic groups viz NW, CC, FG, KW, NC and NK and they were assigned codes 1, 2, 3, 4, 5 and 6 respectively while the bucks were of NW, CC, FG and KW genetic groups and were assigned codes similar to the does.

Parities numbers ranged from 2 in some does to as high as 22 in others. Each parity was assigned a code corresponding to its number i.e. parity 1 was assigned code 1with the rest following. However, few does attained parities beyond parity 9. To avoid confounding the effects of the does and these parities, any parity beyond the parity 9 were absorbed into code 9.

Production and Reproduction periods and intervals of the doe were derived from the data using SSC STATS an Ms Excel® statistical add-in and they included; age at first successful mating and at each parity, gestation, weaning, total number of parities and those weaned successfully, reproductive longevity in months (period from first kindling to final culling of the doe) and kindling interval. Litter traits obtained were litter size at birth (LSB) and at weaning (LSW) in each parity, number of kits weaned per doe per year (a year meaning 365 days) and pre weaning litter survival.

3.4.2 Climatic condition

Weather records affecting the center between 1984 and 2004 were obtained from Kenya Meteorological Department headquarters (Dagoretti corner meteorological sub-station). They included minimum and maximum monthly rainfall and ambient temperature and monthly relative humidity (RH) measured at 0600h and 1200h GMT.

The months that had temperatures below the 18°C (mean for the period of study) were considered cold (June, July and August). The rest were considered warm. Likewise, months that recorded average monthly rainfall of below 88.9mm were considered to be dry (January, February, June, July, August, September and October) while those above it wet. The Coefficients of variation (CV) calculated for temperature and RH constituted less than 30% of their respective values, an indication of their stability within the months during this period. However, rainfall had very high CV, with some being more than twice their respective values hence this showed high variation within these months across the years. Dry months usually have CVs greater than their respective values as opposed to wet months.

Table 3 shows average rainfall, temperature, Relative humidity and their CV for the months in a year.

TABLE 3: Temperature, Rainfall, Relative humidity (RH %) and their Coefficients of variation (CV%) for the months in a year **at NFTC Nairobi, Kenya.**

Months	Mean	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature°C	18.7	19.4	20.0	20.4	19.7	18.8	17.3	16.5	16.8	18.7	19.3	18.9	18.8
CV%	4.20	5.00	6.00	4.50	3.50	3.50	4.00	5.50	4.50	4.00	4.00	2.00	4.00
Rainfall mm	88.9	77.6	44.9	109	231	170	35.8	17.2	22.4	22.9	52.7	177	106
CV%	90.5	150	107	79.0	59.0	59.0	84.0	131	96.0	103	77.0	59.0	103
RH %	65.6	60.6	53.1	61.3	70.2	72.8	71.9	71.8	69.6	62.3	61.8	72.5	68.1
CV%	11.2	14.5	16.5	13.5	11.5	8.50	9.50	8.50	10.0	13.0	12.5	6.50	10.0

Definitive seasons were found to be 3 after combining average monthly rainfall amounts and calculating the Temperature-Humidity Indices using the formula of LPHSI, (1990).

THI = td – (0.55 – 0.0055 RH) x (td – 58),

Where;

THI = Temperature-Humidity Index,

Td = Dry bulb temperature (°F)

RH = Relative Humidity, (RH%/100)

Therefore, January, February, September and October were considered warm and dry and assigned code 1 while March, April, May, November and December, warm and wet and assigned code 2. June, July and August were cold and dry months and were assigned code 3.

Figure 3 illustrates the seasons as classified using rainfall and THI values.

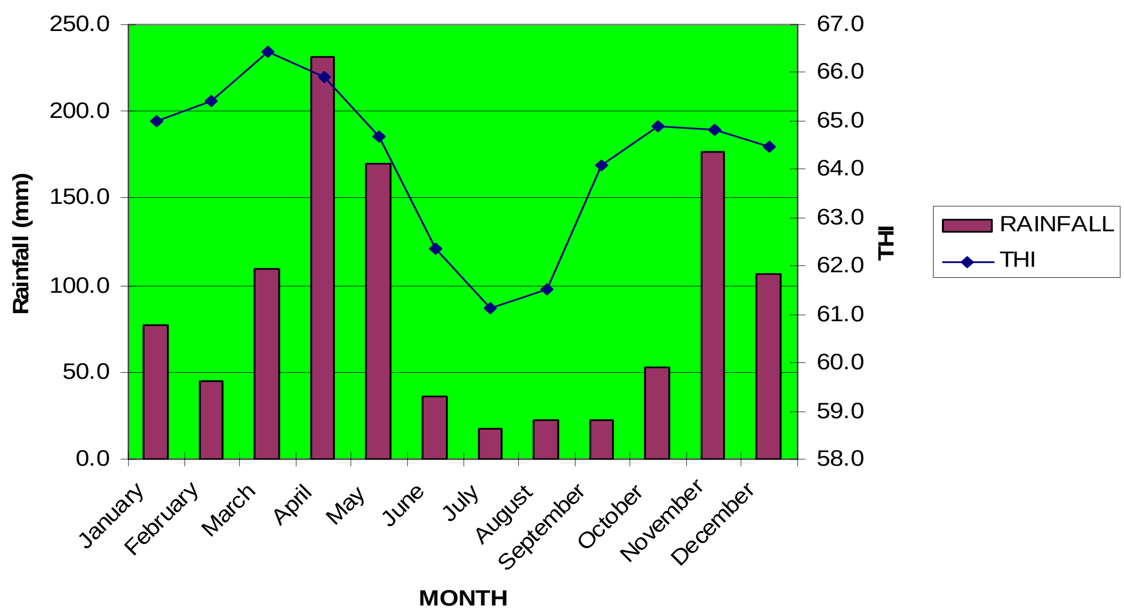

FIGURE 1: Average Rainfall amount and THI values between for months in a year at NFTC Nairobi, Kenya.

3.4.3 Data analysis

The litter traits obtained and doe production (and reproduction) periods and intervals derived were subjected to ANOVA under Restricted Maximum likelihood (ReML) using GENSTAT with the fixed effects model;-

$Y_{ijkmn} = \mu + S_i + G_j + P_k + Se_m + E_{ijklm,}$

Where

Y_{ijkm} = observation on the ijkmth doe.

μ = underlying constant in all observations values of Y_{ijkmn}

D_i = effect of the ith doe genetic group (i = 1 (NW), 2 (CC), 3 (FG), 4 (KW), 5 (NC), 6 (NK))

S_j = effect of the jth buck genetic group (j = 1 (NZW), 2 (CC), 3 (FG), 4 (KW)

P_k = effect of the kth parity (k = 1, 2, 3, 4…9)

Se $_m$= effect of the mth season of mating, kindling or weaning (m = 1 (Jan, Feb, Sep, Oct), 2 (Jun, Jul Aug), 3 (Mar, Apr, May, Nov, Dec)

E_{ijkm} = random residual error N $(0, \sigma\ e)$

Interactions from factors found significant ($p<0.05$) were considered in a subsequent final model after the first successful trial run without interactions of these factors.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Doe genetic groups

4.1.1 Reproductive performance

The means and standard errors of gestation, weaning, open days and kindling interval in days according to the doe genetic groups are shown in Table 4.

Table 4. Production and **(**Reproduction) intervals and periods of the, doe in days, at NFTC, Nairobi Kenya.

Doe Genetic Group	Gestation (days)	Weaning (days)	Open days	Kindling Interval (days)
New Zealand white	31.5 ± 0.08^a	36.7 ± 0.85^a	37.0 ± 1.48^a	63.9 ± 1.98^a
Californian	31.2 ± 0.13^a	32.2 ± 1.37^b	41.8 ± 2.67^a	68.8 ± 3.27^a
Flemish giant	30.7 ± 0.13^a	37.7 ± 1.53^a	41.3 ± 2.63^a	67.5 ± 3.47^a
Kenya white	31.3 ± 0.14^a	$39.7 \pm 1.91_a$	33.3 ± 2.80^b	60.6 ± 3.87^a
Newzeand white x Californian cross	32.5 ± 0.43^a	40.6 ± 3.07^a	40.7 ± 6.34^a	69.1 ± 8.36^a
New Zealand white x Kenya white cross	31.4 ± 0.14^a	31.7 ± 1.94^b	37.5 ± 2.49^a	65.2 ± 3.28^a
Overall mean	31.3 ± 0.05	35.6 ± 0.60	38.5 ± 1.00	65.5 ± 1.30

Means with similar superscripts in the same column do not differ significantly (P<0.05)

The overall mean gestation period was 31.3 ± 0.05 days. It ranged from 30.7 ± 0.13 in the FG 32.5 ± 0.43 days in the NC with no significant ($P>0.05$) differences observed between the DGG. The NK had the lowest weaning period followed by the CC and both were significantly ($p<0.05$) different from the other DGG as shown in Table 4. The average kindling interval was 65.5 ± 1.30 days and was not significantly ($p>0.05$) different between the DGG. The open days viz the number of days between kindling and the next successful mating were highest in the CC at 41.8 ± 2.67 days) followed by the FG and NC respectively and these three DGG were significantly ($p<0.05$) different from the remaining genetic groups that had the KW (33.3 ± 2.80 days) as the lowest. Gestation is a physiological state and constant. It is not dependent on the breed and management but rather by the species in this case the rabbit, which ranged between 28 to 30 days (Chineke, 2006 and Fayeye and Aroninde, 2008). Weaning period and open days (a component of kindling interval) are normally determined by management e.g. 5 to 6 week weaning period, after which does were taken to the buck for mating (2 days later). Pregnancy diagnosis at 2 weeks and remating of non-pregnant does 4 weeks after initial mating could have led to these extended periods. Also, the long weaning periods meant that lactation was extended and this might have led to lower sexual receptivity (Brecchia et al., 2008) in the does. Other studies, (Rafel et al., 2001 and Rosell 2003) reported weaning periods of 3 to 4 weeks and 10 open days in the NW under intensive reproduction rates. Lebas et al. (1997) described values in this study as extensive reproduction rates in which open days ranged between 28 to 34 days, weaning period of between 35 and 42 days and kindling intervals of between 44 to 65 days.

Table 5 shows mean age at first successful mating and longevity in months for the doe genetic groups.

Table 5. Age at first successful mating and reproductive longevity of the doe genetic groups in months at the NFTC

Doe Genetic Group	Age at first successful mating	Longevity
New Zealand white	5.60 ± 0.24^{a}	20.16 ± 1.94^{a}
Californian	5.95 ± 0.41^{a}	19.5 ± 1.91^{a}
Flemish giant	6.69 ± 0.51^{b}	17.7 ± 2.97^{a}
Kenya white	5.29 ± 0.20^{a}	$32.2 \pm .6.85^{b}$
New Zealand x Californian cross	5.02 ± 0.02^{a}	27.2 ± 10.18^{b}
New Zealand white x Kenya white cross	6.05 ± 0.40^{a}	23.7 ± 3.97^{a}
Overall mean	5.85 ± 0.16	21.4 ± 1.28

Means with similar superscripts in the same column do not differ significantly (P<0.05)

The overall means for the age to first successful mating and longevity were 5.85 ± 0.16 and 21.4 ± 1.28 months respectively (Table 5). The age to first successful mating ranged from 5.02 ± 0.02 in the NC, the lowest to 6.69 ± 0.51 in the FG. The age at first successful mating in the FG was significantly ($p<0.05$) different from the other DGG. The FG is considered a large breed of rabbits and good for commercial meat production. Large breeds of rabbits take a longer period (6 to 8 months) to reach sexual maturity (Mcnitt et al., 1996 and Lebas et al., 1997) compared to small and medium sized breeds like the NW and CC at 4 to 6 months (Lebas et al., 1997).

Lukefahr et al (1983) had the NZW and Xiccato et al (1999) had a hybrid maternal line being bred earlier than the 168 days (5.6 ±0.24 months) for the same breed in this study. Reproductive longevity i.e. the number of months between the first successful kindling and the day the doe exits the rabbitery, was highest in the KW at 32.2 ± 6.85 months followed by the NC at 27.2 ± 10.18 and they were significantly ($p<0.05$) different from the other DGG that had the lowest, the FG, at 17.7 ± 2.97 months (Table 5). The reproductive longevity of the Kenya white could be attributed to the fact that it is well adapted to the local climatic conditions and moderate standards of management at the center compared to the other pure exotic breeds. On the other hand the short longevity observed in the purebreds could be attributed to management selling them while they still had good quality meat or preference of buyers over their crosses and KW. The values for KW and NC approximate those reported by Barkok and Jaouzi (2000) of 31 months for Zemmouri rabbits but much higher than those reported by Rosell (2003) of 12 months for NW.

4.1.2 Litter size

The average litter size at birth and at weaning and the number of kits weaned per doe per year are presented in Table 6.

Table 6. Average litter size at birth and at weaning and Number weaned per doe per year at the NFTC

Doe Genetic Group	litter size at birth	Litter size at weaning	Parities per year	Number weaned/doe/yr
New Zealand white	7.68 ± 0.15^{b}	5.78 ± 0.18^{b}	5.90 ± 0.22^{b}	34.1 ± 0.18^{b}
Californian	6.70 ± 0.21^{a}	4.78 ± 0.26^{a}	5.52 ± 0.34^{b}	26.4 ± 0.25^{a}
Flemish giant	8.24 ± 0.25^{b}	5.87 ± 0.30^{b}	5.47 ± 0.17^{b}	32.1 ± 0.25^{b}
Kenya white	7.20 ± 0.25^{b}	5.87 ± 0.34^{b}	5.51 ± 0.24^{b}	32.3 ± 0.26^{b}
New Zealand white x Californian cross	8.81 ± 0.47^{c}	6.69 ± 0.60^{c}	5.04 ± 0.10^{a}	33.7 ± 3.31^{b}
New Zealand white x Kenya white cross	7.48 ± 0.26^{b}	5.10 ± 0.33^{b}	5.58 ± 0.31^{b}	28.5 ± 0.53^{a}
Overall mean	7.52 ± 0.10	5.52 ± 0.11	5.67 ± 0.13	33.4 ± 0.41

Means with similar superscripts in the same column do not differ significantly ($P<0.05$)

From Table 6, total LSB (number of alive and stillborn kits) was highest in the NC at 8.81 ± 0.47 followed by the FG and these 2 were significantly ($p<0.05$) different from the other DGG which had the CC at 6.7 ± 0.21 being the lowest. LSW was lowest in the CC at 4.78 ± 0.26 whose value was significantly ($p<0.05$) different from the other genetic groups. The parities per year (derived from a 365 day year divided by the average kindling interval for each genetic group) was lowest in the NC at 5.04 ± 0.10 and was significantly ($p<0.05$) different from the other DGG. The number of kits weaned per doe per year (a product of average litter size at weaning and average parities per year for each doe genetic group) was lowest in the CC followed by the NK and these two DGG were significantly ($p<0.05$) different from the others led by the NZW at 34.1 ± 0.18 followed by the NC, KW and FG at 33.7± 3.31, 32.3± 0.26 and 32.1± 0.25 respectively. The low LSB in the CC could be due to low ovulation rate, smaller uterine capacity or that few embryos or fetuses survived in the uterus during pregnancy. The subsequent low LSW could be attributed to low LSB, inferiority of the CC in maternal ability (lactation, maternal behavior and nesting) and low survival rates of the litter. As a consequence, the number of kits weaned per doe per year was low in the CC. In rabbit breeding, does are selected with the main trait of focus being LSB and LSW (Sanchez et al 2006). From Table 6, on average, the means of LSB and LSW were significantly ($p<0.05$) different between the DGG and were higher than those reported by Iraqi et al (2006) of 6.7 kits born and 5.8 kits weaned by the NW and gaballi rabbits. Laxmi et al (2009) reported a figure of 5.52 and 3.81 for LSB and LSW respectively for the FG and NW. They were however lower (8.7 and 6.09 for LSB and LSW) as reported by Youssef et al (2008) in the NW. The number of kits weaned per doe year (productivity) approximates the figures (20 to 32 kits) suggested for the tropics by Lebas et al (1997). Lukefahr and Cheeke (1990) reported 4 crops per year of 6 kits each and El Raffa (2004) reported an estimate of 24 kits per doe per year.

Figure 2 shows the pre-weaning litter survival and mortality rates of the doe genetic groups at NFTC.

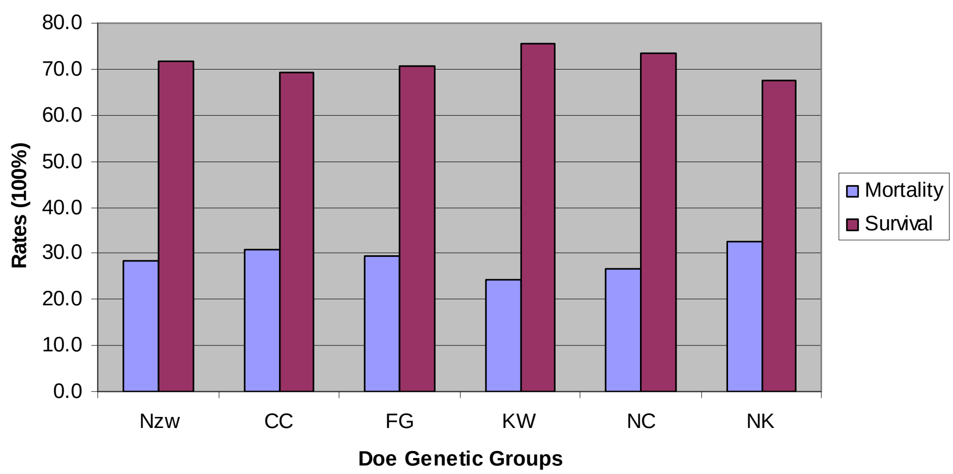

FIGURE 2: Pre weaning Litter Survival and Mortality Rates

Pre-weaning litter survival viz the total number of kits weaned over the number of kits born at the rabbitery during the study expressed as a percentage ranged from 65.6% in the NK to 74.8% in the KW, though significant ($p>0.05$) differences were not observed between the doe genetic groups. The pre weaning litter survival is lower than those reported in other studies. Zerouki et al (2005) reported pre weaning survival rates of between 84% and 89%. Other studies (Bonnano et al., 2008; Brecchia et al., 2008; Matics et al 2008) recorded survival rates of above 80%. These low values can be attributed to the semi intensive system of production adopted by NFTC as compared to the intensive systems cited. Here, the weaning periods of between 5 to 6 weeks at NFTC were longer than those of 4 weeks used in most studies (Iraqi et al., 2006; Youssef et al., 2008; Sanchez et al., 2006) in intensive systems. Also, the method of estimation used in this study where litters with complete mortalities at weaning and total number of kits born (alive and dead) could be a contributing factor to the lower estimates.

4.2 Effects of seasons on doe performance

4.2.1 Litter size

Table 7 shows means and their standard errors of matings per conception (Number of times the doe is taken to the buck before conceiving), Lsb and Lsw as per the three seasons of mating.

Table 7: Matings per conception, litter size at birth (LSB) and at weaning (LSW) of the doe per season of mating at NFTC

Season	Matings per conception	LSB	LSW
1 (warm and dry)	1.14±0.02 [a]	7.12±0.15 [a]	4.76±0.18 [a]
2 (warm and wet)	1.20±0.02 [a]	7.20±0.14 [a]	5.24±0.16 [b]
3 (cold and dry)	1.18±0.03 [a]	7.55±0.16 [a]	5.45±0.18 [b]
Overall mean	1.17±0.03	7.28±0.14	5.15±0.16

Means with similar superscripts in the same row do not differ significantly (P<0.05)

Results in Table 7 show that Seasons had no effect on matings per conception and LSB. Season 3 had the highest LSW, followed by season 2 and 1 at 5.45, 5.24 and 4.76 kits respectively. There was a significant ($P<0.05$) difference in LSW between season 1 and seasons 2 and 3. This could be because of the kits being born in season 2 (warm and wet) but being reared in the cold and dry season 3 (Figure 2). Fayeye and Ayorinde (2008) reported season not to affect litter size at birth and percent survival of the kits whereas Marai et al (2001) reported that rabbits exposed to heat stress had reduced conception rates and LSW. Abdel-Samee (1995) noted the comfort zone of rabbits to be between the temperatures of 13-20^{o} C and THI values of below 82 which is reflected in this study.

4.2.2 Reproductive performance

Table 8 shows effect of the seasons on the production (reproduction) intervals and periods of the doe during different seasons.

Table 8: Mean values of production and reproduction parameters of the doe, in days, during different seasons at NFTC, Kenya.

Season	Gestation (days)	Weaning (days)	Open days	Kindling interval
1 (warm and dry)	31.2±0.09[a]	32.3±1.00[a]	42.3±1.45[a]	71.4±1.71[a]
2 (warm and wet)	31.2±0.07[a]	35.3±0.90[a]	40.9±1.36[a]	69.4±1.66[a]
3 (cold and dry)	31.3±0.09[a]	37.3±0.90[b]	38.3±1.77[a]	64.0±2.37[a]
Overall mean	31.3±0.05	34.8±0.55	40.6±0.87	68.6±1.09

Means with similar superscripts in the same row do not differ significantly (P<0.05)

Gestation period ranged from 31.2 days in season 2 to 31.3 days in season 3. There were however no significant (P>0.05) differences observed between the seasons. Weaning period was highest in season 3 at 37.3±0.90 and this was significantly (P<0.05) different from seasons 1 and 2 respectively at 32.3±1.00 and 35.3±0.90. Open days ranged from 38.3±1.77 to 42.3±1.45 days but Significant (P>0.05) differences were not observed between the seasons. Since the open days have a high co-linearity with kindling interval, kindling interval was longer when open days were long and shorter when open days were short. Gestation is a physiological stage and is constant irrespective of the season. The long weaning period in season 3(cold and dry) could be due to management allowing the young kits to nurse longer and keep them warm with their does thus increasing their chances of survival. Akpo et al.,(2008)reported season not to affect production intervals in a local rabbit population. Other studies (Abdel-Samee, 1995, Marai 2002 and El raffa 2004) reported heat stress (THI>82) to affect rabbits while Lebas et al., (1997) attributed ceasing of reproduction in the doe to the cold winter in temperate countries.

Table 9 shows the LSB and LSW in the different parities at NFTC.

Table 9. Mean Litter size at birth (LSB) and at Weaning (LSW) in different parities of the doe at NFTC.

Parity	Number	LSB	LSW
1	92	$7.10^{a}\pm0.21$	$5.21^{a}\pm0.28$
2	92	$7.40^{a}\pm0.24$	$5.46^{a}\pm0.27$
3	84	$7.86^{b}\pm0.26$	$6.21^{b}\pm0.31$
4	83	$7.45^{a}\pm0.31$	$5.25^{a}\pm0.33$
5	72	$7.61^{a}\pm0.34$	$5.88^{b}\pm0.34$
6	66	$7.80^{b}\pm0.33$	$5.34^{a}\pm0.41$
7	64	$7.25^{a}\pm0.31$	$5.27^{a}\pm0.36$
8	57	$7.58^{a}\pm0.34$	$5.53^{a}\pm0.42$
9	251	$6.78^{a}\pm0.16$	$4.20^{a}\pm0.42$

Overall mean		7.28±0.28	5.15±0.35
Means with similar superscripts in the same column do not differ significantly (P<0.05)			

LSB had an increasing trend from parities 1 to 3 at 7.10±0.21, 7.40±0.24 and 7.86±0.26 kits respectively before dropping at parity 4 to rise again in parity 5 and 6. Parities beyond 7 had a decreasing trend. Significant (P<0.05) differences in LSB were observed between parities 3 and 5 and the other parities. LSW first peaked in parity 3 at 6.21 kits and at parity 5 at 5.88 kits. There were significant (P<0.05) differences in LSW between these parities and the other parities. The lower LSB at first and second parity as compared to subsequent parities in this study could be because the does were still growing and had not attained their adult sizes and weights. This combined with additional demands for maintaining gestation and lactation could have lowered prolificacy and ovulation potential in the growing rabbits. Rabbits are known to attain adult weight at parity number 3 (Lebas et al 1997). Akpo et al (2008) and Das and Yadav (2007) reported the same trend in the first three parities though with lower figures. Fayeye and Aroninde (2008) however had lower estimates and noted a decreasing trend in LSB from parity 1 to 4. Fluctuations in LSB in subsequent parities could have been due to body condition as affected by among others, Reproduction rates, previous LSW and nutrition. The increase in LSW from parity 1 to 3 could be due to learning or experience of the doe in the preceding litters, LSB, viability of the kits and lactation (Wang and Novak 1994; Ostermeyer and Elwood 1984). The low values seen in parity 4 and beyond could be because of the ageing of the does and depressed lactation. This could be attributed to reduced inability of these does to mobilize body reserves towards lactation (Theilgaard et al., 2007) in the latter parities and replacement of glandular tissue with fibrous tissue in the mammary glands (Lebas et al., 1997).

Table 10 shows the average reproduction parameters of the does for the three seasons.

Table 10: Reproduction parameters in different parities of the doe at NFTC Nairobi, Kenya

Parity	Gestation	Weaning	Open days	Kindling interval
1	31.05^{a}±0.17	36.09^{a}±1.71	0	0
2	31.21^{a}±0.16	37.04^{a}±1.45	43.40^{a}±2.15	74.60^{a} ±2.15
3	31.31^{a}±0.17	40.00^{a}±1.49	40.70^{a}±2.07	72.00^{a} ±2.04
4	31.3 ^{0a}±0.17	34.40^{a}±1.79	49.10^{b}±2.35	80.50^{a} ±2.38
5	31.50^{a}±0.14	37.81^{a}±1.50	43.30^{a}±2.88	74.80^{a} ±2.89
6	31.28^{a}±0.18	31.75^{b}±2.11	46.54^{b}±2.00	77 .80^{a}±2.39
7	31.51^{a}±0.15	33.13^{b}±1.97	45.19^{b}±3.06	76.70^{a}±3.06
8	31.24^{a}±0.15	33.42^{b}±2.29	42.90^{a}±3.17	74.10^{a}±3.21
9	31.15^{a}±0.09	32.43^{b}±1.11	47.70^{b}±1.46	78.90^{a}±1.45
Overall mean	31.3±0.40	34.0±0.01	45.5 ±0.04	76.8±0.05

Means with similar superscripts in the same column do not differ significantly ($P<0.05$)

Gestation length ranged from 31.05±0.17 to 31.51±0.15 with no significant (P>0.05) differences observed between the parities. Weaning period ranged from 31.8 days in parity 6 to 40.0 days in parity 3. Parities 1, 2, 3, 4, and 5 had weaning periods of 36.09±1.71, 37.04±1.45, 40.00±1.49, 34.40±1.79 and 37.81±1.50 and were significantly (P<0.05) different from that of the remaining parities. The open days were lowest in parities 3, 8, 5 and 2 respectively at 40.70±2.07, 42.90±3.17, 43.30±2.88 and 43.40±2.15. They were significantly (P<0.05) different from the remaining parities. The kindling interval was highest in parity 4 followed by 9 and 6 respectively at 80.5, 78.9 and 77.8 days respectively. They were significantly (P<0.05) different from parities 2, 3, 5 and 8 at 74.6, 72.0, 74.8 and 78.9 days respectively.

As with season and genetic group, gestation was not affected by parity since it is a physiological state and varies from species to species. The short weaning periods observed in parities beyond 5 could be attributed to the management since from Table 9 the LSW diminished in parities beyond 4 as the doe aged. This was maybe to reduce the pressure of lactation to prolificacy and allow the doe to rebreed hence maximize on more litter. In general, the doe production and reproduction intervals had an undulating trend with parity, strengthening the effect of management eg weaning at 21 or 28 postpartum (Mcnitt and Lukefahr., 1990 and Ozimba 2006) and mating does at between 11 to 14 days post kindling

(Piles et al, 2006) among others. Khalil (1993) reported parity not to affect doe reproduction intervals and was inconsistent from trait to trait.

CHAPTER 5

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

(i). Reproduction and production parameters of the doe thus established were age at first successful mating, gestation, weaning, open days, kindling interval and reproductive longevity while litter traits include Litter size at birth and at weaning, pre-weaning litter survival and number of kits weaned per doe per year.

(ii). The NZW performed better than the other DGG in terms of doe productivity and LSB and LSW. The NC, KW and the FG followed closely and therefore this indicates that any of these genetic groups can be successfully raised at the center. The CC and the NK performed poorly in comparison to the other genetic groups.

(iii). Does at the NFTC can be bred all year round regardless of the season without adverse effects to Litter size at birth and at weaning hence emphasis should be on the management aspects like nutrition and housing. Only does considered to be genetically superior should be bred since litter sizes in latter parities (beyond parity 6) have fewer litter sizes at birth and at weaning.

5.2 Recommendations

(i). Since gestation is a component of Kindling interval and it is constant, the option of accelerating reproduction rates and by extension the number of kits weaned per doe per year is by reducing the open days which can be manipulated hence improve the number weaned per doe per year. Furthermore, the weaning period should be shortened to 3 to 4 weeks.

(ii). Studies involving litter sizes and their weights at birth and at weaning and the weights of the does at service, kindling and weaning of the litter need to be carried out. They will give more information and fair comparisons of the DGG in terms of productivity.

REFERENCES

Abdel-Samee , A. M. (1995). Using some antibiotics and probiotics in alleviating heat stress on growing and doe rabbits in Egypt. World Rabbit Science, 3(3): 107-111.

Akpo Y., Kpodékon T.M., Tanimomo E., Djago A.Y., Youssao A.K.I. and Coudert P. (2008). Evaluation of the reproductive performance of a local population of rabbits in Benin. In the proceedings of the 9th World Rabbit Congress – June 10-13, 2008 – Verona – Italy.

Argente M, Santacreu M A, Climent A, and Blasco A(2003)**.** Relationships between uterine and fetal traits in rabbits selected on uterine capacity1 Journal of Animal Science volume 81:1265-1273. http://jas.fass.org/cgi/content/full/81/5/1265.

Barkok A. and Jaouzi T. **(2000).** The Zemmouri Rabbits (Morocco). Publication du Ciheam No. 38: 179-185. http://ressources.ciheam.org/om/pdf/b38/02600022.pdf.

Baselga M (2002). Line A (Spain). Rabbit genetic resources in Mediterranean countries. Options méditerranéennes, sérd B: Etudes et recherches 38:221–242.

Baselga M, Gómez E., Cifre P. and Camacho J. (1992). Genetic diversity of litter size traits between parities in rabbits. J. Appl. Rabbit Res. 15:198–205.

Blasco A. (1996). Genetics of litter size and does fertility in the rabbit. In Proc. 6th World Rabbit Cong., Toulouse, France. Association Française de Cuniculture (AFC), Lempdes, France. Pages 219–227.

Bonnano A, Mazza F, Di Grigoli A and Alicata M L (2008)**.** Body condition score and related productive responses in rabbit does. In the proceedings of the 9th world rabbit congress held at Verona, Italy, 10th – 13th June, 2008. P 297-301.

Bridges R.S. (1975). Long term effects of pregnancy and parturition upon maternal responsiveness in the rats. Physiology and behavior, 14:245-249.

Brecchia G, Cardinali R, Dal Bosco, Boiti C and Castellini C (2008)**.** Effect of reproductive rhythm based on rabbit doe body condition on fertility and hormones. In proceedings of the 9th world rabbit congress held at Verona, Italy, 10th – 13th June, 2008. P 309-31.

Bridges R.S. (1978). Retention of rapid onset of maternal behavior during pregnancy in primiparous rats. Behavioral biology, 24:113-117.

Carlier C. and Noirot E. (1963). Effects of pregnancy experience on maternal retrieving by rats. Animal behavior, 13: 423-426.

Chineke C (2006). Evaluation of Rabbit breeds and crosses for pre weaning and reproductive performance in the humid tropics. Journal of Animal and Veterinary advances 5(7): 528-537.

Christenson R.K. and Leymanster K.A. (2000**)**. Effects of selection for ovulation rate or uterine capacity on gravid uterine, farrowing, and weaning traits in swine. Journal of Animal Science volume 78(Suppl. 1):202. (Abstract.) http://www.asas.org/jas/00meet/abstracts.html

Das S.K. and Yadav B.P.S. (2007). Effect of mating system, parity and breed on the reproductive performances of broiler rabbits under the agro - climatic condition of Meghalaya. Livestock Research for Rural Development 19 (2): http://www.lrrd.org/lrrd19/2/das19025.htm

Deltoro J and Lopez A M (1985). Allometric changes in rabbits. Journal of agricultural science volume 105 339-346.

de Rochambeau H., Bolet G., and Tudela F. (1994). Long term selection. Comparison of two rabbit strains. Proc. 5th World Congr. Genet. Appl. Livest. Prod. 19:257–260.

de Rochambeau H, Duzert R., and F. Tudela. (1998). Long term selection experiments in rabbit. Estimation of genetic progress on litter size at weaning. Proc. 6th World Cong. Genet. Appl. Livest. Prod., Armidale, NSW, Australia. 26:112–115.

El-raffa A M (2004). Rabbit production in hot climates. In the proceedings of the 8th world Rabbit congress held at Puebla, Mexico, 7th-10th September,2004, P 1172-1180.

Falconer D.S. and Trudy M. (1996). Introduction to quantitative genetics. 4th ed. Longman, Burnt mill, Harlow, Essex, Engl.

Farid A., Crober D.C., Van der Steen H., Patterson D.L. and Sabour M.P. (2002). Reproductive performance of mice selected for reproductive longevity. CD-ROM communication no. 8–13 in Proc. 7th World Congr. Appl. Livest. Prod., Montpellier, France. Universidad Polite´cnica de Valencia, Valencia, Spain.

Fayeye T.R. and, Ayorinde K.L (2008). Effects of season, generation, number of mating, parity and doe number of teat on doe and litter birth characteristics in domestic rabbit in the proceedings 9th world rabbit science congress held at Verona, Italy 10th – 13th July, 2008, p 1529- 1534.

Ferraz J.B.S. and Eler J.P. (1994). Use of different animal models in prediction of genetic parameters in 23 traits of Californian and New Zealand white rabbits raised in the tropics and suggestion for selection criteria.. In proc. 5th world congr. Genet. Appl. Livest. Prod. Guelph, Ontario, Canada, August, 1994. 20:348-351.

García M.L. and Baselga. M. (2002a). Genetic response to selection for reproductive performance in a maternal line of rabbits. World Rabbit Sci. 10:71–76.

García M.L. and Baselga M.(2002b). Estimation of genetic response to selection in litter size of rabbits using a cryopreserved control population. Livest. Prod. Sci. 74:45–53.

Garreau H.M. Piles, C. Larzul, M. Baselga, and H. de Rochambeau. (2004). Selection of maternal lines: Last results and prospects. Pages 14–28 in Proc. 8th World Rabbit Congr., Puebla, Mexico.

Gómez E., Rafel A., Ramon J and Baselga M. (1996). A genetic study of a line selected on litter size at weaning. Pages 289–292 in Proc. 6th World Rabbit Congr., Toulouse, France. Association Française de Cuniculture (AFC), Lempdes, France.

Hamilton H H, Lukefahr S D and Mcnitt J I (1983)**.** Maternal nest quality and its influence on litter survival and weaning performance in commercial rabbits. Journal of animal science volume 75 926-933 http://jas.fass.org/cgi/reprint/75/6/926.

Hermas S.A., Young C.W. and Rust, J.W. (1987). Effects of mild inbreeding on productive and reproductive performance of Guernsey cattle. J. Dairy sci. 70:712.

Hulot F and Matheron G **(1981).** Effets du genotype, de l age et de la saison sur les composantes de la reproduction chez lapine Ann. Genet. Sel. Anim., volume 13(2) 131-150.

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 Http://www.cipav.org.co.lrrd/lrrd18/6/iraq18083.htm

Irgang, R., Fávero J.A. and Kennedy B. W.. (1994). Genetic parameters for litter size of different parities in Duroc, Landrace and Large White sows. J. Anim. Sci. 72:2237–2246.

Khali M.H. (1993). Diversity of repeatabilities between parities for litter traits and reproductive intervals in doe rabbits. World Rabbit Science, 1(4) 147-154

Laxmi J P, Gupta B R, Prakash M G, Ekamabaram B and Amareswari P (2009). A study on the performance of fryer rabbits under different systems of rearing. Livestock research for rural development 21 (8) 2009. http://lrrd.cipav.org.co/lrrd21/3/laxm21118htm

Lebas F, Coudert P, de Rochambeau H and Thebault R G. (1997) The Rabbit-Husbandry, Health and production. FAO Animal Production and Health Series No. 21 (New revised version**)** ISSN 1010-9021.http://www.fao.org/docrep/t1690E/t1690e09.htm#.

Lukefahr S.D. and Cheeke P.R. (1990). Rabbit Project Planning Strategies for developing countries (1) Practical considerations. Livestock Research for Rural Development 2 (3): 2 http://www.cipav.org.co/lrrd/lrrd2/3/cheeke1.htm.

LPSHI, (1990). Livestock stress and poultry heat indices, (Agricultural Engineering Technology Guide, Clemson University, SC, USA).

Lukefahr S.D., Atakora K.A, Opoku. E.M. (1992). Heritability of 90 day body weight in domestic rabbits from tropical Ghana, West Africa. J. Heredity. 83(2):105-108.

Lukefahr S.D. and Hamilton H.H. (2000). Longevity and cumulative litter productivity in straightbred and crossbred Californian and New Zealand white does. Pages 463–468 in Proc. 7th World Rabbit Congr, Vol. A, Valencia, Spain. Universidad Polite´cnica de Valencia, Valencia, Spain.

Marai, I.F.M., Ayyat M. S and Abd El-Monem (2001). Growth performance and reproductive traits of Newzealand White as affected by heat stress and its alleviation under Egyptian conditions. Tropical Animal Production and Health, 33 :451-462.

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.

Matics Zs, Nagy L, Biro-Nemeth, Radnai L, Gerencser Zs, Princz Z and Szendro Zs (2008). Effect of feeding regime during rearing and age at first successful mating on the reproductive performance of rabbit does In proceedings of the 9th world rabbit congress- June 10th – 13th, 2008- Verona- Italy P 399-403.

McAllister A.J. (2002). Is crossbreeding the answer to questions of dairy breed utilization? J. Dairy Sc. 85:2352-2357.

Mcnitt J.I. and Lukefahr S.D., (1983). The effect of environment on conception rate and litter size of domestic rabbits in Oregon and Malawi. J. Appl. Rabbit Res. 6(1)18-20.

Mcnitt J.I. and Lukefahr S.D. (1991). Effects of breed, parity, day of lactation and number of kits on milk production in rabbits. J. Anim. Sci. 69: 1505-1512.

McNitt J.I., Patton N.M.,. Lukefahr S.D and Cheeke. P.R. (2000). Rabbit Production (8th Ed.). Interstate Printers and Publishers. Danville, Illinois.

Mcnitt J.I. and Lukefahr S.D. (1990). Effects of breed, parity, day of lactation and number of kits on milk production in rabbits. Journal of Animal Science volume 69 1505-1512 http://jas.fass.org/cgi/reprint/68/6/1505.

Mcnitt J I, Patton N M, Lukefahr S D and Cheeke P R (1996). Rabbit production (6th edition). Interstate printers and publishers, Danville, Illinois.

Ministry of Livestock Development, (1994). Animal Production in Kenya, An annual report by the Department of Livestock production. P 973-982.

Myers P. and Master, L.L. (1983). Reproduction by *peromyscus maniculatus*. Size and compromise. Journal of mammalogy. 64:1-18.

Nalugwa P.K. (1994) Rabbit Production in Kenya- Achievements, Challenges and Prospects. Annual report of the ministry of livestock development pp 833-844.

Nguyen Q. S., Dinh Van Binh, Le Thi Thu Ha and T R Preston(1996). Effect of housing system (cage *versus* underground shelter) on performance of rabbits on farms. Livestock research for rural development, 8(4) http://www.lrrd.org/lrrd8/4/suc84.htm.

Noguera J.L., Varona L., Babot D., and Estany. J. (2002). Multivariate analysis of litter size for multiple parities with production traits in pigs: I. Bayesian variance components estimation. J. Anim. Sci. 80:2540–2547.

Ostermeyer M.C. and Elwood, R.W. (1984). Helpers in the nest (?) Mongolian gerbil, *meriones unguiculatus.* Behaviour, 91:61-77.

Ozimba C.E. and Lukefahr S.D. (1991). Comparison of rabbit breed types for post weaning litter growth, feed efficiency and survival performance traits. Journal of animal science volume 69 3494-3500. http://jas.fass.org/cgi/reprint/69/6/3494.

Piles M, Garreau H, Rafel O, Larzul C, Ramon J and Ducrocq V (2006**).** Survival analysis in two lines of rabbits selected for reproductive traits. Journal of Animal science volume 84 1658-1655. http://jas.fass.org/cgi/reprint/84/6/1658.

Philipson J., Rege J.E.O. and Okeyo A.M. (2003). Sustainable breeding programs for tropical farming systems. Animal genetic resources version 2: module 3. Http//agtr.ilri.cgiar.org/module/module3/module3.htm.

Rafel O., Piles M. and Ramon J. (2001). GTE espagnole 1999: Une anne´e en suspens. Cuniculture. 158:79–82.

Rastogi, R.K., S.D. Lukefahr, F.B. Lauckner. (2000). Heritability and repeatability of litter traits based on dam records from a tropical rabbit population in Trinidad, West Indies. Pages 483-489 in proc. 7th world rabbit congr. Vol. A, Valencia, Spain. Universidad polec'cnica de Valencia, Valencia, Spain.

Roehe, R. and. Kennedy B.W (1995). Estimation of genetic parameters for litter size in Canadian Yorkshire and Landrace swine with each parity of farrowing treated as a different trait. J. Anim. Sci. 73:2959–2970.[Abstract]

Rommers J M, Meijerhof R, Noordhuizen J and Kemp B (2002)**.** Relationships between body weight at first mating and subsequent body development, feed intake, and reproductive performance of rabbit does. Journal of animal science volume 80 2036-2042 http://jas.fass.org/cgi/content/full/80/8/2036.

Rosell, J. (2003). Health status of commercial rabbits in the Iberian Peninsula. A practitioner's study. World Rabbit Sci. 11:157–169.

Ross S., Sawin P.B., Deneberg V.H. and Zarrow M.X. (1961). Maternal behavior in the rabbit: yearly and seasonal variation in nest building. Behavior 18:154.

Sanchez J P, Baselga M and Ducrocq V (2006)**.** Genetic and environmental correlations between longevity and litter size in rabbits. Journal of animal breeding and genetics volume 123 180-185.

Sánchez J P, Theilgaard P, Mínguez C and Baselga M (2008). Constitution and evaluation of a long-lived productive rabbit line. Journal of Animal science volume 86:515-525, http://jas.fass.org/cgi/content/full/86/3/515.

Sittman, D.B., Rollins W.C., Sittman K and Casady. R.B. (1964). Seasonal variation in reproductive traits of New Zealand white rabbits. J. Reprod. Fert. **8** :29.

Tudela F., Hurtaud J., Garreau G. and de Rochambeau H. (2003). Comparaison des performances zootechniques de femelles parentales issues d’une souche te´moin et d’une souche se´lectionne ´e sur la productivite´ nume´rique. Pages 53–56 in Proc. 10e`mes Journ. Rech. Cun. Paris, France.

Wang Z and Novak, M. A. (1994). Parental care and litter development in primiparous and multiparous prairie voles (*microtus acrogastus*). Journal of mammalogy, **75**(1):18-23.

Wright L.L. and Bell, R. (1978). Interactive effects of parity and early pup stress on the open field behavior of laboratory rats. Developmental psychobiology, **11**:413-418.

Xiccato G, Bernardini M, Castellini C, Dalle Zotte A, Queaque P I and Trocino A (1999**)**. Effect of postweaning feeding on the performance and energy balance of female rabbits at different physiological states. Journal of Animal Science volume 77, pp 416-426, http://jas.fass.org/cgi/reprint/77/2/416.

Youssef Y.M.K., Khalil M. H, Afifi, E.A. El-Raffa, A.M.E. and Zaheds. M. (2000). Heritability and non genetic factors for lifetime production traits in New Zealand white rabbits raised in intensive system of production. Pages 497–503 in Proc. 7th World Rabbit Congr. Vol A, Valencia, Spain.

Youssef Y.M.K (2008). Evaluation of litter traits in a crossing project of V-line and Baladi red rabbits in Egypt. Livestock research for rural development, 20 (9) 2008. http://www.lrrd.org/lrrd20/9/yous20135.htm.

Zerrouki N, Bolet G, Berchiche M and Lebas F (2005). Evaluation of breeding performance of local Algerian rabbit population raised in the Tizi-Ouzu area (Kabilya). World rabbit science volume 13 29-37.

APPENDIX 1: Doe Record Card

Doe…………………. DATE OF BIRTH………………………………SIRE/BREED……………………………..
DAM/BREED………………………………………..

SERVICE	DATE OF SERVICE	BUCK	DATE OF KINDLING	ALIVE	DEAD	WEANED	DATE OF WEANING	WEIGHT AT BIRTH	2 WEEKS	4 WEEKS	REMARKS