GROWTH PERFORMANCE OF BROILER RABBITS UNDER 3 x 3 DIALLEL CROSSING

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Thesis submitted in partial fulfilment of the requirement for the degree of

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DECLARATION

I hereby declare that this thesis, entitled "**Growth performance of broiler rabbits under 3 x 3 diallel crossing"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Mannuthy **ROJAN P. M.**

CERTIFICATE

Certified that this thesis, entitled "**Growth performance of broiler rabbits under 3 x 3 diallel crossing"** is a record of research work done independently by **Rojan P. M.**, under my guidance and supervision and it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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Introduction

1. INTRODUCTION

According to the forecast from the World Food Summit (1996), food and feed production will need to be tripled in the developing countries to keep pace with the projected doubling of the human population by 2050. The existing livestock population in the third world countries will not solve the problem of increasing food shortage. Rabbit has a unique role in meeting the needs of the world population, especially for the vast majority of limited resources farmers that occupy the planet and more specifically so in developing countries (Lukefahr, 2004). In these countries, there exist a tremendous potential for rabbits based on economic traits like high rate of reproduction, early maturity, rapid growth rate and efficient feed utilization. Moreover they pose limited competition for human foods and produce high quality nutritious meat. This potential of rabbits can be well utilized at a commercial or small scale to address the problems of food scarcity.

In the recent years there has been a rise in global awareness on the virtues of rabbit meat, especially in developing countries, depicting it as an alternative means of alleviating world food shortages. India which faces enormous shortages in meat supply has the greatest chance to tap the potentials of rabbit production. Due to the fact that India doesn't have a rabbit breed of its own, a few meat breeds were imported. The population of valuable purebred rabbits in the State of Kerala is facing a rapid decline due to adoption of indiscriminate breeding programme. In this context it is essential to study the performance of these breeds and their crosses in our diversified environmental conditions, under proper feeding, management, housing and health measures, the result of which can form the basis for formulating future breeding strategies of rabbits in the State.

Only limited genetic studies have been conducted in rabbits in tropical countries, where climate, diet, management and stock resources can differ markedly from those in temperate countries. Therefore, to provide quality breeding stock to farmers, a basic study on the growth and litter traits and genetic and non-genetic factors affecting these traits are necessary.

Diallel mating design is one of the most popular mating designs among breeders and geneticists to study some of the quantitative traits in plants and animals. A diallel cross is defined as the set of all possible matings between several genotypes, like individuals, clones, homozygous lines, etc. (Hayman, 1954). Diallel crossing systems are commonly used to compare the performance of hybrid combinations of lines with or without the parental inbreds.

As an initial step in helping the formulation of a rabbit breeding strategy for Kerala, the first requirement would be the identification of the best performing breeds and crosses in our agroclimatic scenario. Keeping these in view, this study was undertaken with the following objectives:

1) Study the growth performance of purebred and crossbred broiler rabbits up to three months of age.

2) Estimate general combining ability of the purebred and specific combining ability of crossbred broiler rabbits.

3) Estimate different genetic and non-genetic factors affecting growth traits in broiler rabbits.

4) Study the survivability of purebred and crossbred rabbits.

Review of literature

2. REVIEW OF LITERATURE

2.1 RABBIT PRODUCTION

Cheeke (1986) documented potentials and limitations of rabbit production in tropical and subtropical agriculture systems.

According to Chaudhury (1987) though rabbit production was still in its infancy, rabbit meat production in India had a great scope as small backyard as well as commercial scale.

El-Raffa (2004) discussed in detail about the requirements of successful rabbit farming and the effect of heat stress on the performance of rabbits in hot climate. He emphasized the essentiality of intensive rabbit production for maximizing food production.

Lukefahr (2004) proposed the small-scale rabbit production model as a holistic and sustainable model for subsistence rabbit project development, predominately in the lesser-developed countries.

2.2 GROWTH TRAITS

2.2.1 Body weights at different ages

Table 2.1 summarizes body weights of broiler rabbits at different ages.

Table 2.1 Body weights of broiler rabbits at different ages in grams.

Breed	4 weeks	6 weeks	8 weeks	10 weeks	12 weeks	Reference
NZW (New Zealand White)	383.3	573.4	788.6	1000.5	1000.6	Radhakrishnan (1992)
SC (Soviet Chinchilla)	452.3	679.1	903.9	1129.5	1354.1	
Breed	Birth	4 weeks	12 weeks	24 weeks	28 weeks	
NZW	59.68 ±7.25	625.32 ±91.31	1601.92 ±51.67	2210.71 ±74.93	2472.35 ±141.25	Mukundan *et al.* (1993)

SC	62.38 ±8.44	607.62 ±126.85	1544.29 ±62.08	2240.28 ±80.48	2582.35 ±93.26	
SC x NZW	57.98 ±7.34	568.57 ±89.23	1507.14 ±59.55	2412.07 ±78.46	2682.68 ±71.43	
NZW x SC	57.14 ±7.94	478.93 ±90.29	1417.92 ±64.06	2127.50 ±79.08	2359.17 ±38.25	
Breed	Birth	21 days	28 days	35 days	42 days	Bhasin *et al.* (1996)
SC	54.7 ±3.3	273.0 ±13.1	410.2 ±17.4	580.2 ±23.9	778.0 ±32.3	
NZW	54.0 ±2.0	266.0 ±18.7	380.3 ±24.1	540.4 ±41.7	713.5 ±43.8	
Breed	4 weeks	6 weeks	8 weeks	10 weeks	12 weeks	Kasiviswanathan (2000)
NZW	236.7 ±20.6	461.7 ±27.4	678.2 ±31.0	934.2 ±44.1	1117.7 ±51.5	
SC	268.6 ±18.2	568.1 ±24.2	809.6 ±27.4	1007.1 ±38.9	1272.3 ±45.4	
NZW x SC	319.0 ±21.6	506.6 ±28.8	708.1 ±32.5	1019 ±46.3	1214.2 ±54.0	
Breed	6 weeks	8 weeks	10 weeks	12 weeks	14 weeks	Gupta *et al.* (2002)
NZW	497.40 ±10.25	679.61 ±13.17	834.92 ±15.79	1050.38 ±18.55	1241.88 ±20.55	
SC	512.25 ±11.59	689.23 ±14.69	836.52 ±17.48	994.92 ±19.93	1172.86 ±22.72	
GG (Grey Giant)	508.65 ±11.01	686.34 ±14.07	836.68 ±17.02	991.98 ±19.84	1173.83 ±22.06	
NZW x SC	524.02 ±24.43	692.43 ±30.95	862.94 ±36.82	1069.55 ±41.80	1202.93 ±45.22	
NZW x GG	511.56 ±19.81	696.91 ±25.10	849.93 ±29.87	1024.24 ±36.39	1197.08 ±41.98	
GG x SC	471.95 ±19.56	649.16 ±24.78	793.46 ±29.48	994.33 ±33.91	1149.95 ±36.67	
CW (Californian white)	469.01 ±11.47	705.24 ±19.27	896.65 ±22.04	1113.18 ±25.15	1330.35 ±28.81	Poornima *et al.* (2002)
Breed	Birth	1 weeks	2 weeks	3 weeks	4 weeks	Devi *et al.* (2007)
SC	57.98	104.53	161.68	225.87	332.45	

2.3 LITTER TRAITS AND GESTATION PERIOD

A brief review on litter traits and gestation period of broiler breeds of rabbits is presented in table 2.2

Table 2.2 Litter traits and gestation period

Breed	Gestation period (Days)	Litter size at birth (Nos)	Litter size at weaning (Nos)	Litter weight at birth (g)	Litter weight at weaning (g)	Reference
NZW x NZW	32.14 ±0.40	7.83 ±0.79	4.80 ±0.48 a	450 ±18	3452 ±438	Lahiri and Mahajan (1983)
NZW x GG	31.42 ±0.20	8.00 ±0.51	6.00 ±1.00 a	455 ±38	3286 ±881	
WG x WG (White Giant)	32.71 ±0.42	8.66 ±1.05	5.33 ±0.71 a	596 ±59	2843 ±447	
NZW x WG	32.00 ±0.91	7.25 ±0.75	4.33 ±0.33 a	412 ±41	2633 ±338	
NZW x SC	31.85 ±0.26	7.16 ±0.74	4.66 ±0.66 a	440 ±20	2670 ±357	
GG x GG	31.25 ±0.29	10.50 ±0.76	5.5 ±1.19 a	570 ±32	3260 ±813	
GG x WG	32.00 ±0.25	7.00 ±1.06	5.75 ±0.47 a	411 ±28	3495 ±404	
GG x NZW	32.50 ±0.28	7.50 ±0.28	6.00 ±0.70 a	462 ±51	3987 ±521	
GG x SC	31.83 ±0.16	7.83 ±0.94	4.66 ±0.66 a	458 ±51	2680 ±363	
SC x SC	32.57 ±0.29	8.00 ±1.15	6.75 ±0.62 a	443 ±46	4070 ±537	
SC x GG	33.50 ±0.71	7.33 ±1.02	4.83 ±0.30 a	503 ±33	2770 ±291	
SC x WG	32.83 ±0.70	7.50 ±0.42	6.60 ±0.50 a	506 ±44	4250 ±526	
SC x NZW	33.00 ±0.42	7.33 ±0.66	5.00 ±0.83 a	431 ±44	2818 ±515	
WG x GG	31.75 ±0.25	8.25 ±0.47	4.75 ±0.47 a	470 ±17	2775 ±577	
WG x NZW	32.66 ±0.42	7.20 ±0.73	4.60 ±1.07 a	424 ±27	2307 ±212	
WG x SC	32.50 ±0.61	7.80 ±1.24	4.00 ±0.00 a	480 ±73	2850 ±354	
NZW	30.77 ±0.24	5.35 ±0.37				Bujarbaruah *et al.* (1989)
SC	31.90 ±0.24	5.90 ±0.41				
SC	32.3 ±0.82	6.0 ±2.40	4.4 ±1.50 b		1950 ±370	Sundaram and Bhattacharyya (1992)
NZW	31.3	6.7				
WG	31.6	5.3				
GG	32.3	5.0				

SC	32.38 ±0.68	5.7 ±2.10	3.0 ±2.58 a	377.45 ±70.39	2098.57 ±372.76	Mukundan *et al.* (1993)
NZW	32.90 ±0.73	6.1 ±1.18	4.0 ±1.07 a	365.36 ±70.92	1804.29 ±289.06	
SC x NZW	32.33 ±0.89	6.8 ±1.65	2.8 ±2.03 a	372.14 ±36.48	2536.71 ±368.56	
NZWx SC	33.08 ±0.38	5.6 ±2.7	3.85 ±1.06 a	443.00 ±93.59	1656.00 ±228.52	
SC		6.16 ±0.29	3.69 ±0.23 a	331.06 ±15.82		Rathor *et al.* (2000)
WG		6.68 ±0.27	4.87 ±0.23 a	304.06 ±15.32		
GG		6.13 ±0.24	4.53 ±0.2 a	263.34 ±13.32		
SCx WG		6.31 ±0.29	4.29 ±0.25 a	302.29 ±16.52		
SC x GG		7.54 ±0.28	4.44 ±0.23 a	341.31 ±15.84		
WG x SC		5.93 ±0.28	3.4 ±0.23 a	298.32 ±15.78		
WG x GG		7.3 ±0.24	4.42 ±0.2 a	328.99 ±13.36		
GG x SC		6.09 ±0.3	3.98 ±0.25 a	260.72 ±16.76		
GG	32.4 ±1.12	6.9 ±0.16	5.3 ±0.13 c	336.0 ±4.28	2771 ±77.60	Pannu *et al.* (2005)
SC	32.4 ±0.94	5.9 ±0.13	5.1 ±0.11 c	344.8± 3.48	2804 ±64.23	
WG	30.9 ±1.01	6.5 ±0.13	5.3 ±0.11 c	347.4 ±3.63	2886.2 ±67.31	
GG		6.39 ±0.12	5.48 ±0.12 d	313.75 ±5.90	3398.08 ±75.24	Singh *et al.* (2007a)

a- Weaning at 6 weeks, b- 28 days, c- Not mentioned, d -42 days

2.4 EFFECT OF LITTERSIZE

Lukefahr *et al.* (1983) concluded litter size as the major determinant of total litter growth and performance during the post-weaning period, based on residual correlation estimates.

Das *et al.* (1997) found the high genetic group effect on litter weight at birth and non significant effect of season of conception.

According to Rommers *et al.* (2001) litter size before weaning affected body weight at weaning and litter size after first pregnancy.

Gupta *et al.* (2002) reported that the body weights at all post-weaning ages were affected significantly by the litter size at birth, so also the body weight of bunnies declined gradually as the litter size at birth increased.

Pannu *et al.* (2005) suggested that the litter size at birth was highly significant on litter size at weaning and litter weight at birth and weaning.

According to Piles *et al.* (2006a) as the litter size was mainly determined by the doe component, it was unnecessary to include the buck component in selection models for litter size.

2.5 MATERNAL EFFECTS

The observations recorded by Yamani *et al.*(1991) pointed at lower rates of stillbirth and pre-weaning mortality coupled with higher conception rates, total milk yield and litter weight at weaning in does weighing four kilograms or more, than those with the does weighing less than four kilograms live weight.

Doe weight significantly affected litter weight and size at weaning and average daily weight but had no significant effect on litter size and weight at birth, average litter weight at birth and average weaning weight (Aina *et al.,* 1998).

Belhadi (2004) observed no significant effect of doe's body weight on litter size and mortalities from birth to seventy days.

Milisits and Levai (2004) observed higher conception rate and smaller litters at birth for rabbit does selected for high body fat content. They had larger and heavier litters at 21 days after parturition in comparison to non fatty does.

Pannu *et al.* (2005) reported that litter weight at weaning, gestation length, kindling interval and litter size at birth were influenced by the weight of dam at weaning.

2.6 EFFECT OF SEX

Significant influence of sex on body weights was observed upto12 weeks of age and non significant influence from 22 to 24 weeks of age (APAU, 1989).

Radhakrishnan (1992) reported non significant effect of sex on body weights from four to 12 weeks of age among NZW, SC and GG rabbits.

Kasiviswanathan (2000) reported significant effect of sex on fourth week body weight only.

Gupta *et al.* (2002) revealed that there was no differential effect of male and female sex hormones on post-weaning body weights.

Singh *et al.* (2007a) reported nonsignificant effect of sex on 42, 84 and 168 days body weight in a study on growth and reproductive performance of WG rabbits under sub temperate conditions.

2.7 EFFECT OF SEASON

Yamani *et al.* (1991) reported that average gestation length, stillbirths and pre-weaning mortality percentages were significantly higher in spring and summer than in autumn and winter while litter size at weaning, total milk yield, and litter weight increased significantly during autumn and winter in comparison to spring and summer. The lowest mean bunny weight was recorded during summer while the highest bunny weight throughout the whole pre-weaning period (0 - 25 days) except at birth was noticed in spring. The highest bunny weight at birth was recorded during winter. The differences in mean bunny weight due to season were significant. The effect of season on conception rate and litter size at birth was not significant.

McNitt and Lukefahr (1993) reported poor post-weaning growth performance during the summer, but the NZW tended to be less affected by the environmental extremes than other breeds.

Feki *et al.* (1996) reported highly significant line x season interaction in a comparison among different rabbit lines.

Das *et al.* (1997) reported non significant influence of season on conception rate and litter size at birth.

Das *et al.* (2001) observed highest morbidity percentage in summer (41.01 per cent), intermediate in rainy (30.90 per cent) and lowest in winter season (28.09 per cent). Mortality rate was found to be same (12.50 per cent) in all seasons.

Poornima *et al.* (2002) reported significant influence of month of birth on body weights throughout the post-weaning period under study. The bunnies born in January attained higher body weights than those in other months.

Surendran *et al.* (2003) reported a heavy loss in terms of percentage of young ones of rabbits weaned during winter and therefore suggested avoidance of breeding during the winter.

Belhadi (2004) observed positive effect of kindlings in spring season on litter sizes from birth to weaning in relation to autumn of the same year. He also observed that the mean weaning weight was higher during winter and autumn.

Ghosh *et al.* (2004) indicated that the winter is the most favourable season for conception, kindling and after-birth care of newborns under the subtropical condition of Tripura.

Pannu *et al.* (2005) observed highly significant effect of year of kindling for all reproductive traits except gestation length.

Significant seasonal variation in birth weight and one week weight was reported by Devi *et al.* (2007) but the average daily gain and cumulative average daily gain remained unaffected.

Singh *et al.* (2007a) noticed significant differences in body weights at 42, 84 and 168 days in three seasons.

2.8 SURVIVABILITY

Mukundan *et al.* (1993) opined that SC inheritance seemed to lower the pre-weaning survivability. They recorded lowest pre-weaning survivability in SC x NZW genetic group (43.5 per cent) followed by SC x SC group (48.64 per cent).

Rao *et al.* (1994) reported pre-weaning mortality of 17.0, 25.0, 32.7 and 47.8 per cent and post-weaning mortality of 8.9, 6.4, 3.7 and 6.6 per cent in NZW, GG, SC and WG breeds, respectively.

Farghaly (1996) recorded low additive genetic variance and maternal effects and high residual environment values for stillbirths and pre-weaning mortality traits.

Pre-weaning mortality was highest (32.16 per cent) in one to four kits born alive group followed by nine to eleven kits (25.78) and five to eight kits (22.05 per cent) categories. The effect of breeds was non significant for overall mortality (Singh *et al.* 1997).

Surendran *et al.* (2003) observed that the litter with higher average birth weight had higher weaning percentage and the litter size at birth did not affect the weaning percentage.

Garreau *et al.* (2004) reported significantly lower mortality of kits at birth in a divergently selected homogeneous line with low variability of birth weight.

According to Gyovai *et al.* (2004), the survival of new-born rabbits was effected by their birth weight. The survival rate of low birth weight group (35-45g) was significantly lower than that of high birth weight group (65-70g) and medium birth weight group (53-58g).

Pannu *et al.* (2005) observed high rate of mortality in larger litters at birth.

Das *et al.* (2007) reported that about 22 per cent of total mortality was occurred in zero to fifteen days, four to eight per cent in 16 to 180 days age group and maximum of 58 per cent in the age group beyond six months. They also observed higher susceptibility of female rabbits to diseases.

2.9 HERITABILITY ESTIMATES

2.9.1 Heritability of growth traits

Radhakrishnan (1992) estimated heritabilities of post-weaning body weights at four, six, eight, ten and 12 weeks as 0.54±0.37, 0.52±0.38, 0.49±0.37, 0.49±0.37and 0.56±0.37, respectively for SC breed

Lukefahr *et al.* (1996) estimated heritabilities as 0.04, 0.11, 0.17, and 0.37 for 28 day weaning weight, 70 day body weight, 28 to 70 day average daily gain and carcass yield percentage, respectively in rabbits by Restricted Maximum Likelihood (REML) procedure.

Estimates of heritability of average daily gain and feed conversion were 0.48 and 0.29, respectively. The genetic correlation between the said traits was found to be -0.82. (Moura *et al.,* 1997)

Farghaly and El-Mahdy (1999) reported that paternal half-sib estimates of heritability for live weight were moderate and ranged from 0.18 to 0.30.

Kasiviswanathan (2000) recorded heritability values of 0.204±0.469, 0.363±0.534, 0.528±0.546, 0.720±0.685 and 0.816±0.713 for four, six, eight, ten and 12 weeks of age, respectively based on sire + dam component for SC breed.

Poornima *et al.* (2002) estimated heritabilities of post-weaning body weights at six, eight, ten, 12, 14 and 16 weeks of age as 0.13, 0.14, 0.14, 0.23, 0.32, 0.36, 0.27, 0.11, 0.18, 0.07 and 0.22, respectively.

Larzul *et al.* (2004) estimated heritability with REML methodology for the 63 day body weight in rabbits as 0.22 ± 0.02 and that of weaning weight was 0.13 ± 0.02. Estimated heritability value for average daily gain between fourth and nineth weeks of age was 0.29 ± 0.03.

Piles *et al.* (2004) estimated heritabilities of growth rate to be 0.31 and 0.21, respectively in line C and R, which predicted successful selection for these traits.

The heritability estimates obtained from paternal half-sib correlation for individual body weight at six, nine and twelve weeks of age were 0.43±0.35, 0.11±0.22 and 0.36±0.35, respectively (Akanno and Ibe 2005).

Estimated heritabilities for pre-weaning body weights in rabbits ranged from 0.07±0.19 to 0.65±0.31 (Devi *et al.,* 2007).

Heritability estimates for body weights at seven, 21, 42 and 56 days of age were 0.49, 0.23, 2.10 and 1.34 using paternal half sib method and were 0.17, 0.67, 1.26 and 0.90 using maternal half sib method of estimation (Ibrahim *et al.,* 2007).

2.9.2 Heritability of litter traits

Lahiri and Mahajan (1982) reported estimates of heritability for litter size and litter weight at birth, litter size and litter weight at weaning as 0.1072±0.0972, 0.1240±0.0994, 0.1277±0.1002 and 0.1414±0.1021, respectively.

Heritability estimates for total litter size born and born alive, litter size at 21, 28 and 84 days were 0.09, 0.12, 0.06, 0.09, and 0.07, respectively. For litter weights at 21, 28 and 84 days heritability estimates were 0.08, 0.09, and 0.02, respectively (Rastogi *et al.,* 2000).

Choudhary *et al.* (2001) observed that heritability values of litter size at weaning to six week (0.072±0.026), litter weight at birth (0.060±0.008) and litter weight at weaning (0.181±0.101) were low. Heritability of litter size at birth was 0.052±0.103.

Pannu *et al.* (2005) estimated heritabilities for litter size and litter weight at birth, litter size and litter weight at weaning as 0.24, 0.22, 0.11, and 0.60, respectively.

Iraqi *et al.* (2006) presented low heritability estimates of 0.04, 0.01, 0.08, and 0.09 for litter size and litter weight at birth, litter size and litter weight at weaning, respectively.

Singh *et al.* (2007b) recorded heritability of litter size and litter weight at birth in GG rabbits as 0.15±0.10 and 0.12±0.09, respectively. A medium heritability of 0.38±0.10 was observed for litter weight at weaning.

Al-Saef *et al.* (2008) reported estimates of the proportion of the phenotypic variance due to genetic additive effects for litter size at birth and weaning, litter weight at 0, 21 and 30 days of age and pre-weaning litter mortality as 0.04±0.009, 0.05±0.021, 0.15±0.021, 0.17±0.018, 0.15±0.003 and 0.03±0.018, respectively.

2.10 CORRELATION

2.10.1 Phenotypic correlation among growth traits

The review of phenotypic correlation among growth traits is summarized below.

Table 2.3 Phenotypic correlation among growth traits in broiler rabbits

Correlation	Breed	Estimate	Reference
Body weight at 4 and 6 weeks	SC	0.970±0.559	Kasiviswanathan (2000)
Body weight at 4 and 8 weeks	SC	0.817±0.219	
Body weight at 4 and 10 weeks	SC	0.612	
Body weight at 4 and 12 weeks	SC	0.819	
Body weight at 6 and 8 weeks	SC	0.849±0.237	
Body weight at 6 and 10 weeks	SC	0.624	
Body weight at 6 and 12 weeks	SC	0.866	
Body weight at 8 and 10 weeks	SC	0.503	
Body weight at 8 and 12 weeks	SC	0.859±0.783	
Body weight at 10 and 12 weeks	SC	0.596	
Body weight at 6 and 8 weeks	CW	0.90	Poornima *et al.* (2002)
Body weight at 6 and 10 weeks	CW	0.75	
Body weight at 6 and 12 weeks	CW	0.80	
Body weight at 6 and 14 weeks	CW	0.72	
Body weight at 8 and 10 weeks	CW	0.86	
Body weight at 8 and 12 weeks	CW	0.88	
Body weight at 8 and 14 weeks	CW	0.83	
Body weight at 10 and 12 weeks	CW	0.89	
Body weight at 10 and 14 weeks	CW	0.81	
Body weight at 12 and 14 weeks	CW	0.90	

2.10.2 Phenotypic correlation among litter traits

The estimates of phenotypic correlation among reproductive and litter traits are reviewed in table 2.4

Table 2.4 Phenotypic correlation among reproductive and litter traits in broiler rabbits

Correlation	Breed	Estimate	Reference
Age at first breeding and litter size at birth	SC	-0.3833±0.0707	Lahiri and Mahajan (1982)
Age at first breeding and litter weight at birth	SC	-0.7504±0.0122	
Age at first breeding and litter size at weaning	SC	-0.0442±0.0268	
Age at first breeding and litter weight at weaning	SC	0.0007±0.0769	

Litter size at birth and litter weight at birth	SC	0.288±0.073	
Litter size at birth and litter size at weaning	SC	0.6354±0.0592	
Litter size at birth and litter weight at weaning	SC	0.3747±0.0714	
Litter weight at birth and litter size at weaning	SC	0.2773±0.0742	
Litter weight at birth and litter weight at weaning	SC	0.1469±0.0762	
Litter size at weaning and litter weight at weaning	SC	0.632±0.06	
Gestation period and litter size at birth	SC	-0.034±0.067	Choudhary *et al.* (2001)
Gestation period and litter size at 6 weeks	SC	0.081±0.071	
Gestation period and litter weight at birth	SC	-0.080±0.066	
Gestation period and litter weight at 6 weeks	SC	0.032±0.144	
Litter size at birth and litter size at 6 weeks	SC	0.590±0.047	
Litter size at birth and litter weight at birth	SC	0.670±0.037	
Litter size at birth and litter weight at 6 weeks	SC	0.265±0.106	
Litter size at 6 weeks and litter weight at birth	SC	0.619±0.044	
Litter size at 6 weeks and litter weight at 6 weeks	SC	0.471±0.089	
Litter weight at 6 weeks and litter weight at birth	SC	0.373±0.098	
Litter size at weaning and litter size at birth	GG	0.81	Singh *et al.*(2007c)
Litter size at weaning and litter size at weaning	GG	0.77	
Litter size at weaning and litter weight at weaning	GG	0.40	
Litter size at birth and 42 day body weight	GG	-0.35	
Litter size at birth and 84 day body weight	GG	-0.23	
Litter size at weaning and 42 day body weight	GG	-0.29	
Litter size at weaning and 84 day body weight	GG	-0.16	
42 and 84 day body weight	GG	0.68	

2.10.3 Genetic correlation among growth traits

The estimates of genetic correlation are reviewed in table 2.5

Table 2.5 Genetic correlation among growth traits in broiler rabbits

Correlation	Breed	Estimate	Reference
Body weight at 4 and 8 weeks	SC	0.823±1.314	Kasiviswanathan (2000)
Body weight at 4 and 10 weeks	SC	-0.186±1.314	
Body weight at 6 and 8 weeks	SC	0.895±1.654	
Body weight at 6 and 10 weeks	SC	-0.114±0.661	
Body weight at 8 and 10 weeks	SC	-0.215±0.497	
Body weight at 8 and 12 weeks	SC	0.964±0.512	
Body weight at 10 and 12 weeks	SC	0.017±0.210	
Body weight at 6 and 8 weeks	CW	0.87	Poornima *et al.* (2002)
Body weight at 6 and 10 weeks	CW	0.61	
Body weight at 6 and 12 weeks	CW	0.79	
Body weight at 6 and 14 weeks	CW	0.70	

Body weight at 8 and 10 weeks	CW	0.86	
Body weight at 8 and 12 weeks	CW	0.96	
Body weight at 8 and 14 weeks	CW	0.92	
Body weight at 10 and 12 weeks	CW	0.99	
Body weight at 10 and 14 weeks	CW	1.01	
Body weight at 12 and 14 weeks	CW	1.03	

2.10.4 Genetic correlation among litter traits

The review of genetic correlation among reproductive and litter traits is summarized in table 2.6

Table 2.6 Genetic correlation among reproductive and litter traits in broiler rabbits

Correlation	Breed	Estimate	Reference
Age at first breeding and litter size at birth		-0.7786±0.4271	Lahiri and Mahajan (1982)
Age at first breeding and litter weight at birth		-0.7093±0.5745	
Age at first breeding and litter size at weaning		-0.7466±0.3672	
Age at first breeding and litter weight at weaning		0.0792±0.7949	
Litter size at birth and litter weight at birth		0.184±0.138	
Litter size at birth and litter size at weaning		0.7135±0.4956	
Litter size at birth and litter weight at weaning		0.0811±0.598	
Litter weight at birth and litter size at weaning		0.7489±0.43	
Litter weight at birth and litter weight at weaning		-0.013±0.642	
Litter size at weaning and litter weight at weaning		0.7637±0.043	
Gestation period and litter size at birth	SC	>1	Choudhary *et al.* (2001)
Gestation period and litter size at 6 weeks	SC	0.057±0.701	
Gestation period and litter weight at birth	SC	>1	
Gestation period and litter weight at 6 weeks	SC	0.407±0.240	
Litter size at birth and litter size at 6 weeks	SC	0.936±0.160	
Litter size at birth and litter weight at birth	SC	>1	
Litter size at birth and litter weight at 6 weeks	SC	0.438±0.533	
Litter size at 6 weeks and litter weight at birth	SC	0.607±0.698	
Litter size at 6 weeks and litter weight at 6 weeks	SC	0.827±0.510	
Litter weight at 6 weeks and litter weight at birth	SC	0.507±0.260	
Litter size and litter weight at weaning	GG	0.72±0.18	Singh *et al.*(2007b)
Litter weight at weaning and doe weight at kindling	GG	0.13±0.36	
Litter weight at weaning and doe weight at service	GG	-0.01±0.41	

2.11 DIALLEL CROSSING

2.11.1 Diallel crossing experiments in rabbit

Specific and general combining abilities, genetic components of variance, maternal and environmental influences were experimentally estimated through a 4 x 4 diallel cross involving four breeds of rabbit (APAU, 1989).

Bokade *et al.* (1993) studied a 4 x 4 diallel cross involving GG, NZW, SC and WG. The results showed that among the crossbreds, WG x GG crossbred group had the highest body weight.

Mukundan *et al.* (1993) studied the breed crosses involving Non-descript, SC and NZW breeds and obtained information on maternal influence, specific and general combining abilities.

Jensen *et al.* (1996) conducted a diallel cross using three lines each of Danish White (DW) and Pannon White (PW) and reported the growth rates. The overall mortality averaged to 2.7 per cent.

Rohilla and Bujarbaruh (1999) in a diallel cross, using NZW, SC, GG, Local White and crossbreds studied the growth and reproductive traits. According to them GG x SC crossbreds produced the heaviest litters at birth.

Baselga *et al.* (2003) conducted a diallel experiment with three lines of rabbits to estimate the reproductive traits and reported favourable heterosis for prolificacy traits in crosses.

Rubio-rubio *et al.* (2004) analyzed the specific combining ability in a diallel cross using NZW, Californian, Chinchilla and Criollo in terms of litter size at birth and weaning. Results showed that litters from NZW and Californian had better performance for litter size and litter weight at birth and litter weight at weaning than litters form Chinchilla and Criollo.

Orengo *et al.* (2004) concluded that growth traits were less dependent on maternal effects than genetic effects following a diallel-crossbreeding experiment among five lines of rabbit.

Piles *et al.* (2006b) performed a complete diallel cross involving three maternal lines of rabbit to estimate crossbreeding parameters.

A crossbreeding experiment involving PW, Maternal line (ML) and that of their diallel crossbred does (MLxPW, PWxML) was carried out to evaluate the reproductive performance of purebred and crossbred rabbit does. No heterosis was found to be associated with litter size and litter weight at 21 days of age and the best crossing combination was PWxML (Szendrő *et al.,* 2007).

2.11.2 Statistical analysis of diallel crossing

Hayman (1954) explained the theory and analysis of diallel crosses.

Allard (1956) presented an extension of the analysis of diallel crosses which permited an assessment of the stability of the values assumed by dominance, additive and interaction components of variation under different environmental circumstances.

Dickinson and Jinks (1956) developed a technique for analyzing diallel crosses between homozygous parents.

Kempthorne (1956) presented a general approach to the genetical theory and analysis of the diallel table and removed the assumptions of two alleles at each locus and no epistacy.

Singh and Chaudhary (1985) described the estimation of variances, general and specific combining abilities in diallel crosses.

Venkateswarlu *et al.* (1998) addressed the problem of estimation of variance components based on diallel model for unbalanced data and adopted the least squares approach to quadratic estimation in obtaining the explicit solutions for the design and genetic components of variance.

Lal and Jeisobers (2002) investigated the robustness of universal optimal balanced block designs for diallel crosses for the loss of any crosses in a single block.

2.12 COMBINING ABILITY ESTIMATES

2.12.1 General combining ability

The brief review of general combining ability estimates is given below.

Table 2.7 General combining ability for body weight at different ages.

Breed	4th week	8th week	10th week	12th week	14th week	APAU (1989)
NZWxNZW	-2.164	-10.351	-31.193	-55.241	-60.616	
GGxGG	-3.268	9.867	2.979	18.03	6.118	
SCxSC	5.138	2.424	-1.812	-16.814	10.098	
WGxWG	0.294	-1.94	30.025	54.025	44.399	
Breed	Birth weight	4th week	12th week	24th week	28th week	Mukundan *et al.* (1993)
NZWxNZW	1.56	31.43	73.2	81.12	72.49	
SCxSC	1.47	19.56	1.44	105.66	134.04	
LocalxLocal	-3.03	-50.99	-74.64	-189.78	-206.54	
Breed	6th week	10th week	12th week	14th week	16th week	Gupta *et al.* (2002)
NZWxNZW	3.88	-19.06	-1.21	3.16	3.56	
GGxGG	11.39	-1.31	-9.53	-4.37	-5.57	
SCxSC	-2.2	-24.38	-32.53	-38.58	-35.98	

Table 2.8 General combining ability for litter traits at different ages.

Breed	Litter size at birth	Litter Weight at birth (g)	Litter size at Weaning	Litter Weight at Weaning(g)	Rubio-rubio *et al.* (2004)
NZW	7.9±0.29	474.1±23.0	7.6±0.32	3769.0±243.7	
Californian	7.8±0.27	459.5±22.2	7.6±0.31	3586.8±235.5	
Chinchilla	7.5±0.31	444.9±24.8	7.1±0.36	3458.7±275.3	
Criollo	7.3±0.31	415.3±24.8	6.8±0.38	3324.5±288.4	

2.12.2 Specific combining ability

Table 2.9 gives the review of specific combining ability estimates.

Table 2.9 Specific combining ability for body weight at different ages

Breed	4th week	8th week	10th week	12th week	14th week	APAU (1989)
NZWxGG	2.193	15.791	21.253	-4.112	36.59	
NZWxSC	8.594	-30.228	-33.868	-36.605	-60.112	
NZWxWG	3.049	4.055	-32.347	-30.326	-51.551	
GGxSC	-3.268	-2.977	-26.815	-10.491	-25.866	
GGxWG	3.43	38.289	7.553	70.501	44.429	
SCxWG	9.866	-11.359	-19.163	-25.106	12.438	
Breed	Birth weight	4th week	12th week	24th week	28th week	Mukundan *et al.* (1993)
NZWx SC	-1.73	-59.96	-41.94	16.16	-18.25	
NZWx Local	1.44	29.39	16.27	5.22	23.47	
SCx Local	-1.43	24.94	69.66	18.71	36.61	
Breed	6th week	10th week	12th week	14th week	16th week	Gupta *et al.* (2002)
NZWxGG	0.02	6.81	-16.94	-27.77	2.42	
NZWxSC	26.08	43.40	51.34	15.29	-8.63	
GGxSC	-33.51	-43.83	-15.33	-30.17	-55.86	

2.13 HETEROSIS

Lahiri and Mahajan (1983) recorded positive heterosis of 29.03 per cent for litter size in NZW x GG while for litter weight the values for heterosis were 8.35, 2.73 and 2.70 per cent in NZW x GG, GG x WG and SC x WG crosses, respectively.

Lukefahr *et al.* (1983) reported significant maternal heterosis for litter feed intake and feed efficiency as well as total mortality. Maternal heterosis percentage was higher for litter size and weight at 28 days (12 and 10.3 per cent) than for the same traits expressed at 56 days (8.2 and 5.6 per cent).

Lahiri and Mahajan (1984) in a study involving crossbred groups of rabbits found that the heterosis was exhibited only by SCxGG crossbreds with regard to individual body weight.

Medellin and Lukefahr (2001) estimated direct heterosis for growth and litter traits from straight bred and reciprocally crossbred Altex and NZW breeds of rabbits. Heterosis estimates were small for weaning weight (28 days) 2.9 per cent and market weight (70 days) 3.4 per cent.

Materials and Methods

3. MATERIALS AND METHODS

3.1 LOCATION OF THE STUDY

The experiment was carried out at the University rabbit farm, Centre for Advanced Studies in Animal Genetics and Breeding, College of Veterinary and Animal Sciences, Mannuthy, Thrissur between March 2007 and July 2008.

3.2 ANIMALS

A complete 3 x 3 diallel cross was performed involving three rabbit breeds *viz.* White Giant, Soviet Chinchilla and Grey Giant in two different seasons, with four replications in each set. The data were generated from first filial generation produced by crossing of the three parental groups in all possible combinations.

3.3 MANAGEMENT OF RABBITS

3.3.1 Housing

Individual cages made of galvanized iron were employed to house rabbits. The dimensions of the cages used were 60x80x45cm placed at a height of 75cm from the ground.

3.3.2 Breeding

White Giant, Soviet Chinchilla and Grey Giant breeds of rabbits formed the foundation stocks in this program. A complete 3 x 3 diallel mating was made to obtain purebred and crossbred progeny along with their reciprocals.

Does were transferred to the buck's hutch for breeding. Pregnancy was confirmed in does by abdominal palpation at ten to fifteen days of mating. In cases where conception failed, the doe was again presented to the same buck. After 28 days of pregnancy, females were provided with nest boxes in cages.

Weaning of bunnies was done at the age of four weeks and housed together in groups there after.

3.3.3 Feeding

Daily ration consisted of *ad libitum* green fodder and 50 to 200g of concentrates depending on the age and size. The composition of the concentrate mixture was

Bengal gram	: 35 %
Wheat	: 30 %
Ground nut cake	: 23.5 %
Meat cum bone meal	: 10 %
Mineral mixture	: 1%
Salt	: 0.5%

The animals had access to drinking water round the clock.

3.4 OBSERVATIONS

3.4.1 Litter size

The litter size was recorded within 24 hours of kindling. The litter size at weaning was recorded at four weeks of age.

3.4.5 Litter weight

The litter weights of bunnies were recorded at birth and weaning.

3.4.6 Body weight

Body weight of each animal was recorded from birth to fourteenth week of age at fortnightly intervals.

3.4.7 Mortality rate

Pre weaning and post weaning mortality was recorded in bunnies.

3.4.8 Season of birth

The experiment was scheduled in two seasons *viz.* cold season and hot season. In the course of the experiment, the period from May to September was considered as cold season and the remaining period was hot season.

3.4.9 Body weight of dam at kindling

Body weight of dam was recorded in kilograms within 24 hours of kindling. The animals were divided into three groups based on their body weights as 2 to 2.5, 2.5 to 3 and above 3 kg.

3.4.10 Age of dam at kindling

The age of dam at kindling was recorded and the animals were categorized into three groups as dam aged below 1000, 1000 to 2000 and above 2000 days.

3.5 STATISTICAL METHODS

3.5.1 Least squares analysis

The data on body weights were analysed by least squares technique using LSMLMW and MIXMDL programme (Harvey, 1990) to study the influence of genetic and non-genetic factors. The data adjusted for non-genetic factors like sex, season of birth, litter size at birth, age and weight of dam at kindling, were used for further genetic analysis.

The model used was

$$Y_{ijklmn} = \mu + S_i + E_j + Z_k + A_l + M_m + e_{ijklmn}$$

Y_{ijklmn}- Observation of n^{th} rabbit of the i^{th} sex, j^{th} season, k^{th} litter size, l^{th} dam age, m^{th} dam weight.

μ- Overall mean

S_i- Effect of i^{th} sex

E_j – Effect of j^{th} season

Z_k - Effect of k^{th} litter size at birth

A_l - Effect of l^{th} dam age at kindling

M_m – Effect of m^{th} dam weight at kindling

e_{ijklmn} – Random error

The random errors were assumed to be normally and independently distributed with mean [E(e_i)] zero and variance σ^2_{ei}.

Duncan's multiple range test as modified by Kramer (1957) was used to compare means.

3.5.2 Estimation of heritability

The calculations of heritability for pooled data and for individual purebred animals were done by the SPAB 2.0- Software Statistical package for animal breeding (Sethi, 2002). Heritability was estimated by parental half sib correlation method. The model used was

$$Y_{ij} = \mu + S_i + e_{ij}$$

Y_{ij} - Observation of j^{th} progeny of i^{th} sire

μ - Effect common to all individuals

S_i – Effect due to i^{th} sire with E(S_i)= 0 and V(S_i)= σ^2_{si}

e_{ij} – Random effect due to error with E(e_i)= 0 and V(e_i)= σ^2_{ei}

3.5.3 Estimation of correlation

Genetic, phenotypic and environmental correlations were calculated by using parental half sib method with help of SPAB 2.0 (Sethi, 2002).

3.5.4 Combining ability analysis

Analysis of combining ability was done using SPAB 2.0 (Sethi, 2002). The model used was

$Y_{hijk} = \mu + a_h + p_{1ii} + g_i + g_j + m_j + r_{2ij} + e_{hijk}$

Y_{hijk} -Observation of k^{th} progeny of the j^{th} dam for the i^{th} sire in the h^{th} type of breeding (h=1 for purebreds, h=2 for crossbreds)

μ -Effect common to all individuals

a_h -An effect common to all progeny of h^{th} type of breeding (h=1 for purebreds, h=2 for crossbreds)

p_{1ii} -An effect common to all progeny of a mating between sire and dam of i^{th} line

g_i (g_j) -The GCA effect of i^{th} (j^{th}) line

m_j -Maternal effect for the j^{th} line of dam

r_{2ij} -Sex linkage or reciprocal effect

e_{hijk} -Random effect due to error with $E(e_i) = 0$ and $V(ei) = \sigma^2_{ei}$

Specific combining ability was calculated as per the fixed effects model (parents+F_1s+reciprocals) of Griffing (1956).

Results

4. RESULTS

4.1 GROWTH TRAITS

4.1.1 Body weight at different ages

The overall mean body weights of rabbits at birth, second, fourth, sixth, eighth, tenth, twelfth and fourteenth weeks were recorded as 46.98±0.38, 177.43±2.79, 345.13±6.13, 540.12±10.08, 713.88±12.85, 866.29±15.25, 1057.24±16.51 and 1270.81±16.69g, respectively (Table 4.1).

4.1.2 Effect of different genetic groups on body weight at different ages

Least squares means according to the genetic group of the bunnies are presented in table 4.1 and fig. 4.1. Body weights of rabbits from birth to twelfth week of age were significantly ($P \leq 0.01$) influenced by genetic group.

4.1.2.1 Pre-weaning body weights

Among purebreds the highest mean birth weight of 53.22±1.35g was recorded for WG breed and the lowest for GG (47.32±0.99g). Among crossbreds, the highest mean birth weight was obtained for WG male x SC female cross (51.56±1.60g) whereas the GG x WG cross recorded the lowest (42.54±1.09g).

In purebreds the highest mean body weight at second week of age was obtained for WG breed (197.50±9.40g) while that of SC was found to be the lowest (160.83±6.65g). As for the crossbreds, the highest mean body weight at second week of age was obtained for WG x GG (215.65±8.31g) whereas the GG x WG cross recorded the lowest (140.96±7.82g).

4.1.2.2 Post-weaning body weights

The highest and the lowest mean body weights at fourth week of age were recorded for the WG (357.94±20.41g) and SC (321.94±15.1g), respectively from among the purebreds. The corresponding values obtained for the crossbreds were of WG x GG (444.35±17.55g) and GG x WG (257.50±17.94g).

A highest body weight of 548.33±35.07g was recorded for WG while the lowest for GG (505.33±24.80g) at the age of sixth week. Among the crossbreds WG x GG cross topped with 702.17±28.32g while the lowest values (435.00±35.07g) were obtained for the GG x WG cross.

Among purebreds the highest mean body weight at eight weeks of age was 705.95±36.17g recorded for SC, and the lowest for GG (687.50±33.83g). Among crossbreds, WG x GG recorded the highest (865.87±34.56g) while that of SC x WG cross was the lowest (644.71±40.20g).

In purebreds the highest tenth week mean body weight was obtained for WG (906.54±50.23g) while that of SC was found to be the lowest (766.11±42.69g). As for the crossbreds, the highest mean body weight was obtained for WG x GG (986.59±38.61g) whereas the GG x WG cross recorded the lowest (761.92±50.23g).

The highest and the lowest mean body weights at twelfth week of age were recorded for the WG (1101.92±50.07g) and GG (981.79±48.25g), respectively from among the purebreds. The values obtained for crossbreds, WG x GG and GG x WG were 1179.50±40.37g and 968.50±57.09g, respectively.

Among purebreds the highest fourteenth week mean body weight was obtained for WG (1351.92±50.73g) while that of SC was found to be the lowest (1216.54±50.73g). As for the crossbreds, the highest mean body weight was obtained for WG x SC (1364.29±48.88g) whereas the GG x SC cross recorded the lowest (1186.00±47.22g). The weaning (four weeks) and slaughter weights (twelve weeks) of different genetic groups are depicted in fig. 4.2

4.1.3 Effect of non-genetic factors on body weight at different ages

Least squares means of body weights at different ages in accordance with litter size at birth, weight of dam at kindling, age of dam at kindling, season of birth and sex are presented in table 4.2

4.1.3.1 Effect of litter size at birth

Effect of litter size was found to be significant ($P \leq 0.01$) on weights at birth, second, fourth, sixth and eighth weeks of age and significant ($P \leq 0.05$) on weight at tenth week. As depicted in fig. 4.3 and table 4.2 the individual body weight of bunnies declined gradually as the litter size at birth increased. Least squares means of body weights were highest for the litter containing one to four bunnies and lowest for litter containing nine to eleven bunnies. This trend continued till tenth weeks of age after which there were no difference between different groups (Fig. 4.3).

4.1.3.2 Effect of weight of dam at kindling

Effect of weight of dam at kindling was highly significant ($P \leq 0.01$) on body weights at second, fourth and eighth weeks and significant ($P \leq 0.05$) on sixth week body weight. As regards the body weight at second to eighth weeks, highest least squares means were noticed in bunnies whose mothers weighed between two and 2.5 kg. Highest least squares means were noticed at birth, tenth, twelfth and fourteenth week body weights in bunnies born out of dams weighing three kilograms or more .

4.1.3.3 Effect of age of dam at kindling

The age of dam at kindling was highly significant ($P \leq 0.01$) on body weights at birth and sixth week and significant ($P \leq 0.05$) on fourth and eighth week body weights. Highest least squares means of weight from birth to tenth week were noticed in those bunnies whose dam's age at kindling was above 2000 days while the body weight at twelfth and fourteenth weeks were the highest for bunnies born out of dams aged between 1000 and 2000 days.

4.1.3.4 Effect of season of birth

Effect of season was highly significant ($P \leq 0.01$) on fourth and sixth week weights and significant on birth weight ($P \leq 0.05$). The least squares means of body weight were higher in cold season for body weights at fourth and sixth week. The least squares means for birth weight was higher in hot season.

4.1.3.5 Effect of sex

Even though higher means were observed for females at all ages, the sex of the bunny was found to have no significant influence on any of the pre and post-weaning weights.

4.2 LITTER TRAITS AND GESTATION PERIOD

4.2.1 Effect of genetic groups on litter traits and gestation period

Least squares means of gestation period as well as litter size and litter weight at birth and weaning, in different genetic groups of rabbits are given in table 4.3

The effect of genetic groups of bunnies was non significant for all traits studied.

The litter size at birth and weaning averaged 4.68±0.19 and 3.44±0.16 while litter weight at birth and weaning stood at 221.56±7.59g and 1194.41±43.46g, respectively. The average gestation length was found to be 32.03±0.13 days.

4.2.2 Effect of non-genetic factors on litter traits and gestation period

Least squares means of litter traits and gestation period based on weight of dam at kindling, age of dam at kindling and season are given in table 4.4

4.2.2.1 Effect of non-genetic factors on litter size at birth

The litter size at birth was found to be influenced significantly ($P \leq 0.05$) by the weight of dam at kindling. Dams weighing 2.5 to 3.0 kg had the highest mean litter size at birth (4.3±0.38) while the lowest least squares means (2.99±0.53) were observed for dam group with lower body weights (2 to 2.5 kg).

Age of dam at kindling had no influence on litter size.

Litter size at birth was influenced significantly ($P \leq 0.05$) by season of birth. Litter size was significantly ($P \leq 0.05$) higher in hot season (4.23±0.39) compared to cold season (3.34±0.45).

4.2.2.2 Effect of non-genetic factors on litter weight at birth

Litter weight at birth was significantly ($P \leq 0.05$) influenced by weight of dam at kindling. Highest mean litter weight at birth (210.52±15.00g) was recorded for the medium weighed dam group (2.5 to 3.0 kg) while the dam group with lower body weights (2 to 2.5 kg) gave lower mean values (156.90±21.15g).

Effect of age of dam at kindling was non significant ($P \leq 0.05$) on litter weight at birth.

The influence of season of birth was high (P≤0.01) on the litter weight at birth. The highest least square means for litter weight at birth (214.09±15.43g) were recorded in hot season. Cold season recorded 162.35±17.73g.

4.2.2.3 Effect of non-genetic factors on litter size at weaning

A highly significant influence was noticed for litter size at weaning based on body weight of dam at kindling, with the highest values (3.3±0.27) obtained for the dam group weighing 2.5 to three kilograms and the lowest for dams weighing more than three kilograms.

The age of dam at kindling had significant effect on litter size at weaning (P≤0.05) with a maximum value of 3.23±0.17 for dams below 1000 days of age while those above 2000 days recorded the minimum (1.30±0.67).

Season was found to have significant (P≤0.01) effect on litter size at weaning with maximum litter size observed in hot season (2.91±0.28).

4.2.2.4 Effect of non-genetic factors on litter weight at weaning

Weight of dam at kindling significantly influenced the litter weight at weaning (P≤0.01) with a maximum litter weight of 1201.09±80.53g obtained for dams weighing 2.5 to 3.0 kg. The minimum litter weight was (857.39±104.77g) observed for dam group weighing above 3.0 kg.

No significant influence of age of dam was noticed for litter weight at weaning.

Season was found to have no significant effect (P≤0.05) on litter weight at weaning. An average litter weight of 1116.92±84.46g was recorded in hot season and 966.33±99.14g during cold season.

4.2.2.5 Effect of non-genetic factors on gestation period

Data suggested that effect of weight and age of dam at kindling was non significant as against the highly significant ($P \leq 0.01$) effect of season of kindling on gestation period. The least squares means of gestation period for cold and hot season were 31.71±0.32 and 32.32±0.28 days, respectively.

4.3 MORTALITY

4.3.1 Pre-weaning mortality

The mortality percentages among the genetic groups are given in table 4.5. In purebreds SC recorded highest (31.33 per cent) pre-weaning mortality while GG had the lowest (29.09 per cent). For crossbreds highest pre-weaning mortality was for SC x WG (35.06 per cent) while the lowest for WG x SC (15.62 per cent).

Pre-weaning mortality in the cold season was higher (61.66 per cent of the total mortality) than in hot season (38.34 per cent).

4.3.2 Post-weaning mortality

Highest post-weaning mortality was for SC (29.03 per cent) while lowest for WG (11.76 per cent) among purebreds. In crossbreds, highest post-weaning mortality was observed in GG x WG (27.27 per cent) cross as against the lowest recorded for WG x GG (8.69 per cent).

Higher post-weaning mortality occurred in hot season (57.42 per cent of the total mortality) and mortality of female bunnies was found to be higher than of males (52.55 per cent of the total mortality).

4.4 HERITABILITY

The heritability estimates of body weights at different ages of rabbits from the pooled data are presented in table 4.6.

Heritability estimates for body weights at birth, two, four, six, eight, ten, twelve and fourteen weeks of age were 0.193±0.165, 0.355±0.229, 0.380±0.239, 0.499±0.287, 0.089±0.141, 0.644±0.358, 0.657±0.379 and 0.727±0.407, respectively in rabbits under study.

Estimated heritability for WG, SC and GG are presented diagonally in tables 4.7, 4.8 and 4.9, respectively.

Heritability estimates for body weights of WG at birth, second, fourth, sixth, eighth, twelfth and fourteenth weeks stood at 0.2235±0.3942, 0.3381±0.4837, 0.3489±0.4918, 0.0701±0.2696, 0.0769±0.2944, 0.0479±0.3112 and 0.4774±0.6386, respectively. Value for tenth week was below zero.

For SC, high estimates of heritability were obtained for tenth (0.8017±0.7859), twelfth (0.6558±0.7673) and fourteenth (0.7138±0.7993) week's body weight. Corresponding values for other age groups were medium and few were negative.

Heritability estimates for body weights for GG at fourth, sixth and fourteenth weeks were 0.2211±0.3490, 0.4227±0.5307 and 0.2571±0.5876, respectively.

4.5 CORRELATION AMONG BODY WEIGHTS AT DIFFERENT AGES

4.5.1 Genetic correlation

The genetic correlation estimates among body weights for the pooled data, WG, SC and GG breeds are presented above the diagonal in table 4.6, 4.7, 4.8 and 4.9, respectively. The estimates were above one in few cases.

4.5.2 Phenotypic correlation

The phenotypic correlation estimates for the pooled data of body weights at different ages are presented below the diagonal in table 4.6.

The highest correlation was 0.885±0.042, between twelfth and fourteenth weeks of age, while the lowest was 0.140±0.074, between birth and eighth week body weight.

The phenotypic correlation estimates for WG, SC and GG are presented in tables 4.7, 4.8 and 4.9, respectively.

4.6 COMBINING ABILITY ANALYSIS

4.6.1 General combining ability (GCA) effects

The estimates of GCA are presented in table 4.10. GCA effects were highest in WG genetic group for body weights at all ages and were positive ranging from 2.3110 to 89.2674. For body weights up to tenth week of age, GCA effects were lowest and negative for SC. The values were negative for GG except for eighth week body weight. GCA effects were highly significant ($P \leq 0.01$) at all ages except for eighth week.

4.6.2 Specific combining ability (SCA) effects

The SCA effects for the cross SC x GG was highest for second, fourth and tenth week and the corresponding values were 8.9861, 14.4389 and 45.9006, respectively (Table 4.10). Highest values were obtained for WG x GG cross for sixth, eighth and twelfth week weight and the values obtained were 23.8256, 32.3094 and 14.6489. WG x SC exhibited highest combining ability (7. 4494) at fourteenth week weight.

4.6.3 Maternal effects

The maternal effects in SC were positive at all ages (Table 4.10). Highly significant (P≤0.01) maternal effects were noticed at second, fourth, sixth, tenth and twelfth weeks of growth. The maternal effects for GG were highest for sixth, eighth, twelfth and fourteenth week and were 35.4407, 35.7926, 93.3918 and 42.8536, respectively. Effect was highest for SC from birth to fourth week as well as at tenth week. At all ages WG remained lowest with negative estimates.

4.6.4 Reciprocal effects

Reciprocal effects in WG x GG, SC x WG and GG x SC crosses were positive at all ages except twelfth and fourteenth week, while WG x SC, SC x GG and GG x WG had negative reciprocal effects except at twelfth and fourteenth week body weight (Table 4.13). At fourth and sixth weeks of age, reciprocal effects were found to be highly significant (P≤0.01) and significant (P≤0.05) for birth weight.

Table 4.1. Least squares means of body weights (g) in different genetic groups of rabbits

Genetic group (male x female)		Birth weight	2nd week weight	4th week weight	6th week weight	8th week weight	10th week weight	12th week weight	14th week weight
Purebred	WGxWG	53.22±1.35^{d}	197.50±9.40^{de}	357.94±20.41^{b}	548.33±35.07^{b}	694.00±42.80^{a}	906.54±50.23^{bc}	1101.92±50.07^{abc}	1351.92±50.73
	SCxSC	48.09±1.04^{bc}	160.83±6.65^{ab}	321.94±15.11^{b}	521.79±25.67^{ab}	705.95±36.17^{a}	766.11±42.69^{a}	1019.23±50.07^{ab}	1216.54±50.73
	GGxGG	47.32±0.99^{b}	178.61±6.65^{bcd}	339.71±14.22^{b}	505.33±24.80^{ab}	687.50±33.83^{a}	812.63±41.55^{ab}	981.79±48.25^{a}	1264.09±55.15
Crossbred	WGxSC	51.56±1.60^{cd}	185.83±8.14^{cd}	338.86±17.94^{b}	521.36±28.96^{ab}	698.24±40.20^{a}	981.79±48.40^{c}	1156.07±48.25^{bc}	1364.29±48.88
	WGxGG	48.75±1.17^{bc}	215.65±8.31^{e}	444.35±17.55^{c}	702.17±28.32^{c}	865.87±34.56^{b}	986.59±38.61^{c}	1179.50±40.37^{c}	1341.25±40.90
	SCxWG	42.92±1.03^{a}	162.17±8.31^{abc}	320.68±17.94^{b}	488.86±28.96^{ab}	644.71±40.20^{a}	835.00±50.23^{ab}	981.11±60.18^{a}	1209.38±64.66
	SCxGG	47.27±1.22^{b}	181.86±6.74^{bcd}	362.71±14.22^{b}	559.14±22.96^{b}	732.59±30.78^{a}	868.04±34.23^{abc}	1058.04±37.65^{abc}	1228.57±39.91
	GGxWG	42.54±1.09^{a}	140.96±7.82^{a}	257.50±17.94^{a}	435.00±35.07^{a}	653.46±45.97^{a}	761.92±50.23^{a}	968.50±57.09^{a}	1232.78±60.97
	GGxSC	46.29±1.11^{b}	187.31±7.82^{d}	360.39±16.50^{b}	546.15±26.64^{b}	684.17±33.83^{a}	853.16±41.55^{abc}	984.72±42.55^{a}	1186.00±47.22
Overall mean		46.98±0.38 (562)	177.43±2.79 (247)	345.13±6.13 (233)	540.12±10.08 (216)	713.88±12.85 (183)	866.29±15.25 (159)	1057.24±16.51 (134)	1270.81±16.69 (124)

Sample size is given in brackets.
Letters with different superscript in a column differ significantly ($P \leq 0.05$).

Table 4.2. Least squares means of body weight (g) according to litter size at birth, weight and age of dam at kindling, season of birth and sex

Source	Birth weight	2nd week weight	4th week weight	6th week weight	8th week weight	10th week weight	12th week weight	14th week weight
Litter size								
1 to 4	58.17±1.23[a]	208.63±6.15[a]	437.42±12.10[a]	679.18±19.99[a]	839.40±25.95[a]	953.51±31.52[a]	1107.77±34.37	1319.18±36.63
5 to 8	51.94±1.43[b]	188.43±7.20[b]	373.11±14.18[b]	570.76±23.48[b]	741.23±31.44[b]	871.98±39.09[b]	1105.79±42.16	1291.49±43.87
9 to 11	42.40±2.39[c]	158.52±12.01[c]	315.61±23.65[c]	494.29±42.12[c]	673.97±55.24[b]	836.69±84.57[b]	996.86±93.06	1326.27±119.34
Weight of dam at kindling								
2 to 2.5 kg	49.74±1.91	194.33±9.60[a]	399.61±18.91[a]	599.36±31.52[a]	787.31±41.70[a]	883.36±54.11	1082.35±58.05	1309.32±66.99
2.5 to 3 kg	50.01±1.34	173.37±6.71[b]	344.28±13.22[b]	546.57±22.61[b]	697.55±29.28[b]	853.17±38.60	1040.56±42.34	1288.37±49.44
Above 3 kg	52.76±1.55	187.89±7.77[a]	382.25±15.30[a]	598.31±25.62[a]	769.73±34.70[a]	925.65±48.40	1087.50±52.36	1339.25±62.20
Age of dam at kindling								
Below 1000 days	47.46±0.94[a]	175.85±4.70	343.16±9.26[a]	529.84±16.26[a]	689.44±21.46[a]	840.14±31.73	1006.38±35.29	1255.16±41.47
1000 to 2000 days	45.35±1.46[a]	178.32±7.32	353.68±14.41[a]	529.21±24.19[a]	731.54±33.52[b]	891.74±46.38	1106.15±50.54	1384.11±63.67
Above 2000 days	59.70±3.12[b]	201.42±15.68	429.30±30.88[b]	685.18±50.96[b]	833.61±64.92[b]	930.29±80.29	1097.89±87.60	1297.67±96.52
Season of birth								
Cold	49.59±1.64[a]	189.75±8.25	394.17±16.25[a]	610.24±27.16[a]	759.15±35.98	889.39±48.71	1061.00±51.84	1293.78±60.69
Hot	52.09±1.34[b]	180.64±6.71	356.59±13.21[b]	552.58±22.23[b]	743.91±28.72	885.40±38.89	1079.27±42.70	1330.85±52.02
Sex								
Male	50.60±1.48	182.33±7.42	372.03±14.60	574.86±24.72	739.82±32.44	868.62±44.85	1046.83±48.06	1303.45±57.23
Female	51.08±1.43	188.06±7.17	378.73±14.12	587.97±23.65	763.24±31.32	906.16±41.80	1093.45±45.60	1321.18±54.82

Letters with different superscript within a specific source in a column differ significantly ($P \leq 0.05$).

Table 4.3. Least squares means of litter traits and gestation period in different genetic groups of rabbits

Genetic group (male x female)		Litter size at birth (Nos)	Litter weight at birth (g)	Litter size at weaning (Nos)	Litter weight at weaning (g)	Gestation period (days)
Purebred	WGxWG	4.50±0.59	241.50±25.17	3.40±0.57	33.20±0.41	1217.00±157.09
	SCxSC	4.53±0.49	220.33±20.55	3.44±0.43	32.23±0.36	1108.89±117.09
	GGxGG	4.12±0.46	199.41±19.31	3.89±0.43	31.40±0.34	1321.11±117.09
Crossbred	WGxSC	4.57±0.72	235.71±30.09	3.67±0.52	32.50±0.53	1242.50±143.40
	WGxGG	4.31±0.53	210.77±22.08	2.88±0.45	31.77±0.36	1277.50±124.19
	SCxWG	5.92±0.53	254.23±22.08	2.75±0.45	32.00±0.39	881.88±124.19
	SCxGG	4.25±0.55	202.08±22.98	3.18±0.39	32.17±0.38	1154.09±105.91
	GGxWG	6.20±0.59	265.50±25.17	5.50±0.64	31.40±0.41	1416.25±175.63
	GGxSC	4.20±0.49	195.33±20.55	3.38±0.45	32.07±0.35	1271.88±124.19
Overall mean		4.68±0.19 (112)	221.56±7.59 (112)	3.44±0.16 (68)	1194.41±43.46 (68)	32.03±0.13 (104)

Sample size is given in brackets.

Table 4.4. Least squares means of litter traits and gestation period in rabbits according to weight and age of dam at kindling and season of birth

Source	Litter size at birth (Nos)	Litter weight at birth (g)	Litter size at weaning (Nos)	Litter weight at weaning (g)	Gestation period (days)
Weight of dam at kindling					
2 to 2.5 kg	2.99±0.53[a]	156.90±21.15[a]	2.09±0.39[a]	1066.39±117.18[a]	31.95±0.39
2.5 to 3 kg	4.30±0.38[b]	210.52±15.00[b]	3.30±0.27[b]	1201.09±80.53[a]	31.90±0.27
Above 3 kg	4.05±0.47[b]	197.25±18.52[b]	1.90±0.35[a]	857.39±104.77[b]	32.20±0.34
Age of dam at kindling					
Below 1000 days	4.48±0.21	211.93±8.53	3.23±0.17[a]	1154.77±51.21	31.95±0.16
1000 to 2000 days	4.11±0.43	187.96±16.99	2.76±0.32[a]	1141.33±96.92	31.89±0.32
Above 2000 days	2.76±0.97	164.77±38.54	1.30±0.67[b]	828.77±201.29	32.21±0.70
Season of birth					
Cold	3.34±0.45[a]	162.35±17.73[a]	1.95±0.33[a]	966.33±99.14	31.71±0.32[a]
Hot	4.23±0.39[b]	214.09±15.43[b]	2.91±0.28[b]	1116.92±84.46	32.32±0.28[b]

Letters with different superscript within a specific source in a column differ significantly ($P \leq 0.05$).

Table 4.5
Pre-weaning and post-weaning mortality percentages of different genetic groups of rabbits

Genetic group		Pre-weaning (%)	Post-weaning (%)
Purebred	WG	31.11	11.76
	SC	31.33	29.03
	GG	29.07	28.57
Crossbred	WG x SC	15.62	18.18
	WG x GG	30.65	8.69
	SC x WG	35.06	18.18
	SC x GG	17.86	20.00
	GG x WG	34.25	27.27
	GG xSC	31.51	19.23

Table 4.6. Heritability, genetic and phenotypic correlations of body weights from pooled data

	Birth weight	2nd week weight	4th week weight	6th week weight	8th week weight	10th week weight	12th week weight	14th week weight
Birth weight	**0.193±0.165**	1.015±0.180	0.736±0.329	0.556±0.375	0.464±0.689	0.296±0.468	-0.008±0.548	-0.139±0.550
2nd week weight	0.437±0.059	**0.355±0.229**	0.886±0.114	0.687±0.254	0.892±0.393	0.707±0.288	1.068±0.431	2.241±6.354
4th week weight	0.350±0.062	0.828±0.037	**0.380±0.239**	0.826±0.138	0.894±0.152	0.483±0.352	0.466±0.424	1.122±0.176
6th week weight	0.158±0.068	0.690±0.050	0.830±0.038	**0.499±0.287**	0.855±0.221	0.910±0.091	0.916±0.179	0.622±0.464
8th week weight	0.140±0.074	0.589±0.060	0.655±0.056	0.814±0.043	**0.089±0.141**	0.807±0.235	1.133±5.529	/
10th week weight	0.220±0.078	0.491±0.070	0.490±0.070	0.668±0.059	0.795±0.049	**0.644±0.358**	1.017±0.085	0.083±0.187
12th week weight	0.172±0.086	0.414±0.079	0.388±0.080	0.512±0.075	0.667±0.065	0.853±0.045	**0.657±0.379**	1.00±0.033
14th week weight	0.216±0.088	0.44±0.081	0.410±0.083	0.424±0.082	0.549±0.076	0.668±0.067	0.885±0.042	**0.727±0.407**

/ =not estimable.

Diagonal values are heritability, above diagonal genetic correlations and below diagonal phenotypic correlations.

Table 4.7. Heritability, genetic and phenotypic correlations of body weights in White Giant

	Birth weight	2nd week weight	4th week weight	6th week weight	8th week weight	10th week weight	12th week weight	14th week weight
Birth weight	**0.2235±0.3942**	0.4731±0.8719	-0.1374±1.0938	1.0071±0.0243	-0.4829±1.0458	-0.9970±0.0043	/	-1.4271±0.8698
2nd week weight	0.3436±0.1212	**0.3381±0.4837**	0.9789±0.0419	1.7654±3.8676	1.9150±4.7818	0.3143±0.7907	0.4834±1.9659	0.500±0.8730
4th week weight	0.2013±0.1265	0.8041±0.0768	**0.3489±0.4918**	0.8487±0.5199	1.4567±1.8914	0.5408±0.6005	1.7084±3.9413	1.1092±0.2147
6th week weight	-0.0260±0.1313	0.5952±0.1055	0.8377±0.0717	**0.0701±0.2696**	3.1107±91.6386	-1.6815±5.9565	0.4139±1.9393	0.5045±0.7915
8th week weight	-0.0327±0.1373	0.4949±0.1194	0.7048±0.0974	0.8808±0.0650	**0.0769±0.2944**	-0.0916±1.0156	0.2408±2.6364	0.7890±0.4794
10th week weight	0.1140±0.1449	0.3318±0.1376	0.5459±0.1222	0.6246±0.1139	0.8004±0.0874	**-0.1320±0.1346**	-0.5594±1.2004	0.4392±0.6398
12th week weight	0.1028±0.1483	0.3694±0.1385	0.5680±0.1227	0.5619±0.1233	0.7240±0.1028	0.8449±0.0798	**0.0479±0.3112**	1.6853±3.8366
14th week weight	0.1081±0.1482	0.4077±0.1361	0.4715±0.1315	0.3829±0.1377	0.5440±0.1251	0.6582±0.1122	0.8656±0.0747	**0.4774±0.6386**

/ =not estimable.

Diagonal values are heritability, above diagonal genetic correlations and below diagonal phenotypic correlations.

Table 4.8. Heritability, genetic and phenotypic correlations of body weights in Soviet Chinchilla

	Birth weight	2^{nd} week weight	4^{th} week weight	6^{th} week weight	8^{th} week weight	10^{th} week weight	12^{th} week weight	14^{th} week weight
Birth weight	**-0.1222±0.0201**	-0.3408±0.0995	-0.4864±0.0735	-0.5588±0.2404	-0.5608±0.2795	-0.8391±0.1435	-1.0302±0.0414	-1.1113±0.1553
2^{nd} week weight	0.3600±0.106	**-0.1233±0.0190**	-1.0410±.0078	-0.4420±0.3059	-0.8063±0.2563	-0.1198±0.8095	-0.1452±0.2969	-0.1906±0.2859
4^{th} week weight	0.3258±0.1019	0.8198±0.0618	**-0.1279±0.0144**	0.0082±0.3948	-0.4497±0.0625	-0.4197±0.1059	-0.6478±0.1848	-0.6291±0.1882
6^{th} week weight	0.1045±0.1092	0.710±0.0773	0.8049±0.0651	**0.3692±0.4582**	1.0014±0.0048	1.7244±5.8375	-0.2193±0.8085	0.0063±0.8309
8^{th} week weight	0.1715±0.1222	0.6760±0.0914	0.6011±0.0991	0.7576±0.0810	**0.2211±0.3754**	1.1691±0.3539	1.0478±0.1379	1.4101±1.3639
10^{th} week weight	0.0933±0.1319	0.5454±0.110	0.4430±0.1187	0.6157±0.1044	0.8116±0.0774	**0.8017±0.7859**	1.1122±0.2322	1.3067±0.6783
12^{th} week weight	-0.0480±0.1579	0.3559±0.1478	0.1980±0.1550	0.3026±0.1507	0.6015±0.1263	0.7592±0.1029	**0.6558±0.7673**	1.0702±0.1177
14^{th} week weight	0.0715±0.1577	0.3520±0.1480	0.1935±0.1551	0.2531±0.1530	0.4353±0.1423	0.5143±0.1356	0.8199±0.0905	**0.7138±0.7993**

Diagonal values are heritability, above diagonal genetic correlations and below diagonal phenotypic correlations.

Table 4.9. Heritability, genetic and phenotypic correlations of body weights in Grey Giant

	Birth weight	2nd week weight	4th week weight	6th week weight	8th week weight	10th week weight	12th week weight	14th week weight
Birth weight	**-0.0899±0.068**	-1.1217±0.1050	-1.2325±0.4008	-1.4641±1.5708	-1.1018±0.1879	-1.5032±1.1837	-0.2923±2.4200	/
2nd week weight	0.4921±0.0967	**-0.1101±0.0481**	-0.9088±0.1022	-0.7944±0.0867	-1.7732±1.0535	-1.7313±1.5888	1.3128±1.2944	0.5160±0.6741
4th week weight	0.3477±0.1042	0.8029±0.0662	**0.2211±0.3490**	0.9071±0.2081	-0.7833±0.1741	-2.5146±5.9728	0.3487±2.7070	0.2032±0.8297
6th week weight	0.1576±0.1189	0.6375±0.0928	0.8255±0.0679	**0.4227±0.5307**	-0.5316±0.3113	-1.1343±0.1811	-1.7206±1.2803	-2.1267±4.4054
8th week weight	0.1497±0.1287	0.5281±0.1106	0.6467±0.0993	0.8168±0.0751	**-0.194±0.0341**	-1.1089±0.0521	-0.5395±0.5195	-0.0309±0.7717
10th week weight	0.2202±0.1394	0.3826±0.1320	0.3874±0.1317	0.6819±0.1045	0.8156±0.0827	**-0.1381±0.1436**	-1.7289±0.7525	-1.3137±0.1942
12th week weight	0.1823±0.1555	0.3641±0.1473	0.3766±0.1465	0.5508±0.1320	0.7588±0.1030	0.8524±0.0827	**-0.1329±0.2055**	/
14th week weight	0.2770±0.1673	0.5247±0.1482	0.5780±0.1420	0.5494±0.1455	0.7351±0.1180	0.7145±0.1218	0.9220±0.0674	**0.2571±0.5876**

/ =not estimable.

Diagonal values are heritability, above diagonal genetic correlations and below diagonal phenotypic correlations.

Table 4.10. Estimates of GCA, SCA, maternal effects and reciprocal effects for body weights at different ages in rabbits

Source	Birth weight	2nd week weight	4th week weight	6th week weight	8th week weight	10th week weight	12th week weight	14th week weight
GCA effects								
WG	2.3110	12.7847	26.0999	43.9571	19.1738	83.3778	87.9929	89.2674
SC	-2.0024	-12.2389	-23.8398	-31.7121	-41.5375	-42.1689	-29.2800	-53.3389
GG	-0.3086	-0.5458	-2.2601	-12.2449	22.3637	-41.2090	-58.7129	-35.9285
SCA effects								
WGxSC	0.2667	-2.95389	-2.8444	-18.0111	-22.5672	24.8006	-1.4378	7.4494
WGxGG	-0.3600	-3.49056	-3.4411	23.8256	32.3094	-1.2278	14.6489	-8.28056
SCxGG	-0.4467	8.98611	14.4389	22.5289	17.1094	45.9006	7.1322	-16.3072
Maternal effects								
WG	-1.6452	-21.5035	-32.8169	-52.855	-48.5308	-102.483	-123.2546	-84.3352
SC	2.1255	14.5278	20.0627	17.4148	12.7382	53.2521	29.8628	41.4816
GG	-0.4803	6.9757	12.7542	35.4407	35.7926	49.2309	93.3918	42.8536
Reciprocal effects								
WGxSC	-1.2620	-4.711	-19.2575	-29.6215	-6.0660	-2.6825	4.9120	16.4913
WGxGG	1.2620	4.711	19.2575	29.6215	6.0660	2.6825	-4.9120	-16.4913
SCxWG	1.2620	4.711	19.2575	29.6215	6.0660	2.6825	-4.9120	-16.4913
SCxGG	-1.2620	-4.711	-19.2575	-29.6215	-6.0660	-2.6825	4.9120	16.4913
GGxWG	-1.2620	-4.711	-19.2575	-29.6215	-6.0660	-2.6825	4.9120	16.4913
GGxSC	1.2620	4.711	19.2575	29.6215	6.0660	2.6825	-4.9120	-16.4913

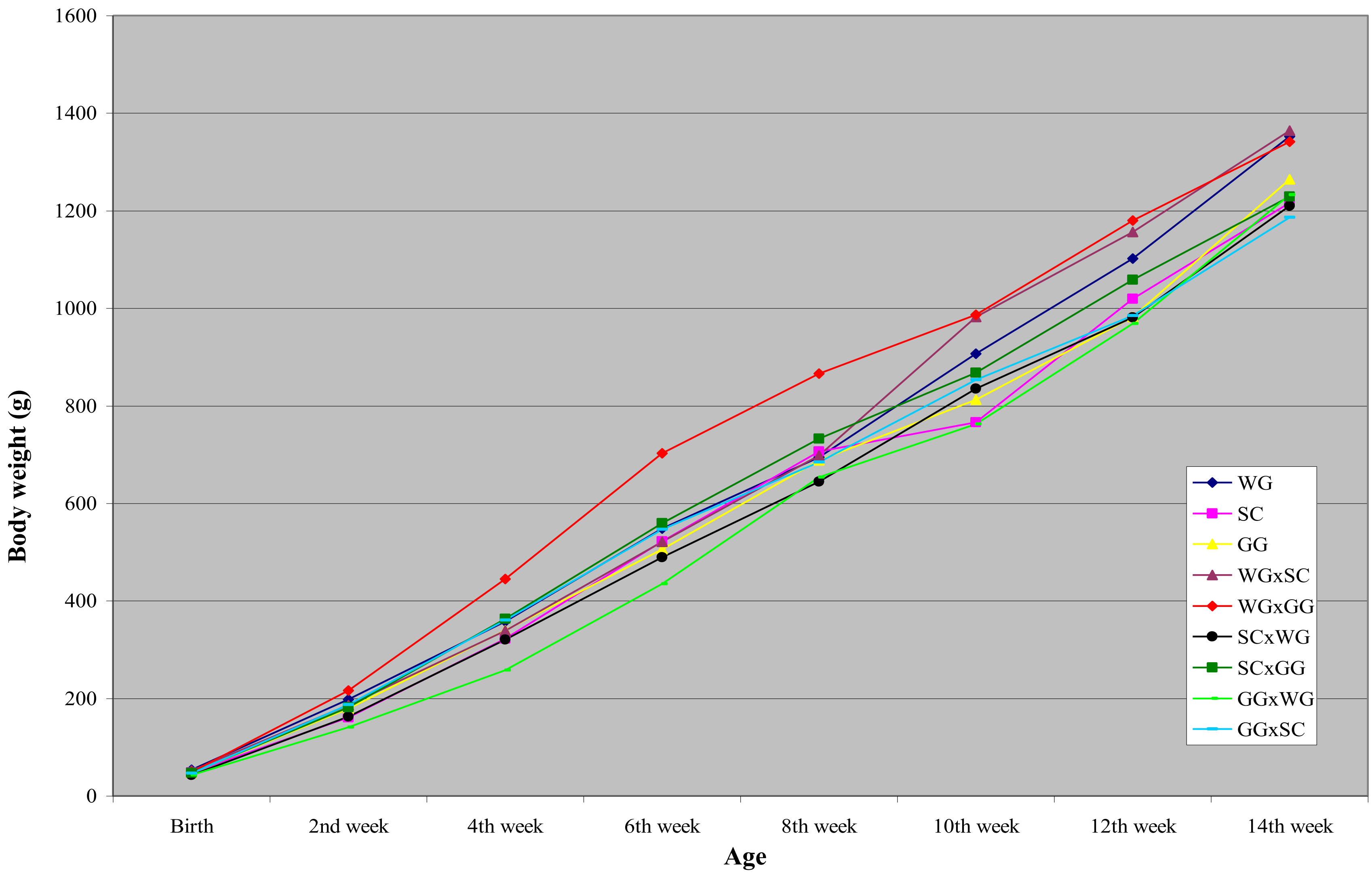

Fig 4.1. Growth curve in different genetic groups of rabbits

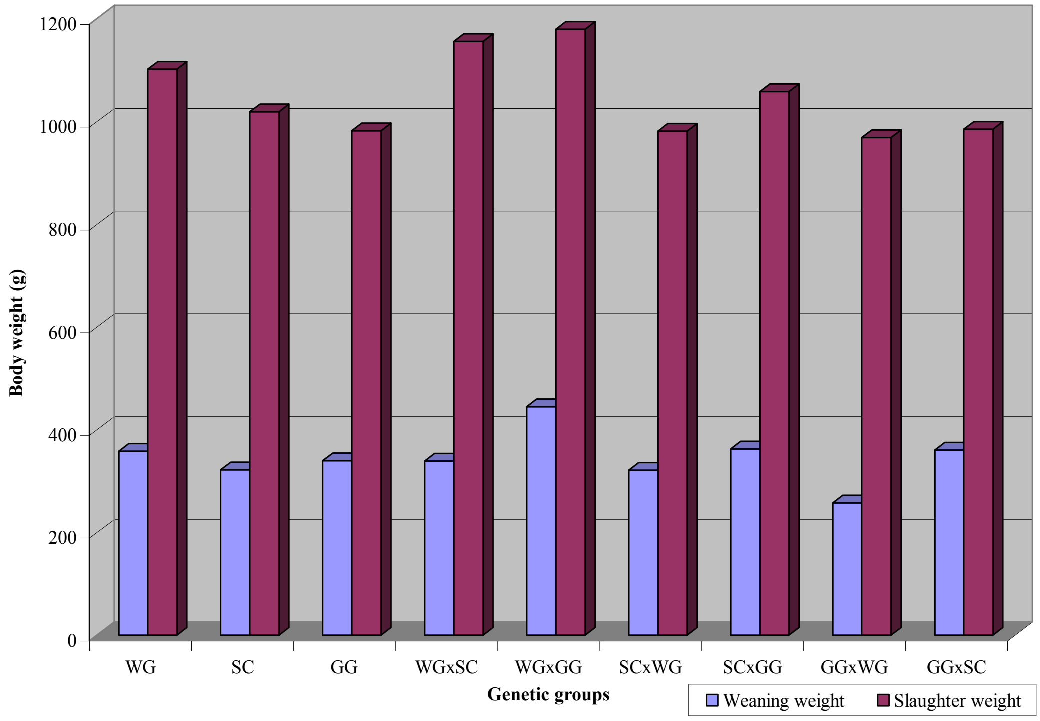

Fig 4.2. Weaning and slaughter weights in different genetic groups

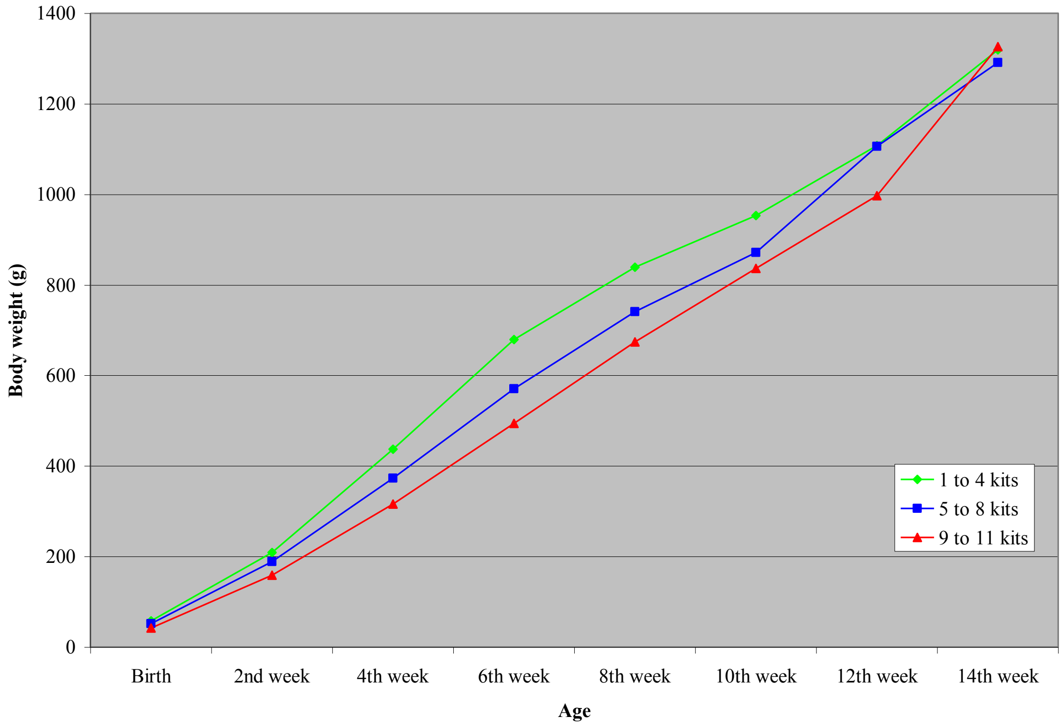

Fig. 4.3. Growth curve in relation to litter size

Discussion

5. DISCUSSION

5.1 GROWTH TRAITS

5.1.1 Body weight at different ages

The overall mean body weights of rabbits at birth, second, fourth, sixth, eighth, tenth, twelfth and fourteenth weeks were recorded as 46.98±0.38, 177.43±2.79, 345.13±6.13, 540.12±10.08, 713.88±12.85, 866.29±15.25, 1057.24±16.51 and 1270.81±16.69g, respectively.

Similar observations were made by Radhakrishnan (1992), Kasiviswanathan (2000) and Gupta *et al.* (2002) who recorded body weights of rabbits in similar age groups. According to Kasiviswanathan (2000) the body weights of rabbits at fourth, sixth, eighth, tenth and twelfth weeks of age were 274.8, 512.1, 732.0, 986.9 and 1201.4g, respectively. Body weights of 383.3, 573.4, 788.6, 1000.5 and 1000.6 g were recorded in age groups of fourth, sixth, eighth, tenth and twelfth weeks in rabbits by Radhakrishnan (1992).

Higher body weights have been reported in rabbits of similar age groups by Mukundan *et al.* (1993) and Poornima *et al.* (2002)

5.1.2 Effect of different genetic groups on body weight

The present study suggested that body weights of rabbits from birth to twelfth week of age were significantly ($P \leq 0.01$) influenced by genetic groups.

5.1.2.1 Pre-weaning body weights

According to the present study the highest mean birth weight among purebreds was 53.22±1.35g, recorded in WG. The highest birth weight for WG among purebreds was also reported by Lahiri and Mahajan (1984) who recorded 70.03±2.52g. They also recorded a birth weight of 54.76±2.20g in GG. The highest birth weight in crossbreds was obtained for WG x SC (51.56±1.60g) which is lower than that reported by Lahiri and Mahajan (1984) in the same cross (63.83±5.15g).

The highest second week weight recording of 197.50±9.40g was also observed in WG. Significant effect of genetic group on birth weight was reported by Reddy *et al.* (2003). Reddy *et al*. (2002) observed significant effect of genetic group on body weight at one, two, three and four weeks of age and reported birth weights of SC and GG as 54.88 and 55.93g, respectively. Second week weights were 142.86 and 175.35g.

5.1.2.2 Post-weaning body weights

Among the purebreds, highest post-weaning body weights at fourth, sixth, tenth, twelfth and fourteenth week were recorded in WG while eighth week body weight was higher for SC. Among crossbreds and purebreds progenies of WG male crossed to GG female recorded the highest post-weaning weights from second to twelfth week. Fourteenth week body weight was higher for WG x SC.

Lahiri and Mahajan (1983) reported highest weight at sixth week for NZW breed (775g) followed by GG x NZW cross (664g). Bokade *et al*. (1993) reported highest body weight at three month weight for WG x GG breed (1579.55g) among crossbreds and for WG (1412.00g) among purebreds. The superiority of WG x GG is in accordance with the present study. Mukundan *et al*. (1993) reported higher fourth week weights of 607.62g and 625.32g for SC and NZW breeds. The respective weights at twelve weeks of age were 1544.29 and 1601g.

Kasiviswanathan (2000) reported significant effect of breed on fourth, sixth, eighth, tenth and twelfth week weight. Reddy *et al*. (2002) reported fourth week weights for SC and GG as 306.74 and 348.11g, respectively. The weights are comparable with the weights obtained in the present study. Kumar *et al*. (2001) reported significant effect of breed at 12 weeks of age. In the study highest body weight at 4 week was in SC but 12 weeks of age, WG breed attained higher body weight than SC and Black Brown. Singh *et al.* (2007c) reported sixth week body weights in GG and WG as 616.82g and 646.55g, respectively. Choudhury *et al.* (2002) reported sixth week body weight in SC as 721.35g.

5.1.3 Effect of non-genetic factors on body weight at different ages

5.1.3.1 Effect of litter size at birth

The litter size at birth significantly affected the body weight at all post-weaning ages except twelfth and fourteenth weeks of age. Further, the body weight of bunnies declined gradually as the litter size at birth increased. Choudhury *et al.* (2002) Gupta *et al.* (2002) and Reddy *et al.* (2003) have also made similar observations in their experiments. The reason to this finding could be the competition among the individual fetuses in the uterus and the limited capacity of the doe to provide nutrients to the large number of fetuses in the wombs during pregnancy as explained by Gupta *et al.* (2002). The effect of litter size on body weight of bunnies was significant only up to tenth week of age indicating that increased litter size does not affect body weight beyond ten weeks.

5.1.3.2 Effect of weight of dam at kindling

According to the observations made in the present study, the effect of weight of dam at kindling was significant for body weights at second, fourth, sixth and eighth weeks. Similar observations were recorded by Kumar *et al.* (2001) who reported significant effect of doe weight at kindling on weight of kits up to 11^{th} week of age. The dam weight at kindling was reported to have a significant effect on the body weight of kits at three weeks of age (APAU, 1989), which is in accordance with the findings of the present study. The bunnies born to lower weight does recorded better body weight which could be due to the decreased litter size.

5.1.3.3 Effect of age of dam at kindling

The age of dam at kindling was significant on body weights at birth, fourth, sixth and eighth week. Highest means were noticed in bunnies born to dams aged above 2000 days at kindling. The reasons attributed by Adams (1970) for reduced fertility in aged dams were decline in ovulation rate, defects of oocytes and uterus which in turn resulted in reduced litter size and higher individual bunny weights.

5.1.3.4 Effect of season of birth

Effect of season of birth was significant on the birth weight and body weights at fourth and sixth weeks. The least squares means of body weights were higher in cold season for body weights at fourth and sixth week. This is in accordance with the observations made by Yamani *et al.* (1991), Poornima *et al.* (2002), Belhadi (2004), Devi *et al.* (2007) and Singh *et al.* (2007a). During hot season rabbits in hot semi arid region recorded lower body weight due to lower feed, digestible protein and digestible energy intake compared to winter and monsoon (Prasad and Karim, 1996).

The adult body weights recorded was highest for bunnies born in the season from October to April. Similar results have been reported by APAU (1989), Choudhury *et al.* (2002) and also by Poornima *et al.* (2002)

5.1.3.5 Effect of sex

Sex of the bunny had no significant influence on all the pre and post-weaning weights even though higher means were observed for females at all ages.

The study attributed no significance to sex of the animals with regard to their body weights at any stage. This observation is in accordance with the findings of Choudhury *et al.* (2002), who reported no significant sex effect on post-weaning body weights from sixth week to twenty four weeks. Poornima *et al.* (2002) also reported non significant effect of sex on all post-weaning body weights up to twelve weeks of age. Gupta *et al.* (2002) observed that there was no differential effect of male and female sex hormones on the post-weaning body weights.

5.2 LITTER TRAITS AND GESTATION PERIOD

5.2.1 Effect of genetic groups on litter traits and gestation period

As per the present study, the litter size at birth and weaning averaged 4.68±0.19 and 3.44±0.16 while litter weight at birth and weaning stood at 221.56±7.59g and 1194.41±43.46g, respectively. Average gestation period of dams was 32.03±0.13 days.

The observations made under the present study pointed no significant difference between the genetic groups for litter size and litter weight at birth and weaning. Similar observations of non significant effect of breed on litter size and litter weight were made by Lahiri and Mahajan (1984) and Kumar *et al.* (2006). In the present study, gestation period among genetic groups showed no significant difference. Non significant effect of genetic groups on gestation period was reported by Mukundan *et al.* (1993) Das *et al.* (1997) and Pannu *et al.* (2005).

5.2.2 Effect of non-genetic factors on litter traits and gestation period

5.2.2.1 Effect of non-genetic factors on litter size at birth

The litter size at birth was found to be influenced significantly by the weight of dam at kindling. But Aina *et al.* (1998) and Belhadi (2004) reported a non significant effect. In the present study lowest least squares means for litter size at birth (2.99±0.53) were observed for dam group with lower body weights (2 to 2.5 kg). This may be attributed to the increased ovulation rate in the heavier and healthier does. According to Hulot *et al*. (1982) the number of ova increased more than two units for a weight increase of one kilogram of live weight of doe rabbit.

No significant influence of age of dam noticed on litter size at birth.

The litter size at birth was influenced significantly by season of birth. This result is in agreement with that of Randi (1982), Rathor *et al.* (2000) and Belhadi (2004). However Yamani *et al.* (1991) reported that litter size at birth was not influenced significantly by season. In the present study litter size at birth was higher during hot season. Photoperiod might have an influence on this effect. Smelser *et al*. (1934) reported slightly higher number of ovulations in rabbits subjected to light.

5.2.2.2 Effect of non-genetic factors on litter weight at birth

The findings of this study revealed that litter weight at birth was significantly influenced by weight of dam at kindling. In contrast to the present study Aina *et al.* (1998) reported non significant effect of weight of dam at kindling on litter weight at birth. Lowest mean litter weight at birth (156.90±21.15) was recorded for the low weighed dam group (2 to 2.5 kg) while the dam group with higher body weights (2.5 to 3.0 kg and above 3 kg) gave higher mean values (210.52±15.00 and 197.25±18.52). Increased ovulation rate and litter size at birth for higher body weight does resulted in higher litter weight at birth.

Age of the dam had no significant influence on litter weight at birth.

The influence of season of birth was high ($P \leq 0.01$) on the litter weight at birth. The highest least square mean for litter weight at birth (214.09±15.43) was recorded in hot season. During hot season increased litter size at birth caused an increase in the litter weight at birth.

5.2.2.3 Effect of non-genetic factors on litter size at weaning

A highly significant influence was noticed for litter size at weaning based on body weight of dam at kindling. Litter size at weaning was found to be highest for does weighing two and a half to three kilograms. Ibrahim (1985) indicated that the best milk production came from does weighing below three kilograms. Higher litter size at weaning could be due to the higher lactating status of the does. Similar reports have been put forth by Aina *et al.* (1998).

The age of dam at kindling had significant effect on litter size at weaning ($P \leq 0.05$) with a maximum value of 3.23±0.17 for dams below 1000 days of age while those above 2000 days recorded the minimum (1.30±0.67). The observation was found to be in accordance with Maurer and Foote (1972). The lower reproductive efficiency of ageing female was partly attributed to the lower concentration of Luteotropic Hormone in the pituitary gland and lower progesterone content in the ovarian venous blood of old during pregnancy.

Season of birth was found to have significant effect on litter size at weaning in the present study which agreed with observations of Yamani *et al.* (1991) and Rathor *et al.* (2000). In the present study, the litter size at weaning was found to be smaller in cold season compared to hot which may be attributed to the heavier mortality rate due to high humidity.

5.2.2.4 Effect of non-genetic factors on litter weight at weaning

Weight of dam at kindling significantly influenced the litter weight at weaning as per the findings of this study. This finding agrees with that of Aina *et al.* (1998).

No significant influence was noticed for litter weight at weaning as regards the age of the dam.

Season of birth was found to have no significant effect on litter weight at weaning.

5.2.2.5 Effect of non-genetic factors on gestation period

A significant ($P \leq 0.05$) effect of season of kindling on gestation period was a finding of this study. This observation is in accordance with the findings recorded by Rodriguez *et al.* (1985) and Yamani *et al.* (1991). Paci *et al*. (2003) opined that environmental stimuli associated with the natural day-length changings could modify the reproductive performance and the hormonal balance, consequently, the onset of the deliveries in rabbits.

5.3 MORTALITY

5.3.1 Pre-weaning mortality

Highest pre-weaning mortality in purebreds was recorded for SC (31.33 per cent) while GG had the lowest (29.09 per cent). Highest pre-weaning mortality in SC x WG (35.06 per cent) cross might be indicative of the lower mothering ability of the WG dams. The total mortality percentages were comparable to the reports by Nandakumar and Thomas (1999) who recorded slightly higher mortality percentages for GG and SC.

In the present study 61.66 per cent of the total pre-weaning mortality was observed during the cold season which may be due to the increased humid tropical stresses on the SC temperate breeds.

5.3.2 Post-weaning mortality

Lowest post-weaning mortality was recorded in WG among purebreds. The reason for lower mortality in light coloured animals have been reported earlier by Shafie *et al*. (1970) who attributed the possible reasons to it as absorption of greater amounts of the visible spectrum by dark coloured animals resulting in an excessive heat load to them. In the present study highest post-weaning mortality was observed in SC breed. Mukundan *et al*. (1993) reported lower pre-weaning survivability with SC inheritance.

The post-weaning mortality was lower in cold season, higher availability and better nutritive value of green fodder in addition to milder weather may be the reason to the finding.

5.4 HERITABILITY

Heritability estimates for body weights at birth, two, four, six, eight, ten, twelve and fourteen weeks of age were 0.193±0.165, 0.355±0.225, 0.380±0.229, 0.499±0.287, 0.089±0.141, 0.644±0.358, 0.657±0.379 and 0.727±0.407, respectively in rabbits under study. In rabbits, heritability estimate component showed an increasing trend from birth to fourteenth week of age. This might be a reflection of the fact that as age advanced the genetic make up or the additive genetic effects became more pronounced than environmental effects. Heritability estimates were higher for ten, twelve and fourteen week age groups. For high values of heritability, trait's phenotype is good indicator of underlying breeding values (Farghaly and El-Mahdy, 1999). So phenotypic selection will be effective for higher age body weights. At fourteenth week of age heritability estimate was 0.7138 in SC similar to the reported heritability estimates in SC by Bhushan *et al*. (1998) and Kasiviswanathan (2000).

Some heritability estimates arrived at was found to be above one which may be due to low sample size. Discrepancies between the estimates, heritability values depend on the genetic make up of the stocks, management and climatic conditions and period of study as well as differences in data size, models of data correction and method of analysis (Khalil *et al*, 1986).

5.5 CORRELATION AMONG BODY WEIGHTS

5.5.1 Phenotypic correlation

Phenotypic correlation ranged from 0.172 (between second and twelfth weeks of age) to 0.885 (between twelfth and fourteenth weeks of age). Phenotypic correlations values with respect to body weight between age groups of minimal separation was found to be higher than those the widely separated. Similar observations were made by Bhushan and Ahlawat (1999).

Singh *et al.* (2007c) reported positive correlation (0.68) between sixth and twelfth weeks body weight.

5.5.2 Genetic correlation

Genetic correlations of body weight between immediate age groups were greater than those widely separated. High genetic correlation between body weights indicates the synergestic control of the same additive gene. Genetic correlation observed between second and eighth week weight was high, indicating that selection of body weight at second week also improves the eighth week body weight.

5.6 COMBINING ABILITY ANALYSIS

5.6.1 General combining ability (GCA) effects

As per the present analysis, GCA effects were highest in WG genetic group for body weights at all ages and were positive ranging from 2.6546 to 195.5582. For body weights up to weaning age, GCA effects were lowest and negative for SC. GG had the lowest and negative GCA effects for body weights from sixth to fourteenth week ranging from -41.1757 to -198.6252. The highly positive GCA effects in WG of all ages indicated predominant additive gene action for expression of pre and post-weaning body weights. So this breed is a good general combiner and can be advantageously employed in breeding programs. The result is in accordance with APAU (1989) where GCA effects were highest in WG genetic group, followed by SC and GG genetic groups.

5.6.2 Specific combining ability (SCA) effects

The specific combining ability (SCA) is a joint attribute of two strains and signifies the deviation of a cross from the sum of the GCA's of its parent strains (Pirchner, 1983). Results of the present study suggested higher combining ability of the WG x GG cross at slaughter age of three months. This indicated the importance of non additive gene action for improving body weight of rabbits. Combining ability was highest for SC x GG cross for weaning weight. Crossing of WG male with GG female can be successfully recommended to increase the weight at slaughter age. In a diallel crossing experiment Bokade *et al.* (1993) recorded highest body weight in WG x GG crossbred group at three months of age, as was the case with the present study.

5.6.3 Maternal effects

Maternal ability implies the influence of the dam on her progeny other than through the genes she transmits to them (Afifi and Emara, 1990). Significance of maternal effect on body weight was seen from second to twelfth week. Higher values for maternal effects on body weight was observed in the initial stages of growth for SC while the influence was more in GG during the later periods. The superiority shown by some breeds of doe for maternal ability can be attributed to increased milk production, maternal behaviour and care of the litter (Rubio-rubio *et al.*, 2004).

5.6.4 Reciprocal effects

Reciprocal effects or sex-linked effects measures the residual differences between reciprocal crosses after taking general, specific and maternal ability effects into account (Afifi and Emara, 1990). WG x GG, SC x WG and GG x SC cross showed significant positive sex linked effects at birth, fourth and sixth week weight.

For getting better body weight, utilization of non additive gene action is suggested. Though both GG and SC had high estimates for mothering ability, increased mean body weights were recorded in crosses where GG used as female parent, suggesting the better performance of GG as mothers in various crosses. Taking SCA and maternal effects also into consideration, it is advised to cross WG males to GG females for higher body weight at slaughter age. Further studies on age at first kindling, kindling interval, fertility and feed efficiency should be carried out to find out the economic viability of different genetic groups.

Summary

6. SUMMARY

The growth performance of rabbits belonging to three different breeds *viz.* White Giant (WG), Soviet Chinchilla (SC) and Grey Giant (GG) were studied from birth to fourteen weeks of age by performing a complete 3 x 3 diallel crossing. The experiment was carried out at the University rabbit farm, Centre for Advanced Studies in Animal Genetics and Breeding, College of Veterinary and Animal Sciences, Mannuthy, Thrissur. Does were transferred to the buck's hutch for breeding and pregnant females were provided with nest boxes in cages after 28 days of pregnancy. Bunnies were weaned at four weeks and housed in groups thereafter. Growth records were taken at fortnightly interval up to fourteen weeks. Rabbits were fed with concentrate mixture and fodder as per recommendations.

Least squares analysis was performed to find the effect of genetic and non-genetic factors on various growth and reproductive traits. Genetic groups were significant source of variation for body weights from birth to twelfth weeks of age. Among purebreds highest mean body weights from birth to fourteenth week were recorded by WG. The mean body weights at birth, second, fourth, eighth, tenth and twelfth weeks of age were 53.22±1.35, 197.50±9.40, 357.94±20.41, 548.33±35.07, 906.54±50.23 and 1101.92±50.07g, respectively. The lowest weaning (321.94±15.11g) and slaughter weight at twelfth weeks of age (981.79±48.25g) were obtained for SC and GG breeds, respectively. Among crossbreds, highest mean body weights from second to twelfth week were recorded when WG male crossed with GG female. The mean body weights of WG x GG at second, fourth, sixth, eighth, tenth and twelfth weeks of age were 215.65±8.31, 444.35±17.55, 702.17±28.32, 865.87±34.56, 986.59±38.61 and 1179.50±40.37g, respectively. The lowest weights at birth, fourth and twelfth weeks of age were recorded for GG x WG and the mean weights were 42.54±1.09, 257.50±17.94 and 968.50±57.09g, respectively.

Litter size at birth influenced individual body weights from birth to tenth week of age. Individual bunny weights declined gradually as the litter size increased. The reason could be the competition among the individual fetuses in the uterus and the limited capacity of the doe to provide nutrients to the large number of fetuses in the wombs during pregnancy. Least squares means of body weights were highest for the litter containing one to four bunnies and lowest for litter containing nine to eleven bunnies. The mean body weights of bunnies belonging to a litter size of one to four recorded 58.17±1.23 and 437.42±12.10g while bunnies of nine to eleven litter size recorded 42.40±2.39 and 315.61±23.65g, respectively at birth and weaning. This trend continued till tenth weeks of age after which there were no difference between different groups. This indicated that increased litter size does not affect body weight beyond ten weeks of age.

Weight of dam at kindling influenced body weights of bunnies from second to eighth week. Higher body weights were recorded for bunnies of does weighing two to two and a half kilograms. The corresponding mean values for body weight at second, fourth and sixth weeks of age were 194.33±9.60, 399.61±18.91 and 599.36±31.52g, respectively. The lowest values were recorded in bunnies whose mothers weighed between 2.5 and three kilograms. In the present study the bunnies born to lighter does recorded better body weight which could be due to the decreased litter size.

Body weight of bunnies at birth, fourth, sixth and eighth weeks of age was influenced significantly by the age of dam at kindling. Higher weights were obtained for bunnies born to does aged more than 2000 days. The means obtained at birth and weaning for bunnies of does that aged more than 2000 days were 59.70±3.12 and 429.30±30.88g, respectively. The mean birth weight was lowest for bunnies of does aged between 1000 to 2000 days (45.35±1.46g). For bunnies of does aged below 1000 days the mean body weight at weaning was found to be the lowest (343.16±9.26g). This could be due to the decreased litter size in aged does.

Season of birth had an influence on birth, fourth and sixth week body weights. Weaning weight was higher (394.17±16.25g) in cold season compared to hot season (356.59±13.21g). During hot season rabbits in hot semi arid region recorded lower body weight due to lower feed, digestible protein and digestible energy intake.

The sex of the bunny had no significant influence on the pre and post-weaning weights.

Least squares analysis revealed no significant influence among genetic groups on litter traits and gestation period.

Weight of dam had significant influence on litter size and litter weight at birth and weaning. The litter size and body weight at birth and weaning were more for bunnies born to does weighing 2.5 to three kilograms. The mean litter size and weight at birth and weaning were 4.30±0.38, 210.52±15.00g, 3.30±0.27, and 1201.09±80.53g, respectively. This may be attributed to the increased ovulation rate in heavier and healthier does. The highest means for litter size (2.99±0.53) and weight (156.90±21.15g) at birth were recorded in litters of does weighing two to 2.5 kg while the corresponding values were lowest 1.90±0.35 and 857. 39±104.77g, respectively in litters of does weighing more than three kilograms.

Litter size at weaning was influenced significantly by the age of dam with a highest average of 3.23±0.17 in does aged below 1000 days while the lowest 1.30±0.67 was recorded in does aged above 2000 days.

Season of birth had an influence on gestation period, litter size at birth and weaning and litter weight at birth. Hot season recorded higher averages for gestation period (32.32±0.28 days), litter size at birth (4.23±0.39), litter weight at birth (214.09±15.43g) and litter size at weaning (2.91±0.28). Photoperiod might have an influence on this effect. Lower litter size at weaning (1.95±0.33) in cold season was due to the heavier mortality rate due to high humidity.

The mortality was highest for SC among purebreds during pre and post-weaning periods. Highest mortality was recorded for SC x WG and WG x GG, respectively among crossbreds. Pre-weaning mortality in the cold season was higher (61.66 per cent of the total mortality), which may be due to the increased humid tropical stress. Post-weaning mortality was lower in cold season (42.58 per cent of the total mortality), probably due to higher availability and better nutritive value of green fodder in addition to milder weather.

The data corrected for significant non-genetic effects were used for estimating genetic parameters. Heritability estimates of weight at fourth, twelfth and fourteenth weeks were 0.380±0.239, 0.657±0.379 and 0.727±0.407, respectively, indicating effectiveness of selection for body weight at weaning age. Genetic and phenotypic correlations of body weight between immediate age groups were greater than those widely separated. The genotypic correlation between second and eighth week body weight were high and positive.

Analysis of variance representing combining abilities for body weights revealed that General Combining Ability (GCA) effect was significant at birth, second, fourth, sixth, tenth, twelfth and fourteenth weeks of growth. GCA effects of WG at all ages were highly positive indicating the predominant additive gene action for expression of pre and post-weaning body weights. The GCA effects obtained for WG for birth; second, fourth, sixth, tenth, twelfth and fourteenth weeks of age were 2.3110, 12.7847, 26.0999, 43.9571, 83.3778, 87.9929 and 89.2674, respectively. Thus WG breed can be advantageously employed in breeding programs. Higher values for maternal effects on body weight was observed in the initial stages of growth for SC while the influence was more in

GG during the later periods. The values of 14.5278, 20.0627 and 53.2521 were recorded for SC in second, fourth and tenth weeks of age, respectively. GG recorded highest values of 35.4407, 35.7926 and 93.3918 at sixth, eighth and twelfth weeks of age, respectively. Though both GG and SC had high estimates for mothering ability, higher mean body weights were recorded in crosses where GG was the female parent, suggesting better performance of GG as mothers in various crosses. Higher Specific Combining Ability (SCA) was obtained for WG x GG cross at slaughter age (14.6489) suggested the possibility of crossbreeding WG with GG to increase the weight at slaughter. The study recommends crossing WG male with GG female for better slaughter weight so that the higher estimates of GCA of WG, maternal ability of GG as well as SCA of WG x GG cross can be exploited.

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GROWTH PERFORMANCE OF BROILER RABBITS UNDER 3 x 3 DIALLEL CROSSING

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ABSTRACT

A complete 3 x 3 diallel crossing was performed to study the growth performance of rabbits belonging to three different breeds *viz.* White Giant (WG), Soviet Chinchilla (SC) and Grey Giant (GG) at the University rabbit farm, Centre for Advanced Studies in Animal Genetics and Breeding, College of Veterinary and Animal Sciences, Mannuthy, Thrissur. Growth records of F1 progeny were taken at fortnightly interval up to fourteen weeks of age. Bunnies were weaned at four weeks.

Effect of genetic and non-genetic factors on various growth and litter traits were analysed. Genetic groups were significant source of variation for body weights from birth to twelfth week. Among purebreds highest mean body weight from birth to fourteenth week were recorded by WG. While WG x GG averaged highest among crossbreds.

Individual bunny weights declined gradually as litter size increased. This trend continued till ten weeks of age after which there were no significant difference between different litter groups.

Weight of dam at kindling influenced body weights of second to eighth week. Higher bunny weights were recorded for does weighing two to two and a half kilograms.

Body weights of bunnies at birth, fourth, sixth and eighth weeks of age were influenced significantly by age of dam at kindling. Season of birth had an influence on birth, fourth and sixth week body weights. Higher individual weaning weights were obtained in cold season.

Genetic groups had no significant effect on litter traits and gestation period. Weight of dam had significant influence on litter size and weight at birth and weaning. Litter weight at weaning was influenced significantly by the age of dam.

Season of birth had an influence on gestation period, litter size at birth and weaning and litter weight at birth. Among purebreds, SC recorded the highest mortality. Highest pre and post-weaning mortality was recorded for SC x WG and WG x GG, respectively among crossbreds. Pre-weaning mortality was high in cold season while, in hot season maximum of post-weaning mortality was recorded.

Heritability estimates of weight at weaning, twelfth and fourteenth week were 0.380±0.239, 0.657±0.379 and 0.727±0.407, respectively.

Highly positive General Combining Ability (GCA) effects of WG indicated predominant additive gene action for expression of pre and post-weaning body weights. Higher Specific Combining Ability (SCA) was recorded for WG x GG cross at slaughter age of three months. The maternal effects were highest for GG from sixth to fourteenth week and highest in SC during early periods. As per the findings of the study it would be beneficial to use WG male on GG female so that the higher GCA effect of WG breed, maternal ability of GG as well as higher estimates of SCA of particular WG x GG cross could be exploited.