GENETIC ANALYSIS OF BODY WEIGHT AND LITTER TRAITS OF PURE BRED RABBITS

By

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THESIS

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DECLARATION

I hereby declare that the thesis entitled **GENETIC ANALYSIS OF BODY WEIGHT AND LITTER TRAITS OF PUREBRED RABBITS** 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.

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Certified that this thesis, entitled **GENETIC ANALYSIS OF BODY WEIGHT AND LITTER TRAITS OF PUREBRED RABBITS** is a record of research work done independently by Dr. J. Radhakrishnan under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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Introduction

INTRODUCTION

Rabbits belong to the class Mammalia, order lagomorpha, family Leporidae and Genus Oryctolagus and species Cuniculus. The phoenicians were the discoverers of the rabbit in historical times. In their journeys to the coast of Africa and the Iberian Peninsula in 1100 B.C. they observed numerous creatures similar to their cliff terriers, the description of which resembles our rabbit very closely. Because of the number of these terrier like creatures they named the coast or island as the land of this creature and called it "i-shephan-im". Later, this name for the Iberian Peninsula was renamed in the Latin form by the Romans as "Hispania". The Hebrew word "Saphan and Shaphan", for cliff terrier (Hyrax syriacus) was later incorrectly translated by Luther in his Bible translation to the word rabbit.

True domestication, with breeding in captivity, probably started in the monastries during the sixteenth century. Currently there are well over 50 well established breeds of domestic rabbits.

Now-a-days rabbits are a subject of tremendous interest with regard to their potential as meat producing animals. The local meat production has failed to satisfy the increased consumption needs. If the need for meat consumption is to be met, much of the increase in production will have to come from short cycle animals, especially those animals being kept by the small scale farmers like rabbits.

Further rabbits are characterized by small body size and they also have the economic advantage of thriving on feed stuffs rich in roughage. Hence rabbit seems to have a good potential as a meat producing animal especially when its prolificacy and growth rate are considered.

The lack of sufficient rersearch regarding the genetic improvement of rabbits has severely impeded the development of rabbit as an alternative source of meat.

The ability of a doe to produce thrifty young at birth, referred to as prolificacy and to raise these young to weaning, referred to as nursing ability are the main characters determining her productivity. Litter size and weight at weaning are usually regarded as the best estimates of the number and weights of young produced by the doe since they are a function of all preweaning effects.

Moreover the quality of the genetic material mainly decides the success of any livestock industry. Selection is considered to be the best tool available for genetic improvement and heritability an important factor for predicting the outcome. At present there are few published studies of body weights and litter traits till the age of slaughter in rabbits.

In India, at present several pure bred rabbits are available. The objective of the present study was to find out the difference among the three pure breds of rabbits used in this study with regard to their body weights till their age of slaughter and certain litter traits and to estimate the inheritance of these traits.

Review of Literature

REVIEW OF LITERATURE

Body weight

Velora *et al.* (1980) reported that Norflok femeles imported into Brazil from UK at 60, 72, 84, 96 and 110 days averaged 1430, 1780, 2180, 2620, and 3040g respectively versus 1640, 1900, 22100, 2580 and 2920 for 32 of their female offsprings born in Brazil and 1700, 1920, 2220, 2590 and 2930 for the male offspring.

Trojan and Mach (1980) reported the body weight at 93 days of age for Danish White Land, California White, New Zealand White, Argente de Champagne and Giant Chinchilla rabbits as 2424, 2082, 2141, 2551 and 2526g respectively.

Parillo and Vasenina (1981) found that Soviet Chinchilla, White Giant and Cabifornian White and German Giant rabbits averaged 2208 and 2704g respectively.

Kosko (1981) found that the twelve-week body weight of Californian Whitel and German Giant rabbits averaged 2208 and 2704g respectively.

Breeding value test conducted at the German Federal Republic (1981) revealed that the eight-week body weight of

New Zealand White and German Giants averaged 1702 and 1904g respectively and weight at slaugher at Eleven-week of age was 2560g and 2880g.

Niedzwiadek and Kawinska (1982) found that for New Zealand White, Danish White Land and Californian White rabbits, body weight of offspring at twelve-weeks of age were 2100g, 1950 and 2090g respectively.

Randi (1982) reported that for Californian and New Zealand White rabbits body weight at 77 days averaged 1960g and 1990g respectively. In New Zealand White rabbits parity had a significant effect on body weight at 77 days of age.

Gogeliya et al. (1982) found that the body weight at 120 days of age averaged 1080g for Soviet Chinchilla and Grey Giant rabbits and there was no significant breed difference.

Mgheni et al. (1982) reported that in New Zealand White rabbits body weight at 28, 42, 56, 84 and 112 days of age averaged 384±87, 551±121, 785±149, 1180±202 and 1528±279g respectively. He found that in all these ages body weight decreased with increasing size of litter but the differences in body weight were only significant in litters comprising of greater than four rabbits.

Damyanva *et al.* (1983) reported that the average body weight of New Zealand White rabbits was 599g at weaning at 30 days, 1584g at 60 days, 2338g at 90 days and 3036g at 120 days of age.

Niedzwiadek (1983a) found that the body weight for New Zealand White rabbits averaged 545g at 28 days of age and 2360g at 90 days of age.

Carregal and Lui (1984) reported that for Dutch New Zealand White, Californian and Baladi Grey rabbits the average body weight at weaning were 600.53, 600.57 and 687.22g. At slaughter (70 day) the respective body weights were 1930.18, 2121.50 and 2255.52g.

Desalvo and Zucchi found that for Champagne Silver, New Zealand White and Blue Vienna rabbits the final live weight at 90 days of age were 2299.50, 2251.00 and 2886.50g respectively.

Kosba *et al.* (1985) reported that for Chinchilla, Bauscat, Baladi Grey and Baladi Yellow rabbits the first year 60 day weight of purebreds were 629.0±32.9, 565.3±28.4, 626.1±41.3 and 553.9±73.3g. In the following year the 60 day weight of purebreds were 705.3±50., 634.0±58.8, 422.3±40.7g respectively for Chinchilla, Bauscat and Baladi Yellow rabbits. Body weight at 90 days were 1084.8±51.0, 1114.6±56.7 and 875.3±35.5 for Chinchilla, Bouscat and Baladi Yellow rabbits resepctively.

Damodar and Jatkar (1985) found that the ten week weight for New Zealand White and Grey Giant rabbits were 1880 and 2170g respectively.

Patras (1985) reported that for Argente de Champagne rabbits that had weighed 200-250, 251-300, 301-350, 351-400, 401-450 and greater than 450g at 21 days of age, the body weight at 90 days were 1446, 1986, 2070, 2140, 2190 and 2530g respectively.

Nunes _et_ _al_. (1985) reported that for Norfolk, californian and New Zealand White rabbits the body weights at eight week were 1674, 1607 and 1572g respectively.

Ahmed _et_ _al_. (1986) reported that body weight of Baladi and Flemish rabbits were 308.0±7.7 and 362.0±7.6g respectively at one month of age.

Mach (1986) reported that for Californian White and New Zealand White rabbits body weight of young were 594 and 680g at weaning at 28 days of age and 2631 and 2623g at 93 days of age.

Khalil *et al.* (1987) reported that the body weight of Bauscat and Giza White rabbits at six, eight, ten and twelve-weeks were 516.8, 672.6, 853.1 and 1033.6 and 546.5, 691.7, 870.9 and 1052.2g respectively.

Lui *et al.* (1987) reported that Californian, Dutch and New Zealand White rabbits were 498.47, 530.94 and 523.00g at 28 days of age. Dam and parity had a significant effect on the body weight with body weight increasing with parity (upto 4th parity).

Grand and Stefanetti (1987) found that the 77 days weight of New Zealand White and Californian rabbits were 2260 and 2291g respectively.

Ledur and Carregal (1988) reported that for purebred (New Zealand White or Californian) rabbits body weight at 21, 28 and 70 days were 296.31 ± 6.65, 475.33 ± 10.94 and 1715.92 ± 29.23g respectively.

Reodecha and Kjparkorn (1988) reported that for New Zealand White and Thai native rabbits body weight at ten weeks of age were 2420g and 2300g respectively.

Stawinski and Asias (1988) found that for Californian and Chinchilla rabbits weaning weight at 42 days were 1051.29 and 1009.10g respectively.

Rastogi (1988) reported that in a rabbitry body weight of a offspring at four and twelve week of age were 318 and 1536g.

Zimmermann et al. (1988) found that New Zealand White rabbit body weight at eight and twelve-weeks of age were 1766±368g and 2770±316g respectively for males 1702±285 and 2718±324g for females.

Opoku and Lukefahr (1990) found that for the stock maintained at Nungua Livestock Breeding Station, Toma in Ghana, the individual body weight at 90 days were 1355.0±23.8g.

Mishra (1990) found that body weight at various ages of New Zealand White-SH and New Zealand White-S strain and an English albino strain were 409.1±20.1, 407.4±16.4 and 509.4±233.0g.

Heritability estimates

Four-week body weight

Mostageer *et al*. (1970) while working on Giza White rabbits found that the heritability estimate based on maternal half sib was higher (0.931) than the estimate based of full sibs (0.538) and that based on paternal half sib was lowest (0.178).

Ouhayoun *et al*. (1973) reported a heritability estimate of 0.55 based on paternal half sib method in cross bred rabbits.

Chevalet (1976) reported a heritability estimate of 0.20 in New Zealand white rabbits based on paternal half sib method.

Niedzwiadek (1978) found a heritability estimate of 0.332 ± 0.027 in New Zealand White rabbits based on paternal half sib method.

Vrillon *et al*. (1979) reported a heritability of 0.170 ± 0.110 based on paternal half sib method in crossbred rabbits.

Blasco *et al*. (1982) reported negative sire component of variation in both New Zealand White and Californian rabbit. The corresponding heritability estimates based on maternal half sibs were above one in both breeds. They reported low heritability estimates based on intra sire regression of offspring on dam and sire offspring regression methods.

One month weight

Zotova and Bogdanov (1972) found the heritability to be 0.04 based on paternal half sib method.

El-Amin (1974) while working on Nez Zealand White and Californian rabbits reported, the heritability to be 0.10 ± 0.05 and 6.45 ± 0.36 respectively based on paternal half sib method, 0.55 ± 0.15 and 3.2 ± 2.58 respectively based on maternal half sib method, 0.33 ± 0.11 and 1.87 ± 0.95 respectively based on full sib method, 0.04 ± 0.10 and 0.12 ± 0.28 respectively based on sire off spring regression method and 0.12 ± 0.10 and 0.14 ± 0.36 respectively based on dam offspring regression methods.

Merkushin (1979) reported a heritability estimate of 0.509 based on paternal half sib method and 0.082 based on maternal half sib method in Californian rabbits.

Six-week weight

Mostageer *et al*. (1970) found the heritability estimates to be higher based on maternal half sib method in Giza White rabbits. The estimate was 0.185 based on paternal half sib method, 0.529 based on maternal half sib method and 0.357 based on full sib method.

Alvarez *et al*. (1974) reported a heritability estimate of 0.45±0.15 in Criollo native breed based on paternal half sib method.

Diaz and Alvarez (1975) reported a heritability estimate of 0.66±0.13 in the same breed based on paternal half sib method.

Lampo and Broeck (1975) found the heritability estimate to be very low ie. 0.108±0.07 in Dendermonde White rabbits based on paternal half sib method.

Khalil (1986) estimated the heritability based on Bauscat and Giza White rabbits. The estimates were 0.46±0.13 and 0.65±0.19 respectively based on paternal half sib method, 0.60±0.12, 0.45±0.15 respectively based on maternal half sib method and 0.63±0.08 and 0.80±0.10 respectively based on full sib method.

Eight-week weight

Mostageer et al. (1970) found a very high heritability estimate of 0.929 based on maternal half sib method in Giza White rabbits. The her[illegible]ty estimate based on paternal half sib was only 0.226 and the one based on full sibs was 0.578 in the same breed.

McReynolds (1974) found the heritability estimate in New Zealand White rabbits to be 0.300±0.25 is based on paternal half sib method.

Randi and Scossirolli (1980) found that the heritability estimate based on maternal half sibs and full sib method in New Zealand White rabbits were above one whereas the estimate based on paternal half sibs was 0.566±0.16.

Khalil (1986) found that in Bauscat and Giza White rabbits the heritability estimate was high based on maternal half sib method ie. 0.98±0.14 and 0.92±0.17 respectively in the two breeds. The heritability estimate based on paternal half sibs were lowest ie. 0.20±0.09 and 0.29±0.13 respectively in the two breeds and these based on full sibs were 0.59±0.08 and 0.61±0.10 respectively in the two breeds.

Sixty day weight

Zotova and Bogdanov (1972) reported a very low heritability of 0.08 based on paternal half sib method in White Giant rabbits.

El-Amin (1974) estimated heritabilities based on five different methods in New Zealand White and Californian rabbits and reported varying results. The estimates based on paternal half sibs were 0.720 ± 0.310 and 0.570 ± 0.380 respectively in the two breeds. The estimates based on maternal half sibs were above one, with high standard error in both breeds ie. 1.61 ± 1.09 and 1.40 ± 1.22 respectively. The heritability estimate based on full sibs were 1.17 ± 0.86 and 0.98 ± 0.86 respectively in the two breeds.

The heritability estimate based on regression of sire on offspring were 0.20 ± 0.12 and 0.58 ± 0.22 respectively in the two breeds and those based on regression of dam on offspring were 0.20 ± 0.14 and 0.40 ± 0.18 respectively in the two breeds.

Ten-week body weight

Mostageer *et al.* (1970) reported the heritability estimate to be low ie. 0.15 based on paternal half sib method in Giza White rabbits. While the estimate based on maternal half sib was one and that based on full sibs was 0.575.

Ouhayoun et al. (1973) found the heritability estimate to be 0.55 based on paternal half sib method in crossbred rabbits.

Vrillon et al. (1979) found the heritability estimate to be 0.38±0.09 in crossbred rabbit based on paternal half sib method.

Khalil et al. (1987) found the heritability estimate to be very high in Bauscat and Giza White rabbits based on maternal half sib methods. The estimates were 0.94±0.15 and 0.97±0.19 respectively in the two breeds. The estimate based on paternal half sibs were 0.24±0.11 and 0.39±0.17 respectively in the two breeds and 0.59±0.09 and 0.68±0.11 respectively based on full sibs in the two breeds.

Twelve-week body weight

Darwish et al. (1970) reported a very low heritability ie. 0.03 based on paternal half sib method in Giza White rabbits.

Mostageer <u>et</u> <u>al</u>. (1970) found that the heritability estimate was very low based on paternal half sib method in Giza White rabbits. It was found to be 0.001. The heritability estimate based on maternal half sib was higher ie. 0.562 and that based on full sibs was 0.281 in the same breed.

Khalil <u>et</u> <u>al</u>. (1987) found that the heritability estimate based on maternal half sib continued to be higher even at twelve-weeks in Bauscat and Giza White rabbits. They were 0.70±0.16 and 0.91±0.20 respectively in the two breeds. The heritability estimate was 0.09±0.08 and 0.37±0.17 respectively based on paternal half sibs in the two breeds and that based on full sibs were 0.39±0.08 and 0.64±0.12 respectively in the two breeds.

<u>Ninety day weight</u>

Zotova and Bogdanov (1972) reported a low estimate of heritability in White Giant breed. It was found to be 0.04 based on paternal half sib method.

Niedzwiadek <u>et</u> <u>al</u>. (1983) found the estimate to be 0.219±0.097 in New Zealand White based on paternal half sib method.

Merkushin (1979) worked out separate heritabilities for male and female Californian rabbits. It was 0.167 and 0.118 respectively in the two sexes based on paternal half sib method and 0.143 and 0.203 respectively based on two sexes maternal half sib method.

Carregal *et al*. (1980) found the heritability estimate based on paternal half sib method to be 0.540 in New Zealand White rabbits.

Correlations between rabbit body weight

Phenotypic correlations

Mostageer *et al*. (1970) showed that the phenotypic correlations between the body weights at different ages were positive and high. The values tend to decrease as the difference between the two ages increased.

Nossier (1970) reported very low phenotypic correlation in both Bauscat and Baladi Red rabbit.

Diaz and Alvarez (1975) also reported positive phenotypic correlations among the body weights with very high correlation between fourth and fifth and fifth and sixth week.

Afifi _et al_. (1980) while working on data collected on Bauscat, Chinchilla, Giza White and some other crossbred rabbits in three consecutive years 1965-66, 1966-67 and 1967-68 found that the phenotypic correlations were high and positive and they tended to decrease as the difference between the two ages increased.

Randi and Scossiroli (1980) also found high and positive phenotypic correlations in New Zealand White rabbits.

Blasco _et al_. (1983) reported a phenotypic correlation of 0.61 and 0.72 in New Zealand White and Californian rabbit between four-week weight and eleven-week weight.

Khalil (1986) also reported high and positive phenotypic correlations which tended to decrease as the gap between the ages increased.

Genetic correlations

Three week weight and eight-week weight

McReynolds (1974) found the estimate from paternal half sibs to be 0.87 in New Zealand White rabbits.

Four-week weight and five week weight

Diaz and Alvarez (1975) reported an estimate of 0.97±0.02 based on paternal half sibs in Criollo rabbits.

Four-week and six-week weight

Mostageer *et al.* (1970) found the estimate from paternal half sibs to be 0.769 in Giza White rabbits.

Diaz and Alvarez (1975) found the estimate in Criollo rabbits to be 0.89±0.05 based on paternal half sibs.

Four-week weight and Eight-week weight

Mostageer *et al.* (1970) found the estimate to be 0.717 based on paternal half sibs in Giza White rabbits.

One month weight and two month weight

El-Amin (1974) found the estimates in New Zealand White and Californian rabbits to be 0.82 and 0.67 respectively based on paternal half sibs.

Four-week weight and ten-week weight

Mostageer *et al*. (1970) found the estimate to be 0.501 in Giza White rabbits based on paternal half sibs.

Four-week weight and twelve-week weight

Mostageer *et al*. (1970) found the estimate to be 0.455 in Giza white rabbits based on paternal half sibs.

Four-week weight and Ninety day weight

Niedzwiadek (1978) found a high estimate of 0.879 ± 0.079 based on paternal half sibs in New Zealand White rabbits.

Six-week weight and Eight-week weight

Mostageer *et al*. (1970) reported a low but positive estimate of 0.046 in Giza White rabbits based on paternal half sibs.

Khalil (1986) estimated the genetic correlations based on paternal half sibs, maternal half sibs and full sibs in Bauscat and Giza White rabbits. The estimates were 1.16 ± 0.07

and 1.17+0.08 respectively based on paternal half sibs 0.72+0.07 and 0.62+0.12 respectively based on maternal half sibs and 0.81+0.05 and 0.79+0.07 respectively based on full sibs in the two breeds.

Six-week weight and Twelve-week weight

Mostageer *et al*. (1970) reported the estimate to be 0.448 based on paternal half sibs in Giza White rabbits.

Khalil (1986) found the estimates in Bauscat and Giza White rabbits to be 1.04+0.24 and 0.91+0.10 respectively based on paternal half sibs, 0.49+0.14 and 0.34+0.19 respectively based on maternal half sibs and 0.58+0.12 and 0.54+0.14 respectively based on full sibs.

Eight-week weight and ten-week weight

Mostageer *et al*. (1970) reported the estimate to be 0.86 based on paternal half sibs.

Khalil *et al*. (1987) found the estimates in Basucat and Giza White rabbits to be 1.15+0.17 and 0.99+0.04 respectively based on maternal half sibs and 0.83+0.05 and 0.78+0.08 based on full sibs.

Eight-week weight and Twelve-week weight

Mostageer et al. (1970) found the estimate to be 0.332 in Giza White rabbits based on paternal half ibs.

Nossier (1970) reported low but positive estimates in Baladi Red rabbits based on paternal half sibs and full sibs which were 0.033 and 0.058 respectively. The estimate based on maternal half sibs was positive and high ie. 0.789.

Khalil et al. (1987) found the estimates in Bouscat and Giza White rabbits tobe 1.34±0.64 and 1.25±0.13 respectively in the two breeds based on paternal half sibs, 0.70±0.10 and 0.46±0.16 respectively in the two breeds based on maternal half sibs and 0.73±0.09 and 0.66±0.11 respectively in the two breeds based on full sibs.

Ten-week weight and Twelve-week weight

Mostageer et al. (1970) reported an estimate of 0.641 based on paternal half sibs in Giza White rabbits.

Nossier et al. (1970) reported low estimates based on paternal half sibs and full sibs in Baladi Red rabbits. They were 0.030 and 0.056 respectively.

Khalil et al. (1986) found the estimates in Bouscat rabbits to be 1.24±0.20 based on paternal half sibs, 0.76±0.08 based on maternal half sibs and 0.82±0.06 based on full sibs.

Litter traits

Teresa et al. (1979) reported that litter size in New Zealand White rabbits at birth averaged 6.63. Mortality from birth to weaning was 23 per cent, the majority of deaths occurring within a few days of birth.

Mach and Trojan (1979) reported that for Californian White, New Zealand White, Danish White and 18 Burgundi rabbits litter size averaged 7.7, 8.1, 7.3, 6.3 at births and 6.0, 5.2, 6.0 and 4.7 at weaning.

Trojan and Mach (1980) reported that data were obtained on Danish White Land, Californian White, New Zealand White, Argente de Champagne and Giant Chinchilla rabbits. The litter size at birth averaged 6.4, 9.1, 7.6, 8.6, 5.9 and litter size at weaning at 42 days averaged 4.5, 7.3, 6.3, 6.2 and 3.0 respectively.

Tsvetkova and Serova (1981) reported that for Soviet Chinchilla and Californian White females litter size averaged 8.6 and 7.4 respectively at the first kindling, 9.2 and 7.6 at the second kindling, 9 and 8 at the third kindling, 7.8 and 8.4 at the fourth kindling and 7.9 and 8.5 at the fifth kindling.

Kosko (1981) reported that for Californian White and Grey Giant rabbits litter size averaged 4.7 and 9.6 at birth.

Patridge et al. (1981) found that for New Zealand White and Californian rabbits litter size averaged 6.9 and 6.6 at birth and at weaning at four-weeks of age litter size was 5 and 4.9 respectively.

Gugushvili (1981) reported that for Grey Giant, Soviet Chinchilla, New Zealand White and Californian White rabbits litter size averaged 7.6, 8.8 and 6.6 respectively at birth.

Niedzwiadek and Kawinska (1982) reported that for New Zealand, Danish White Land and Californian White rabbits litter size averaged 5.1, 4.4 and 5.4 respectively at birth.

Randi (1982) found that for Californian and New Zealand White rabbits litter size at birth averaged 8.35 and 7.96 respectively. In both breeds months of birth and parity had a significant effect on litter size.

Gogeliya *et al.* (1982) reported that the sizes of the first and second litters were 8.04±0.2 and 9.91±0.43 respectively in Soviet Chinchilla versus 7.76±0.02 and 9.54±0.40 in Grey Giant rabbits.

Lahiri and Mahajan (1982) found that for New Zealand White rabbits litter size at birth was 6.93±0.16, litter size at weaning at six-weeks was 5.60±0.13 and litter weight at weaning was 3.93±0.08 kg.

Miros and Mikhno (1982) reported for Soviet Chinchilla and Grey Giant males aged four months and for similar groups of males aged five months, mated with females of proven fecundity in spring and in winter the litter size averaged, 6.2, 6.3, 8.7, 9.2, 6.2, 6.7, 8.9 and 8.4 at birth and 3.8, 4.0, 6.5, 6.9, 3.5, 3.9, 7.0 and 6.9 at weaning. When artificial insemination was used instead of natural service litter size averaged 5.7, 6.3, 7.9, 8.5, 6.2, 6.6, 6.6, 9.1 and 8.8 at birth and 4.3, 4.9, 6.4, 4.3, 7.0 and 7.0 at weaning.

Niedzwiadek *et al.* (1983 b) reported that for 100 New Zealand White females having a premating body weight at six successive parities averaged 3689, 3717, 3938, 4096, 4249 and 4165g. The duration of six successive pregnancies averaged 30.2, 31.5, 31.4, 31.8 31.8 and 32.1 days, litter size at birth 6.9, 7.4, 7.1, 7.9, 7.3 and 6.8 and birth and 5.3, 6.3, 6.1, 6.4, 6.1 and 5.5 at weaning litter weight averaged 2460, 3646, 3264, 3436 and 3442g at 28 days.

Pinkavova (1984) reported that in New Zealand White rabbits for litter size averaging 7.00, 7.25, 8.00, 8.43, 8.62, 8.98 and 9.00 pregnancy duration averaged 29, 28, 34, 31, 30, 32 and 33 days. The most frequent being 31-32 days (68 per cent) least frequent being 34 days (8.2 per cent). The most frequent litter size 8-10 (65.79 per cent) and least frequent less than five and greater than 13 (2.44 per cent).

Lahiri (1984) reported that in New Zealand White rabbits litter size averaged 6.93±0.16 at birth and 5.60±0.13 at weaning and litter weight at weaning was 3.92±0.08 at weaning.

Kliment and Jamriska (1985) found that for litters of Russian rabbits that was 25.0, 37.5, 50.0, 59.4, 67.2, 73.4

and 78.5 per cent inbred and for outbred controls litter size averaged 5.57, 5.26, 4.87, 5.82, 5.67, 4.08, 5.00 and 5.61 respectively and the differences of litter sizes of less than five from litter sizes greater than 5.56 being significant. For Giant Chinchillas, that were 25.0, 37.5 and 50.0 per cent inbred, and for outbred controls litter size averaged 8.09, 7.0, 7.50 and 7.98 respectively, the differences being non-significant.

Nunes and Moura (1985) reported that for Nosfolk hybrid, New Zealand White and Californian rabbit the number of live born young averaged 6.18±0.29, 5.92±0.30 and 5.52±0.35 respectively, the number of still born young 0.82±0.29, 1.08±0.34 and 1.48±0.35 and the number of young surviving to weaning 3.36±0.36, 3.55±0.42 and 3.80±0.43 respectively and the differences between the breed were not significant.

Damodar and Jatkar (1985) reported that four New Zealand and Grey Giant rabbits gestation length averaged 31.04 and 31.70 days respectively, litter size averaged 4.88 and 5.65 at birth. Survival rates of offspring to three weeks of age were 73.81 and 45.20 per cent respectively.

Mach et al. (1986) reported that for the young from Californian White and New Zealand White rabbits litter size at birth averaged 8.7 and 6.6 respectively and litter size at weaning 7.5 and 6.4 respectively.

Rahmathulla et al. (1986) reported that for New Zealand White and Sandy rabbit litter size averaged 5.9±2.64 and 5.29±1.57 and number of live born offspring per litter 5.26±3.03 and 4.96±1.91.

Mach (1986) found that for Californian White and New Zealand White litter size averaged 10.11 and 6.6, the number of live born young per litter 8.67 and 6.60 and pre-weaning mortality was 12.8 and 6.1 per cent and litter size at weaning was 7.56 and 6.20.

Khalil et al. (1987) while working in Bauscat and Giza White rabbits litter size at birth were 6.48 and 6.36 respectively. Litter size at weaning 4.91 and 4.68 respectively. Weaning litter weight 2071 and 2000.30g. Mean offspring weight at weaning was 441.80 and 434.30g. Pre-weaning mortality was 29.0 and 28.1 per cent.

Grandi and Stefanetti (1987) reported that for New Zealand White and Californian rabbits each of the first three parities the number of live born offsprings per litter averaged 5.6 and 5.4 respectively for the first litter, 6.9 and 6.8 for the second litter and 7.3 and 7.1 for the third litter. The effect of genetic group and parity were significant.

Zhang and Weng (1988) while reporting on the reproductive performance of German Angora doe in China found that litter size at birth and weaning averaged 6.73±1.81 and 5.55±1.74 respectively.

Matheron and Dolet (1988) found that litter size at birth and litter size at weaning was affected by season, being lower during rainy season than during the dry season, but an annual rainfall of greater than 2000 mm is conducive to good reproductive performance. For Creole, New Zealand White and other breeds of rabbits total litter size averaged 6.55, 7.44 and 7.33 respectively. The number of live born young per litter 6.32, 6.72. Litter size at weaning 4.42, 5.14 and 4.54 and pre-weaning mortality being 29, 23 and 32 per cent. The effect of breed being significant for litter size at weaning and pre-weaning mortality. When interval from kindling to mating was 30-39, 40-49, 50-69 or greater than or equal to 70 days, litter size averaged 7.09, 7.81, 7.84 and 7.70 respectively, numbers of live born young per litter 6.42, 7.09, 7.30 and 7.10 and litter size at weaning 4.31, 4.34, 5.14 and 4.99 respectively, the effect of interval being highly significant for each trait. When females were mated immediately after parturition, at 10 days postpartum or at weaning, total litter size averaged 7.57, 7.50 and 8.70 respectively, number of live born young per litter 6.71, 6.43 and 7.43 and litter size at weaning 5.59, 4.42 and 5.26 respectively (P > 0.01).

Lee et al. (1988) reported that for New Zealand White and Californian rabbits breed differences were significant for litter size at birth (7.61±0.29 and 7.30±0.10) respectively and at weaning (6.45±0.21) and 6.75±0.20). Gestation length were 31.2±0.18 and 31.8±0.27 days. Litter size was also significantly affected by season and year.

Slawinski and Asias (1988) found that for Californian and Chinchilla rabbits number of live young at birth averaged 8.93 and 10.08 respectively.

El-Maghawry et al. (1988) reported that in New Zealand White and Californian rabbits litter size at birth averaged 7.05 and 5.59 respectively and at weaning litter size averaged 6.70 and 5.52. Parity significantly affected the litter size at birth in New Zealand White rabbits. Month of parturition affected litter size in the two breeds, Litter weight at weaning in the two breeds averaged 3484.61 and 3095.31 at weaning respectively. Pre-weaning mortality was 28 and 51.9 per cent in the two breeds.

Rastogi (1988) while reporting on the performance from a rabbitry in Trinidad found that the litter size at birth averaged 4.9, number of live born per litter 4.4 and litter size at weaning at 4 weeks of age was 3.4. Preweaning mortality was found to be 22.7 per cent.

Zimmermann et al. (1988) found that for New Zealand White rabbit litter size averaged 8.6 ± 3.1, number of live born per litter 7.64 ± 3.5 and number weaned per litter 6.11 ± 3.4.

Dim et al. (1989) found that for Dutch breed of rabbits litter size averaged 4.5 after single hand mating, 6.5 after hand mating twice within one hour and 3.75 after uncontrolled mating. Pregnancy duration was significantly shorter for double hand mated females than for other females.

Bhasin et al. (1989) reported that for New Zealand White, White Giant, Soviet Chinchilla and Grey Giant rabits litter size averaged 6.06, 6.37, 6.04 and 6.276 at birth and 4.57, 4.56, 4.51 and 4.39 at weaning. Litter weight at weaning were 2280, 3300, 3190 and 3030g respectively.

Afifi and Khalil (1989) reported that for Giza White, Grey Giant Flanders and reciprocal Giza White x Grey Giant Flander litter produced over one year period litter size averaged 6.4±0.3 at birth and 3.4±0.5 at weaning. Litter weight at weaning averaged 47 per cent. The effect of breed type, age of female and parity on litter traits were not significant, but month of kindling influenced all traits. Pre-weaning mortality did not increase with litter size at birth.

Opuku and Lukefahr (1990) found that in the rabbits of various breeds at the Nungua Livestock Breeding Station, Toma in Ghana litter size averaged 4.9±0.19 at birth and litter size at weaning at 56 days averaged 3.81±0.147. Litter weight at weaning was 2596±73.6g.

Mishra (1990) found that in two strains of New Zealand White rabbits and an English albino strain the average gestation period and litter size at Kindling and at weaning were 30.61±0.22 days, 5.34±0.25 and 2.56±0.26 respectively.

Heritability estimates

Number born alive

Rollins *et al*. (1963) while working on New Zealand White rabbits reported heritability estimate to be 0.026 based on paternal half sib method and 1.13 based on maternal half sib method. They found that the sire components of variance were only slightly greater than zero.

Lampo and Broeck (1975) while working on Dendermonde White rabbits reported the heritability estimate of 0.021 ± 0.040 based on paternal half sib method.

Garcia *et al*. (1980) found heritability estimate to be negative due to negative sire component of variance in both New Zealand White and Californian rabbit based on paternal half sib method and Intra sire dam daughter regression methods while it was 0.44 and 0.84 respectively in the two breeds based on maternal half sib method.

Litter size at birth

Randi and Scossirolli (1980) while working on New Zealand White rabbits found a negative estimate of sire component of variance based on paternal half sib method and 0.464±0.240 based on maternal half sib method and 0.155 based on full sib method.

Baselga et al. (1982) reported a heritability estimate of 0.25 based on maternal half sib method in meat rabbit.

Lahiri and Mahajan (1982) reported the heritability to be 0.107±0.097 based on paternal half sib method in New Zealand White rabbits.

Kadry and Afifi (1984) reported heritability estimate of 0.485±0.403 based on paternal half sib method and 0.164±0.011 based on intrasire dam daughter regression method in Bouscat rabbits.

Khalil (1986) found the heritability in Bauscat and Giza White rabbits based on paternal half sib method to be 0.250±0.168 respectively.

Litter size at weaning

Lampo and Broeck (1975) found the heritability estimate on Dendermonde White to be negative due to negative sire component of variation based on paternal half sib method when the rabbits were weaned at 42 days of age.

Garcia *et al*. (1980) also reported a negative sire component of variation based on paternal half sib method in New Zealand White and Californian rabbits weaned at 28 days. The heritability based on maternal half sib method was fund to be 0.28 and 0.52 in the two breeds respectively and 0.36 and 0.44 based on intra-sire dam daughter regression.

Baselga *et al*. (1982) reported a heritability estimate of 0.29 based on maternal half sib method in meat rabbits when the rabbits were weaned at 28 days.

Lahiri and Mahajan (1982) reported the heritability estimate to be 0.127±0.100 in New Zealand White rabbits based on paternal half sib method.

Kadry and Afifi (1984) reported the heritability estimate to be 0.318±0.012 based on paternal half sib method and 0.521±0.423 based on intra-sire dam daughter regression method for rabbits weaned at five weeks of age.

Khalil (1986) reported the heritability estimate based on paternal half sib method to be 0.24±0.149 and 0.27±0.185 in Bauscat and Giza White rabbits.

Materials and Methods

MATERIALS AND METHODS

The experimental work was carried out at the Rabbit Research Station, Centre for Advanced Studies in Animal Genetics and Breeding attached to the College of Veterinary and Animal Sciences, Mannuthy in the period from October 1990 to February 1992.

Rabbits belonging to three pure breeds viz. Grey Giant, Soviet Chinchilla and New Zealand White formed the materials for the study. From each breed, seven males were taken and each male was mated to two females of the same breed selected at random. In all 14 females and seven males were considered in each breed. Care was taken to avoid matings with full sibs or half sibs (paternal or maternal).

According to the breeding plan, each doe was transferred to the buck's hutch to be mated. Hand mating was exercised by restraining the doe to assure copulation. Does were palpated ten days after the date of copulation to determine pregnancy. The does that failed to conceive were returned to the same buck for service once again. The date of crossing and the date of kindling were recorded. The litter of young rabbits were examined and recorded within 24 h of birth. Weaning was done six weeks after birth to allow maximum time for milk feeding.

Feeding

Rabbits were always fed *ad libitum* and green grass was offered twice daily. A dry concentrate was provided in the morning and evening. The ingredients of the diet were

Bengal gram	25 %
Tapioca flour	20 %
Wheat	20 %
Ground nut cake	23.5 %
Meat cum bone meal	10 %
Mineral mixture	1 %
Common salt	0.5 %

Fresh clean water was provided to the rabbits in a saline bottle fitted to the cages at all times.

Body weight

Individual rabbits were weighed at four, six, eight, ten and twelve weeks of age. Records were not taken after twelve weeks of age. Body weights were taken on the day of completion of that age.

Litter traits

Each breed was analysed separately for seven measurements of reproductive efficiency and litter traits. The seven measurements were

1. Gestation length
2. Litter size at birth
3. Pre-weaning mortality percentage
4. Litter size at weaning
5. Litter weight at weaning
6. Mean weight of young at weaning
7. Sex ratio at weaning as percentage of males relative all males and females

Statistical Analysis

For both body weights and litter traits the mean, standard error and coefficient of variation were obtained for all the characters studied, for each breed separately by methods given by Snedecor and Cochran (1967).

Between breed differences were studied by Least square analysis for non orthogonal data using the technique described by Harvey (1966).

The model used was

$$Y_{ij} = u + B_i + e_{ij}$$

where

Y_{ij} = Observation on the j^{th} rabbit of the i^{th} breed.

B_i = Effect of the i^{th} breed

e_{ij} = Random deviation of the j^{th} member of the i^{th} breed and assumed to be independently and normally distributed $(0, 6_e^2)$. It includes all the effects not described in the model.

The significance of the breed effects were tested by 'F' test.

<u>Sex effect on body weight</u>

Within each breed, sex effect was studied by least square analysis for non-orthogonal data using the technique described by Harvey (1966). The model used was

$$Y_{ij} = u + X_i + e_{ij}$$

where

Y_{ij} = Observation on the j^{th} rabbit of the i^{th} sex.

X_i = Fixed effect of the i^{th} sex

e_{ij} = Random deviation of the j^{th} member of the i^{th} sex and assumed to be independently and normally distributed $(0, \sigma_e^2)$. It includes all the other effects not included in the model.

The restriction $Y_i = 0$ was imposed and least square constants for sex effects were estimated. The significance of the sex effects were tested by 'F' test. The data on both sexes were pooled later for heritability estimations.

Estimation of heritability

The model used for the estimation of heritability (Becker, 1975) was

$$Y_{ijk} = u + S_i + D_{ij} + e_{ijk}$$

where

Y_{ijk} = Observation of the k^{th} progeny of the j^{th} dam mated to the i^{th} sire.

u = Common mean

S_i = Effect of the i^{th} sire

D_{ij} = Effect of the j^{th} dam mated to the i^{th} sire.

e_{ijk} = Uncontrolled environmental and genetic deviations attributed to the individual.

All effects are random, normal and independent with expectations equal to zero.

Analysis of variance

Source	df	SS	MSS	EMS
Between sires	S-1	SS_S	MS_S	$6^2_W + K_2\ 6^2_D + K_3\ 6^2_S$
Between dams within sires	D-S	SS_D	MS_D	$6^2_W + K_1\ 6^2_D$
Between progeny	$n_{..}$-S	SS_W	MS_W	6^2_W

S = Number of sires $\quad$ $n_{..}$ = Total number of progeny
D = Totall number of Dams

SS_S, SS_D, SS_W are the sum of squares due to sire, dam and progeny respectively and MS_S, MS_D, MS_W are the concerned mean sum of squares.

K_1 = Number of progeny dams

$$= \left[\left(n_{..} - \sum_i \frac{\sum_j ni^2 j}{n_i} \right] \right/ \text{df (dams)}$$

K^2 = Number oof progeny per dam

$$\left[\sum \frac{\sum_j ni^2 j}{ni_{.}} - \frac{\sum_i \sum_j ni^2 j}{n_{..}} \right] \Big/ \text{df (sire)}$$

K_3 = Number of progeny per sire

$$\left[\sum_i \sum_i \frac{ni^2}{n_{..}} \right] \Big/ \text{df (sire)}$$

Where

n_{ij} = Number of progeny per dam

ni = Number of progeny per sire

6^2_W = Variance among progeny, within dams within sires.

$= MS_W$

6^2_D = Dam component of variance

$$= \frac{MS_D - MS_W}{K_1}$$

6^2_S = Sire component of variance

$$= \frac{MS_S - MS_W - K_2 6^2_D}{K_3}$$

The heritabilities were then estimated by the formula

$$h^2_S = \frac{4\ 6^2_S}{6^2_S + 6^2_D + 6^2_W}$$

$$h^2_D = \frac{4\ 6^2_D}{6^2_S + 6^2_D + 6^2_W}$$

$$h^2_{S+D} = \frac{2\ (6^2_S + 6^2_D)}{6^2_S + 6^2_D + 6^2_W}$$

The standard errors of heritabilities were estimated from sire and dam components of variance.

$$\text{Var}\ (6^2_S) = \frac{2}{K_3^2} \left[\frac{MS_S^2}{df\ (s) + 2} + \frac{MS_D^2}{df(D)} \right]$$

$$SE\ (6^2_S) = \sqrt{\hat{\text{Var}}\ (6^2S)}$$

$$SE\ (6^2_S) = \frac{4 \times SE\ (6^2S)}{6^2S + 6^2D + 6^2W}$$

$$\text{Var}\ (6^2_D) = \frac{2}{K_2 2} \left[\frac{MS_D^2}{df_{(D)} + 2} + \frac{MS^2_W}{df_{(W)} + 2} \right]$$

$$SE\ (6^2_D) = \sqrt{\hat{\text{Var}}\ (6^2D)}$$

$$SE\ (h^2_D) = \frac{4 \times SE\ (6^2D)}{6^2S + 6^2D + 6^2W}$$

$$\text{Var}\ (6^2_W) = \frac{2(MS_W)^2}{df_{(W)} + 2}$$

$$Cov\ (\sigma^2_S\ \sigma^2_D) = Var\ (\sigma^2_W) - \frac{K_1^2\ Var\ (\sigma^2_D)}{K_1\ \ K_3}$$

$$SE\ (h^2_{S+D}) = \sqrt[2]{\frac{Var\ (\sigma^2_S) + Var\ (\sigma^2_D) + 2\ Cov\ (\sigma^2_S\ \sigma^2_D)}{\sigma^2_S + \sigma^2_D + \sigma^2_W}}$$

Estimation of correlations

The analysis of covariance models and procedures for X and Y (two characters considered at one time) are the same as given for the estimation of heritability. The variance components $\sigma^2 S(X)$, $\sigma^2 S(Y)$, $\sigma^2 D(X)$, $\sigma^2 D(Y)$, $\sigma^2 W(X)$ and $\sigma^2 W(Y)$ are obtained as before.

Analysis of Co-variance

Source	df	SCP	MSCP	EMCP
Between sires	S-1	SCP^S	MCP^S	$Cov_W+K_2Cov_D+K_3Cov_S$
Between dams within sires	D-S	SCP^D	MCP^D	$Cov_W+K_1Cov_D$
Between progeny within dams	$n_{..}$-D	SCP^W	MCP^W	Cov_W

K_1, K_2 and K_3 are estimated as in the case of analysis of variance.

Phenotypic correlation

$$r_P = \frac{Cov_W - Cov_S - Cov_D}{\sqrt{6\ ^2W(X)+6\ ^2\ S(X)+6\ ^2D(X)}\ \sqrt{(6\ ^2\ W(Y)+6\ ^2\ S(Y)-6\ ^2D(Y)}}$$

Genetic correlations

$$r_{GS} = \frac{4\ Cov_S}{\sqrt{4\ 6\ ^2S(X)\ 4\ 6\ ^2S(Y)}}$$

$$r_{GD} = \frac{4\ Cov_D}{\sqrt{4\ 6\ ^2D(X)\ 4\ 6\ ^2D(Y)}}$$

$$r_{G(S+D)} = \frac{Cov_S + Cov_D}{\sqrt{6\ ^2S(X) + 6\ ^2D(X)}\ \ \sqrt{6\ ^2S(Y) + 6\ ^2D(Y)}}$$

Environmental correlations

$$r_{ES} = \frac{Cov_W - 2\ Cov_S}{\sqrt{6\ ^2W(X) - 2\ 6\ ^2\ S(X)}\ \ \sqrt{6\ ^2W(Y) - 2\ \ 6\ ^2\ S(Y)}}$$

$$r_{ED} = \frac{Cov_W - 2\ Cov_D}{\sqrt{6\ ^2W(X) - 2\ 6\ ^2D(X)}\ \sqrt{6\ ^2W(Y) - 2\ 6\ ^2D(Y)}}$$

$$r_{E(S+D)} = \frac{Cov_W - Cov_S - Cov_D}{\sqrt{6\ ^2W(X) - 6\ ^2S(X) - 6\ ^2D(X)\ (6\ ^2W(Y) - 6\ ^2S(Y) - 6\ ^2D(Y)}}$$

Cov_S - Sire component of covariance.

Cov_D - Dam component of covariance.

Cov_W - Covariance among progeny within dams within sires.

Standard error of correlations were estimated based on the formula outlined by Becker (1975)

Estimation of heritability for litter traits

For the litter traits the data generated consisted of seven sires in each breed mated to two dams each. With the available data it was possible only to estimate the genotypic heritability due to the sires.

The model used for estimation of h^2 now.

$$Y_{ij} = u + x_i + e_{ij}$$

Y_{ij} = Measurement on the j_{th} doe mated to the ith sire

u = Common mean

x_i = effect of i_{th} sire

e_{ij} = uncontrolled environmental and genetic deviations attributable to individuals within sire groups.

All effects are random normal and independent with expectations equal to zero.

Analysis of variance

Source	df	SS	MS	EMS
Between sires	S-1	SS^S	MS^S	$6^{2}_{W} + K_1 \; 6^{2}_{S}$
Between dams within sires	S(D-1)	SS^W	MS^W	6^{2}_{W}

S = Number of sires

D = Number of dams per sire, here equal number four each individual

K_1 = D

Genetic model

The variance component 6^2_S has a value because of difference among sires sires whiles 6^2_W represents the differences among dams within sire group.

The componet 6^2_S estimates all the genetic variance due to the sire while 6^2_W estimates the uncontrolled evironmental and genetic deviations attributed to the dams. SS_S and SS_W are the sum of squares, due to sire and dams respectively and MS_S and MS_W are the concerned mean sum of squares.

K_1 = D number of dams per sire (here equal numbers were taken)

$$6^2_W = MS_W$$

$$6^2_S = \frac{MS_S - MS_W}{K_1}$$

$$\text{Genotypic heritability} = \frac{6^2_S}{6^2_S + 6^2_W}$$

The standard error in the sqare root of the sampling variance of the intraclass correlation, R (Fisher, 1954).

$$SE\ R = \sqrt{\frac{2(1-k)^2\ (1 + K-1) + 1^2}{k(K-1)\ (N-1)}}$$

Results

RESULTS

Body weight

The mean, standard error and the coefficient of variation of four-week, six-week, eight-week, ten-week and twelve-week body weight in Grey Giant, Soviet Chinchilla and New Zealand White rabbits are presented in the tables 1-5.

Least square analysis of variance for the breed effect for the four-week, six-week, eight-week, ten-week and twelve-week body weight are presented in tables 6-10.

In all the weeks the body weights varied significantly between breeds. New Zealand White rabbits had the lowest weight throughout the period of study in all the respective weeks while Soviet Chinchilla had maximum weight from among the breeds throughout the period of study.

The mean values of body weight at four, six, eight, ten and twelve weeks for New Zealand rabbits were 383.3±12.4, 573.1±18.1, 788.6±23.2, 1000.5±24.0 and 1205±29.9g respectively. The corresponding figures for the Grey Giant rabbits were 404.0±9.7, 614.1±13.2, 820.0±17.3, 1028.0±22.2 and 1226.1±28.1g respectively and the corresponding figures for the Soviet Chinchilla rabbits were 452.3±8.7, 679.1±12.8, 903.9±17.0, 1129.0±21.7 and 1354.1±24.4g respectively.

The mean, standard error and coefficient of variation of body weight of male and female rabbits at 4, 6, 8, 10 and 12 weeks of age in Grey Giant, Soviet Chinchilla and New Zealand White rabbits are presented in tables 11-13 respectively.

The mean values of the male rabbits in Grey Giant rabbits at 4, 6, 8, 10 and 12 week were 394.2±13.9, 597.2±19.6, 795.4±26.1, 1005.2±33.0 and 1199.8±42.0g respectively and the mean values of the female rabbits in Grey Giant rabbits at 4, 6, 8, 10 and 12 weeks were 411.9±13.4, 626.9±17.7, 838.6±23.0, 1046.0±29.9 and 1245.9±35.6g respectively. The corresponding mean values in male Soviet Chinchilla rabbits were 452.9±9.9, 679.3±14.6, 904.8±20.1, 1130.4±24.3 and 1357.4±24.2g and the corresponding mean values in female Soviet Chinchilla were 452.3±16.8, 678.7±25.2, 902.3±33.1, 1126.7±41.2 and 1349.1±51.2g respectively. The corresponding mean values in male New Zealand White rabbits were 388.4±16.1, 584.6±23.2, 785.2±28.1, 989.8±28.2 and 1189.0±35.1g respectively and the corresponding mean values in female New Zealand White rabbits were 377.5±19.5, 560.7±28.7, 792.9±38.1, 1025.0±41.2

and 1227.7$\pm$49.1g respectively. The body weight of females was slightly higher in Grey Giant rabbits throughout the period of study. In Soviet Chinchilla rabbits the males were marginally higher than the females throughout the period of study whereas in New Zealand White rabbits until weaning (6 weeks) male rabbits were slightly heavier compared to female rabbits but at 8, 10 and 12 weeks of age the females had higher weights compared to males.

Least square analysis of variance for sex effect at 4, 6, 8, 10 and 12 weeks of age in Grey Giant rabbits are presented in table 14 to 18 respectively. It was found that the sex effect was non significant at all the stages of study. The unadjusted and the least square mean are presented in table 19.

The least square analysis of variance for sex effect at 4, 6, 8, 10 and 12 week in Soviet Chinchilla rabbits are presented in tables 20 to 24 respectively. It was found that the sex effect was non significant at all the stages of study. The unadjusted and the least square mean are presented in table 25.

The least square analysis of variance for sex effect at 4, 6, 8, 10 and 12 week in New Zealand White rabbits are

1703 79

presented in tables 26 to 30 respectively. It was found that the sex effect was non significant at all the stages of study. The unadjusted and least square mean are presented in table 31.

Genetic and Phenotypic analysis of body weight

The analysis of variance in the heritability estimates for four-week, six-week, eight-week, ten-week and twelve-week body weight for Grey Giant rabbits are presented in tables 32 to 36 respectively.

The corresponding analysis of variance for Soviet Chinchilla rabbits are presented in tables 37 to 41 respectively and for New Zealand White rabbits are presented in tables 42 to 46 respectively.

Variance components attributed to sire, doe within sire and within doe (error).

The variance component estimates and the proportion of variation due to random effects for Grey Giant rabbits are presented in table 47. The corresponding estimates for Soviet Chinchilla rabbits are presented in table 48 and for New Zealand White rabbits are presented in table 49.

The proportion of variation due to the sire at 4, 6, 8, 10 and 12 week for Grey Giant rabbits were 18.48 per cent, 17.31 per cent, 17.51 per cent, 23.58 per cent and 25.77 per cent respectively.

The corresponding sire components for Soviet Chinchilla rabbits were 8.77 per cent, 11.71 per cent, 10.24 per cent, 10.07 per cent and 5.99 per cent respectively and for New Zealand White Rabbits were 21.19 per cent, 20.18 per cent, 17.28 per cent, 14.35 per cent and 11.81 per cent respectively.

The proportion of variation attributed to the progency ie. error component at 4, 6, 8, 10 and 12 week in Grey Giant rabbits were 59.67 per cent, 58.60 per cent, 57.92 per cent, 52.23 per cent and 55.45 per cent respectively. The corresponding error component in Soviet Chinchilla rabbits were 72.20 per cent, 74.24 per cent, 75.68 per cnt, 75.42 per cent and 71.81 per cent respectively and in New Zealand White rabbits were 57.04 per cent, 61.57 per cent, 69.06 per cent, 79.89 per cent and 87.65 per cent respectively.

Heritability estimate

The estimate of heritability for body weight at four, six, eight, ten and twelve weeks for Grey Giant rabbit are presented in table 50. The corresponding figures for Soviet Chinchilla rabbits are presented in table 51 and for New Zealand White rabbits are presented in table 52.

The heritability etimates for four-week body weight were 0.74±0.81, 0.87±0.70 and 0.80±0.40 for Grey Giant, 0.35±0.73, 0.72±0.88 and 0.54±0.37 for Soviet Chinchilla rabbits and 0.85±0.89, 0.87±0.75 and 0.86±0.45 for New Zealand White rabbits based on sire, dam and sire + dam components of variance respectively. The estimates for six-week body weight were 0.69±0.81, 0.96±0.74 and 0.83±0.41 for Grey Giant rabbits, 0.46±0.73, 0.56±0.82 and 0.52±0.38 for Soviet Chinchilla rabbits and 0.81±0.84, 0.72±0.72 and 0.77±0.43 for New Zealand White rabbits based on sire, dam and sire + dam components of variance respectively. The estimates for eight-week body weight were 0.70±0.83, 0.98±0.74 and 0.84±0.41 for Grey Giat rabbits, 0.41±0.71, 0.58±0.82 and 0.49±0.37 for Soviet Chinchilla rabbits and 0.69±0.82, 0.55±0.80 and 0.62±0.43 for New Zealand White rabbits based on sire, dam and sire + dam components of variance respectively. The estimates for ten-week body weight were 0.94±0.90, 0.93±0.69 and 0.93±0.45 for Grey Giant rabbits, 0.40±0.71, 0.58±0.83 and 0.49±0.37 for Soviet Chinchilla rabbits and 0.57±0.75, 0.23±0.80 and 0.40±0.41

based on sire, dam and sire + dam components of variance respectively. The estimate for twelve-week body weight were 1.00 ± 0.89, 0.75 ± 0.63 and 0.89 ± 0.45 for Grey Giant rabbits, 0.23 ± 0.73, 0.89 ± 0.94 and 0.56 ± 0.37 for Soviet Chinchilla rabbits and 0.47 ± 0.73, 0.26 ± 0.82 and 0.37 ± 0.41 for New Zealand White rabbits based on sire, dam and sire + dam components of variance respectively.

Interrelationship between body weight at different ages

The analysis of covariance between four-week and six-week, four-week and eight-week, four-week and ten-week, four-week and twelve-week, six-week and eight-week, six-week and ten-week and six-week and twelve-week, eight-week and ten-week, eight-week and twelve-week and between ten-week and twelve-week for Grey Giant rabbits are presented in tables 53 to 62 respectively.

The corresponding analysis of covariance for Soviet Chinchilla rabbits are presented in tables 63 to 72 respectively and for New Zealand White rabbits are presented in tables 73 to 82 respectively.

Correlations

Phenotypic correlations

The estimates of phenotypic correlations in Grey Giant rabbits are presented in table 83. The corresponding estimates for Soviet Chinchilla rabbits are presented in table 84 and those for New Zealand White rabbits are shown in table 85.

The phenotypic correlation estimates between four-week and six-week body weight were found to be 0.981 ± 0.026 for Grey Giant rabbits, 0.995 ± 0.015 for Soviet Chinchilla rabbits and 0.985 ± 0.026 for New Zealand White rabbits.

The phenotypic correlation estimates between four-week and eight-week body weight were found to be 0.972 ± 0.031 for Grey Giant rabbits, 0.995 ± 0.016 for Soviet Chinchilla rabbits and 0.948 ± 0.053 for New Zealand White rabbits.

The phenotypic correlation estimates between four-week and ten-week body weight were found to be 0.948 ± 0.042 for Grey Giant rabbits, 0.993 ± 0.019 for Soviet Chinchilla rabbits and 0.886 ± 0.079 for New Zealand White rabbits.

The phenotypic correlation estimates between four-week and twelve-week body weight were found to be 0.935±0.047 for Grey Giant rabbits, 0.962±0.043 for Soviet Chinchilla rabbits and 0.888±0.079 for New Zealand White rabbits.

The phenotypic correlation estimates between six-week and eight-week body weight were found to be 0.997±0.009 for Grey Giant rabbits, 0.999±0.006 for Soviet Chinchilla rabbits and 0.956±0.048 for New Zealand White rabbits.

The phenotypic correlation estimates between six-week and ten-week body weight were found to be 0.973±0.031 for Grey Giant rabbits, 0.998±0.008 for Soviet Chinchilla rabbits and 0.887±0.079 for New Zealand White rabbits.

The phenotypic correlation estimates between six-week and twelve-week body weight were found to be 0.962±0.036 for Grey Giant rabbits, 0.966±0.041 for Soviet Chinchilla rabbits and 0.888±0.079 for New Zealand White rabbits.

The phenotypic correlation estimates between eight-week and ten-week body weight were found to be 0.975±0.030 for Grey Giant rabbits, 0.999±0.005 for Soviet Chinchilla rabbits and 0.950±0.054 for New Zealand White rabbits.

The phenotypic correlation estimates between eight-week and twelve-week body weight were found to be 0.965±0.035 for Grey Giant rabbits, 0.966±0.040 for Soviet Chinchilla rabbits and 0.951±0.054 for New Zealand White rabbits

The phenotypic correlation estimates between ten-week and twelve-week body weight were found to be 0.990±0.019 for Grey Giant rabbits, 0.968±0.040 for Soviet Chinchilla rabbits and 0.996±0.015 for New Zealand White rabbits

Genetic correlations

Estimates of genetic correlations among different body weight in Grey Giant rabbits are presented in Table 86. The corresponding estimates for Soviet Chinchilla rabbits are presented in table 87 and for New Zealand White rabbits are presented in table 88.

The genetic correlation estimates between four-week and six-week body weight were found to be 0.996±0.005, 1.002±0.003 and 0.999±0.001 for Grey Giant rabbits, 1.020±0.052, 0.996±0.007 and 0.997±0.003 for Soviet Chinchilla rabbits and 1.002±0.004, 0.989±0.013 and 0.996±0.003 for New Zealand White rabbits based on sire, dam and sire + dam components of variance respectively.

The genetic correlation estimates between four-week and eight-week body weight were found to be 0.995 ± 0.007, 0.999 ± 0.001 and 0.996 ± 0.002 for Grey Giant rabbits, 1.017 ± 0.047, 0.993 ± 0.013 and 0.998 ± 0.002 for Soviet Chinchilla rabbits and 1.002 ± 0.004, 0.989 ± 0.013 and 0.996 ± 0.003 for New Zealand White rabbits based on sire, dam and sire + dam components of variance respectively.

The genetic correlation estimates between four-week and ten-week body weight were found to be 0.998 ± 0.020, 1.006 ± 0.008 and 1.001 ± 0.001 for Grey Giant rabbits, 1.016 ± 0.043, 0.991 ± 0.017 and 0.997 ± 0.004 for Soviet Chinchilla rabbits and 0.934 ± 0.105, 1.109 ± 0.283 and 0.987 ± 0.030 for New Zealand White rabbits based on sire, dam and sire + dam components of variance respectively.

The genetic correlation estimates between four-week and twelve-week body weight were found to be 0.979 ± 0.028, 1.019 ± 0.023 and 0.991 ± 0.006 for Grey Giant rabbits, 0.927 ± 0.250, 1.030 ± 0.049 and 0.994 ± 0.006 for Soviet Chinchilla rabbits and 0.492 ± 0.013, 1.007 ± 0.016 and 0.997 ± 0.004 for New Zealand White rabbits based on sire, dam and sire + dam components of variance respectively.

The genetic correlation estimates between six-week and eight-week body weight were found to be 0.999 ± 0.002, 1.000 ± 0.001 and 0.999 ± 0.001 for Grey Giant rabbits, 1.002 ± 0.004, 1.001 ± 0.003 and 1.001 ± 0.001 for Soviet Chinchilla rabbits and 0.952 ± 0.074, 0.941 ± 0.098 and 0.944 ± 0.048 for New Zealand White rabbits based on sire, dam and sire + dam components of variance respectively.

The genetic correlation estimates between six-week and ten-week body weight were found to be 1.018 ± 0.027, 1.008 ± 0.008 and 1.009 ± 0.006 for Grey Giant rabbits, 1.002 ± 0.005, 1.000 ± 0.002 and 1.001 ± 0.001 for Soviet Chinchilla rabbits and 0.973 ± 0.043, 0.967 ± 0.084 and 0.971 ± 0.030 for New Zealand White rabbits based on sire, dam and sire + dam components of variance respectively.

The genetic correlation estimates between six week and twelve-week body weight were found to be 1.616 ± 0.023, 1.017 ± 0.019 and 1.003 ± 0.002 for Grey Giant rabbits, 1.048 ± 0.152, 1.017 ± 0.030 and 0.992 ± 0.007 for Soviet Chinchilla rabbits and 1.038 ± 0.070, 0.851 ± 0.348 and 0.976 ± 0.027 for New Zealand White rabbits based on sire, dam and sire + dam components of variance respectively.

The genetic correlation estimates between eight-week and ten-week body weight were found to be 1.019±0.028, 1.006±0.006 and 1.008±0.005 for Grey Giant rabbits, 0.999±0.001, 1.001±0.001 and 0.999±0.001 for Soviet Chinchilla rabbits and 1.016±0.028, 0.959±0.290 and 0.998±0.003 for New Zealand White rabbits based on sire, dam and sire + dam components of variance respectively.

The genetic correlation estimates between eight-week and twelve-week body weight were found to be 1.017±0.024, 1.016±0.019 and 1.010±0.002 for Grey Giant rabbits, 1.022±0.072, 1.014±0.024 and 0.992±0.008 for Soviet Chinchilla rabbits and 1.072±0.143, 0.846±0.006 and 0.996±0.005 for New Zealand White rabbits based on sire, dam and sire + dam components of variance respectively.

The genetic correlation estimates between ten-week and twelve-week body weight were found to be 0.998±0.002, 1.007±0.007 and 0.999±0.001 for Grey Giant rabbits, 1.027±0.090, 1.009±0.015 and 0.991±0.009 for Soviet Chinchilla rabbits and 1.009±0.018, 1.004±0.020 and 0.997±0.005 for New Zealand White rabbits based on sire, dam and sire + dam components of variance respectively.

Environmental correlations

Estimates of environmental correlations of Grey Giant rabbits are presented in table 89. The corresponding estimates for Soviet Chinchilla rabbits are shown in table 90 and those for New Zealand White rabbits in table 91.

The environmental correlation estimates between four-week and six-week body weights were found to be 0.928, 0.878 and 0.583 for Grey Giant rabbits, 0.990, 1.006 and 1.364 for Soviet Chinchilla rabbits and 0.939, 1.010 and 0.756 for New Zealand White rabbits based on sire, dam and sire + dam components of variance respectively.

The environmental correlation estimates between four-week and eight-week body weights were found to be 0.891, 0.830 and 0.529 for Grey Giant rabbits, 0.987, 1.004 and 1.414 for Soviet Chinchilla rabbits and 0.979, 0.932 and 1.058 for New Zealand White rabbits based on sire, dam and sire + dam components of variance respectively.

The environmental correlation estimates between four-week and ten-week body weights were found to be 0.821, 0.576 and 0.260 for Grey Giant rabbits, 0.984, 1.003 and 1.425 for Soviet Chinchilla rabbits and 0.857, 0.820 and 1.440 for New

Zealand White rabbits based on sire, dam and sire + dam components of variance respectively.

The environmental correlation estimates between four-week and twelve-week body weights were found to be 0.922, 0.601 and 0.321 for Grey Giant rabbits, 0.960, 0.866 and 1.148 for Soviet Chinchilla rabbits and 0.848, 0.840 and 1.560 for New Zealand White rabbits based on sire, dam and sire + dam components of variance respectively.

The environmental correlation estimates between six-week and eight-week body weights were found to be 0.992, 0.981 and 0.607 for Grey Giant rabbits, 0.999, 0.997 and 1.420 for Soviet Chinchilla rabbits and 0.978, 0.976 and 1.083 for New Zealand White rabbits based on sire, dam and sire + dam components of variance respectively.

The environmental correlation estimates between six-week and ten-week body weights were found to be 0.975, 0.621 and 0.299 for Grey Giant rabbits, 0.998, 0.996 and 1.434 for Soviet Chinchilla rabbits and 0.825, 0.858 and 1.450 for New Zealand White rabbits based on sire, dam and sire + dam components of variance respectively.

The environmental correlation estimates between eight-week and ten-week body weights were found to be 0.967, 0.616 and 0.297 for Grey Giant rabbits, 0.999, 0.999 and 1.440 for Soviet Chinchilla rabbits and 0.972, 0.969 and 1.664 for New Zealand White rabbits based on sire, dam and sire + dam components of variance respectively.

The environmental correlation estimates between eight-week and twelve-week body weights were found to be 1.043, 0.752 and 0.364 for Grey Giant rabbits, 0.951, 0.955 and 1.172 for Soviet Chinchilla rabbits and 0.966, 0.987 and 1.802 for New Zealand White rabbits based on sire, dam and sire + dam components of variance respectively.

The environmental correlation estimates between ten-week and twelve-week body weights were found to be 0.861, 1.030 and 0.459 for Grey Giant rabbits, 0.952, 0.967 and 1.179 for Soviet Chinchilla rabbits and 0.992, 1.001 and 1.849 for New Zealand White rabbits based on sire, dam and sire + dam components of variance respectively.

Litter traits

Gestation length

The mean, standard error and the coefficient of variation of gestation length in Grey Giants, Soviet

Chinchilla and New Zealand White rabbits are presented in table 92.

The mean values for gestation length (days) were found to be 32.21±0.28 in Grey Giant rabbits, 32.71±0.33 for Soviet Chinchilla rabbits and 31.93±0.24 for New Zealand White rabbits.

Least square analysis of variance for breed effect is presented in table 93. The effect of breed on the gestation period was found to be non-significant.

Litter size at birth

The mean, standard error and the coefficient of variation of gestation length in Grey Giants, Soviet Chinchilla and New Zealand White rabbits are presented in table 94.

The mean values for litter size at birth were 5.29±0.28 in Grey Giant rabbits, 4.28±0.32 for Soviet Chinchilla rabbits and 4.36±0.24 for New Zealand White rabbits. Least square analysis of variance for breed effect on litter size at birth are presented in table 95. The breed of the rabbit was found effect the litter size at birth significantly.

Litter size at weaning

The mean, standard error and the coefficient of variation of litter size at weaning for Grey Giants, Soviet Chinchilla and New Zealand White rabbits are presented in table 96. The mean values for litter size at weaning were 4.14±0.27 for Grey Giant rabbits, 3.00±0.31 for Soviet Chinchilla rabbits and 3.35±0.23 for New Zealand White rabbits.

Least square analysis of variance for breed effect on litter size at weaning is presented in table 97. The breed of the rabbit was found to effect the litter size at weaning significantly.

Pre-weaning mortality

The mean, standard error and the coefficient of variation of pre-weaning mortality in Grey Giants, Soviet Chinchilla and New Zealand White rabbits are presented in table 98.

The mean values for pre-weaning mortality (%) were 21.07±3.89 in Grey Giant rabbits, 27.41±6.07 for Soviet Chinchilla rabbits and 19.64±5.89 for New Zealand White rabbits.

Least square analysis of variance for breed effect on pre-weaning mortality is presented in table 99. The effect of the breed of the rabbit on the pre-weanming mortality was found to be non-significant.

Litter weight at weaning

The mean, standard error and the coefficient of variation of litter weight at weaning in Grey Giants, Soviet Chinchilla and New Zealand White rabbits are presented in table 100.

The mean values for litter weight at weaning were found to be 2544.30 ± 143.40 in Grey Giant rabbits, 2079.60 ± 188.50 for Soviet Chinchilla rabbits and 1835.0 ± 107.5 for New Zealand White rabbits.

Least square analysis of variance for the effect of breed on the litter weight at weaning is presented in table 101. The breed of the rabbit was found to significantly effect the litter weight at weaning.

Mean litter weight at weaning

The mean, standard error and the coefficient of variation for the mean litter weight at weaning are presented in table 102.

The mean values of mean litter weight at weaning were 623.51$\pm$20.54 for Grey Giant rabbits, 696.56$\pm$16.64 for Soviet Chinchilla rabbits and 555.74$\pm$29.95 for New Zealand White rabbits.

Least square analysis of variance for breed effect on the mean litter weight at weaning is presented in table 103. The breed of the rabbit was found significantly influence the mean litter weight at weaning in rabbits.

Sex ratio at weaning

Sex ratio at weaning was calculated as percentage of males relative to all males and females alive at weanning age.

The percentage of males relative to all males and females in rabbits used for this study is presented in table 104. The overall percentage was found to be 52.

Heritability estimates

Heritability estimates of the litter size at birth and at weaning in all the three breeds were negative and hence adjusted to zero.

Table 1. Mean, Standard error and coefficient of variation of four-week body weight in rabbits

Breed	Number	Mean S.E	C.V
Grey Giant	58	404.3 ± 9.7	18.3
Soviet Chinchilla	42	452.3 ± 8.7	12.4
New Zealand White	47	383.3 ± 12.4	22.1

Table 2. Mean, Standard error and coefficient of variation of six-week body weight in rabbits

Breed	Number	Mean S.E	C.V
Grey Giant	58	614.1 ± 13.2	16.4
Soviet Chinchilla	42	679.1 ± 12.8	12.2
New Zealand White	47	573.4 ± 18.1	21.7

Table 3. Mean, Standard error and coefficient of variation of eight-week body weight in rabbits

Breed	Number	Mean S.E	C.V
Grey Giant	58	820.0 ± 17.3	16.1
Soviet Chinchilla	42	903.9 ± 17.0	12.2
New Zealand White	39	788.6 ± 23.2	18.1

Table 4. Mean, Standard error and coefficient of variation of ten-week body weight in rabbits

Breed	Number	Mean S.E	C.V
Grey Giant	58	1028.5 ± 22.2	16.4
Soviet Chinchilla	42	1129.0 ± 21.7	12.2
New Zealand White	36	1000.5 ± 24.0	14.3

Table 5. Mean Standard error and coefficient of variation of twelve-week body weight in rabbits

Breed	Number	Mean S.E	C.V
Grey Giant	58	1226.1 ± 27.1	16.8
Soviet Chinchilla	42	1354.1 ± 24.4	11.3
New Zealand White	35	1005.6 ± 29.2	14.0

Table 6. Least square analysis of variance for four-week body weight between different breeds of rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F value
Between breeds	2	51323.6	25661.8	4.56**
Within breeds	144	771896.4	5630.4	
Total	146	823220.0		

** P <0.01

Table 7. Least square analysis of variance for six-week body weight between different breeds of rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F value
Between breeds	2	159368.9	79684.5	7.32**
Within breeds	144	1566914.1	10881.4	
Total	146	1726283.0		

** P <0.01

Table 8. Least square analysis of variance for eight-week body weight between different breeds of rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F value
Between breeds	2	296268.2	148134.1	8.81**
Within breeds	136	2270964.2	16698.3	
Total	138	2300592.4		

** P <0.01

Table 9. Least square analysis of variance for ten-week body weight between different breeds of rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F value
Between breeds	2	359344.1	179672.1	7.6**
Within breeds	133	3119606.0	23455.7	
Total	135	3478950.1		

** P <0.01

Table 10. Least square analysis of variance for twelve-week body weight between different breeds of rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F value
Between breeds	2	545159.1	272579.6	8.2**
Within breeds	132	4363616.8	33057.7	
Total	134	4908775.9		

** P <0.01

Table 11. Mean, Standard error and coefficient of variation of body weight of male and female Grey Giant rabbits

Character Body weight	Number	Mean ± S.E	C.V	Number	Mean ± S.E	C.V
Four-week	25	394.2 ± 13.9	17.7	33	411.9 ± 13.4	18.7
Six-week	25	597.2 ± 19.6	16.4	33	626.9 ± 17.7	16.2
Eight-week	25	795.4 ± 26.1	16.4	33	838.6 ± 23.0	15.8
Ten-week	25	1005.2 ± 33.0	16.4	33	1040.0 ± 29.9	16.4
Twelve-week	25	1199.8 ± 42.0	17.5	33	1245.9 ± 35.6	16.4

Table 12. Mean, Standard error and coefficient of variation of body weight of male and female Soviet Chinchilla rabbits

Character Body weight	Number	Mean ± S.E	C.V	Number	Mean ± S.E	C.V
Four-week	27	452.9 ± 9.9	11.4	15	452.3 ± 16.8	14.4
Six-week	27	679.3 ± 14.6	11.2	15	678.7 ± 25.2	14.4
Eight-week	27	904.8 ± 20.1	11.2	15	902.3 ± 33.1	14.2
Ten-week	27	1130.4 ± 24.3	11.2	15	1126.7 ± 41.2	14.1
Twelve-week	27	1357.4 ± 24.2	9.3	15	1349.1 ± 51.2	14.8

Table 13. Mean, Standard error and coefficient of variation of body weight of male and female New Zealand White rabbits

Character Body weight	Number	Mean ± S.E	C.V	Number	Mean ± S.E	C.V
Four-week	25	388.4 ± 16.1	20.7	22	377.5 ± 19.5	24.2
Six-week	25	584.6 ± 23.2	19.8	22	560.7 ± 28.7	24.0
Eight-week	22	785.2 ± 28.1	16.9	17	792.9 ± 38.1	20.0
Ten-week	20	989.8 ± 28.2	12.9	16	1025.0 ± 41.2	16.0
Twelve-week	20	1189.0 ± 35.1	13.1	15	1227.7 ± 49.1	15.3

Table 14. Least square analysis of variance for four-week body weight between male and female sexes in Grey Giant rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F value
Between sexes	1	4491.0	4491.0	0.82[NS]
Within sexes	56	307031.0	5482.7	
Total	57	311522.0		

NS - Not Significant

Table 15. Least square analysis of variance for six-week body weight between male and female sexes in Grey Giant rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F value
Between sexes	1	12606.0	12606.0	1.26[NS]
Within sexes	56	561844.0	10032.9	
Total	57	574450.0		

NS - Not Significant

Table 16. Least square analysis of variance for eight-week body weight between male and female sexes in Grey Giant rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F value
Between sexes	1	26592.0	26592.0	1.50^{NS}
Within sexes	56	967800.0	17282.1	
Total	57	994392.0		

NS - Not Significant

Table 17. Least square analysis of variance for ten-week body weight between male and female sexes in Grey Giant rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F value
Between sexes	1	23748.0	23748.0	0.80^{NS}
Within sexes	56	1602548.0	28616.9	
Total	57	1626296.0		

NS - Not Significant

Table 18. Least square analysis of variance for twelwe-week body weight between male and female sexes in Grey Giant rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F value
Between sexes	1	30280.0	30280.0	0.70^{NS}
Within sexes	56	2397856.0	42818.9	
Total	57	2428136.0		

NS - Not Significant

Table 19. Unadjusted and Least square means of body weight at different ages in Grey Giant rabbits

Character Body weight	Number	Unadjusted mean	Least square mean
Four-week	58	404.3	403.1
Six-week	58	614.1	612.0
Eight-week	58	820.0	817.0
Ten-week	58	1029.4	1025.6
Twelve week	58	1226.1	1222.9

Table 20. Least square analysis of variance for four-week body weight between male and female sexes in Soviet Chinchilla rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F value
Between sexes	1	3.8	3.8	0.0012[NS]
Within sexes	40	128406.0	3210.2	
Total	41	128409.8		

NS - Not Significant

Table 21. Least square analysis of variance for six-week body weight between male and female sexes in Soviet Chinchilla rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F value
Between sexes	1	3.4	3.4	0.0005[NS]
Within sexes	40	282606.0	7065.2	
Total	41	282609.4		

NS - Not Significant

Table 22. Least square analysis of variance for eight-week body weight between male and female sexes in Soviet Chinchilla rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F value
Between sexes	1	59.4	59.4	0.0047[NS]
Within sexes	40	499192.4	18479.8	
Total	41	499251.7		

NS - Not Significant

Table 23. Least square analysis of variance for ten-week body weight between male and female sexes in Soviet Chinchilla rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F value
Between sexes	1	132.3	132.3	0.0070[NS]
Within sexes	40	770929.6	19273.2	
Total	41	771061.9		

NS - Not Significant

Table 24. Least square analysis of variance for twelwe-week body weight between male and female sexes in Soviet Chinchilla rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F value
Between sexes	1	660.2	660.2	0.0270[NS]
Within sexes	40	966207.3	24155.2	
Total	41	966867.5		

NS - Not Significant

Table 25. Unadjusted and Least square means of body weight at different ages in Grey Giant rabbits

Character Body weight	Number	Unadjusted mean	Least square mean
Four-week	42	452.7	452.6
Six-week	42	679.0	678.0
Eight-week	42	903.9	903.6
Ten-week	42	1129.0	1128.5
Twelve week	42	1354.5	1353.3

Table 26. Least square analysis of variance for four-week body weight between male and female sexes in New Zealand rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F value
Between sexes	1	1390.5	1390.5	0.189[NS]
Within sexes	45	330573.5	7346.1	
Total	46	331964.0		

NS - Not Significant

Table 27. Least square analysis of variance for six-week body weight between male and female sexes in New Zealand White rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F value
Between sexes	1	6694.0	6694.0	0.498[NS]
Within sexes	45	703161.0	15625.8	
Total	46	709855.0		

NS - Not Significant

Table 28. Least square analysis of variance for eight-week body weight between male and female sexes in New Zealand White rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F value
Between sexes	1	670.6	670.6	0.027^{NS}
Within sexes	37	976751.8	209933.0	
Total	38	977422.4		

Table 29. Least square analysis of variance for ten-week body weight between male and female sexes in New Zealand White rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F value
Between sexes	1	11045.0	11045.0	0.528^{NS}
Within sexes	34	711198.7	20917.6	
Total	35	722243.7		

NS - Not Significant

Table 30. Least square analysis of variance for twelwe-week body weight between male and female sexes in New Zealand White rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F value
Between sexes	1	12815.2	12815.2	0.042^{NS}
Within sexes	33	955798.3	28963.6	
Total	34	968613.5		

NS - Not Significant

Table 31. Unadjusted and Least square means of body weight at different ages in New Zealand White rabbits

Character Body weight	Number	Unadjusted mean	Least square mean
Four-week	47	383.3	383.0
Six-week	47	573.4	572.6
Eight-week	39	788.6	789.1
Ten-week	36	1005.4	1007.4
Twelve week	35	1205.6	1208.3

Table 32. Heritability estimates for four-week body weight in Grey Giant rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	Variance Component
Between sires	6	104151.0	17358.5	$\sigma^2_S = 1049.9$
Between dams within sires	7	58351.0	8335.8	$\sigma^2_D = 1239.2$
Between progeny within dams	44	149020.0	3386.8	$\sigma^2_W = 3386.8$
Total	57	311522.0		$\sigma^2_P = 5675.9$
K Values		$K_1=3.99$	$k_2=4.28$	$K_3=8.26$
Heritability estimates	Sire 0.74 ± 0.81		Dam 0.87 ± 0.70	Sire + Dam 0.80 ± 0.40

Table 33. Heritability estimates for six-week body weight in Grey Giant rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	Variance Component
Between sires	6	191222.0	31870.3	$\sigma^2_S = 1811.1$
Between dams within sires	7	113384.0	16199.1	$\sigma^2_D = 2520.5$
Between progeny within dams	44	269836.0	6132.6	$\sigma^2_W = 6132.6$
Total	57	574452.0		$\sigma^2_P = 10464.2$
K Values		$K_1 = 3.99$	$k_2 = 4.28$	$K_3 = 8.26$
Heritability estimates	Sire 0.69 ± 0.81	Dam 0.96 ± 0.74		Sire + Dam 0.83 ± 0.41

Table 34. Heritability estimates for eight-week body weight in Grey Giant rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	Variance Component
Between sires	6	334508.0	55751.3	$\sigma^2_S = 3173.6$
Between dams within sires	7	197960.0	28280.0	$\sigma^2_D = 4452.2$
Between progeny within dams	44	461924.0	10498.3	$\sigma^2_W = 10498.3$
Total	57	994392.0		$\sigma^2_P = 18124.1$
K Values		$K_1 = 3.99$	$k_2 = 4.28$	$K_3 = 8.26$

Heritability estimates	Sire	Dam	Sire + Dam
	0.70 ± 0.83	0.98 ± 0.74	0.84 ± 0.41

Table 35. Heritability estimates for ten-week body weight in Grey Giant rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	Variance Component
Between sires	6	621996.0	103666.0	$\sigma^2_S = 7040.7$
Between dams within sires	7	304900.0	43557.1	$\sigma^2_D = 6926.0$
Between progeny within dams	44	609400.0	15895.5	$\sigma^2_W = 15895.5$
Total	57	1626296.0		$\sigma^2_P = 29862.1$
K Values		$K_1 = 3.99$	$k_2 = 4.28$	$K_3 = 8.26$
Heritability estimates	Sire 0.94 ± 0.90	Dam 0.93 ± 0.69		Sire + Dam 0.93 ± 0.45

Table 36. Heritability estimates for twelve-week body weight in Grey Giant rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	Variance Component
Between sires	6	932712.0	155452.0	σ^2_S =11490.6
Between dams within sires	7	407272.0	58181.7	σ^2_D = 8375.5
Between progeny within dams	44	1088160.0	24730.9	σ^2_W =24730.9
Total	57	2428144.0		σ^2_P =44597.0
K Values		K_1=3.99	k_2=4.28	K_3=8.26
Heritability estimates	Sire 1.0 ± 0.89	Dam 0.75 ± 0.63		Sire + Dam 0.89 ± 0.45

Table 37. Heritability estimates for four-week body weight in Soviet Chinchilla rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	Variance Component
Between sires	6	35200.0	5866.7	σ^2_S = 280.8
Between dams within sires	7	27618.0	3945.4	σ^2_D = 576.9
Between progeny within dams	28	65592.0	2343.6	σ^2_W = 2343.6
Total	41	128410.0		σ^2_P = 3200.3
K Values		K_1=2.78	k_2=3.20	K_3=5.97
Heritability estimates	Sire 0.35 ± 0.73	Dam 0.72 ± 0.88		Sire + Dam 0.54 ± 0.37

Table 38. Heritability estimates for six-week body weight in Soviet Chinchilla rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	Variance Component
Between sires	6	8004.4	13340.0	σ^2_S = 825.9
Between dams within sires	7	55930.0	7990.0	σ^2_D = 990.9
Between progeny within dams	28	146640.0	5237.1	σ^2_W = 5237.1
Total	41	282610.0		σ^2_P = 7053.9
K Values		K_1=2.78	k_{2}=3.20	K_{3}=5.97
Heritability estimates	Sire 0.46 ± 0.73		Dam 0.56 ± 0.82	Sire + Dam 0.52 ± 0.38

Table 39. Heritability estimates for eight-week body weight in Soviet Chinchilla rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	Variance Component
Between sires	6	136604.0	22767.3	$\sigma^2_S = 1274.1$
Between dams within sires	7	100748.0	14392.6	$\sigma^2_D = 9352.6$
Between progeny within dams	28	261872.0	9352.6	$\sigma^2_W = 9352.6$
Total	41	499224.0		$\sigma^2_P = 12440.8$
K Values		$K_1=2.78$	$k_2=3.20$	$K_3=5.97$

Heritability estimates	Sire	Dam	Sire + Dam
	0.44 ± 0.71	0.58 ± 0.83	0.49 ± 0.37

Table 40. Heritability estimates for ten-week body weight in Soviet Chinchilla rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	Variance Component
Between sires	6	209768.0	34961.2	$\sigma^2_S = 1935.1$
Between dams within sires	7	155596.0	22228.0	$\sigma^2_D = 2786.3$
Between progeny within dams	28	405636.0	14487.0	$\sigma^2_W = 14487.0$
Total	41	771000.0		$\sigma^2_P = 19208.4$
K Values		$K_1 = 2.78$	$k_2 = 3.20$	$K_3 = 5.97$
Heritability estimates	Sire 0.40 ± 0.71		Dam 0.58 ± 0.83	Sire + Dam 0.40 ± 0.37

Table 41. Heritability estimates for twelve-week body weight in Soviet Chinchilla rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	Variance Component
Between sires	6	258032.0	43005.3	σ^2_S = 1443.4
Between dams within sires	7	224848.0	32121.1	σ^2_D = 5340.9
Between progeny within dams	28	483920.0	17282.9	σ^2_W =17282.9
Total	41	966800.0		σ^2_P =24067.2
K Values		K_1=2.78	k_2=3.20	K_3=5.97

Heritability estimates	Sire	Dam	Sire + Dam
	0.23 ± 0.73	0.89 ± 0.94	0.56 ± 0.37

Table 42. Heritability estimates for four-week body weight in New Zealand White

Source	Degrees of freedom	Sum of squares	Mean sum of squares	Variance Component
Between sires	6	122942.5	5866.7	$\sigma^2_S = 280.8$
Between dams within sires	7	27618.0	3945.4	$\sigma^2_D = 576.9$
Between progeny within dams	33	65592.0	2343.6	$\sigma^2_W = 2343.6$
Total	46	128410.0		$\sigma^2_P = 3200.3$
K Values		$K_1=2.78$	$k_2=3.20$	$K_3=5.97$

Heritability estimates	Sire	Dam	Sire + Dam
	0.35 ± 0.73	0.72 ± 0.88	0.54 ± 0.37

Table 43. Heritability estimates for six-week body weight in New Zealand White rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	Variance Component
Between sires	6	248699.0	41449.8	$\sigma^2_S = 3243.9$
Between dams within sires	7	136074.0	19439.1	$\sigma^2_D = 2903.7$
Between progeny within dams	33	325082.0	9850.9	$\sigma^2_W = 9850.9$
Total	46	709855.0		$\sigma^2_P = 15998.5$
K Values		$K_1 = 3.30$	$k_2 = 3.40$	$K_3 = 6.70$

Heritability estimates	Sire	Dam	Sire + Dam
	0.81 ± 0.84	0.72 ± 0.72	0.77 ± 0.43

Table 44. Heritability estimates for eight-week body weight in New Zealand White rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	Variance Component
Between sires	6	136604.0	22767.3	$\sigma^2_S = 1274.1$
Between dams within sires	7	155586.0	22226.6	$\sigma^2_D = 2879.7$
Between progeny within dams	25	363686.0	14547.4	$\sigma^2_W = 14547.4$
Total	38	777346.0		$\sigma^2_P = 21064.5$
K Values		$K_1=2.67$	$k_2=2.89$	$K_3= 5.54$
Heritability estimates	Sire 0.69 ± 0.82		Dam 0.55 ± 0.80	Sire + Dam 0.62 ± 0.43

Table 45. Heritability estimates for ten-week body weight in New Zealand White rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	Variance Component
Between sires	6	212444.0	35407.3	σ^2_S = 3025.6
Between dams within sires	7	139236.0	19890.9	σ^2_D = 1212.4
Between progeny within dams	22	370536.0	16842.5	σ^2_W =16842.5
Total	35	722216.0		σ^2_P =21080.5
K Values		K_1= 2.51	k_2= 2.60	K_3= 5.09
Heritability estimates	Sire 0.57 ± 0.75		Dam 0.23 ± 0.80	Sire + Dam 0.40 ± 0.37

Table 46. Heritability estimates for twelve-week body weight in New Zealand White rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	Variance Component
Between sires	6	272444.0	45407.3	$\sigma^2_S = 3427.5$
Between dams within sires	7	198500.0	28357.1	$\sigma^2_D = 1896.3$
Between progeny within dams	21	497640.0	23697.1	$\sigma^2_W = 23697.1$
Total	34	968584.0		$\sigma^2_P = 29021.1$
K Values		$K_1 = 2.45$	$k_2 = 2.51$	$K_3 = 4.94$
Heritability estimates	Sire 0.47 ± 0.73	Dam 0.26 ± 0.85		Sire + Dam 0.37 ± 0.41

Table 47. Variance covariance estimates and proportion of variation due to random effects for body weight in Grey Giant rabbits

Characters Body weight	Variance components								
	Paternal half sibs			Maternal half sibs			error		
	d.f	σ^2_S	V	d.f	σ^2_D	V	d.f	σ^2_W	V
Four-week	6	1049.9	0.1849	7	1239.2	0.2183	44	3386.8	0.5967
Six-week	6	1811.1	0.1731	7	2520.5	0.2409	44	6132.6	0.5860
Eight-week	6	3173.6	0.1751	7	4452.2	0.2457	44	10498.3	0.5792
Ten-week	6	7040.7	0.2358	7	6926.0	0.2319	44	15895.5	0.5323
Twelve-week	6	11490.6	0.2577	7	8375.5	0.1878	44	24730.9	0.5545

Table 48. Variance covariance estimates and proportion of variation due to random effects for body weight in Soviet Chinchilla rabbits

Characters Body weight	Variance components								
	Paternal half sibs			Maternal half sibs			error		
	d.f	σ^2_S	V	d.f	σ^2_D	V	d.f	σ^2_W	V
Four-week	6	280.8	0.0877	7	576.9	0.1803	28	2342.6	0.7320
Six-week	6	825.9	0.1171	7	990.9	0.1405	28	5237.1	0.7424
Eight-week	6	1274.1	0.1024	7	1814.1	0.1458	28	9352.6	0.7568
Ten-week	6	1935.1	0.1007	7	2786.3	0.1451	28	14487.0	0.7542
Twelve-week	6	1443.4	0.0599	7	5340.9	0.2219	28	17282.9	0.7181

Table 49. Variance covariance estimates and proportion of variation due to random effects for body weight in New Zealand White rabbits

Characters Body weight	Variance components								
	Paternal half sibs			Maternal half sibs			error		
	d.f	σ^2_S	V	d.f	σ^2_D	V	d.f	σ^2_W	V
Four-week	6	1590.6	0.2119	7	1633.9	0.2176	33	4281.4	0.5704
Six-week	6	3243.9	0.2028	7	2903.7	0.1815	33	9850.3	0.6157
Eight-week	6	3637.4	0.1728	7	2879.7	0.1367	25	14547.4	0.6906
Ten-week	6	3025.6	0.1435	7	1212.4	0.0575	22	16842.5	0.7985
Twelve-week	6	3427.5	0.1181	7	1896.5	0.6539	21	23697.1	0.8165

Table 50. Estimates of heritability for body weight in Grey Giant rabbits

Characters Body weight	Method		
	Sire	Dam	Sire + Dam
Four-week	0.74 ± 0.81	0.87 ± 0.70	0.80 ± 0.40
Six-week	0.69 ± 0.81	0.96 ± 0.74	0.83 ± 0.41
Eight-week	0.70 ± 0.83	0.98 ± 0.74	0.84 ± 0.41
Ten-week	0.94 ± 0.90	0.93 ± 0.69	0.93 ± 0.45
Twelve-week	1.00 ± 0.89	0.75 ± 0.63	0.89 ± 0.45

Table 51. Estimates of heritability for body weight in Soviet Chinchilla rabbits

Characters Body weight	Method		
	Sire	Dam	Sire + Dam
Four-week	0.35 ± 0.73	0.72 ± 0.88	0.54 ± 0.37
Six-week	0.46 ± 0.73	0.56 ± 0.82	0.52 ± 0.38
Eight-week	0.41 ± 0.71	0.58 ± 0.82	0.49 ± 0.37
Ten-week	0.40 ± 0.71	0.58 ± 0.23	0.49 ± 0.37
Twelve-week	0.23 ± 0.73	0.89 ± 0.94	0.56 ± 0.37

Table 52. Estimates of heritability for body weight in New Zealand White rabbits.

Characters Body weight	Method		
	Sire	Dam	Sire + Dam
Four-week	0.85 ± 0.89	0.87 ± 0.75	0.86 ± 0.45
Six-week	0.81 ± 0.84	0.72 ± 0.72	0.77 ± 0.43
Eight-week	0.69 ± 0.82	0.55 ± 0.80	0.62 ± 0.43
Ten-week	0.57 ± 0.75	0.23 ± 0.80	0.40 ± 0.41
Twelve-week	0.47 ± 0.73	0.26 ± 0.85	0.37 ± 0.41

Table 53. Estimation of correlations between four-week and six-week body weight in Grey Giant rabbits.

Source	Degrees of freedom	Sum of cross product	Mean sum of cross product	Variance Component
Between sires	6	140074.0	23345.7	Cov_S = 1374.3
Between dams within sires	7	80457.0	11493.9	Cov_D = 1771.7
Between progeny within dams	44	194385.0	4417.8	Cov_W = 4417.8
Total	57	414916.0		Cov_P = 7563.8
K Values		K_1=3.99	k_2=4.28	K_3=8.26

r_{GS} 0.996±0.005 r_{GS} 0.928

r_{GD} 1.002±0.003 r_{GD} 0.878

$r_{G(S+D)}$ 0.999±0.001 $r_{G(S+D)}$ 0.583

r_P = 0.981 ± 0.026

Table 54. Estimation of correlations between four-week and eight-week body weight in Grey Giant rabbits.

Source	Degrees of freedom	Sum of cross product	Mean sum of cross product		Variance Component
Between sires	6	184486.3	30747.7		Cov_S = 1817.4
Between dams within sires	7	105513.7	15073.4		Cov_D = 2348.1
Between progeny within dams	44	250597.7	5695.4		Cov_W = 5695.4
Total	57	540597.7			Cov_P = 9860.9
K Values		K_1=3.99	k_2=4.28	K_3=8.26	

r_{GS}	0.995 ± 0.007	r_{GS}	0.891
r_{GD}	0.999 ± 0.001	r_{GD}	0.830
$r_{G(S+D)}$	0.996 ± 0.002	$r_{G(S+D)}$	0.529

$r_P = 0.972 \pm 0.031$

Table 55. Estimation of correlations between four-week and ten-week body weight in Grey Giant rabbits.

Source	Degrees of freedom	Sum of cross product	Mean sum of cross product	Variance Component
Between sires	6	250318.4	41719.7	Cov_S = 2714.7
Between dams within sires	7	129252.0	18464.6	Cov_D = 2949.7
Between progeny within dams	44	294091.8	6683.9	Cov_W = 6683.9
Total	57	673662.1		Cov_P =12348.3
K Values		K_1=3.99	k_2=4.28	K_3=8.26

r_{GS}	0.998 ± 0.002	r_{GS}	0.821
r_{GD}	1.006 ± 0.008	r_{GD}	0.576
$r_{G(S+D)}$	1.001 ± 0.001	$r_{G(S+D)}$	0.260

$r_P = 0.948 \pm 0.042$

Table 56. Estimation of correlations between four-week and twelve-week body weight in Grey Giant rabbits.

Source	Degrees of freedom	Sum of cross-product	Mean sum of cross product	Variance Component
Between sires	6	301939.5	50323.2	Cov_S = 3401.1
Between dams within sires	7	149127.0	21303.9	Cov_D = 3284.4
Between progeny within dams	44	360192.4	8186.2	Cov_W = 8186.2
Total	57	811259.9		Cov_P =14871.8
K Values		K_1=3.99	k_2=4.28	K_3=8.26

r_{GS}	0.979$\pm$0.028	r_{GS}	0.922
r_{GD}	1.020$\pm$0.023	r_{GD}	0.601
$r_{G(S+D)}$	0.991$\pm$0.006	$r_{G(S+D)}$	0.321

$r_P = 0.935 \pm 0.047$

Table 57. Estimation of correlations between six-week and eight-week body weight in Grey Giant rabbits.

Source	Degrees of freedom	Sum of cross product	Mean sum of cross product		Variance Component
Between sires	6	252627.0	42104.5		Cov_S = 2395.4
Between dams within sires	7	149609.4	81372.8		Cov_D = 3349.9
Between progeny within dams	44	351714.8	7993.5		Cov_W = 7993.5
Total	57	753951.2			Cov_P =13738.8
K Values		K_1=3.99	k_2=4.28	K_3=8.26	

r_{GS}	0.999 ± 0.002	r_{GS}	0.992
r_{GD}	1.000 ± 0.001	r_{GD}	0.981
$r_{G(S+D)}$	0.999 ± 0.001	$r_{G(S+D)}$	0.507

$r_P = 0.997 \pm 0.009$

Table 58. Estimation of correlations between six-week and ten-week body weight in Grey Giant rabbits.

Source	Degrees of freedom	Sum of cross product	Mean sum of cross product	Variance Component
Between sires	6	344195.3	57365.9	Cov_S = 3633.7
Between dams within sires	7	183144.5	26163.5	Cov_D = 4210.4
Between progeny within dams	44	411304.7	9347.8	Cov_W = 9347.8
Total	57	938644.5		Cov_P =17191.9
K Values		K_1=3.99	k_2=4.28	K_3=8.26

r_{GS}	1.018 ± 0.026	r_{GS}	0.975
r_{GD}	1.008 ± 0.008	r_{GD}	0.621
$r_{G(S+D)}$	1.009 ± 0.006	$r_{G(S+D)}$	0.299

$r_P = 0.973 \pm 0.031$

Table 59. Estimation of correlations between six-week and twelve-week body weight in Grey Giant rabbits.

Source	Degrees of freedom	Sum of cross product	Mean sum of cross product	Variance Component
Between sires	6	418554.7	69759.1	Cov_S = 4636.5
Between dams within sires	7	211007.8	30144.0	Cov_D = 4673.9
Between progeny within dams	44	505062.5	11478.7	Cov_W =11478.7
Total	57	1134625.0		Cov_P =20788.6
K Values		K_1=3.99	k_2=4.28	K_3=8.26

r_{GS}	1.016$\pm$0.023	r_{GS}	1.052
r_{GD}	1.017$\pm$0.019	r_{GD}	0.722
$r_{G(S+D)}$	1.003$\pm$0.002	$r_{G(S+D)}$	0.363

$r_P = 0.962 \pm 0.036$

Table 60. Estimation of correlations between eight-week and ten-week body weight in Grey Giant rabbits.

Source	Degrees of freedom	Sum of cross product	Mean sum of cross product	Variance Component
Between sires	6	455508.0	75934.7	Cov_S = 4809.6
Between dams within sires	7	242102.0	34586.0	Cov_D = 5590.0
Between progeny within dams	44	540406.0	12281.9	Cov_W =12281.9
Total	57	1238116.0		Cov_P =22681.5
K Values		K_1=3.99	k_2=4.28	K_3=8.26

r_{GS}	1.019 ± 0.028	r_{GS}	0.967
r_{GD}	1.006 ± 0.006	r_{GD}	0.616
$r_{G(S+D)}$	1.008 ± 0.006	$r_{G(S+D)}$	0.297

$r_P = 0.975 \pm 0.030$

Table 61. Estimation of correlations between eight-week and twelve-week body weight in Grey Giant rabbits.

Source	Degrees of freedom	Sum of cross product	Mean sum of cross product	Variance Component
Between sires	6	554108.0	92351.3	Cov_S = 6133.5
Between dams within sires	7	279204.0	39886.3	Cov_D = 6213.8
Between progeny within dams	44	664106.0	15093.3	Cov_W =15093.3
Total	57	1497418.0		Cov_P =27440.6
K Values		K_1=3.99	k_2=4.28	K_3=8.26

r_{GS}	1.017$\pm$0.024	r_{GS}	1.043
r_{GD}	1.016$\pm$0.019	r_{GD}	0.752
$r_{G(S+D)}$	1.010$\pm$0.002	$r_{G(S+D)}$	0.364

r_P = 0.965 $\pm$ 0.035

Table 62. Estimation of correlations between ten-week and twelve-week body weight in Grey Giant rabbits.

Source	Degrees of freedom	Sum of cross product	Mean sum of cross product		Variance Component
Between sires	6	758612.0	126435.3		Cov_S = 8980.9
Between dams within sires	7	350814.0	50116.3		Cov_D = 7674.9
Between progeny within dams	44	857708.0	19493.4		Cov_W =19493.0
Total	57	1967134.0			Cov_P =36149.2
K Values		K_1=3.99	k_2=4.28	K_3=8.26	

r_{GS}	0.998$\pm$0.002	r_{GS}	0.861
r_{GD}	1.007$\pm$0.001	r_{GD}	1.030
$r_{G(S+D)}$	0.999$\pm$0.001	$r_{G(S+D)}$	0.459

$r_P = 0.990 \pm 0.019$

Table 63. Estimation of correlations between four-week and six-week body weight in Soviet Chinchilla rabbits.

Source	Degrees of freedom	Sum of cross product	Mean sum of cross product	Variance Component
Between sires	6	52979.0	8829.8	Cov_S = 491.3
Between dams within sires	7	39043.0	5577.6	Cov_D = 753.1
Between progeny within dams	28	97588.0	3485.3	Cov_W = 3485.3
Total	41	189610.0		Cov_P = 4729.7
K Values		K_1=2.78	k_2=3.20	K_3=5.97

r_{GS}	1.020±0.052	r_{GS}	0.990
r_{GD}	0.996±0.007	r_{GD}	1.006
$r_{G(S+D)}$	0.997±0.003	$r_{G(S+D)}$	1.364

r_P = 0.995 ± 0.015

Table 64. Estimation of correlations between four-week and eight-week body weight in Soviet Chinchilla rabbits.

Source	Degrees of freedom	Sum of cross product	Mean sum of cross product		Variance Component
Between sires	6	69220.7	11536.8		Cov_S = 608.5
Between dams within sires	7	52314.5	7473.5		Cov_D = 1015.8
Between progeny within dams	28	130238.3	4651.4	——	Cov_W = 4651.4
Total	41	251773.5			Cov_P = 6275.7
K Values		K_1=2.78	k_2=3.20	K_3=5.97	

r_{GS}	1.017 ± 0.047	r_{GS}	0.987
r_{GD}	0.993 ± 0.013	r_{GD}	1.004
$r_{G(S+D)}$	0.998 ± 0.002	$r_{G(S+D)}$	1.414

$r_P = 0.995 \pm 0.016$

Table 65. Estimation of correlations between four-week and ten-week body weight in Soviet Chinchilla rabbits.

Source	Degrees of freedom	Sum of cross product	Mean sum of cross product	Variance Component
Between sires	6	85636.7	14272.8	Cov_S = 749.0
Between dams within sires	7	64880.9	9268.7	Cov_D = 1256.3
Between progeny within dams	28	161793.0	5778.3	Cov_W = 5778.3
Total	41	312310.5		Cov_P = 7783.6
K Values		K_1=2.78	k_2=3.20	K_3=5.97

r_{GS}	1.016±0.043	r_{GS}	0.984
r_{GD}	1.991±0.017	r_{GD}	1.003
$r_{G(S+D)}$	0.997±0.040	$r_{G(S+D)}$	1.425

r_P = 0.993 ± 0.019

Table 66. Estimation of correlations between four-week and twelve-week body weight in Soviet Chinchilla rabbits.

Source	Degrees of freedom	Sum of cross product	Mean sum of cross product	Variance Component
Between sires	6	92130.9	15355.1	Cov_S = 590.4
Between dams within sires	7	77445.3	11063.6	Cov_D = 807.7
Between progeny within dams	28	169160.2	6041.4	Cov_W = 6041.4
Total	41	338736.3		Cov_P = 7439.5
K Values		K_1=2.78	k_2=3.20	K_3=5.97

r_{GS}	0.927 ± 0.250	r_{GS}	0.960
r_{GD}	1.030 ± 0.049	r_{GD}	0.866
$r_{G(S+D)}$	0.994 ± 0.006	$r_{G(S+D)}$	1.148

$r_P = 0.962 \pm 0.043$

Table 67. Estimation of correlations between six-week and eight-week body weight in Soviet Chinchilla rabbits.

Source	Degrees of freedom	Sum of cross product	Mean sum of cross product	Variance Component
Between sires	6	104544.9	17424.2	Cov_S = 1027.5
Between dams within sires	7	75050.8	10721.5	Cov_D = 1342.5
Between progeny within dams	28	195765.6	6991.6	Cov_W = 6991.6
Total	41	375361.3		Cov_P = 9361.8
K Values		K_1=2.78	k_2=3.20	K_3=5.97

r_{GS}	1.002±0.004	r_{GS}	0.997
r_{GD}	1.001±0.003	r_{GD}	0.987
$r_{G(S+D)}$	1.001±0.001	$r_{G(S+D)}$	1.420

$r_P = 0.999 \pm 0.006$

Table 68. Estimation of correlations between six-week and ten-week body weight in Soviet Chinchilla rabbits.

Source	Degrees of freedom	Sum of cross product	Mean sum of cross product		Variance Component
Between sires	6	129494.1	21582.4		Cov_S = 1266.8
Between dams within sires	7	93203.1	13314.7		Cov_D = 1663.4
Between progeny within dams	28	243418.0	8693.5		Cov_W = 8693.5
Total	41	466115.2			Cov_P =11623.7
K Values		K_1=2.78	k_2=3.20	K_3=5.97	

r_{GS}	1.002±0.005	r_{GS}	0.998
r_{GD}	1.001±0.002	r_{GD}	0.996
$r_{G(S+D)}$	1.001±0.001	$r_{G(S+D)}$	1.434

r_P = 0.998 ± 0.008

Table 69. Estimation of correlations between six-week and twelve-week body weight in Soviet Chinchilla rabbits.

Source	Degrees of freedom	Sum of cross product	Mean sum of cross product		Variance Component
Between sires	6	140582.0	23430.3		Cov_S = 1144.7
Between dams within sires	7	109230.5	15604.4		Cov_D = 2339.0
Between progeny within dams	44	254972.7	91006.2		Cov_W = 9106.2
Total	57	504785.2			Cov_P =12589.9
K Values		K_1=2.78	k_2=3.20	K_3=5.97	

r_{GS}	1.048±0.152	r_{GS}	0.949
r_{GD}	1.017±0.030	r_{GD}	0.955
$r_{G(S+D)}$	0.992±0.007	$r_{G(S+D)}$	1.167

$r_P = 0.966 \pm 0.041$

Table 70. Estimation of correlations between eight-week and ten-week body weight in Soviet Chinchilla rabbits.

Source	Degrees of freedom	Sum of cross product	Mean sum of cross product		Variance Component
Between sires	6	189212.0	28202.0		Cov_S = 1568.0
Between dams within sires	7	125208.5	17886.9		Cov_D = 2251.3
Between progeny within dams	28	325706.0	11632.4		Cov_W =11632.4
Total	41	620126.0			Cov_P =15451.7
K Values		K_1=2.78	k_2=3.20	K_3=5.97	

r_{GS}	0.999±0.001	r_{GS}	0.999
r_{GD}	1.001±0.001	r_{GD}	0.999
$r_{G(S+D)}$	0.999±0.001	$r_{G(S+D)}$	1.440

r_P = 0.999 ± 0.005

Table 71. Estimation of correlations between eight-week and twelve-week body weight in Soviet Chinchilla rabbits.

Source	Degrees of freedom	Sum of cross product	Mean sum of cross product	Variance Component
Between sires	6	183404.0	30567.3	Cov_S = 1388.0
Between dams within sires	7	146602.0	20943.1	Cov_D = 3153.3
Between progeny within dams	28	341112.0	12182.6	Cov_W =12182.6
Total	41	671118.0		Cov_P =16723.9
K Values		K_1=2.78	k_2=3.20	K_3=5.97

r_{GS}	1.002±0.072	r_{GS}	0.951
r_{GD}	1.014±0.024	r_{GD}	0.955
$r_{G(S+D)}$	0.992±0.008	$r_{G(S+D)}$	1.172

$r_P = 0.966 \pm 0.040$

Table 72. Estimation of correlations between ten-week and twelve-week body weight in Soviet Chinchilla rabbits.

Source	Degrees of freedom	Sum of cross product	Mean sum of cross product	Variance Component
Between sires	6	227514.0	37919.0	Cov_S = 1719.4
Between dams within sires	7	182112.0	20016.0	Cov_D = 3890.5
Between progeny within dams	28	425810.0	15207.5	Cov_W =15207.5
Total	41	835436.0		Cov_P =20817.4
K Values		K_1=2.78	k_2=3.20	K_3=5.97

r_{GS}	1.027$\pm$0.090	r_{GS}	0.952
r_{GD}	1.009$\pm$0.015	r_{GD}	0.967
$r_{G(S+D)}$	0.991$\pm$0.009	$r_{G(S+D)}$	1.179

$r_P = 0.968 \pm 0.040$

Table 73. Estimation of correlations between four-week and six-week body weight in New Zealand White rabbits.

Source	Degrees of freedom	Sum of cross product	Mean sum of cross product		Variance Component
Between sires	6	173654.0	28942.3		Cov_S = 2277.1
Between dams within sires	7	94356.0	13479.4		Cov_D = 2155.8
Between progeny within dams	33	209912.0	6360.9		Cov_W = 6360.9
Total	46	477922.0			Cov_P =10793.9
K Values		K_1=3.30	k_2=3.40	K_3=6.70	

r_{GS}	1.002$\pm$0.004	r_{GS}	0.939
r_{GD}	0.989$\pm$0.013	r_{GD}	1.010
$r_{G(S+D)}$	0.996$\pm$0.003	$r_{G(S+D)}$	0.756

r_P = 0.985$\pm$0.026

Table 74. Estimation of correlations between four-week and eight-week body weight in New Zealand White rabbits.

Source	Degrees of freedom	Sum of cross product	Mean sum of cross product	Variance Component
Between sires	6	132637.7	22106.3	Cov_S = 1676.4
Between dams within sires	7	87168.0	12452.6	Cov_D = 1659.5
Between progeny within dams	25	200681.6	8027.3	Cov_W = 8027.3
Total	38	420287.3		Cov_P =11363.2
K Values		K_1=2.67	k_2=2.89	K_3=5.54

r_{GS}	0.930±0.106	r_{GS}	0.979
r_{GD}	0.973±0.043	r_{GD}	0.932
$r_{G(S+D)}$	0.947±0.044	$r_{G(S+D)}$	1.053

$r_P = 0.948 \pm 0.053$

Table 75. Estimation of correlations between four-week and ten-week body weight in New Zealand White rabbits.

Source	Degrees of freedom	Sum of cross product	Mean sum of cross product	Variance Component
Between sires	6	110280.3	18380.0	Cov_S = 1766.3
Between dams within sires	7	65093.8	9299.1	Cov_D = 959.1
Between progeny within dams	22	151528.3	6887.7	Cov_W = 6877.7
Total	35	326902.3		Cov_P = 9613.1
K Values		K_1=2.51	k_2=2.60	K_3=5.09

r_{GS}	0.934 ± 0.105	r_{GS}	0.857
r_{GD}	1.109 ± 0.283	r_{GD}	0.820
$r_{G(S+D)}$	0.987 ± 0.013	$r_{G(S+D)}$	1.440

$r_P = 0.886 \pm 0.079$

Table 76. Estimation of correlations between four-week and twelve-week body weight in New Zealand White rabbits.

Source	Degrees of freedom	Sum of cross product	Mean sum of cross product		Variance Component
Between sires	6	124656.3	10776.0		Cov_S = 1989.4
Between dams within sires	7	76191.4	10884.5		Cov_D = 1021.9
Between progeny within dams	21	175841.8	8373.4		Cov_W = 8373.4
Total	34	376689.5			Cov_P =11384.7
K Values		K_1=2.46	k_2=2.51	K_3=4.94	

r_{GS}	0.992±0.013	r_{GS}	0.848
r_{GD}	1.007±0.016	r_{GD}	0.840
$r_{G(S+D)}$	0.997±0.004	$r_{G(S+D)}$	1.560

$r_P = 0.888 \pm 0.079$

Table 77. Estimation of correlations between six-week and eight-week body weight in New Zealand White rabbits.

Source	Degrees of freedom	Sum of cross product	Mean sum of cross product	Variance Component
Between sires	6	198587.9	33098.0	Cov_S = 2618.7
Between dams within sires	7	126509.8	18072.8	Cov_D = 2347.7
Between progeny within dams	25	295306.6	11812.3	Cov_W =11812.3
Total	38	620404.3		Cov_P =16778.7
K Values		K_1=2.67	k_2=2.89	K_3=5.54

r_{GS}	$0.952 \pm 0.0.074$	r_{GS}	0.978
r_{GD}	0.941 ± 0.098	r_{GD}	0.976
$r_{G(S+D)}$	0.944 ± 0.048	$r_{G(S+D)}$	1.083

$r_P = 0.956 \pm 0.048$

Table 78. Estimation of correlations between six-week and ten-week body weight in New Zealand White rabbits.

Source	Degrees of freedom	Sum of cross product	Mean sum of cross product	Variance Component
Between sires	6	162496.1	17082.7	Cov_S = 2708.3
Between dams within sires	7	92320.3	13188.6	Cov_D = 1139.6
Between progeny within dams	22	227111.3	10323.2	Cov_W =14171.2
Total	35	481927.7		Cov_P =14171.2
K Values		K_1=2.51	k_2=2.60	K_3=5.09

r_{GS}	0.973 ± 0.043	r_{GS}	0.825
r_{GD}	0.967 ± 0.084	r_{GD}	0.858
$r_{G(S+D)}$	0.971 ± 0.030	$r_{G(S+D)}$	1.450

$r_P = 0.887 \pm 0.079$

Table 79. Estimation of correlations between six-week and twelve-week body weight in New Zealand White rabbits.

Source	Degrees of freedom	Sum of cross product	Mean sum of cross product	Variance Component
Between sires	6	183330.1	30555.0	Cov_S = 3056.7
Between dams within sires	7	107660.2	15380.0	Cov_D = 1160.5
Between progeny within dams	21	263097.7	12528.5	Cov_W =12528.5
Total	34	554087.9		Cov_P =16745.6
K Values		K_1=2.46	k_2=2.51	K_3=4.94

r_{GS}	1.038±0.070	r_{GS}	0.815
r_{GD}	0.851±0.348	r_{GD}	0.873
$r_{G(S+D)}$	0.976±0.027	$r_{G(S+D)}$	1.576

r_P = 0.888 ± 0.079

Table 80. Estimation of correlations between eight-week and ten-week body weight in New Zealand White rabbits.

Source	Degrees of freedom	Sum of cross product	Mean sum of cross product	Variance Component
Between sires	6	216302.0	36050.3	Cov_S = 3616.5
Between dams within sires	7	122504.0	17500.6	Cov_D = 1480.6
Between progeny within dams	22	303102.0	13777.8	Cov_W =13777.8
Total	35	641908.0		Cov_P =18874.9
K Values		K_1=2.51	k_2=2.60	K_3=5.09

r_{GS}	1.016$\pm$0.028	r_{GS}	0.972
r_{GD}	0.959$\pm$0.129	r_{GD}	0.969
$r_{G(S+D)}$	0.998$\pm$0.003	$r_{G(S+D)}$	1.664

$r_P = 0.950 \pm 0.054$

Table 81. Estimation of correlations between eight-week and twelve-week body weight in New Zealand White rabbits.

Source	Degrees of freedom	Sum of cross product	Mean sum of cross product		Variance Component
Between sires	6	243698.0	40616.3		Cov_S = 4054.8
Between dams within sires	7	143402.0	20486.0		Cov_D = 1532.9
Between progeny within dams	21	351106.0	16719.3		Cov_W =16719.3
Total	34	387100.0			Cov_P =22307.0
K Values		K_1=2.46	k_2=2.51	K_3=4.94	

r_{GS}	1.072±0.143	r_{GS}	0.966
r_{GD}	0.846±0.437	r_{GD}	0.987
$r_{G(S+D)}$	0.996±0.005	$r_{G(S+D)}$	1.802

r_P = 0.951 ± 0.054

Table 82 Estimation of correlations between ten-week and twelve-week body weight in New Zealand White rabbits.

Source	Degrees of freedom	Sum of cross product	Mean sum of cross product	Variance Component
Between sires	6	235296.0	39216.0	Cov_S = 3184.6
Between dams within sires	7	163812.0	23401.7	Cov_D = 1277.8
Between progeny within dams	21	425502.0	20262.0	Cov_W =20262.0
Total	34	824610.0		Cov_P =24724.4
K Values		K_1=2.46	k_2=2.51	K_3=4.94

r_{GS}	1.009 ± 0.018	r_{GS}	0.992
r_{GD}	1.004 ± 0.020	r_{GD}	1.001
$r_{G(S+D)}$	0.997 ± 0.005	$r_{G(S+D)}$	1.001

$r_P = 0.996 \pm 0.040$

Table 83. Estimate of phenotypic correlations with standard errors among different body weights in Grey Giant Rabbits.

Characters Body weight	rp ± S.E
Four-week and Six-week	0.981 ± 0.026
Four-week and Eight-week	0.972 ± 0.031
Four-week and Ten-week	0.948 ± 0.042
Four-week and Twelve-week	0.935 ± 0.047
Six-week and Eight-week	0.997 ± 0.009
Six-week and Ten-week	0.973 ± 0.031
Six-week and Twelve-week	0.962 ± 0.036
Eight-week and Ten-week	0.975 ± 0.030
Eight-week and Twelve-week	0.965 ± 0.035
Ten-week and Twelve-week	0.990 ± 0.019

Table 84. Estimate of phenotypic correlations with standard errors among different body weights in Soviet Chinchilla Rabbits.

Characters Body weight	rp ± S.E
Four-week and Six-week	0.995 ± 0.015
Four-week and Eight-week	0.995 ± 0.016
Four-week and Ten-week	0.993 ± 0.019
Four-week and Twelve-week	0.962 ± 0.043
Six-week and Eight-week	0.999 ± 0.006
Six-week and Ten-week	0.998 ± 0.008
Six-week and Twelve-week	0.966 ± 0.041
Eight-week and Ten-week	0.999 ± 0.005
Eight-week and Twelve-week	0.966 ± 0.040
Ten-week and Twelve-week	0.968 ± 0.040

Table 85. Estimate of phenotypic correlations with standard errors among different body weights in New Zealand White rabbits

Characters Body weight	rp ± S.E
Four-week and Six-week	0.985 ± 0.026
Four-week and Eight-week	0.948 ± 0.053
Four-week and Ten-week	0.886 ± 0.079
Four-week and Twelve-week	0.888 ± 0.079
Six-week and Eight-week	0.956 ± 0.048
Six-week and Ten-week	0.887 ± 0.079
Six-week and Twelve-week	0.888 ± 0.079
Eight-week and Ten-week	0.950 ± 0.054
Eight-week and Twelve-week	0.951 ± 0.054
Ten-week and Twelve-week	0.996 ± 0.015

Table 86. Estimate of genetic correlations with standard errors among different body weights in Grey Giant Rabbits.

Characters Body weight	Sire	Dam	Sire + Dam
Four-week and Six-week	0.996±0.005	1.002±0.003	0.999±0.001
Four-week and Eight-week	0.995±0.007	0.999±0.001	0.996±0.002
Four-week and Ten-week	0.998±0.002	1.006±0.008	1.001±0.001
Four-week and Twelve-week	0.979±0.028	1.029±0.023	0.991±0.006
Six-week and Eight-week	0.999±0.002	1.000±0.001	0.999±0.001
Six-week and Ten-week	1.018±0.027	1.008±0.008	1.009±0.006
Six-week and Twelve-week	1.016±0.023	1.017±0.019	1.003±0.002
Eight-week and Ten-week	1.019±0.028	1.006±0.006	1.008±0.005
Eight-week and Twelve-week	1.017±0.024	1.016±0.019	1.010±0.002
Ten-week and Twelve-week	0.998±0.002	1.007±0.007	0.999±0.001

correlation estimates more than one may be taken as one

Table 87. Estimate of genetic correlations with standard errors among different body weights in Soviet Chinchilla Rabbits.

Characters Body weight	Sire	Dam	Sire + Dam
Four-week and Six-week	1.020±0.052	0.996±0.007	0.997±0.003
Four-week and Eight-week	1.017±0.047	0.993±0.013	0.998±0.002
Four-week and Ten-week	1.016±0.043	0.991±0.017	0.997±0.004
Four-week and Twelve-week	0.927±0.250	1.030±0.049	0.994±0.006
Six-week and Eight-week	1.002±0.004	1.001±0.003	1.001±0.001
Six-week and Ten-week	1.002±0.005	1.001±0.002	1.001±0.001
Six-week and Twelve-week	1.048±0.152	1.017±0.030	0.992±0.007
Eight-week and Ten-week	0.999±0.001	1.001±0.001	0.999±0.001
Eight-week and Twelve-week	1.022±0.072	1.014±0.024	1.992±0.008
Ten-week and Twelve-week	1.027±0.090	1.009±0.015	0.991±0.009

Correlation estimates more than one may be taken as one

Table 88. Estimate of genetic correlations with standard errors among different body weights in New Zealand White rabbits

Characters Body weight	Sire	Dam	Sire + Dam
Four-week and Six-week	1.002±0.004	0.989±0.013	0.996±0.003
Four-week and Eight-week	0.930±0.106	0.973±0.043	0.947±0.044
Four-week and Ten-week	0.934±0.105	1.109±0.283	0.987±0.013
Four-week and Twelve-week	0.992±0.013	1.007±0.016	0.997±0.004
Six-week and Eight-week	0.952±0.074	0.941±0.098	0.944±0.048
Six-week and Ten-week	0.973±0.043	0.967±0.084	0.971±0.030
Six-week and Twelve-week	1.038±0.070	0.851±0.348	0.976±0.027
Eight-week and Ten-week	1.016±0.028	1.959±0.129	0.998±0.003
Eight-week and Twelve-week	1.072±0.143	0.846±0.996	0.996±0.005
Ten-week and Twelve-week	1.009±0.018	1.004±0.020	0.997±0.005

Correlation estimates more than one may be taken as one

Table 89. Estimate of enviromental correlations among different body weight in Grey Griant Rabbits.

Characters Body weight	Sire	Dam	Sire + Dam
Four-week and Six-week	0.928	0.878	0.583
Four-week and Eight-week	0.891	0.830	0.529
Four-week and Ten-week	0.821	0.576	0.260
Four-week and Twelve-week	0.922	0.601	0.321
Six-week and Eight-week	0.992	0.981	0.607
Six-week and Ten-week	0.975	0.621	0.299
Six-week and Twelve-week	1.052	0.722	0.363
Eight-week and Ten-week	0.967	0.616	0.297
Eight-week and Twelve-week	1.043	0.752	0.364
Ten-week and Twelve-week	0.861	1.030	0.459

Correlation estimates more than one may be taken as one

Table 90. Estimate of enviromental correlations among different body weight in Soviet Chinchilla rabbits

Characters Body weight	Sire	Dam	Sire + Dam
Four-week and Six-week	0.990	1.006	1.364
Four-week and Eight-week	0.987	1.004	1.414
Four-week and Ten-week	0.984	1.003	1.425
Four-week and Twelve-week	0.960	0.886	1.148
Six-week and Eight-week	0.999	0.997	1.420
Six-week and Ten-week	0.998	0.996	1.434
Six-week and Twelve-week	0.949	0.955	1.167
Eight-week and Ten-week	0.999	0.999	1.440
Eight-week and Twelve-week	0.951	0.955	1.172
Ten-week and Twelve-week	0.952	0.967	1.179

Correlation estimates more than one may be taken as one

Table 91. Estimate of enviromental correlations among different body weight in New Zealand White rabbits

Characters Body weight	Sire	Dam	Sire + Dam
Four-week and Six-week	0.939	1.010	0.756
Four-week and Eight-week	0.979	0.932	1.058
Four-week and Ten-week	0.857	0.820	1.440
Four-week and Twelve-week	0.848	0.840	1.560
Six-week and Eight-week	0.978	0.976	1.083
Six-week and Ten-week	0.825	0.858	1.450
Six-week and Twelve-week	0.815	0.879	1.576
Eight-week and Ten-week	0.972	0.969	1.664
Eight-week and Twelve-week	0.966	0.987	1.802
Ten-week and Twelve-week	0.992	1.001	1.849

Correlation estimates more than one may be taken as one

Table 92. Mean, Standard error and coefficient of variation gestation length in rabbits.

Breed	Number	Mean S.E	C.V
Grey Giant	14	31.21 ± 0.28	3.26
Soviet Chinchilla	14	32.71 ± 0.33	3.87
New Zealand White	14	31.93 ± 0.24	2.87

Table 93. Least square analysis of variance for gestation length between different breeds of rabbits.

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F value
Between breeds	2	4.429	2.214	1.87^{NS}
Within breeds	39	46.143	1.183	
Total	41	50.572		

NS Not Significant

Table 94. Mean, Standard error and coefficient of variation of litter size at birth in rabbits.

Breed	Number	Mean S.E	C.V
Grey Giant	14	5.29 ± 0.28	20.22
Soviet Chinchilla	14	4.28 ± 0.32	28.10
New Zealand White	14	4.36 ± 0.24	21.32

Table 95. Least square analysis of variance for litter size at birth between different breeds of rabbits.

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F value
Between breeds	2	8.714	4.357	3.78**
Within breeds	39	44.929	1.152	
Total	41	53.643		

** $P < 0.01$

Table 96. Mean, Standard error and coefficient of variation of litter size at weaning in rabbits.

Breed	Number	Mean S.E	C.V
Grey Giant	14	4.14 ± 0.27	24.79
Soviet Chinchilla	14	3.00 ± 0.31	39.22
New Zealand White	14	3.35 ± 0.23	25.07

Table 97. Least square analysis of variance for litter size at weaning between different breeds of rabbits.

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F value
Between breeds	2	8.337	4.169	4.76**
Within breeds	39	34.142	0.875	
Total	41	42.479		

** $P < 0.01$

Table 98. Mean, Standard error and coefficient of variation of pre-weaning mortality in rabbits.

Breed	Number	Mean S.E	C.V
Grey Giant	14	21.07 ± 3.89	68.99
Soviet Chinchilla	14	27.41 ± 6.07	82.90
New Zealand White	14	19.64 ± 5.89	112.27

Table 99. Least square analysis of variance for preweaning mortality between different breeds of rabbits

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F value
Between breeds	2	463.95	231.98	0.57[NS]
Within breeds	39	15798.67	405.09	
Total	41	16262.62		

NS Not significant

Table 100. Mean,Standard error and coefficient of variation of litter weight at weaning in rabbits.

Breed	Number	Mean S.E	C.V
Grey Giant	14	2544.3 $\pm$ 143.4	21.08
Soviet Chinchilla	14	2079.6 $\pm$ 188.5	33.91
New Zealand White	14	1835.0 $\pm$ 107.5	21.91

Table 101. Least square analysis of variance for litter weight at weaning between different breeds of rabbits.

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F value
Between breeds	2	3634536.91	18117268.5	5.76**
Within breeds	39	12306866.07	315560.7	
Total	41	15941402.98		

** P < 0.01

Table 102. Mean,Standard error and coefficient of variation of mean litter weight at weaning in rabbits.

Breed	Number	Mean S.E	C.V
Grey Giant	14	623.51 ± 20.54	12.33
Soviet Chinchilla	14	696.56 ± 16.64	8.94
New Zealand White	14	555.74 ± 29.95	20.17

Table 103. Least square analysis of variance for mean weaning between different breeds of rabbits.

Source	Degrees of freedom	Sum of squares	Mean sum of squares	F value
Between breeds	2	138878.59	69439.30	9.32**
Within breeds	39	290502.52	7448.78	
Total	41	429381.11		

** $P < 0.01$

Table 104. Sex ratio at weaning as percentage of males relative to all males and females in rabbits.

Breed	Percentage
Grey Gaint	43.00
Soviet Chinchilla	61.90
New Zealand White	53.91
Total	52.00

Discussion

DISCUSSION

Body weight

The mean values of body weight at four, six, eight, ten and 12 weeks were highest in Soviet Chinchilla rabbits compared to Grey Giant and New Zealand White which had the lowest weights among the three breeds. Least square analysis of variance revealed significant breed effect for the body weights in all the weeks. Coefficient of variation (CV) in the corresponding values body weights were higher in New Zealand White than Grey Giant and Soviet Chinchilla which had the lowest coefficient of variation. Also the CV in rabbit body weights at younger ages were higher than at older ages, ie. CV decreased with advance of age of young rabbits. Lukefahr (1982) reported higher variation at (28 days) than at marketing at 56 days of age (0.251 at weaning versus 0.118 at marketing). Khalil et al. (1987) also reported similar results in Bauscat and Giza White rabbits.

The mean body weight at 4, 6, 8, 10 and 12 weeks in all the three breeds were lower than the estimates reported by most other investigators. But the estimate for New Zealand White were higher than that reported by Mishra (1990). The lower weights for all the three breeds than those reported by other investigators in the literature might possibly be attributed to one or more of the following reasons.

1. Rearing rabbits under different climatic, nutritional and managerial conditions.

2. Genetic differences among the breeds in growth potential.

Sex effects

In Grey Giant rabbits the females were found to be heavier than the males whereas in New Zealand White and Soviet Chinchilla rabbits the males were heavier than females. But the least square analysis of variance for the sex effect revealed that the effect of sex was non-significant in all the three breeds throughout the period of study.

In the respect of the effect of sex Khalil *et al.* (1987) also reported that in Bauscat rabbits a slight general trend for males to be heavier than females. On the other hand the reverse was observed in Giza White Rabbits. In this respect, the results of many workers working on different breeds of rabbits at various ages showed that female rabbits were heavier than males at different stages of life (El-Amin, 1974; Carregal, 1980) while the contrary was observed by some others (Mostageer et al., 1970). The trends in sex difference in body weight in this study were small and not statistically significant and consequently can be ignored.

The sire of the offspring affected the body weight at each stage in all the three breeds the proportion of variation due to the sire component was least in Soviet Chinchilla rabbits followed by Grey Giant and New Zealand White rabbits.

Valderrama de Diaz and Varela-Alvarez(1975) and Khalil et al. (1987) have concluded that sire effects on rabbit body weight at different ages were highly significant. On the contrary,the results of McReynolds(1974) indicated that differences in body weight due to sire effect were not significant. In the present study it is clear that there is considerable additive genetic variance in this stock for body weight.

and by El-Amin (1974) for the same breed together with Californian rabbits and by Khalil et al. (1987) in Bauscat and Giza White rabbits. However the expected influence of the dams on their offsprings weights is due not only to genes transmitted by the dams to their offspring but also by the large maternal environmental effects in the pre and post natal period. Mgheni et al. (1982) reported that although maternal effect decreased in relative importance after weaning, they were still present at sexual maturity and could complicate any conclusions drawn, particularly in selection experiment for pre-weaning growth in rabbits.

Heritability estimated within breed from the sire, dams within sire and sire + dam components revealed that estimate of heritability from sire component of variance for body weight in Soviet Chinchilla rabbits are in general, substantially lower than that of Grey Giant and New Zealand White rabbits. The differences in the estimates could be due to reduction in the sire genetic variability within Soviet Chinchilla rabbits through previous selection in this breed. In practice, these high estimates indicate the possibility for rabbit breeders to improve body weight through selection. Moreover estimates of heritability based on maternal component (h^2D) were very high in Grey Giant rabbits. Even in Soviet Chinchilla these estimates were higher than the estimates based on sire component (h^2S) or sire + dam [$h^2(S+D)$] component. In New Zealand White rabbits the (h^2D) estimates were low in the tenth and twelfth week. The reason for high h^2D estimates in Grey Giant rabbits indicates a lower variance of milking and maternal ability of these rabbits compared to the other two breeds. The sudden drop in h^2D may be due to the small sample size being affected by sudden mortality in the flock.

Reasons for the higher estimates compared to other investigators may be differences in

1. the method of analysis and estimation
2. the available number of observations
3. sampling error.

The estimates of heritabilities for body weight show some marked effects of age. In particular, the pre-weaning weights has a high or moderate value compared with the lower estimates obtained for post weaning weights. In this respect the average of reviewed estimates for heritability, for body weight at different ages were generally higher at younger ages (2 months and under) than at older ages (Mostageer et al., 1970; Niedzwiadek, 1978). However, this pattern needs more study to confirm it. Bogdan (1970) reported that heritability for rabbit body weight was highest for weight at birth and declined to the lowest values at six months of age. In the present study there was obviously a large effect of maternal environment and/or maternal genotype on animals performance during pre-weaning or post-weaning periods of growth. Similarly, weight characteristics in New Zealand White rabbits from weaning and upto 77 and 84 days of age give evidence of this maternal effect, probably due to correlation of growth with litter conditions (Randi and Scossiroli, 1980). At the same time litter size is an example of specific maternal environmental effect that persisted almost through the animal's production life. Accordingly variation within litter sizes of dam could have masked any additive genetic variance, ie. biasing non-additive genetic variance upward. However findings of the reviewed studies (Khalil et al., 1986) showed that selection for rabbit body weights may be a useful and practical method for improving early rabbit growth.

Estimates of heritability from the dam component revealed generally larger heritabilities than those of sire component except in New Zealand White rabbits where heritability based on sire component was higher in all weeks except the fourth week. These estimates indicate that all body weights were subjected to a large maternal influence. The dam component of variance included all of the maternal additive genetic variance, the covariance between direct and maternal additive effects and both the maternal dominance and maternal environmental variances. These were not included in the sire component of variance and fewer times their contributions would lead to differences between maternal and paternal estimates of heritability. A suggestion of possible maternal effects upon body weight of rabbits would agree with other reports such as those of Mgheni et al. (1982). The lower heritability based on maternal half sibs in New Zealand White rabbits is probably due to small sample size which was further reduced due to mortalities during the course of study.

Correlations

Phenotypic correlations

The phenotypic correlations between body weight at the four ages studied were practically identical in the three data sets and positive at all ages. In practice, these positive and generally high phenotypic correlations among body weights at different ages give considerable advantage in management and culling decisions. Most of the estimates in the literature showed that the phenotypic correlations between rabbit body weights were positive and generally high. In the present study, and also in the estimates reviewed from the literature except those of Nossier (1970), showed that the phenotype correlations between the body weights at different ages were positive and generally high, and tended to decrease in value as the differences between the two ages increased.

Genetic correlation

The genetic correlations between body weights for the three breeds showed that all of these relationships were positive, like the corresponding phenotypic estimates. Genetic correlations did not show any definite trend as the differences between two age increased. Khalil et al. (1987) reported that the correlations decreased as the difference between ages increased. Estimates in the present study show that the genetic correlations between body weights at all ages studied were higher than the phenotypic correlations. Similar findings have been reported by Khalil et al. (1987) while working on Bauscat and Giza White rabbits. From these estimates together with heritability estimates it could be safely concluded that rabbit body weights at early ages could be used for selection and improvement of body weight at later ages. However it showed that estimates of the genetic correlations among different body weights reported by most investigators cited in the review are lower than those obtained in the present study.

The estimates of the genetic correlations r_D and r_{S+D} among body weights of three breeds at the five ages studied were also positive and high. These estimates represent similarity among non litter males (maternal half sibs) caused by additive maternal, non additive maternal and non-genetic maternal effects.

Environmental correlations

The environmental correlations were generally very high in all the three breeds except in Grey Giant rabbits when estimated based on (Sire+dam) method which may be due to sampling error. The significance of high environmental correlation is that when environmental effect upon two weights could be so strong and positively correlated than a negative genetic correlation may get masked. Hence in such circumstances significant and positive phenotypic correlations between two weights do not necessarily indicate that selecting one of these will lead to improve in the other, because a phenotypic correlation is not always a reliable estimate of the genetic relationship existing between traits in such situations.

Litter traits

Gestation length

It was found that the effect of the breed on the gestation length was non-significant. Damodar and Jatkar (1985) reported that for New Zealand and Grey Giant rabbits gestation length averaged 31.04 and 31.70 days respectively. The smaller sample size may be the cause of higher values for the average gestation period in the present study.

Litter size at birth

The breed of the rabbit significantly affected the litter size at birth. The average values in all the three breeds were found to be lower than that of the average reported by most workers whose work has been reviewed. Soviet Chinchilla breeds had the lowest litter size at bith with a high coefficient of variation. Poorer maternal ability of the Soviet Chinchilla does at kindling ie.

failure to provide an adequate nest, was chiefly responsible for the lowered proportion of rabbits born alive to that breed compared to the other two breeds.

Litter size at weaning

The efffect of breed was again highly significant for the litter size at weaning. This trait showed a higher coefficient of variation than the corresponding values for the litter size at birth in all the three breeds. Similarly Lukefahr (1985) and Khalil et al. reported higher coefficients at weaning than at birth. The higher coefficients of variation is more likely due to higher maternal effects on offspring (lactation). The young remain solely on mother's milk till they open their eyes and thereafter also uptil weaning milk provided the main supply of nutrition. Thus the coefficient of variation of litter weight at weaning includes a contribution due to the variation in milk production of dams. In the present study the great variation in litter size at weaning may be attributed to the differences in litter losses that occurred during the suckling period.

Pre-weaning mortality

Maximum pre-weaning moratlity was seen in the Soviet Chinchilla breed though the effect of the breed was found to be non-significant. Poor maternal ability, in the present case poor nursing ability may be the cause of such high percentage of pre-weaning mortality in this breed.

Litter weight at weaning

The highest litter weight at weaning was seen in Grey Giant rabbits and the lowest in the New Zealand White rabbits though the number of rabbits alive in New Zealand White rabbits were more than in the Soviet Chinchilla rabbits. The cause of lower litter weights in the New Zealand White rabbits may be genetic as the effect of the breed was found to be highly significant.

Mean litter weight at weaning

The mean litter weight at weaning was highest in Soviet Chinchilla rabbits. The mean weights showed a higher coefficent of variation in Grey Giant and New Zealand White rabbits than in the Soviet Chinchilla. The cause of low mean litter weight in New Zealand White rabbits may be genetic.

Sex ratio at weaning

The sex ratio at weaning as percentage of males relative to the number of all males and females revealed that Grey Giant, Soviet Chinchilla and New Zealand White had 43.00, 61.90, and 53.91 percent males while the overall percentage was 52.00. The differnces may be due to the small sample used in the study.

The evidence from the differences between the estimates of all the litter traits studied and those reported in the reviewed literature for the same and/or different breeds of rabbits could possibly be attributed to one or more of the following reasons:

1. the herds were reared under differnt climatic and managerial conditions,

2. different herds could possibly be geneticlly different from each other and/or

3. differences in the models of ananlysis used by different workers.

Heritability estimates

The estimates of heritability for the litter size at birth and at weaning were negative and hence adjusted to zero. The small sample size may be the cause in this study even though with large samples also the estimates for the reproductive traits are very low as seen in the estimates of most of the workers whose work had been reviewed.

Summary

SUMMARY

1. Three purebred rabbits viz., Grey Giant, Soviet Chinchilla and New Zealand White were used for studying the body weights and traits of reproductive efficiency (litter traits).

2. The mean values of body weight at four, six, eight, ten, and 12 weeks were highest in Soviet Chinchilla rabbits compared to Grey Giant and New Zealand White rabbits. New Zealand White breed of rabbits had the lowest weights among the three breeds. Breed effect was highly significant ($P < 0.01$) for the body weights in all the weeks.

3. The effect of sex was non-significant in all the three breeds throughout the period of study.

4. The sire of the offspring affected the body weights at each stage in all the three breeds. It revealed that there is considerable additive genetic variance in this stock for body weight.

5. There was also a dam effect on body weight. However the expected influence of the dams on their offsprings

weights is due not only to genes transmitted by the dams to their offsprings but also by the large maternal environmental effects in the pre-natal and post-natal periods.

6. Heritability estimated within breed from the sire, dams within sire, and sire + dam components revealed that estimates of heritability from sire components of variance for body weight in Soviet Chinchilla rabbits were in general, substantially lowere than that of Grey Giant and New Zealand White rabbits.In general the estimates of heritability were high in all the three breeds.

7. High h^2D estimates in Grey Giant rabbits indicated a lower variance of milking and maternal ability of these rabbits compared to the other two breeds.

8. The estimates of heritabilities for body weight showed marked effects of age. In particular, the pre-weaning weights had a high or moderate value compared to the lower estimates obtained for post-weaning weights.

9. Estimates of heritabilities from the dam component revealed generally larger values than those obtained from sire component except in New Zealand White rabbits. These estimates indicated that all body weights were subjected to a large maternal influence.

10. The phenotypic correlations between the body weights at different ages were positive and generally high, and tended to decrease in value as the differences between the two ages increased.

11. The genetic correlations between body weights for the three breeds showed that all of these relationships were positive, like the corresponding phenotypic estimates.

12. The environmental correlations were generally very high in all the three breeds except in Grey Giant rabbits when estimated based on (Sire + dam) method which may be due to sampling error.

13. It was found that the effect of the breed on the gestiation length was non-significant.

14. The breed of the rabbit significantly affected the litter size at birth ($P < 0.01$). Soviet Chinchilla breeds had the lowest litter size at birth.

15. The effect of breed was again highly significant for the litter size at weaning ($P < 0.01$). Soviet Chinchilla rabbits had the lowest litter size at weaning.

16. Maximum pre-weaning mortality was seen in the Soviet Chinchilla breed though the effect of the breed was found to be non-significant.

17. The highest litter weight at weaning was seen in Grey Giant rabbits and the lowest in the New Zealand White rabbits though the number of rabbits alive in New Zealand White breed were more than in the Soviet Chinchilla rabbits.

18. The mean litter weight at weaning was highest in Soviet Chinchilla rabbits.

19. The overall sex ratio was 52 per cent.

20. The estimates of heritability for the litter size at birth and at weaning were negative and hence adjusted to zero.

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GENETIC ANALYSIS OF BODY WEIGHT AND LITTER TRAITS OF PURE BRED RABBITS

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ABSTRACT OF A THESIS

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ABSTRACT

The experimental work was carried out at the Rabbit Research Station attached to the Centre for Advavnced Studies in Animal Genetics and Breeding, Mannuthy.

Rabbits belonging to three pure breeds viz. Grey Giant, Soviet Chinchilla and New Zealand White formed the materials for the study. From each breed, seven males were taken and each male was mated to two females each and in all 14 females and seven males were considered in each breed. Seven parameters of reproductive efficiency of the dam were taken and body weights of rabbits born were recorded at four, six, eight, ten and twelve weeks of age.

The mean values of body weight at four, six, eight, ten and 12 weeks were highest in Soviet Chinchilla rabbits compared to Grey Giant and New Zealand White, which had the lowest weights among the three breeds. Breed effect was significant for the body weights in all the weeks. The effect of sex on the body weight of rabbit was non-significant in all the three breeds. The sire of the offspring affected the body weight at each stage in all the three breeds. There was also a dam effect on body weight.

In general the estimates of heriatbility were high in all the three breeds. The estimates of heritabilities for body weight show some marked effects of age. In particular, the pre-weaning weights had a high or moderate value compared with the lower estimates obtained for post-weaning weights. Estimates of heritability from the dam component revealed generally larger heritabilities than those of sire component except in New Zealand White rabbits.

The phenotypic correlations between the body weights at different ages were positive and generally high, and tended to decrease in value as the differences between the two ages increased.

The genetic correlations between body weights for the three breeds showed that all of these relationships were positive, like the corresponding phenotypic estimates. The environmental correlations were generally very high in all the three breeds except in Grey Giant rabbits when estimated based on (Sire+dam) method which may be due to sampling error.

It was found that the effect of the breed on the gestation length was non-significant.

The breed of the rabbit significantly affected the litter size at birth. Soviet Chinchilla breeds had the lowest litter size at birth.

The efffect of breed was again highly significant for the litter size at weaning. Soviet Chinchilla rabbits had the lowest litter size at weaning also.

Maximum pre-weaning moratlity was seen in the Soviet Chinchilla breed though the effect of the breed was found to be non-significant. The highest litter weight at weaning was seen in Grey Giant rabbits and the lowest in the New Zealand White rabbits though the number of rabbits alive in New Zealand White breed were more than that in the Soviet Chinchilla rabbits.

The mean litter weight at weaning was highest in Soviet Chinchilla rabbits.

The overall sex ratio was 52 percent.

The estimates of heritability for the litter size at birth and at weaning were negative and hence adjusted to zero.