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Genetic Analysis of Productive Performance in New Zealand White Rabbits

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ABSTRACT: In this study, the genetic parmeters of the New Zealand white (NZW) rabbit were evaluated and clarified, including heritability and the common-litter effect, as well as genetic, common-litter, phenotypic correlations, and breeding values. For this purpose, 656 rabbits were kept at the Sakha research farm, for two years. A multi-trait animal model was used to analyze the body weights and relative growth rates data. Heritability estimations ($\mathbf{h^2_a}$) for various body weights ranged from 0.15 to 0.30 and were low to moderate. The minimum estimate of $\mathbf{h^2_a}$ for relative growth rates at 4 to 6 weeks was 0.13, and the maximum estimate of $\mathbf{h^2_a}$ for relative growth rates at 10 to 12 weeks was 0.24. Moderate to high and positive genetic correlation (**rg**) between body weights, 0.36 to 0.73. $\mathbf{r_g}$ estimates between relative growth rates ranged from moderate (0.45) to high (0.84) and positive. Common-litter correlation ($\mathbf{r_c}$) between body weights ranged from moderate (0.32) to high (0.71) and positive. $\mathbf{r_c}$ estimates between relative growth rates ranged from moderate (0.43) to high (0.71) and positive. The phenotypic correlation ($\mathbf{r_p}$) between body weights was moderate (0.41) to high (0.80) and positive. **rp** estimates between the relative growth rates were high and positive. The estimated ranges of breeding values were 175.07, 263.89, 299.48, 267.78, and 279.86 for 4, 6, 8, 10, and 12 weeks, respectively. While were 24.56, 27.04, 31.80, 35.14, and 29.28 during the period of 4-6, 6-8, 8-10, 10-12, and 4-12 weeks, respectively.

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KEYWORDS: Heritability, genetic, common-litter and phenotypic correlations, breeding values.

INTRODUCTION

The New Zealand white rabbit, which has been designated as a commercial meat rabbit breed, is one of the breeds of rabbit that is regularly imported and introduced into many developing countries (Lukefahr and Cheeke, 1991). Due to the breed's exceptional maternal and prolific qualities, it is especially well known as a desirable dam breed and is accessible in practically every country in the world. Therefore, investigating the genetic factors that affect growth in this breed of rabbit would serve as a template for similar research in developing countries.

In rabbits, weaning weight has a complicated character that reflects the effect of many different kinds of biological processes, including growth, viability, maternal instinct, and fertility (Lukefahr *et al.*, 1981). Average body weights and daily increases after weaning are important elements in determining the profit function. It's important to comprehend development and body weight after weaning. Although the environment and genotype of the rabbit before weaning have an impact on growth performance after weaning (El-Deghadi, 2005).

Heritability, a function of variance components, provides details regarding the genetic underpinnings of a trait for the purposes of genetic evaluation and selection techniques (El-Raffa, 2005). Environmental factors attributed to the dam and/or litter and/or the short interval between weaning and marketing age are frequently reported to outweigh phenotypic variance for growth traits in rabbits (McNitt and Lukefahr 1996). This phenomenon could potentially be the cause of the reported low heritability estimates and sluggish rates of genetic responses to selection for growth traits (Lukefahr *et al.*, 1996). The genetic potential for improvement in rabbits depends primarily on the heritability of the trait being assessed and how it relates to other qualities that are significant economically. At the zootechnical level, the estimation of heritability (h^2), repeatability (r), and correlations (rxy) among the qualities that are important economically serves to establish the proper selection procedure and to serve as a determining factor in the selection response. They must therefore estimate with the greatest degree of accuracy (Ossa *et al.*, 2017). Quantitative techniques are used in animal genetic improvement programmes to make it easier to choose the best animals based on their breeding values in order to improve their productive and reproductive efficiency genetically (El-Deghadi, 2019). When selecting the best rabbits among those with high estimates of breeding values for growth qualities, variations in breeding values can help make the right culling decision (El-Deghadi, 2022). In this study, the genetic parmeters of the New Zealand white (NZW) rabbit were evaluated and clarified, including heritability and the common-litter effect, as well as genetic, common-litter, phenotypic correlations, and breeding values.

MATERIALS AND METHODS

Source of data:

For two years, this study was conducted at the Sakha research farm, which is a part of the Agricultural Research Centre under Egypt's Animal Production Research Institute (APRI). The traits noted included individual body weight (BW) at 4, 6, 8, 10 and 12 weeks of age, using a total of 656 New Zealand white (NZW) rabbits. The relative growth rate was defined by Broody (1945) as equal to {(W2-W1)/ ½ (W1+W2)} x 100, where W1 represented the body weight at the start of the period and W2 represented the body weight at the end of the period. At varied age intervals, relative growth rates were measured at 4-6, 6-8, 8-10, 10-12 and 4-12weeks.

Management:

Breeding sires and dams were kept apart in hierarchical rabbit batteries that were set up in two rows along the farm and had an appropriate service entrance. The animals were kept under standard management procedures for housing, feeding, health care, and other aspects of care. According to a breeding plan, each sire received three dams at random, with the requirement that any inbreeding should be avoided. At the age of 4 weeks, weaned young rabbits were moved to standard progeny wire cages with feeding hoppers and drinking nipples. Additionally, they are ear-tagged, sexed, and moved into cages with 3–4 rabbits each. Following that, weights are taken every two weeks. The rabbits were fed commercial pelleted diets containing 2600 kcal/kg digestible energy, 17.5% crude protein, and 14–16% crude fibres. The manure was removed from the cages each day, and the house's ventilation and temperature were kept as favorable as feasible.

Data analysis:

Genetic parameters

The post-weaning body weight and relative growth rates data were analysed using a multi-trait animal model utilising the best model by REML methods using the WOMBAT programme (Meyer, 2007). As starting values, variances computed using the REML method of the VARCOMP function (SAS, 2003) were used to calculate variance components. The analyses were carried out using the general model:

$$\mathbf{y = Xb + Za + Wpe + e,}$$

where: y is the vector of phenotypic observations; b is the vector of fixed effects including year-season combination (8 levels), parity (4 levels), and progeny sex (2 levels); a is the vector of random additive genetic effects of the progeny; pe is the vector of random common litter effects of the dam; e is the vector of residual effects; and x, z, and w incidence matrices that, respectively, link phenotypic observations to fixed and random additive genetic effects. Heritability coefficients were calculated as additive direct $h^2a = \sigma a^2 / \sigma p^2$, where σa^2 and σp^2 are the variances component due to the additive genetic and phenotypic effects; respectively,

RESULTS AND DISCUSSIONS

Means

The means, standard deviations (SD), and coefficients of variation (CV%) for the various attributes under investigation are shown

Table 1. shows the mean body weights, standard errors, and coefficients of variation (CV%) in NZW rabbits.

Traits	Mean	SD	CV (%)
Body weight(g)			
4 weeks	392.29	87.41	22.30
6 weeks	649.08	105.61	16.27
8 weeks	946.49	126.99	13.42
10 weeks	1244.5	127.45	10.24
12 weeks	1539.55	104.71	9.14
Relative growth rates			
RG4-6	51.72	8.23	15.91
RG6-8	26.44	3.45	13.04
RG8-10	26.56	3.52	13.25
RG10-12	21.24	2.62	12.33
RG4-12	118.93	9.84	8.27

in Table 1. The rapid growth of young rabbits may be the cause of the rapid increase in body weight with age, despite a decline in the relative growth rates at various ages. CV% estimates for body weights and relative growth rates decreased with age and this trend may be because bunnies get older, Numerous elements, including as the genetic make-up of the does, non genetic elements (parity, season and year), and flock management, could alter these traits. They grow less dependent on non-genetic maternal effects.This suggests that it might be simpler to increase these traits through phenotypic selection. The mean body weights and relative growth rates at all ages fell within the indicated range (El-Badawy, 2015; El-Deghadi and Ibrahim, 2018; Abdel-Kafy *et al.*, 2021; Farouk *et al.*, 2022).

Heritability (h^2_a):

For different body weights, heritability estimates were low to moderate and varied from 0.15 to 0.30, with the body weight estimate at 4 weeks was the lowest (0.15), and the body weight estimate at 12 weeks was the highest (0.30). Also the fact that the lowest estimate of $\mathbf{h^2_a}$ for relative growth rates at 4 to 6 weeks was 0.13 and the maximum estimate of $\mathbf{h^2_a}$ for relative growth rates at 10 to 12 weeks was 0.24 (Table 2), it's possible that with time, the effects of the mother and common environmental effects rapidly decline. Low heritability estimates for some traits may be caused by the substantial phenotypic variance resulting from significant environmental fluctuations. This suggests that rather than relying primarily on genetic selection, a large portion of the increase in these traits could be obtained by enhancing the production environment. Moderate heritability estimates for other traits may suggest that improving traits through selection is possible. Estimates of low to moderate heritability for body weights and relative growth rates in this presented study were within the range shown by El-Deghadi and Ibrahim, (2018) observed that estimates of the heritability for body weights were low and moderate, ranging from 0.13 to 0.20, at ages 4, 6, 8, 10, and 12. Heritability estimates for growth rate for the studied periods ranged from 0.06 to 0.13, which is low and inconsistent. The heritability estimates Garcia and Argente, (2020) presented included a wide range (weaning weight: 0.03 to 0.48; slaughter weight: 0.06 to 0.67). In contrast, the estimations of the growth rate heritability show a narrow range (0.12 to 0.34) and a moderate average value (0.22). Rym Ezzeroug *et al.*, (2020) identified low heritability estimates for growth traits, with 0.033 for weaning weight and 0.059 for fattening period weight. Abdel-Kafy *et al.*, (2021) indicated that estimates of the heritabilities of body weights and relative growth rates tend to be moderate and varied from 0.10 to 0.24. El-Deghadi *et al.*, (2022) established heritability estimates for body weights at different ages ranging from 0.03 to 0.10. Farouk *et al.* (2022) found estimates of $\mathbf{h^2_a}$ were 0.05, 0.20, 0.23, 0.24, 0.31, and 0.34 for LSB, LWB, BW4, BW6, BW8, and BW10, respectively, and he was suggested that the moderate estimates of $\mathbf{h^2_a}$ for these traits indicated that improvement of body weight at one month, body weight at two months, and weaning weight could be possible by selection in a short period and that these traits could be used as selection criteria in NZW rabbits.

Table 2. presents estimated heritabilities (h^2_a), common-litter effect (c^2), and errors (e^2) for traits relating to body weights and relative growth rates, as well as the standard errors (SE) in NZW rabbits.

Traits	h^2_a ± SE	C^2 ± SE	e^2 ± SE
Body weight (g)			
4 weeks	0.15 ± 0.02	0.55 ± 0.01	0.30 ± 0.01
6 weeks	0.19 ± 0.02	0.50 ± 0.01	0.30 ± 0.01
8 weeks	0.22 ± 0.01	0.45 ± 0.01	0.33 ± 0.01
10 weeks	0.28 ± 0.01	0.38 ± 0.01	0.35 ± 0.01
12 weeks	0.30± 0.01	0.33 ± 0.01	0.37 ± 0.01
Relative growth rates			
RG4-6	0.13± 0.06	0.52 ± 0.03	0.35 ± 0.04
RG6-8	0.16± 0.09	0.44 ± 0.05	0.40 ± 0.06
RG8-10	0.20± 0.09	0.40 ± 0.05	0.40 ± 0.06
RG10-12	0.24± 0.03	0.27 ± 0.06	0.49 ± 0.01
RG4-12	0.17± 0.05	0.48 ± 0.03	0.35 ± 0.03

Common-litter effect (c^2)

The range of $\mathbf{c^2}$ estimates for various body weights was moderate to high, ranging from 0.33 to 0.55, with the highest estimate for body weight at 4 weeks (0.55) and the lowest estimate for body weight at 12 weeks (0.33). Also the fact that the maximum estimate for relative growth rates at 4 to 6 weeks was 0.52 and the lowest estimate for relative growth rates at 10 to 12 weeks was 0.27 (Table 2). The greater estimate of $\mathbf{c^2}$ was caused by the fact that litters were raised in the same cage and breastfed by the same dam, Additionally, the maternal or common-litter effect rapidly declines as individuals get older. According to Youssef *et al.*, (2009), the common-litter effect might be explained by shared maternal environmental variation, non-additive genetic variation, and any possible sire x dam interaction because this component predominantly represented covariance between full-sib families. Furthermore, dietary and/or climatic factors may also contribute to the common maternal environmental variation among families. Based on these findings, breeding programs' genetic evaluations should take the common litter impact into account. Estimates of $\mathbf{c^2}$ for mean body weights and relative growth rates at all are in agreement with El-Deghadi and Ibrahim, (2018) noted that the estimate of $\mathbf{c^2}$ for body weight at weaning was larger than at succeeding ages, indicating that $\mathbf{c^2}$ at weaning are exceedingly variable. At ages 4, 6, 8, 10, and 12 weeks, the percentages were 74%, 46%, 34%, 41, and 35%, respectively. According to Rym Ezzeroug *et al.*, (2020), the largest proportion of phenotypic variance was explained by $\mathbf{c^2}$, which was 0.64 for weight at weaning and 0.38 for weight during the fattening phase. According to El-Deghadi *et al.*, (2022), weaning body weight had a bigger effect (0.47) on a common litter than an older one did. As the bunnies aged, it declined progressively between 0.31 and 0.36, indicating that their genetic potential was starting to emerge. Additionally, as maternal influences decline, its variability increase.

Genetic Correlations

Estimates of genetic correlation ($\mathbf{r_g}$) among body weights and relative growth rates are presented in Table 3. Moderate to high and positive genetic correlation between body weights, 0.36 to 0.73, shows the additive gene's synergistic regulation. The high genetic correlation (0.73) between body weight at weaning and body weight at six weeks suggests that selecting a body weight at weaning also increases body weight at six weeks. Additionally, it is suggested that selecting a body weight at 10 weeks will result in a rise in body weight at 12 weeks. $\mathbf{r_g}$ estimates between relative growth rates ranged from moderate (0.45) to high (0.84) and positive. Additionally, it is predicted that choosing an RG6-8 will cause RG8-10 to increase and that choosing an RG8-10 will cause RG10-12 to improve. Similar findings were reported by El-Deghadi and Ibrahim, (2018) demonstrated that $\mathbf{r_g}$ estimations ranged from 0.37 to 0.91 for all possible genetic correlations between body weights at various ages. Garcia and Argente (2020) discovered that genetic correlations between growth parameters and weight at slaughter ranged from 0.61 to 0.74 and were both positive and highly associated. $\mathbf{r_g}$ is stronger (0.56 vs. 0.31) between growth rate and weight at slaughter than between growth rate and weight at weaning. Rym Ezzeroug *et al.* (2020) found that genetic correlations for weight at weaning were positive and strongly correlated with weight at slaughter (0.61). According to El-Deghadi et al. (2022), there were moderate to high and positive genetic correlations between body weights at various ages, including 0.27 between body weights at 4 weeks and 8 weeks, 0.84 between body weights at 8 weeks and 12 weeks, and 0.44 between body weights at 4 weeks and 12 weeks. According to Farouk et al. (2022), the calculated $\mathbf{r_g}$ of LSB with LWB and BW4 were both positive and modest (0.04 and 0.04, respectively). LSB and BW6, BW8, and BW10 showed positive and significant genetic correlations, with values of 0.12, 0.15, and 0.35, respectively. He claimed that because weaning weight (as a selection criterion) and other body weight traits exhibit a positive genetic relationship, the same relative improvement in all traits may be projected. Furthermore, it would be expected that selection for body weight at market age would greatly accelerate the growth rate.

Table 3. shows the estimated genetic correlation ± SE between body weights (BW) at ages 4, 6, 8, 10 and 12 weeks and relative growth rates (RG) between ages 4-6, 6-8, 8-10, 10-12, and 4-12 weeks in NZW rabbits.

Traits	**BW6**	**BW8**	**BW10**	**BW12**
Body weight (g)				
BW4	0.73±0.04	0.69±0.02	0.51±0.03	0.36±0.04
BW6		0.60±0.02	0.51±0.04	0.38±0.03
BW8			0.66±0.04	0.58±0.03
BW10				0.73±0.03
Relative growth rates	**RG6-8**	**RG8-10**	**RG10-12**	**RG4-12**
RG4-6	0.62±0.19	0.58±0.16	0.45±0.26	0.75±0.11
RG6-8		0.80±0.17	0.74±0.37	0.73±0.10
RG8-10			0.84±0.16	0.74±0.09
RG10-12				0.70±0.12

Common-Litter Correlations

Estimates of the common litter correlation (**r_c**) between body weights were moderate to high and positive, ranging from 0.32 to 0.71. (Table 4). The high **rc** (0.71) between body weight at weaning and body weight at six weeks, might be a result of the mother's ability, which declines as the rabbit ages. **r_c** estimates between relative growth rates ranged from moderate (0.43) to high (0.71) and positive. These estimations are within the authorized range when estimated with El-Deghadi and Ibrahim, (2018) reported that estimates of **r_c** were generally high (ranging from 0.53 to 0.94) and positive for all potential genetic correlations between body weight at different ages. El-Deghadi *et al.*, (2022) showed that the **r_c** estimates between the body weights at 4 weeks and 8 weeks, 8 weeks and 12 weeks, and 4 weeks and 12 weeks were moderate to high and positive, with values of 0.59, 0.81, and 0.40, respectively.

Table 4. shows estimates of the common-litter correlation ± SE between body weights (BW) at 4, 6, 8, 10 and 12 weeks of age and relative growth rate (RG) between the ages of 4-6, 6-8, 8-10, 10-12, and 4-12 weeks in NZW rabbits.

Traits	**BW6**	**BW8**	**BW10**	**BW12**
Body weight (g)				
BW4	0.71±0.01	0.67±0.01	0.45±0.02	0.32±0.02
BW6		0.48±0.01	0.41±0.02	0.38±0.02
BW8			0.53±0.02	0.52±0.02
BW10				0.50±0.01
Relative growth rates	**RG6-8**	**RG8-10**	**RG10-12**	**RG4-12**
RG4-6	0.63±0.04	0.61±0.04	0.56±0.05	0.71±0.02
RG6-8		0.53±0.07	0.50±0.08	0.64±0.03
RG8-10			0.43±0.10	0.64±0.03
RG10-12				0.59±0.04

Phenotypic correlations

Between 0.41 and 0.80, there was a moderate to strong, positive phenotypic correlation (**r_p**) between body weights. (Table 5). likewise, the **r_p** estimates between the relative growth rates were high and positive, ranging from 0.71 to as high as 0.82. High and positive estimates of the phenotypic correlation between growth traits at various ages give rabbit breeders a significant advantage in their management and culling decisions. These estimations agree with the finding reported by El-Deghadi and Ibrahim, (2018) found that estimates of the positive, moderately to highly significant phenotypic correlations ranged from 0.48 to 0.82. According to Rym Ezzeroug *et al.*, (2020), **r_p** estimations for weight during weaning had a positive and strong correlation (0.63) with the weight at slaughter. El-Deghadi *et al.*, (2022) proved that the estimated **r_p** between various body weights was all positive and moderate to high, with values between body weights at 4 weeks and 8 weeks, 8 weeks and 12 weeks, and 4 weeks and 12 weeks, respectively, of 0.62, 0.67, and 0.31.

Table 5. Estimates of Phenotypic correlation ± SE for body weights (BW) at 4, 6, 8, 10 and 12 weeks of age and relative growth rate (RG) during the period of 4-6, 6-8, 8-10 , 10-12 and 4-12 weeks of age in NZW rabbits.

Traits	**BW6**	**BW8**	**BW10**	**BW12**
Body weight (g)				
BW4	0.80±0.01	0.78±0.01	0.51±0.01	0.43±0.01
BW6		0.65±0.01	0.49±0.01	0.41±0.01
BW8			0.60±0.01	0.58±0.01
BW10				0.68±0.01
Relative growth rates	**RG6-8**	**RG8-10**	**RG10-12**	**RG4-12**
RG4-6	0.77±0.01	0.75±0.01	0.82±0.01	0.71±0.03
RG6-8		0.77±0.02	0.77±0.02	0.78±0.01
RG8-10			0.76±0.02	0.79±0.01
RG10-12				0.76±0.01

Breeding value

The estimated minimum and maximum breeding values for each individual's body weight and relative growth rate are shown in Table 6, along with their respective ranges For all animals, the estimated ranges of breeding values were 175.07, 263.89, 299.48, 267.78, and 279.86 for 4, 6, 8, 10, and 12 weeks, respectively. While were 24.56, 27.04, 31.80, 35.14, and 29.28 during the period of 4-6, 6-8, 8-10, 10-12, and 4-12 weeks, respectively. Since the breeding value is passed down to the progeny and is thus related to the typical genotypes of offspring in the following generations, it is crucial to estimate it. Therefore, evaluating the breeding value for rabbit breeders is important since it helps them to make the best decision. For selection, the best rabbits are based on high breeding value, which improves growth traits. These estimates, when obtained using, are within the acceptable range according to Moustafa, (2014), for weaning weight, slaughter weight, and daily weight gain, respectively, the ranges for transmitting ability for all animals investigated were 512, 878, and 22.4. El-Deighadi and Ibrahim, (2017) noted that the evaluations of all progeny body weight breeding value ranged from -0.244 to 0.389, -0.245 to 0.362, -0.259 to 0.346, - 0.195 to 0.235, and -0.233 to 0.265 g, respectively. The breeding value ranges at 4, 6, 8, 10, and 12 weeks were smaller as the animals aged (0.633, 0.607, 0.605, 0.403, and 0.498 g, respectively). El-Deghadi *et al.*, (2022) research, in contrast, showed that breeding values for all attributes were lower than those noted in the review. The estimates of breeding value for body weight at 4, 8, and 12 weeks ranged from -105.39 to 115.33, 33.42 to 35.66, and 23.44 to 20.55. They also ranged from -1.56 to 2.12, 0.94 to 0.98, and 0.14 to 0.72 for daily gains at 4 to 8 weeks, 8 to 12 weeks, and 4 to 12 weeks.

Table 6. shows the animal's predicted breeding values (PBV), minimum and maximum ranges, and standard errors (SE) and accuracy (r_A) of body weight and relative growth rate for NZW rabbits.

Trait	**Minimum**			**Maximum**			**range**
	PBV	**SE**	**r_A**	**PBV**	**SE**	**r_A**	
Body weight (g)							
4 weeks	-61.89	0.43	0.52	113.18	0.44	050	175.07
6 weeks	-152.60	0.44	0.61	111.29	0.46	0.56	263.89
8 weeks	-105.44	0.42	0.52	194.04	0.40	0.73	299.48
10weeks	-127.07	0.49	0.65	140.71	0.46	0.70	267.78
12 weeks	-125.42	0.51	0.65	154.44	0.48	0.71	279.86
Relative growth rates							
RG4-6	-12.52	0.61	0.52	12.04	0.62	0.48	24.56
RG6-8	-13.78	0.63	0.53	13.26	0.61	0.58	27.04
RG8-10	-15.82	0.51	0.52	15.98	0.50	0.54	31.80
RG10-12	-15.40	0.65	0.67	19.74	0.64	0.69	35.14
RG4-12	-13.72	0.92	0.57	15.56	0.92	0.57	29.28

CONCLUSION

Low heritability estimates for some traits may be caused by the substantial phenotypic variance resulting from significant environmental fluctuations. This suggests that rather than relying primarily on genetic selection, a large portion of the increase in these traits could be obtained by enhancing the production environment.

In making management and culling decisions, rabbit breeders benefit greatly from high and positive estimations of the phenotypic correlation between growth traits at different ages.

Since the breeding value is passed down to the progeny and is thus related to the typical genotypes of offspring in the following generations, it is crucial to estimate it. Therefore, evaluating the breeding value for rabbit breeders is important since it helps them to make the best decision. For selection, the best rabbits are based on high breeding value, which improves growth traits.

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