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Genetic analysis of pre-weaning litter traits in V-line rabbits using a single-trait animal model

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Abstract

The objective of this study was to obtain heritability (h^2_a), permanent environment (pe^2) effect, repeatability (R) estimates and predicted breeding values (PBV$_S$) for litter traits which include; litter size at birth (LSB), number of live bunnies at birth (NBA), litter size at weaning (LSW), litter weight at birth (LWB), litter weight at weaning (LWW) and litter body gain from birth to weaning (PLG) in V-Line rabbits maintained by the faculty of agriculture, Al-Azhar University in Nasr City, Cairo, Egypt using repeatability single-trait animal model analysis. h^2_a estimates for litter size traits (LSB, NBA, and LSW) were low, ranging from 0.05 to 0.07 and from 0.09 to 0.14 for litter weight traits (LWB, LWW, and PLG). The proportions of pe^2 effect were also small, ranging from 0.0006 to 0.001. Due to the smallness of *pe2*, the estimated pe^2 was about the same magnitude as for h^2_a. Estimates of genetic correlation (r_g) were positive across all correlated traits. It is closely correlated between LSB and NBA and between LWW and PLG (0.99). The rest of r_g values, among other traits, were positive, moderate to high, ranging from 0.50 to 0.79. As for rank correlation (r_s), it was positive, moderate, and highly significant and ranged from 0.45 to 0.99. Ranges of PBV$_S$ for litter size traits revealed that these ranges decreased with the advance of age of the litter from birth up to weaning, and the opposite has been observed for litter weight traits. Based on the results of the current study, this herd needs an environment (non-genetic factors) that is as similar as possible with continuous genetic evaluation and selection based on high breeding animal values.

Keywords: rabbits, genetic, litter traits, heritability, repeatability, breeding value.

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1. Introduction

The accurate understanding of both environmental and genetic evaluation is required for the establishment and assessment of sound breeding programs (El-Raffa, 2005). Knowledge of the genetic parameters of essential economic traits is required for genetic improvement (Akanno and Ibe, 2005). The possibility of genetic improvement largely depends on the estimates of variance-covariance components and the genetic parameters of those traits being accurate (Sakthivel *et al*., 2017). Heritability, which is a function of variance components, provides information about a trait's genetic nature and is required for genetic evaluation and selection procedures (El-Amin *et al*., 2011). Traits indicating prolificacy, such as litter size at birth and/or weaning, and litter weight, are critical for profitable rabbit meat production (Apori *et al*. 2014; Moustafa *et al*., 2014; Youssef *et al*., 2008). This is especially true given how simple and inexpensive it is to measure these characteristics (Santacreu *et al*., 2005). In this respect, litter traits have low heritability and repeatability but are very variable, with significant genetic diversity between breeds (Iraqi and Youssef, 2006). Depending on this variation, litter size at birth or weaning and litter weight has recently been considered as the basis for the selection criteria for various maternal lines (Khalil and Al-Saef, 2008). Besides genetic parameters, the breeding value of an animal for a given trait is the average effect of its genes that determines the mean genetic value of its offspring for the considered trait (Bourdon, 2000). Also, the accuracy of the individual's breeding value estimation becomes more precise with the extension of the information not only of their performance test but also of both the full and half-sibs as well as of the ancestors (Wezyk and Szwaczkowski, 1993). Animal model method is increasingly becoming one of the preferred methods of estimation that account for selection and descending bias in the data. So, in recent years, genetic evaluation of rabbits has most often been performed using an animal model (Abou-Khadiga *et al*., 2010; Khalil and Al-Homidan, 2014; Youssef *et al*., 2008). This study aims to identify non-genetic factors influencing litter traits, including the age of the doe (parity), year and season of kindling in V-Line rabbits. It also aims to estimate genetic parameters (e.g. variance components, heritability, repeatability and determination of genetic and rank correlations) for the studied traits. Besides, predict the breeding values of these traits.

2. Materials and methods

2.1 Animals and location

In the present investigation, the data on V-Line rabbits collected on 441 litters produced from 102 does fathered by 40 sires and mothered by 65 dams for three consecutive years starting in September 2018 till October 2021, maintained at

Rabbitry of Faculty of Agriculture, Al-Azhar University in Nasr City, Cairo, Egypt.

2.2 Management

Breeding does and bucks were separately kept in wire cages of standard dimensions in pyramidal rabbit batteries placed in two rows along the rabbitry with service passageways. Each buck was allocated at random for every 3-5 does at sexual maturity (6 months of age), with the constraint of avoiding full-sib, half-sib, and parent-offspring mating. Ten days after mating does were palpated to detect pregnancy and those who failed to conceive were returned to their assigned bucks to be re-mated. At the 27^{th} day of pregnancy, nest boxes were supplied with some rice straw. Litters were checked after 12 hours of kindling and the total litter size born, a live litter size born and litter weight at birth were recorded. The nest boxes were examined every morning to remove dead bunnies from the nest. At 4 weeks of age, young rabbits are weaned, ear-tagged, sexed and moved to standard progeny wire cages equipped with feeding hoppers and drinking nipples in groups of 3-4 rabbits per cage.

2.3 Studied traits

The data under study were, litter traits (LSB = litter size at birth, NBA = number of live bunnies at birth, LSW = litter size at weaning, LWB= litter weight at birth, LWW = litter weight at weaning and PLG= Preweaning litter gain from birth to weaning).

2.4 Statistical analysis

2.4.1 Fixed effects

To determine the fixed effects contained in the statistical model data were analyzed using the general linear model (GLM) procedure (SAS, 2003) according to the following statistical mixed model:

$$Y_{ijkl} = \mu + P_i + Y_j + SE_k + e_{ijkl}$$

Where: Yijkl= LSB, NBA, LSW, LWB, LWW and PLG. μ= overall mean for each trait, Pi= the fixed effect of ith parity i, (i=1, 2…, 5), Yj= the fixed effect of jth year of kindling j, (j=2019…2021), SEk=the fixed effect of kth season of kindling k, (k=1, 2…, 4), were 1= Autumn, 2= Winter, 3= Spring and 4= Summer, eijkl = random residual assumed to be independent and normally distributed with mean zero and variance σ^2e.

2.4.2 Genetic parameters

Data were analyzed using a repeatability single-trait animal model of litter traits using MTDFREML program of Boldman *et al*. (1995). Variances obtained by REML method of VARCOMP procedure (SAS, 2003) were used as starting values for the estimation of variance components. Analyses were done according to the general model:

y = Xb + Za +Wpe + e

Where: y = a vector of phenotypic observations; b = a vector of fixed effects; a = a vector of random additive genetic effects of the doe; pe = a vector of random permanent environmental effects of the doe; e = a vector of residual effects; and X, Z, and W = incidence matrices relating the phenotypic observations to fixed, random additive genetic, and permanent environmental effects, respectively. It was assumed that random effects are independent and normally distributed:

$a \sim N(0, A\,\sigma^2_a)$, $pe \sim N(0, I\,\sigma^2_{pe})$ and $e \sim N(0, I\,\sigma^2_e)$

Where: A = the numerator relationship matrix, I = the identity matrix, σ^2_α = the direct additive genetic variance, σ^2_{pe} = the random permanent environmental variance, and σ^2_e = the residual variance. Year of kindling (2018 to 2020), parity (5 levels), and season of kindling (4 levels) were included in the statistical analysis as fixed effects. Phenotypic variance was calculated as:

$$\sigma^2_p = \sigma^2_a + \sigma^2_{pe} + \sigma^2_e.$$

Heritability (h^2_a) was calculated as:

$$h^2_a = \frac{\sigma^2_a}{\sigma^2_p}$$

Where: σ^2_a and σ^2_p are the variances due to effects of additive genetic and phenotypic, respectively. Repeatability (R) was calculated as the ratio of variances by summing additive genetic and permanent environmental (σ^2_{pe}) to total phenotypic variance according to

$$R = \frac{\sigma^2_a + \sigma^2_{pe}}{\sigma^2_p}.$$

2.4.3 Genetic and rank correlation

Genetic correlation among doe's predicted breeding values (PBV) (using Best Linear Unbiased Predictor (BLUP) estimated by MTDFREML program of Boldman *et al*. (1995), as well as spearman rank correlation among ranks of (PBV) according to Spearman (1904) were estimated by SAS (2003).

3. Results and discussion

3.1 Means

Means, standard deviations and coefficients of variation for litter traits in V-line rabbits are given in Table 1. Actual means of litter traits were in the range of reviewed estimates (Khalil and Al-Saef, 2012; Shehab El-Din, 2016), but were lower than those reported by Abou-Khadiga, (2004), Youssef *et al*. (2008), Abou - Khadiga *et al*. (2010), and El-Sabrout and Shebl, (2015). These differences might be attributable to changes in management or environmental conditions throughout the experimental period. CV % estimates for litter traits (Table 1) increased from birth to weaning, showing that phenotypic variance was lower at birth than at weaning. However, these estimates showed that improving these traits through phenotypic selection is quite possible (Shehab El-Din, 2016; El-Deghadi, 2019). In this respect, Youssef *et al*. (2008) suggest that the higher variation in litter traits at weaning than at birth would lead to greater phenotypic improvement in these traits by selection associated with good management during the suckling period.

Table (1): Actual means, standard deviations (SD) and coefficients of variation (CV %) for litter traits in V-Line rabbits.

Traits[1]	Number	Mean	SD	CV (%)
Litter size				
LSB (bunny)	441	8.46	2.38	28.19
NBA (bunny)	441	7.86	2.33	29.65
LSW (bunny)	423	6.31	1.96	31.16
Litter weight				
LWB (gm)	441	419.01	124.17	29.63
LWW (gm)	423	2980.35	856.22	28.72
PLG (gm)	423	2561.37	778.43	30.39

[1] LSB= Litter size at birth, LSW= Litter size at weaning, LWB= litter weight at birth, LWW litter weight at weaning and PLG= preweaning litter gain

3.2 Non-genetic effects

The least-square means of different factors affecting litter size and litter weight traits studied in V-Line rabbits are given in Table (2).

3.2.1 Year of kindling

The effect of kindling year was found to be significant (P≤0.001) on all studied traits. Least-square means of litter traits show a gradual increase in litter traits from the first to the last year, which recorded larger size, heavier weight, and gain compared to first-year litter. This is consistent with most researchers (Gharib, 2008; Habib, 2011; Shehab El-Din, 2016).

3.2.2 Season of kindling

In the current study, the season of kindling had a highly significant effect on litter traits (P≤0.001) (Table 2). These results confirm the report of Gharib (2008). For most of the investigated traits, winter kindling had the greatest mean, followed by spring kindling, but for LSB, autumn had the highest mean, followed by winter. Furthermore, the performance of all traits was at its lowest during the summer. In this regard, changes in the kindling season may be attributed to seasonal climatic conditions in the rabbitry's geographical location, particularly for ambient temperature and relative humidity in open or semi-opened rabbitries (Abd El-Azeem *et al*., 2007; Abou-Khadiga, 2004; Farid *et al*., 2004).

3.2.3 Parity

The parity effect was found to be significant (P≤0.05 or P≤0.01) on LWB, LWW and PLG. On the contrary, a non-significant parity effect on all litter size traits was found in the current study (Table 2). Least-square means of litter traits were observed to be higher in the 3rd parity than in the others, with an inconsistent trend in which parity is the poorest performing (Abou-Khadiga, 2004; Gharib, 2008; Habib, 2011). Changes in weather conditions and physiological efficiency of the doe, particularly those associated with the mean age of the doe and differences in the intra-uterine environment provided during gestation length, which occurs with the advance of parity, and milk production, which is related to the udder capacity and ability of the doe to suckle her young, could explain the pattern of change observed on litter traits.

Table (2): Least-squares means and standard errors (LSM ±SE) for factors affecting litter traits in V-Line rabbits.

Item		No.	Litter size			Litter weight		
			LSB	NBA	LSW	LWB	LWW	PLG
Overall mean LSM ± SE[1]		441	8.27±0.07	7.73±0.08	6.20±0.07	413.22±4.94	2937.37±34.7	2503.53±32.41
Year	2019	157	7.64±0.18	7.17±0.17	5.59±0.17	378.71±8.17	2658.16±57.1	2279.44±52.7
	2020	147	8.21±0.21	7.63±0.19	6.03±0.18	413.6±10.59	2905.94±73.9	2429.33±68.3
	2021	134	8.97±0.19	8.38±0.22	6.99±0.19	447.36±11.8	3248.00±82.4	2801.29±76.1
Season	Winter	95	9.02±0.21	8.58±0.23	6.77±0.19	467.95±12.1	3228.37±85.1	2760.41±68.0
	Autumn	130	9.16±0.19	7.92±0.19	6.39±0.16	417.63±10.5	2941.97±73.6	2524.34±68.8
	Spring	147	8.89±0.18	8.50±0.18	6.72±0.16	438.14±10.1	3123.29±71.0	2685.15±78.7
	Summer	69	6.01±0.23	5.92±0.24	4.93±0.20	329.17±12.9	2456.70±90.5	2127.52±83.6
Parity	1	102	8.22±0.20	7.52±0.21	6.23±0.18	396.82±11.2	2913.60±78.2	2516.78±72.3
	2	97	8.09±0.22	7.63±0.23	6.31±0.20	423.17±11.8	3098.35±82.5	2675.18±76.2
	3	86	8.62±0.23	8.17±0.24	6.38±0.21	453.39±12.3	3081.98±86.4	2628.58±79.8
	4	86	8.24±0.21	7.68±0.22	6.11±0.19	389.01±12.9	2758.92±90.3	2369.91±83.5
	5	70	8.19±0.24	7.64±0.22	5.89±0.21	403.74±12.1	2835.07±91.7	2431.33±84.7
Source of variance		P ≤ values						
Year		<0.0001		0.0003	<0.0001	0.0002	<0.0001	<0.0001
Season		<0.0001						
Parity		0.50		0.32	0.58	0.002	0.017	0.03

[1]Least square means ± standard error.

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3.3 Genetic parameters

3.3.1 Heritability (h^2_a) and ratio of permanent environmental variance (pe^2)

The heritability (h^2_a) and the ratio of permanent environmental variance (pe^2) for litter traits from the single-trait animal model analysis are given in table 3. In general, estimates of h^2_a for litter traits were lower and ranged from 0.05 to 0.08 for litter size traits, 0.09 for both litter weight traits, and 0.14 for pre-weaning litter gain. These estimates were consistent with estimates of h^2_a in the relevant literature (Abou-Khadiga *et al*., 2012; El-Deghadi, 2019; Habib, 2011; Nagy *et al*., 2014; Nguyen *et al*., 2017). Consistent with these studies, the lower estimates of h^2_a for litter traits may be due to the relative importance of additive genetic factors being low. Most improvements in these traits can be achieved through environmental improvement and postnatal litter management, as the period from birth to weaning is the most sensitive to environmental and management changes. However, Iraqi *et al*. (2006) reported that small estimates of h^2_a for litter traits might be due to the large maternal effects and/or variation due to permanent environmental effects, *i.e*. increasing non-additive genetic effects. Moreover, Behiry *et al*. (2021) working on APRI rabbits, attributed low estimates of h^2_a for litter traits (ranging from 0.08 and 0.14) to high non-additive genetic effects for all litter. They recommend applying crossbreeding programs to improve these traits. Differences in h^2_a estimates throughout the literature might be attributed to, the estimation approach utilized, statistical models and the amount of data studied. Furthermore, the genetic makeup of the herd, as well as the selection criteria employed, impacts the value of the h^2 estimate.

Table (3): Variance components and estimates of heritability (h^2_a), permanent (P^2), error effects (e^2), and repeatability (R) for litter traits in V-Line rabbits.

Traits	Variance components[1]				Genetic parameters[2]			
	σ^2_a	σ^2_{pe}	σ^2_e	σ^2_p	h^2_a±SE	Pe^2±SE	e^2 ±SE	*R*
Litter size								
LSB	0.28	0.006	3.80	4.08	0.07±0.052	0.001±0.070	0.93±0.09	0.07
NBA	0.29	0.009	3.2	3.50	0.08±0.043	0.003±0.060	0.91±0.08	0.08
LSW	0.15	0.005	2.83	2.98	0.05±0.046	0.002±0.062	0.95±0.07	0.05
Litter weight								
LWB	0.70	0.009	7.08	7.79	0.09±0.0001	0.001±0.00010	0.91±0.002	0.09
LWW	1.09	0.009	10.68	11.78	0.09±0.0001	0.0008±0.0001	0.91±0.001	0.09
PLG	1.14	0.005	7.10	8.25	0.14±0.0010	0.0006±0.0020	0.86±0.001	0.14

[1]σ^2a= additive genetic variance, σ^2pe=permanent environmental variance; σ^2e = residual variance and σ^2p = phenotypic variance. [2] h^2a = heritability, Pe^2 = proportion of permanent environmental effect, e^2=error effect and R= repeatability.

3.3.2 Permanent environmental effects (pe^2)

The proportions of pe^2 effect for litter traits in V-Line were also small, ranging from 0.0006 to 0.001 (Table 3). These results were within the range recorded by many authors (El-Deghadi, 2019; Iraqi *et al*., 2007; Youssef *et al.*, 2008). Minor values of permanent environmental effects in the current study may be due to the small number of does used (Iraqi *et al*., 2007). However, Nguyen *et al*. (2017) noted no clear trend in the literature on whether additive genetic variances or pe^2 provide a greater portion of the phenotypic variances for LSB and NBA. Generally, small proportions of pe^2 may be partially attributed to the large proportions of temporary environmental variance, which cannot be taken into account in statistical models including climatic, health, managerial conditions, etc. (Moura *et al*., 1991).

3.3.3 Repeatability(R)

Repeatability estimates (*R*) for litter traits are presented in Table (3). Due to the smallness of the estimated values of pe^2, which tended to be low in magnitude (ranging between 0.001 and 0.0006), *R* estimates for litter traits were about the same as for h^2_a. These estimates are within the range of 0.01 to 0.15 reported in some literature (Behiry *et al*., 2021; El-Deghadi, 2019). In this respect, Behiry *et al*. (2021) noted that lower estimates of *R* for most litter traits imply that assessing numerous parities before selecting parents for these traits is required for effective selection. Garcia *et al.* (1982) revealed some of the more important explanations for low estimates of *R* to litter size in which the doe was born, coefficient of inbreeding of the doe and diseases. In addition, the connectedness between records of close relatives (dam-daughter), which may decrease with the increase of parity order and consequently, a reduction in the doe component of the variance for litter traits in rabbits, will be obtained. Moreover, enlarged seasonal differences and other physiological ones between traits are slightly more repeatable than litter traits. Considering the low values of h^2_a and *R* in the current study, such herds should ensure that the environment is as homogeneous as possible. In other words, to manage animals in such a manner that the effects of the environment on the performance of different animals are as comparable as possible (Bourdon, 2000).

3.3.4 Error proportion (σ^2e)

As shown in table 3, the σ^2e for litter traits in this study were high, ranging from 0.86 to 0.95. These findings agreed with Iraqi and Youssef (2006), Abdel-Kafy, (2012), Hassan *et al*. (2015), El-Deghadi (2019) and Behiry *et al*. (2021). In this regard, Behiry *et al*. (2021) noted that high estimates of σ^2e for litter traits in Baladi Black rabbits ranged from 0.66 to 0.89, and attributed that, to some factors that couldn't be included in the statistical model.

3.3.5 Genetic and phenotypic correlations

Estimates of genetic (r_g) and phenotypic correlations (r_p) among litter traits in V-Line rabbits are presented in table 4. Regarding the issue of genetic correlation (r_g), estimates of r_g in table 4 were positive across all correlated traits. It is closely correlated between LSB and NBA (0.99) and between LWW and PLG (0.99). The rest of r_g values, among other traits, were positive, moderate to high, which ranged from 0.50 to 0.79. In this study, higher levels of r_g between litter traits indicated that these traits were regulated by the same genes and the improvement of one would lead to an improvement in the other as a correlated response. The r_g estimates in the present study are in agreement with the results of Iraqi *et al.* (2007), Moustafa *et al*. (2014), El-Deghadi (2019) and Behiry *et al*. (2021). In this regard, more accurate selection programs may be employed depending on this value, taking into account the direction and strength of the correlation between traits and the awareness of this correlation (El-Deghadi, 2019). Estimates of phenotypic correlations (r_p), for litter traits in table 3 showed that r_p follows the same trend as r_g with some relatively high correlation between traits of r_p compared with r_g. The strongest r_p was between LSB and LSW (0.98) and between LWW and PLG (0.98). The same trends were shown by Iraqi *et al*. (2007). Phenotypic correlation includes the value of both genetic and environmental correlation (*i.e.*, non-genetic effects). This may be the reason for the difference between the r_g and r_p magnitudes, where r_p was greater than r_g. In this respect, differences in genetic and phenotypic correlation estimates may arise as a result of disjunction between patterns of environmental and genetic effects on the developing phenotype and/or random sampling error present in true population estimates, which is caused by the difficulty in identifying and directly measuring all of the important environmental factors affecting trait variation and covariation (Cheverud, 1988).

Table (4): Estimates of genetic (r_g), phenotypic (r_p) and rank(r_s) correlations for litter traits in V-Line rabbits.

Correlated traits	Correlation coefficient[1]		
	r_g	r_p	r_s
Between LSB and			
NBA	0.99***	0.98***	0.99***
LSW	0.78***	0.77***	0.74**
LWB	0.75***	0.73***	0.72**
LWW	0.52**	0.67**	0.45**
PLG	0.50**	0.62**	0.46**
Between NBA and			
LSW	0.78***	0.84***	0.75**
LWB	0.74***	0.77***	0.72**
LWW	0.52**	0.72**	0.46**
PLG	0.50**	0.67**	0.47**
Between LSW and			
LWB	0.71**	0.70**	0.72**
LWW	0.79***	0.86**	0.79**
PLG	0.72***	0.83**	0.72**
Between LWB and			
LWW	0.61***	0.67**	0.60**
PLG	0.53**	0.57**	0.54**
Between LWW and			
PLG	0.99***	0.99***	0.98***

[1]r_g= genetic correlation; r_p= phenotypic correlations and r_s= rank correlations.

3.3.6 Rank correlations (r_s)

Among breeding value estimates for litter traits, estimates of rank correlations (r_s) and their significance are presented in Table (4). Rank correlations were positive, moderate and highly significant for litter size and litter weight traits and ranged from 0.45 (the minimum value of r_s between LSB and LWW) to 0.99 (the highest value of r_s between LSB and NBA). Moreover, r_s between traits indicate that there is no extreme re-ranking among them, so animals tend to maintain the same ranking using these traits as selection criteria. In this respect, Moustafa *et al.* (2014) found that the rank correlation of LSW and LSB was moderate and suggested that LSW seems to be the most consistent trait that could be used as a selection criterion for improving reproductive performance in rabbits.

3.3.7 Predicted breeding values of doe (PBV_S)

The predicted breeding values of litter traits for does were estimated using a single-trait animal model (PBV_S). Table 5 shows the minimum and maximum estimates of PBV_S, their ranges, and the percent of positive records of PBV_S. Ranges of PBV_S for litter size traits (LSB, NBA, and LSW) (Table 5) revealed that these ranges decreased with the advanced age of the litter from birth up to weaning. Concerning litter weight traits (LWB, LWW and PLG), PBV_S were increased with the advanced age of litter. In this regard, and by referring to the h^2_a in Table (3), we note that these values were decreasing for litter size traits, and vice versa, to some extent, for litter weight traits. Farid *et al*. (2000) attributed this, to the expression of the genotype becoming clearer at weaning than at an earlier age. Also, the same authors added that selection for LWW might be more effective for improving many traits than selection for a simple trait at birth. The percentage of does with positive PBV_S estimates for litter traits in Table (5) indicates that, in general, more than 50% of does have positive values, and the only exception was for NBA (34%). The same trends were shown by Farid *et al*. (2000). In this regard, El-Deghadi, (2019), using transmitting abilities (half of PBVS), noted that the percentages of positive transmitting ability estimates for litter traits ranged from 46.37 to 52.99. Moreover, Moustafa *et al*. (2014) using transmitting abilities reported that the percentages of positive transmitting ability estimates for litter size traits ranged from 53.21 to 59.91. In parallel with similar results, these findings are sufficient to allow for genetic improvement, given that around 25% of parents will be chosen for replacement each year (El-Deghadi, 2019). In this regard, and by referring to the h^2_a in Table (3), we note that these values were decreasing for litter size traits, and vice versa, to some extent, for litter weight traits. Farid *et al*. (2000) attributed this, to the expression of the genotype becoming clearer at weaning than at an earlier age. Also, the same authors added that selection for LWW might be more effective for improving many traits than selection for a simple trait at birth. The percentage of does with positive PBV_S estimates for litter traits in Table (5) indicates that, in general, more than 50% of does have positive values, and the only exception was for NBA (34%). The same trends were shown by

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Table (5): Minimum, Maximum, range of doe predicted breeding values and percent of positive records for litter traits in V-Line rabbits.

Trait	Minimum	Maximum	Range[1]	% Positive record[2]
Litter size				
LSB (bunny)	-1.13±0.54	1.23±0.530	2.36	54.7
NBA (bunny)	-0.86±0.45	0.968±0.45	1.82	34.9
LSW (bunny)	-0.62±0.44	0.786±0.41	1.40	55.7
Litter weight				
LWB (gram)	-46.56±0.78	43.95±0.73	90.51	53.8
LWW (gram)	-298.61±0.8	340.3±0.82	638.9	53.8
PLG (gram)	-267.49±0.7	313.04±0.7	580.5	50.9

[1]Range as the difference between the maximum and minimum values. [2]As percent from all number of doe (102 does).

4. Conclusion

The current results revealed that litter traits are influenced by environmental factors, as evidenced by the significance of the fixed effect under study, which was offset by a decrease in the values of the genetic parameters. Despite this, the herd has positive breeding values in the majority of its does, as well as a positive and strong genetic correlation between most of the traits. Due to genetic improvement, future generations will be able to benefit from this advantage.

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