



Assessment of Genetic Capability for Post-Weaning Growth Traits of Reciprocal Cross between Gabali and V-Line Rabbits Using an Animal Model

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ABSTRACT

This study aimed to assess the conceivable impact of hereditary factors on the crossbreeding rabbit groups set up by proportional going between Sinai Gabali and V-Line. Reciprocal cross on the post-weaning performances was performed by estimating the genetic capability for their crosses. The study samples included two pure rabbit breeds (a male Saini Gabali (G) and a female V-Line (V)), and reciprocal crosses to compromise 10 groups. Records of 448 kits delivered by 45 does and 16 bucks were utilized to estimate Heritability (h^2), genetic and phenotypic correlations, and breeding values of litter weight traits. First generation was created from the consequences of four parities ($\frac{1}{2}G \frac{1}{2}V$, and $\frac{1}{2}V \frac{1}{2}G$; sire breed was demonstrated first). Weaning was implemented on the 28th day of the kits' age. Post-weaning litter traits were measured Body weight (BW) at 4, 5, 6, 8, 10, and 12 weeks of their age; and average daily gain was measured during 4-8 weeks (ADG₄₋₈, ADG₄₋₁₂, ADG₈₋₁₀, and ADG₈₋₁₂). Data were examined by animal model, which was performed utilizing derivate free limited maximum likelihood. The results revealed that h^2 was moderate for both breeds, and its reciprocal cross ranged from 0.2 to 0.25, and BW at weaning was 0.22 ± 0.07 . Meanwhile, there was a positive genetic correlation between BW and ADG at different age ranges (ranged 0.02 to 0.77, 0.04 to 0.76, respectively). Assessments of environmental correlation between BW at different age ranges were negative, except of those between BW₈ and BW₁₂ which were positive, but not significant. Additionally, the progeny had higher predicting breeding values for BW at 4, 8, 10, and 12 weeks for both breeds, but that was obtained from G×V exceeding those from their reciprocal cross. In conclusion, direct additive variance was considerably effective, and consequently body weight at weaning and post-weaning growth traits could be improved by utilizing bucks of Sinai Gabali with does of V-line based on the performance of their progenies, and selection of sires and dams.

Keywords: Genetic correlation, Heritability, Post-weaning, Sinai gabali, V-line, Weaning weight

INTRODUCTION

The expected global needs for the meat at 2050 are about 73% compared to present mass production. The developing countries will contribute for most of this expansion due to fast population growth and ascending of capital income (FAO, 2011; OECD, 2017). Obike and Ibe (2010) conveyed that rabbits are considered as a high-quality source of protein with cheap price, which can be used to improve the animal production of protein in low revenue populations (Makkar et al., 2014). Furthermore, the rabbits had many compensations above other animals for low cost meat production, for instance, high growth rate, high feed conversion, and their ability to utilize fibrous feeds, both of sexual maturity and short gestation length resulted in a short generation interval, also, the rabbits' meat was classified as a high-quality meat (Herbert, 2011). In addition, growth rate in rabbits, particularly their post-weaning was intensely affected by genotype and environmental condition including the availability of both quality and quantity of feed. Furthermore, the diversity of the rabbit breeds gave more opportunities to improve the meat production by divergent breeds crossing (Piles et al., 2004).

Heritability, which is an element of variance components, gave data about the hereditary idea of a characteristic and is required for genetic assessment and selection procedures (El-Raffa, 2005). Phenotypic variance assumed a vital part for post-weaning traits in rabbits was generally depicted to be overwhelmed by ecological impacts inferable from the does or potentially litter, which might owe the short interval from the weaning to marketing. Moreover, low heritability and direct proportions of genetic responses to select for post-weaning growth traits were conveyed (Lukefahr

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et al., 1996). The rabbits' genetic improvements were mainly conditional on the heritability of the defined traits, and its association with different other traits of economic importance were measured. A moderate to high heritability (0.7-0.9) for litter weight at 7-8 weeks old, while the repeatability generally indicating low estimates (0.003-0.008) were obtained by Okoro et al. (2012). In oppose with Iraqi, 2008 who found that estimating of heritability were 0.05 to 0.38 body weight (BW) at 4, 8, and 12 weeks old, while these estimations were 0.23 and 0.19 for daily gain from 4 to 8, and 8 to 12 weeks of age, correspondingly. Though, additive genetic variability was far from being considered negligible. To facilitate, and to make rapid improvements in rabbits' performance, it could be inaugurated from selection and use of divergent breeds in the crossbreeding (Chineke and Raheem, 2009). In addition, crossbreeding is efficient for improving the post-weaning growth potential (Piles et al., 2004). Besides, selection in maternal lines in rabbit was somewhat considering determination inside limited population which amassed in mating grouping impacts (Ragab et al., 2015), extending the hereditary variety amongst lines and, verifiably, changing the gene frequencies between population. Furthermore, to employ genetic resources effectively, the genetic and environmental causes of phenotypic alteration in economic attributes need to be differentiated (Gorbani and Salamatdoust, 2011). The intention of rabbits' breeding was to improve execution characteristics of rabbits' population through both mating and selection. Accordingly, the targets of the existing research were to assess conceivable impact of hereditary factors on crossbreeding rabbit groups set up by proportional going between Sinai Gabali and V-Line (as a unique lines) by reciprocal cross on post-weaning performances by estimate the genetic capability for their crosses.

MATERIALS AND METHODS

Ethical approval

The experiment was carried out according to the National Regulations on Animal Welfare and Institutional Animal Ethics Committee, Egypt.

Breeding plan

Two pure rabbit breeds were used in current study (Saini Gabali (G), and V-Line (V) as a standard exotic line). Does and bucks of the V were acclimatized descendants of the Spanish synthetic line. Crossbreeding system was applied in ten mating groups which contained 4 to 5 does per group. The first five groups consisted of V does which were mated with five G bucks ($G^{\sigma} \times V^{\phi}$), and reciprocal crosses ($V^{\sigma} \times G^{\phi}$) for the further five groups. Each buck was represented as a sire to all litters in each group to produce F_1 ($\frac{1}{2} G \frac{1}{2} V$ and $\frac{1}{2} V \frac{1}{2} G$; sire breed was indicated first). Weaning was implemented at 28 days of kits' age.

Rabbitry, housing and management

Animals were raised in a semi closed rabbitry, depending on the natural ventilation. Does were housed individually in pens where there were settle boxes, feeders, and automatic drinkers. All rabbits were fed on a commercial lactating-pelleted-diet containing approximately 2600 Kcal/kg ration as digestible energy; 16.3% crude protein; 13.2% crude fiber and 2.5% fat. Both of feed and water were provided *ad libitum*. Does mated their same respective group assigned bucks 10 days post-kindling. Pregnancy was ascertained by palpation 10 days of succeeding mating. Females that neglected to conceive were come back to the same assigned buck to be re-reproduced. Inside 12 hours once encouraging, litters were checked and recorded. In this way, weaned a month kits were sexed and exchanged for additional study to standard descendants prepared pens.

Source of data

Post-weaning litter traits were body weight (BW_4) at , 5, 6, 8, 10, and 12 weeks old, average daily gain between 4 to 8 weeks (ADG_{4-8}), 4 to 12 weeks (ADG_{4-12}), 8 to 10 weeks (ADG_{8-10}), and 8 to 12 weeks (ADG_{8-12}).

Statistical analysis

Linear model

Data were preliminary analyzed using general linear model (GLM) and VARCOMP procedures of Statistical Analysis System (SAS, 2001, version 8.1). In addition, single and multi-traits animal model analyses (AM), were performed using derivate free restricted maximum likelihood as recommended by Boldman et al. (1995). For the derivative- free model, convergence (co) variance components estimation was when the global maximum of the log likelihood function was found.

Estimation of heritability (h^2)

The following formula was used by the animal model software to estimate h^2

$$h^2 = \frac{\sigma^2 a}{\sigma^2 a + \sigma^2 P_e + \sigma^2 e}$$

Where,

$\sigma^2 a$: was additive genetic variance $\sigma^2 P_e$: was permanent environmental variance, and $\sigma^2 e$: were random residual associated with each observation.

Estimation of correlations

The following formula was used as recommended by Franzese and Iuliano (2019).

$$r_{XY} = \frac{cov(xy)_{ij}}{\sqrt{\sigma^2 x_{ij}} \sqrt{\sigma^2 y_{ij}}}$$

Where,

$COV(xy)_{ij}$ = The additive genetic covariance, $\sigma^2 x_{ij}$ = The additive genetic variance of the trait (or permanent environmental, environmental and phenotypic). $\sigma^2 y_{ij}$ = ?????

Estimation of Predicted breeding value

The mixed model equations (MME) for the best linear unbiased estimator (BLUE) of Estimable function of b , and for the BLUP of a and p , in matrix notation was as follows:

$$\begin{bmatrix} X'X & X'Z & X'w \\ Z'X & Z'Z + A^{-1}\alpha_1 & Z'Z \\ W'X & W'Z & W'w + I\alpha_2 \end{bmatrix} \begin{bmatrix} b^{\wedge} \\ a^{\wedge} \\ p^{\wedge} \end{bmatrix} = \begin{bmatrix} Xy^{\wedge} \\ Zy^{\wedge} \\ wy^{\wedge} \end{bmatrix}$$

Where, A^{-1} is the inverse of the numerator relationship matrix,

$$\alpha_1 = \sigma_e^2 / \sigma_a^2 \quad \text{and} \quad \alpha_2 = \sigma_e^2 / \sigma_{pe}^2$$

Estimation of Accuracy of Predicted breeding value

The accuracy of predicted breeding values for each animal was assessed as follows:

$$R A^{\wedge} A = (1 - d_j a)^2$$

Where,

$R A^{\wedge} A$ = the accuracy of prediction of the individual breeding values, d_j = the j th diagonal elements of inverse of the appropriate block coefficient matrix standard error, (Se) was estimated by the following relation: $Se = d_j \sigma_e^2$. In addition, simple correlations between breeding values for litter traits and progeny weight were estimated.

RESULTS AND DISCUSSION

Heritability estimates for body weight and average daily gain

Heritability estimates h^2 for BW at 4, 6, 8, and 12 weeks were 0.65 ± 0.169 , 0.09 ± 0.224 , 0.01 ± 0.118 and 0.29 ± 0.143 , respectively which were estimated from MTAM, and using all data. h^2 are moderate for both breeds and ranged from 0.22 to 0.25 and 0.20 to 0.25 for $G^{\wedge} X V^{\wedge}$, and $V^{\wedge} X G^{\wedge}$ crosses, respectively (Table 1). In addition, the moderate h^2 for BW at weaning 0.23 and 0.22 for $G^{\wedge} X V^{\wedge}$, and $V^{\wedge} X G^{\wedge}$ respectively, which suggested that the selection for weaning weight will give greater improvement for BW at marketing, thus, this could be situated as the endorsement goal of animal breeder. Furthermore, a little higher h^2 of BW for $G^{\wedge} X V^{\wedge}$ than its reciprocal indicated the importance of using bucks of Saini Gabali to improve BW at different ages.

The extant results indicated that h^2 estimates were higher for BW at weaning and decreased gradually, and then increased at older ages. The equivalent results were confirmed by Khalil (1986). Also, the moderate h^2 for BW_4 , and BW_{12} suggested that the selection for weaning weight will give a greater improvement in BW at marketing. Similarly, according to El-Kelany (2005) who concluded that the additive genetic variances at younger age (4 weeks) for the five breeds (New Zealand White, California, Basucat, Flander and Black and Baladi) were beneath those at older age (8 weeks). This could be a direct result of non-added substance of genetic impacts and changeless environmental impacts at 4 weeks than at 8 weeks. In addition, Anous (2000) found that h^2 estimates for BW at 4, 6, 8 and 10 weeks old were 0.67, 0.81, 0.98 and 0.67, respectively, and concluded that the selection for BW at earlier ages may be convenient procedure for improving early rabbit growth. The present estimate of h^2 for weaning weight were exceeding those reported before (0.224-0.26) (Argente et al., 1999; García and Baselga, 2002). These differences among results may be attributed to differences in sampling errors, available number of observations, methods of analysis and statistical model used. Contritely, low h^2 for BW at various ages of California were 0.17 and 0.18 for 8 and 12 weeks old, while h^2 were

0.16 and 0.19 for daily gain during the period of 4 to 8 and 8 to 12 weeks old, respectively (Gharib, 2008). At the present study, the favorable estimates of h^2 for post-weaning growth traits were underneath those obtained by other scientists using the AM ranged from 0.30 to 0.72 (Iraqi et al., 2002). The acquired outcomes were correspondingly to the small sample size of progeny per generation, second the inadequacy of progeny per sire, and third to the non-randomness in the allocation of progeny within sire group and sampling errors (Khalil et al., 2000). Intestinally, it will be an encouraging factor to enrich growth performance of these standard breeds raised in hot climates through the selection of sires in future. Regarding to gain weight, the present estimates of ADG among different ages were lower than those reported by many authors working on various rabbits' breeds and ranged from 0.018 to 0.61. These results implied that the post-weaning ADG tends to be low to moderate heritable. Alike body weights, the h^2 for post-weaning ADG estimated from sire components were inferior to those estimated from dam components, which it was due to the maternal effect on BW from birth to weaning. These results corresponded to the previous studies where maternal genetic effects were realized significantly positive for the favors of V-Line dams, BW₈ and BW₁₂ (Abou Khadiga et al., 2008). The V-line had an unfavorable maternal genetic effect on the BW at 32 days old (ranging from 54.3 to 86.0 gram). In addition, Orengo et al. (2009) reported that maternal genetic effects were significant for BW at 60 days. Furthermore, the estimate of h^2 was higher for BW₈ weeks than other ages, and the selection of the animals would be more effective at 8 weeks of age to improve post-weaning growth traits in Gabali rabbits (Iraqi, 2008).

Table 1. Estimates of heritability for body weights, and average daily gains from weaning to marketing weight for Gabali X V-line, and its reciprocal cross by animal model

Traits	Heritability ($h^2 \pm SE$)		
	All data	Gabali x V- line (G♂ X V♀)	V- line x Gabali (V♂ X G♀)
BW ₄	0.65 ± 0.16	0.23 ± 0.07	0.23 ± 0.07
BW ₆	0.09 ± 0.22	0.25 ± 0.10	0.25 ± 0.10
BW ₈	0.01 ± 0.11	0.25 ± 0.05	0.25 ± 0.05
BW ₁₂	0.29 ± 0.14	0.22 ± 0.02	0.22 ± 0.02
ADG _{4,8}	0.01 ± 0.13	0.36 ± 0.135	0.15 ± 0.135
ADG _{4,12}	0.12 ± 0.06	0.38 ± 0.069	0.61 ± 0.069
ADG _{8,12}	0.08 ± 0.05	0.08 ± 0.055	0.04 ± 0.055

BW: Body weight at 4, 6, 8, and 12 weeks of age (BW₄, BW₆, BW₈, and BW₁₂, respectively). ADG_{4,8}: Average daily gain between 4-8 weeks interval, 4-12 weeks (ADG_{4,12}), and 8-12 weeks (ADG_{8,12})

Genetics and environmental correlations

The MTAM analysis of variance and covariance were performed on the data of V-Line and Saini Gabali breed to derive estimates of direct additive genetic (r_g) and environmental correlations (r_e) among different traits studied. Genetic correlation for both BW and ADG at distinctive ages were positive, and ranged from 0.02 to 0.77, and 0.04 to 0.76, respectively. The highest genetic correlation was 0.76 between ADG_{4,12} and ADG_{8,10} (Tables 2 and 3). These results possibly explained by that the selection for higher BW at weaning would cause an associated increase in marketing body weight. Assessments of environmental correlation among BW at different ages were negative, except the r_e between BW₈, and BW₁₂ were positive (0.08, 0.124), but not significant (Table 2). Also, r_e among ADG in different intervals were lower in most incidents than the genetic correlation (Table 3). The present findings advocated that using early information for higher BW selection at weaning would cause a correlated increase in marketing BW. Comparable results were acquired where r_g ranged from 0.31 to 1.0 (El-Kelany, 2005; Khalil et al., 2000). Moreover, Shebl et al. (1997) stated that r_g amongst BW at 8, 12 and 16 weeks of age, and the daily gain (8 and 12 weeks) for New Zealand White (NZW) and Gabali line (G) were positive. The current estimates of r_g indicated that BW₈ was more correlated than BW₄, and BW₆ compared to r_g for BW₄ with that at BW₆, and BW₁₂, indicating that high weaning weight was associated with heavier body weight as BW₄, and BW₁₂. Enab et al. (2000) found that r_g were positive and generally high in Cal and NZW breeds at all ages (4, 8, and 12 weeks). Also, it was noted that r_g in general tended to diminish the value as the intervals between two ages increased in both breeds (Enab et al., 2000). Prospectively, r_g between ADG in different ages were positive; the highest r_g between ADG_{4,12} and ADG_{8,10} indicated that the selection of animals that have heavy BW at 4 weeks of age, would increase BW at marketing in the next generation. Analogously, Shebl et al. (1997) found that the r_g between BW₈, and ADG_{8,12} weeks was lower than the corresponding r_g between BW₁₂ and ADG in the same period. Regarding to estimates of environmental correlation (r_e) concerning BW at different ages were negative, except for r_e between BW₈ and BW₁₂ which was positive, but not significant. In addition, r_e between average daily gains in different ages were lower than the genetic correlation in most incidents (Table 3). In other incidents, both r_g and r_e had the same indication, and they were not distinct in magnitude. Accordingly, this tendency might possibly be owing to several physiological mechanisms.

Table 2. Estimates of genetic (above diagonal) and environmental (below diagonal) correlations among weekly body weights from weaning to marketing weight in rabbits as estimated by Multi-trait animal model

Correlated traits ^a	BW ₄	BW ₆	BW ₈	BW ₁₂
BW ₄	-	0.14 (0.683)	0.51 (2.257)	0.20 (0.346)
BW ₆	-0.17 (0.231)	-	0.77 (1.472)	0.02 (0.579)
BW ₈	-0.29 (0.196)	-0.38 (0.114)	-	0.02 (1.207)
BW ₁₂	-0.75 (0.122)	0.00 (0.139)	0.08 (0.124)	-

^a Body weight at 4, 6, 8, and 12 weeks of age (BW₄, BW₆, BW₈, and BW₁₂, respectively);

Table 3. Estimates of genetic (above diagonal) and environmental (below diagonal) correlations between post weaning average daily gains in rabbits as estimated by Multi-trait animal model

Correlated traits ^a	ADG ₄₋₈	ADG ₄₋₁₂	ADG ₈₋₁₀	ADG ₈₋₁₂
ADG ₄₋₈	-	0.13 (2.298)	0.53 (5.410)	0.08 (2.637)
ADG ₄₋₁₂	-0.18 (0.081)	-	0.76 (0.338)	0.04 (0.385)
ADG ₈₋₁₀	0.01 (0.076)	0.35 (0.071)	-	0.02 (0.360)
ADG ₈₋₁₂	-0.09 (0.119)	1.00 (0.026)	0.34 (0.084)	-

^a Average daily gain between 4-8 weeks interval (ADG₄₋₈), 4-12 weeks (ADG₄₋₁₂), 8-10 weeks (ADG₈₋₁₀), and 8-12 weeks (ADG₈₋₁₂).

Breeding values

Body weight

Estimates of minimum and maximum predicted breeding values (PBV), and their accuracies (*r*) for BW at various ages estimated from does breeding values (DBVs), bucks breeding values (BBVs) and progeny breeding values (PBVs) were presented in table 4. The range of DBV for BW at four, five, six, eight, 10, and 12 weeks of age were 360, 584, 541, 561, 600, and 232 gram, respectively, and that of BBV were 219, 247, 250, 213, 270, and 290 gram, respectively. Whereas the range of PBV was 517, 575, 550, 505, 535 and 548 gram for BW at 4, 5, 6, 8, 10, and 12 weeks of age, respectively. Table 5 shows the higher numbers of PPVs which were obtained from crossing between bucks of G♂ X V♀, and V♂ X G♀, respectively. The present results indicated that for both breeds, progeny had higher breeding values for BW at different ages (4, 8, 10, and 12 week). Also, the predicted breeding values achieved from G♂ X V♀ cross are superior to those attained from reciprocal cross. Then, it is important to recognize that there was a potentially moderate improvement in BW at weaning and marketing (12 weeks) in G♂ X V♀ raised in adverse environmental through sire selection. According to high ranges in breeding values for most body weights obtained Does and progeny, indicated the importance of selection of doe and progeny in the second line to improve BW for different ages. The similar results were also obtained by Khalil et al. (2000) and Sabra et al. (2001). Moreover, Khalil et al. (2000) concluded that among all sires in NZW and California breeds, percentage of sires with positive estimates of sire transmitting ability (46.20 to 61.10%) for BW (At 5, 6, 8, 10 and 12 weeks). From the genetic point of view, there is a potentially for a moderate improvement in post-weaning growth traits in NZW and Cal rabbits raised in adverse environmental through sire selection. In addition, Sabra et al. (2001) noticed that the PBV for BW at 8 weeks and 12 weeks of age ranged from 269 to 303 grams, and from -315 to 324 grams in NZW, and Z-line. Also, wide variations in PBV of BW between the two strains was found to be in favor of Z-Line rabbits (Iraqi et al., 2002). The exactness of lowest and greatest evaluations of PBV were for the most part higher in NZW than those in Z-Line.

Average daily gain

Estimates of minimum and maximum PBV with standard errors (SE) and their accuracies (*r*) for ADG between 4 to 8 weeks (ADG₄₋₈), between 4-12 weeks (ADG₄₋₁₂), between 8 to 10 weeks (ADG₈₋₁₀), and between 8 to 12 weeks (ADG₈₋₁₂) estimated from DBVs, and PBVs are presented in table 6. The range of DBVs were 6.29, 1.845, 8.31, and 11.38 gram for ADG₄₋₈, ADG₄₋₁₂, ADG₈₋₁₀, and ADG₈₋₁₂, respectively. Also, the BBVs for the above-mentioned traits were 3.08, 1.32, 6.11, and 15.29 gram, respectively. Whereas, the range of PBVs were 6.95, 1.86, 6.16, and 15.36 gram, respectively. The present results indicated that the range of predicted breeding values of does for most traits studied were higher than those of progeny and sires. The obtained results revealed the importance of dams, since it gives the higher range of breeding values and selection of dams for the next generation in maternal line would place emphasis on good genetic maternal effects. Similar results have found where the genetic trend of post-weaning daily gain in lines A and V rabbits, had positive trend, small for line V, and considerably higher for line A (Baselga and García, 2002).

Table 4. The ranges of predicted breeding values for does, bucks and progeny in weekly body weights from weaning to marketing for Gabali, V-line rabbits and their crosses as estimated by multi-trait animal model

Traits ^{a)}	Predicted breeding values ^{b)}																	
	DBVs						BBVs						PBVs					
	Minimum			Maximum			Minimum			Maximum			Minimum			Maximum		
	BV	SE	R	BV	SE	r	BV	SE	r	BV	SE	R	BV	SE	r	BV	SE	r
BW₄	-0.207	0.10	0.88	0.153	0.05	0.37	-0.143	0.04	0.73	0.076	0.07	0.92	-0.201	0.06	0.68	0.316	0.08	0.85
BW₅	-0.241	0.05	0.37	0.343	0.11	0.88	-0.174	0.05	0.73	0.073	0.08	0.91	-0.223	0.07	0.00	0.352	0.11	0.85
BW₆	-0.214	0.06	0.35	0.327	0.11	0.87	-0.184	0.05	0.71	0.066	0.08	0.79	-0.217	0.07	0.00	0.333	0.11	0.83
BW₈	-0.228	0.06	0.00	0.333	0.83	0.81	-0.116	0.05	0.00	0.097	0.08	0.89	-0.197	0.07	0.00	0.314	0.11	0.82
BW₁₀	-0.254	0.07	0.00	0.346	0.13	0.80	-0.141	0.06	0.39	0.129	0.12	0.89	-0.229	0.08	0.00	0.323	0.13	0.84
BW₁₂	-0.113	0.08	0.00	0.119	0.14	0.83	-0.100	0.06	0.38	0.198	0.13	0.88	-0.212	0.09	0.00	0.336	0.14	0.83

^{a)} Body weight at 4, 5, 6, 8, 10, and 12 weeks of age (BW₄, BW₅, BW₆, BW₈, BW₁₀, and BW₁₂, respectively), ^{b)} DBVs: Doe predicted breeding value, BBVs: buck predicted breeding value, PBVs: progeny predicted breeding value, BV: Breeding value, SE: Standard error, R/r: Accuracies of breeding value.

Table 5. Predicted breeding values for higher number of progenies of body weight (g) at different ages (4, 8, 10 and 12 weeks of age) for Gabali x V-line and its reciprocal cross

Gabali x V- line (G♂ X V♀)					V- line x Gabali (V♂ X G♀)				
No.	BW ₄ ^{a)}	BW ₈	BW ₁₀	BW ₁₂	No.	BW ₄	BW ₈	BW ₁₀	BW ₁₂
100	-293	-272	-197	-185	351	-185	-177	-223	214
101	426	292	601	350	357	120	210	153	112
216	212	164	253	282	354	136	035	150	164
274	326	279	285	113	356	040	101	080	122
277	503	395	552	301	369	013	078	039	059
279	328	270	320	133	370	104	162	151	173
282	117	111	067	060	384	024	088	051	069
301	303	270	237	169	385	-113	-106	-166	240
387	673	550	676	454	401	071	095	-110	-152
910	478	404	440	318	406	220	240	304	374
915	353	259	445	406	410	036	026	007	053
960	190	170	145	065	441	097	092	128	145
967	134	117	107	041	487	087	039	082	090
4006	209	155	263	203	489	418	384	573	739
4008	678	599	544	378	498	133	192	175	168
4009	-071	-060	-068	-393	4055	472	525	654	801
4016	130	020	423	257	4056	354	480	446	390
4098	270	220	270	068	5001	044	104	060	038
					5002	188	207	268	347

^{a)} Body weight at 4, 8, 10, and 12 weeks of age (BW₄, BW₈, BW₁₀, BW₁₂, respectively)

Table 6. The ranges of predicted breeding values for does, bucks and progeny in post-weaning average daily gain for Gabali, V-line rabbits and their crosses as estimated by multi-trait animal model

Traits ^{a)}	Predicted breeding values ^{b)}																	
	DBVs						BBVs						PBVs					
	Minimum		R	Maximum			Minimum		r	Maximum			Minimum		r	Maximum		
BV	SE	BV		SE	r	BV	SE	BV		SE	R	BV	SE	BV		SE	r	
ADG ₄₋₈	-2.850	3.58	0.16	3.444	4.460	0.61	-1.421	3.12	0.40	1.656	4.15	0.72	-4.542	3.77	0.32	2.404	4.30	0.63
ADG ₄₋₁₂	-1.004	0.67	0.17	0.841	0.92	0.69	-0.702	0.66	0.41	0.612	0.85	0.74	-0.840	0.34	0.33	1.024	0.88	0.63
ADG ₈₋₁₀	-3.735	2.73	0.14	4.577	3.49	0.63	-2.862	2.60	0.36	3.245	3.30	0.68	-2.886	0.303	0.28	3.273	3.82	0.59
ADG ₈₋₁₂	-4.590	4.31	0.23	6.786	6.58	0.77	-10.25	3.88	0.51	5.032	5.81	0.82	-8.327	5.15	0.43	7.033	6.090	0.72

^{a)} Average daily gain between 4-8 weeks interval (ADG₄₋₈), 4-12 weeks (ADG₄₋₁₂), 8-10 weeks (ADG₈₋₁₀), and 8-12 weeks (ADG₈₋₁₂); ^{b)} DBVs: Doe predicted breeding value, BBVs: buck predicted breeding value, PBVs: progeny predicted breeding value

DECLARATIONS

Competing interests

There is no conflict of interest.

Authors' contributions

Rabie T., Khattab A., and Abou-Zeid A. designed research. Rabie T. wrote the paper. Khattab A. and Nowier A. analyzed the data. All authors read and approved the final manuscript.

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