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Evaluation of litter traits in purebred and crossbred rabbits raised under Egyptian conditions

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Abstract

This study was carried out within a project for production of purebred and crossbred parental stocks of rabbits to be distributed to small-scale breeders in Qalyoubia Governorate, Egypt for five consecutive production years started in September 1995. This project involving Egyptian Gabali and New Zealand White (NZW) rabbits. Data of 1089 litter traits (litter size at birth, LSB, and at weaning, LSW, and litter weight at birth, LWB, and at weaning, LWW) produced from 8 genetic groups (2 purebreds and 6 crossbreds) were used. Data were analyzed using crossbreeding effect program to estimate crossbreeding components (additive, heterosis and recombination effects of direct individual, maternal and paternal components) and repeatability multi-trait animal model to estimate genetic parameters (additive variance, permanent environmental variance, heritability and repeatability).

Results showed that differences between NZW and Gabali breeds were non-significant for all the studied litter traits, in spite of favorable of Gabali for all litter traits except LWB. The differences among some crossbred groups and purebreds were significant ($P<0.05$) for LSW and LWW. Direct additive genetic effects of individual, maternal and paternal were negative and significant ($P<0.05$ or $P<0.01$) and they reduced the general mean of LSB by 1.8, 1.5% and 1.4%, respectively. Estimates of dominance (direct heterosis) effect were of moderate importance on LSB as these were negative (decreased the general mean by 4.03%) and significant ($P<0.05$). While positive insignificant maternal and paternal heterotic effects on LSB trait were obtained. Estimates of recombination effects of direct individual, maternal and paternal were negative for all traits and significant ($P<0.01$) only for LSB and LSW traits. It is concluded that crossbred of NGxNG was the highest mean of LSW, followed by G-GNxG-GN crossbred. While, the crossbred of G-GNxG-GN was the highest mean of LWW. Percentages of additive genetic variance were somewhat low or moderate and were 4.19%, 0.85%, 7.58% and 8.96% for LSB, LWB, LSW, and LWW, respectively. Proportions of permanent environmental variance for doe performance of litter traits were low or somewhat moderate and were 2.36%, 8.88%, 4.31%, and 18.65% for LSB, LWB, LSW, and LWW, respectively. Heritability estimates were (generally low) 0.04, 0.01, 0.08, and 0.09 for LSB, LWB, LSW and LWW, respectively. Repeatability estimates for LSB and LWW were moderate (0.278 and 0.276, respectively), but low estimates of 0.097 and 0.076, respectively for LSW and LWB.

Generally, it is concluded that hybrid vigor with respect to maternal and paternal additive effects was positive which explains the influence of maternal and paternal effects at earlier ages.

Key words: direct additive, heritability, heterosis and recombination effects of direct individual, maternal and paternal, litter traits in rabbits, repeatability

Introduction

Crossbreeding has been established to exploit the heterosis in animal breeding and it could be successfully employed in rabbit breeding for increased productivity. Gabali rabbits raised under the Egyptian desert conditions, introduced from Sinai desert, are characterized by large litter size of 8-12 young and heavy body weight of 3.5-4.5 kg (Galal and Khalil 1994). New Zealand White (NZW) breed was found to exhibit out-standing maternal abilities related to maternal behavior, fecundity, fertility, lactation and pre-weaning growth and survival (Ozimba and Lukefahr 1991). Crossbreeding program of NZW rabbit with local Gabali breed may be suitable to increase rabbit meat production. Paternal and maternal additive direct effects, maternal and paternal heterosis from crossbreeding experiments including Gabali and NZW rabbits were expected to be important especially for litter traits (Khalil 1996). Results of most crossbreeding experiments carried out in Egypt reported that crossing does of NZW breed with bucks of local breeds were generally associated with heterotic effects on most litter and growth traits (Afifi et al 1994 and Khalil et al 1995). The diversity in crossbred genetic groups that exists between standard NZW breed and the local Gabali breed is likely to provide genetic combinations that suit a variety of environment and production systems in Egypt. Pure breeding and crossbreeding experiments have been carried out to improve reproductive traits of local Egyptian breeds, under the local Egyptian conditions. But more trials in Egypt are needed to produce crossbred does that have superiority in litter traits.

Nowadays, the multi-trait animal model is widely used for evaluation of rabbit breeding programs and facilitates obtaining good estimates of variance components (Baselga et al 1992; Iraqi 2003). The inclusion of common or permanent environmental effects allows to obtain true estimates of additive genetic variance (Iraqi 2003). But, most of the reviewed studies have neglected the effect of permanent environment effects in the model of analysis for these traits in rabbits. This effect may be more important than direct additive genetic effects (Ferraz and Eler 1996).

This research was conducted to: (1) compare the performance of pure breeds of Gabali and NZW rabbits and their different crossbred groups for litter traits (litter size at birth, LSB, and at weaning, LSW, and weight at birth, LWB, and at weaning, LWW); (2) estimate of crossbreeding effects, i.e. direct additive, heterotic and recombination effects in direct individual, maternal and paternal components using Dickerson models (Dickerson 1969 and 1973); and (3) estimate genetic aspects (e.g. direct additive genetic and permanent environmental variances, heritability and repeatability (using multi-trait animal model).

Material and methods

The data used in the present study were from a project for production of purebred and crossbred parental stocks of rabbits to be distributed to small-scale breeders in Qalyoubia Governorate. This project involved Egyptian Gabali (were brought from the rabbitry of Maryout Experimental Station) and New Zealand White (were descendants of NZW rabbits belonging to Bank El-Nil rabbitry) rabbits. Mating of rabbits was started in September 1995 in the experimental rabbitry, Faculty of Agriculture at Moshtohor, Zagazig University, Banha Branch, Egypt. The experimental work of this study was conducted for five consecutive production years from 1995 to 1999.

Breeding program and management

Breeding stock (bucks and does) was individually housed in wire cages with standard dimension arranged in one-tire batteries. Cages of does were provided with metal nest boxes. At sexual maturity (at 6 month), each doe was transferred to the buck's cage to be bred. Each doe was palpated 10 days thereafter to detect pregnancy. Does that failed to conceive were returned to the same mating buck to be rebred, and were returned to the same buck every other day thereafter until a service was observed. On the 25th day after the fruitful conception, the nest boxes were supplied with rice straw to provide a comfortable warm nest for members of the litters. Litters were weaned at 28 day post-kindling. At weaning, litters were weighed and separated from their dams. A commercial pelleted ration (contained 16.3% crude protein, 13.2% crude fiber, 2.5% fat) was provided in the morning and in the afternoon. The ingredients of this ration were 33% barely, 21% wheat bran, 10% Soya bean meal (44% C.P.), 22% hay, 6% berseem straw, 3% corticated cotton seed meal, 3.3% molasses, 1% lime stone, 0.34% salt, 0.3% minerals and vitamins and 0.06% methionine. In winter and early months of spring, berseem (*Trifolium alexandrinum*) was supplied for does at midday. Fresh clean water was available at all time. Cages of bucks were cleaned and disinfected regularly while that of does and nest boxes at each kindling. All breed groups of rabbits were subjected to the same environmental, medication and managerial conditions.

Data and statistical analysis

Doe traits of litter size at birth (LSB), litter weight at birth (LWB), litter size at weaning (LSW) and litter weight at weaning (LWW) were recorded. Data structure of mating groups and numbers of does, sire of doe, dam of doe and litters used from different genetic groups in this study are illustrated in Table 1.

Table 1. Structure of mating groups and numbers of doe, sire of doe, dam of doe and litters used for litter traits of rabbits in the present study.

No. of genetic group	Breed of sire of the doe	Breed of dam of the doe	Breed of doe	No. of does	No. of sires of the doe	No. of buck used	No. of dam of the doe	No. of litters produced
1	N	N	N	292	96	78	138	738
2	G	G	G	22	9	8	14	44
3	½ G ½ N	½ G ½ N	½ G ½ N	48	23	14	35	125
4	½ N ½ G	½ N ½ G	½ N ½ G	7	2	2	5	14

5	¼ G ¾ N	¼ G ¾ N	¼ G ¾ N	19	13	4	17	57
6	¾ N ¼ G	¾ N ¼ G	¾ N ¼ G	22	12	5	19	62
7	$(½G½N)^2$	$(½G½N)^2$	$(½G½N)^2$	14	7	3	12	41
8	¾ G ¼ N	¾ G ¼ N	¾ G ¼ N	3	1	1	2	8
	Total			427	163	115	242	1089

Data of 1089 litters produced from 427 does fathered by 163 and mothered by 242 were analyzed using repeatability multi-trait animal model (RMTAM) based on the following model (Boldman et al *19*95):

$$\boldsymbol{y} = \boldsymbol{Xb} + \boldsymbol{Z}_a \boldsymbol{u}_a + \boldsymbol{Z}_p \boldsymbol{u}_p + \boldsymbol{e} \quad \text{(Model 1)}$$

Where:

y = vector of observation of the doe,
b = vector of fixed effects of breed group (8 levels) and year-season combination (13 levels),
u_a = vector of random direct additive genetic effect of the doe for the i^{th} trait,
u_p = vector of random permanent environmental effect (doe x parity combination),
X, Z_a and Z_p are incidence matrices relating records of the i^{th} trait to the fixed effects (breed group and year-season), random doe effects and random permanent environmental effect, respectively, and
e= vector of random error.

The crossbreeding components for the studied traits were estimated using three sub-models of the Dickerson-Model (Dickerson 1969 and 1973).

Software of crossbreeding effect, CBE (Wolf 1996) was used to analyze the crossbreeding data. Coefficients of expected contribution for genetic effects in the eight genetic groups of purebreds and crossbreds rabbits are illustrated in Table 2 as computed by program of CBE (Wolf 1996) based on Dickerson (1969, 1973).

Table 2. Coefficients of expected contribution for genetic effects in different genetic component groups of purebreds and crossbreds as computed by Dickerson (1969, 1973) model for litter traits in rabbits.

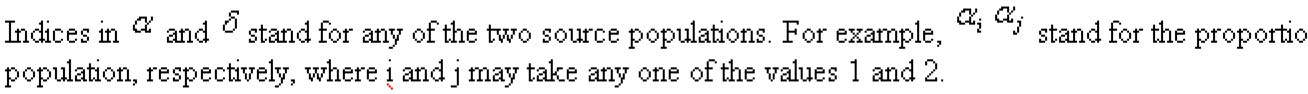
No of breed group	**Sire**	**Dam**	**Breed group**	**Individual effects**			**Maternal effects**			**Paternal effects**		
				a^i (g^i)	**d^i (h^i)**	**aa^i (r^i)**	**a^m (g^m)**	**d^m (h^m)**	**aa^m (r^m)**	**a^p (g^p)**	**d^p (h^p)**	**aa^p (r^p)**
1	N	N	N	1	0	0	1	0	0	1	0	0
2	G	G	G	-1	0	0	-1	0	0	-1	0	0
3	½ G ½ N	½G ½ N	½ G ½ N	0	0.5	0.5	0	1	0	0	1	0
4	½ N ½ G	½ N ½ G	½ N ½ G	0	0.5	0.5	0	1	0	0	1	0

5	¼ G ¾ N	¼ G ¾ N	¼ G ¾ N	0.5	0.375	0.375	0.5	0.5	0.25	0.5	0.5	0.25
6	¾ N ¼ G	¾ N ¼ G	¾ N ¼ G	0.5	0.375	0.375	0.5	0.5	0.25	0.5	0.5	0.25
7	(½G½N)^2	(½G½N)^2	(½G½N)^2	0	0.5	0.5	0	0.5	0.5	0	0.5	0.5
8	¾ G ¼ N	¾ G ¼ N	¾ G ¼ N	-0.5	0.375	0.375	-0.5	0.5	0.25	-0.5	0.5	

The general form of the Dickerson-model (1969, 1973) not including maternal effects can be written as (Wolf 1996):

$$G = m_D + (\alpha_1 - \alpha_2)g + \delta_{12}h + (\alpha_1\alpha_2 - \delta_{12})r \quad \text{(Model 2)}$$

Where:
m_D = general mean;
g = direct genetic effects (breed difference),
h = effect of heterosis,
r = recombination effect,
α_i = proportion of genes in G from the i^th source population (i=1, 2), and
δ_{ij} = probability that at a randomly chosen locus of a randomly chosen individual of G one allele is from the i^th source population and other allele is from the j^th source population (i, j = 1, 2 and i< j).



Indices in α and δ stand for any of the two source populations. For example, α_i α_j stand for the proportio
population, respectively, where i and j may take any one of the values 1 and 2.

Three sub-models were used to estimate genetic components, respectively, Sub-model 1: model with direct additive, dominance and epistatic effects; Sub-model 2: model with maternal additive, dominance and epistatic effects; Sub-model 3: model with paternal additive, dominance and epistatic effects. All analyses were carried out without considering any reference population. The method of weighted least squares was used for parameter estimation. The goodness of fit of the individual models was tested by the χ^2-test.

Heritability and repeatability

Direct heritability (h_a^2) were computed as: $h_a^2 = \sigma_a^2 / (\sigma_a^2 + \sigma_{Pe}^2 + \sigma)$

Where:
σ_a^2 = direct additive genetic variance,
σ_{Pe}^2 = permanent environmental variance,
and σ = error variance.

Repeatability was expressed as the ratio of variances by summing of additive genetic and permanent environmental variances ($\sigma_a^2 + \sigma_{Pe}^2$) to total phenotypic variance ($\sigma_a^2 + \sigma_{Pe}^2 + \sigma$).

Results and discussion

Actual means

Actual means given in Table 3 indicated the differences between NZW and Gabali breeds were non-significant for LSB, LSW, LWB and LWW, in spite of favorable result of Gabali for all litter trait except LWB.

Table 3. Actual means and their standard errors (SE) for litter traits in genetic groups of rabbits.

Genetic group$^+$	**No.**	**%**	**LSB**$^{++}$	**LWB**$^{++}$	**LSW**$^{++}$	**LWW**$^{++}$
			Mean±SE	**Mean±SE**	**Mean±SE**	**Mean±SE**
Purebred:						
NxN	738	67.8	6.6±0.07^a	429.4± 4.7^a	4.8±0.07^{ab}	2968.1± 44.8^{ab}
GxG	44	4.0	6.8±0.30^a	422.7±19.3^a	5.2±0.30^{ab}	3133.1±183.3^{ab}
Average:			6.5	423.8	5.4	3050.6
Crossbred:						
GNxGN	125	11.5	6.8±0.18^a	423.8±11.4^a	5.4±0.18^{ab}	2965.6±108.8^{ab}
NGxNG	14	1.3	6.9±0.53^a	417.9±34.2^a	5.9±0.54^a	3267.5±325.0^{ab}
GN-NxGN-N	57	5.2	6.1±0.26^a	374.8±16.9^a	4.6±0.27^b	2614.3±161.1^b
NG-NxNG-N	62	5.7	6.7±0.25^a	405.9±16.2^a	5.5±0.25^{ab}	3095.1±154.4^{ab}
(GN-GN)2x(GN-GN)^2	41	3.8	6.3±0.31^a	401.2±20.0^a	4.8±0.31^{ab}	2711.7±189.9^{ab}
G-GNxG-GN	8	0.7	6.6±0.70^a	438.8±45.2^a	5.8±0.71^{ab}	3381.3±430.0^a
Average:			6.7	414.3	5.8	3005.9

$^+$N= New Zealand White breed and G = Gabali breed; $^{++}$LSB, LWB, LSW and LWW= litter size at birth, litter weight at birth, litter size at weaning and litter weight at weaning, respectively. Means with the same letters within each column for purebreds and crossbreds are non-significantly ($P \leq 0.05$) different.

These means are within ranges of the available literature for the same traits of NZW (raised in Egypt) and Gabali local Egyptian breed. The differences among means of LSB and LWB in different genetic crossbred groups were also non-significant. Meanwhile, the differences among some crossbred groups and purebreds were significant ($p<0.05$) for LSW and LWW. Crossbred of NGxNG was the highest mean of LSW, followed by G-GNxG-GN crossbred. Moreover, the crossbred of G-GNxG-GN was the highest mean of LWW, followed by NGxNG group (Table 3). On the other hand, average of all crossbred groups was somewhat high for LSB and LSW comparing with average of purebreds. One could be conclude that crossing between NZW and Gabali increased the litter size traits in rabbits (Khalil 1996).

Direct (g^i), maternal (g^m) and paternal (g^p) breed additive effects

Table 4 showed that additive genetic effects of direct, maternal and paternal were negative and significant ($P<0.05$ or $P<0.01$) and they reduced the general mean of LSB by 1.8, 1.5% and 1.4%, respectively. The negative values for this trait may be due to somewhat higher mean in the local Gabali rabbit breed than in the foreign NZW breed. This is confirmed by the results of the present experiment, as the average LSB of Gabali rabbits was 6.8 slightly higher than NZW rabbits as it was 6.6. This result is in agreement with (Abd El-Aziz 1998; Nayera et al 1999; Abd El-Aziz et al 2002) who reported results in favour of Gabali rabbits.

Table 4. Estimates of crossbreeding effects using Dickerson sub-models for litter size at birth and at weaning in rabbits.

	Sub-models of Dickerson (1969, 1973)$^{++}$		
Effect^{+}	**Model (1)**	**Model (2)**	**Model (3)**
	Litter size at birth (LSB)		
μ	$6.7\pm0.04^{**}$	$6.9\pm0.04^{**}$	$6.7\pm0.04^{**}$
$a^i(g^i)$	$-0.12\pm0.04^{**}$		
$d^i(h^i)$	$-0.27\pm0.13^{*}$		
$aa^i(r^i)$	-0.17 ± 0.12^{ns}		
$a^m\,(g^m)$		$-0.10\pm0.04^{*}$	
$d^m(h^m)$		0.09 ± 0.07^{ns}	
$aa^m(r^m)$		$-1.04\pm0.17^{**}$	
$a^p\,(g^p)$			$-0.10\pm0.04^{*}$
$a^p\,(h^p)$			0.09 ± 0.07^{ns}
$aa^p(r^p)$			$-1.04\pm0.17^{**}$
χ^2	74.6^{**}	40.1^{**}	40.1^{**}
DF	5	4	4
Effect^{+}	**Litter size at weaning (LSW)**		
μ	$5.0\pm0.15^{**}$	$5.0\pm0.15^{**}$	$5.0\pm0.15^{**}$
$a^i(g^i)$	-0.18 ± 0.15^{ns}		
$d^i(h^i)$	0.54 ± 0.38^{ns}		
$aa^i(r^i)$	-22.6 ± 2041.0^{ns}		
$a^m\,(g^m)$		-0.17 ± 0.15^{ns}	
$d^m(h^m)$		0.37 ± 0.23^{ns}	
$aa^m(r^m)$		-0.12 ± 0.48^{ns}	
$a^p\,(g^p)$			-0.17 ± 0.15^{ns}
$a^p\,(h^p)$			0.37 ± 0.23^{ns}
$aa^p(r^p)$			-0.12 ± 0.48^{ns}
χ^2	10.2^{ns}	9.4^{ns}	9.4^{ns}
DF	5	4	4

$^{+}a^i$, a^m and a^p = direct, maternal and paternal additive effects, respectively; d^i, d^m and d^p = direct, maternal and paternal heterosis, respectively; aa^i, aa^m and aa^p = direct, maternal and paternal recombination effects, respectively; χ^2 = chi-calculated value and DF= degrees freedom of model
$^{++}$Model 1 = direct additive, dominance and epistatic effects; Model (2) = maternal additive, dominance and epistatic effects and Model (3) paternal additive, dominance and epistatic effects.

Results in Tables 4 and 5 showed also that negative estimates and non-significant direct, maternal and paternal additive genetic effects (g^i, g^m and g^p) for traits of LSW, LWB and LWW. The negative values for these traits may be attributed to higher means of Gabali breed than NZW rabbits.

Table 5. Estimates of crossbreeding effects using Dickerson sub-model for litter weight at birth and at weaning in rabbits.

Effect$^+$	**Sub-models of Dickerson (1969, 1973)$^{++}$**		
	Model (1)	**Model (2)**	**Model (3)**
	Litter weight at birth (LWB)		
μ	429.9±9.7**	428.8±9.7**	428.8±9.7**
$a^i(g^i)$	-1.8±9.6^{ns}		
$d^i(h^i)$	-43.3±24.6^{ns}		
$aa^i(r^i)$	-40.4±19.0*		
$a^m (g^m)$		-0.13±9.6^{ns}	
$d^m(h^m)$		-8.4±14.5^{ns}	
$aa^m(r^m)$		-70.2±30.6*	
$a^p (g^p)$			-0.13±9.6^{ns}
$a^p (h^p)$			-8.4±14.5^{ns}
$aa^p(r^p)$			-70.2±30.6*
χ^2	7.8^{ns}	4.8^{ns}	4.8^{ns}
DF	5	4	4
Effect$^+$	**Litter weight at weaning (LWW)**		
μ	3068.8±92.3**	3064.1±92.5**	3064.1±92.5**
$a^i(g^i)$	-103.8±91.2^{ns}		
$d^i(h^i)$	-292.5±233.5^{ns}		
$aa^i(r^i)$	-123.8±180.34^{ns}		
$a^m (g^m)$		-96.6±91.7^{ns}	
$d^m(h^m)$		-89.8±137.5^{ns}	
$aa^m(r^m)$		-352.9±290.7^{ns}	
$a^p (g^p)$			-96.6±91.7^{ns}
$a^p (h^p)$			-89.8±137.5^{ns}
$aa^p(r^p)$			-352.9±290.7^{ns}
χ^2	8.1^{ns}	7.5^{ns}	7.5^{ns}
DF	5	4	4

$^+$$a^i$, a^m and a^p = direct, maternal and paternal additive effects, respectively; d^i, d^m and d^p = direct, maternal and paternal heterosis, respectively; aa^i, aa^m and aa^p = direct, maternal and paternal recombination effects, respectively; χ^2 = chi-calculated value and DF= degrees freedom of model .
$^{++}$Model 1 = direct additive, dominance and epistatic effects; Model (2) = maternal additive, dominance and epistatic effects and Model (3) paternal additive, dominance and epistatic effects.

Direct (h^i), maternal (h^m) and paternal (h^p) heterosis

Estimate of dominance (direct heterosis, h^i) effect in Table 4 was of moderate importance on LSB as its negative (decreased the general mean by 4.03%) and significant ($P<0.05$) value could be attributed, in some cases, to the nature of the measurements. Positive insignificant maternal and paternal heterotic effects on LSB trait were observed; they increased the general mean by 1.30 and 1.34%, respectively. Estimates of hybrid vigor with respect to maternal and paternal additive effects were positive which explain the influence of maternal and paternal effects at earlier ages. Negative values of heterotic effects of LSB were obtained by Grandi and Stefantti (1987). Different crossbreeding experiments carried out in Egypt (Khalil et al 1995; Khalil and Afifi 2000) revealed that heterotic effects were evidenced in most of the possible crossbreds for litter size, litter weight and milk yield. Results in Tables 4 and 5 showed that positive and insignificant dominance or heterotic effects (h^i, h^m and h^p) for LSW trait and negative for traits of LWB and LWW. Khalil (1996) and Afifi (1999) reported that crossing between Gabali and NZW rabbits was associated with positive significant direct heterosis, which caused some superiority over mid parents for litter weight at weaning.

Direct (r^i), maternal (r^m) and paternal (r^p) recombination effects

Estimates of recombination effects of r^i, r^m and r^p in Tables 4 and 5 were negative and significant ($P<0.01$) for LSB trait, but negative and non-significant for trait of LSW. They were in adequate respectively percentages as obtained from sub-models 1, 2 and 3 for trait of LSB (reduced the general mean by 9.4, 15.1 and 15.5%) due to crossbreeding effect.

Estimates of recombination effects of r^i, r^m and r^p in Table 5 were negative and non-significant effects on traits of LWB and LWW. These effects reduced the general mean of LWB by 9.4, 16.4 and 16.4%, and mean of LWW by 4.16, 11.5 and 11.5%, respectively. Khalil et al (1995); Khalil (1996); Afifi (1997) and Nayera et al (1999) noted that differences in litter weight due to maternal additive effect were not significant. However, most of the Egyptian findings reported a general trend indicating that litters mothered (direct plus maternal additive effect) by exotic breeds (NZW and California, Chinchilla, ...etc) recorded better performance than litters mothered by native breeds (e.g. Giza White and Baladi rabbits). The estimates of maternal additive effect in the present study were mainly in favour of Gabali dams. This result is in agreement with Abd El-Aziz (1998) who reported the superiority of Gabali breed when compared with NZW one.

Comparing estimates of direct recombination with maternal recombination effects for trait of LWB, it is evident that estimates of direct recombination for LWB were lower (-9.4% of the mean) than the estimate of maternal recombination effect for LWB (-16.4% of the mean). Negative direct recombination losses for litter weight reveal that crossbred does with Gabali genes (NGxNG) could mother litters with higher litter weight at weaning (3267.5 gm) vs 2965.6 gm with Gabali x NZW genes (GNxGN) as found in Table 3.

Comparing the three Dickerson sub-models based on χ^2 - calculated value in Tables 4 and 5, the results indicated that all the three sub-models gave a good fit for traits of LSW, LWB and LWW. But, none of the three sub-models gave a good fit for trait of LSB. It is concluded that using any one of the three Dickerson sub-models could be appropriate to analysis of crossbreeding data.

Genetic parameters

Variance components of additive genetic (σ^2_a), permanent environmental (σ^2_{Pe}), error ($\sigma^{.}_{.}$) and phenotypic (σ^2_p) variances, heritability and repeatability for litter traits of LSB, LWB, LSW and LWW are shown in Table 6.

Table 6. Variance components (direct additive genetic (σ^2_a), permanent environment effect (σ^2_{Pe}), error ($\sigma^{.}_{.}$), phenotypic (σ^2_p), heritability (h^2_a) and repeatability (t) for litter traits in rabbits.

Traits$^+$	**Additive**		**Permanent**		**Error**		**Phenotypic**	**Heritability**	**Repeatability**
	σ^2_a	**%**	σ^2_{Pe}	**%**	$\sigma^{.}_{.}$	**%**	σ^2_p	h^2_a	**t**
LSB	0.1711	4.19	0.962	2.36	3.0815	75.47	4.083	0.04±0.01	0.278
LWB	146.4	0.85	1522.9	8.88	15487.1	90.27	17156.5	0.01±0.008	0.097
LSW	0.3537	7.58	0.0013	4.31	4.312	92.39	4.667	0.08±0.012	0.076
LWW	151286.6	8.96	314863	18.7	1221715	72.38	1687865	0.09±0.009	0.276

$^+$ *Trait as defined in Table (3).*

Percentages of σ^2_a presented in Table 6 were somewhat low or moderate and were 4.19%, 0.85%, 7.58% and 8.96% for LSB, LWB, LSW, and LWW, respectively.

These results showed that the percentage of σ^2_a increased from birth of litter up to weaning. These results are in agreement with reviewed percentage of variance for litter traits estimated by Henderson or REML method, which showed that contribution of sire or dam was generally low or moderate, reflecting the large environmental components of variance associated with the sire (Farid et al 2000). On other hand, results in the present study were higher than values of 0.90 and 0.19 for LSB and LSW traits as obtained by El-Raffa (2000) and Sorensen et al (2001) using animal model analysis.

The proportions of permanent environmental variance (σ^2_{Pe}) for doe performance of litter traits in Table 6 were low or somewhat moderate and were 2.36%, 8.88%, 4.31%, and 18.65% for LSB, LWB, LSW, and LWW, respectively. In general, the small percentages of σ^2_{Pe} may be attributed partially to the large temporary environmental variation (including climatic, sanitary, managerial conditions, ..etc.), which could not be considered in the mathematical model of analysis (Moura et al 1991). Proportions of σ^2_{Pe} were within the ranges of 0.10 to 0.22 % reported by Sorensen et al (2001) and grater than the ranges of 0.0 to 0.10 % reported by Lukefahr and Hamilton (1997).

The proportions of σ^2_{Pe} were generally low at the early ages and increased thereafter with advancing of age till weaning age. This may be due to variation in milk production since the pattern of change in pre-weaning litter traits has also the same curvilinear pattern in milk production; reaching its peak at weaning. Khalil (1996) reported the same conclusion. *Moreover*, permanent environmental effect was higher for traits of LWB and LWW compared to additive genetic variance for the same traits. This indicates the importance of permanent environmental effect on litter weight traits than direct additive genetic variance (Table 6). This conclusion is agreed with findings of Ferraz and Eler (1996).

Heritability

Heritability estimates presented in Table 6 were low and values were 0.04, 0.01, 0.08, and 0.09 for LSB, LWB, LSW and LWW, respectively. These estimates were within the range of reviewed estimates (ranged from 0.0 to 0.20) for litter traits using animal model (Ferraz and Eler 1996; Lukefahr and Hamilton 1997 and Sorensen et al 2001). Small estimates of heritability for litter traits in the present study might be due to the large maternal effects and/or variation due to permanent environmental effect, i.e. increasing non-additive genetic effects. Sampling effects and non-randomness in the distribution of does within sire groups could be added as another causes in this respect (Garcia et al 1982).

Repeatability

Repeatability estimates for litter traits were low or moderate in magnitude (Table 6). Repeatability estimates for LSB and LWW were moderate (0.278 and 0.276, respectively), but low estimate of 0.097 and 0.076, respectively for LSW and LWB. Repeatability estimates presented in this study tended to be close to or within the range of values reported in the literature (Moura et al 1991; Afifi et al 1992 and Lukefahr and Hamilton 1997). Moreover, Afifi et al (1992) reported that repeatability estimates for litter weight at various ages were relatively higher than that for litter size at the corresponding ages. Based on the repeatability estimate for LSB and LWW, this traits could potentially be used, as a culling criterion to improve doe herd productivity in terms of litter mass production**,** *i.e.* LWW is an economically important composite trait for the doe. This is because litter weight at weaning is affected by litter size, kit viability, mothering and milking ability, and growth response of the litter (Lukefahr and Hamilton 1997). On the other hand, for all pre-weaning maternal performance traits, the estimates of repeatability were higher than the estimates of heritability and consequently other permanent contributions to doe production besides direct additive genetic effects could be suggested (e.g. maternal additive and non-additive genetic, direct non-additive genetic, epistatic and environmental effects).

Conclusions

- Based on the comparisons among performance of crossbreds, it is concluded that crossbred of NGxNG was the highest mean of LSW, followed by G-GNxG-GN crossbred. While, the crossbred of G-GNxG-GN was the highest mean of LWW.

- Estimates of hybrid vigor with respect to maternal and paternal additive effects were positive which explain the influence of maternal and paternal effects at earlier ages.

- Based on chi-square computed values for the three Dickerson's sub-models, it is conclude that using any one of sub-models could be appropriate to analysis of crossbreeding data of litter traits in rabbits.

- Proportions of permanent environmental effect (σ^2_{Pe}) were higher for traits of LWB and LWW compared to additive genetic variance for the same traits. This indicates the importance of σ^2_{Pe} on litter weight traits than direct additive genetic variance. Thus, the random effect of σ^2_{Pe} should be considered in animal model analysis for litter traits in rabbits.

- Based on the repeatability estimates for LSB and LWW, these traits could potentially be used, as a culling criterion to improve doe herd productivity in terms of litter mass production**,** *i.e.* LWW is an economically important composite trait for the doe.

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