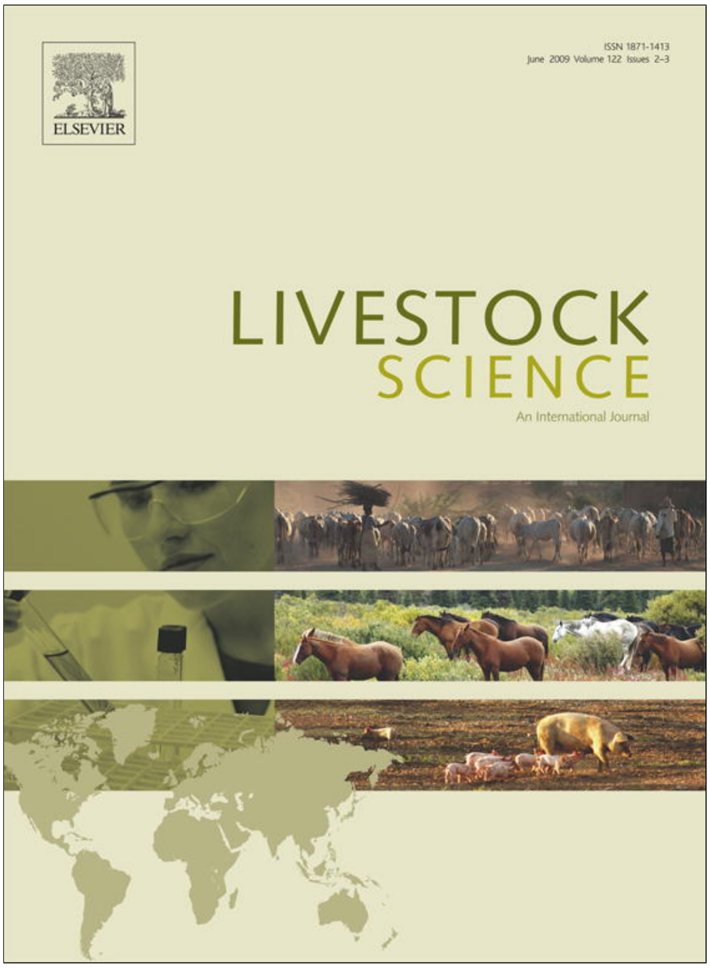
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Crossbreeding effects for post-weaning growth traits in a project of Spanish V-line with Baladi Red Rabbits in Egypt

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A four-year crossing scheme involving Spanish V line (V) and Egyptian Baladi Red (B) rabbits was carried out to produce five genetic groups: V, B, 1/2B1/2V(F_1), $(1/2B1/2V)^2$(F_2), and $((1/2B1/2V)^2)^2$. The last genetic group was considered a new line, named APRI. Body weights (BW) and daily gains in weight (DG) from four to twelve weeks were evaluated for 13,383 rabbits produced by 330 sires and 1074 dams. An animal model was used to estimate heritabilities and common litter effects and a generalized least squares procedure was used to estimate direct additive effects, and direct and maternal heterosis.

Heritabilities for growth traits were mostly moderate, ranging from 0.075 to 0.240 for BW and from 0.020 to 0.104 for DG. The V line was heavier and had better gains at each weighing than B rabbits. The F_2 and APRI were also lower in most post-weaning growth performance measures than V line rabbits. APRI rabbits were significantly lighter by 39, 26, 46, 64, and 50 g at ages of 4, 6, 8, 10, and 12 weeks, respectively, relative to the purebred V line, while APRI was significantly heavier by 36 and 127 g relative to the B line at 4 and 12 weeks. The V line, in general, had a higher DG than B line. The differences were 3.15, 7.91 and 1.95 g/d at age intervals of 8–10, 10–12 and 4–12 weeks. Differences in direct additive effects between the two lines were in favor of V line rabbits reaching 15.0% (76 g) at 4 weeks and 13.3% (195 g) at 12 weeks. Direct additive effects for DG were significant during most age intervals reaching 35.7% (7.19 g/d) in the interval of 10–12 weeks. All estimates of direct heterosis were positive and ranged from 4.9 to 16.7% for BW and 14.4 to 29.5% for DG, but the estimates for maternal heterosis were, in most cases, significantly negative and ranging from −4.5 to −15.2% for BW and from 20.6 to −36.9% for DG. If the results are confirmed at commercial farms, the APRI line could be reared in heat stress conditions.

1. Introduction

Studies concerning formation and genetic analysis of new synthetic lines of rabbits in hot climate countries are scarce; particularly in the Arabian areas (Khalil et al., 2002). Recently, a co-operative rabbit project was established between Egypt and Spain and V line rabbits were used in a crossing program with a local breed named Baladi Red to develop a new line of meat rabbits that could be suitable for the hot climate in Egypt (Youssef et al., 2008). Breeds used in this program were described by Baselga (2002) and Khalil (2002). The synthetic line in the present study has been developed to be used in the future as a pure line or within a crossbred scheme depending on the climatic conditions and production systems in different areas of Egypt. Genetic analyses for some traits in this synthetic line such as litter traits have been made by Youssef et al. (2008), while other traits like growth performance are not yet analyzed. The objectives of the present study were: (i) to evaluate the genetic groups produced when crossing the Spanish V line with Baladi Red (B) to synthesize a new line in Egypt for post-weaning growth traits and (ii) to estimate

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direct additive effects, direct heterosis, and maternal heterosis for these traits in such crosses.

2. Materials and methods

2.1. Animals and breeding plan

A four-year crossbreeding project involving Egyptian B rabbits and the Spanish V line was started in 2003 in Gemmiza and Sakha Experimental Rabbitries which belong to the Animal Production Research Institute (APRI), Agriculture Research Center, Ministry of Agriculture. According to the breeding scheme shown in Table 1, B bucks were mated to V does to get the F_1 (1/2B1/2V), then does and bucks of this F_1 were mated to get the F_2 $(1/2B1/2V)^2$, followed by two generations of *inter se* mating to get a new synthetic line named APRI with a genetic structure of $((1/2B1/2V)^2)^2$. The bucks were randomly assigned to mate the does with the restriction to avoid the matings of animals with common grandparents. Details of the procedures and crossbreeding plan used to form this synthetic line were described by Youssef et al. (2008).

2.2. Housing and feeding

Rabbits were raised in semi-closed rabbitries 15 m long, 12 m wide and 4 m high that extended from east to west. These rabbitries had windows in its northern and southern sides and fans were used to provide enough ventilation. Breeding females and males were housed individually in wire cages with dimensions of 60×35×35 cm arranged in one tier in rows along the rabbitry. The cages of does were equipped with a metal nest box for kindling and nursing the progeny up to weaning. All cages of does and bucks were provided with automatic feeders and nipple-drinkers.

The age at weaning was 4 weeks. Rabbits were fed a standard pelleted diet offered *ad libitum*. The diet was composed by 32% barley, 21% wheat bran, 10% soybean meal, 22% alfalfa hay, 6% berseem straw, 3% corticated cottonseed meal, 3% molasses, 1% limestone, 0.34% table salt, 0.3% minerals and vitamins, 0.06% methionine and 1.3% anti-coccidial. This diet provides 16.3% crude protein, 13.2% crude fiber, 2.5% ether extract, 0.6% mineral mixture, 67.4% soluble carbohydrates and 2600 kcal/kg.

Table 1
Genetic groups of rabbits with their sires and dams and coefficients of the matrix relating genetic group means of rabbits with crossbreeding parameters.

Genetic group				Mean	Coefficients of the matrix			
Rabbit	Sire	Dam	Grand-dam		D_B	D_V	H^I	H^M
Baladi Red (B)	B	B	B	1	1	0	0	0
V line (V)	V	V	V	1	0	1	0	0
1/2B1/2V	B	V	V	1	.5	.5	1	0
$(1/2B1/2V)^2$	1/2B1/2V	1/2B1/2V	V	1	.5	.5	.5	1
APRI	$(1/2B1/2V)^2$	$(1/2B1/2V)^2$	1/2B1/2V	1	.5	.5	.5	.5

D_B and D_V = direct additive genetic effects for the Baladi Red breed and the V line, respectively; H^I = direct heterosis; H^M = maternal heterosis; APRI = name of the new synthetic line which nominates to Animal Production Research Institute.

Table 2
Summary statistics for post-weaning growth traits.

Trait	Number	Average	Standard deviation	Minimum	Maximum
Body weight (g)					
4 weeks	13,383	501	67	305	1090
6 weeks	12,788	740	97	440	1715
8 weeks	12,304	1028	128	520	1910
10 weeks	11,539	1323	151	820	2140
12 weeks	10,957	1651	174	1090	2480
Daily gain (g/d)					
4–6 weeks	12,779	17.04	4.35	0.71	53.93
6–8 weeks	12,298	20.54	4.22	0.71	53.57
8–10 weeks	11,536	20.90	4.29	1.79	51.43
10–12 weeks	10,950	23.23	4.57	1.73	57.86
4–10 weeks	11,539	19.53	2.72	9.64	35.00
4–12 weeks	10,957	20.50	2.42	9.91	34.64

2.3. Model of analysis and estimation of crossbreeding genetic effects

A total of 13,383 rabbits produced by 330 sires and 1074 dams were used in the analysis. Data on post-weaning body weights and gains were analyzed using a single-trait animal model as:

$$\mathbf{y} = \mathbf{Xb} + \mathbf{Z}_a\mathbf{u}_a + \mathbf{Z}_c\mathbf{u}_c + \mathbf{e}$$

where $\boldsymbol{y}$ = vector of records of the trait: $\boldsymbol{b}$ = vector of fixed effects: genetic groups of the rabbits (5 levels, see Table 1), year-season of birth (17 levels), and parity order (5 levels); $\boldsymbol{u}_a$ = vector of random additive effects; $\boldsymbol{u}_c$ = vector of random effects of the litter of birth; $\mathbf{X}$, $\mathbf{Z}_a$ and $\mathbf{Z}_c$ = incidence matrices relating records to the fixed effects, additive genetic effects, and litter effects, respectively; and $\boldsymbol{e}$ = vector of random errors. The inverse of the numerator relationship (A^{-1}) was considered; $\mathrm{Var}(\boldsymbol{u}_a) = A\sigma^2_a$, $\mathrm{Var}(\boldsymbol{u}_c) = I\sigma^2_c$, $\mathrm{Var}(\boldsymbol{e}) = I\sigma^2_e$. The heritabilities were computed from estimates of variance components as $\frac{\sigma^2_a}{\sigma^2_a + \sigma^2_c + \sigma^2_e}$.

Variance components of random effects were estimated by a derivate-free restricted maximum likelihood procedure using MTDFREML software of Boldmann et al. (1995). These estimates were used to solve the corresponding mixed model equations, obtaining solutions for the genetic group means and their error variance–covariance matrix, using the PEST program (Groenoveld, 2006). To get the estimates of the crossbreeding genetic parameters of the lines (Dickerson, 1992), a procedure of generalized least squares was applied using the following linear model:

$$\mathbf{y} = \mathbf{Xb} + \mathbf{e}, \quad \mathrm{Var}(\mathbf{y}) = \mathbf{V}$$

where $\boldsymbol{y}$ = vector of estimated group means, using the genetic group of the B line as a reference population; $\mathbf{X}$ = incidence matrix; $\boldsymbol{b}$ = vector of estimable crossbreeding genetic effects; $\boldsymbol{e}$ = vector of random errors and V = the error variance–covariance matrix of $\boldsymbol{y}$. The coefficients relating genetic crossbreeding parameters to the means of the genetic groups are shown in Table 1 (Wolf et al., 1995). Because the reciprocal cross, V×B, was not carried out, the maternal additive effects

Table 3
Heritabilities (h^2) and ratios of the variance of the common litter effect to the phenotypic variance (c^2), with their standard errors (±SE) for post-weaning growth traits.

Trait	$h^2 \pm$ SE	$c^2 \pm$ SE
Body weight (g)		
4 weeks	0.240 ± 0.073	0.489 ± 0.030
6 weeks	0.096 ± 0.025	0.396 ± 0.011
8 weeks	0.075 ± 0.019	0.347 ± 0.010
10 weeks	0.192 ± 0.020	0.285 ± 0.010
12 weeks	0.127 ± 0.023	0.255 ± 0.010
Daily gain (g/d)		
4–6 weeks	0.086 ± 0.034	0.253 ± 0.017
6–8 weeks	0.041 ± 0.010	0.223 ± 0.008
8–10 weeks	0.020 ± 0.011	0.237 ± 0.009
10–12 weeks	0.020 ± 0.008	0.183 ± 0.009
4–10 weeks	0.094 ± 0.030	0.227 ± 0.015
4–12 weeks	0.104 ± 0.040	0.263 ± 0.019

showed a high co-linearity with the direct additive effects because the corresponding errors highly correlated. For this reason the maternal additive effects have been excluded from the model and the estimates of the direct additive effects must be interpreted as a balance between the direct and maternal additive effects. The crossbreeding parameters of direct additive effects and direct and maternal heterosis were estimated using the CBE program of Wolf (1996).

2.4. Data set

Live body weights were recorded biweekly at 4 (W4, g), 6 (W6, g), 8 (W8, g), 10 (W10, g), and 12 weeks (W12, g) of age, while daily gain in weight was computed at intervals of 4–6 (DG46, g/day), 6–8 (DG68, g/day), 8–10 (DG810, g/day), 10–12 (DG1012, g/day), 4–10 (DG410, g/day), and 4–12 weeks (DG412, g/day) of age.

3. Results and discussion

3.1. Actual means and variations

Results in Table 2 describe the post-weaning performance. Wide phenotypic variance was observed in all traits.

The mean individual weight at 4 weeks (501 g., Table 2) was similar to values obtained for V line reared in Spain (García and Baselga, 2002) and in Egypt (El-Raffa, 2000), but this weight was lower in Saudi Arabia (Al-Saef et al., 2008). Nevertheless, at the end of the fattening period the weight was lower in hot climates (1831 g at 9 weeks, García and Baselga, 2002), so the V line in Spain grew faster than rabbits in Egypt (37.9 g/day between weaning and 9 weeks of age; García and Baselga, 2002).

3.2. Heritabilities (h^2) and litter effects (c^2)

Estimates of h^2 for body weights were mostly moderate and ranged from 0.075 to 0.240, while the estimates for average daily gain ranged from 0.020 to 0.104 (Table 3). Moderate heritabilities obtained here for body weights were similar to the estimates obtained in other studies in Egypt (Khalil et al., 1993; Khalil et al., 2000), in Spain (Estany et al., 1989; Gómez et al., 2000), and in Brazil (Ferraz et al., 1991, 1992; Ferraz and Eler, 1996). Published estimates of heritability of daily gain were higher than in this experiment (Moura et al., 1997; Piles et al., 2004a).

Estimates of c^2 for post-weaning body weights were mostly high and ranged from 0.255 to 0.489, but moderate for daily gains which ranged from 0.183 to 0.263 (Table 3). Ferraz and Eler (1996) found that the magnitudes of c^2 for post-weaning body weights were moderate with a range between 0.21 and 0.32. The values of c^2 were always higher than the heritabilities, and the importance of litter effects decreased over the time (Table 3). These tendencies agree with the results reported by McNitt and Lukefhar (1996) and García and Baselga (2002).

3.3. Comparing the genetic groups

Table 4 shows the contrasts of the differences for the effects of B line, F_1, F_2 and APRI relative to V line. The weight at 4, 10 and 12 weeks of age was higher for V than B rabbits (14.6%, 5.1% and 10.7%, respectively). The F_1 was heavier than V line from 6 to 12 weeks of age. The F_2 and APRI had lower weights than V line rabbits. The lower values observed in the F_2 compared to F_1 for the majority of traits would be expected

Table 4
Contrasts of differences for the effects of Baladi Red (B), F_1, F_2 and APRI relative to V line for post-weaning growth traits.

Trait	Line V vs. B		Line V vs. F_1		Line V vs. F_2		Line V vs. APRI	
	Contrast ± SE	%+	Contrast ± SE	%	Contrast ± SE	%	Contrast ± SE	%
Body weight (g)								
4 weeks	75 ± 13*	14.6	13 ± 10	2.5	49 ± 9*	9.6	39 ± 10*	7.6
6 weeks	15 ± 16	2.0	−90 ± 12*	−12.0	74 ± 10*	9.9	26 ± 10*	3.5
8 weeks	25 ± 20	2.4	−128 ± 15*	−12.3	86 ± 13*	8.3	46 ± 12*	4.4
10 weeks	68 ± 26*	5.1	−163 ± 20*	−12.3	85 ± 18*	6.4	64 ± 19*	4.8
12 weeks	177 ± 28*	10.7	−155 ± 21*	−9.4	60 ± 19*	3.6	50 ± 19*	3.0
Daily gain (g/d)								
4–6 weeks	−4.33 ± 0.64*	−25.5	−7.66 ± 0.49*	−45.1	2.11 ± 0.42*	12.4	−0.46 ± 0.42	−2.7
6–8 weeks	0.78 ± 0.58	3.7	−2.75 ± 0.43*	−13.1	0.74 ± 0.35*	3.5	1.39 ± 0.32*	6.6
8–10 weeks	3.15 ± 0.58*	15.0	−2.22 ± 0.43*	−10.6	−1.12 ± 0.33*	−5.3	−0.02 ± 0.26	−0.1
10–12 weeks	7.91 ± 0.62*	34.4	0.38 ± 0.45	1.6	−2.05 ± 0.34*	−8.9	−0.99 ± 0.28*	−4.3
4–10 weeks	−0.05 ± 0.41	−0.3	−4.14 ± 0.31*	−21.8	0.74 ± 0.27*	3.9	0.52 ± 0.27	2.7
4–12 weeks	1.95 ± 0.38*	9.8	−2.99 ± 0.29*	−15.0	0.19 ± 0.25	0.9	0.23 ± 0.25	1.1

+Estimates expressed as percentages relative to Baladi Red breed.
*$P<0.05$.

under our model of crossbreeding (Table 1) if the direct heterosis is positive and the maternal heterosis is negative. Table 7 shows that the estimates of direct heterosis were positive for all traits and the estimates of maternal heterosis negative for all traits, excepted daily gains between 8–10 weeks and 10–12 weeks. These results showed good performance of V line rabbits in post-weaning growth, reflecting also the fact that involving V line genes in crossbreeding programs with local rabbits in hot climate countries was associated with an improvement in post-weaning growth performance of the crossbred rabbits obtained.

The F_1, F_2 and APRI genetic groups of this study had higher post-weaning growth performance than crossbreds involving V line and Gabali rabbits in the Arabian areas (Abdel-Aziz, 1998; Ali, 1998; Khalil and Afifi, 2000). Medellin and Lukefahr (2001) studied body weights at weaning at 28d (WW), at marketing at 70d (MW) and average daily gain during this period (ADG) in Altex, New Zealand White (NZW) and their crosses in USA. They found that in Altex-sired rabbits, relative to NZW-sired rabbits, the WW was increased by 40 g, the MW by 152 g and the ADG by 2.5 g/d. The straight bred Altex rabbits compared to NZW were superior by 216 g in MW and by 3.6 g/d in ADG.

In order to evaluate the results of the synthetic line (APRI), contrasts between this line and V line (Table 4) and B line (Table 5) were estimated. These contrasts were used to evaluate the possibility of using these rabbits as a synthetic line. APRI rabbits were significantly heavier by 36 and 127 g in weights at 4 and 12 weeks, respectively, relative to the B line (Table 5). In comparison with the purebred V line, the estimates for APRI rabbits were significantly lighter by 39, 26, 46, 64, and 50 g at ages of 4, 6, 8, 10, and 12 weeks, respectively (Table 4).

Concerning daily gains, APRI rabbits were superior to the B rabbits by 3.17, 8.90 and 1.72 g/d at age intervals of 8–10, 10–12, and 4–12 weeks, respectively (Table 5). Analyses of crossbreeding experiments carried out in the Arabian countries (Afifi et al., 1994; El-Deghadi, 2005) showed lower estimates in growth traits than the obtained here for the synthetic line.

Table 6
Estimates of difference between Baladi Red and V line in direct additive effect (D_{B-V}) and their standard errors (SE) for post-weaning growth traits.

Trait	D_{B-V} in units ± SE	D_{B-V} %
Body weight (g)		
4 weeks	−76 ± 13*	−15.0
6 weeks	−20 ± 15	−2.7
8 weeks	−42 ± 19*	−4.2
10 weeks	−92 ± 25*	−7.4
12 weeks	−195 ± 27*	−13.3
Daily gain (g/d)		
4–6 weeks	3.86 ± 0.62*	20.9
6–8 weeks	−1.71 ± 0.55*	−8.3
8–10 weeks	−3.62 ± 0.54*	−17.7
10–12 weeks	−7.19 ± 0.58*	−35.7
4–10 weeks	−0.55 ± 0.39	−2.8
4–12 weeks	−2.26 ± 0.36*	−11.5

D_{B-V} % = [D_{B-V} in units / (average of V line and Baladi Red groups)] × 100.
*P<0.05.

3.4. Direct breed additive effects

Differences in direct additive effects between the two lines were in favour of V line rabbits with differences as high as 15.0% at 4 weeks and 13.3% at 12 weeks (Table 6). The difference in direct additive effects between V line and B rabbits was 195 g at 12 weeks (Table 6). The difference in daily gains was significant and in favor of V line in most age intervals reaching 35.7% at 10–12 weeks of age. Masoero et al. (1985, 1992) also reported significant direct additive effects for body weights at later ages in a crossing experiment with New Zealand White, Californian, Burgundy Fawn, Flemish Giant, Argenté de Champagne and Blue Vienna. When paternal lines were involved in the cross there was a difference between the lines in the live weight at 60 days of age but not in the growth rate (Piles et al., 2004b).

In Egypt, Abdel-Ghany et al. (2000a,b) noted that direct additive effects from crossing NZW with Baladi Red or Baladi Black were consistently in favour of Baladi Red or Baladi Black for post-weaning body weights and gains. When V line was

Table 5
Contrasts of differences for the effects of F_1, F_2 and APRI relative to Baladi Red (B) for post-weaning growth traits.

Trait	B vs. F_1 Contrast ± SE	B vs. F_1 %[+]	B vs. F_2 Contrast ± SE	B vs. F_2 %	B vs. APRI Contrast ± SE	B vs. APRI %
Body weight (g)						
4 weeks	−62 ± 14*	−12.3	−26 ± 15	−5.2	−36 ± 16*	−7.2
6 weeks	−105 ± 17*	−14.0	60 ± 19*	8.0	12 ± 19	1.6
8 weeks	−153 ± 22*	−16.3	61 ± 23*	6.5	21 ± 23	2.2
10 weeks	−230 ± 28*	−20.0	18 ± 31	1.6	−4 ± 31	−0.3
12 weeks	−332 ± 30*	−26.0	−117 ± 33*	−9.2	−127 ± 33*	−10.0
Daily gain (g/d)						
4–6 weeks	−3.33 ± 0.70*	−16.7	6.44 ± 0.76*	32.4	3.87 ± 0.76*	19.4
6–8 weeks	−3.53 ± 0.63*	−17.6	−0.04 ± 0.67	−0.2	0.61 ± 0.65	3.0
8–10 weeks	−5.37 ± 0.62*	−27.0	−4.27 ± 0.66*	−21.4	−3.17 ± 0.63*	−15.9
10–12 weeks	−7.53 ± 0.66*	−43.5	−9.95 ± 0.70*	−57.5	−8.90 ± 0.67*	−51.4
4–10 weeks	−4.09 ± 0.44*	−20.5	0.79 ± 0.48	4.0	0.57 ± 0.48	2.9
4–12 weeks	−4.94 ± 0.41*	−25.6	−1.75 ± 0.44*	−9.1	−1.72 ± 0.45*	−8.9

[+]Estimates expressed as percentages relative to Baladi Red breed.
*P<0.05.

Table 7
Estimates of direct (H^I) and maternal (H^M) heterosis and their standard errors (SE) for post-weaning growth traits.

Trait	H^I in units ± SE	H^I %	H^M in units ± SE	H^M %
Body weight (g)				
4 weeks	25 ± 11*	4.9	−23 ± 9*	−4.5
6 weeks	97 ± 13*	13.0	−114 ± 12*	−15.2
8 weeks	138 ± 16*	14.0	−138 ± 15*	−14.0
10 weeks	199 ± 21*	16.1	−132 ± 18*	−10.6
12 weeks	244 ± 22*	16.7	−84 ± 20*	−5.7
Daily gain in weight (g/d)				
4–6 weeks	5.46 ± 0.51*	29.5	−6.82 ± 0.47*	−36.9
6–8 weeks	2.95 ± 0.45*	14.4	−1.69 ± 0.42*	−8.2
8–10 weeks	3.65 ± 0.45*	17.8	0.84 ± 0.42*	4.1
10–12 weeks	3.77 ± 0.47*	18.8	4.13 ± 0.44*	20.6
4–10 weeks	4.09 ± 0.32*	20.9	−2.53 ± 0.29*	−13.0
4–12 weeks	3.95 ± 0.30*	20.1	−1.05 ± 0.27*	−5.3

H^I% = [H^I in units / average of V line and Baladi groups] × 100; H^M% = [H^M in units / average of V line and Baladi groups] × 100.
*P<0.05.

crossed with another maternal line (A line) and one paternal line (R line), the body weights and gains from 32 to 60 day in V and A line and their crosses were the least while the R line and its crosses were the greatest (Gómez et al., 1999).

3.5. Direct and maternal heterosis

The estimates of direct and maternal heterosis for all growth traits were significant (Table 7). Percentages of direct heterosis for post-weaning body weights showed that the pattern of heterotic effects increased generally with advance of the rabbit's age. The estimates of direct heterosis were positive and ranging from 4.9 to 16.7% for body weights and 14.4 to 29.5% for daily gains, but the estimates for maternal heterosis were mainly negative and ranging from −4.5 to −15.2% for body weights and from 20.6 to −36.9% for daily gains.

Results of direct heterosis in the present study are similar to those estimates obtained in other crossbreeding experiments involving maternal lines (Orengo et al., 2004). Gómez et al. (1999, 2002) for a crossbreeding experiment including the V line in Spain reported non significant direct and maternal heterosis for body weights at 32 and 60 days and daily gains between the two ages. Afifi et al. (1994) when crossing NZW with B rabbits in Egypt found that heterosis percentages ranged from 2.7 to 9.5% for post-weaning body weights and gains. Medellin and Lukefahr (2001) in USA stated that estimates of direct heterosis for the cross between Altex rabbits and NZW were 66 g for weaning weight at 28 days and 1.7 g/d for average daily gain between 28–70 days. Nevertheless, heterosis was not found for growth in a complete diallel cross between two large-size lines of rabbit, both selected for growth rate in the fattening period (Piles et al., 2004b).

4. Conclusion

The synthetic line between V line and B rabbits, the APRI line, appears intermediate between the founders in growth traits, when raised in environmental conditions of experimental stations, placed in the delta of Nile. In these conditions the APRI is a better alternative than the B line but worse than the V line. More studies are needed to know the performance of this line and its crosses in other conditions such as with the small holders of the delta of Nile and the experimental station and small holders in Upper Egypt.

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References

Abdel-Aziz, M.M.,1998. Crossbreeding between Al-Gabali and New Zealand White rabbits in the North Coast-Belt of the Egyptian Western Desert. Ph. D. Thesis, Faculty of Agriculture at Moshtohor, Zagazig University, Egypt.

Abdel-Ghany, A.M., Ahmed, E.G., Hassan, N.S., 2000a. Crossbreeding genetic parameters of post-weaning growth traits of the Egyptian acclimatised New Zealand White and native Baladi Black rabbits. 7th World Rabbit Congr. Valencia, (Spain), vol. A, pp. 317–323.

Abdel-Ghany, A.M., Hassan, N.S., Amin, A.A., 2000b. Heterosis, direct and maternal abilities of post-weaning daily gain in weight traits of two Egyptian native breeds on account of crossing with New Zealand White rabbits. 7th World Rabbit Congr., Valencia, (Spain), vol. A, pp. 325–331.

Afifi, E.A., Khalil, M.H., Khadr, Amina, F., Youssef, Y.M.K., 1994. Heterosis, maternal and direct effects for postweaning growth traits and carcass performance in rabbit crosses. J. Anim. Breed. Genet. 111, 138–147.

Ali, S.M., 1998. Evaluation of growth and production performance of Al-Gabali rabbits and their crosses under semi-arid conditions. Ph.D. Thesis, Faculty of Agriculture at Moshtoher, Zagazig University, Egypt.

Al-Saef, A.M., Khalil, M.H., AL-Homidan, A.H., Al-Dobaib, S.N., Al-Sobayil, K.A., García, M.I., Baselga, M., 2008. Crossbreeding effects for litter and lactation traits in a Saudi Project to develop new lines of rabbits suitable for hot climates. Livest. Sci. 118, 238–246.

Baselga, M., 2002. Line V. Rabbit Genetic Resources in Mediterranean Countries. Options Méditerranénnes, Ed. Series B, No 38, 231–241.

Boldmann, K.G., Kriese, L.A., Van Tassell, C.P., Kachman, S.D., 1995. A manual for use of MTDFREML. A set programs to obtain estimates of variances and covariance [DRAFT]. U.S. Department of Agriculture, Agricultural Research Service, USA.

Dickerson, G.E., 1992. Manual for evaluation of breeds and crosses of domestic animals. Food and Agriculture Organization of the United Nations, Rome, p. 47.

El-Deghady, A.S., 2005. Genetic evaluation for some productive traits in rabbits. Ph.D. Thesis, Faculty of Agriculture, Banha University, Egypt.

El-Raffa, A.M., 2000. Animal model evaluation of V Line Rabbits raised under Egyptian conditions. Egypt. Poult. Sci. 20, 1003–1016.

Estany, J., Baselga, M., Blasco, A., Camacho, J., 1989. Mixed model methodology for the estimation of genetic response to selection in litter size of rabbits. Livest. Prod. Sci. 21, 67–76.

Ferraz, J.B.S., Eler, J.P., 1996. Comparison of animal models for estimation of (co)variance components and genetic parameters of reproductive, growth and slaughter traits of California and New Zealand rabbits raised under tropical conditions. 6th World Rabbit Cong. Toulouse, (France), vol. 2, pp. 279–284.

Ferraz, J.B.S., Johnson, R.K., Eler, J.P., 1991. Genetic parameters for growth and carcass traits of rabbits. J. Appl. Rabbit Res. 14, 187–192.

Ferraz, J.B.S., Johnson, R.K., Van Vleck, L.D., 1992. Estimation of genetic trends and genetic parameters for reproductive and growth traits of rabbits raised in subtropics with animal model. J. Appl. Rabbit Res. 15, 131–142.

García, M.L., Baselga, M., 2002. Estimation of correlated response on growth traits to selection in litter size of rabbits using a cryopreserved control population and genetic trends. Livest. Prod. Sci. 78, 91–98.

Gómez, E.A., Rafel, O., Ramon, J., Baselga, M., 1999. Feeding efficiency in crossbreeding among three of the strains selected in Spain. 2nd International Conference on Rabbit Production in Hot Climates, Adana, (Turkey), vol. 41, pp. 153–158.

Gómez, E.A., Rafel, O., Ramon, J., 2000. Preliminary genetic analysis of Caldes line: A selection experiment for a global objective. 7th World Rabbit Congr. Valencia, (Spain), vol. A, pp. 417–423.

Gómez, E.A., Piles, M., Orengo, J., Rabel, O., Ramon, J., 2002. Estimation of crossbreeding parameters for average daily gain, feed intake and feed conversion rate in five rabbit lines. 7th World Congr. on Genet. Appl. to Livest. Prod. Montpellier, (France), Communication no 04-40.

Groenoveld, E., 2006. PEST User's Manual, Institute of Animal Science, Holtystrabe 10, D-31535 Neustadt, Germany.

Khalil, M.H., 2002. The Baladi rabbits. Options Méditerranénnes, Series B, No, 38, pp. 37–50.

Khalil, M.H., Afifi, E.A., 2000. Heterosis, maternal and direct additive effects for litter performance and post-weaning growth in Gabali rabbits and their F_1 crosses with New Zealand White. 7th World Rabbit Congr. Valencia, (Spain), vol. A, pp. 431–437.

Khalil, M.H., Soliman, A.M., Khalil, H.H., 1993. Genetic aspects and litter size correction factors for postweaning growth in New Zealand White and Californian rabbits. Egypt. J. Rabbit Sci. 3 (2), 199–217.

Khalil, M.H., Ibrahim, M.K., Youssef, Y.M.K., Daghady, A.S., 2000. Estimation of sire transmitting abilities for post-weaning growth traits in New Zealand White and Californian rabbits raised in adverse hot climatic Egyptian conditions using animal model. Egypt. Poult. Sci. 20 (1), 65–90.

Khalil, M.H., Al-Sobayel, K., Hermes, I.H., Al-Homidan, A.H., 2002. Crossbreeding effects for post weaning growth, rectal and ear temperatures and respiration rates in crossing Saudi Gabali with Spanish V-line rabbits. 7th World Congr. on Genet. Appl. to Livest. Prod. Montpellier, (France), Communication no 04-12.

Masoero, G., Ubertalle, A., Mazzocco, P., Battaglini, L.M., 1985. Terminal crossing of New Zealand White and Californian Rabbits. (2) Characteristics on the live animal. Annalidell Istituto Sperimentale per la Zootecnia, 18(2): 93-109 (Animal Breeding Abstract, 55, No. 1264).

Masoero, G., Napolitano, F., Bergoglio, G., Riccioni, L., Zoccarato, I., 1992. Crossbreeding experiment of New Zealand White females with White

Giant, Pure and synthetic and stabilized strains in conventional or fasted preslaughter condition. J. Appl. Rabbit Res. 15, 166–173.

McNitt, J.I., Lukhefahr, S.D., 1996. Genetic and environmental parameters for postweaning growth traits of rabbits using an animal model. 6th World Rabbit Congr. Toulouse, (France), vol. 2, pp. 325–329.

Medellin, M.F., Lukefahr, S.D., 2001. Breed and heterosis effects on post-weaning traits in Altex and New Zealand White straightbred and crossbred rabbits. J. Anim. Sci. 79 (5), 1173–1178.

Moura, A.S.A.M.T., Kaps, M., Vogt, D.W., Lamberson, W.R., 1997. Two-way selection for daily gain and feed conversion in a composite rabbit population. J. Anim. Sci. 75, 2344–2349.

Orengo, J., Gómez, E.A., Piles, M., Rafel, O., Ramón, J., 2004. Growth traits in simple crossbreeding among dam and sire lines. 8th World Rabbit Congr. Puebla, (Mexico), pp. 114–120.

Piles, M., Gómez, E.A., Rafel, O., Ramón, J., Blasco, A., 2004a. Elliptical selection experiment for the estimation of genetic parameters of growth rate and feed conversion ratio in rabbits. J. Anim. Sci., 82, 654–660.

Piles, M., Rafel, O., Ramon, J., Gómez, E.A., 2004b. Crossbreeding parameters of some productive traits in meat rabbits. World Rabbit Sci. 12, 139–148.

Wolf, J., 1996. User's Manual for the Software Package CBE, Version 4.0 (A universal program for estimating crossbreeding effects). Research Institute of Animal Production, Prague-Uhrineves, Czech Republic.

Wolf, J., Distl, O., Grosshan, T., Seeland, G., 1995. Crossbreeding in farm animals. V. Analysis of crossbreeding plans with secondary crossbred generations. J. Anim. Breed. and Genet. 112, 81–94.

Youssef, Y.K., Baselga, M., Khalil, M.H., Gad-Alla, S., García, M.L., 2008. Evaluation of litter traits in a crossing project of Spanish V-line and Baladi Red rabbits in Egypt. Livestock Research for Rural Development 20(9), Article 135.