ISSN 1110-0419

Annals Of Agric. Sc., Moshtohor,
Vol. 45(3): 1091-1109, (2007).

CROSSBREEDING GENETIC EFFECTS FOR GROWTH AND LIVABILITY TRAITS IN RABBITS RAISED UNDER HOT CLIMATE CONDITIONS

BY

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ABSTRACT

This study was carried out within a project for five consecutive production years. This project involved Egyptian Gabali and New Zealand White (NZW) rabbits. Data of Fourteen different genetic groups of rabbits (represented by 4208 NZW and 255 Gabali purebreds and 4022 crossbreds of different genetic combinations between them with different genetic percentages in progeny produced rabbits) were used. Traits of growth (body weight at weaning (BW4), 8 (BW8) and 12 (BW12) weeks of age, as well as daily gain during intervals of 4-8 (DG4-8), 8-12 (DG8-12) and 4-12 (DG4-12) weeks of age and post-weaning livability traits during the periods from 4-8 (L4-8) and 8-12 (L8-12) weeks of age were studied. Data were analyzed using crossbreeding effect program to estimate crossbreeding genetic components (additive, heterosis and recombination effects of direct individual, maternal and paternal components, respectively).

Results showed that the differences between NZW and Gabali breeds were non-significance for all the studied traits, in spite of favorable results of Gabali breed for all traits except DG8-12.The crossbred genetic group contained 75% of Gabali and 25% of NZW blood was the heaviest in body weights at 4, 8 and 12 weeks of age. These results explained the good mothering ability of Gabali rabbit breed. Direct additive genetic effects were negative and significant for most traits. Maternal additive effects (g^M) on traits of BW8, BW12 and L8-12 were significant ($P<0.01$) and negative estimates, beyond L8-12. Estimates of additive paternal (g^P) were negative and significant ($P<0.01$) effect for traits of BW8 and BW12 and significantly ($P<0.01$) positive on livability trait of L8-12. Most estimates of direct heterosis (h^I) were positive and significant ($P<0.05$-0.01) for all the studied traits, except DG4-12. Percentages of h^I ranged from –3.9 to 32.3%, -17.33 to 5.04% and –95 to 43.75% for body weight, daily gain and livability traits, respectively. Estimates of maternal (h^M) and paternal (h^P) heterosis were significant ($P<0.05$-0.01) and negative estimates for most the studied traits. Effects of direct recombination (r^I) were positive and significant ($P<0.01$) for traits of BW4, BW8 and L4-8. Effects of maternal recombination (r^M) were negative for most the studied traits and significant ($P<0.01$) only for traits of BW12, DG8-12 and DG4-12. Positive and significant ($P<0.01$) effect of r^M on L8-12 (0.72%) was obtained. Effects of paternal recombination (r^P) were negative for all the studied traits and significant (P<0.01) only for traits of BW12, DG4-8, DG8-12 and DG4-8. Epistatic effects of direct, maternal and paternal effects of additive x dominance and dominance x dominance are important on post-weaning growth and livability traits. Models of 3 and/or 4 are preferred to analysis crossbreeding data of rabbits, because these models included most of genetic components influencing traits.

Key words: additive, dominance, epistatic effects, heterosis, recombination effects.

INTRODUCTION

Crossbreeding has been established breeding systems to exploit the heterosis in animal breeding and it could be successfully employed in rabbit breeding for increased productivity. Results of most crossbreeding experiments carried out in Egypt reported that crossing does of New Zealand White (NZW) breed with bucks of local breeds were generally associated with heterotic effects on growth traits (Afifi *et al.*, 1994 and Khalil *et al.*, 1995). Crossbreeding program of NZW rabbits with local Gabali breed may be suitable to increase rabbit meat production. Paternal and maternal additive effects, maternal and paternal heterosis from crossbreeding experiments including Gabali and NZW rabbits were expected to be important especially for growth traits (Khalil *et al.*, 1995)

Sinai Gabali rabbits raised under Egyptian conditions characterized by large litter size of 8-12 young and heavy body weight of 3.5-4.5 kg (Galal and Khalil 1994). Breed of NZW 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). In Egypt, we need more trails to produce crossbred does that have superiority in growth and livability traits.

Objectives of this work were: (1) compare the performance of pure breeds of Gabali and NZW rabbits and their different crossbred groups for traits of growth and post-weaning livability traits, (2) estimate of crossbreeding effects, i.e. direct additive, heterotic and recombination effects in direct, maternal and paternal components for the previous traits, (3) determine the superior genetic group/groups adapted to be produce baby rabbits characterized by high livability and meat production in Egypt and (4) fit models to be used for analysis of crossbreeding data.

MATERIAL AND METHODS

Data used in the present study were 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. This project involving Egyptian Gabali (were brought from the rabbitry of Maryout Experimental Station) and New Zealand White, NZW, (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. Each cage of doe was 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 then after 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 25^{th} 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 buck were cleaned and disinfected regularly while that of does and nest boxes each kindling. All breed groups of rabbits were subjected to the same environmental, medication and managerial conditions.

Data and statistical analysis

Individual post-weaning body weight at 4 (BW4), 8 (BW8) and 12 (BW12) weeks of age were recorded; daily gain weight during the periods from 4-8 (DG4-8), 8-12 (DG8-12) and 4-12 (DG4-12) weeks were computed, as well as post weaning livability traits during the periods from 4-8 (L4-8) and 8-12 (L8-12) weeks of age were recorded for 14 genetic groups. Data structure of mating groups and numbers of offspring weaned, sires, dams used from different genetic groups in this study are illustrated in Table 1.

$$y = Xb + Z_a u_a + Z_c u_c + e \qquad \text{(Model 1)}$$

where: y= vector of observations of the i^{th} trait on animals; b= vector of fixed effects of breed group (14 levels), sex (2 levels, male and female) and year-season of birth (15 levels); u_a= vector of random direct additive genetic effect of the animal for the i^{th} trait; u_c= vector of random common environmental litter effect (dam x litter size at birth x parity combination); X, Z_a and Z_c are incidence matrices relating records of the i^{th} trait to the fixed effects (breed group, sex and year-season), random animal effects and random common litter effects, respectively, e= vector of random error. Three traits for each body weights and daily gains, two traits for livability were analyzed at the same time in MTAM, respectively.

Table (1). Data structure of mating groups and numbers of sires, dams and offspring weaned to study post-weaning growth traits and livability in rabbits.

No. of genetic group	Breed of sire	Breed of dam	Breed group of offspring	No. of sire	No. of dam	No. of weaned offspring
1	N	N	N	76	259	4208
2	G	G	G	9	18	255
3	G	N	½ G ½ N	2	11	98
4	N	G	½ N ½ G	12	71	916
5	½ G ½ N	½ G ½ N	½ G ½ N	12	35	827
6	½ N ½ G	½ N ½ G	½ N ½ G	2	7	97
7	G	½ G ½ N	¾ G ¼ N	4	12	118
8	½ G ½ N	G	¾ G ¼ N	1	3	21
9	½ G ½ N	N	¼ G ¾ N	9	42	570
10	½ N ½ G	N	¾ N ¼ G	3	17	210
11	¼ G ¾ N	¼ G ¾ N	¼ G ¾ N	4	19	457
12	¾ N ¼ G	¾ N ¼ G	¾ N ¼ G	5	22	417
13	$(½G½N)^2$	$(½G½N)^2$	$(½G½N)^2$	3	14	218
14	¾ G ¼ N	¾ G ¼ N	¾ G ¼ N	1	3	73
Total				143	533	8485

Data of 8485 individual rabbits sired by 143 sire and mothered by 533 dam were analyzed using multi-trait animal model (MTAM) based on the following model (Boldman *et al 1995*):

The crossbreeding components for the studied traits were estimated using four sub-models of the Hill-Model (Hill 1982). Software of crossbreeding effect, CBE (Wolf 1996) was used to analyze the crossbreeding data. Coefficients of expected contribution for genetic effects in the fourteen genetic groups of purebreds and crossbreds rabbits are illustrated in Table 2 as computed by program of CBE (Wolf 1996) based on Hill model (Hill 1982).

Hill-Model can be written for any genetic group as follows (Wolf *et al.*, 1995):

$$\overline{G} = m_D + (\alpha_1 - \alpha_2)\,a + (\delta_{12} - \delta_{11} - \delta_{22})\,d + (\alpha_1 - \alpha_2)^2\,aa + (\alpha_1 - \alpha_2)(\delta_{12} - \delta_{11} - \delta_{22})\,ad + (\delta_{12} - \delta_{11} - \delta_{22})^2\,dd + (\alpha_1^M - \alpha_2^M)\,a^M + (\delta_{12}^M - \delta_{11}^N - \delta_{22}^M)\,d^M$$

(Model 2)

where:

$\overline{G}$ = least squares mean of the given genetic group G,

m_D = general mean ("genetic background", reference value for remaining genetic effects),

a = additive genetic effect,

d = dominance effect,

aa = additive x additive interaction (represent the direct recombination effect),

Table (2): Coefficients of expected contribution for genetic effects in different genetic groups of purebreds and crossbreds as computed by Hill model (Hill 1982) for traits of post-weaning growth and livability traits in rabbits.

No. of genetic group	Sire	Dam	Genetic group	Direct components[+]					Maternal components[++]					Paternal components[+++]				
				a^I (g^I)	d^I (h^I)	aa^I (r^I)	ad^I	dd^I	a^M (g^M)	d^M (h^M)	aa^M (r^M)	ad^M	dd^M	a^P $(g)^P$	d^P (h^P)	aa^P (r^P)	ad^P	dd^P
1	N	N	N	1	-1	1	-1	1	1	-1	1	-1	1	1	-1	1	-1	1
2	G	G	G	-1	-1	1	1	1	-1	-1	1	1	1	-1	-1	1	1	1
3	N	G	½ N ½ G	0	1	0	0	1	-1	-1	1	1	1	1	-1	1	1	1
4	G	N	½ G ½ N	0	1	0	0	1	1	-1	1	-1	1	-1	-1	1	1	1
5	½ G ½ N	½G ½ N	½ G ½ N	0	0	0	0	0	0	1	0	0	1	0	1	0	0	1
6	½ N ½ G	½ N ½ G	½ N ½ G	0	0	0	0	0	0	1	0	0	1	0	1	0	0	1
7	G	½ G ½ N	¾ G ¼ N	-0.5	0	0.25	0	0	0	1	0	0	1	-1	-1	1	1	1
8	½ G ½ N	G	¾ G ¼ N	-0.5	0	0.25	0	0	-1	-1	1	1	1	0	1	0	0	1
9	½ G ½ N	N	¼ G ¾ N	0.5	0	0.25	0	0	1	-1	1	-1	1	0	1	0	0	1
10	½ N ½ G	N	¾ N ¼ G	0.5	0	0.25	0	0	1	-1	1	-1	1	0	1	0	0	1
11	¼ G ¾ N	¼ G ¾ N	¼ G ¾ N	0.5	-0.25	0.25	-0125	0.0625	0.5	0	0.25	0	0	0.5	0	0.25	0	0
12	¾ N ¼ G	¾ N ¼ G	¾ N ¼ G	0.5	-0.25	0.25	-0.125	0.0625	0.5	0	0.25	0	0	0.5	0	0.25	0	0
13	$(½G½N)^2$	$(½G½N)^2$	$(½G½N)^2$	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	¾ G ¼ N	¾ G ¼ N	¾ G ¼ N	-0.5	-0.25	0.25	125	0.0625	-0.5	0	0.25	0	0	-0.5	0	0.25	0	0

[+] a^I (g^I), d^I (h^I), aa^I (r^I), ad^I and dd^I= direct additive genetic effect, direct heterosis, direct additive x additive interaction (direct recombination effect), direct additive x dominance interaction (epistasis effect) and direct dominance x dominance interaction, respectively.

[++] a^M (g^M), d^M (h^M), aa^M (r^M), ad^M and dd^M= maternal additive genetic effect, maternal heterosis, maternal additive x additive interaction (maternal recombination effect), maternal additive x dominance interaction (epistasis effect) and maternal dominance x dominance interaction, respectively.

[+++] a^P (g^P), d^P (h^P), aa^P (r^P), ad^P and dd^P= parternal additive genetic effect, paternal heterosis, paternal additive x additive interaction (paternal recombination effect), paternal additive x dominance interaction (epistasis effect) and paternal dominance x dominance interaction, respectively.

ad = additive x dominance interaction (represent the epistasis),
dd = dominance x dominance interaction (represent the epistasis),
a^M = additive maternal effect,
d^M = dominance maternal effect (maternal heterosis),
α_i = proportion of genes in G from the i^{th} source population (i=1, 2)
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),
α_i^M = proportion of genes in the dam population of G from the i^{th} source population (i=1, 2),
Z_c = probability that at a randomly chosen locus of a randomly chosen individual of the dam population of G one allele is from the i^{th} source population and the other allele is from the j^{th} source population (i, j = 1, 2 and i≤ j),
Remark: Indices in α and δ stand for any of the two source populations. For example, α_i α_j stand for the proportion of genes from the i^{th} and j^{th} source population, respectively, where i and j may take any one of the values 1 and 2.

Four Hill sub-models of (Model 2) containing 1, 2, 3 and 4 genetic parameters, respectively, sub-model 1: direct additive model; sub-model 2: direct additive-dominance model; Sub-model 3: the sub-model 2 and maternal effects; and sub-model 4: the sub-model 2 and paternal 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 model was tested by the χ^2 -test.

RESULTS AND DISCUSSIONS

Actual means

Actual means given in Tables 3 and 4 showed that the differences between NZW and Gabali breeds were non-significance for all the studied traits, in spite of favorable results of Gabali breed for all traits, except DG8-12. This may be due to a good genetic makeup of Gabali and it is more adapted to the environmental conditions in Egypt comparable with NZW rabbits. Means of body weights for Gabali and NZW rabbits in the present study are fall within the range of reports of Khalil *et al.* (1995), Abd El-Aziz (1998), Gad (1998), El-Maghawry *et al.* (1999), Soliman *et al.* (1999) and Khalil and Afifi, (2000), Toson, (2000) and Youssef (2004). Results in Table 4 showed that means of post-weaning livability of L4-8 in purebreds were nearly equal, but higher for L8-12 in Gabali compared to NZW, and the differences between them for both traits was also non-significant. These means are in agreement with foundation of Hanna, (1992), Gad (1998) and Aboul-Ela *et al.* (2000).

When compared purebreds with crossbreds, it is showed that means of crossbred rabbits for most productive traits were somewhat higher than purebreds. Moreover, means of GNxG cross were significantly ($P<0.05$) higher than purebreds for body weights, daily gains (except DG8-12) and livability traits (Tables 3&4). This may be due to good mothering ability of Gabali dams to their bunnies. Thus, it is recommended that utilizing this cross to increase rabbits' meat production in Egypt. Also, crossbred of $(GN-GN)^2$ x $(GN-GN)^2$ gave the highest daily gains during different periods of growth (Table 4).

Table (3): Actual means and standard errors (SE) for post-weaning body weight at 4, 8 and 12 weeks in different genetic groups.

Genetic group[+]	BW4[++]		BW8[++]		BW12[++]	
	No.	Means[*]±SE	No.	Means[*]±SE	No.	Means[*]±SE
Purebred:						
NxN	4208	583.9 ± 2.9 ^{bcd}	3454	1240.7 ± 4.3 ^{cd}	2109	1892.1 ± 6.4 ^{cd}
GxG	255	589.9 ±11.8 ^{bc}	212	1303.0 ±17.2 ^{cb}	160	1958.3 ±23.1 ^{bc}
Average:		586.9		1271.9		1925.2
Crossbred:						
NxG	98	640.5 ±19.0 ^{a}	89	1299.0 ± 26.6 ^{cbd}	66	1942.4 ±36.0 ^{bc}
GxN	916	599.3 ± 6.2 ^{b}	820	1292.5 ± 8.7 ^{cbd}	566	1950.3 ±12.3 ^{bc}
GNxGN	827	545.3 ± 6.5 ^{d}	696	1260. 0± 9.5 ^{cd}	518	1938.5 ±12.9 ^{c}
NGxNG	97	573.7 ±19.1 ^{bcd}	83	1258.2 ±27.5 ^{cd}	55	1899.8 ±39.5 ^{cd}
GxGN	118	587.4 ±17.3 ^{bcd}	10 8	1301.9 ±24.1 ^{cb}	67	1963.1 ±35.7 ^{bc}
GNxG	21	674.3 ±41.1 ^{a}	21	1424.3 ±54.8 ^{a}	21	2024.3 ±63.9 ^{ab}
GNxN	570	589.6 ± 7.9 ^{bc}	562	1276.7 ±10.6 ^{cd}	257	1926.7 ±18.3 ^{cd}
NGxN	210	564.2 ±13.0 ^{bcd}	208	1248.4 ±17.4 ^{cd}	81	1854.8 ±32.5 ^{d}
GN-NxGN-N	457	557.8 ± 8.8 ^{bcd}	377	1253.5 ±12.9 ^{cd}	286	1897.4 ±17.3 ^{cd}
NG-NxNG-N	417	554.21 ± 9.2 ^{cd}	348	1238.9 ±13.4 ^{d}	255	1882.9 ±18.3 ^{cd}
$(GN\text{-}GN)^2x(GN\text{-}GN)^2$	218	547.4 ±12.7 ^{cd}	174	1337.1 ±19.0 ^{b}	130	2051.3 ±25.7 ^{a}
G-GNxG-GN	73	559.7 ±22.0 ^{bcd}	57	1337.5 ±33.2 ^{b}	47	1942.8 ±42.7 ^{cb}
Average:		582.8		1293.3		1939.5

[+] N = New Zealand White and G = Gabali rabbits.

[++] BW4, BW8 and BW12= body weight at 4, 8 and 12 weeks of age, respectively.

[*] Means with the same letters within each column for purebreds and crossbreds are non-significantly (P≤0.05) different, otherwise they do.

Table (4): Actual means and standard errors (SE) for post-weaning daily gains during the periods from 4-8 (DG4-8), 8-12 (DG8-12) and 4-12 (DG4-12) weeks of age as well as livability traits during the periods from 4-8 and 8-12 weeks of age in different genetic groups of rabbits.

Genetic groups[+]	Daily gain traits[++]						Livability traits[++]		
	DG4-8		DG8-12		DG4-12		No.	L4-8	L8-12
	No.	Means[*]±SE	No.	Means[*]±SE	No.	Means[*]±SE		Means[*]±SE	Means[*]±SE
Purebred:									
NxN	3454	22.8 ± 0.11^{de}	2109	22.8 ± 0.14^{abcd}	2109	23.1 ± 0.10^{cde}	4208	0.82 ± 0.005^{cd}	0.50 ± 0.007^{cde}
GxG	212	25.1 ± 0.43^{bc}	160	22.5 ± 0.52^{bcde}	160	23.9 ± 0.35^{bcd}	255	0.83 ± 0.021^{cd}	0.63 ± 0.028^{cb}
Average:		24.0		22.7		23.5		0.83	0.57
Crossbreds:									
NxG	89	23.0 ± 0.67^{de}	66	20.8 ± 0.81^{de}	66	22.3 ± 0.54^{e}	98	0.91 ± 0.034^{bc}	0.67 ± 0.045^{b}
GxN	820	24.6 ± 0.22^{bc}	566	23.1 ± 0.28^{abc}	566	23.8 ± 0.19^{bcd}	916	0.90 ± 0.011^{c}	0.62 ± 0.015^{cb}
GNxGN	696	25.2 ± 0.24^{bc}	518	23.4 ± 0.29^{ab}	518	24.6 ± 0.20^{b}	827	0.84 ± 0.012^{cd}	0.62 ± 0.016^{cb}
NGxNG	83	23.8 ± 0.70^{cde}	55	21.3 ± 0.89^{bcde}	55	22.9 ± 0.60^{de}	97	0.86 ± 0.034^{cd}	0.57 ± 0.045^{cbd}
GxGN	108	25.4 ± 0.61^{b}	67	22.3 ± 0.81^{bcde}	67	24.3 ± 0.54^{bc}	118	0.92 ± 0.031^{abc}	0.57 ± 0.041^{cbd}
GNxG	21	27.0 ± 1.38^{a}	21	21.0 ± 1.44^{cde}	21	24.0 ± 0.97^{bcd}	21	1.00 ± 0.072^{a}	1.00 ± 0.098^{a}
GNxN	562	24.6 ± 0.27^{bc}	257	21.8 ± 0.41^{bcde}	257	23.8 ± 0.28^{bcd}	570	0.99 ± 0.014^{ab}	0.45 ± 0.019^{de}
NGxN	208	24.5 ± 0.44^{bc}	81	20.4 ± 0.73^{e}	81	23.5 ± 0.50^{bcde}	210	0.99 ± 0.072^{ab}	0.39 ± 0.031^{e}
GN-NxGN-N	377	24.6 ± 0.33^{bc}	286	21.9 ± 0.39^{bcde}	286	23.5 ± 0.26^{bcde}	457	0.82 ± 0.016^{cd}	0.63 ± 0.021^{cb}
NG-NxNG-N	348	24.3 ± 0.34^{bc}	255	21.9 ± 0.41^{bcde}	255	23.5 ± 0.28^{bcde}	417	0.83 ± 0.016^{cd}	0.61 ± 0.022^{cb}
(GN-GN)^{2}x(GN-GN)^2	174	27.6 ± 0.48^{a}	130	24.7 ± 0.58^{a}	130	26.3 ± 0.39^{a}	218	0.80 ± 0.022^{d}	0.60 ± 0.030^{cb}
G-GNxG-GN	57	27.6 ± 0.84^{a}	47	21.4 ± 0.96^{bcde}	47	24.6 ± 0.65^{b}	73	0.78 ± 0.039^{d}	0.64 ± 0.052^{b}
Average:		25.2		22.1		23.9		0.89	0.61

[+] N = New Zealand White and G = Gabali rabbits.

[++] DG4-8, DG8-12 and DG4-12= daily gain during the period from 4-8, 8-12 and 8-12 weeks of age, respectively; L4-8 and L8-12 = livability during the period from 4-8 and 8-12 weeks of age, respectively.

[*] Means with the same letters within each column for pure and crossbred are non-significantly (P≤0.05) different, otherwise they do.

Direct (g^I), maternal (g^M) and paternal (g^P) additive genetic effects

Results in Tables 5 up to 8 showed, in general, negative direct effect of (g^I) (across all the four sub-models of Hill) on traits of body weights (BW4, BW8 and BW12), daily gains (DG4-8, DG8-12 and DG4-12) and livability (L4-8 and L8-12) traits, but this effect was significant ($P<0.05$-0.01) for all previous traits, except for DG8-12 and L4-8. Percentages of g^I estimates to the general means of the two purebreds were ranged from –11.6 to 1.72% (Tables 5 & 6), -14.6 to 6.73% (Tables 6 & 7) and –95 to 1.23% (Table 8) for traits of body weight, daily gain and livability, respectively. Piles *et al.* (2004) reported that linear contrasts for g^I were significant for live body weight at 60 days. Khalil and Afifi (1991) reported that linear contrasts of g^I, obtained by Dickerson model, were significant for post-weaning body weight at 12 weeks of age, but insignificant for BW4 and BW8. Negative estimates of g^I in this study may be due to that Gabali had higher means for growth traits than NZW rabbits (Tables 3 and 4), which are considered as an encouraging factor for rabbit breeders in hot climate countries to use native breeds in any crossbreeding programs.

Effects of maternal additive (g^M) on traits of BW8, BW12 and L8-12 were significant ($P<0.01$) and negative estimates, beyond L8-12. On the other hand, values of g^M were mostly positive and non-significant effect for traits of BW4, DG8-12, DG4-12, L4-8 and L8-12. Gomez *et al.* (1999) and Medellin and Lukefahr (2001) found that g^M effect was positive and non-significant on body weights at 4, 9 and 10 weeks of age. Meanwhile, Abd El-Aziz (1998), Gad (1998), Khalil and Afifi (2000), Zaky (2001) Abou-Khadiga (2004) reported that significant effect of g^M on body weights and daily gain traits. They added that most estimates were negative for body weights at 8 and 12 weeks of age and daily gains, but significant and positive for livability traits from weaning up to 12 weeks of age (Abd El-Aziz, 1998). Gad (1998) found non- significant effect of g^M on livability traits. Percentages of g^M estimates to the general means of the two purebreds were ranged from 2.06 to 5.44% (Tables 5 & 6), -1.30 to 8.62% (Tables 6 & 7) and 5.0 to 61.67% (Table 8) for traits of body weight, daily gain and livability, respectively. Positive values of g^M in the present study indicates that maternal additive effect plays a large role in post-weaning growth and livability traits in rabbits through its contribution to their progeny.

Estimates of additive paternal (g^P) were negative and significant ($P<0.01$) effect for traits of BW8 and BW12 and significantly ($P<0.01$) positive on livability trait of L8-12 (Tables 5 up to 8). The same results showed by Gomez *et al.* (1999) and Medellin and Lukefahr (2001) for body weights and post-weaning daily gain traits. Abd El-Aziz (1998) and Gad (1998) found that positive and non-significant effect of g^P on post-weaning livability traits up to 8 and 12 weeks of age. Another point of view, maternal and paternal estimates were mostly positive and higher effect than direct additive for body weight traits up to 12 weeks as well as for livability traits especially during the last period (from 8-12 weeks of age). This indicates that these effects played a large role on post-weaning body weight and livability traits.

Direct (h^I), maternal (h^M) and paternal (h^P) heterosis

Results given in Tables 5 up to 8 showed that most estimates of direct heterosis (h^I) were positive and significant ($P<0.05$-0.01) for all the studied traits, except DG4-12. This indicates that present dominance and/or over-dominance genes effects in direct effect produced from the two purebreds of Gabali and NZW. Afifi (1971) and Emara (1982) found significant (P<0.05-0.01) heterotic effects on body weight at 8 and 24 week of age. The magnitude of heterosis percentages (ranged from –3.9 to 32.3%, -17.33 to 5.04% and –95 to 43.75% for body weight, daily gains and livability traits, respectively) in this study are larger compared with the values obtained by Khalil and Afifi (2000), when used Dickerson model. They found that estimates of h^I were negative and low (-2.2 to –0.6%) for post-weaning body weight at 4, 8 and 12 weeks of age. Gomez *et al.* (1998) reported low heterosis effects in crossbreeding on weaning weight at 60 days and daily gain. French experiments also detected low effect on weaning weight (1.5-2%)(Brun and Rouvier, 1998). Abou Khadiga (2004) found heterotic effects were ranged from 8.0 to 10.9% for post-weaning body weight at 4, 8 and 12 weeks of age.

Estimates of maternal heterosis (h^M) were significant (P<0.05-0.01) and negative estimates for traits of BW8, BW12, DG4-8, DG8-12 and DG4-12. But it was non-significant and negative on BW4, L4-8 and positive non-significant on L8-12 (Tables 5 up to 8). Percentages of h^M estimates to the general means were ranged from –12.9 to –2.39% (Tables 5 & 6), -19.23 to –9.75% (Tables 6&7) and –7.5 to 25% (Table 8) for traits of body weight, daily gain and livability, respectively. Estimates of paternal heterosis (h^P) were also negative for all the studied traits, except L8-12 and significant (P<0.05-0.01) effects on all traits, except BW4 and L4-8. Values of h^M and h^P are closely the same for all the studied traits.

It is notice that effects of h^I, h^M **and** h^P were positive on livability traits during the period from 8-12 weeks of age. This indicates the important of heterotic effects on livability trait. Estimates of h^I were generally higher than estimates of h^M **and** h^P, which may be due to nature of the genetic components in individual compared to presented in maternal and paternal components.

Direct (r^I), maternal (r^M) and paternal (r^P) recombination effects

Results in Tables 5 up to 8 cleared that effect of r^I were positive and significant (P<0.01) for traits of BW4 (+177.0 g), BW8 (+185.7 g) and L4-8 (0.61%), but negative and significant (P<0.0.05-0.01) for traits of DG8-12, DG4-12 and L8-12. It was negative and non-significant for the other traits.

Effects of r^M were negative for most the studied traits and significant (P<0.01) only for traits of BW12, DG8-12, DG4-12. Positive and significant (P<0.01) effect of r^M on L8-12 (0.72%) was obtained. Effects of r^P were negative for all the studied traits and significant (P<0.01) only for traits of BW12, DG4-8, DG8-12 and DG4-8. From the previous, estimates of of r^M and r^P were mostly negative, but the effect of r^I was significantly positive on body weights and livability traits. Thus, this effect is very important for these traits. Bosch *et al.* (1991) reported that backcrossing should perform of the grandmother and grandfather worse than expected from main additive effects, since their expected values carry ¼ additive x additive.

Table (5): Estimates of crossbreeding effects using four sub model's Hill for body weights at 4 and 8 weeks of age in rabbits.

Estimate^{+}	Sub models of the Hill-Model^{++} (1982)							
	Body weight at 4 weeks (BW4)				Body weight at 8 weeks (BW8)			
	Model (1)	Model (2)	Model (3)	Model (4)	Model (1)	Model (2)	Model (3)	Model (4)
μ	576.0±3.0**	547.1± 5.1**	547.4± 12.7**	547.4±12.7**	1280.9±4.2**	1272.7± 7.4**	1337.1± 19.0**	1337.1± 19.0**
$a^I (g^I)$	9.9±5.2^{ns}	-16.9±14.1^{ns}	-50.3± 46.2^{ns}	-91.5±41.7*	-33.3±7.5**	-67.8±19.8**	-148.7± 62.2**	-155.3±55.5**
$d^I (h^I)$	6.4±4.0^{ns}	95.2±19.6**	44.5± 60.7^{ns}	177.0±43.8**	8.7±5.7^{ns}	65.0±27.4*	-52.6± 83.1^{ns}	185.7±59.0**
$aa^I (r^I)$		173.5±38.4**	56.0±118.0^{ns}	321.0±86.9**		108.9±53.6*	-129.1±161.4^{ns}	347.5±116.8**
ad^I		-14.2±15.4^{ns}	-67.9± 43.3^{ns}	-67.9±43.3^{ns}		-36.2±21.9^{ns}	-120.9± 58.0*	-120.9± 58.0*
dd^I		-38.8±17.6*	-39.1± 20.9^{ns}	-39.1± 20.9^{ns}		-44.4±24.5^{ns}	-30.6± 29.2^{ns}	-30.6±29.0^{ns}
$a^M(g^M)$			29.8± 42.5^{ns}				27.5± 59.4^{ns}	
$d^M(h^M)$			-13.1± 35.5^{ns}				-107.6± 53.0*	
$aa^M(r^M)$			40.0± 87.5^{ns}				-96.1±126.7^{ns}	
ad^M			50.4± 39.5^{ns}				30.7± 55.1^{ns}	
dd^M			13.9± 27.3^{ns}				30.3± 40.8ns	
$a^P(g^P)$				70.9±38.8^{ns}				34.0± 54.2^{ns}
$d^P(h^P)$				-13.1± 35.5^{ns}				-107.6± 53.0*
$aa^P(r^P)$				-92.3±81.1^{ns}				-334.5±112.2**
ad^P				50.3±39.5^{ns}				30.7± 55.1^{ns}
dd^P				13.9± 27.3^{ns}				30.3± 40.8ns
χ^2	76.8^{ns}	13.3^{ns}	4.9^{ns}	4.9^{ns}	27.3**	21.7**	2.6^{ns}	2.6^{ns}
df	11	8	3	3	11	8	3	3

$^{+}\mu$ = general mean of the two purbreds and the other estimates are defined in Table (2).

$^{++}$ model 1: direct additive model; model 2: direct additive-dominance model; model 3: the model 2 and maternal effects; and model 4: the model 2 and paternal effects.

^{ns}= non-significant; *= $P\leq 0.05$; **= $P\leq 0.01$.

Table (6): Estimates of crossbreeding effects using four sub model's Hill for body weight at 12 weeks and daily gains at 4-12 weeks of age in rabbits.

Estimate[+]	Sub models of the Hill-Model[++] (1982)							
	Body weight at 12 weeks (BW12)				Daily gain during the period from 4-12 weeks (DG4-12)			
	Model (1)	Model (2)	Model (3)	Model (4)	Model (1)	Model (2)	Model (3)	Model (4)
μ	1939.8±5.9**	1948.8±10.2**	2051.3± 25.7**	2051.3± 25.7**	24.0±0.09**	24.6±0.16**	26.3±0.39**	26.3±0.39**
a^{I} (g^{I})	-42.0±10.3**	-86.6±27.8**	-122.9±76.1^{ns}	-114.8± 65.9^{ns}	-0.77±0.16**	-1.13±0.42**	1.77±1.15^{ns}	-0.27±1.00^{ns}
d^{I} (h^{I})	8.8±8.0^{ns}	-3.0±40.5^{ns}	-55.8± 110.4^{ns}	74.6±71.2^{ns}	0.07±0.12^{ns}	-1.19±0.62^{ns}	-2.26±1.67^{ns}	-1.36±1.08^{ns}
aa^{I} (r^{I})		-33.0±79.2^{ns}	-132.3±214.3^{ns}	128.1±140.6^{ns}		-2.56±1.21*	-4.06±3.25^{ns}	-2.26±1.67^{ns}
ad^{I}		-54.3±30.5^{ns}	-85.8± 69.6^{ns}	-85.6± 69.6^{ns}		-0.74±0.46^{ns}	-0.62±1.06^{ns}	-0.62±1.06^{ns}
dd^{I}		5.1±36.2^{ns}	2.1± 43.4^{ns}	1.9± 43.4^{ns}		0.22±0.55^{ns}	0.43±0.66^{ns}	0.43±0.66^{ns}
a^{M}(g^{M})			49.2± 74.4^{ns}				0.52±1.13^{ns}	
d^{M}(h^{M})			-263.7± 70.6**				-3.88±1.07**	
aa^{M}(r^{M})			-462.3±167.1**				-7.30±2.54**	
ad^{M}			45.2± 68.1^{ns}				-0.23±1.03^{ns}	
dd^{M}			147.2±53.8**				2.01±0.82**	
a^{P}(g^{P})				41.1± 66.7^{ns}				-0.98±1.01^{ns}
d^{P}(h^{P})				-263.7± 70.6**				-3.88±1.07**
aa^{P}(r^{P})				-592.5±153.1**				-8.20±2.32**
ad^{P}				45.0± 68.1^{ns}				-0.23±1.03^{ns}
dd^{P}				147.2±53.8**				2.01±0.82**
χ^2	30.4**	25.6**	4.9**	4.9**	66.6**	39.0**	7.5^{ns}	7.5^{ns}
df	11	8	3	3	11	8	3	3

[+] μ = general mean of the two purbreds and the other estimates are defined in Table (2).

[++] model 1: direct additive model; model 2: direct additive-dominance model; model 3: the model 2 and maternal effects; and model 4: the model 2 and paternal effects.

^{ns}= non-significant; *= P≤0.05; **= P≤0.01.

Table (7): Estimates of crossbreeding effects using four sub model's Hill for daily gain in weight during the period from 4-8 and 8-12 weeks of age in rabbits.

Estimate[+]	Sub models of the Hill-Model[++] (1982)							
	Daily gain in weight during the intervals of 4-8 weeks (DG4-8)				Daily gain in weight during the intervals of 8-12 weeks (DG8-12)			
	Model (1)	Model (2)	Model (3)	Model (4)	Model (1)	Model (2)	Model (3)	Model (4)
μ	24.9±0.11**	25.5±0.19**	27.6±0.48**	27.6±0.48**	22.7±0.13**	23.26±0.23**	24.70±0.58**	24.70±0.58**
a^I (g^I)	-1.61±0.19**	-1.64±0.50**	-4.03±1.57**	-2.43±1.40^{ns}	-0.06±0.23^{ns}	-0.82±0.63^{ns}	-1.83±1.71^{ns}	0.46±1.48^{ns}
d^I (h^I)	0.30±0.14*	-0.19±0.69^{ns}	-3.41±2.10^{ns}	1.39±1.49^{ns}	-0.04±0.18^{ns}	-3.22±0.91**	-3.98±2.49^{ns}	-4.28±1.60**
aa^I (r^I)		-0.84±1.36^{ns}	-6.66±4.07^{ns}	2.94±2.94^{ns}		-6.73±1.79**	-7.25±4.84^{ns}	-7.86±3.17**
ad^I		-0.46±0.55^{ns}	-2.08±1.46^{ns}	-2.08±1.46^{ns}		-1.00±0.69^{ns}	-0.83±1.57^{ns}	-0.83±1.57^{ns}
dd^I		-0.90±0.62^{ns}	-0.24±0.74^{ns}	-0.24±0.74^{ns}		2.86±0.82**	2.88±0.98**	2.88±0.98**
a^M(g^M)			-0.36±1.50^{ns}				2.13±1.68^{ns}	
d^M(h^M)			-2.69±1.34*				-4.75±1.59**	
aa^M(r^M)			-2.97±3.20^{ns}				-9.65±3.77**	
ad^M			-0.44±1.39^{ns}				-0.97±1.53^{ns}	
dd^M			0.14±1.03^{ns}				3.24±1.21**	
a^P(g^P)				-1.24±1.37^{ns}				-0.17±1.50^{ns}
d^P(h^P)				-2.69±1.34*				-4.75±1.59**
aa^P(r^P)				-7.78±2.99**				-9.34±3.45**
ad^P				-0.44±1.39^{ns}				0.98±1.53^{ns}
dd^P				0.14±1.03^{ns}				3.24±1.21**
χ^2	78.2**	37.6**	4.0^{ns}	4.0^{ns}	54.4**	26.7**	7.8**	7.8**
df	11	8	3	3	11	8	3	3

[+] μ = general mean of the two purbreds and the other estimates are defined in Table (2).

[++] model 1: direct additive model; model 2: direct additive-dominance model; model 3: the model 2 and maternal effects; and model 4: the model 2 and paternal effects.

^{ns}= non-significant; *= P≤0.05; **= P≤0.01.

Table (8): Estimates of crossbreeding effects using four sub model's Hill for livability during the period from 4-8 and 8-12 weeks of age in rabbits.

Estimate^{+}	Sub models of the Hill-Model (1982)*							
	Livability during the period from 4-8 weeks (L4-8)				Livability during the period from 8-12 weeks (L8-12)			
	Model (1)	Model (2)	Model (3)	Model (4)	Model (1)	Model (2)	Model (3)	Model (4)
μ	$0.86\pm0.01^{**}$	$0.81\pm0.01^{**}$	$0.80\pm0.02^{**}$	$0.80\pm0.02^{**}$	$0.60\pm0.01^{**}$	$0.64\pm0.01^{**}$	$0.60\pm0.03^{**}$	$0.60\pm0.03^{**}$
a^{I} (g^{I})	0.01 ± 0.01^{ns}	0.01 ± 0.02^{ns}	-0.0002 ± 0.08^{ns}	-0.01 ± 0.07^{ns}	$-0.08\pm0.01^{**}$	$-0.07\pm0.03^{*}$	$-0.52\pm0.11^{**}$	$-0.57\pm0.10^{**}$
d^{I} (h^{I})	$0.05\pm0.01^{**}$	$0.33\pm0.04^{**}$	0.20 ± 0.11^{ns}	$0.35\pm0.08^{**}$	0.02 ± 0.01^{ns}	$-0.23\pm0.05^{**}$	$-0.57\pm0.14^{**}$	$0.24\pm0.10^{*}$
aa^{I} (r^{I})		$0.57\pm0.07^{**}$	0.31 ± 0.21^{ns}	$0.61\pm0.15^{**}$		$-0.50\pm0.09^{**}$	$-1.21\pm0.28^{**}$	$0.41\pm0.21^{*}$
ad^{I}		0.01 ± 0.02^{ns}	0.0001 ± 0.07^{ns}	-0.001 ± 0.07^{ns}		-0.01 ± 0.03^{ns}	$-0.48\pm0.10^{**}$	$-0.47\pm0.10^{**}$
dd^{I}		$0.24\pm0.03^{**}$	$-0.21\pm0.04^{**}$	$-0.21\pm0.04^{**}$		$0.20\pm0.04^{**}$	$0.19\pm0.05^{**}$	$0.19\pm0.05^{**}$
$a^{M}(g^{M})$			0.04 ± 0.07^{ns}				$0.37\pm0.10^{**}$	
$d^{M}(h^{M})$			-0.06 ± 0.06^{ns}				0.15 ± 0.08^{ns}	
$aa^{M}(r^{M})$			-0.05 ± 0.15^{ns}				$0.72\pm0.21^{**}$	
ad^{M}			0.05 ± 0.07^{ns}				$0.40\pm0.09^{**}$	
dd^{M}			0.11 ± 0.05^{ns}				$-0.14\pm0.06^{*}$	
$a^{P}(g^{P})$				0.05 ± 0.07^{ns}				$0.43\pm0.09^{**}$
$d^{P}(h^{P})$				-0.06 ± 0.06^{ns}				0.15 ± 0.08^{ns}
$aa^{P}(r^{P})$				-0.20 ± 0.14^{ns}				-0.09 ± 0.19^{ns}
ad^{P}				0.05 ± 0.07^{ns}				$0.40\pm0.09^{**}$
dd^{P}				$0.11\pm0.05^{*}$				$-0.14\pm0.06^{*}$
χ^{2}	112.27^{**}	28.7^{**}	0.50^{ns}	0.50^{ns}	102.5^{**}	61.8^{**}	4.3^{ns}	4.3^{ns}
df	11	8	3	3	11	8	3	3

$^{+}\mu$ = general mean of the two purbreds and the other estimates are defined in Table (2).

$^{++}$ model 1: direct additive model; model 2: direct additive-dominance model; model 3: the model 2 and maternal effects; and model 4: the model 2 and paternal effects.

^{ns}= non-significant; *= $P\leq0.05$; **= $P\leq0.01$.

Epistatic effects:

Most of direct epistatic effect of additive x dominance (ad^I) interaction was negative and non-significant. While effect of direct dominance x dominance (dd^I) was positive for traits of BW12, DG8-12, DG4-12 and L8-12 and significant (P<0.01) only for traits of DG8-12 (+2.88 g) and L8-12 (0.19%) (Tables 5 up to 8). This indicates that epistatic effects of ad^I and dd^I are the important enough to be account for growth and livability traits. Thus, these effects should be considered in studied of crossbreeding experiments.

Effect of maternal additive x dominance (ad^M) interaction was positive on all the body weight and livability traits. It was significant (P <0.01) only for L8-12 (+0.40%). Also, effect of dominance x dominance (dd^M) interaction was positive for all the studied traits, except for L8-12. This effect was significant (P<0.05-0.01) for traits of BW12 (+147.2 g), DG8-12 (+3.24 g), DG4-12 (+2.01 g) and L8-12 (-0.14%). The same trends were observed for the effects of paternal additive x dominance (ad^P) and dominance x dominance (dd^P) on all the studied traits. From the previous, epistatic effects of ad^I, dd^I, ad^M, dd^M, ad^P and dd^P are important on post-weaning growth and livability traits. Thus, these effects should be considered in studied of crossbreeding experiments.

Fitting models

The four Hill's sub models used in this analysis were fitted by x^2 values for each model within each trait separately (Tables 5 up to 8). Results showed that the four models were fit for traits of BW4 and BW8, in spit of models 3 and 4 are the best, on the other hand, models 3 and 4 were fitted for all the studied traits, except only for trait of DG8-12. This indicates that models 3 and/or 4 are preferred to analysis crossbreeding data, because these models included most of genetic components influencing traits. Another point of view, most of genetic components were gradually increased in values from model 1 up to model 4 (sub-models within each traits in Tables 5 up to 8). This may be due to increasing the accuracy in models 3 and 4 comparable with models 1 and 2.

CONCLUSIONS

- From the previous results, positive and significant effects of genetic components for all the studied traits indicates that present additive, dominance and/or over-dominance gene effects in individuals produced from the two purebreds of Gabali and NZW.
- Positive values of g^M in the present study indicates that maternal additive effects plays a large role in post-weaning growth and livability traits in rabbits through its contribution to their progeny.
- It is notice that effects of h^I, h^M and h^P were positive on livability trait during the period from 8-12 weeks of age, while effect of h^I was positive and very important for all the studied traits. This indicates the important of heterotic effects on post-weaning growth and livability traits.
- Epistatic effects of ad^I, dd^I, ad^M, dd^M, ad^P and dd^P are important on post-weaning growth and livability traits. Thus, these effects should be considered in studies of crossbreeding experiments.

- Results explained that good mothering ability of Gabali rabbit breed and paternal of NZW rabbit breed. This could be encouraging the rabbit breeders in Egypt to utilizing the two breeds in crossbreeding program in hot climate conditions.

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التأثيرات الوراثية للتربية بالخلط لصفات النمو والحياتية فى الأرانب المرباه تحت ظروف الجوالحار

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**معهد بحوث الانتاج الحيوانى - وزارة الزراعة - الدقى - القاهرة

أجريت هذه الدراسة خلال مشروع استمر خمس سنوات متتالية، بكلية الزراعة بمشتهر حيث استخدم أرانب الجبلى المصرى والنيوزيلاندى الأبيض فى تجربة خلط . وقد سجلت بيانات أربعة عشر مجموعة وراثية مختلفة من الأرانب المفطومة حديثا (٤٢٠٨ أرنب من سلالة النيوزيلاندى الأبيض، ٢٥٥ جبلى، ٤٠٢٢ من الخلطان). وكانت الصفات المدروسة عبارة عن صفات النمووالتى تتمثل فى صفات وزن الجسم عند عمر الفطام (عمر الفطام ٤ أسابيع)، ٨ أسابع، ١٢ أسبوع، صفات الزيادة اليومية فى الفترات من ٤-٨، ٨-١٢، ٤-١٢ أسبوع من العمر، وصفات الحياتية خلال الفترات من ٤-٨ أسبوع، ٨-١٢ أسبوع. وقد حللت تلك البيانات باستخدام برنامج تقدير أثر مكونات الخلط الوراثية مثل الأثر التجمعى وقوة الهجين والأثر الاندماجى للمكون الفردى المباشر، الأمى، الأبوى - على التوالى.

وقد أظهرت النتائج ما يلى:

وجدت اختلافات غير معنوية بين أرانب الجبلى والنيوزيلاندى لكل الصفات المدروسة رغم تفوق أرانب الجبلى فى كل الصفات فيما عدا الزيادة اليومية فى الفترة من ٨-١٢ أسبوع . كانت المجموعة الوراثية المحتوية على نسبة دم قدرها ٧٥% جبلى، ٢٥% نيوزيلاندى الأعلى فى أوزان الجسم عند عمر ٤، ٨، ١٢ أسبوع مما يفسر تفوق الأرانب الجبلى فى المقدرة الأمية عن النيوزيلاندى . كانت التأثيرات الوراثية التجمعية المباشرة سالبة ومعنوية الأثر لمعظم الصفات، وكانت التأثيرات التجمعية الأمية سالبة ومعنوية (١%) على صفات وزن الجسم عند ٨ أسابيع، ١٢ أسبوع، بينما كانت موجبة ومعنوية (١%) لصفة الحياتية فى الفترة من ٨-١٢ أسبوع. كانت التقديرات التجمعية الأبوية سالبة ومعنوية لصفات وزن الجسم عند ٨ أسابيع، ١٢ أسبوع ومعنوية (١%) وموجبة لصفات الحياتية فى الفترة من ٨-١٢ أسبوع.

كانت معظم قيم قوة الهجين المباشرة موجبة ومعنوية لكل الصفات المدروسة فيما عدا الزيادة اليومية فى الفترات من ٤-١٢ أسبوع، وتراوحت نسبة قوة الهجين من -٣,٩-٣٢,٣%، -١٧,٣٣-٥,٠٤%، ٩٥-٤٣,٧٥% لصفات وزن الجسم والزيادة اليومية والحياتية - على التوالى . بينما كانت تقديرات قوة الهجين الأمية والأبوية معنوية وسالبة لمعظم الصفات المدروسة.

كانت التأثيرات الاندماجية المباشرة موجبة ومعنوية لصفات وزن الجسم عند عمر ٤، ٨ أسابيع والحياتية فى الفترة من ٤-٨ أسابيع . بينما كانت التأثيرات الاندماجية الأمية سالبة لمعظم الصفات المدروسة ومعنوية فقط لصفات وزن الجسم عند عمر ١٢ أسبوع، الزيادة اليومية فى الفترة من ٤-١٢ أسبوع. وكانت التأثيرات الاندماجية الأبوية موجبة ومعنوية لصفات الحياتية عند الفترة من ٨-١٢ أسبوع

(٧٢%)، والتأثيرات الاندماجية سالبة لكل الصفات المدروسة ومعنوية فقط لصفات وزن الجسم عند عمر ١٢ أسبوع، الزيادة اليومية فى الفترة من ٤-٨، ٨-١٢ أسبوع. كانت التأثيرات التفوقية المباشرة والأمية والأبوية للأثر التجمعى x السيادى، السيادى x السيادى مهمة لصفات النمو والحياتية فى الأرانب حديثة الفطام .

كما أظهر النموذج ٣، ٤ أنهما الأفضل فى تحليل بيانات التربية بالخلط فى الأرانب لأن هذين النموذجين شملا معظم مكونات الخلط الوراثية للصفات المدروسة.