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ORIGINAL ARTICLE

Evaluation of milk yield and some related maternal traits in a crossbreeding project of Egyptian Gabali breed with Spanish V-line in rabbits

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Summary

This study was conducted in a four-year rabbit project that aimed to develop a synthetic line named Moshtohor (M) by crossing Sinai Gabali breed (G) with the Spanish V-line (V). The G, V, F_1 (G × V), F_2 $(G \times V)^2$ and M line were analysed. Traits of doe body weight at delivery (DBW), litter size at birth (LSB) and at weaning (LSW), milk production during the first, second, third and fourth week of lactation and total milk yield (TMY) were recorded. Data were analysed using a repeatability uni-trait animal model to estimate the genetic parameters and estimable functions of genetic group effects. Based on them and the matrix of their variance–covariance, the crossbreeding parameters were also estimated. Estimates of heritabilities for all the studied traits were low ranging from 0.06 to 0.11 for DBW, LSB and LSW and from 0.0 to 0.06 for milk production traits. Permanent environmental effects were very low ranging from 0.0 to 0.10 for all the traits, except for DBW (0.41). Least square means of V line were superior ($p < 0.05$) in DBW (3253 versus 3037 g) and LSB (6.71 versus 6.28 young) relative to G breed. M line had superiority in LSB (6.94 young) compared with G breed. M line and G breed were better than V line for milk production traits (3415 and 3236 versus 2893 g for TMY). Significant effects of direct additive were observed for most traits studied (ranged from −6.8 to 20.7%). Effects of individual heterosis for most milk production traits were significant and ranged from 2.1 to 13.9%, but they were not significant for DBW, LSB and LSW. On the opposite side, effects of maternal heterosis for all the traits were not significant.

Introduction

Milk yield is an important factor in rabbit production, because growth rate of newborn rabbits is dependent on milk production of the doe (Mcnitt & Moody 1988; Khalil *et al.* 2004; Iraqi *et al.* 2007). Selection of existing dam breeds for milk production and for reproductive traits could be a feasible approach to increase production in the commercial meat rabbit industry. Moreover, intensive rabbit production necessitates knowledge of the lactation curve of the doe. This curve may be affected by breed of doe (Cowie 1969; Lukefahr *et al.* 1983), parity (Abo-Elezz *et al.* 1981) and number of

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suckling kits (Lukefahr *et al.* 1983; Iraqi & Youssef 2006). Lukefahr *et al.* (1983) based on residual correlations, found that both litter size and weight traits at birth and at 21 days were related to milk production of the dam (correlations ranging from 0.48 to 0.99). But, doe weight at delivery was lowly related ($r = 0.10$).

Traits related to productivity of the does, such as doe weight, litter size, and milk production are considered as the most important traits for efficient production and some of these traits are the main criteria of selection to develop maternal lines of rabbits (Estany *et al.* 1989; Baselga 2004; Khalil & Al-Saef 2008). A deep knowledge involving crossbreeding parameters for these traits is lacking in hot and temperate areas, so far the topic has been covered by Khalil *et al.* (1995), Khalil & Afifi (2000), Baselga *et al.* (2003), Khalil *et al.* (2004, 2005), Brun & Baselga (2005), Al-Saef *et al.* (2008). Thus, the objective of the present study was to estimate the crossbreeding parameters for prolificacy and milk yields for rabbits in terms of additive and heterotic effects (direct and maternal) in a crossbreeding program involving one Egyptian breed (Sinai Gabali) and one Spanish line (V-line), and to compare, for those traits, the performances of a new synthetic line and its two purebred parents.

Materials and methods

Animals and plan of breeding

Animals used in this study were Sinai Gabali rabbits bought from Bedouins living in northern of Sinai in Egypt and V line (Estany *et al.* 1989) rabbits imported by the Faculty of Agriculture of Alexandria from Valencia in 1999. A 4-year crossbreeding project was started in March 2003, trying to produce a synthetic line. The procedure began by getting the F_1 (G × V) and continued with the F_2, F_3 and successive generations. The rabbits pertaining to a generation posterior to F_2 were considered as rabbits of the new synthetic line, named Moshtohor line (M). The genetic groups and number of animals involved in this study are shown in Table 1.

The animals were housed in the rabbitry of the Department of Animal Production, Faculty of Agriculture at Moshtohor, Benha University, Egypt. The rabbits were raised in one floor farm, oriented from east to west. The temperature ranged from 15 to 35°C, the relative humidity ranged from 30 to 70% and the photoperiod was 16L:8D. The natural mating was used and the reproductive rhythm was intensive, mating 24 h after delivery.

Table 1 Distribution of the does used and lactations obtained in different genetic groups

Genetic group of the does[1]	Lactations	Does	Sires	Dams
Gabali (G × G)	272	141	32	52
V-line (V × V)	594	231	103	129
F_1 (G × V)	115	57	18	30
F_2 $(G \times V)^2$	75	38	10	23
F_3 $((G \times V)^2)^2$, M-line	148	72	29	39
Total	1204	539	192	273

[1]Sire is given first, M = Moshtohor.

Data collected

The litters were maintained in the closed nest at 18:00 h. The litters and the does were weighed before suckling at 8:00 h of the following day. At this moment, the does were allowed to enter the nest and be suckled by their litters. Each doe and her litter were re-weighed after sulking within 20 min. The weights were controlled on the 2nd and the 5th day of each week. The difference in weight of each does and its litter before and after suckling were computed. The average of these differences, for the 2 days of week, was computed and recorded as the daily milk yield of the doe. The milk yield in each week of lactation was computed multiplying the daily milk yield by seven. The total milk yield (TMY) was computed as summation of milk yield during the first, second third and fourth week of lactation.

The recorded traits were: doe body weight (g) at the day of delivery (DBW), litter size at birth (LSB) and at weaning (LSW), milk yield (g/week) at the first (MY7), second (MY14), third (MY21) and fourth (MY28) week of lactation, and TMY (g/lactation) for the 4 weeks of lactation.

Statistical analysis

Data of 1204 lactations produced by 539 does which were progeny of 192 sires and 273 dams (Table 1) were analysed using a repeatability uni-trait animal model:

$$\mathbf{y} = \mathbf{Xb} + \mathbf{Z_a u_a} + \mathbf{Z_p u_p} + \mathbf{e}$$

where $\mathbf{y}$ is the vector of observations of the trait; $\mathbf{b}$ is the vector of fixed effects of genetic groups (five levels), parity (four levels; parity 1, 2, 3 and ≥4) and year-season of delivery (12–14 levels depending on the trait); $\mathbf{Z_a}$ and $\mathbf{Z_p}$ are the incidence matrices corresponding to the additive ($\mathbf{u_a}$)

Table 2 Estimable genetic group effects (EGG) and estimable functions of crossbreeding parameters

EGG[1]	D^I	H^I	R^I	M^I	H^M
G-V	1	0	0	1	0
F_1-V	0.5	1	0	0	0
F_2-V	0.5	0.5	0.5	0.5	1
M-V	0.5	0.5	0.5	0.5	0.5

G, Sinai Gabali breed; V, V line; M, Moshtohor line; D^I, difference between direct additive effects; H^I, direct heterosis; R^I, recombination loss; M^I, difference between maternal additive effects; H^M, maternal heterosis.

[1]Deviation of each genetic group from V line.

and permanent environmental ($\mathbf{u_p}$) random doe effects, respectively; and $\mathbf{e}$ is the vector of random errors.

DFREML variance components were estimated (Boldman *et al.* 1995) and these estimates were used to solve the repeatability animal model to estimate the fixed effects (Boldman *et al.* 1995). The ratio of the additive variance to the phenotypic variance (h^2), and the ratio of the permanent environmental variance to the phenotypic variance (p^2) were also estimated.

The estimable functions of the crossbreeding genetic parameters were estimated using a mixed model methodology based on the coefficients presented in Table 2 that relates the crossbreeding genetic parameters to the estimated genetic group effects (Baselga *et al.* 2003). There are five genetic groups and this means that four estimable functions of crossbreeding parameters (Table 2) could be estimated. Some results show that the recombination losses (R^I) are negligible in many cases (Khalil *et al.* 2005; Al-Saef *et al.* 2008). Moreover, the absence of the reciprocal F1 increases the colinearity between direct and maternal effects (M^I) that makes difficult the separate estimation of both. Thus, we must reduce the estimation to the difference between direct additive effects (D^I), the direct heterosis (H^I) and the maternal heterosis (H^M).

Results and discussion

Parity and season effects

Table 3 shows the parity effect in prolificacy and milk yield. Litter size and the milk yield during the fourth week of lactation at first parity was lower than second, third or fourth parity. Poujardieu & Theau-Clément (1995) showed that parity has no effect on reproductive performance anymore after second parity. The lower reproductive performance (size and weight of the litter, milk production) observed in primiparous females compared with multiparous ones has been studied by Pascual *et al.* (1998), Fortun-Lamothe & Gidenne (2003), Rebollar *et al.* (2008). These results confirm that parity affects the energy balance of the rabbit doe. In fact, feed consumption is lower in primiporous females than in multiporous ones (Fortun-Lamothe & Gidenne 2003). Moreover, the energy balance of does is therefore more negative during the first lactation than the following lactations (Castellini *et al.* 2006). Nevertheless, we have not found differences between parities in DBW at delivery.

No matter the parity effect, the milk yield was maximum on the first 14 days of lactation and decreased between 21 and 28 days of lactation. The milk yield was lower than the results obtained by Al-Saef *et al.* (2008) and Rebollar *et al.* (2008).

All the measured traits in this experiment were affected by the year-season. When the traits were measured in summer, the milk production decreased and the prolificacy were lower than in winter (data not shown in tables). Iraqi *et al.* (2007) showed that TMY and its composition were influenced by year-season in Gabali, V-line and G × V cross. They found means of TMYs had the highest values in winter

Table 3 Least-squares means (± standard error) of the parity effect for prolificacy and milk yield in different periods

Trait[1]	DBW	LSB	LSW	MY7	MY14	MY21	MY28	TMY
1	3147 ± 160	6.39 ± 0.11^a	5.28 ± 0.12	713 ± 15	836 ± 18	806 ± 21	527 ± 21^a	2997 ± 56
2	3204 ± 205	6.92 ± 0.14^b	5.44 ± 0.14	745 ± 19	852 ± 23	814 ± 26	612 ± 27^{ab}	3102 ± 71
3	3247 ± 258	6.94 ± 0.18^b	5.66 ± 0.18	707 ± 24	847 ± 29	856 ± 34	620 ± 33^b	3081 ± 90
4	3223 ± 241	7.09 ± 0.17^b	5.60 ± 0.18	698 ± 22	860 ± 28	827 ± 32	636 ± 32^b	3115 ± 86

[1]DBW (g), doe body weight at delivery; LSB, litter size at birth; LSW, litter size at weaning; MY7 (g/week), MY14 (g/week), MY21(g/week), MY28(g/week) and TMY(g/lactation), milk yield during the first, second, third, fourth week of lactation and total milk yield during the whole 4 weeks of lactation, respectively.

Means within trait not sharing any alphabets are significant (α = 0.05).

(3749.1 g), followed by autumn (3644.0 g) and the lowest in summer (3222.0 g).

Heritability and permanent environmental effect

Estimates of heritability (h^2) for DBW, LSB and LSW seem to be low and ranging from 0.06 to 0.11 (Table 4). Iraqi (2008) found that h^2 estimate for DBW was 0.0 in New Zealand White breed, while Lukefahr & Hamilton (1997) found a higher estimate (0.53) for the same trait when they used pooled data collected on purebreds and crossbreds. The low estimate of h^2 for DBW in this study corresponds to a high p^2 (0.41). Estimates of h^2 for LSB and LSW in the present study fall within the range between 0.00 and 0.08 reported by Baselga *et al.* (2003), Iraqi *et al.* (2006) and Youssef *et al.* (2008).

Estimates of h^2 for milk production traits were low ranging between 0.0 and 0.06 (Table 3). Similar estimates ranging from 0.001 to 0.11, for these traits in different populations of rabbits were obtained by Ayyat *et al.* (1995), Lukefahr *et al.* (1996) and Iraqi & Youssef (2006). On the other hand, Al-Sobayil *et al.* (2005) found higher estimates of h^2 ranging from 0.18 to 0.22 with combined data of purebreds and crossbreds.

The estimates of p^2 were generally low, ranging from 0.0 to 0.10 for all traits studied (Table 3), except for DBW which had the highest value (0.41). Similar results were obtained by El-Maghawry (1997), Lukefahr & Hamilton (1997) and Iraqi (2008).

Genetic groups

Estimates of least squares means for DBW, LSB and LSW are presented in Table 5. These means showed that V line does were superior to Gabali breed does in DBW (3253 versus 3037 g) and LSB (6.71 versus 6.28 young). On the other hand, M line had superiority in LSB (6.94 versus 6.28 young) and in DBW (3252 versus 3037 g) compared with Gabali breed. Iraqi *et al.* (2007) found superiority in prolificacy for V line compared with Gabali breed. Similarly, Lukefahr *et al.* (1983) found that does of New Zealand White were more prolific than Californian does and their reciprocal crosses. Conversely, Mcnitt & Lukefahr (1990) found that differences in DBW between four purebreds rabbits were not significant. Means of LSB and LSW in this study are within the ranges reviewed in the Egyptian literature (El-Maghawry 1999; Khalil & Afifi 2000; Nofal *et al.*

Table 4 Heritability (h^2) and ratio of permanent environmental variance to the phenotypic variance (p^2) (± standard error) for prolificacy and milk yield in different periods

Trait[1]	DBW	LSB	LSW	MY7	MY14	MY21	MY28	TMY
h^2	0.11 ± 0.07	0.06 ± 0.04	0.07 ± 0.05	0.01 ± 0.03	0.00 ± 0.03	0.00 ± 0.04	0.05 ± 0.05	0.06 ± 0.06
p^2	0.41 ± 0.07	0.00 ± 0.05	0.01 ± 0.06	0.03 ± 0.04	0.04 ± 0.05	0.10 ± 0.06	0.03 ± 0.06	0.05 ± 0.07

[1]DBW (g), doe body weight at delivery; LSB, lit; LSW, litter size at weaning; MY7 (g/week), MY14 (g/week), MY21(g/week), MY28(g/week) and TMY(g/lactation), milk yield during the first, second, third, fourth week of lactation and total milk yield during the whole 4 weeks of lactation, respectively.

Table 5 Least-squares means of the genetic groups (± standard error) for prolificacy and milk yield in different periods

	Trait[1]							
Genetic Group[2]	DBW	LSB	LSW	MY7	MY14	MY21	MY28	TMY
G	3037 ± 34^{a}	6.28 ± 0.19^{a}	5.32 ± 0.19^{a}	719 ± 23^{bc}	871 ± 27^{a}	884 ± 32^{a}	688 ± 32^{a}	3236 ± 89^{a}
V	3253 ± 25^{b}	6.71 ± 0.14^{b}	5.24 ± 0.13^{a}	698 ± 17^{c}	802 ± 20^{b}	747 ± 24^{b}	559 ± 23^{b}	2893 ± 64^{b}
F_1	3121 ± 45^{ac}	6.69 ± 0.26^{ab}	5.32 ± 0.26^{a}	791 ± 34^{ab}	907 ± 42^{a}	910 ± 48^{a}	635 ± 46^{ab}	3371 ± 127^{a}
F_2	3185 ± 56^{bc}	6.68 ± 0.31^{ab}	5.51 ± 0.34^{a}	793 ± 41^{ab}	872 ± 52^{ab}	751 ± 61^{b}	625 ± 61^{ab}	3069 ± 167^{ab}
M	3252 ± 43^{b}	6.94 ± 0.24^{b}	5.77 ± 0.27^{a}	793 ± 31^{a}	916 ± 40^{a}	896 ± 47^{a}	634 ± 47^{ab}	3415 ± 130^{a}

[1]DBW (g), doe body weight at delivery; LSB, litter size at birth; LSW, litter size at weaning; MY7 (g/week), MY14 (g/week), MY21(g/week), MY28(g/week) and TMY(g/lactation), milk yield during the first, second, third, fourth week of lactation and total milk yield during the whole 4 weeks of lactation, respectively.

[2]G, Sinai Gabali breed; V, V line; M, Moshtohor line.

Means within trait not sharing any alphabets are significant (α = 0.05).

2002; Iraqi 2008). Higher means ranging between 3.43 and 3.98 kg for DBW were obtained by Lukefahr *et al.* (1983).

For milk production traits, M and G does were superior in TMY relative to V line (3415 and 3236 versus 2893 g). Similarly, results obtained by Iraqi *et al.* (2007) confirmed our results in this study, reporting that Gabali could produce more milk than V line. Lukefahr *et al.* (1983) stated that New Zealand White does were superior in milk yield ($p < 0.01$) compared with Californian rabbits.

Direct additive effects of Gabali and V line

Results in Table 6 showed that differences in D^I were significant for DBW (−6.8%) and LSB (−6.8%), but not for LSW. That means that, in the does, the V line genes were better than the Gabali breed genes for DBW and LSB. This superiority of V line genes was 215 g in doe weight at delivery and 0.44 young. Similarly, Baselga *et al.* (2003) found significant differences in direct additive effects for LSB, showing that V line had a higher prolificacy than A and H lines. Mcnitt & Lukefahr (1990) found a significant contrast between Californian and average of Palomino and White Satin rabbits for DBW, but not for LSW. Khalil *et al.* (2005), Iraqi *et al.* (2006) and Youssef *et al.* (2008) reported significant direct additive effects on litter size traits. Khalil & Afifi (2000) in a crossbreeding project of New Zealand White with Gabali rabbits, reported that New Zealand White rabbits had higher estimates of direct additive effects than Gabali rabbits for litter size.

Percentages of D^I relative to the average of the founder breeds were 3.0, 8.2, 16.7, 20.7 and 11.0% for MY7, MY14, MY21, MY28 and TMY, respectively (Table 6). These estimates were significant for all traits, except milk yield during the first week of lactation. The estimates were in favour of Gabali genes and the additive effect of the Gabali breed was 337 g higher than the corresponding effect of the V line in TMY. Conversely, Al-Sobayil *et al.* (2005) pointed a superiority of V line genes in direct additive effects for milk production traits compared with Gabali Saudi. Lukefahr *et al.* (1983) in USA showed that estimates of direct additive effects for milk yield traits were mostly in favour of New Zealand White compared with Californian rabbits. Also, Abd El-Aziz *et al.* (2002) found that estimates of direct additive effects for milk production were mostly in favour of New Zealand White relative to Gabali rabbits in Egypt.

Direct heterosis

Estimates of H^I in Table 6 indicate that crossbred does were not associated with heterotic effects in DBW and litter size traits. Also, Lukefahr *et al.* (1983) found that H^I on DBW (3.5%) was not significant. While, Iraqi *et al.* (2006) found a significant direct heterosis for LSB (4.03%), but not for LSW when crossing New Zealand White with Gabali breed in Egypt. Baselga *et al.* (2003) and Youssef *et al.* (2008) reported significant values of H^I for LSB and LSW.

Estimates of H^I for milk yield traits were mostly significant and positive (Table 6). Percentages of these estimates relative to the average of the founder breeds were 12.3, 9.6, 13.9, 2.1 and 11.8% for MY7, MY14, MY21, MY28 and TMY, respectively. Lukefahr *et al.* (1983) found a significant H^I for milk yield during the first 21 days (9.2%) in a crossing program

Table 6 Crossbreeding parameters of direct additive effect (D^I), individual heterosis (H^I) and maternal heterosis (H^M) (± standard error) for prolificacy and milk yield in different periods

Trait[1]	DBW	LSB	LSW	MY7	MY14	MY21	MY28	TMY
D^I	−215 ± 40*	−0.44 ± 0.21*	0.07 ± 0.22	21 ± 25	69 ± 31*	136 ± 36*	129 ± 37*	337 ± 104*
D^I %[2]	−6.8	−6.8	1.3	3.0	8.2	16.7	20.7	11.0
H^I	−6 ± 46	0.26 ± 0.25	0.11 ± 0.26	87 ± 33*	80 ± 41	113 ± 47*	13 ± 47	361 ± 130*
H^I %[2]	−0.2	4.0	2.1	12.3	9.6	13.9	2.1	11.8
H^M	90 ± 55	0.21 ± 0.31	0.37 ± 0.33	52 ± 40	19 ± 51	−74 ± 59	−1 ± 59	−34 ± 161
H^M %[2]	2.9	3.2	7.0	7.3	2.3	−9.1	−0.2	−1.1

[1]DBW (g), doe body weight at delivery; LSB, litter size at birth; LSW, litter size at weaning; MY7 (g/week), MY14 (g/week), MY21(g/week), MY28(g/week) and TMY(g/lactation), milk yield during the first, second, third, fourth week of lactation and total milk yield during the whole 4 weeks of lactation, respectively.

[2]Percentages of crossbreeding parameters were computed as proportion of D^I, H^I and H^M in units relative to the corresponding average of Gabali and V line purebreds.

*Significant ddifference at $\alpha = 0.05$.

of New Zealand White and Californian rabbits. Results of Khalil & Afifi (2000) indicated that crossing Gabali with New Zealand White was associated with non-significant heterotic effects on milk yield during the first 21 days of suckling and the whole period of lactation. Abd El-Aziz *et al.* (2002) reported that direct heterotic effects on milk yield traits were not significant (0.12–2.4%).

Maternal heterosis

Estimates of H^M for DBW, LSB and LSW were not significant (Table 6). Similarly, Youssef *et al.* (2008) found that H^M for LSB (−4.8%) and LSW (1.8%) were not significant. Iraqi *et al.* (2006) found a significant H^M for LSB, but not for LSW. Also, the estimates of H^M for milk production traits were not significant. On the contrary, Al-Sobayil *et al.* (2005) reported significant and positive values of H^M (ranging from 7.4 to 15.2%) for milk production traits.

Conclusions

The Sinai Gabali breed has higher milk yield than V line. Moreover, values and signs of individual heterosis along with the complementarity between Sinai Gabali (that is better in milk production traits) and V line (that is better in DBW at delivery and prolificacy) justify the interest of crossing Sinai Gabali breed with V line to produce the synthetic line named Moshtohor line (M). Thus, M line has showed similar performances in litter and lactation traits to the best purebred parent.

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