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Programs established to synthesize new lines of rabbits in hot climate countries

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ABSTRACT

In hot climate countries, little numbers of synthetic maternal, paternal and multi-purpose lines were synthesized using different criteria and methods of selection and crossbreeding. Synthetic lines of rabbits naming Saudi 2 and APRI (as maternal lines) and Alexandria and Saudi 3 (as paternal lines) and Moshtohor (as multipurpose line) were being formed to be convenient in hot climate in the Arabian areas. These synthetic lines have the adaptability to be reproducing efficiently in different systems of production of hot climates and they have also good capability to grow profitably in these hot areas. The most common selection criteria used in selection programs to develop new maternal lines were related with litter size at birth or at weaning and milk production, while in paternal lines, post-weaning daily gain or marketing weight are commonly selected individually. Spanish V-line rabbits genetically selected for more than 35 generations were introduced in various countries (as alive animals or as frozen embryos) and by using recent bio-techniques and applying selection and /or crossbreeding programs with local lines, this line was widely distributed in some hot countries of the world like Egypt, Saudi Arabia, Uruguay, etc. Involving V-line rabbits in crossbreeding plans was an encouraging factor since V line showed higher direct and maternal genetic effects for litter and lactational performances and most post-weaning growth and carcass traits than native rabbits. However, direct and maternal genetic effects for most carcass traits (e.g. weights of hot carcass, meat, offal, and bone) were in favour of V line, but these estimates were in favour of the local rabbits for meat quality traits. The estimates of direct and maternal heterosis reviewed for lactation, growth and carcass traits and heat-stress physiological parameters were favourable. Reviewed estimates of recombination effects for milk yields and components and growth traits were insignificant and negligible; indicating that crossing V-line with native breeds of rabbits in hot climate countries could be effective to develop synthetic maternal and paternal lines characterized by high milk production associated with rich milk components and high growth rate. Direct selection had little or moderate effects on litter size, prenatal litter components, meat quality traits, while it had considerable effects on post weaning growth and carcass traits, feed conversion. Direct selection for feed efficiency is less efficient than selection for growth rate for improving feed conversion ratio. Selection responses obtained in crossbred rabbits were slightly higher than responses obtained in the pure lines. In hot climate countries, new biological and molecular techniques commonly used as tools in selection programs are so far from what reached in developed countries.

Key words: Rabbits, hot climate, selection, crossbreeding, synthetic lines, direct response.

INTRODUCTION

Nowadays, synthetic lines are being developed in hot climate countries by crossbreeding and selection for defined objectives (El-Raffa, 2007; Khalil and Al-Saef 2008; Youssef et al, 2008; Iraqi et al, 2009). These lines, depending on their specialization, perform better than the standard of the original breeds and the current production tends to rely on them. For instance, **V**-line originated in Spain being selected in places where the climate is closer to a hot climate than to a temperate one and testing this line in hot climate countries could be interesting. Some attempts already done and **V**-line has proved to be advantageous to standard Californian and New Zealand White for litter size traits and daily gain in Egypt (Yamani, 1994).

Long-term selection experiments carried out in rabbits for more than 10 generations in some hot countries were few relative to the other livestock (El-Raffa, 2000; Khalil *et al.*, 2005; Youssef et al, 2008; Iraqi et al, 2009). However, selection to improve productivity in rabbits was performed in three directions: (1) to improve prolificacy and lactation (maternal lines), (2) to improve growth rate and carcass and meat quality traits (paternal lines) and (3) to improve globally litter traits and growth traits together (multipurpose lines). In the first case, selection was practiced mainly for litter size at birth or weaning, while in the second case the weight gain and/or carcass traits were regarded as the most important selection criteria and the third case dealing with selection for litter size, litter weight, milk yield, and post weaning growth traits. As a result of selection, some synthetic maternal lines were developed in Saudi Arabia (line Saudi-2), in Egypt (line APRI) and in Uruguay (line NZW and V), while the synthetic paternal lines developed were Alexandria in Egypt, and Saudi-3 in Saudi Arabia. But, the synthetic multi-purpose line developed was Moshtohor in Egypt.

The main objectives of this article are concentrated in dealing with overlooking and evaluating selection and crossbreeding experiments carried out in hot climate countries in terms of: (1) programs of selection and crossbreeding to develop new synthetic lines of rabbits; (2) criteria and methodologies used in selection and crossbreeding; (3) estimation of selection responses; (4) possibility of applying molecular techniques in selection.

Crossbreeding effects obtained in experiments of synthesizing new lines of rabbits in hot climate countries

Direct and maternal breed additive effects

In program of crossing V-line and Saudi rabbits, Khalil et al (2004, 2005) found that estimates of direct and maternal additive effects for different litter traits, milk yield and components and feed consumption and conversion parameters were significantly moderate and in favour of V-line does (Figures 1&2). Most estimates of maternal additive effects for litter and lactation traits and feed consumption and conversion parameters were in favour of V-line dams. However, this superiority of V-line does in direct additive effects for litter traits is in agreement with its long history of selection for litter size at weaning and its high average for this trait since the animals were genetically evaluated by a BLUP methodology under an animal-repeatability model (Estany *et al.*, 1989). The superiority of V-line does in direct additive effects indicate that V-line rabbits could produce, lactate and converse feed efficiently under hot climatic conditions. Khalil and Afifi (2000) in crossing experiment between NZW and Gabali rabbits reported that NZW rabbits had higher estimates of direct additive effects than Gabali rabbits for litter weight at birth and weaning ($P<0.01$ or $P<0.001$). The other crossbreeding experiment carried out in

Egypt by Abd El-Aziz *et al* (2002) indicated that estimates of direct additive effects for milk production were mostly in favour of NZW relative to Gabali rabbits.Crossbreeding experiments carried out in Egypt (Afifi and Khalil, 1989; Khalil et al, 1995; Khalil and Afifi, 2000) reported similar results; indicating that estimates of maternal additive effects for pre-weaning litter traits were significant. In Saudi Arabia, most estimates of maternal additive effects for milk yields were in favour of V-line dams (Figure 2).

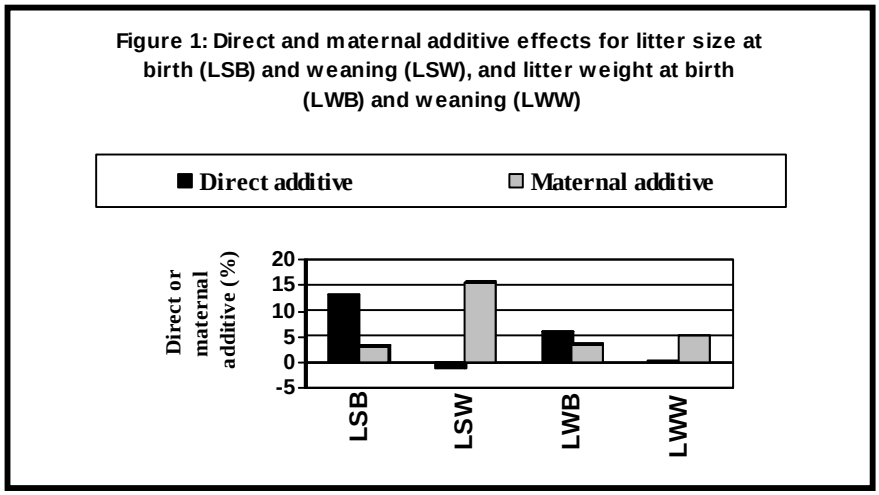


Figure 1: Direct and maternal additive effects for litter size at birth (LSB) and weaning (LSW), and litter weight at birth (LWB) and weaning (LWW)

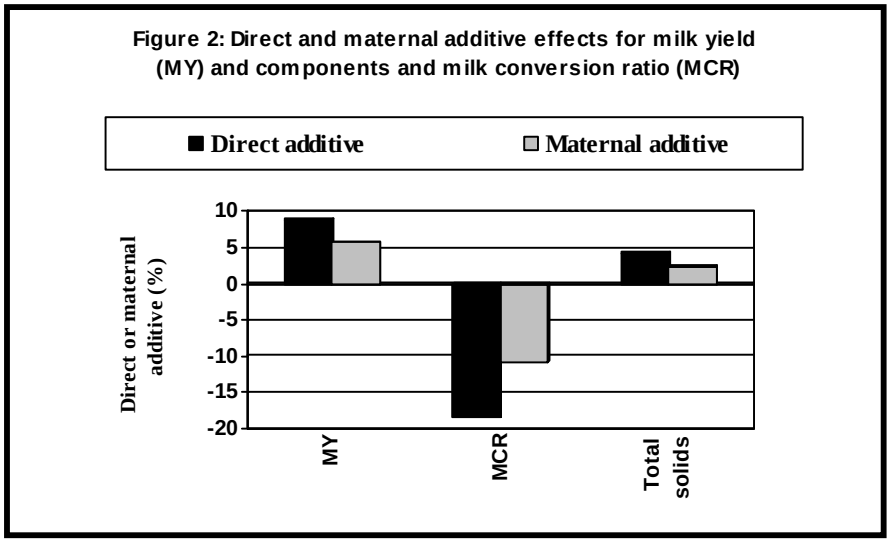


Figure 2: Direct and maternal additive effects for milk yield (MY) and components and milk conversion ratio (MCR)

For body weights, most estimates of direct additive effects were in favour of **V**-line rabbits (Figure 3); leading to state that V-line rabbits could be used in crossbreeding programmes in other hot climatic countries. V line dams showed unfavorable decrease in maternal genetic effects for post-weaning body weights; ranging from 48.5 g to 93.8 g in comparison with the Saudi dams and this is due to the consequences of that litter size in V-line was higher and for the fact also that both breeds are medium in size. In most cases, the estimates of direct and maternal genetic effects for carcass traits were in favour of V line, but these estimates were in favour of Saudi rabbits for

meat quality traits (Figure 4). Maternal additive effects for carcass and meat quality traits were not significant (Figure 5).

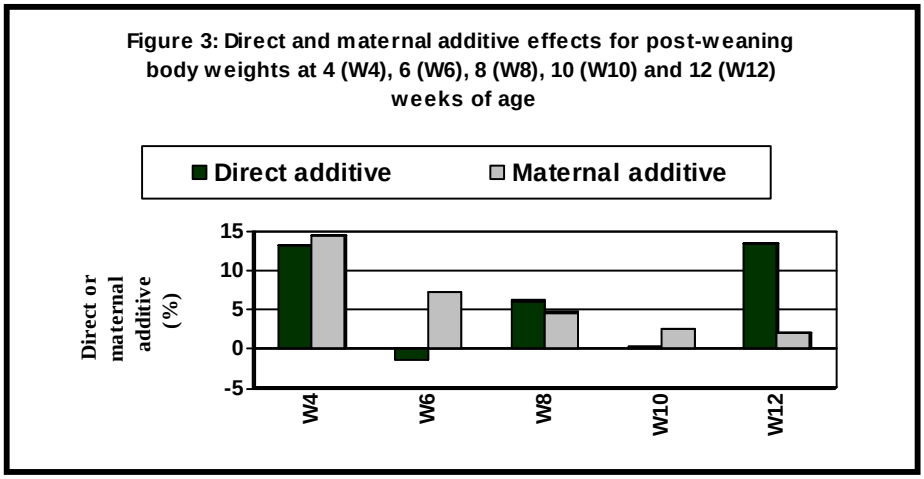


Figure 3: Direct and maternal additive effects for post-weaning body weights at 4 (W4), 6 (W6), 8 (W8), 10 (W10) and 12 (W12) weeks of age

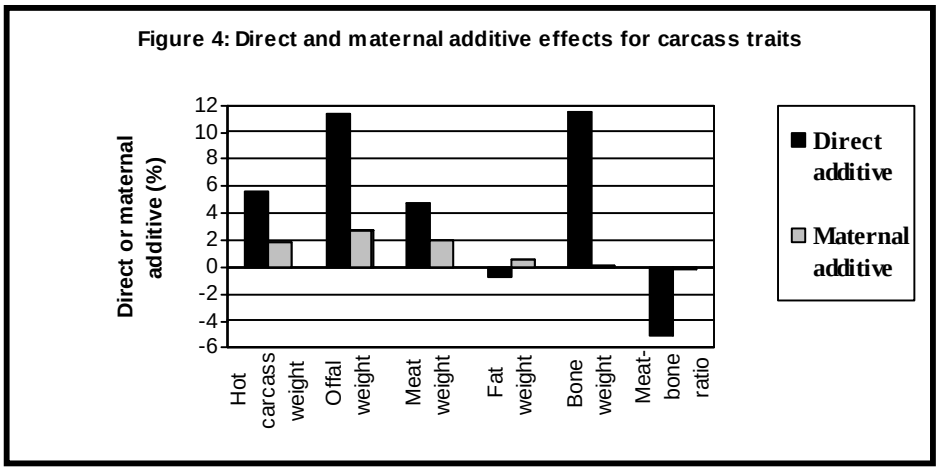


Figure 4: Direct and maternal additive effects for carcass traits

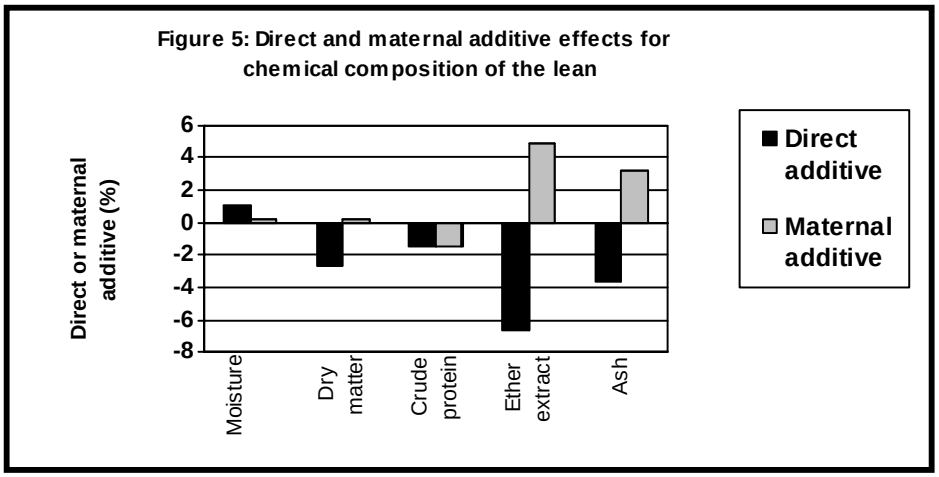
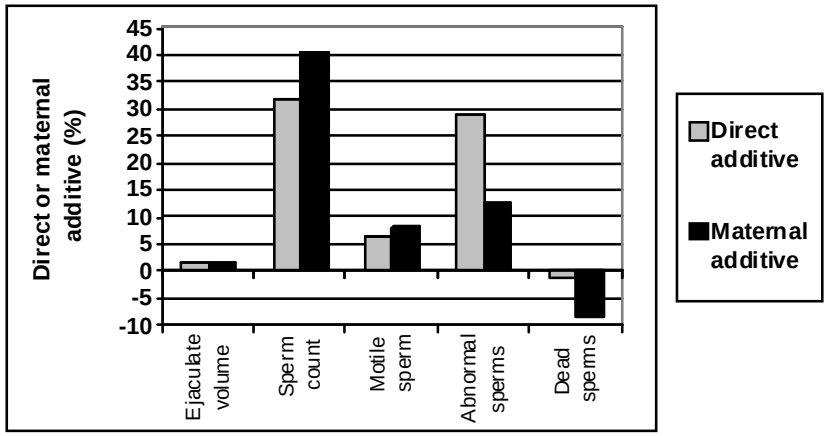


Figure 5: Direct and maternal additive effects for chemical composition of the lean

The estimates of direct and maternal additive effects for semen parameters were mostly moderate and in favour of Saudi Gabali bucks relative to V-line bucks (Figure 6). Khalil et al (2007) found that the estimates of direct additive effect were moderate for sperm count (17.7%) and dead (21.5%) and abnormal (23.0%) sperms; indicating that Saudi-sired bucks had higher estimates of direct additive effect than **V**-sired bucks. The significant estimates of direct additive effect for these important semen characters gave an indication to state that Saudi bucks could be used as a terminal buck breed for improving conception rates of does to be inseminated by this breed.

Maternal additive effect for ejaculate volume (26.4%) was in favour of **V**-line dams (Khalil et al, 2007). As shown in Figure 6, the high estimates of maternal additive effects for sperm concentration in semen (26.4%) and abnormal sperms (21.2%) and the moderate estimates for dead sperms (13.9%) and sperm motility (-9.5%) indicate that Saudi dams of bucks gave better semen characteristics than V-line dams of bucks, i.e. maternal additive effects for semen parameters were in favour of Saudi dams of bucks. This trend gave an indication to state that Saudi dams could be used to produce crossbred bucks superior in their semen parameters to improve the conception rates of does to be inseminated by these crossbred bucks.

Figure 6: Direct and maternal additive effects for semen characteristics



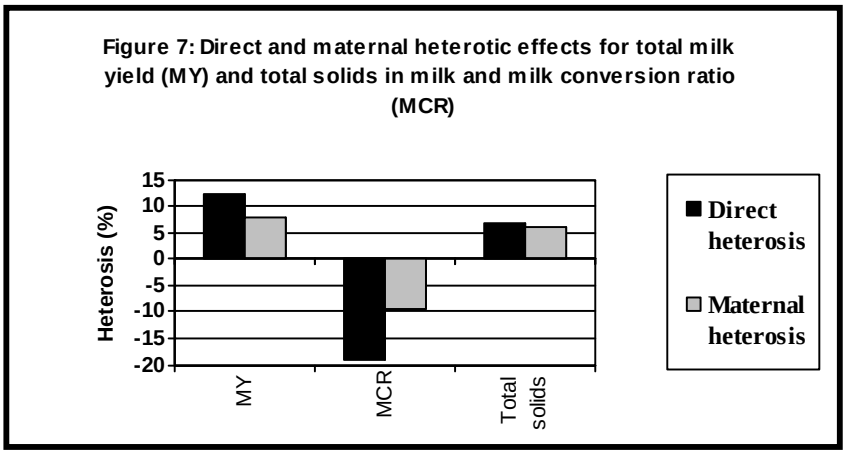
Direct and maternal heterosis

Different crossbreeding experiments carried out in the Arabian area particularly in Egypt (e.g. Afifi and Emara, 1984; Afifi and Khalil, 1989; Khalil et al, 1995; Khalil and Afifi, 2000; Abd El-Aziz *et al*, 2002; Iraqi et al, 2007; Youssef et al, 2009) reported results indicating that heterotic effects were evidenced for litter size, litter weight, and milk yield in most of the possible crossbred does obtained. Consequently, both producers and processors in the Arabian area could potentially benefit economically through using crossbred does. However, most reviewed estimates were favourable and indicating that crossbred dams had considerable maternal heterotic effects in terms of larger litter size, heavier litter weight at birth and weaning, favourable feed conversion ratio, and efficient milk to litter gain conversion ratio than their crossbred daughters (Khalil et al, 2005). Also, results of different crossbreeding experiments carried out in the Arabian area (*e.g.* Afifi and Emara, 1984; Khalil et al, 2004; Youssef et al,

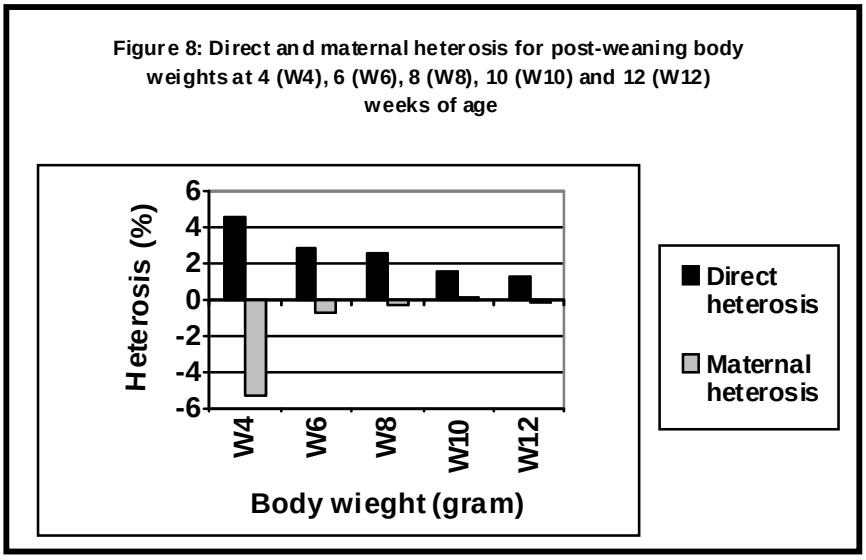
2009) revealed that heterotic effects for pre-weaning litter traits were evidenced in most of the crossbred dams obtained.

Reviewed estimates of direct heterosis obtained by Khalil et al (2005) indicated that crossbred does were associated with heterotic effects in milk yields and components and milk conversion ratio (Figure 7); *i.e.* crossbred does and dams gave favourable heterotic effects on milk yields and components and milk conversion ratio. Results of Khalil and Afifi (2000) revealed that crossing Gabali rabbits with New Zealand White in Egypt was associated with negative low non-significant heterotic effects on milk yields 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 production traits were non-significant (0.12 to 2.4 %).

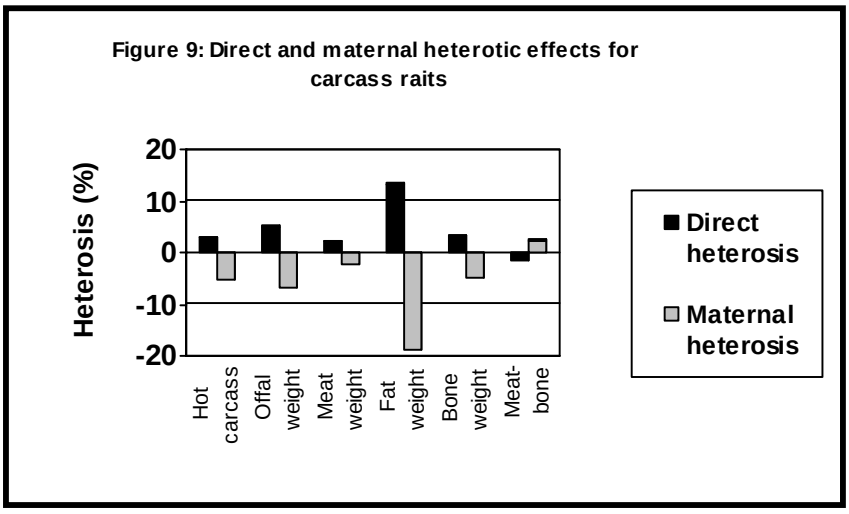
Figure 7: Direct and maternal heterotic effects for total milk yield (MY) and total solids in milk and milk conversion ratio (MCR)



Reviewed estimates of direct heterosis for body weights raised in hot Arabian countries were mainly positive and ranging from 1.3 to 4.5 %, but the estimates for maternal heterosis were mainly negative and ranging from 0.2 to 5.3 % (Figure 8). The negative estimates of maternal heterosis for body weights indicate that crossbred dams had little or adverse heterotic maternity over their purebred dams in these growth traits. These results of direct heterosis could be similar to those estimates obtained in other crossbreeding experiments involving maternal lines (*e.g* Gomez *et al*., 1999). Gomez *et al*. (1999) for crossbreeding experiment including V-line rabbits in Spain reported insignificant direct heterosis for body weights at 32 and 60 days and daily gains between the two ages. Abdel-Ghany et al (2000a,b) and Afifi *et al*. (1994) for crossing New Zealand White with Baladi Black or Baladi Red in Egypt found that heterosis percentages ranged from 2.7 to 9.5% for post-weaning body weights and gains. Medellin and Lukefahr (2001) stated that estimates of direct heterosis from crossing Altex rabbits with New Zealand White were 66 grams for weaning weight at 28 days ($P < 0.01$) and 1.7 gram/day for average daily gain between 28-70 days ($P<0.01$).



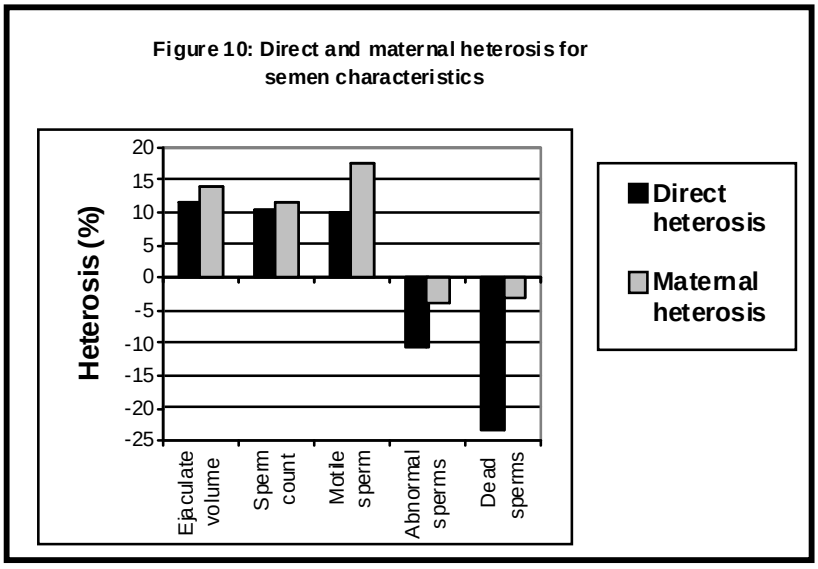
For carcass traits, Afifi et al. (1994) for crossing New Zealand White X Baladi Red in Egypt found that direct heterosis percentages ranged from 1.0 to 4.7 %; indicating that crossbreeding in rabbits was associated with a little improvement in the carcass performance. In Saudi Arabia, Al-Saef et al (2008) showed non-favorable negative estimates of maternal heterosis of -65.5 g, -6.7 g, -5.3 g and –12.2 g for hot carcass, offal, fat and bone weights, respectively (Figure 9); i.e. crossbred dams gave significant negative maternal heterotic effects ranging from 4.8 to 18.7% (Figure 9). For meat quality traits, neither individual heterosis, nor maternal heterosis were significant.



Estimates of direct heterosis for semen parameters given by Khalil et al (2007) indicated that crossbred bucks were associated with an existence of heterotic effects in some semen parameters. The positive estimates of direct heterosis recorded in this study for volume of ejaculate (11.6%), sperms concentration (10.5 %) and motility of sperms (9.8%) were favorable

as shown in Figure 10. Also, the negative and moderate estimates recorded for percentage of abnormal sperms (-10.8%) and dead sperms (-23.5%) were favorable; i.e. crossing **V**-line with Saudi rabbits was associated with heterotic effects on most semen characteristics of the individual bucks. Such crossing was associated with an increase in ejaculate volume ($P<0.05$), sperm concentration ($P<0.05$), percentages of motile and living sperms, and libido of bucks ($P<0.05$) along with a reduction in percentages of abnormal and dead sperms ($P<0.05$), i.e. superiority of crossbred bucks has been proved for the lines used and the traits investigated. One of the explanations for positive heterotic effects in percent sperm viability could be possibly to that sexual maturation in crossbred males was faster than purebred males. Brun *et al.* (2002) reported high variability in the estimates of heterosis in function of the seminal trait since they observed a 6.8% of heterosis in mass motility and 4.1% in percentage of motile spermatozoa and high values of heterosis in sperm concentration (37.5%), total number of spermatozoa per ejaculate (37.6%) and number of motile spermatozoa per ejaculate (42.3%). Garcia et al (2004) found that individual heterosis were favourable and significant for percentage of sperm viability ($P<0.10$), while heterosis for pH was almost negligible (1.6%).

Reviewed estimates of maternal heterosis for semen characteristics were favourable and moderate (Khalil et al, 2007; Figure 10); indicating that crossbred dams gave maternal heterotic effects on some semen parameters in their progeny of crossbred bucks. Consequently, crossbred dams could produce crossbred bucks characterized by higher volume of ejaculate, higher semen quality with more concentration and motile sperms, along with lesser percentages of abnormal sperms and dead sperms than their crossbred daughters.



Direct recombination effects

Comparing estimates of direct recombination losses with direct heterosis in crossing V-line with local rabbits, we found that estimates of direct heterosis for the majority of traits were generally larger than the estimates of direct recombination effects (Khalil et al, 2004). Most estimates of direct recombination effects reviewed reported that there is a potential advantage to use crossbred does and bucks including V-line genes to develop parental lines (maternal and paternal lines having more available heterosis) to be used in hot climate countries.

Negative direct recombination losses for feed consumption and conversion per litter reveal that crossbred does having **V** genes could mother does with lower feed consumption and higher feed conversion than purebred **V** does when both groups of does were mated to bucks from the same V purebred (Khalil et al, 2005). For post-weaning growth performance, the estimates of direct recombination losses were always not significant and favourable (Khalil *et al* , 2002); gaving an impression to indicate that crossbred dams having V-line genes could be effective to improve post-weaning growth performance by crossing V-line with native Saudi rabbits. Fortunately, estimates of direct recombination losses for the majority of the semen traits were non-significant and indicate that epistatic recombination losses for these traits in crossbred bucks were of limited importance.

Selection programs used to develop new synthetic maternal lines in hot climate countries

Selection criteria used

The most common direct criteria used in selection programs of maternal lines in hot climate countries were related with litter size at birth or at weaning (El-Raffa, 2000), while in other cases selection programs were practiced for traits related with the ability of the doe for lactating and nourishing the progeny, such as litter weight at weaning or total milk production (Khalil *et al.,* 2002; Al-Saef *et al.,* 2008; Iraqi *et al.,* 2008; Youssef *et al.,* 2008).

Selection programs used

Summaries for maternal lines developed in hot climate countries through crossbreeding and selection are presented in Table 1.

In Egypt, great efforts have been made since 1998 to select one exotic maternal line under local conditions and to develop and select local lines based partially on local breeds. Faculty of Agriculture of Alexandria University, Animal Production Research Institute (APRI, Cairo) and Faculty of Agriculture at Moshtohor of Benha University are involved in this Egyptian-Spanish programme. V-line rabbits were imported from Spain and various selection experiments were practiced. On one hand, three replicates of V-line were created: one line (Egyptian-Alexandria V) is selected for litter size at weaning (El-Raffa, 2000); the second one (Egyptian-Moshtohor V) is selected for litter weight and live weight at 56 days, and the third one (Egyptian –APRI V) is selected for litter weight at weaning. On the other hand, two synthetic lines were developed: the Egyptian- Moshtohor Synthetic line that is a cross between Sinai Gabali and V-line and this line is selected for litter weight at weaning and live weight at 56 days. The Egyptian–APRI synthetic that is a cross between Baladi Red and V-line and this line is selected for litter weight at weaning.

In Saudi Arabia, a national project was established to develop rabbit production in this country and to detect the possibilities of producing meat rabbits under industrialized conditions (Khalil et al, 2002, 2005). For this reason, special emphases were paid to construct a genetic improvement programme to develop new lines of meat rabbits convenient for this hot climate country. V-line rabbits were imported in 2000 from Spain and were crossed with desert Saudi rabbits (Gabali). There were some evidences that V-line rabbits and their crosses could produce efficiently under hot climatic conditions (Khalil et al. 2002, Mehaia et al. 2002, Al-Sobayil and Khalil 2002). One synthetic maternal line (Saudi-2) and one synthetic paternal line (Saudi-3)

were developed from crossing Saudi Gabali with V-line rabbits, both selected for litter weight at weaning and individual weight at 84 d.

Table 1: Selection programs used for developing synthetic maternal lines in hot climate countries

Synthetic line and authors	Founder breeds	Selection criteria	Selection methodology	Number (interval) of generations	Selection response per generation
Saudi-2, Saudi Arabia, Khalil *et al* (2005)	V line and Saudi Gabali	LWW + weight at 84-d	BLUP procedure under an animal-repeatability model	10 (8 months)	LSB= 0.18 kit per litter; LSW= 0.16 kit per litter; LWW= 62 g per litter; WW= 8.6 g per rabbit
APRI, Egypt, Youssef *et al* (2008)	V line, Baladi Red	LWW	BLUP procedure under an animal-repeatability model	5	

LSB = litter size at birth; NBA= Number born alive; LSW = litter size at weaning; LWW= litter weight at weaning; WW = weaning weight.

Selection programs used to develop new synthetic paternal lines in hot climate countries

Selection criteria

Selection for high growth rate has been largely introduced in sire lines to modify the whole pattern of growth, feed efficiency, and tissue composition, thus affecting carcass and meat quality traits. Current programs of rabbit selection normally include terminal sires produced from selection schemes commonly practiced for post-weaning daily gain in some countries of hot climate (El-Raffa, 2007) or for body weight at the market age (Khalil *et al.*, 2002, 2005; Al-Saef *et al.*, 2008). In practice, criterion of post-weaning growth is effective in selection programs because it is very easy to record and it has a negative and favourable genetic correlation with feed conversion index, and therefore this trait is very important for an efficient rabbit production (Khalil *et al.*, 2008).

Average daily gain is the preferred trait for selection during post-weaning period, suggesting that individual selection could be used successfully to improve this trait, because this trait is less affected by the common litter effects than the individual weights at specific ages and it has moderate or high heritability estimates varied in magnitude from 0.13 to 0.48 (Moura *et al.*, 1997, 2001). Moura *et al.* (1997) stated that selection based on an index including both growth rate and feed conversion ratio would be more efficient for improving feed efficiency than a sole selection for growth rate. Although feed conversion ratio is the most important trait in meat rabbit production (Khalil and Al-Saef, 2008), this criterion was not considered commonly in selection programs. Baselga (2004) reported that feed conversion index is not used directly in

selection because it is expensive to record and would need electronic devices to enable recording of the individual feed intake. Since feeding costs represent about 70% of the rabbit meat production costs, therefore feed conversion (g feed per g gain) could be an economic trait in direct selection (Moura *et al.*, 1997; Larzul and Rochambeau, 2005).

Selection programs used

The paternal lines developed in hot climate countries to be used on small and large commercial scales are presented in Table 2. In Saudi Arabia, Saudi-3 was founded from ¼ V line and ¾ Saudi Gabali and selected for litter weight at weaning and individual weight at 84 d and details concerning the development of this new line were presented by Khalil *et al.* (2002, 2005) and Al-Saef *et al.* (2008). In Egypt, a synthetic paternal line of Alexandria was originated in Alexandria University from crossing V line with Baladi Black and selection was practiced for daily weight gain during 28-63 days of age (El-Raffa, 2007).

Table 2: Selection programs used for developing synthetic paternal lines in hot climate countries

Synthetic line and country of work	Authors	Founder breeds	Selection criteria	Selection methodology	Number (interval) of generations	Selection responses per generation
Alexandria, Egypt	El-Raffa, 2007	Line V, Baladi Black	ADG (28-63d)	Individual selection using BLUP	5 generations (10 months)	
Saudi-3, Saudi Arabia	Khalil *et al.*, 2002, 2005	Line V and Saudi Gabali	LWW + W12	Individual selection using BLUP	8 generations (9 months)	W12= 38 g; ADG= 0.6 g; LSB= 0.14 kit per litter; LSW= 0.12 kit per litter; LWW= 35 g per litter

ADG: average daily gain; W12: weight at 12 weeks; LSB: litter size at birth; LWW: litter weight at weaning**.**

Multipurpose (global objectives) synthetic lines developed in hot climate countries

Criteria and methods of selection

Multi-purpose lines were developed as a global objective through simultaneous selection for litter size and growth traits. This selection strategy was successfully developed in Brazil, and

Egypt as hot climate countries. In Brazil, a selection index including litter size at weaning, individual weaning weight, weaning litter weight and individual weight at 70 days of age was used (Moura *et al.,* 2001), while in Egypt, selection was practiced for litter weight at weaning and individual weight at 56 days (Iraqi *et al.,* 2008).

Selection programs used

Table 3 shows multipurpose synthetic lines developed in hot climate countries. In Brazi, a multi-purpose selection program was initiated in 1992 to develop a multipurpose line using a selection index including litter size and weight at weaning and post-weaning growth traits and this line named Botucatu (Moura *et al.,* 2001). In Egypt, a multi-purpose selection program was started in March 2003 to produce a synthetic line named Moshtohor resulting from crossing Sinai Gabali with V-line and selection was practiced for litter weight at weaning and live weight at 56 days (Iraqi *et al.,* 2007, 2008).

Table 3: Selection programs used for developing multi-purpose synthetic lines in hot climate countries

Synthetic line and country of work	Authors	Founder breeds	Selection criteria	Selection methodology	Direct response per generation
Moshtohor, Egypt	Iraqi *et al.,* 2008	Sinai Gabali, line V	LWW+ 56-d weight	Two-stage selection using BLUP	
Botucatu, Brazil	Moura *et al* (2001)	Norfolk English line	Weaning litter + daily gain in weight (28-70 d)	Selection index	

LWW: litter weight at weaning**.**

Selection responses

In selection experiments, several methodologies have been proposed to estimate selection responses. One of them is based on regressing the estimates of the breeding values on generations and this approach depends on the genetic parameters and the model used (Garreau *et al.,* 2000; Gómez *et al.,* 2000; Moura *et al.,* 2001; Ibañez *et al.,* 2006). The other methodologies are not depend on the genetic parameters and the model itself but they are dependent on another approach through using the control population which could be an unselected population (Lukefahr *et al.,* 1996; Sánchez *et al.,* 2004b), or using the population selected divergently (Moura *et al.,* 1997; Gondret *et al.,* 2002; Blasco *et al.,* 2005; Mocé *et al.,* 2004,2005; Santacreu *et al.,* 2005; Rafat *et al.,* 2007, 2008) or using the cryopreserved populations that are free of the genetic drift to compare the contemporaries of two different generations (Santacreu *et al.,* 2000; Baselga and García, 2002; García and Baselga, 2002a, 2002b, 2002c; Blasco *et al.,* 2003; Piles and Blasco, 2003; Gil *et al.,* 2006).

As presented in Tables 1 and 2, genetic responses obtained from long-term selection experiments for litter size and other litter traits were found to be moderately considerable. In the European studies, some responses in litter traits were estimated exclusively by mixed model methods (Estany *et al.,* 1989; Rochambeau *et al.,* 1994; Gómez *et al.,* 1996) where the estimates ranged from 0.05 to 0.129 rabbit born alive or weaned per litter and generation. In other cases, Rochambeau *et al.* (1998), Tudela *et al.* (2003), and García and Baselga (2002a, 2002b) found that direct responses using the control population or frozen embryos ranged from 0.08 to 0.14 rabbits for total number born, number born alive or weaned per litter and generation; responses estimated as genetic trends or by mixed model were nearly similar. These responses were lower than expected and this could be attributed to that: (1) additive genetic variance for litter size at weaning was low, (2) heterogeneity between parities was high (Baselga *et al.,* 1992), (3) correlations between direct and maternal effects were negative, and (4) intensity of selection was low.

Selection experiments for growth rate in rabbits notifying successful responses in most experiments carried out in some parts of the world. In this concept, direct selection responses for average daily gain or for body weight at market time were verified (Lukefahr *et al.,* 1996; McNitt and Lukefahr, 1996; Moura *et al.,* 1997; Blasco *et al.,* 2003; Piles and Blasco, 2003; Nagy *et al.,* 2006), while in some cases the responses were less than expected (Estany *et al.,* 1992; Gondret *et al.,* 2002; Sánchez *et al.,* 2004b). Such contradictions in results of selection responses may be due to the overlapping of generations especially when the control population was not used in the same generation of the selected population or may be due to the appearance of some diseases such as enterocilitis.

As reviewed by Khalil and Al-Saef (2008), does selected for litter size at weaning presented significant responses in feed intake (3%) and milk yield (6%). A response of 62 g per litter was recorded when selecting for litter weight at weaning. Estimates of direct selection responses per generation were moderate and ranged from 8.7 to 12.6 g for weaning weight, 18 to 68 g for marketing weight, 0.45 to 1.73 g/d for weight gain from weaning to marketing. Selection for growth rate has little or somewhat moderate effects on carcass characteristics and meat quality when the rabbits were selected at the same stage of maturity. Selection for litter weight at weaning achieved considerable responses in growth rate with maintaining high litter components and feed conversion.

The rate of genetic progress in marketing weight per generation (29.4 g or 1.3% per generation) obtained by Lukefahr *et al.* (1996) was similar to the annual genetic improvement often reported for this trait in other livestock species, i.e. producers willing to select for increased 70-day body weight may have genetic improvement in weaning weights and in average daily gains and also in lean-to-bone ratio. Using the control line or mixed model methodology, the direct responses obtained for growth rate from weaning to marketing age were moderate and ranged from 0.45 to 1.73 gram per day per generation for daily weight gain, while the responses for weight at market age ranged between 18 and 68 g per generation (Rochambeau *et al.,* 1994; Estany *et al.,* 1992; Lukefahr *et al.,* 1996; Moura *et al.,* 1997; Szendrő *et al.,* 1998; Garreau *et al.,* 2000; Khalil *et al.,* 2002, 2005; Hernández *et al.,* 2004; Sánchez *et al.,* 2004b). At commercial slaughter age (9 wk), Blasco *et al.,* (2003) and Piles and Blasco (2003) found that selected animals had a higher growth rate of 7% relative to the population mean before selection, while slaughter weight was higher in the selected group, but weaning weight remained practically the same; the two methods used in estimating the selection response (control population vs. Bayesian inference) gave the same results, thus validating the model used for the analysis. Also, Gondret *et al.,* (2002) and Larzul *et al.* (2005) found that body weights have been increased by selection,

while carcass and muscle traits did not differ significantly between highly selected animals and the animals of cryopreserved control population.

QTL analysis in selection programs

Khalil *et al* (2008) used RAPD markers to search for the linkage between markers and quantitative traits since they used 526 rabbits in this analysis from granddaughter design in selection program. From a total of 40 primers (10-mer) used in their study, five primers (OPA12, OPA19, OPA20, OPF09, and OPF12) were able to identify five polymorphic fragments at molecular weight of 1500, 1100, 1200, 700 and 900bp, respectively and only three markers of these markers ($OPF12_{900}$, $OPF09_{700}$, and $OPA19_{1100}$) showed significant associations with phenotypic traits which indicating the presence of linkage of these three markers with litter weight at birth, 7 and 21 days, and at weaning, litter gain at interval of 0-21 days, pre-weaning litter mortality, milk yield at lactation intervals of 0-7 and 0-21days, and body weight at 4 and 8 weeks of age.

Ways of maintaining and diffusing the synthesized genetic resources

(1) Multiplication of synthesized lines in nucleus stock (Qassim University, Alexanderia University, APRI, Benha University) to get more generations then diffusing the rabbits genetically improved to the commercial farms. In order to minimize de-multiplication program, it is possible to contract with some commercial companies to achieve this purpose.
(2) The synthesized lines will be selected more, under the responsibility of the geneticists of the nucleus in these scientific units in the same way practiced before in the programs.
(3) Collecting and freezing of embryos and semen from the lines synthesized in the programs or introducing them to various hot climate countries.

CONCLUSIONS

1) In hot climate countries, specialized maternal or paternal lines were mostly developed to be used in commercial farms although synthesizing multi-purpose lines are necessary to be established in the national rabbit industry.
2) Synthetic maternal lines could be used in commercial scale as a pure line or to be crossed with other maternal males to get crossbred does, while the paternal lines will be specialised in high rates of growth.
3) The favourable estimates of direct and maternal heterosis reviewed for lactation, growth and carcass traits and heat-stress physiological parameters (Khalil et al, 2002) would be an encouraging factor for the rabbit producers in hot climate countries to use crossbred does and dams on commercial scale; i.e. crossing V-line with Saudi rabbits for example was associated with an improvement in milk production along with a reduction in conversion ratio of milk to litter gain (Al-Saef et al, 2008).
4) Insignificant recombination effects for milk yields and components gave an impression to conclude that crossbred does resulting from crossing V-line with native breeds of rabbits in hot climate countries could be effective to develop synthetic maternal line characterized by high milk production associated with rich milk components and consequently higher productivity in does could be attained.

5) The insignificant effects for direct recombination for most growth traits indicating that epistatic recombination losses for these traits in crossbred rabbits were negligible, and therefore, there is a potential advantage to use crossbred dams and sires including V-line genes to develop parental lines (maternal and paternal) having more available heterosis to be used in crossbreeding stratification systems in hot Arabian countries.
6) Till now, marker-assisted selection (MAS) is not generally used in current rabbits' selection programs and the recent molecular technologies were used only to identify the genetic diversity, gene mapping and DNA fingerprinting in different breeds of rabbits.
7) As future prospects, localizing the loci of genes of economic interest are necessary to identify the candidate animals in selection programs and to elucidate the molecular nature of few already verified proven major genes.

REFERENCES

Abd El-Aziz, M.M.; Afifi, E.A.; Bedier, Nayera Z.; Azamel, A.A. and Khalil, M. H. 2002. Genetic evaluation of milk production and litter weight traits in Gabali, New Zealand White rabbits and their crosses in a newly reclaimed area of Egypt. In: Proceedings of the 3rd Scientific Conference on Rabbit Production in Hot Climates, Hurghada, 8-11 October 2002, 103-116, Egypt.

Abdel-Ghany, A. M.; Ahmed, E. G.; Hassan, N. S. 2000a. Crossbreeding genetic parameters of post-weaning growth traits of the Egyptian acclimatized New Zealand White and native Baladi Black rabbits. 7th World Rabbit Congress, Valencia, Spain, Volume **A**: 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 Congress,

Afifi, E.A.; Emara, M.E.1984. Litter weight in local Egyptian and exotic breeds of rabbits and their crosses. Proceeding 3rd World Rabbit Congress, 4-8 April 1984, Rome, Italy, Vol. **QG1**:126-135.

Afifi, E.A.; Khalil, M.H.1989. Observations on purebred and crossbred litters of Giza White and Grey Giant Flander rabbits in Egypt. Journal of Applied Rabbit Research, **12**: 273-277.

Afifi, E.A.; Khalil, M.H.; Khadr, Amina F. and Youssef, Y.M.K.1994. Heterosis, maternal and direct effects for post weaning growth traits and carcass performance in rabbit crosses. J. Animal Breeding and Genetics, **111**:138-147.

Al-Saef A.M., Khalil M.H., Al-Homidan A.H., Al-Dobaib S.N., Al-Sobayil K.A., García M.L, Baselga M. 2008. Crossbreeding effects for litter and lactation traits in a Saudi project to develop new lines of rabbits suitable for hot climates. *Livestock Science, 110, In Press.*

Al-Sobayil, K. and Khalil, M. H. 2002. Semen characteristics of bucks in crossbreeding project involving Saudi Gabali with V-Line rabbits in Saudi Arabia. 3rd Scientific Conference on Rabbit Production in Hot Climates, 8-11 October 2002, 151-163.

Baselga M. 2004. Genetic improvement of meat rabbits. Programmes and diffusion. *In Proc. 8th World Rabbit Congress, 2004 September, Puebla, Mexico,* 1-13.

Baselga M., García M.L. 2002. Evaluating the response to selection in meat rabbit programmes. *In Proc. 3rd Scientific Conference of Rabbit Production in Hot Climates, 2002 October, Hurghada, Egypt, 1-10.*

Baselga M., Gómez E., Cifre P., Camacho J. 1992. Genetic diversity of litter size traits between parities in rabbits. *In Proc. 5th World Rabbit Congress, 1992 July, Oregon, USA, Vol. A, 198-205.*

Blasco A., Piles M., Varona L. 2003. A Bayesian analysis of the effect of selection for growth rate on growth curves in rabbits. *Genet. Sel. Evol., 35, 21-41.*

Blasco A., Ortega J.A., Climent A., Santacreu M.A. 2005. Divergent selection for uterine capacity in rabbits. I. Genetic parameters and response to selection. *J. Anim. Sci., 83, 2297-2302.*

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

El-Raffa A.M. 2007. Formation of a rabbit synthetic line (Alexandria Line) and primary analysis of its productive and reproductive performance. *Egyptian Poultry Sci., 27(2), 321-334.*

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.*

García M.L., Baselga M. 2002a. Estimation of genetic response to selection in litter size of rabbits using a cryopreserved control population. *Livest. Prod. Sci., 74, 45-53.*

García M.L., Baselga M. 2002b. Genetic response to selection for reproductive performance in a maternal line of rabbits. *World Rabbit Sci., 10, 71-76.*

García M.L., Baselga M. 2002c. 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.*

Garreau H., Szendrő Zs., Larzul C., Rochambeau H. 2000. Genetic parameters and genetic trends of growth and litter size traits in the White Pannon breed. *In Proc. 7th World Rabbit Congress, 2000 July, Valencia, Spain, Vol. A, 403-408.*

Gil M., Ramirez J.A., Pla M., Arino B., Hernández P., Pascual M., Blasco A., Guerrero L., Hajos G., Szerdahelyi E.N., Oliver M.A. 2006. Effect of selection for growth rate on the ageing of myofibrils, meat texture properties and the muscle proteolytic potential of *m. Longissimus* in rabbits. *Meat Science, 72, 121-129.*

Gómez E.A., Rafel O., Ramón J., Baselga M. 1996. A genetic study of a line selected on litter size at weaning. *In Proc. 6th World Rabbit Congress, 1996 July, Toulouse, France, 289-292.*

Gomez, E. A.; Baselga, M.; Rafel, O.; Garcia, M. L.; Ramon, J. 1999a. Selection, diffusion and performances of six Spanish lines of meat rabbits. Cahiers Options Mediterraneennes (2nd International Conference on Rabbit Production in Hot Climates, Adana, Turkey, 7-9 September 1998),Volume **41**:147-152

Gomez, E. A.; Rafel, O.; Ramon, J.; Baselga, M. 1999b. Feeding efficiency in crossbreeding among three of the strains selected in Spain. Cahiers Options Mediterraneennes (2nd International Conference on Rabbit Production in Hot Climates, Adana, Turkey, 7-9 September 1998), Volume **41**:153-158.

Gómez E.A., Rafel O., Ramón J. 2000. Preliminary genetic analysis of Caldes line: a selection experiment for a global objective. *In Proc. 7th World Rabbit Congress, 2000 July, Valencia, Spain, Vol. A, 417-424.*

Gondret F., Combes S., Larzul C., Rochambeau H. de 2002. Effects of divergent selection for body weight at a fixed age on histological, chemical and rheological characteristics of rabbit muscles. *Livest. Prod. Sci., 76, 81-89.*

Hernández P., Aliaga S., Pla M., Blasco A. 2004. The effect of selection for growth rate and slaughter age on carcass composition and meat quality traits in rabbits. *J. Anim. Sci., 2, 3138-3143.*

Ibañez N., Santacreu M.A., Martinez M., Climent A., Blasco A. 2006. Selection for ovulation rate in rabbits. *Livest. Sci., 101, 126-133.*

Iraqi M.M., Shenana M.E., Baselga M. 2007. Some factors affecting productive and milk composition characters in a crossbreeding experiment involving Gabali and V-line rabbits in Egypt. *World Rabbit Sci., 15, 151-159.*

Iraqi M.M., Afifi E.A., Baselga M., Khalil M.H., García M.L. 2008. Additive and heterotic components for post-weaning growth traits in a crossing project of V-line with Gabali rabbits in Egypt. *In Proc. 9th World Rabbit Congress, 2008 June, Verona, Italy (In press).*

Iraqi M.M.1, Baselga M.2, Khalil M.H.3, Afifi E.A.1, García M.L. 2009. Line Moshtohor (Egypt). In Khalil M.H., Baselga, M. (Eds). Rabbit Genetic Resources in Mediterranean Countries. Options Méditerranénnes, Series B, Nº 38, **Spain,** http://www.iamz.ciheam.org/medrabbit/docs/moshtohor.pdf.

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 Congress, Valencia, Spain, Volume **A**: 431- 437.

Khalil M.H. and Al-Saef A.M., 2008. Methods, criteria, techniques and genetic responses for rabbit selection: A review. In proceedings of 9th World Rabbit Congress, 10-13 June 2008, Verona, **Italy**, Invited paper, Genetics Session, pp 3-34.Khalil, M.H., Afifi, E.A., Youssef, Y.M.K. and Khadr, A.F. 1995. Heterosis, maternal and direct genetic effects for litter performance and reproductive intervals in rabbit crosses. World Rabbit Science, **3**(3):99-105.

Khalil M.H., Al-Sobayel K., Hermes I.H., Al-Homidan A.H. 2002. Crossbreeding effects for post-weaning growth, rectal and ears temperatures and respiration rates in crossing Saudi Gabali with Spanish V-Line rabbits. *In Proc. 7th World Congress on Genetics Applied to Livestock Production, 2002 August, Montpellier, France, Communication n. 04-12.*

Khalil M.H., Mehaia M.A., Al-Homidan A.H., Al-Sobayl K.A. 2004. Genetic analysis for milk yield and components and milk conversion ratio in crossing of Saudi rabbits with V-line. *In Proc. 8th World Rabbit Congress, 2004 September, Puebla, Mexico, 82-89.*

Khalil M.H., García M.L., Al-Dobaib S.N., AL-Homidan A.H., Baselga M. 2005. Genetic evaluation of crossbreeding project involving Saudi and Spanish V-line rabbits to synthesize new maternal lines in Saudi Arabia: I. Pre-weaning litter, lactation traits and feeding parameters. *In Proc. 4th International Conference of Rabbit Production in Hot Climate, 2005 February, Sharm El-Sheikh, Egypt, pp 89-99.*

Khalil M.H., Al-Sobayl K.A., Al-Saef A.M., García M.L., Baselga M. 2007. Genetic evaluation for semen characteristics in a crossbreeding project involving Saudi and Spanish V-line rabbits. *Animal, International Journal of Animal Bio-Science, 1, 923-928.*

Khalil M.H., Motawei M.I., AL-Saef A.M., Al-Sobayil K.A., El-Zarei M.F. 2008. RAPD markers linked to litter, lactation and growth traits in rabbits. *In Proc. 9th World Rabbit Congress, 2008 June, Verona, Italy (In press).*

Larzul C., Rochambeau H. 2005. Selection for residual feed consumption in the rabbit. *Livest. Prod. Sci., 95, 67-72.*

Lukefahr S.D., Odi H.B., Atakora J.K.A. 1996. Mass selection for 70-day body weight in rabbits. *J. Anim. Sci., 74, 1481-1489.*

McNitt J.I., Lukefahr S.D. 1996. Genetic and environmental parameters for postweaning growth traits of rabbits using an animal model. *In Proc. 6th World Rabbit Congress, 1996 July, Toulouse, France, 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. Animal Sci., **79**(5):1173-1178.

Mehaia, M. A., Khalil, M. H., Al-Homidan, A. H. Al-Sobayil, K. 2002. Milk yield and components and milk to litter-gain conversion ratio in crossing of Saudi Gabali rabbits with V-Line. 3rd Scientific Conference on Rabbit Production in Hot Climates, 8-11 October 2002, 139-150.

Mocé M.L., Piles, M., Santacreu M.A., Blasco A. 2000. Correlated response to selection for uterine capacity on teat number and effect of teat number on survival rate. *In Proc. 7th World Rabbit Congress, 2000 July, Valencia, Spain, Vol. A, 469-473.*

Mocé M.L., Santacreu M.A., Climent A. 2002. Effect of divergent selection for uterine capacity on progesterone, estradiol and cholesterol levels around implantation time in rabbits. *World Rabbit Sci., 10, 89-97.*

Mocé M.L., Santacreu M.A., Climent A., Blasco A. 2004. The effect of divergent selection for uterine capacity on prenatal survival in rabbits: Maternal and embryonic genetic effects. *J. Anim. Sci., 82, 68-73.*

Mocé M.L., Santacreu M.A., Climent A., Blasco A. 2005. Divergent selection for uterine capacity in rabbits. III. Responses in uterine capacity and its components estimated with a cryopreserved control population1. *J. Anim. Sci., 83, 2308-2312.*

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.*

Moura A.S.A.M.T., Costa A.R.C., Polastre R. 2001. Variance components and response to selection for reproductive litter and growth traits through a multi-purpose index. *World Rabbit Sci., 9, 77-86.*

Nagy I., Ibañez N., Romvári R., Mekkawy W., Metzger S.Z., Horn P., Szendrő Zs. 2006. Genetic parameters of growth and in vivo computerized tomography based carcass traits in Pannon White rabbits. *Livest. Sci., 104, 46-52.*

Piles M., Blasco A. 2003. Response to selection for growth rate in rabbits estimated by using a control cryopreserved population. *World Rabbit Sci., 11, 53-62.*

Rafat S.A., Allain D., Thébault R.G., Rochambeau H. de 2007. Divergent selection for fleece weight in French Angora rabbits: Non-genetic effects, genetic parameters and response to selection. *Livest. Sci., 106, 169-175.*

Rafat S.A., Rochambeau H. de, Thébault R.G., David I., Deretz S., Bonnet M., Pena-Arnaud B., Allain D. 2008. Divergent selection for total fleece weight in Angora rabbits: Correlated responses in wool characteristics. *Livest. Sci., 113, 8-13.*

Rochambeau H. de, Bolet G., Tudela F. 1994. Long-term selection. Comparison of two rabbit strains. *In Proc. 5th World Congress Genetics Applied Livestock Production, Guelph, Ontario, Canada, 19, 257-260.*

Rochambeau H. de, Duzert R., Tudela F. 1998. Long-term selection experiment in rabbit. Estimation of genetic progress on litter size at weaning. *In Proc. 6th World Congress Genetics Applied Livestock Production, Armidale, Australia, 26, 112-115.*

Sánchez J.P., Baselga M., Ducrocq V. 2004a. Estimation of the correlation between longevity and litter size. *In Proc. 8th World Rabbit Congress, 2004 September, Puebla, Mexico, 163-168.*

Sánchez J.P., Baselga M., Silvestre M.A., Sahuquillo J. 2004b. Direct and correlated responses to selection for daily gain in rabbits. *In Proc. 8th World Rabbit Congress, 2004 September, Puebla, Mexico, 169-174.*

Santacreu M.A., Argente M.J., Mocé M.L., Blasco A. 2000. Selection for uterine capacity. II response to selection estimated with a cryopreserved control population. *In Proc. 7th World Rabbit Congress, 2000 July, Valencia, Spain, 491-495.*

Santacreu M.A., Mocé M.L., Climent A., Blasco A. 2005. Divergent selection for uterine capacity in rabbits. II. Correlated response on litter size and its components estimated with a cryopreserved control population. *J. Anim. Sci., 83, 2303-2307.*

Szendrő Zs., Biró-Németh E., Radnai I. 1998. Development of the Pannon White rabbit breed and changes in results for production between 1988 and 1997. *Kmetijstvo, 30, 125-130.*

Tudela F., Hurtaud J., Garreau H., Rochambeau H. de 2003. Comparaison des performances zootechniques des femelles parentales issues d´une souche témoin et d´une souche sélectionnée pour la productivité numérique. *In Proc. 10èmes Journées Recherche Cunicole, 2003 November, Paris, France, 53-56.*

Yamani, K. A. 1994. Rabbit meat production in Egypt. Cahiers Option Mediterraneennes, Spain, **8**:57-64.

Youssef Y.K., Iraqi M.M., El-Raffa A.M., Afifi E. A., Khalil M.H., García M.L., Baselga M. 2008. A joint project to synthesize new lines of rabbits in egypt and saudi arabia: emphasis for results and prospects. *In Proc. 9th World Rabbit Congress, 2008 June, Verona, Italy (In press).*

Youssef, Y.K., Baselga, M., Khalil, M.H. Omara, M.E., García, M.L. 2009. Crossbreeding effects for post-weaning growth traits in a project of Spanish V-line with Baladi Red rabbits in Egypt. Livestock Science, 122: 302-307.