**Evaluation of performance of two-way crossing of rabbits raised in hot climates**

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Evaluation of performance of two-way crossing of rabbits raised in hot climates

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SUMMARY - Crossbreeding effects (additives maternal, additive direct and direct heterosis) on performance of economic traits in rabbits in hot climate countries were evaluated. Crossbreeding experiments carried out in Egypt reflected desirable additive maternal breed effect in New Zealand White (NZW) rabbits compared to other breeds. For postweaning growth traits, dams of NZW breed may not be the best dam breed. In USA, NZW breed is well recognized as a suitable dam breed resource with outstanding maternal abilities based on its high fecundity and milk production. Also, heavy vs medium weight sire breed comparisons revealed significant advantage for growth traits in favour of heavy breeds (Flemish Giant, FG). The FG used in USA as a Fancy breed may be less efficient in its overall productivity as a purebred than the NZW (as commercial purebred) due to less favorable maternal abilities (e.g. higher preweaning kit mortality). Consequently, the more appropriate role of the FG seems to be that of a terminal sire breed. In Egypt, superiority of NZW bucks during preweaning period indicates that this breed could be used as an effective terminal buck breed in a crossbreeding stratification system. In Europe and USA, FG has potential advantages as a terminal-sire breed for improving postweaning growth and carcass performance. The other breeds noted for outstanding dress-out and lean cutability traits in crossing systems include Champagne D'Argent and Californian (CAL) rabbits.

In Egypt, direct genetic effects in NZW-sired litters were more pronounced at birth and during the first 21 days of suckling period than at weaning, while Baladi-sired litters recorded the highest direct genetic effect at weaning, the differences between the Baladi and NZW were not significant. The FG-sired rabbits had the heaviest carcass weights but not the best carcass and lean yield values. In Europe and USA, direct genetic effects on pre- and post-weaning litter and growth traits were mostly in favour of CAL litters vs litters sired by NZW. Moreover, direct genetic effect of FG on these traits were positive and high when compared with litters of NZW and CAL paternity. For carcass traits, slight differences in paternity between NZW, CAL and FG were observed.

In Egypt, rabbits mothered by exotic breeds (NZW and CAL in particular) surpassed in their maternity those rabbits mothered by native breeds. Breed superiority of NZW maternity compared with CAL and FG for preweaning litter traits has been demonstrated in Europe and USA. For postweaning growth and carcass performance, breed maternity was in favour of CAL and FG dams. Based on reviewed results, maternal-breed effects appear to be less important than paternal-breed effects in influencing most growth and carcass traits.

In Egypt, crossbreeding between different breeds of rabbits under the

Egyptian conditions was associated with the presence of heterotic effects on litter traits and growth performance. Also, native x NZW crossbred rabbits had heavier carcass and leaner cut weights than did native and NZW purebreds. Consequently, both producers and processors could potentially benefit economically through commercial production of this simple cross. In Mexico and Europe, heterosis from including American breeds (e.g. NZW, CAL .. etc.) in crossbreeding experiments was equal to or superior to those estimates of heterosis from French breeds (e.g. Bouscat). In Brazil, the crossbreeding experiments on NZW, CAL, Chinchilla and Bouscat Giant breeds revealed that crossbreds including CAL had the highest postweaning growth rate. In Europe, heterosis obtained from crosses including Giant breeds was superior to that of medium-sized breeds (NZW and CAL). Generally, crossbreeding is associated with little improvement in carcass performance.

Key words: Hot climate, evaluation, two-way crossing, heterosis, maternal and direct effects.
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## Introduction

Diversity of rabbit breeds offers the opportunity to increase the efficiency of meat production through crossbreeding. Preweaning litter traits and postweaning growth traits along with carcass performance are chiefly governed by additive breed effects as opposed to other genetic breed effects (LUKEFAHR, 1988; AFIFI and KHALIL, 1991; YOUSSEF, 1992). Sire-breed (buck-breed) effect plays an important role in the inheritance of these traits through its contribution of direct additive genetic effect, while dam-breed (doe-breed) effect plays a role in variation of these traits through its contribution of additive maternal and nonadditive maternal effects. Significant sire-breed x dam-breed interaction has a meaningful role in the existence of non-additive breed effects in rabbits (i.e. presence of heterotic effects) which could be exploited in the production of heavy commercial broilers characterized with good quality carcass. In practice, some breeds performed the best as sire-breeds through the transmitting of outstanding genes for their progeny, while other breeds performed the best as dam-breeds based upon their superiority in maternal abilities. Therefore, it is necessary to point out the effects of sire-breed, dam-breed and sire-breed x dam-breed interaction on performance of crossbred rabbits.

Although heterosis in first generation of two-way crossing and the other effects of crossbreeding (e.g. maternal and direct sire effects) are generally great for preweaning litter performance (Youssef, 1992), their effects on post weaning performance of growing rabbits and carcass merit should not be ignored (AFIFI et al, 1993).

The objective of the present article is to review and evaluate the importance of heterosis and maternal and direct sire effects on the rabbits' performance of the first generation of two-way crossing in hot climate countries. Effects of sire-breed and dam-breed (i.e. which breeds performed the best as sires and which breeds performed the best as dams) and sire-breed X dam-breed interaction on performance of crossbred rabbits were also investigated. More over, a comparison of such genetic components relative to estimates of cross breeding effects for rabbits raised in Europe and USA was attempted.

Genetic model and estimation of crossbreeding effects in two-way crossing
According to DICKERSON (1992), crossbreeding effects (additive maternal, additive direct and heterosis direct) on different economic traits in rabbits could be estimated according to the genetic model shown in Table 1. Such genetic model permits to derive a selected set of orthogonal linear contrasts. To quantify differences attributable to sire breed, dam breed and direct heterotic effects in two-way crossing system (e.g. breed A and B), the following linear contrasts of mating type least-squares means are computed as:

Direct heterotic effect (units):

HiAxB = [(A x B + B x A) - (AxA +BxB)]

Maternal additive effect (i.e. reciprocal cross differences):

(GmA - GmB) = [(B x A) - (A x B)]

Direct additive effect (i.e. breed group of sire differences):

(GiA-GiB)= {[(AxA)+(A x B)] - [(B x B)+(B x A)]}

Where Gi and Gm represent direct additive and maternal additive effects, respectively, of the subscripted genetic group. However, decomposition of breed means in the first generation into DICKERSON's genetic effects (DICKERSON, 1969) was carried out in rabbits by ROUVIER and BRUN (1990) and are given in Table 2.

## LITTER TRAITS AND REPRODUCTIVE INTERVALS

In addition to heterosis another genetic factor contributing towards the success of hybrid rabbit breeding programmes is the role of breed complementing (LUKEFAHR, 1988; ROUVIER and BRUN, 1990). Combining breed strengths through appropriate crossing of superior dam and sire breeds is one definition of breed complementing. Some breeds perform best as sire or bucks for conferring out standing genes for litter traits, while other breeds perform best as dam or does based upon unsurpassed maternal abilities, such as for high milk production and favorable maternal behavior (DICKERSON, 1969&1992).

## BUCK-BREED AND DOE-BREED AND DIRECT AND MATERNAL EFFECTS

### Buck-breed and doe-breed

Reviewed results of tests of significance for effects of buck-breed (BB), doe-breed (DB) and buck-breed x doe-breed interaction (BB x DB) on litter traits are presented in Table 3. Most of these studies (e.g. PONCE De LEON, 1978; LUKE FAHR et al, 1989; MASOERO et al, 1986) reported a significant effect for buck-breed on litter traits at different ages (through direct additive genetic effect), while other investigators reported non-significant effects. Youssef (1992) found that differences due to buck-breed for litter size and weight traits along with reproductive intervals were little and nonsignificant, i.e. little contribution of direct additive effects in the inheritance of such traits was observed. Considering doe-breed, MASOERO et al (1986) and YOUSSEF (1992) reported generally a significant effect for doe-breed (through additive and non-additive maternal effects) on litter performance along with reproductive intervals of doe rabbits (Table 3).

(i) In hot climate countries
Numerous studies on breed comparison and evaluation conducted in Egypt have been reviewed by AFIFI and KHALIL (1991). In terms of litter size traits, AFIFI (1971) with Bouscat, Chinchilla, Giza White and their

crosses observed that Giza White does produced purebred and crossbred litters with larger size at birth than did both Bouscat and Chinchilla does. This may be due to that Giza White ranked first in prenatal maternal ability when compared with Bouscat and Chin chilla does. AFIFI and KHALIL (1989) using Giza White, Grey Giant Flander and their crosses found that Giza White bucks when mated to Grey Giant Flander does produced litters with larger sizes than when mated to Giza White does. This may refer to the importance of the breed of doe in crossbreeding programmes and to the lower performance of Giza White does (for prenatal maternal ability) when compared to Grey Giant Flander does. This lower maternal ability may have masked the effect of crossbreeding on Grey Giant Flander x Giza White litters. Results of AFIFI and EMARA (1987) with Bouscat, Giza White, White Flander, Baladi Red and their possible combinations, showed that Baladi Red as dams or as sires or both were the best performing crossbred groups for litter size at birth and at weaning (8.4 and 5.8 young, respectively). These groups excelled significantly their two parental breeds for litter size at birth. With Bouscat and Baladi White rabbits, TAG EL-DIN (1979) found that each of the two crossbred combinations produced (Bouscat x Baladi White and Baladi White x Bouscat) surpassed their parental breeds for litter size at birth and at weaning except Baladi White x Bouscat at weaning which showed intermediate performance between its parental breeds. OUDAH (1990) using NZW, CAL, Baladi and some of their crosses and Youssef (1992) with NZW, Baladi Red and their crosses, found that the best crossbred combination for litter size at birth and weaning was that resulting from mating Baladi bucks to NZW does.

Referring to traits of weight and gain in litter, results of AFIFI (1971) on purebred and crossbred litters produced by Bouscat, Chinchilla and Giza White does indicate the superiority of Giza White does for litter weight at birth while Bouscat does was superior in litter weight at weaning, i.e. Giza White does was superior in pre-natal maternal abilities while Bouscat does are superior in post-natal maternal abilities (AFIFI and KHALIL, 1991). They referred to the importance of breed of doe than the breed of buck in influencing litter weight and mean bunny weight per litter at birth and weaning of the crossbred combinations. AFIFI and KHALIL (1989) found that litters resulting from mating Giza White bucks to Grey Giant Flander does were heavier than those of either of the parental breeds at birth and at weaning while litters of the reciprocal crossbreed combination (Grey Giant Flander x Giza White) showed intermediate performance between its parental breeds. These results may suggest that Grey Giant Flander does have better prenatal maternal abilities than Giza White ones while Giza White does have better postnatal maternal abilities (i.e. more ability to produce milk and to suckle and care their young more efficiently) than those of Grey Giant Flander does. Findings of EMARA (1982) indicated that most of the crossbred combinations had heavier litters than their parental purebred groups. They concluded that crossbreeding among Bouscat, Giza White, White Flander and Baladi Red rabbits was generally associated with an increase in litter weight at birth and at weaning. Recently, Youssef (1992) found that does of NZW were the best performing as a doe-breed compared to Baladi Red (BR) rabbits while performances of BR bucks are nearly similar to NZ bucks, i.e. using of NZ rabbits as doe-breed gives an advantage in litter performance in terms of larger litter size, heavier litter weight and gain along with lower mortality rate. This

superiority of NZ does is attributed to favourable maternal abilities, persumably due to increased milk production levels compared to BR does.

Comprehensive breed evaluation and crossbreeding studies conducted in other hot climate countries have been reported by PONCE DE LEON (1978), CAMPOS et al (1980) and CARREGAL (1980) in Cuba, Mexico and Brazil, respectively. Closely parallel to European report findings, CAL buck x New Zealand White doe matings produce high-performance for total number born and weaned per litter and litter weight at weaning. This observation may be attributed to both individual heterosis and to favorable natural breed influences derived from purebred NZW does, presumably due to increased milk production levels compared to purebred CAL does.

(ii) In cold climate countries

ROUVIER and BRUN (1980) In France, presented information on doe and buck breed evaluation for preweaning litter traits. Using NZW as a control breed, litter size at birth and at weaning of NZW bucks yielded the lowest performances while litter weight and average kit weight at weaning were most similar to other breeds under comparison (Burgandy Fawn, Champagne de Argent, Bouscat, Californian and Small Russian). On the other hand, NZW does were consistently superior to other doe breeds for the same traits, reflecting desirable additive maternal genetic breed effect. Therefore, these European studies indicate that Champagne d'Argent and Burgandy Fawn bucks crossed with NZW does recorded the highest performances in preweaning litter traits.

The reports for breed evaluation in cold states of USA, although limited in number (LUKEFAHR et al, 1983abc) are consistent with conclusive studies published in the European rabbit literature. In USA commercial meat production, the traditional choice of the purebred NZW breed does not appear to be the most economically productive genetic source available in contrast to the more favorable breed combinations (i.e. hybrid stock), as confirmed experimentally (LUKEFAHR, 1982). Doe-breed contrasts reported by LUKEFAHR et al (1983 abc) showed significant contrasts in favour of CAL does than NZW.

**DIRECT SIRE EFFECT**

According to ROUVIER and BRUN (1990) and DICKERSON (1992), direct effects (or breed group of sire differences) reflect one-half of the differences in direct effects between any two breed groups.

(i) In hot climate countries

In Egypt, the NZW sires generally produced litters with larger size and heavier weight along with heavier mean bunny weight at birth and at 21 days of age than did the Baladi Red (BR) sires (YOUSSEF, 1992), i.e. NZW-sired litters had higher direct sire values than BR-sired litters did. The observed direct paternity effects on litter traits during the first 21 days of lactation lead to indicate that NZW breed could be used a terminal sire breed. At weaning, BR-sired litters had higher values than the NZW-sired litters. In terms of reproductive intervals, the same author found that BR-sired litters was associated with shorter lengths of insemination period, days open and kindling interval compared to NZW-sired litters, although the differences were not significant (Table 3). Higher direct paternity effects for lactation ability of NZW rabbits (which had strong negative association with the reproductive intervals in NZW does.

In Brazil, CARREGAL (1980) demonstrated minor differences in litter traits attributable to NZW vs CAL sires.

(ii) In cold climate countries

In France, BRUN and ROUVIER (1984) reported negative direct genetic effect for number born and weaned of NZW rabbits, while positive estimates for the same traits were observed for CAL rabbits. Also, ROUVIER and BRUN (1990) found that CAL-sired litters had higher direct genetic effects on preweaning litter traits than that of NZW-sired litters. LUKEFAHR et al (1983ac) in USA stated that direct sire-breed effects were mostly in favour of CAL litters vs litters sired by NZW rabbits for litter size and weight at birth, weaning (28 days) and at 56 days of age, preweaning litter gain and preweaning litter mortality. Moreover, LUKEFAHR (1982) and LUKEFAHR (1988) reported that direct sire-breed effects of FG on preweaning litters were positive and high when compared with litters of NZW and CAL paternity. Since the additive breed effects of FG litters were superior than that of New Zealand White and CAL litters, the observed direct paternity effects on preweaning litter traits reported by the American studies indicated a consistent desirable trend associated with using the FG as a terminal sire breed.

**MATERNAL EFFECTS**

According to DICKERSON (1969) and ROUVIER and BRUN (1990), maternal effects or reciprocal cross differences between any two breeds reflect differences in maternal ability between such two breeds. Based upon results of literature, maternal-breed effects appear to be much more important than paternal-breed effects in influencing preweaning litter traits (e.g. LUKEFAHR et al, 1983ab; Youssef, 1992).

(i) In hot climate countries

Tests of significance given in Table 4 showed that maternal effects (expressed as the differences between reciprocal crosses) on litter traits at birth and during the preweaning period were not significant (AFIFI et al, 1976a&b, TAG EL-DIN, 1979; DORA, 1979; EMARA, 1982; EL-QEN, 1988; AFIFI and KHLIL, 1989; OUDAH, 1990; Youssef, 1992). However, there was a general trend indicating that litters mothered by exotic breeds recorded better performance than litters mothered by native breeds. This evidenced the superiority of exotic breeds (e.g. NZW, CAL, Bouscat, Giant Flander, etc.) in their maternal ability (in terms of milk production and care for young) than native breeds. Blasco et al (1992) and Santacreu et al (1992) explained the components contributing to the variation of litter traits at birth to the variation related to ovulation rate, ova wastage, implantation sites, embryonic mortality, embryo survival, foetal survival, uterine capacity and intra-utrine environment. While at weaning, litters are largely dependent upon the maternal care provided by the dam to her young during the suckling period.

(ii) In cold climate countries

LUKEFAHR et al (1983 abc) in USA revealed important maternal breed differences (expressed as reciprocal crossbreed contrasts) between NZW dams and Californian ones for litter size and weight at birth, 21 days and weaning (28 days) and for preweaning litter gain (Table 4). The differences suggest the existence of maternal breed effect in favour of the NZW group, possibly due to increased milk production of NZW does over

CAL ones (LUKEFAHR et al, 1983b). These differences in maternity may have been a reflection of heavier body weight (P<0.05) of NZW does compared with CAL ones (LUKEFAHR et al, 1983a). However, breed superiority of NZW maternity compared with CAL maternity for preweaning litter traits has been demonstrated in the European studies (PARTRIDGE et al, 1981; BRUN and ROUVIER, 1984; ROUVIER and BRUN, 1990).

## BUCK-BREED x DOE-BREED INTERACTION AND HETEROTIC EFFECTS

### Buck-breed x doe-breed interaction

In Egypt, Youssef (1992) found that litter traits at birth and at 21 days and reproductive intervals were insignificantly affected by interaction between buck-breed and doe-breed (Table 3). On the other hand, litter traits at weaning were significantly (P<0.05 or P<0.01) affected by such interaction (Table 3). This significant interaction was expected because the same buck of a given breed was shifted in mating to does of another breed which they were widely different in their maternal abilities (additive and non-additive) and consequently such significant interaction could be utilized in planning crossbreeding programmes to produce litters with better performance. On the contrary, AFIFI and EMARA (1987) evidenced that interaction between buck-breed and doe-breed was significant for litter size and weight at birth (P<0.05 or P<0.01), while non-significant effects were observed for these traits at weaning along with pre weaning litter mortality (Table 3), i.e. the effects of buck-breed changes significantly with the change of doe-breed for traits measured at birth and not at weaning.

### HETEROTIC EFFECTS

(i) In hot climate countries

Results of the different crossbreeding experiments carried out in Egypt (Table 5) revealed that heterotic effects were evident in most of the possible single crossbred combinations for litter size (AFIFI, 1971; AFIFI et al, 1976b; EMARA, 1982; SOLIMAN, 1983; AFIFI and EMARA, 1987; AFIFI and KHALIL, 1989), litter weight (AFIFI, 1971; AFIFI et al 1976a; TAG EL-DIN, 1979; EMARA, 1982; AFIFI and KHALIL, 1989), preweaning gain in weight of litter (AFIFI, 1971; SOLIMAN, 1983) and average birth and weaning weight per litter (AFIFI, 1971; YOUSSEF, 1992). Also, results of SOLIMAN (1983), AFIFI and KHALIL (1989) and YOUSSEF (1992) evidenced that crossbreeding was associated with a reduction in the pre weaning mortality and reproductive intervals. Comparison of percentages of heterosis for litter traits at birth and at weaning showed that heterotic effects on litter traits were more pronounced at weaning than at birth in most cases (Table 5).

Crossing between exotic breeds of rabbits with other Egyptian breeds was generally associated with an existence of heterotic effects on preweaning doe traits (AFIFI, 1971; AFIFI et al, 1976b; TAG EL-DIN, 1979; DORA, 1979; EMARA, 1982; SOLIMAN, 1983; Youssef, 1992). In most cases, crossbred litters obtained at weaning from mating bucks of Egyptian breeds with does of exotic breeds were better than those litters obtained from the reverse mating (AFIFI, 1971; EMARA, 1982; OUDAH, 1990; Youssef, 1992), i.e. mothering and milking abilities of exotic breeds are better than those of Egyptian breeds. Results of AFIFI and EMARA (1987) and AFIFI and KHALIL (1989) showed that heterosis from including Giant breeds

(Grey Giant Flander, White Giant.. etc.) in crossbreeding experiments with Egyptian breeds was equal to or superior to those estimates of heterosis for medium-sized breeds (NZW, CAL) as reported by OUDAH (1990).

Crossing between exotic breeds with each other in Egypt, generally exhibited heterotic effects on litter performance of doe rabbits (AFIFI, 1971; AFIFI et al, 1976b; EMARA, 1982). This means that exotic breeds are higher in their non-additive genetic effects compared to the other Egyptian breeds. On the contrary, findings of EMARA (1982) and SOLIMAN (1983) showed that crossbreeding between Egyptian breeds with each others showed little or no heterotic effects on litter traits of their crossbred litters.

In Mexico, results of CAMPOS et al (1980) showed that heterosis from including American breeds (e.g. NZW, CAL .. etc.) in crossbreeding experiments was equal to or superior to those estimates of heterosis from French breeds (e.g. Bouscat).

(ii) In cold climate countries

Results of European and cold states of USA (e.g. PARTRIDGE et al, 1981; LUKEFAHR, 1982) indicate that crossbred litters exceeded their parental breeds in doe litter performance, i.e. heterotic effects in most crossbreed groups were observed. Estimates of heterosis in these studies ranged from 2.0 to 15.4%.

**BODY WEIGHT AND DAILY GAIN**

Improvement through crossbreeding (among the available breeds) for postweaning growth traits has been extensively used in Europe (e.g. OUHAYOUN and Poujardieu, 1979; MASOERO, 1982, MASOERO et al, 1985; ROCHAMBEAU, 1988), in USA (OZIMBA and LUKEFAHR, 1991) and in Egypt (AFIFI, 1971; EMARA, 1982; SOLIMAN, 1983; AFIFI and EMARA, 1990; Youssef, 1992; AFIFI et al, 1993) where existing breed differences from a heterotic and complementary stand point are utilized. As such and for postweaning growth, the potential economic benefits associated with crossbreeding using optimal breed combinations (i.e. determining the best breeds of sires and dams) has not been adequately investigated in the different locations.

**Sire-breed and dam-breed and direct and maternal effects**

**Sire-breed and dam-breed**

An evidence for the significant sire-breed effect on postweaning growth was obtained by MASOERO et al (1985) with NZW, CAL, Burgandi Fawn, Flemish Giant, Argenta de Champagne and Blue Veina. AFIFI et al (1993) with New Zealand White, Baladi Red and their crosses concluded that sire-breed effects were of consider able importance for postweaning growth, while dam-breed effect was not significant.

(i) In hot climate countries

AFIFI (1971) with Bouscat, Chinchilla and Giza White rabbits found that rabbits mothered by Chinchilla and Bouscat dams recorded the heaviest weight and gain at different ages from four (weaning) up to 24 weeks of age. These results indicated the importance of breed of dam or common litter environment effects on body weight and gain of crossbreds. TAG EL-DIN (1979) and DORA (1979) found that the average weights of Baladi White x Bouscat crossbreds (from 30 to 105 days of age) excelled

generally those of Bouscat x Baladi White crossbred rabbits. Findings of EMARA (1982) on Bouscat, Giza White, White Flander and Baladi Red rabbits and their crosses gave evidence that body weights and gains of crossbred rabbits mothered by Bouscat dams showed heavier weights and gains than other crossbred rabbits obtained. SALLAM and HAFEZ (1984) showed that two-way crossbred rabbits resulting from mating either Bouscat or Chinchilla bucks to Baladi Red does (Bouscat x Baladi Red or Chinchilla x Baladi Red) excelled Baladi Red ones. EL-QEN (1988) showed that body weight of Bouscat x Flander crossbred excelled that of Bouscat, Flander or Flander x Bouscat rabbits at 4, 8 and 12 weeks of age. Findings of OUDAH (1990), EL-DESOKI (1991) and AFIFI et al (1993) on body weight at 4, 6 and 10 weeks of age indicated that all crossbred groups mothered by NZW or CAL dams showed heavier weights while those mothered by Baladi dams showed lower weights.

(ii) In cold climate countries

An American study by LUKEFAHR et al (1983c) reported that NZW-sired progeny were inferior to CAL- and FG-sired progeny for all growth traits of this study. Although purebred differences in post-weaning growth were not significant, the terminal crossbreds were more productive and consequently using NZW breed in terminal crossbreeding in the rabbit industry is recommended.

**Direct sire effect**
(i) In hot climate countries

In Egypt EL-DESOKI (1991) reported that New Zealand-sired progeny were superior to those sired by Baladi rabbit for body weights and gains to 12 weeks of age. Such superiority of New Zealand-sired rabbits suggests to use this breed in crossbreeding. AFIFI et al (1993) found that growth performance at early ages (5 and 6 weeks) of New Zealand-sired rabbits was not significantly different from rabbits sired by Baladi Red breed, while significant differences were evidenced during the later ages of growth at 10 and 12 weeks. Direct genetic effects were also pronounced in favour of New Zealand sires, i.e. rabbits were heavier in weights and gains compared to Baladi-sired rabbits.

(ii) In cold climate countries

OUHAYOUN and Poujardieu (1979), in French, appraised different breeds of rabbits (Bouscat, FG, Rex Havana and Polish) were appraised for growth traits. For the four breeds used, terminal-crossbred progeny sired by the two large breeds (Bouscat and FG) generally yielded the best performance in terms of body weight and daily gain from weaning at 4 weeks up to 11 weeks of age.

**Maternal breed effect**

Tests of significance of maternal breed effects on postweaning body weights and daily gains of rabbits (expressed as the differences between reciprocal crosses) are reviewed and presented in Table 6. In the Egyptian studies, maternal breed effects on postweaning growth traits were not significant (Table 6). Some of these findings (e.g. HASSAN, 1988; OUDAH, 1990; El-DESOKI, 1991; AFIFI et al, 1993) reported a general trend indicating also that rabbits mothered by the exotic breeds (Bouscat, White Flander, New Zealand White, CAl) surpassed significantly in their maternity than those rabbits mothered by Egyptian ones. This

confirmed the superiority of exotic breeds in their breed maternity (in terms of milk production, growth and survival) than the Egyptian ones.

In Japan, OETTING et al (1989) with NZW and Japanese rabbits and their reciprocal crosses reported that maternal-breed effects on body weight at weaning (4 weeks) and up to 9 weeks of age were not significant. In Thailand, REODECHA and Kipakorn (1989) found that body weights and daily gains from 6 to 14 weeks of age of NZW x Thai rabbits were not significantly different from their reciprocal cross and the maternal-breed effects were in favour of NZW dams.

## Sire-breed X dam-breed interaction and heterotic effect

### Sire-breed X dam-breed interaction

Results of AFIFI et al (1993) showed that the effect of sire-breed X dam-breed interaction on body weights increased as the rabbit's age advanced, while a reverse trend was observed for daily gains. Significant interaction on growth traits reflects a considerable non-additive breed effect and this could be utilized in the planning work to produce heavy weights of commercial broiler rabbits.

### Heterotic effects
(i) In hot climate countries

In Egypt, most of the crossbreeding experiments (AFIFI, 1971; TAG EL-DIN, 1979; DORA, 1979; SOLIMAN, 1983; KOSBA et al, 1985; SALLAM and HAFEZ, 1984; El-SAYED, 1988; OUDAH, 1990; EL-DESOKI, 1991; AFIFI et al, 1993) indicated the presence of positive heterotic effects on body weights and gains of rabbits at different ages of growth (Tables 7&8). Other crossbreeding experiments carried out by EL-QEN (1988) showed that crossbreeding was of little importance in improving body weights and gains in rabbits. Results of AFIFI (1971), TAG El-DIN, (1979), EMARA, (1982), AFIFI and EMARA (1990), OUDAH (1990) and AFIFI et al (1993) reported that body weight and daily gain of crossbred rabbits obtained from the mating of sires of Egyptian breeds with dams of exotic ones have surpassed those weights and gains obtained from the reverse matings, i.e. heterosis in crossbred rabbits were in favour of using exotic dams. This could be explained on the basis that the exotic dams (e.g. Bouscat, NZW, CA1) are superior in their mothering and milking abilities than Egyptian ones. Crossbred rabbits obtained from crossing of exotic breeds with each other were associated with an existence of heterotic effects in their weights and gains (AFIFI, 1971; EMARA, 1982, OUDAH, 1990), while crossbred rabbits obtained from mating of Egyptian breeds with each others were generally associated with negative heterosis (EMARA, 1982). This means that exotic breeds (e.g. NZW, CAL, FG and Bouscat) are higher in their non-additive genetic effects along with better maternal abilities compared to the other Egyptian breeds (Giza White, Baladi Red, Baladi White).

In Brazil, the crossbreeding experiment carried out by MARTINS et al (1988) on NZW, CAL, Chinchilla and Bouscat Giant breeds revealed that crossbreds included CAL breed had the best postweaning growth rate.

(ii) In cold climate countries

The Italian studies (e.g. MASOERO, 1982) confirmed that heterosis for growth traits (body weight and daily gain) obtained from crosses

included Giant breeds was superior to that of medium-sized breeds (NZW and CAL). Results of OZIMBA and LUKEFAHR (1991) in USA provide corroborative evidence in support of obtaining heterotic effects on post-weaning growth traits via mating CAL sires to NZW dams or mating purebred or crossbred FG sires to purebred or crossbred CAL or Chinchilla dams, as opposed to NZW and CAL purebreds in the commercial rabbit industry.

Carcass Traits

In the literature, there is conclusive evidence of variation among rabbit breeds and crossbreds for carcass characters (OUHAYOUN and POUJARDIEU, 1979; LUKEFAHR, 1982; LUKEFAHR et al, 1983d; MASOERO et al, 1986; LUKEFAHR and OZIMBA, 1991; OZIMBA and LUKEFAHR, 1991; YOUSSEF, 1992; AFIFI et al, 1993). Performances of rabbit breeds and Their crosses for carcass traits have not been extensively investigated in the United States, although commercial crossbreeding items to improve carcass traits showed successful advantage in Europe (MASOERO, 1982; MASOERO et al, 1986). In Egypt, findings of SALLAM and El-ASHMAWY (1985), EL-QEN (1988), HASSAN (1988), YOUSSEF (1992) and AFIFI et al (1993) gave an evidence for breed differences in carcass traits and consequently using a cross breeding programme may be effective to improve such traits in rabbits.

**Sire-breed and dam-breed and direct and maternal effects**

**Sire-breed and dam-breed**

(i) In Egypt

Results of EL-QEN (1988) with Bouscat, Flander and their crosses showed that there are slight differences in carcass traits between the two breeds, i.e. either of the two breeds may be used as a sire- or a dam-breed under the Egyptian conditions. HASSAN (1988) with NZW, Baladi Black and Baladi Red rabbits found that carcass performances of Baladi Black and Baladi Red rabbits used as sires are better than carcass performances of such native breeds when used as dams. Results of AFIFI et al (1993) with NZW and Baladi Red rabbits and their crosses indicated that sire-breed effects were of considerable importance in the variation of carcass traits.

(ii) In Europe

In France, OUHAYOUN and Poujardieu (1979) with Bouscat, FG, Rex Havana and Polish rabbits, found that carcass yield was not most favorable in Flemish Giant-and Polish-sired rabbits. On the other hand, some European investigators (NIEDZWIADEK and KAWINSKA, 1982; BRUN and OUHAYOUN, 1989) reported slight differences in carcass performance between NZW and CAl rabbits in terms of sire-breed and dam-breed.

(iii) In USA

CAL-sired rabbits were lighter than NZW-sired rabbits for pre-slaughter and carcass weight (LUKEFAHR et al, 1983d; OZIMBA and Lukefahr, 1991), although the differences were not significant. Dressing percentage was significantly (P<0.05) improved by 1.0 % in CAL-sired rabbits. In CAL vs NZW dam breed contrast, LUKE FAHR et al (1983d) stated that rabbits damed by CAL breed were lighter in pre-slaughter (P<0.05) and carcass weights and giblets % (P<0.01) than rabbits damed by NZW breed. A reverse

trend was observed for dressing percentage. The similarity between sire and dam breed effects in this study suggests that maternal breed effects on carcass traits are of minor importance.

## Direct sire effect

### (i) In Egypt

EL-QEN (1988) with Bouscat, Flander and their crosses showed that there were slight differences in carcass traits between these breeds. HASSAN (1988) found that carcass performance of offspring from Baladi Black and Baladi Red bucks were better than these native breeds when used as dams. Baladi Red-sired rabbits were significantly different from New Zealand-sired rabbits in their carcass performance (AFIFI et al, 1993). The edible carcass traits were in favour of New Zealand-sired rabbits along with lighter non-edible carcass wastes of blood and viscera. In this study, New Zealand-sired rabbits were superior in carcass weight and such favourableness leads to state that NZ rabbits could be used as a terminal sire breed in Egypt.

### (ii) In Europe and USA

Some European studies (e.g. NIEDIADEK and KAWINSKA, 1982; BRUN and OUHAYOUN, 1989) reported slight differences in carcass performance between New Zealand and CAL sired rabbits. In CAL vs NZW sire breed contrast, LUKEFAHR and OZIMBA (1991) in USA reported that CAL-sired rabbits were lighter than New Zeal and-sired rabbits for pre-slaughter weight and carcass weight, although the differences were not significant.

## Maternal breed effects

Maternal breed effects (expressed as the reciprocal cross differences) on some carcass traits in rabbits are reviewed from literature and given in Table 9.

### (i) In Egypt

EL-QEN (1988) with Bouscat and Flander rabbits found that rabbits mothered by Flander dams significantly (P<0.05) surpassed Bouscat dams in their carcass performance. HASSAN (1988) with carcass yield of NZW, Baladi Red and Baladi Black rabbits reported insignificantly higher breed maternity in favour of New Zealand White dams (Table 9). These findings evidenced the superiority of exotic breeds in their breed maternity (in terms of milk production, growth and survival) compared to the native breeds. AFIFI et al (1993) found that carcass performance of rabbits mothered by New Zealand breed were nearly similar to those rabbits mothered by Baladi Red breed, i.e. both breeds could be used as breed of dam. In this later study, blood and viscera wastes recorded by Baladi Red-damed rabbits were lower than New Zealand-damed rabbits. These results were expected because Baladi Red rabbits originated from Giants breed which has superior breed maternity on postweaning performance (in terms of growth and survival) compared to NZW breed. They concluded, therefore, that it may be effective to use Baladi Red as a breed of dam in any crossbreeding stratification system for producing broiler rabbits with heavy weights and carcasses.

### (ii) In Europe and USA

With NZW and CAL rabbits and their crosses, some European and American studies (POMYTKO and MIROSHNICHENKO, 1978; Niedwiakek and

Kawinska, 1982; LUKE FAHR et al, 1983d; OZIMBA and LUKEFAHR, 1991) reported a general trend indicating that NZW damed rabbits were significantly slightly lower in major carcass traits compared to CAL damed ones. BRUN and OUHAYOUN (1989) found that carcass performance of NZW dams was significantly (P<0.05) different with CAL ones and the breed maternity was in favour of CAL dams (Table 9). In CAl vs NZW dam breed contrast, LUKEFAHR et al (1983d) in USA found that rabbits from CAL dams were lighter in preslaughter weights (P<0.05), carcass weights and giblets percent ages (P<0.01).

## Sire-breed x dam-breed interaction and heterotic effect

### Sire-breed x dam-breed interaction
Literature discussing the effect of sire-breed x dam-breed interaction on carcass traits are limited. The only available literature in such aspect will be represented here. In France, BRUN and OUHAYOUN (1989) with NZW and CAl rabbits evidenced that the interaction between sire-breed and dam-breed was significant (P<0.01) for carcass yield. In Egypt, AFIFI et al (1993) stated that this inter action contributed little to the variation of all carcass traits, i.e. little heterotic effects could be expected.

### Heterotic effects
Most estimates of heterosis obtained from crossbreeding experiments carried by LUKEFAHR et al (1983d), EL-QEN (1988), HASSAN (1988), BRUN and OUHAYOUN (1989), Youssef (1992) and AFIFI et al (1993) indicated that crossbreeding between different breeds of rabbits are associated with a little improvement in the carcass performance of the crossbred rabbits (Table 10).

(i) In Egypt
Crossbred rabbits obtained by SALLAM and EL-ASHMAWY (1985) from crossing of Baladi Red x Bouscat and Baladi Red x Chinchilla gave higher performance in carcass than their parental purebred rabbits. Crossing was generally associated with positive insignificant heterotic effects on all carcass traits (AFIFI et al, 1993). When heterosis deviations were expressed on a percentage basis, they ranged from 0% to 4.7% for edible carcass traits (carcass, giblets and head) and from 1.0% to 2.5 for non-edible carcass traits (fur, blood and viscera). How ever, most estimates of heterosis obtained from experiments in Egypt (e.g. El-QEN, 1988; HASSAN, 1988) indicated that crossbreeding was associated with a little improvement in the carcass performance.

(ii) In Europe and USA
In France and USA, most estimates of heterosis obtained from including New Zealand rabbits in the crossbreeding experiments (LUKEFAHR et al, 1983d; BRUN and OUHAYOUN, 1989) indicated that crossbreeding is associated with little improvement in carcass performance. In USA, LUKEFAHR and OZIMBA (1991) with NZW and CAL purebreds, CAL x NZW and FG terminal crossbreds reported that purebred NZW was generally inferior to the other breeds for the major carcass traits, while CAL purebreds had higher dress-out lean yield and fur percentages and lower visceral percentage than did NZW purebreds. The lighter pre-slaughter weight in CAL and poorer dress-out and cutability characters in NZW fryers clearly

seemed to be compensated in the californian x NZW cross.

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Table 1. Model for the estimation of crossbreeding genetic effects of first generation in experiments of two-way crossing.

| Crossbreeding effect | Genotype | | | |
|---|---|---|---|---|
| | A | B | AxB+ | BxA+ |
| Direct heterosis effect | -1 | -1 | 1 | 1 |
| Maternal additive effect | 0 | 0 | -1 | 1 |
| Direct additive effect | 1 | -1 | 1 | -1 |

-+Sire-breed listed before doe-breed.

Table 2. Decomposition of breed mean in the first generation into Dickerson's genetic effects (Dickerson, 1969) as cited by Brun and Rouvier (1984).

| Genotypea | $\mu1$ | g1 Direct genetic effect | | | gM + gM' Maternal genetic effect | | | h1 Individual heterosis | | | r1 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | CA | NZ | PR | CA | NZ | PR | CAxNZ | CAxPR | NZxPR | |
| CA x CA | 1 | 1 | - | - | 1 | - | - | - | - | - | - |
| NZ x NZ | 1 | - | 1 | - | - | 1 | - | - | - | - | - |
| PR x PR | 1 | - | - | 1 | - | - | 1 | - | - | - | - |
| CA x NZ | 1 | ½ | ½ | - | - | 1 | - | 1 | - | - | 1 |
| NZ x CA | 1 | ½ | ½ | - | 1 | - | - | 1 | - | - | -1 |
| CA x PR | 1 | ½ | - | ½ | - | - | 1 | - | 1 | - | -1 |
| PR x CA | 1 | ½ | - | ½ | 1 | - | - | - | 1 | - | 1 |
| NZ x PR | 1 | - | ½ | ½ | - | - | 1 | - | - | 1 | 1 |
| PR x NZ | 1 | - | ½ | ½ | - | 1 | - | - | - | 1 | -1 |
| Σ g1=0 | - | 1 | 1 | 1 | - | - | - | - | - | - | - |
| Σ (gM+gM')=0 | - | - | - | - | 1 | 1 | 1 | - | - | - | - |

CA= Californian, NZ= New Zealand White, PR= Small Russian.
$\mu1$= Mean of parental strains.
g1, gM, gM'= direct, maternal, grand-maternal genetic effect, respectively.
h1= Individual heterosis.
r= Reciprocal effect.
a= Sire strain is given first.

Table 3. Tests of significance for the effects of buck-breed (BB), doe-breed (DB) and BBxDB interaction on litter traits as cited in literature.

| Traits & Reference | Country Of work | Breeds used+ | BB | DB | BBxDB |
|---|---|---|---|---|---|
| **Litter size at birth:** | | | | | |
| Lukefahr et al (1983a) | USA | NZ,Cal | ns | | |
| Afifi and Emara (1987) | Egypt | B,GW,WF,BR | ns | ns | * |
| El-Dosoki (1991) | Egypt | NZ,Cal,Bal | ns | ** | |
| Youssef (1992) | Egypt | NZ, Cal | ns | ns | ns |
| **Number born alive:** | | | | | |
| Rouvier (1980) | France | FB,PR,CA | ns | ns | |
| Ponce and Menchaca (1985) | Cuba | NZ,Cal,CH | * | ns | |
| El-Desoki (1991) | Egypt | NZ,Cal,Bal | ns | ** | |
| Youssef (1992) | Egypt | NZ, Cal | ns | * | ns |
| **Litter size at weaning:** | | | | | |
| Ponce DE Leon (1978) | Cuba | GH,CH,NZ | * | | |
| Rouvier (1980) | France | FB,PR,CA | ns | ns | |
| Lukefahr et al (1983a) | USA | NZ,Cal | ns | | |
| Ponce and Menchaca (1985) | Cuba | NZ,Cal,CH | * | ns | |
| Afifi and Emara (1987) | Egypt | B,GW,WF,BR | ns | ns | ns |
| El-Dosoki (1991) | Egypt | NZ,Cal,Bal | ns | ** | |
| Youssef (1992) | Egypt | NZ, Cal | ns | ** | * |
| **Preweaning litter mortality:** | | | | | |
| Emara (1982) | Egypt | B,GW,WF,BR | ns | ns | ns |
| Lukefahr et al (1983a) | USA | NZ,Cal | ns | | |
| Ponce and Menchaca (1985) | Cuba | NZ,Cal,CH | * | ns | |
| El-Desoki (1991) | Egypt | NZ,Cal,Bal | ns | ns | |
| Youssef (1992) | Egypt | NZ, Cal | ns | ns | ns |
| **Litter weight at birth:** | | | | | |
| Lukefahr et al (1983a) | USA | NZ,Cal | ** | | |
| Afifi and Emara (1984a) | Egypt | B,GW,WF,BR | ns | * | ** |
| Youssef (1992) | Egypt | NZ, Cal | ns | ** | ns |
| **Litter weight at weaning:** | | | | | |
| Lukefahr et al (1983a) | USA | NZ,Cal | ns | | |
| Afifi and Emara (1984a) | Egypt | B,GW,WF,BR | ns | ns | ns |
| Masoero et al (1986) | Italy | NZ,Cal,BF,AC,VB,FG | * | * | |
| El-Dosoki (1991) | Egypt | NZ,Cal,Bal | ** | ** | |
| Youssef (1992) | Egypt | NZ, Cal | ns | ** | ** |
| **Kindling interval:** | | | | | |
| El-Desoki (1991) | Egypt | NZ,Cal,Bal | * | ns | |
| Youssef (1992) | Egypt | NZ, Cal | ns | ** | ns |
| **Days open:** | | | | | |
| El-Desoki (1991) | Egypt | NZ,Cal,Bal | * | ns | |
| Youssef (1992) | Egypt | NZ, Cal | ns | * | ns |

+NZ= New Zealand White, Cal= Californian, BF= Burgundy Fawn, FG= Flemish Giant, AC= Argenta de Champagen, VB= Vienna Blue, FB= Fauve de Baurgogne, PR= Petit Russe, WF= White Flander, GW= Giza White, B= Bouscat, BR= Baladi Red, Bal= Baladi, CA= Champagen de Argenta.
ns= non-significant; *= P<0.05; **= P<0.01.

Table 4. Test of significance of maternal breed effects on litter traits+ as cited in the literature.

| Reference | Breeds used in crossbreeding++ | LSB | LWB | LS21 | LW21 | LSW | LWW | PM | AGW | MBW | MW21 | MWW |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **(i) Studies in hot climate countries** | | | | | | | | | | | | |
| Afifi et al (1976a&b) | B,GW,CH | ns | ns | | ns | ns | ns | | | | | |
| Tag el-Din(1979) | B,BW | ns | | | | ns | ns | * | | | | |
| Khalil (1980) | GW,GF | ns | ns | | | ns | ns | ns | | | | |
| Emara (1982) | B,BR,GW,WF | ns | ns | | | ns | ns | ns | | | | |
| Soliman (1983) | BG,CH,BY,B | ns | | | | | ns | | | | | |
| Afifi and Emara (1984a) | B,GW,WF | | ns | | | | ns | | | | | |
| Afifi and Emara (1984a) | BR,GW,WF | | ns | | | | ns | | | | | |
| Afifi and Emara (1984a) | B,BR | * | | | | | ns | | | | | |
| El-Qen (1988,1st season) | F,B | ns | ns | | | | ns | | | | | |
| El-Qen (1988,2nd season) | F,B | ** | ** | | | | ns | | | | | |
| Afifi and Khalil (1989) | GW,GF | ns | ns | | | ns | ns | ns | | | | |
| Oudah (1990) | NZ,Cal | ns | | | | ns | ns | | | | | |
| Oudah (1990) | NZ,Bal | * | | | | ns | * | | | | | |
| Oudah (1990) | Cal,Bal | | | | | ns | ns | * | | | | |
| Oetting et al (1989) | NZ,J | ns | | | ns | | ns | ns | ns | ns | ns | |
| Youssef (1993) | NZ, Cal | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns | ns |
| **(ii) Studies in USA** | | | | | | | | | | | | |
| Lukefahr et al (1983a&b) | NZ,Cal | ** | ** | ns | * | * | ns | * | | | | |

+LSB= litter size at birth, LWB= litter weight at birth, LS21= litter size at 21 days, LW21= litter weight at 21 days, LSW= litter size at weaning, LWW= litter weight at weaning, PM= preweaning litter mortality,
++NZ= New Zealand white, BF= Burgandy Fawn, Cal= Californian, J= Japanese, B= Bouscat, GW= Giza White, CH= Chinchilla, GF= Grey Giant Flander, BR= Baladi Red, WF= White Flander, BG= Baladi Grey, BY= Baladi Yellow, F= Flander, BW= Baladi White.

Table 5. Reviewed estimates of heterosis percentage for litter+ traits as cited in the Egyptian literature.

| Crossbred++ | LSB | LSW | LWB | LWW | PLG | AWW |
|---|---|---|---|---|---|---|
| **AAfifi (1970) and Afifi et al (1976b)a** | | | | | | |
| BxCH | 6.9( -7.2) | 0.2( -6.9) | 2.2( 1.9) | -5.4( 10.1) | -2.2( 17.9) | -2.3( 2.9) |
| CHxB | 2.1( -8.5) | 14.1( 0.4) | 6.1(20.7) | 0.7( 13.5) | 29.7( 18.4) | 7.3( 3.3) |
| BxGW | -1.5( 4.6) | 9.4( 19.4) | 3.0( 7.7) | 5.1( 15.0) | -14.6( 19.0) | 5.3( 3.1) |
| GWxB | 3.9(-15.0) | 46.3( 9.0) | 3.9(42.2) | -11.3( 7.9) | 55.0( 14.1) | 2.4( 3.3) |
| CHxGW | 14.6( 5.1) | 21.6( 6.9) | 9.6(23.8) | 14.0( -2.4) | 34.9( -4.4) | 1.4( 9.7) |
| GWxCH | 6.6( -4.8) | 14.1(-24.7) | 16.0( 9.4) | -6.6(-29.9) | 12.8(-35.0) | 10.4(-2.9) |
| **Tag El-Din (1979):** | | | | | | |
| BxBW | 20.7 | 20.2 | | 7.3 | | |
| BWxB | 22.1 | 5.6 | | 0.0 | | |
| **Afifi and Emara (1984a) and Afifi and Emara (1987):** | | | | | | |
| BxGW | 1.5 | 10.1 | 14.9 | 17.3 | | |
| BxWF | 10.0 | -0.1 | 16.0 | 1.7 | | |
| BxBR | 30.0 | 42.6 | 38.5 | 31.8 | | |
| GWxWF | 2.8 | 6.8 | 9.8 | 11.7 | | |
| GWxBR | -2.0 | 7.5 | 10.9 | -3.6 | | |
| WFxBR | 16.1 | 13.1 | 18.1 | 11.2 | | |
| **Afifi and Khalil (1989):** | | | | | | |
| GFxGW | -7.4 | 3.3 | 6.3 | 1.1 | | |
| GWxGF | 10.0 | 7.0 | 13.5 | 1.8 | | |
| **Oudah (1990):** | | | | | | |
| NZxCal | 1.4 | 0.0 | | | | |
| CalxNZ | 0.0 | -3.2 | | | | |
| NZxBal | -6.6 | 5.0 | | | | |
| BalxNZ | 15.3 | 10.0 | | | | |
| CalxBal | -9.2 | -8.2 | | | | |
| BalxCal | 2.1 | 3.3 | | | | |
| **El-Desoki (1991):** | | | | | | |
| BalxNZ | -15.2 | -21.0 | | -14.9 | | |
| NZxBal | 12.5 | 12.6 | | -2.4 | | |
| BalxCal | -9.2 | -8.3 | | 20.2 | | |
| CalxBal | 4.9 | 5.0 | | 11.3 | | |
| **Youssef (1993):** | | | | | | |
| NZXBR | -8.2 | 12.6 | 1.4 | 16.5 | 21.4 | 6.2 |

+LSB= litter size at birt, LSW= litter size at weaning, LWB= litter weight at birth, LWW= litter weight at weaning, PLG= preweaning litter gain, AWW= average weightat weaning.
++B= Bouscat; CH= Chinchilla; GW= Giza White; BW= Baladi White; GF= Grey Giant Flander; WF= White Flander; BR= Baladi Red; buck breed listed first.
aEstimates of heterosis for the second year of production are given in parentheses adjacent to those estimates of the first year.

Table 6. Tests of significance of maternal-breed effects on different postweaning body weight (BW) and daily gains (DG) as cited in the Egyptian crossbreeding experiments

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Maternal-breeds used+          Maternal-breed differences
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**(i) Body weight**

Tag El-Din (1979):

| B,BW | 30 days | 90 days |
|---|---|---|
|  | ns | * |

Khalil (1980):

| GW,GF | 5 weeks | 6 weeks | 8 weeks | 10 weeks | 12 weeks | 14 weeks | 16 weeks |
|---|---|---|---|---|---|---|---|
|  | * | ns | ns | ns | ns | * | ns |

Emara (1982):

|  | 5 weeks | 6 weeks | 8 weeks | 12 weeks | 16 weeks |
|---|---|---|---|---|---|
| B,GW | ns | ns | * | * | ns |
| B,WF | ns | ns | ns | ns | ns |
| GW,WF | * | * | ns | ns | ns |
| GW,BR | * | ns | ns | ns | * |
| WF,BR | * | ns | ns | ns | ns |
| B,BR | ns | ns | ns | ns | ns |

Soliman (1983):

|  | 30 days | 37 days | 44 days | 51 days | 58 days |
|---|---|---|---|---|---|
| BG,CH | ns | ns | ns | ns | ns |
| BY,CH | ns | ns | ns | ns | ns |
| B,CH | * | * | * | * | * |
| BY,B | * | * | * | * | * |
| B,BG | ns | ns | ns | * | ns |

El-Qen (1988):

| B,F | 4 weeks | 8 weeks | 12 weeks |
|---|---|---|---|
|  | * | * | * |

Hassan (1988):

|  | 6 weeks | 8 weeks | 10 weeks | 12 weeks |
|---|---|---|---|---|
| BB,NZ | * | * | * | * |
| BR,NZ | * | * | * | * |

Oudah (1990):

|  | 4 weeks | 6 weeks | 10 weeks |
|---|---|---|---|
| NZ,Cal | ns | * | ns |
| NZ,Bal | * | * | * |
| Cal,Bal | * | * | * |

Youssef (1992):

| NZ,BR | 5 weeks | 6 weeks | 8 weeks | 10 weeks | 12 weeks |
|---|---|---|---|---|---|
|  | ns | ns | ns | ns | ns |

**(ii) Daily gain**

Afifi and Emara (1990):

|  | DG 5-6 weeks | DG 6-8 weeks | DG 8-12 weeks | DG 12-16 weeks |
|---|---|---|---|---|
| B,GW | ns | * | * | * |
| B,WF | ns | * | ns | * |
| B,BR | ns | ns | ns | ns |
| GW,WF | * | ns | ns | ns |
| GW,BR | ns | * | * | ns |
| WF,BR | ns | ns | ns | ns |

Youssef (1992):

| NZ,BR | DG 5-6 weeks | DG 6-8 weeks | DG 8-10 weeks | DG 10-12 weeks |
|---|---|---|---|---|
|  | ns | ns | ns | ns |

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+B= Bouscat, BW= Baladi White, GW= Giza White, GF= Grey Flander, Bal= Baladi, WF= White Flander, BR= Baladi Red, BG= Baladi Grey, CH= Chinchilla, BY= Baladi Yellow, F= Flander BB= Baladi Black, NZ= New Zealand White, Cal= Californian.
++ns= non-significant (p>0.05); *= p<0.05; **= p<0.01.

Table 7. Reviewed estimates of heterosis (%) for postweaning body weight at different ages as cited in the Egyptian literature.

| Crossbred+ | 4-week | 5-week | 6-week | 8-week | 10-week | 12-week |
|---|---|---|---|---|---|---|
| **Afifi (1971)++** | | | | | | |
| BxCH | 1.9( 13.9) | | | | | 10.1( 3.8) |
| CHxB | 8.7( 13.0) | | | | | 5.9( 5.6) |
| BxGW | -7.3( 1.5) | | | | | -11.2( 1.6) |
| GWxB | 0.1( 4.0) | | | | | -9.0(-3.1) |
| CHxGW | 4.0( -6.7) | | | | | -3.7(-0.3) |
| WXCH | -8.4(-12.3) | | | | | -6.4( 5.2) |
| **Tag El-Din (1979):** | | | | | | |
| BxBW | -10.3 | | 4.4 | 1.4 | -7.9 | 1.3 |
| BWxB | -4.8 | | 10.8 | 11.8 | -4.5 | 14.4 |
| **Khalil (1980):** | | | | | | |
| GFxGW | | 6.2 | 3.7 | -6.9 | -12.9 | -16.8 |
| GWxGF | | -4.2 | 2.1 | -7.5 | -10.9 | -8.5 |
| **Emara (1982):** | | | | | | |
| BxGW | | 9.5 | 7.3 | 3.9 | | 2.5 |
| GWxB | | 10.5 | 8.3 | 13.4 | | 13.3 |
| BxWF | | 10.9 | 6.1 | -0.7 | | -3.2 |
| WFxB | | 1.8 | 2.4 | 1.6 | | 1.5 |
| BxBR | | 11.2 | 9.0 | 6.8 | | 7.7 |
| BRxB | | 7.3 | 3.5 | 2.6 | | 5.0 |
| GWxWF | | 5.2 | 9.0 | 2.9 | | 7.3 |
| WFxGW | | -2.9 | 2.0 | -3.9 | | 3.3 |
| GWxBR | | -12.6 | -11.1 | -3.7 | | 5.9 |
| RRxGW | | -10.4 | -13.5 | -9.4 | | -3.3 |
| WFxBR | | -3.8 | -5.6 | -4.6 | | -3.6 |
| BRxWF | | 4.5 | -0.5 | 2.0 | | 0.6 |
| **Oudah (1990):** | | | | | | |
| NZxCal | 4.7 | | 7.7 | | 6.4 | |
| CalxNZ | 3.9 | | 3.1 | | 7.1 | |
| NZxBal | -4.5 | | -3.2 | | 3.4 | |
| BALxNZ | 3.3 | | 5.8 | | 6.5 | |
| CalxBal | -4.3 | | -5.8 | | -5.2 | |
| BalxCal | 2.8 | | 8.5 | | 6.6 | |
| **El-Desoki (1991):** | | | | | | |
| BalxNZ | | 4.7 | 5.4 | 6.8 | 7.4 | 7.7 |
| BalxCal | | 6.0 | 5.3 | 6.2 | 5.2 | 6.2 |
| NZxBal | | 9.6 | 10.7 | 11.3 | 11.5 | 10.3 |
| CalxBal | | 6.8 | 6.0 | 5.7 | 7.2 | 6.9 |
| **Afifi et al (1992):** | | | | | | |
| NZxBR | | 2.5 | 4.0 | 5.2 | 4.3 | 3.7 |

+B= Bouscat, CH= Chinchilla, GW= Giza White, BW= Baladi White, GF= Grey Flander, WF= White Flander, BR= Baladi Red, F= Flander, NZ= New Zealand White, Cal= Californian, Bal= Baladi; sire-breed listed first.

++ Figures between brackets are the estimates of the second year of his study.

Table 8. Reviewed estimates of heterosis (%) for gain in body weight during different postweaning age intervals as cited in the Egyptian literature.

| Crossbred combination+ | Heterosis (%) at the interval of: | | | |
|---|---|---|---|---|
| Afifi (1971): | 4-24 weeks | | | |
| BxCH | 15.9(13.3) | | | |
| CHxB | 14.8(18.0) | | | |
| BxGW | -2.1(-2.3) | | | |
| GWxB | 1.1(-1.6) | | | |
| CHxGW | 9.4(17.3) | | | |
| GWxCH | 17.2(12.2) | | | |
| | | | | |
| El-Qen (1988)++: | 4-8 weeks | 8-12 weeks | 12-16 weeks | |
| BxF | -15.59 | -8.13 | -2.07 | |
| FxB | -0.06 | -3.36 | -28.71 | |
| | | | | |
| Afifi and Emara (1990): | 5-6 weeks | 6-8weeks | 8-12 weeks | 12-16 weeks |
| BxGW | 0.1 | 1.0 | 0.8 | -0.1 |
| BxWF | 0.2 | -1.5 | 0.1 | -0.5 |
| BxBR | 0.6 | 0.2 | 0.7 | 1.9 |
| GWxWF | 1.1 | -1.5 | 1.9 | 0.0 |
| GWxBR | -0.8 | 0.8 | 2.0 | 0.4 |
| WFxBR | -1.7 | 0.5 | 0.2 | 0.4 |
| | | | | |
| El-Desoki (1991): | 4-8 weeks | 8-12 weeks | | |
| BalxNZ | 6.9 | 10.4 | | |
| BalxCal | 5.4 | 6.9 | | |
| NZxBal | 12.2 | 9.5 | | |
| CalxBal | 5.4 | 7.3 | | |
| Youssef (1992): | 5-6 weeks | 6-8 week | 8-10 weeks | 10-12 weeks |
| NZxBR | 9.5 | 7.2 | 2.0 | 0.7 |

+B= Bouscat, CH= Chinchilla, GW= Giza White, F= Flander, WF= White
   Flander, NZ= New Zealand White, Cal= Californian, Bal= Baladi;
   sire breed listed first.
 ++ Estimates of the second year of his study.

Table 9. Tests of significance of maternal-breed effects on some carcass traits as cited in literature.

| Reference | Breeds used in crossbreeding+ | Maternal-breed differences | | | | | |
|---|---|---|---|---|---|---|---|
| | | Pre-slaughter weight (gm) | Carcass weight (gm) | Dressing % | Giblets % | Blood % | Fu % |
| Lukefahr et al (1983d) | NZ,Cal | * | ns | * | ** | | |
| Lui et al (1987) | NZ,Cal | * | | | | | |
| El-Qen (1988) | F,B | | * | ns | * | ns | |
| Hassan (1988) | NZ,BB | ns | ns | * | * | | |
| Hassan (1988) | NZ,BR | ns | ns | * | * | | |
| Brun and Ouhayoun (1989) | NZ,Cal | | * | | | | |
| Ozimba and Lukefahr (1991) | NZ,Cal | ns | ns | ** | ns | | ** |
| Youssef (1992) | NZ,BR | ns | ns | ns | ns | ns | ns |

+ NZ= New Zealand White, Cal= Californian, F= Flander, Bouscat, BB= Baladi Black, BR= Baladi Red.

Table 10. Reviewed estimates of heterosis for some carcass traits as cited in the literature.

| Reference and crossbred combination+ | Heterosis % | | | | |
|---|---|---|---|---|---|
| | Pre-slaughter weight (gm) | Carcass weight (gm) | Dressing % | Giblets % | Fur % |
| Lukefahr (1983d): | | | | | |
| NZ x Cal | 6.0 | 18 | 0.9 | -0.01 | |
| EL-Qen (1988):++ | | | | | |
| B x F | | 1.3(2.1) | 2.6(1.9) | 6.6(1.0) | 8.3(2.3) |
| F x B | | -0.3(2.4) | 0.9(2.3) | 6.4(3.5) | 4.8(1.3) |
| Brun and Ouhayoun (1989): | | | | | |
| Cal x NZ | | | 1.2 | | |
| Youssef (1992): | | | | | |
| NZ X BR | 5.7 | 7.0 | 0.2 | 2.5 | 5.0 |

+NZ= New Zealand White, Cal= Californian, B= Bouscat, F= Flander, BR= Baladi Red.
++Estimates of heterosis of the second year of his study are given in parentheses adjacent to the first year.