# Improving growth, carcass and meat composition traits by applying bio-techniques in crossbreeding project between Ardi Saudi and Damascus goats to

**Khalil, M.H.[1*], Al-Saef, A.M.[2], Mohamed, K.M.[3], and El-Zarie, M.F.[2]**

[1] Faculty of Agriculture, Benha University, Moshtohor, zip code 13736 Kalyoubia, Egypt
[2] College of Agriculture & Veterinary Medicine, Qassim University, *Saudi Arabia*
[3]Camel and Range Research Center, Al Jouf, *Saudi Arabia*,
*Email: maher.khalil@fagr.bu.edu.eg

## Abstract

A crossbreeding program between Ardi Saudi goats (A) with Syrian goats (Damascus, D) was started in 2006 in two experiments (Jouf and Qassim) applying bio-techniques of estrous synchronization and artificial insemination. Breeding does of Ardi goats were randomly divided into two groups and each group was subdivided into two subgroups to be inseminated artificially from semen of elite bucks of the same breed and of Damascus breed. Crossbred does of ½D½A were backcrossed with Damascus bucks to get the genetic group of ¾D¼A and such breeding plan permitted to produce four genetic groups of AA, DD, ½D½A and ¾D¼A in each experiment separately. Data collected were: 1) live body weights and gains at birth and biweekly thereafter up 24 weeks of age, 2) carcass traits, and 3) meat compositions involving dry matter, crude protein, ether extract, and ash. The animal models were used to estimate heritabilities and common litter environmental effects, while a generalized least square procedure was used to estimate direct additive genetic effects $(G^I = G^I_A - G^I_D)$, direct heterosis (HI), maternal heterosis (HM) and direct recombination effects (RI). Heritabilities were moderately heritable and ranging from 0.12 to 0.36 for body weights, 0.11 to 0.25 for body gains, and 0.10 to 0.34 for carcass traits. All estimates of direct additive effects for body weights at 0, 4, 8, 12, 16, 20 and 24 weeks of age were significantly in favour of Damascus goats by 0.260, 1.504, 1.337, 1.505, 1.324, 1.873 and 2.080 kg in Jouf experiment and by 0.548, 1.876, 2.168, 2.975, 2.739, 3.594 and 4.046 kg in Qassim experiment, respectively. The respective estimates for body gains at interval of 0-4, 4-8, 8-12, 12-16, 16-20, and 20-24 weeks of age were also significantly in favour of Damascus goats by 47, 31, 7, 30, 33, and 28 g in Jouf experiment and by 47, 35, 22, 42, 18, and 32 g in Qassim experiment. The estimates for most carcass traits were moderate and significantly in favour of Damascus kids by 6.2 kg for pre-slaughter weight, and 4.2 kg for hot carcass weight, while the estimates for meat compositions traits were somewhat low and in favour of Damascus kids relative to Ardi kids by 4.4% in dry matter of the lean and 3.4% in ether extract. The heterotic increments were mostly significant and ranging from 3.0 to 11.4 % for body weights and daily body gains and 2.4 to 28.1 % for carcass traits relative to the parental purebreds, while the estimates for meat composition traits were mostly non-significant although crossbred have shown reductions in moisture, ether extract and ash in meat of the carcass. The maternal heterotic increments in body weights and daily body gains were mostly significant and the estimates ranged from 1.0 to 27.0 %. Direct recombination losses were of little importance for the majority of the traits and they were generally lower than the estimates of direct heterosis.

**Keywords**: Ardi Saudi Goats, Damascus goats, crossbreeding, bio-techniques, growth, carcass, meat compositions, additive and heterotoc effects.

## Introduction

In Saudi Arabia, Ardi, Hibsi and Zumri are the most common breeds. Unfortunately, the genetic knowledge for these breeds is limited. Ardi goat is the best local breeds in Saudi Arabia, heaviest live weight 34.4 kg; faster body gain or growth rate of 149 g/day and milk yield of 160.3 kg/lactation (Dosari *et al.* 1996). Ardi goats could record higher production than the other local breeds under the same conditions and therefore more attention should be paid to this breed. Comparable to these native breeds, other exotic goat breeds like Damascus (Damascus) goats have shown more productivity. In this concept, Damascus breeds are normally dual purpose (meat and milk), and better adapted to the harsh climate. Performance of Damascus goats could record an average daily gain from birth to weaning at 80 days to be 174 and 157 g/day for male and females kids, respectively (ACSAD, 1996). In order to improve the productivity of goats in Saudi Arabia, there is a great deal to increase the productivity of native goat breeds through crossbreeding programs. In the last two decades, new assisted reproductive technologies in goats had been applied successfully (Lazaris *et al*, 2002; Wheeler *et al*, 2003; Baldassarre and Karatzas, 2004). In this concept, artificial insemination and estrus synchronization could be used as new powerful and successively tools in planned breeding programmes to increase the rates of genetic improvement in goats (Thibier, 1996; Leboeuf *et al.*, 2000, 2003). The main objectives of the present study were: (1) To characterize genetically the native

Ardi breed of goats, (2) Improving the productivity of such breed for meat production through crossbreeding, and (3) Applying updated technologies of estrous synchronization and artificial insemination to shorten the generation interval in such genetic improvement program.

## Materials and methods

### Project Breeding Plan

A crossbreeding program between Ardi Saudi goats (A) with Damascus Syrian goats (D) was started in 2006 in Saudi Arabia in two experiments of Jouf station and Qassim University. Breeding does of Ardi goats were randomly divided into two groups, 120 doe each in each experiment. Each group of Ardi does was subdivided into two subgroups to be inseminated artificially from semen of elite bucks of the same breed and of Damascus breed. In both experiments, does of Damascus breed were randomly inseminated from bucks of the same breed to produce purebred kids. Also, crossbred does of ½D½A were backcrossed with Damascus bucks to get the genetic group of ¾D¼A. Accordingly, the breeding plan permitted to produce four genetic groups of AA, DD, ½D½A and ¾D¼A in each experiment separately. The semen of bucks was randomly assigned to inseminate the does. For different genetic groups, a total number of 1400 kids fathered by 115 sires and mothered by 516 dams were obtained.

### Management and feeding

All does were housed in semi-shaded/open front barn and ear-tagged. Goats were fed on a commercial concentrate and alfalfa hay. The amount of concentrate and hay were calculated according to the nutritional requirements for goats which dependent on animal ages and production status. Water, straw, salt and minerals supplemented in blocks were freely available to all animals. Animals were fed *ad libitum* individually.

### Semen collection, evaluation and preparation for artificial insemination

A total number of 1800 ejaculates collected by artificial vagina from 298 bucks were evaluated for semen characteristics. Immediately after collection, the semen tubes were placed in a water bath at 37 °C and samples were evaluated for consistency and examined microscopically for individual motility, sperm concentration and percent of normal spermatozoa. All these steps were done within 10 min of collection using the standard techniques. Semen with good quality were extended with extenders using dilution rate of 1:15 to 1:20 (semen:diluent) according to sperm concentration. The diluted semen samples were gradually cooled and stored in a refrigerator at 5 °C to be used in artificial insemination (Azawi *et al.,* 1993).

### Estrous synchronization and artificial insemination (AI)

Estrous synchronization was applied using intravaginal progesterone impregnated sponges containing 30 or 45 mg fluorogesteone acetate (FGA) where the sponges were administered to does and maintained in situ for 14 days. Forty eight to seventy two hours before sponge withdrawal 200-1000 IU/eCG was injected intramuscular. Artificial insemination (AI) was done 48 and/or 60 hours after sponge removal, using chilled diluted semen (0.5 ml containing at least 150-200x$10^6$ motile spermatozoa). Three types of extenders of milk, Na Citrate and Tris were used as based extenders for semen dilution. AI was carried out using insemination pipette and vaginal speculum. The hind legs of the doe was lifted and placed at an angle of 45° to the horizontal railing. The vaginal speculum was introduced into the vaginal passage and the cervix was located with the help of light and by gentle sideways or downward manipulation of the speculum. Semen was deposited up to a depth of 5-10 mm into the cervix (Cervical insemination). Pregnancy diagnosis was applied 30-45 days post insemination with the aid of ultrasound scanner.

### Growth, slaughter and meat composition traits:

Live body weights were recorded at birth and biweekly thereafter at up to 24 weeks of age, while daily weight gains were computed at four weeks intervals. At 6 months of age, kids of Qassim experiment of the entire genetic groups were randomly taken for slaughtering test. Kids were slaughtered and dissected and hot carcasses were weighed and dressing percentages were calculated. The head, fur, giblets (representing heart + liver + kidneys + spleen) and viscera of the carcasses were also weighed. A sample of the lean were taken from each animal and chemically analysed. Dry matter (using an air-evacuated oven for 16 h), crude protein (N × 6.25), ether extract (EE) and ash in the lean were determined according to the AOAC (1990).

### Models of statistical analysis

For genetic analysis, data of each experiment were analysed separately. Variances calculated by SAS program applying REML procedure (SAS, 1999) were used as starting values in the analyses of single-trait animal model.

Data of individual body weights and gains were analysed applying such single-trait animal model (Boldman *et al*, 1995):

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

Where **y** = vector of observed growth trait for kids, **b**= vector of fixed effects (genetic group, sex, year-season, litter size in which the kid was born); $u_a$= vector of random effect of the kid; $u_c$= vector of random effects of non-additive common litter effects; X, $Z_a$ and $Z_p$ are the incidence matrices relating records to the fixed effects, additive genetic effects, and permanent environment, respectively; and **e**= vector of random error.

Data of carcass traits and meat compositions were analysed applying the following single-trait animal model (Boldman *et al,* 1995):

**y= Xb + $\mathbf{Z_a u_a}$ + $\mathbf{Z_c u_c}$ + e (Model 2)**

Where y = vector of observed growth trait for kids, b= vector of fixed effects (genetic group, year-season, age of kid); $u_a$= vector of random effect of the kid; $u_c$= vector of random effects of non-additive common litter effects; X, $Z_a$ and $Z_c$ are the incidence matrices relating records to the fixed effects, additive genetic effects, and common litter effects, respectively; and **e**= vector of random error.

The inverse of the numerator relationship matrix **($A^{-1}$)** was considered; Var(a)= $A\sigma^2_a$, Var(p)= $I\sigma^2_p$, Var(c)= $I\sigma^2_c$ and Var(e)= $I\sigma^2_e$ . Inbreeding coefficients for progeny, sires and dams were calculated using program of Boldman *et al.* (1995). Heritabilities for different traits were computed by DFREML of the animal model using the following equations:

$h_A^2 = \dfrac{\sigma_A^2}{\sigma_A^2 + \sigma_c^2 + \sigma_e^2}$ where $\sigma^2_A$, $\sigma^2_c$, and $\sigma^2_e$ are variances due to the effects of direct additive effect, common litter environment, and random error, respectively.

### Genetic model and estimation of crossbreeding effects

The procedure of generalized least squares (GLS) using CBE program of Wolf (1996) was used to estimate crossbreeding effects. Model of Dickerson was used in the program as summarized by Dickerson (1992) and Wolf *et al* (1995). The linear model used was:

**y = X*b* + e, Var(y) = V**

Where **y** = vector of genetic groups means, **X** = incidence matrix of the coefficients for crossbreeding effects, **b** = vector of crossbreeding genetic parameters, **e** = vector of residual effects, and **V** = full covariance matrix of **y**. The coefficients relating genetic crossbreeding parameters to the means of the genetic groups are shown in Table 1 (Wolf *et al*., 1995). Because the reciprocal cross, Ardi x Damascus, was not carried out, the maternal additive effects showed a high co-linearity with the direct additive effects where the corresponding errors highly correlated. For this reason, the maternal additive effects have been excluded from the model and the estimates of the direct additive effects must be interpreted as a balance between direct and maternal additive effects. Differences between breeds in terms of direct additive genetic effects $(G^I = G^I_A - G^I_D)$, direct heterosis ($H^I$) and maternal heterosis ($H^M$) were estimated using the CBE program of Wolf (1996). Thus, we have three parameters to be estimated (a vector called b-vector):

$$b = \left[(G^I_A - G^I_D) \quad H^I \quad H^M\right]$$

The estimates of **b** were calculated by the method of generalized least squares (GLS) using the following equation: $\hat{b} = (X'V^{-1}X)^{-1}X'V^{-1}y$

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

| Genetic group | | | | Mean | Coefficients of the matrix | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Kid | Sire | Dam | Grand-dam | | $D_A$ | $D_D$ | $H^I$ | $H^M$ | $R^I$ |
| AA | A | A | | 1 | 1 | 0 | 0 | 0 | 0 |
| DD | D | D | | 1 | 0 | 1 | 0 | 0 | 0 |
| ½D½A | D | A | | 1 | .5 | .5 | 1 | 0 | 0 |
| ¾D¼A | D | ½D½A | A | 1 | .5 | .5 | .5 | 1 | 0.25 |

$D_A$ and $D_D$ = Direct additive genetic effects for the Ardi breed and the Damascus breed, respectively; $H^I$ = Direct heterosis; $H^M$ = Maternal heterosis; $R^I$= Direct recombination genetic loss.

## Results and discussion

### Actual means and variations

Results presented in Tables 2 and 3 describe kid growth performance in this project. However, wide phenotypic variations in all traits were observed. The average individual weights in Jouf experiment were nearly similar to those in Qassim experiment. These lower body weights present a unique opportunity for changing performance while exploiting additive genetic variance and variability within population with the use of familiar methods such as selection based on individual or family merit. Comparing body weights obtained in the present study with those of the large European and Boer breeds that exceed 90 kg in body weight (Warmington and Kirton, 1990) led to the conclusion that European breeds have considerable potential in crossbreeding and formation of composite population for the commercial production of meat from goats (Shrestha, 2005; Shrestha and Fahmy, 2007b).

Results given in Table 3 describe the performance of carcass and meat composition traits. Carcass and meat composition traits were changed markedly with the animal's age or the weight at slaughter.

**Table 2.** Actual means, standard deviations (SD) and ranges for growth traits of kids in Jouf and Qassim experiments

| Trait | Jouf experiment | | | | | Qassim experiment | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | No. of Records | Mean | SD | Min. | Max. | No. of Records | Mean | SD | Min. | Max. |
| **Body weight (kg):** | | | | | | | | | | |
| 0-week | 974 | 3.89 | 0.90 | 0.85 | 6.75 | 423 | 3.37 | 0.72 | 1.80 | 5.80 |
| 4-week | 786 | 8.65 | 2.15 | 3.25 | 17.94 | 356 | 7.23 | 1.98 | 3.00 | 15.85 |
| 8-week | 681 | 12.04 | 3.29 | 5.00 | 24.65 | 326 | 10.67 | 3.01 | 5.20 | 22.90 |
| 12-week | 641 | 15.21 | 4.15 | 5.55 | 27.75 | 299 | 13.86 | 3.77 | 6.00 | 27.30 |
| 16-week | 620 | 18.17 | 4.66 | 5.50 | 34.50 | 275 | 16.62 | 4.14 | 7.40 | 30.90 |
| 20-week | 634 | 20.62 | 5.02 | 8.40 | 42.00 | 263 | 19.17 | 4.78 | 9.50 | 33.41 |
| 24-week | 603 | 23.35 | 5.33 | 8.60 | 45.75 | 249 | 22.11 | 5.32 | 11.00 | 36.40 |
| **Daily gain in weight (kg):** | | | | | | | | | | |
| 0-4 weeks | 786 | 0.17 | 0.07 | 0.00 | 0.43 | 351 | 0.14 | 0.06 | 0.02 | 0.44 |
| 4-8 weeks | 666 | 0.13 | 0.07 | 0.01 | 0.49 | 322 | 0.12 | 0.06 | 0.02 | 0.29 |
| 8-12 weeks | 612 | 0.12 | 0.06 | 0.00 | 0.43 | 294 | 0.12 | 0.06 | 0.01 | 0.32 |
| 12-16 weeks | 594 | 0.11 | 0.07 | 0.00 | 0.79 | 270 | 0.10 | 0.06 | 0.00 | 0.61 |
| 16-20 weeks | 587 | 0.12 | 0.13 | 0.00 | 1.08 | 254 | 0.09 | 0.05 | 0.01 | 0.29 |
| 20-24 weeks | 572 | 0.11 | 0.08 | 0.00 | 1.22 | 238 | 0.11 | 0.05 | 0.01 | 0.40 |

**Table 3.** Actual means, standard deviations (SD) and ranges for carcass traits and meat compositions in Qassim experiment

| Trait | Mean | SD | Minimum | Maximum |
|---|---|---|---|---|
| **Carcass traits:** | | | | |
| Pre-slaughter weight, kg | 26.455 | 6.170 | 22.345 | 42.650 |
| Hot carcass weight, kg | 12.561 | 3.048 | 11.2 | 20.6 |
| Dressing percentage | 47.4 | 2.6 | 41.5 | 54.0 |
| Giblet weight, kg | 0.739 | 0.156 | 0.604 | 1.071 |
| **Chemical composition of meat:** | | | | |
| Moisture (MP), % | 75.3 | 11.4 | 72.4 | 78.2 |
| Dry matter (DM), % | 24.7 | 1.4 | 22.2 | 27.4 |
| Crude protein (CP), %$^+$ | 78.8 | 3.7 | 76.2 | 80.4 |
| Ether extract (EE), %$^+$ | 16.8 | 4.0 | 12.8 | 18.2 |
| Ash content, %$^+$ | 4.3 | 0.7 | 3.6 | 5.4 |

Giblet = heart + liver + kidneys + spleen.

$^+$ On dry matter basis.

The average pre-slaughter weight of the kids of this project was 26.455 kg and ranging from 22.345 to 42.650 kg. Hot carcass weight ranged from 11.2 to 20.6 k*g* with an average of 12.561 k*g*. Reviewed estimates for carcass traits for the same breed indicated that carcass weights are varied from one country or region to another. The dressing out percentage averaged 47.4% across all genetic groups (Table 3). This percentage is higher to that recorded by El-Gallad *et al.* (1988) in Egypt for Zaraibi goats. They found that dressing percentage in Zaraibi goats ranging from 39.4 to 46.4, with an average value of 44.2%. For meat compositions, the results gave an impression to that kids' meat could be appreciated for its high nutritional and dietetic properties since ether extract in the lean was low (16.8 %) and protein content was high (78.8%) on dry matter basis.

### Additive and common litter environmental effects

Estimates of heritability for body weights and gains are moderately heritable in most cases; ranging from 0.12 to 0.36 for body weights and from 0.12 to 0.24 for gains in weight in Jouf experiment and from 0.15 to 0.26 and from 0.11 to 0.25 in Qassim experiment, respectively (Table 4). From the genetic point of view, moderate genetic potentiality could be achieved in body weights or gains through selection. Numerous studies on genetic parameters have shown that body weights and gains are moderately heritable suggesting considerable potentiality for genetic improvement of meat goats (Bigham et al, 1993; Gebrelul *et al*, 1994; Tahir *et al*, 1995; Roy *et al*, 1997; Mourad and Anous, 1998; Fahmy and Shrestha, 2000; Shrestha and Fahmy, 2007b). Heritability estimates observed in this study are within the range of those reported for tropical goats, e.g. Mavrogenis et al. (1984a,b) for Damascus goats; Das *et al*. (1994,2001) for Tanzanian blended goats; Al-Shorepy et al. (2002) for Emirati goats; Portolano *et al.* (2002) for Silican Girgentana goats, and Mugambi *et al* (2006) for native goats in Kenya. Niekerk et al (1996) and Mourad and Anous (1998) reported similar results in Adelide Boer and common African and Alpine crossbred goats, respectively.

Nahardeka *et al*. (2001) reported moderate heritability estimates for body weights at 6, 9 and 12 months in Assam local goats and crosses with the Beetal breed. Mugambi *et al* (2006) found that heritability estimates were 0.13, 0.16, 0.16, 0.24 and 0.10 for birth weight, weaning weight, yearling weight, pre-weaning and post-weaning average daily gains, respectively. Common litter effects for most growth traits were slightly higher than the respective heritabilities since the estimates for body weights and daily gains in weight ranged from 0.08 to 0.20 and 0.11 to 0.34 in Jouf experiment and from 0.07 to 0.20 and 0.08 to 0.14 in Qassim experiment (Table 4). It is important to say that common litter effects appeared to have strong effects on kid's growth even up to late age. In Boer goats and using a comparable model, Schoeman *et al*. (1997) reported lower heritability to be 0.18 and common litter effects to be 0.07. However, Al-Shorepy *et al* (2002) reported that inclusion of maternal litter environmental effects provided reasonable estimates of heritability for growth traits since the estimates of heritability ranged from 0.16 to 0.32 for body weight traits, and 0.09 to 0.42 for daily body gains. Heritabilities given in Table 5 for pre-slaughter weight (0.26) and hot carcass weight (0.34) were moderate, while the estimate for dressing percent was low (0.10). All meat composition traits were not significantly different from zero (Table 5). Unfortunately, little available literature was reported on heritabilities of carcass traits and meat composition of carcass (Fahmy and Shrestha, 2000; Shrestha and Fahmy, 2007b).. The common litter effects for carcass traits and meat compositions were always higher than their respective heritabilities and they ranged from 0.16 to 0.23 for carcass traits and from 0.02 to 0.12 for meat compositions (Table 5), suggesting that common litter effects appeared to have strong effects on kid's growth even up to late age. The common litter effects were low but significantly different from zero for moisture, dry matter and ash contents in the lean.

## Crossbreeding effects

### Direct additive genetic effects

In both experiments, all the estimates of direct additive effects for body weights at 0, 4, 8, 12, 16, 20 and 24 weeks of age were significantly positively in favour of Damascus goats by 0.260, 1.504, 1.337, 1.505, 1.324, 1.873 and 2.080 kg in Jouf experiment and by 0.548, 1.876, 2.168, 2.975, 2.739, 3.594 and 4.046 kg in Qassim experiment, respectively (Table 6). For daily gains in weight, the same trend was observed where the estimates of direct additive effects for gains at interval of 0-4, 4-8, 8-12, 12-16, 16-20, and 20-24 weeks of age were significantly positively in favour of Damascus goats by 47, 31, 7, 30, 33, and 28 g in Jouf experiment and by 47, 35, 22, 42, 18, and 32 g in Qassim experiment, respectively (Table 6). The differences in direct additive effects obtained here for body weights and gains between the two breeds lead to state that Damascus goats could be used in crossbreeding programmes in Saudi Arabia and other hot climatic countries. Mugambi *et al* (2006) with crossing Toggenburg (T), Anglo-Nubian (N), Small East African (E) and Galla (G) breeds found that superiorities of exotic bucks over the indigenous breeds in weaning weight, daily gain in weight and yearling weight were in line with heavy mature body weights and high milk yield in their crosses, which provide favourable maternal influence to the kids.

In both experiments, all estimates of direct additive effects for growth traits were significantly high and in favor of Damascus goats by 7.7 to 18.0 % for body weights and 6.0 to 26.3 % for daily body gains in Jouf experiment relative to the founder breeds, while the respective estimates ranged from 16.7 to 25.3 % and from 18.0 to 38.8 % in Qassim experiment (Table 6). The positive additive effects of the Damascus breed in average body weights and daily gains indicate that its effects are of maternal origin that is expressed in their crosses during nursing period after which they are unable to express their potential under harsh environmental conditions. Mugambi *et al* (2006) in Kenya stated that the positive effect of Galla native goat above exotic breeds in birth weight and post-weaning average daily gains reflects the ability of the breed to survive in harsh environmental conditions and poor quality feeds, during gestation.

**Table 4.** Proportions of the phenotypic variance due to genetic additive effects ($h^2$) and to common litter non-additive effects ($C^2$) and random error ($e^2$) with their standard errors (±SE) for growth traits in Jouf and Qassim experiments

| Trait | Jouf experiment | | | Qassim experiment | | |
|---|---|---|---|---|---|---|
| | $h^2$±SE | $C^2$±SE | $e^2$±SE | $h^2$±SE | $C^2$±SE | $e^2$±SE |
| Body weight: | | | | | | |
| 0-week | 0.20±0.082 | 0.20±0.045 | 0.60±0.070 | 0.15±0.129 | 0.20±0.078 | 0.65±0.102 |
| 4-week | 0.31±0.099 | 0.11±0.037 | 0.58±0.090 | 0.21±0.186 | 0.12±0.104 | 0.68±0.114 |
| 8-week | 0.31±0.125 | 0.12±0.046 | 0.47±0.090 | 0.21±0.179 | 0.11±0.108 | 0.68±0.111 |
| 12-week | 0.22±0.023 | 0.09±0.047 | 0.67±0.025 | 0.22±0.118 | 0.11±0.093 | 0.67±0.176 |
| 16-week | 0.12±0.093 | 0.15±0.055 | 0.73±0.083 | 0.26±0.161 | 0.10±0.109 | 0.64±0.100 |
| 20-week | 0.36±0.017 | 0.08±0.053 | 0.56±0.019 | 0.15 ± 0.165 | 0.10 ± 0.093 | 0.75 ± 0.134 |
| 24-week | 0.24±0.111 | 0.12±0.059 | 0.64±0.095 | 0.19 ± 0.189 | 0.07 ± 0.098 | 0.74 ± 0.151 |

**Table 4**. cont.

| | | | | | | |
|---|---|---|---|---|---|---|
| Daily gain in weight: | | | | | | |
| 0-4 weeks | 0.19±0.084 | 0.11±0.044 | 0.70±0.077 | 0.19±0.098 | 0.13±0.134 | 0.68±0.166 |
| 4-8 weeks | 0.18±0.128 | 0.11±0.054 | 0.71±0.106 | 0.14±0.120 | 0.14±0.122 | 0.72±0.166 |
| 8-12 weeks | 0.12±0.082 | 0.12±0.045 | 0.76±0.086 | 0.19±0.171 | 0.12±0.087 | 0.69±0.140 |
| 12-16 weeks | 0.24±0.085 | 0.21±0.053 | 0.55±0.043 | 0.21±0.145 | 0.12±0.111 | 0.67±0.186 |
| 16-20 weeks | 0.21±0.069 | 0.26±0.059 | 0.53±0.061 | 0.25±0.174 | 0.08±0.099 | 0.67±0.146 |
| 20-24 weeks | 0.20±0.078 | 0.34±0.066 | 0.46±0.055 | 0.11±0.182 | 0.10±0.114 | 0.79±0.150 |

**Table 5.** Proportions of the phenotypic variance due to genetic additive effects ($h^2$) and to common litter non-additive effects ($C^2$) and random error ($e^2$) with their standard errors (±SE) for some carcass and meat composition traits in Qassim experiment

| **Trait** | $h^2$±SE | $C^2$±SE | $e^2$±SE |
|---|---|---|---|
| **Carcass traits:** | | | |
| Pre-slaughter weight, kg | 0.26±0.051 | 0.22±0.029 | 0.52±0.018 |
| Hot carcass weight, kg | 0.34±0.054 | 0.23±0.028 | 0.43±0.021 |
| Dressing percentage | 0.10±0.047 | 0.16±0.029 | 0.74±0.023 |
| Giblet weight, kg | 0.32±0.062 | 0.18±0.024 | 0.50±0.022 |
| **Meat chemical composition** | | | |
| Moisture (MP), % | 0.02±0.024 | 0.08±0.023 | 0.90±0.022 |
| Dry matter (DM), % | 0.02±0.022 | 0.10±0.025 | 0.88±0.024 |
| Crude protein (CP), % | 0.02±0.019 | 0.02±0.031 | 0.96±0.023 |
| Ether extract (EE), % | 0.02±0.018 | 0.02±0.023 | 0.97±0.025 |
| Ash content, % | 0.01±0.001 | 0.12±0.027 | 0.86±0.026 |

**Table 6.** Estimates of direct additive effects and their standard errors ($D^I$±SE) for body weight and daily body gains in Jouf and Qassim experiments

| Trait | Jouf experiment $D^I=(D^I_D-D^I_A)$ | | | Qassim experiment $D^I=(D^I_D-D^I_A)$ | | |
|---|---|---|---|---|---|---|
| | Estimate | SE | $D^I$ %+ | Estimate | SE | $D^I$ %+ |
| Body weight (*kg*): | | | | | | |
| 0-week | 0.260* | 0.124 | 7.8 | 0.548** | 0.162 | 16.7 |
| 4-week | 1.504** | 0.316 | 18.0 | 1.876** | 0.480 | 25.3 |
| 8-week | 1.337** | 0.434 | 11.0 | 2.168** | 0.82 | 21.0 |
| 12-week | 1.505** | 0.252 | 10.2 | 2.975** | 1.086 | 21.4 |
| 16-week | 1.324** | 0.378 | 7.7 | 2.739** | 1.513 | 17.0 |
| 20-week | 1.873** | 0.482 | 9.5 | 3.594** | 1.54 | 18.7 |
| 24-week | 2.080** | 0.434 | 9.0 | 4.046** | 1.645 | 18.0 |
| Daily body gains (*kg*): | | | | | | |
| 0-4 weeks | 0.047** | 0.006 | 26.3 | 0.047** | 0.004 | 32.3 |
| 4-8 weeks | 0.031** | 0.005 | 19.0 | 0.035** | 0.010 | 30.0 |
| 8-12 weeks | 0.007* | 0.004 | 6.0 | 0.022** | 0.005 | 18.0 |
| 12-16 weeks | 0.030** | 0.008 | 22.0 | 0.042** | 0.004 | 38.8 |
| 16-20 weeks | 0.033** | 0.006 | 22.2 | 0.018** | 0.002 | 19.1 |
| 20-24 weeks | 0.028** | 0.005 | 18.7 | 0.032** | 0.004 | 26.4 |

+ $D^I$%= [$D^I$ in units / (average of purebreds)] x 100.
*= P<0.05; **= P<0.01.

With cross-bred kids between Alpines and Nubian breeds, Gebrelul *et al.* (1994) reported estimates of direct additive effects of 0.24, 1.9 and 19.8 kg for birth weight, weaning weight and daily gain in weight, respectively. In most cases, the estimates of direct genetic effects for carcass traits were significant and in favour of Damascus kids by 6.2 kg for pre-slaughter weight, 4.2 kg for hot carcass weight, 4.8 % for dressing out percentage, and 0.173 kg for giblet weight (Table 7). In the corresponding percentages relative to the average of parents, direct genetic effects were moderate and in favour of Damascus kids by 22.1, 29.1, 10.2, and 28.1 %, respectively. Also, the estimates for meat compositions traits were somewhat low and in favour of Damascus kids (Table 7). Damascus kids had slightly more direct additive effects for dry matter content in the lean by 4.4% and ether extract by 3.4% than for Saudi Ardi kids.

**Table 7.** Estimates of direct additive effects and their standard errors ($D^I$±SE) for carcass and meat composition traits in Qassim experiment

| Trait | $D^I=(D^I_D-D^I_A)$ | | |
|---|---|---|---|
| | Estimate | SE | $D^I$ %$^+$ |
| Carcass traits: | | | |
| Pre-slaughter weight, kg | 6.2** | 0.74 | 22.1 |
| Hot carcass weight, kg | 4.2** | 1.6 | 29.1 |
| Dressing percentage | 4.8** | 1.2 | 10.2 |
| Giblet weight, kg | 0.173** | 0.063 | 28.1 |
| Meat chemical composition: | | | |
| Moisture (MP), % | 0.14 | 0.16 | 0.1 |
| Dry matter (DM), % | 1.18 | 0.68 | 4.4 |
| Crude protein (CP), % | 0.32 | 0.44 | 0.4 |
| Ether extract (EE), % | 0.62 | 0.42 | 3.4 |
| Ash content, % | 0.16 | 0.28 | 3.5 |

$^+$ $D^I$%= [$D^I$ in units / (average of purebreds)] x 100.
**= P<0.01.

### Direct ($H^I$) and maternal ($H^M$) heterosis

The actual heterotic increments in body weights of Jouf experiment were 0.205, 0.362, 0.729, 0.481, 0.497, 0.435 and 0.712 kg at 0, 4, 8, 12, 16, 20 and 24 weeks of age, while the respective significant heterotic increments in Qassim experiment were 0.212, 0.551, 0.711, 1.125, 1.497 0.797 and 0.875 kg, respectively (Table 8). For daily body gains, heterotic increments were 18, 55, 45, 60, 45, and 60 g in Jouf experiment and 15, 85, 40, 40, 40, 50 g in Qassim experiment during age intervals of 0-4, 4-8, 8-12, 12-16, 16-20 and 20-24 weeks, respectively (Table 8). The estimates for direct heterosis reported here for growth traits are lower than those reported by Gebrelul *et al.* (1994) who found estimates of 0.24, 1.9 and 19.8 kg for birth weight, weaning weight and daily gain between birth and weaning, respectively, in cross-bred kids between Alpines and Nubian breeds. However, El Fadili and Leroy (2001) reported low estimate of heterosis for weaning weight (0.03 kg) in crosses between two indigenous Moroccan breeds. This may be caused by loss of co-adaptive gene combinations in the crossbreds between divergent breeds or due to environmental conditions where the animals were reared. Mugambi *et al* (2006) found that direct heterosis had positive effects on birth weight (+0.05 kg), yearling weight (+0.36 kg) and post-weaning average daily gains (+3.04 g/day) but negative in pre-weaning traits. The study shows that the developed KDPG composites have not optimized on the positive dominance effects; an effect due to retained recombination loss caused by lack of selection during breed development. They concluded also that the KDPG composites are still segregating and have not stabilized into a new breed as was the aim of the breeding programme. In both experiments, all estimates of direct heterosis expressed as percentages relative to the founder breeds for all body weights and gains were positive and significant (Table 8). The estimates for body weights were ranging from 3.2 to 6.1 % in Jouf experiment and 3.9 to 9.3 % in Qassim experiment. For daily gains in weight, the estimates were ranging from 3.0 to 4.7 % in Jouf experiment and 3.7 to 11.4 % in Qassim experiment relative to the founder breeds. In practice, the positive and significant estimates of direct heterosis for growth traits (Table 8) indicate that the benefits of heterosis were realized after weaning when the favourable maternal common environmental effects are diminished.

**Table 8.** Estimates of direct heterosis and their standard errors ($H^I$±SE) for body weights and daily body gains in Jouf and Qassim experiments

| Body weight | Jouf experiment | | | Qassim experiment | | |
|---|---|---|---|---|---|---|
| | Units | SE | $H^I$ %$^+$ | Units | SE | $H^I$ %$^+$ |
| Body weight (*kg*): | | | | | | |
| 0-week | 0.205* | 0.049 | 6.1 | 0.212* | 0.14 | 6.4 |
| 4-week | 0.362* | 0.059 | 4.3 | 0.551* | 0.21 | 7.4 |
| 8-week | 0.729* | 0.071 | 6.0 | 0.711* | 1.045 | 6.9 |
| 12-week | 0.481* | 0.086 | 3.2 | 1.125** | 0.485 | 8.1 |
| 16-week | 0.497* | 0.103 | 4.3 | 1.497** | 0.686 | 9.3 |
| 20-week | 0.435* | 0.099 | 3.7 | 0.797* | 0.815 | 4.1 |
| 24-week | 0.712* | 0.132 | 3.6 | 0.875* | 0.465 | 3.9 |
| Daily weight gain (kg): | | | | | | |
| 0-4 weeks | 0.018* | 0.003 | 4.7 | 0.015** | 0.002 | 7.2 |
| 4-8 weeks | 0.055* | 0.002 | 3.3 | 0.085** | 0.005 | 7.2 |
| 8-12 weeks | 0.045* | 0.003 | 3.1 | 0.040** | 0.008 | 11.4 |
| 12-16 weeks | 0.060* | 0.002 | 4.4 | 0.040* | 0.006 | 3.7 |
| 16-20 weeks | 0.045* | 0.029 | 3.0 | 0.040* | 0.002 | 4.2 |
| 20-24 weeks | 0.060* | 0.032 | 4.0 | 0.050* | 0.001 | 4.1 |

$^+$ $H^I$%= [$H^I$ in units / (average of purebreds)] x 100.
*= P<0.05; **= P<0.01.

The actual maternal heterotic increments in body weights of Jouf experiment were 0.130, 0.202, 0.219, 0.288, 0.305, 0.300 and 0.554 kg at 0, 4, 8, 12, 16, 20 and 24 weeks of age, while the respective significant heterotic increments in Qassim experiment were 0.165, 0.859, 2.135, 1.421, 1.375, 1.286 and 1.298 kg, respectively (Table 9). For daily body gains, maternal heterotic increments during age intervals of 0-4, 4-8, 8-12, 12-16, 16-20 and 20-24 weeks were 7.5, 4.5, 6.5, 2.0, 3.5 and 3.0 g in Jouf experiment and 33.5, 31.5, 7.0, 15.0, 10.0, and 5.0 g in Qassim experiment, respectively (Table 9). In both experiments, all estimates of maternal heterosis for body weights and gains expressed as percentages relative to the founder breeds were positive, significant and ranging from 1.5 to 3.9 % in Jouf experiment and 5.0 to 20.7 % in Qassim experiment (Table 9). For daily gains in weight, the estimates were ranging from 1.4 to 5.6 % in Jouf experiment and 1.0 to 27.0 % in Qassim experiment. These moderate estimates of maternal heterosis for body weights and gains indicate that crossbred dams had moderate heterotic maternity over their purebred dams in these growth traits. Estimates of direct heterosis for most carcass traits were significant (Table 10). This notation implies that dominance effects on these traits were of considerable importance. Pre-slaughter weight, hot carcass weight, and giblet weight showed favorable positive estimates of direct heterosis of 1.35 kg, 0.8 kg, and 103 g, respectively. Crossbred kids showed considerable improvements in the carcass performance since the estimates of direct heterosis were mostly significant and ranging from 2.4 to 22.1 %. The estimates of direct heterosis for meat composition traits were mostly negative and non-significant (Table 10), although crossbred kids were associated with reductions in moisture, ether extract and ash in meat of the carcass.

**Table 9.** Estimates of maternal heterosis and their standard errors ($H^M \pm SE$) for body weights in Jouf and Qassim experiments

| | Jouf experiment | | | Qassim experiment | | |
|---|---|---|---|---|---|---|
| | Units | SE | $H^M$ %$^+$ | Units | SE | $H^M$ %$^+$ |
| Body weight (*kg*): | | | | | | |
| 0-week | 0.130* | 0.084 | 3.9 | 0.165* | 0.032 | 5.0 |
| 4-week | 0.202* | 0.096 | 2.4 | 0.859** | 0.045 | 11.6 |
| 8-week | 0.219 | 0.092 | 1.8 | 2.135** | 0.067 | 20.7 |
| 12-week | 0.288 | 0.082 | 1.9 | 1.421** | 0.092 | 10.2 |
| 16-week | 0.305 | 0.136 | 1.7 | 1.375** | 0.156 | 8.5 |
| 20-week | 0.300 | 0.214 | 1.5 | 1.286* | 0.234 | 6.7 |
| 24-week | 0.554* | 0.248 | 2.4 | 1.298* | 0.267 | 5.7 |
| Daily weight gain (kg): | | | | | | |
| 0-4 weeks | 7.5* | 0.8 | 4.2 | 33.5** | 1.1 | 23.0 |
| 4-8 weeks | 4.5* | 0.9 | 2.7 | 31.5** | 1.8 | 27.0 |
| 8-12 weeks | 6.5* | 0.7 | 5.6 | 7.0* | 2.2 | 5.7 |
| 12-16 weeks | 2.0 | 0.6 | 1.4 | 15.0** | 2.6 | 13.8 |
| 16-20 weeks | 3.5* | 2.1 | 2.3 | 10.0 | 2.2 | 1.0 |
| 20-24 weeks | 3.0 | 2.8 | 2.0 | 5.0* | 1.2 | 4.1 |

$^+$ $H^M$%= [$H^M$ in units / (average of purebreds)] x 100.
*= P<0.05; **= P<0.01.

**Table 10.** Estimates of direct heterosis and their standard errors ($H^I \pm SE$) for carcass and meat composition traits in Qassim experiment

| Trait | Estimate | SE | $H^I$ %$^+$ |
|---|---|---|---|
| Carcass traits: | | | |
| Pre-slaughter weight, kg | 1.35* | 0.34 | 4.8 |
| Hot carcass weight, kg | 0.8* | 0.13 | 5.5 |
| Dressing percentage | 1.15$^{NS}$ | 0.32 | 2.4 |
| Giblet weight, kg | 0.103* | 0.051 | 22.1 |
| Meat chemical composition: | | | |
| Moisture (MP), % | -0.6 $^{NS}$ | 0.23 | -0.7 |
| Dry matter (DM), % | 0.9 $^{NS}$ | 0.36 | 3.3 |
| Crude protein (CP), % | 0.7 $^{NS}$ | 0.56 | 0.8 |
| Ether extract (EE), % | -0.45 $^{NS}$ | 0.64 | -2.5 |
| Ash content, % | -0.27* | 0.05 | -6 |

$^+$ $H^I$%= [$H^I$ in units / (average of purebreds)] x 100.
NS = Non-significant; *= P<0.05; **= P<0.01.

## Direct recombination effects

The estimates of direct recombination losses in heterosis for growth traits were mostly not-significant (Table 11). These favourable estimates gave an impression to indicate that crossbred dams including Damascus genes could be effective to improve growth performance by crossing Damascus with native Saudi Ardi goats. Information in the literature concerning estimates of direct recombination effects for growth performance of crossbreeding experiments in goats are scarce and most of the available results are contradicted. Pre-slaughter weight, hot carcass weight, dressing percentage and offal weights showed losses of genetic recombination (Table 11). Also, the estimates of direct recombination effects for meat composition traits were non-significant. For all traits, the estimates were mostly with different parameters relative to those estimates of direct heterosis. This notation implies that dominance effects on these traits were of little importance.

**Table 11.** Estimates of direct recombination effects ($R^I$) and their standard errors (SE) for growth performances in Jouf and Qassim experiments

| Trait$^+$ | Direct recombination losses in units ± SE | |
|---|---|---|
| | Jouf experiment | Qassim experiment |
| Body weight (kg): | | |
| 0-week | 0.032±0.013 $^{NS}$ | 0.034±0.011 $^{NS}$ |
| 4-week | 0.035±0.048$^{NS}$ | 0.038±0.036$^{NS}$ |
| 8-week | 0.059±0.056$^{NS}$ | 0.039±0.027$^{NS}$ |
| 12-week | 0.068±0.089$^{NS}$ | 0.057±0.027$^{NS}$ |
| 16-week | 0.067±0.056$^{NS}$ | 0.059±0.046$^{NS}$ |
| 20-week | 0.194±0.034$^{*}$ | 0.234±0.042$^{*}$ |
| 24-week | 0.384±0.045$^{*}$ | 0.245±0.051$^{*}$ |
| Daily gain in weight (g/d): | | |
| 0-4 weeks | 8.2±0.084 $^{NS}$ | 5.6±0.076 $^{NS}$ |
| 4-8 weeks | 6.5±0.057$^{NS}$ | 2.8±0.043$^{NS}$ |
| 8-12 weeks | 4.2±0.064$^{NS}$ | 3.2±0.064$^{NS}$ |
| 12-16 weeks | 5.8±0.044$^{NS}$ | 6.8±0.041$^{NS}$ |
| 16-20 weeks | 8.6±0.034$^{*}$ | 6.2±0.028$^{*}$ |
| 20-24 weeks | 9.2±0.054$^{*}$ | 7.2±0.034$^{*}$ |
| Carcass traits: | | |
| Pre-slaughter weight, kg | | 0.198±0.076* |
| Hot carcass weight, kg | | 0.192±0.066$^{*}$ |
| Dressing percentage | | 2.34±0.72* |
| Giblet weight, kg | | 0.256±0.089$^{*}$ |
| Meat quality: | | |
| Moisture (MP), % | | -0.42±0.45 $^{NS}$ |
| Dry matter (DM), % | | 0.52±0.72 $^{NS}$ |
| Crude protein (CP), % | | 0.14±0.87 $^{NS}$ |
| Ether extract (EE), % | | 0.34±0.52 $^{NS}$ |
| Ash content, % | | 0.046±0.098 $^{NS}$ |

## Conclusions

1) Direct additive effects for most traits studied were in favour of Damascus breed relative to the Ardi breed.
2) Crossing Damascus breed with local goats in hot climatic countries could produce crossbred kids (**½D½A** and **¾D¼A**) with reasonable growth performances.
3) The favourable estimates of direct and maternal heterosis obtained for most growth traits would be an encouraging factor for the goat producers in hot climate countries to use crossbred does and dams on commercial scale.
4) Insignificant direct recombination losses for most growth traits conclude that epistatic recombination losses for these traits in crossbred kids were negligible, and therefore, there is a potential advantage to use crossbred dams and sires including Damascus genes to develop parental lines (maternal and paternal) having more available heterosis to be used in crossbreeding stratification systems in Saudi Arabia and the other hot Arabian countries.

## References

ACSAD, 1996. The Arab Center for the Studies of Arid Zones and Dry Lands. Annual Technical Report. Livestock Studies Department, ACSAD, Damascus, Syria (In Arabic).

Al-Shorepy, S.A., Alhadranu, G.A., and Abdul Wahab, K., 2002. Genetic and phenotypic parameters for early growth traits in Emirati goat. Small Rumin. Res. 45, 217–223.

AOAC., 1990. Official methods of analysis of the Association of Official Agricultural Chemists. Washington DC.

Azawi, O.I., Al-Dahash, S.Y.A. and Juma, F.T. 1993. Effect of different diluents on Damascus goat semen. Small Ruminant Research, 9: 347-352.

Baldassarre, H, Karatzas C.N., 2004. Advanced assisted reproduction technologies (ART) in goats. Animal Reproduction Science 82–83 (2004) 255–266

Bigham, M.L., Morris, C.A. Southey, B.R. and Baker, R.L., 1993. Herirabilities and genetic correlations for live weight and fibre traits in New Zealand Cashmere goats. Livestock Production Science, 33: 91-104.

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

Das, S.M., Rege, J.E.O., and Shibre, M., 1994. Phenotypic and genetic parameters of growth traits of blended goats at Malya, Tanzania. Small Ruminant Research and Development in Africa. In: Proceedings of the 3rd conference of the African Small Ruminant Network U.CC, Kampala, Uganda, 5–9 December, pp. 63–69.

Das, S., Husain, S. S., Hoque, M. A., and Amin, M. R., 2001. Genetic variation and correlation studies of some carcass traits in goats. Asian Australasian J. Anim. Sci. 14, 905–909.

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

Dosari, M. N., Al-Hazab, A. A. and Al-Haj, G. A., 1996. Nutritional and physiological studies to native goat breeds in Saudi Arabia. King Abdul Aziz City for Science technology. Project AT-13-43.

El Fadili, M., and Leroy, P.L., 2001. Estimation of additive and non additive genetic parameters for reproduction, growth, and survival traits in crosses between the Moroccan D'Man and Timahdite breeds. J. Anin. Breed. Genet. 118, 341–353.

El-Gallad, T.T., E.A. Gihad, S.M. Allam and T.M. El-Bedawy., 1988. Effect of energy intake and roughage ratio on the lactation of Egyptian

Nubian (Zaraibi) goats. Small Ruminant Res., 1 (4): 327-341.

Fahmy, M.H. and Shrestha, J.N.B., 2000. Genetics for the improvement of goat meat production. In: Proceedings of the Seventh International Conference on Goats, France, pp. 187-190.

Gebrelul, S., Sartin III., L.S., and Iheanacho, M., 1994. Genetic and non-genetic effects on growth and mortality of Alpine, Nubian and crossbred kids. Small Rumin. Res. 13, 169–176.

Hirooka, H., Mukherjee, T.K., Panandam, J.M., and Horst, P., 1997. Genetic parameters for growth performance of the Malayasian local goats and their crossbreds with the German (improved) Fawn goats. J. Anim. Breed. Genet. 114, 191–199.

Lazaris, A., Keefer, C.L., and Karatzas, C.N., 2002. Transgenic goat founders produced by DNA pronuclear microinjection of in vitro derived zygotes. Mol. Reprod. Dev. 63, 437–443.

Leboeuf B., Forgerit Y., Bernelas D., Pougnard J.L., Senty E., Driancourt M.A., (2003) Efficacy of two types of vaginal sponges to control onset of oestrus, time of preovulatory LH peak and kidding rate in goats inseminated with variable numbers of spermatozoa. Theriogenology, Volume 60, Number 7, 15 October 2003 , pp. 1371-1378(8).

Leboeuf, B., Restall, B., and Salomon, S., 2000. Production and storage of goat semen for artificial insemination. Anim. Reprod. Sci. 62, 113–141.

Mavrogenis, G.A., Constantinou, A., and Louca, A., 1984a. Environmental and genetic cause of variation in production traits of Damascus goats. I. Pre-weaning and Post-weaning growth. Anim. Prod. 38, 91–98.

Mavrogenis A.P., A. Constantinou and A. Louca, 1984b. Environmental and genetic causes of variation in production traits of Damascus goats. 2. Goat productivity, Anim. Prod. 38, pp. 99–104.

Mourad, M. and Anous, M.R., 1998. Estimates of genetic and phenotypic parameters of some growth traits in common African and Alpine crossbred goats. Small Rumin. Res. 27, 197–202.

Mugambi, J.N., J.W. Wakhungu, B.O. Inyangala, W.B. Muhuyic, and T. Muasya, 2006. Evaluation of the performance of the Kenya Dual Purpose Goat composites: Additive and non-additive genetic parameters. Small Rumin. Res. 65.

Nahardeka, N., Das, D., Roy, T.C., Goswami, R.N., Das, G.C., Gogoi, P.K., and Das, B., 2001. Studies on body weights of Assam local goats and their crosses with Beetal. Indian Vet. J. 78, 811–814.

Niekerk, M.M., Van Schoeman, S.J., Botha, M.E., Casey, N., and Van Niekerk, M.M., 1996. Heritability estimates for preweaning growth traits in the Adelaide Boer goat flock. South African J. Anim. Sci. 26, 6–10.

Pawshe, C. H., Totey, S. M. and Jain, S. K., 1994. Methods of recovery of goat oocytes for in vitro maturation and fertilization. Theriogenology 42:177.

Portolano, B., Todaro, M., Finocchiaro, D.R., and Van Kaam, J.H.B.C.M., 2002. Estimation of the genetic and phenotypic variance of several growth traits of the Silican Girgentana goat. Small Rumin. Res. 45, 247–253.

Roy, R., Saxena, V.K., Singh, S.K., and Khan, B.U., 1997. Genetic analysis of body weights at different ages in Jamunapari goats. Indian J. Anim. Sci. 67, 337–339.

SAS, 1999. SAS' Procedure Guide. Versin 6.12 Edition, SAS Institute, INC, Cary, NC, USA.

Shrestha, J.N.B., 2005. Conserving domestic animal diversity among composite populations. Small Ruminant Research, 56, 3–20.

Shrestha, J.N.B., and Fahmy, M.H., 2005. Breeding goats for meat production: a review (1) Genetic resources, management and breed evaluation. Small Rumin. Res. 58, 93–106.

Shrestha, J.N.B. and Fahmy, M.H., 2007a. Breeding goats for meat production: a review (2) Crossbreeding and formation of composite population. Small Ruminant Research, 67: 93–112.

Shrestha, J.N.B. and Fahmy, M.H., 2007b. Breeding goats for meat production: a review (3) Selection and breeding strategies. Small Ruminant Research, 67: 113–125.

Tahir, M., Younas, M., Raza, S.H., Lateef, M., Iqbal, A., and Raza, P.N., 1995. A study on estimation of heritability of birth weight and weaning weight of Teddy goats kept under Pakistani conditions. Asian Australasian J. Anim. Sci. 8, 595–596.

Warmington, B.G. and Kirton, A.H., 1990. Genetic and non-genetic influences of growth and carcass traits of goats. Small Rumin. Res. 3, 147–165.

Wheeler, M.B., Walters, E.M., and Clark, S.G., 2003. Transgenic animals in biomedicine and agriculture: outlook for the future. Anim. Reprod. Sci. 79, 265–289.

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

Wolf, J., Distl, O., Grosshan, T. and Seeland, G., 1995. Crossbreeding in farm animals. V. Analysis of crossbreeding plans with secondary crossbred generations. J. Animal Breeding and Genetics, 112: 81-94.