RESTRICTED SELECTION INDEX FOR GROWTH TRAITS OF SHAMI KIDS

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ABSTRACT

A Restricted Selection Index was constructed to genetically evaluate animals using a dataset composed of body weights of Shami kids at the ages of birth, weaning, and 6-month. The variance-covariance matrix (VCV) was generated and used to estimate genetic parameters for the index construction after adjusting the fixed effects; year, birth month, kid sex, type (single, twin or triplet) of birth, doe age, weights at kidding (KW), birth (BWT) and weaning (WWT) as covariates. General Linear Model and Restricted Maximum Likelihood methods were used to estimate BLUE for fixed effects and variance components for random effects, respectively. BW was 3.6 ± 0.017, WW 16.8 ± 0.10, and weight at 6 months (MWT) was 26.7 ± 0.21 Kg. With the exception of buck origin and doe age, all tested factors significantly affected growth traits. Heritability for BWT, WWT, and MWT was 0.70 ± 0.10, 0.32 ± 0.075, and 0.41 ± 0.12, and repeatability was 0.78, 0.35, and 0.47, respectively. Genetic and phenotypic correlations were positive and significant between BWT and WWT, and between WWT and MWT. The restricted selection index constructed for increasing weights at MWT and WWT with restriction on BWT yielded a strong correlation coefficient (r_{IA}) between the genetic merit and the index at 0.54 (p<0.01).

Keywords: Shami Goat; Genetic gain; fixed effects; meat production genetic selection

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المستخلص

تم استنباط الدليل الانتخابي المقيد لتقييم الحيوانات وراثيًا باستعمال مجموعة بيانات تتكون من أوزان مواليد الماعز الدمشقي (الشامي) عند عمرالولادة والفطام و6 أشهر. تم إنشاء مصفوفة التباين– التغاير (VCV) و استعمالها لتقدير المعالم الوراثية لاستباط الدليل بعد التعديل للتأثيرات الثابتة؛ السنة، وشهر الميلاد، وجنس المولود، والنوع (مفرد ، توأم أو ثلاثة توائم) عند الميلاد، عمر الام عند الولادة، الأوزان عند الولادة والفطام وعند عمر ستة اشهر (عمر التسويق) كمتغيرات كمية. تم استعمال النموذج الخطي العام وطرائق الاحتمالية القصوى المقيدة لتقدير التقديرات الثابتة (Blue effects) للتأثيرات الثابتة ومكونات التباين للتأثيرات العشوائية، على التوالي كان وزن الجسم 3.6 ± 0.017 عند الميلاد ،16.80 ± 0.10، للوزن عند الفطام ولوزن عند 6 أشهر26.7 ± 0.21 كجم. باستثناء أصل او منشأ التيس وعمر الماعز، أثرت جميع العوامل المختبرة بشكل كبير على صفات النمو. كانت تقديرات المكافئ الوراثي لوزن الميلاد ووزن الفطام والوزن عند عمر ستة اشهر (وزن التسويق) 0.10 ± 0.70 و 0.32 ± 0.075 و 0.41 ± 0.12، وكانت تقديرات المعامل التكراري 0.78 و 0.35 و0.47 على التوالي. كانت الارتباطات الوراثية والمظهرية موجبة ومعنوية بين الميلاد والفطام، وبين الفطام والوزن عند عمر التسويق تبين ان استخدام الدليل الانتخابي المقيد الذي تم إنشاؤه لزيادة الأوزان في عند عمر التسويق و الفطام مع تقييد على وزن الميلاد الى معامل ارتباط قوي ((r_{IA}) بين الكسب الوراثي والادليل المستبط عند 0.54 (p <0.01).

الكلمات مفتاحية: الحليب الكلي، المكافئ الوراثي ، الفطام ، الفحص اليومي.

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INTRODUCTION

The Shami goat is considered a prolific high milk producer, raised mainly for meat and milk (12). The income generated from selling meat is slightly higher than that of milk. In Jordan, goats are scattered from north to south, with a high concentration in mountainous areas along the Jordan Valley. Out of a total number of 425,000 goats, 10,880 heads are of the Shami type (2). The annual red meat production sourced from sheep and goats has almost doubled between 1990 and 2012reaching 20,812 tons , though still only providing about 69% of local red meat requirements; goat meat contributes 22% of the total meat production (2). Genetic improvements for goat meat can be of great value to help meet the growing demands of consumers. The rate of genetic improvement is directly related to the accuracy with which animals are ranked, the intensity of selection, the amount of genetic variation available in the trait, and the generation interval (25). Fixed effects including but not limited to year of birth, sex and type (single, twin or triplet) of birth of kids, parity and age of doe can impact growth traits and must be taken into account before estimating the variance-covariance (VCV) matrix used for estimating genetic parameters and constructing selection indices (3,4,5,15,18). Johansson and Rendel (20) reported a negative relationship between birth weight and lambing ease (genetic antagonism). In other words, the ability of selecting animals for increased marketing and weaning weights is possible, however when combined with a restriction on birth weights, the selection is more efficient since complications associated with lambing are avoided(3). The principles of constructing and using a selection index offers the most efficient and pragmatic solution to circumvent problems and attain maximum genetic progress (14,32). Lin (22) developed a restricted selection index that maximized the genetic gain in chosen traits while keeping others at zero levels. The objectives of this study were to calculate some fixed effects (year and month of birth, sex and type of birth of kids, age and weight of doe at kidding, and birth and weaning weights as covariates) that may affect body weights at birth, weaning, and 6-months, and consequently estimate VCV matrix of the studied traits. The VCV matrices were then used for estimating genetic parameters (repeatability, heritability, and genetic and phenotypic correlations) and constructing a restricted selection index for increasing 6-month and weaning weights, while maintaining a constant birth weight.

MATERIALS AND METHODS

All experimental protocols involving animals were approved by the Animal Care and Use committee (ACUC), Jordan University and Science Technology (JUST), approval Number 16/3/3/578. This study was carried out in Al Walla Agricultural Research station, Ministry of Agriculture, located 65 km to the south of Amman, 350 m above sea level with total precipitation of rain ranging between 200 and 250 mm (1). The Shami goat breed was introduced to the station in 1964 from Syria and Cyprus. In 1994, another Shami goat flock of 150 heads was imported from Cyprus. The major goal of this station is to genetically improve the Shami goat breed for the benefit of goat farmers (2).

Feeding and Management

The flock was managed in a semi-intensive management system where animals were allowed to graze year round, four hours in the morning and three hours in the afternoon, except during the final stage of pregnancy. The range consisted of green fodder and natural vegetation (shrubs and herbage) extended mostly from mid-January to late April. A concentrate diet composed of ground barley (67.5%), soybean meal (16%), wheat bran

(15%), salt (0.5%), limestone (1%), and trace minerals (1%) was added to the doe diet at 1.5kg of concentrates with an additional 0.5 kg of alfalfa during the last eight weeks of pregnancy. After kidding, the amount of concentrates was increased to 2 kg. During the breeding season, 18-25 does were allocated to each buck in order to assign a sire for each kid at kidding time. After kidding period, expanding between November and March, occurring in individual kidding pens, kids were ear-tagged and both Dam (BW) and Kid (BWT) weights recorded within 24 hours after kidding. Weaning was achieved at three months of age and weights (WWT) recorded. Creep feeding was offered to kids at 15 days of age. The creep feed was composed of 50% crumbed barley, 20% soybean meal, 25% alfalfa, 4% wheat bran, 0.5% salt, and 0.5% trace minerals and vitamins. Body weight of kids at 6-months of age was also recorded during 1998, 1999, 2000 and 2001. Body weights at birth (BWT), weaning at 90 days (WWT), and marketing/6-months of age (MWT) were studied using 2004, 1811, and 829 Shami kid records, respectively, and then adjusted for 90 days (WWT) and 180 days (MWT) by using Dalton’s (7) method:

Adj. WWT (90d) = BWT + (90 * (WWT – BWT) / Actual Kid Age)

Adj. MWT (180d) = BWT + (180 * (MWT – BWT) / Actual Kid Age)

The station-retrieved data were analyzed using General Linear Model (GLM) of SAS software with buck origin, year and month of birth, sex and type of birth of kids, age and weight of does at kidding as fixed effects, and birth and weaning weights as covariates. Restricted Maximum Likelihood (REML) method (25) was used to estimate variance components for random effects. The mixed model for kid body weights at birth, weaning, and 6-month, in matrix annotation were assumed to be:

$$Y = \sum_{i=1}^{9} X_i b_i + Z_u + e$$

Where :

Y: N*1 vector of observation (that included Birth weight, or weaning weight or six months’ body weight).

$\sum_{i=1}^{9}$ **$X_i b_i$**: fixed effects and their components

X_1: vector of ones of length equal to number of observations.

X_2: matrix of buck origin (local or Cyprus).

X_3: matrix of year of birth (1998, 1999, 2000 or 2001).

X_4: matrix of month of birth (January, February, March, November or December).

X_5: matrix of sex of kids (male or female).

X_6: matrix of type of birth (single, twin or triple).

X_7: matrix of age of doe (< 2, 3, 4, 5, 6 or >7).

X_8: regression on doe weight at kidding.

X_9: regression of weaning weight on birth weight or regression of 6-month weight on weaning weight

b_1: overall mean of the flock.

b_2: vector of buck origin effects.

b_3: vector of year of birth effects.

b_4: vector of month of birth effects.

b_5: vector of sex of kid effects.

b_6: vector of type of birth effects.

b_7: vector of age of doe effects

b_8: value of regression coefficient on doe weight at kidding or birth weight.

b_9: value of regression coefficient on weaning weight

Z_U: random effects and their components

Z: N*S matrix representing the presence of the random effect of kids sire, where S is the number of sires (85) to estimate the genetic and phenotypic variance covariance

Or N*D matrix representing the presence of kids dams that have equal to or more than three births where D is the number of dames (708) to estimate the repeatability of the traits

U: S*1 vector representing the values of the random variable (sire).

Or D*1 vector representing the values of the random variable (dam).

e: unknown non-observable N*1 vector of error effects associated with each observation assumed to be NID (0, I σ^2e).

The solutions of the above equations yielded the "Best linear unbiased estimate" (BLUE), and the least squares means of SAS software was used for means separation.

Genetic Estimates

Variance-covariance (VCV) matrices constructed from sires and error variance-covariance (eVCV) matrices for each trait were tested for positive definiteness. In order to construct efficient selection indices, reliable estimates of variance and covariance were used. Given that genetic parameters should be within an acceptable range (i.e. 0< h^2> 1 and –1< r < 1), the VCV and eVCV matrices were tested for positive definiteness by calculating the eigenvalues. Matrices that did not pass the test were modified by "bending" (13); by reducing the range of eigenvalues and "bending" them towards their mean while keeping the eigenvectors unchanged. The new variance-covariance matrices obtained from the bending method were used to estimate heritability (Paternal half-sib) and genetic and phenotypic correlations (9). Repeatability estimates were estimated from dams and error variances (19). Robertson's method (28) was used to estimate standard error for heritability of the traits.

Selection Index

Restricted selection index, which maximizes genetic gain in chosen traits (6-months and weaning weights), while keeping others (birth weight) at zero level (restriction) as estimated by Kempthorne and Norsdkog(21) and revised by Lin (22), was conducted as follows:

$b^{\circ} = P^{\circ -1} G^{\circ} a^{\circ}$ **and** $b^{*} = P^{* -1} G^{*} a^{*}$

Where:

b: vector of selection index values

P: phenotypic variance-covariance matrix of the traits

G: genetic variance-covariance matrix of the traits

a: vector of traits economical weights. Another set of values depending on the economic importance of each trait included in the selection is used

o" and "*" refer to the non-restricted and desired restriction traits, respectively

The restricted selection indices were constructed according to the equation:

$b = G^{-1} \begin{bmatrix} G^{\circ} & \circ \\ \circ & G^{*} \end{bmatrix} \begin{bmatrix} b^{\circ} \\ b^{*} \end{bmatrix}$, where b is the vector of restricted selection index

For the construction of restricted selection indices for increasing weaning weight and 6-months body weight of Shami kids, while imposing restriction on birth weight, the **a`** vector will be:

$a` = [a_1 \quad a_2 \quad a_3] = [3 \quad 2 \quad 1]$, where a_1, a_2 and a_3 refer to 6-months, weaning, and birth weight economical values, respectively. Priority was given to 6-month weight than to weaning weight with restriction on birth weight.

The correlation between the genetic merit and the index (r_{IA}) was also computed:

$$r_{IA} = \frac{\sigma_I}{\sigma_A}$$

Where:

σI: index standard

eviation

σ^2_I : b`Pb

σ_A: breeding values standard deviation

σ^2_A: a`G_a

b, p, a and G were defined previously

RESULTS AND DISCUSSION

Analysis of factors affecting Shami kid's growth: Mean square analysis of variance of the various factors affecting growth of Shami kids is presented in Table 1, and the least square means are presented in Table 2. Buck origin did not have a significant effect (Table 1) on body weights, whereas year of birth had a significant effect (P<0.01) on each of the birth, weaning, and 6-months weights (Table 1). Similar results were reported by others (16,23,31), and more specifically for birth and weaning weights (21,23). The overall means of kids' body weights were 3.6± 0.01 (BWT), 16.84 ± 0.09 (WWT), and 26.7 ± 0.21 (MWT) kg (Table 2), with maximum averages of 4.05± 0.04 kg (BWT), 19.5± 0.33 kg (WWT), and 28.3 ± 0.77 kg (MWT) reported for the kids born in 1999, 1998, and 1999, respectively (Table 2). The yearly fluctuations in body weights may be attributed to changes in environmental conditions, especially feed availability, and management and health of animals in the flock. Besides, climatic conditions as well as the average annual rainfall and their effects on the range can also indirectly induce weight changes, in agreement with results obtained by many other researchers (11,15,24,33). Month of birth had a significant effect (P<0.01) on all weight groups. Table 2 shows that heavier weights were attained by kids born in March with birth weights of 3.7+0.09 kg, and in November with higher weaning (21.5+0.50) and 6-month weights (29.2+0.83kg). The effect of birth month on body weights could be due to the availability of better ranges, which mainly affect pregnant and lactating dams (24). The action of photoperiods on pregnant does and their embryos can be also another source of influence; dams subjected to longer photoperiods might have better chances to increase their vitamin D resources, vital for bone build up and growth (26). Sex of kids was found to affect (P<0.01) all studied body weights (Table 1). Males were heavier than females at birth (3.6+0.03kg), at weaning (17.7 + 0.26 kg), and at 6-months (27.4±0.65 kg) (Table 2). These findings were in agreement with reports of sex effect on birth weights (24,30), weaning weights (24,30) and 6-months weights (15,17). The effect of sex could be explained by the effect of sex hormones; while estrogen restricts the growth of long bones in the body, androgen acts as an anabolic hormone. As nitrogen retention increases, the growth rate increases and higher body weights are expected (17).

Table 1. Analysis of variance for the factors affecting growth traits in Shami kids

Source of Variance	Birth Weight		Weaning Weight		Weight at 6 month	
	d.f	Mean square	d.f	Mean square	d.f	Mean square
Buck origin	1	0.00005 n.s.	1	24.6224 n.s.	1	0.6701 n.s.
Year of birth	3	63.05**	3	1003.59**	3	641.43**
Month of birth	4	6.66**	4	586.13**	4	227.46**
Sex of kids	1	21.95**	1	1309.76**	1	982.37**
Type of birth	2	99.44**	2	267.82**	2	13.78 n.s.
Age of doe	5	1.33**	5	51.54**	5	40.34 n.s.
Regression on						
Doe weight at kidding	1	9.52**	1	348.59**	1	89.75*
Birth Weight			1	429.58**		
Weaning Weight					1	6325.38**
Residual	2003	0.58	1810	18.08**	828	41.017

n.s. mean square not significant (P>0.05) *, Significant mean square at P<0.05 and P<0.01, respectively**

The effect of type (single, twin, or triplet) of birth on birth and weaning weights of Shami kids was highly significant (P<0.01), however no such effects were observed on 6-months body weights (Table 1). Single born kids were heavier at birth and weaning than twins or triplets. For birth, weights averaged 4.1 ± 0.03, 3.5 ± 0.03 and 3.0 ± 0.05 kg while for weaning, weights averaged 17.8 ± 0.28, 16.4 ± 0.24 and 16.3 ± 0.38 kg for single, twin, and triplet births, respectively (Table 2), while 6-months weights were insignificant with 25.8, 26.1 and 26.4 kg, respectively. Many researchers reported a significant effect of type of birth on birth and weaning weights (6,23,24), and its insignificance on 6-months body weight (6). The effect of type of birth on body weights may due to the fact that twins and triplets develop in a single pre-natal environment with a substantial competition for nutritive resources in the womb, in addition to the impact of the number of cotyledons and birth weights. Additionally, during the post-natal period, kids are again obliged to share the mother's milk, resulting in lesser milk feeding in twin or triplet vs single-reared kids. Age of doe showed a significant effect (P<0.01) on birth, weaning and 6-months weights of kids (Table 1 and 2). 5 years old does produced significantly (P< 0.01) heavier kids at birth (3.6 ± 0.04kg), while heavier weights at weaning (17.4 ± 0.32kg) were attained by kids born from 4 years old does (P<0.01). The results of this study also showed that the influence of doe age declines when approaching the 6-month body weight, at which point it disappears as the kids become more independent from their dam's milk production (maternal effect). The highest 6-months kid weight (27 ± 0.60) came from 2 years old dams, possibly due to compensatory growth. Many results were in agreement with the significant effect of doe age on birth and weaning weights (8,23,24,30). Similarly, Husain et al. (17) showed that age of the dam had no effect on 6-month's weight of Black Bengal goats.

Table 2. Least square means ± S.E. of factors affecting growth traits in Shami kids

	Effect	Birth Weight (Kg)		Weaning Weight (Kg)		Weight at 6 months (Kg)	
		N*	Mean±S.E	N*	Mean± S.E	N*	Mean±S.E.
	Overall Mean	2004	3.6 ±0.01	1811	16.8±0.09	829	26.7±0.21
Buck Origin	Local	1760	3.5±0.04 ^{a}	1594	17.08±0.22 ^{a}	722	26.09±0.59 ^{a}
	Cyprus	244	3.5±0.03 ^{a}	217	16.6±0.34 a	107	26.1±0.73 ^{a}
Year of Birth	1998	451	3.7±0.04 ^{b}	370	19.5±0.33 ^{a}	204	26.51±0.68 ^{b}
	1999	495	4.05±0.04 ^{a}	471	15.7±0.32 ^{b}	148	28.33±0.77 ^{a}
	2000	571	3.5±0.04 ^{c}	544	15.8±0.31 ^{b}	318	23.50±0.71 ^{c}
	2001	487	2.9±0.03 ^{d}	426	16.3±0.28 ^{b}	159	26.20±0.72 ^{b}
Month of Birth	January	231	3.6±0.04 ^{a}	176	14.9±0.31 ^{d}	78	25.1±0.61 ^{b}
	February	395	3.3±.0.3 ^{c}	325	16.5±0.26 ^{c}	41	25.1±0.81 ^{b}
	March	37	3.7±0.09 ^{a}	25	14.2±0.75 ^{d}	4	22.9±2.39 ^{b}
	November	83	3.5±0.07 ^{b}	78	21.5±0.50 ^{a}	70	29.2±0.83 ^{a}
	December	1258	3.6±0.02 ^{a}	1207	17.1±0.17 ^{b}	636	28.1±0.33 ^{a}
Sex of Kids	Male	1044	3.6±0.03 ^{a}	945	17.7±0.26 ^{a}	274	27.4±0.65 ^{a}
	Female	960	3.4±0.03 ^{b}	866	16.02±0.26 ^{b}	555	24.8±0.62 ^{b}
Type of Birth	Single	472	4.1±0.03 ^{a}	434	17.8±0.28 ^{a}	206	25.8±0.65 ^{a}
	Twin	1343	3.5±0.03 ^{b}	1207	16.4±0.24 ^{b}	543	26.1±0.59 ^{a}
	Triplet	189	3.0±0.05 ^{c}	170	16.3±0.38 ^{b}	80	26.4±0.80 ^{a}
Age of Doe	≤2	320	3.4±0.03 ^{b}	540	16.3±0.25 ^{b}	257	27.0±0.60 ^{a}
	3	389	3.5±0.04 ^{b}	327	17.1±0.31 ^{a}	141	25.9±0.70 ^{b}
	4	163	3.6±0.04 ^{a}	320	17.4±0.32 ^{a}	156	25.7±0.74 ^{b}
	5	592	3.6±0.04 ^{a}	308	17.0±0.32 ^{a}	125	26.5±0.75 ^{ab}
	6	171	3.5±0.05 ^{ab}	154	17.08±0.38 ^{a}	69	25.3±0.83 ^{b}
	≥7	369	3.5±0.058 ^{ab}	162	16.2±0.39 ^{b}	8	26.2±0.83^{b}
Regression On	Doe Weight at Kidding	2004	0.0082± 0.0014	1811	0.89±0.101	829	0.041±0.011
	Birth Weight			1811	0.89±0.154	829	
	Weaning Weight					829	0.80±0.046

***Number of animals tested within each parameter.**

^{a,b} within parameter (column), means without a common superscript differ (P< 0.05).

In the present work, a significant (P<0.05) positive regression was found for does weight at kidding on birth (0.0082 ± 0.0014kg), weaning (0.894 ± 0.101 kg) weights, and on 6-

months weights (0.041 ± 0.01) (Table 1 and 2). Das et al. (8) found similar results of doe weight effect on birth and weaning weights, and similar findings of the effect on 6-months weights was reported by Hermiz (15). The effect of doe weight at kidding on growth traits could be explained by the size of the dam's uterus, or in other words, the maturation state of the dam. This includes the amount of milk produced and the amount of nutrients provided via nursing. Further contribution is provided by the carry-over effect of birth and weaning weights to subsequent ages. The regression coefficient of weaning weight on birth weight was 0.893 ± 0.154 kg/kg (P<0.01) and 6-month's weight on weaning weight was 0.803 ± 0.046 kg/kg (P<0.01) as shown in Table 1 and 2.

Genetic and phenotypic parameters

The heritability, repeatability and genetic and phenotypic correlation estimates are presented in Table 3.

Heritability*:* The heritability estimates for birth, weaning, and 6-months weights were 0.70, 0.32 and 0.41, respectively (Table 3). However, heritability estimates for birth weights were higher than those reported by other studies (8,24), ranging between 0.26 to 0.40. Other published results showed similar trends for weaning and 6-month body weights (33). The high heritability estimates of growth traits suggest that these traits can be adopted as valuable markers while carrying out selection programs during different ages; hence early individual selection could be performed with acceptable efficiency.

Repeatability*:* Repeatability estimates for birth and weaning weights were 0.78 and 0.35, respectively (Table 3). These estimates were higher than those indicated by Das et al. (8) for birth weights and Wilson (33) for weaning weights. The estimated repeatability for 6-month body weights (0.47) was lower than those obtained by (0.533) Das et al. (8) and (0.49) Hermiz(15), but higher than the estimates (0.056) by Wilson (33). The high estimates of repeatability in this study propose that poorly producing individuals could be culled on the basis of their first record. The higher the repeatability, the less the predictive value of each additional record on an individual, hence real ability could be estimated on the basis of one record with acceptable precision, as is the case in the Shami goats studies herein.

Genetic correlation*:* The genetic correlation between birth weight and each of the weaning and 6-months body weights were 0.67 (P<0.01) and 0.09 (P<0.01). A higher estimate of 0.73 was found between weaning weight and 6-month body weight (Table 3). Similar positive estimates of genetic correlations between birth, weaning, and 6-month body weighs were confirmed by other researchers (8,31,24).

Phenotypic correlation*:* The phenotypic correlations between weaning weight and each of the birth and 6-months weights were 0.16 and 0.54 (P<0.01), respectively, however no significant correlation (0.06) was detected (P > 0.05) between birth and 6-month's body weights (Table 3). This positive phenotypic correlation between growth traits was observed by Mavrogenis et al., (24).

Table 3. Genetic and phenotypic correlations for the growth traits in Shami kids

Effect	Birth Weight	Weaning Weight	Weight.at six month
Birth Weight	**0.70 ± 0.10**	**0.67^{**}**	**$0.09^{n.s.}$**
Weaning Weight	**0.16^{**}**	**0.32±0.075**	**0.73^{**}**
Weight.at six month	**$0.06^{n.s.}$**	**0.54^{**}**	**0.41±0.12**
Repeatability	**0.78**	**0.35**	**0.47**

Heritabilities are listed on the diagonal while genetic and phenotypic correlations are listed above and below the diagonal, respectively

Selection Index: The restricted selection index was constructed to increase 6-month's (a1) and weaning (a2) weights with restriction on birth (a3) weight (keeping birth weight at a certain level, assuming the progeny test procedure) by using variance-covariance (VCV) matrices (Genetic VCV (GW) and phenotypic VCV (PW)).

a1 a2 a3

$$G_w = \begin{bmatrix} 3.49849 & 1.47314 & 0.04211 \\ 1.473314 & 1.16386 & 0.17559 \\ 0.04211 & 0.17559 & 0.05967 \end{bmatrix}$$

$$P_w = \begin{bmatrix} 34.4166 & 12.0779 & 0.2070 \\ 12.0779 & 14.6285 & 0.3597 \\ 0.2070 & 0.3597 & 0.3409 \end{bmatrix}$$

In this case, the relative economic values will be:

$$: a` = [a_1 \quad a_2 \quad a_3] = [3 \quad 2 \quad 1]$$

In addition, the unrestricted selection index (b^o) for the unrestricted traits will be:

$$b^\circ = P^{\circ -1} G^\circ a^\circ = \begin{bmatrix} 34.1466 & 12.0779 \\ 12.0779 & 14.6285 \end{bmatrix}^{-1} \begin{bmatrix} 3.49849 & 1.47314 \\ 1.47314 & 1.16386 \end{bmatrix} \begin{bmatrix} 3 \\ 2 \end{bmatrix} = \begin{bmatrix} 30.321995 \\ 0.195380 \end{bmatrix}$$

While the restricted selection index (b*) for the desired trait will be equal to:

$$b^* = P^{*-1} G^* a^* = (0.3409)^{-1}(0.05967)(1) = 0.175$$

$$b = G^{-1} \begin{bmatrix} G^\circ & \circ \\ \circ & G^* \end{bmatrix} \begin{bmatrix} b^\circ \\ b^* \end{bmatrix}$$

Thus, we can calculate the restricted selection index (b) as follows:

$$b = \begin{bmatrix} 3.49849 & 1.47314 & 0.04211 \\ 1.47314 & 1.16386 & 0.17559 \\ 0.04211 & 0.17559 & 0.05967 \end{bmatrix}^{-1} \begin{bmatrix} 3.49849 & 1.47314 & 0 \\ 1.47314 & 1.16386 & 0 \\ 0 & 0 & 0.05967 \end{bmatrix} \begin{bmatrix} 0.321995 \\ 0.19538 \\ 0.175 \end{bmatrix}$$

$$= \begin{bmatrix} 0.01218 \\ 1.01147 \\ -2.81003 \end{bmatrix}$$

Finally, the restricted selection index that increased 6-months and weaning weights while keeping birth weight at a certain level is:

$$b = 0.01218(a_1) + 1.01147(a_2) + (-2.81003)(a_3)$$

The correlation coefficient between breeding values and the index (r_{IA}) was calculated to predict the efficiency of the selection index:

$$(r_{IA}) = \frac{\sigma_I}{\sigma_A}$$

$$\sigma_I^2 = b`Pb = b` \begin{bmatrix} 34.4166 & 12.0779 & 0.2070 \\ 12.0779 & 14.6285 & 0.3597 \\ 0.2070 & 0.3597 & 0.3409 \end{bmatrix} \begin{bmatrix} 0.01218 \\ 1.01147 \\ -2.81003 \end{bmatrix}$$

$\sigma_I^2 = 15.9016$ and

$$\sigma_A^{=2} = [3 \quad 2 \quad 1] \begin{bmatrix} 3.49849 & 1.47314 & 0.04211 \\ 1.47314 & 1.16386 & 0.17559 \\ 0.04211 & 0.17559 & 0.05967 \end{bmatrix} \begin{bmatrix} 3 \\ 2 \\ 1 \end{bmatrix} = 54.8342$$

$$\sigma_A = \sqrt{54.8342} = 7.4050118$$

$$(r_{IA}) = \frac{\sigma_I}{\sigma_A} = 0.5385^{**}$$

Aziz (5) observed that the restricted selection index for birth weights, with a concentration on weights in 50 and 100 day old Suffolk and Dorset sheep, does not cause any reduction in the restricted trait. However, Al-Azzawi (3) found that the restricted selection index for birth weights with concentration on 3 and 6-months weights of Awassi lambs did cause a reduction of 0.9504 kg in birth weights , with an efficiency (r_{IA}) of 0.92. More recently, Hermiz (6) constructed a restricted selection index for 18 months weight with a relative importance for 6 and 12 months weights with an efficiency (r_{IA}) of 0.34 (P<0.01).

CONCLUSIONS

In this study, we constructed a restricted selection index from a dataset of Shami kids and the factors impacting kid growth were analyzed. The results showed that all data must be corrected for fixed effects before estimating the variance-covariance matrix. Further, the genetic parameters showed the ability of applying individual selection by using the restricted selection index, as constructed, for increasing 6-month body weights (marketing weight) with restriction on birth weights for all animals, with high efficiency. This novel selection index equation maximizes marketing weight while keeping birth weights at lowest levels, avoiding dystocia.

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