Estimation of Parameters of Growth Curve and Their Heritabilities and Genetic and Phenotypic Correlations in *Watish* Lambs in Sinnar State, Sudan

Rashid bdallah Ahmed[1] and Tagelsir Easa Ali[1]

[1]Faculty of animal Production, University of Sinnar, Sinnar- Sudan.

Corresponding author email: rashid.umbenein@gmail.com

ABSTRACT

This study was carried out in Singa and Um-Benein localities. The first objective of this study was estimating the parameter of growth curve using Brody's non-linear functions. And the second objective was estimating the effect of sex and type of birth on the growth curve parameters of *Watish* lambs. And the third objective was the estimation of heritability of growth curve parameters as well as estimation of genetic and phenotypic correlations among these parameters. A total number of 113 heads (N = 52 male and 61 females) of *Watish* lambs born to 65 ewes. This study was carried out during the breeding years 2021 and 2022 for this study. Each lamb consisted of lamb identification number (ID), dam ID, sire ID, approximate date of birth, sex of lamb, type of birth (single or twin), monthly body weight from day 1 and every 30 days up to 360 days of age. Non-linear (NLIN) procedure of SAS, was used to fit brody's functions and to estimate the growth curve parameters. The A, B, K growth curve parameters which were asymptotic mature weight, proportion of weight gained after birth and weight gain per live weight per day respectively. These parameters were analyzed using model2 cross-classified non-interacting random sire effect and two other fixed effects, namely sex and type of birth and a random residual effect. The overall mean values of growth curve parameters A, B and K were 31.55kg, 0.88 and 0.51×10^{-2}, respectively. Effect of sex on parameter curve of *watish* lambs had a highly significant effect on K parameter ($P\leq0.01$). Heritability for A, B and K parameters was 0.61, 0.00 and 0.12, respectively. These heritabilities were high for A and low for K and non-estimable for B. Estimates of genetic correlation between growth curve parameters A×K and B×K were -0.29 and -0.68, respectively. They considered low for the former parameter and high for the latter. The phenotypic correlations between growth curve parameters A×B and A×K were 0.80 and -0.53, respectively. These correlations were both considered high with one negative value.

Key words: growth curves, sex, type of birth, Brody's function, *Watish* sheep

INTRODUCTION

Sudan has one of the largest livestock populations in Africa, with variations in climatic conditions, vegetation, soil types and animals (Elnagi, 2014). Livestock plays an important role in food production and represents great socio-economic and cultural values in various societies; Animal production is an important sector in Sudan due to the high population, wide distribution and socio-economic impacts (Abdallah, 2019). Livestock is raised in almost all parts of the country; livestock population was estimated at about 109.9 million heads, comprising about 31.8 million cattle, 41 million sheep, 32.2 million goats and 4.9 million camels. Pastoralists efficiently use natural resources, moving herds around the country in response to weather conditions and availability of forage (MARF, 2020).

Watish sheep are found in the area between Sinnar and Elrank and they are considered as the best Desert sheep adapted to clay soil (Devendra and Mc Leroy, 1982). Three colour groups have been recognized namely fawn, red, and white with light spotting (Mc Leroy, 1961). *Watish* are hardy sheep and live under relatively high rainfall conditions between latitudes 10° and 11° N and mainly found along the Blue Nile, south of Wad Medani into the Fung area. They are mainly owned by nomadic and semi-nomadic tribes including Kenana, Rufaa El Hoy and Beni-Meharib. *Watish* dams had the lowest weights at first conception, first parturition and weaning after first parturition, but their weight did not drop during the lactation period as Ashgar and Dubasi ecotypes (Sulieman *et al*., 1990).

Growth is a biological phenomenon that can be interpreted mathematically. It's an economically important trait of farm animals. It is a time (age) dependent. Change is manifested in the weight or size of organ, composition of tissue and/or organ, size of cell and number as well as in live weight (Eisen, 1976). Growth curves have many uses in farm animals. These curves have been used to estimate mature body weight and the increase in live weight in goat and sheep by many research workers (Nasholm and Danell, 1990., Nasholm, 1990., Jenkins and Leymaster, 1993 and Kor *et al.,* 2006).

The Brody's model was the best non-linear function that described the biological growth pattern of male, female, single, twin, and triplet lambs (Ali *et al.*, 2020). In the Sudan no work has been done in specifying growth curve of local breeds using non-liner model. Estimation of the

parameters of growth curve will pave the way to genetic improvement of *Watish* sheep using the pre-mentioned parameters. This study aims to estimate growth curve of *Watish* lambs in Sinnar state, Sudan with the following specific objectives to estimate:

1) The parameters of growth curve of *Watish* lambs using Brody's non-linear function.
2) The effect of lamb sex and type of birth on parameters of growth curve.
3) The heritability of the growth curve parameters, and the genetic and phenotypic correlation among these parameters.

MATERIALS AND METHODS

Study area

This study was carried out in Singa and Um-Benein localities of Sinnar State which is located in the furthest south east corner of the country, occupying the area between latitudes 12.5° and 14° N and longitudes 32.43° and 32.85° E, bordering Gezira state from the North, Blue Nile State from the South, Gedarif State from the East and Ethiopian boarders from the East and White Nile state and South Sudan boarders from the West (Figure 1). Singa city, the capital of Sinnar state which is located about 351 km south of Khartoum. It lies approximately between latitude 12.69°N- 13 46^0N and longitude 33.11^0E- 33.65°E and it is located on the west bank of the Blue Nile

Topography

The climate of Sinnar State varies from poor Savanna in the northern part to rich woodland Savanna in the Southern part of state. Metrological data showed that the average annual rainfall in the study area ranged between 300 to 800 mm with a dry season from November to April**.** The soil of the area resulted from the alluvial action of the Blue Nile, and it is a heavy clay cracking soil of the Vertisol type (Abdalla, 2020).

The state is flat in most of its parts with exception of scattered elevation. The area is characterized by the presence of various soil types, the most important being the southern central clay plain.

The vegetation cover varies in amount and distribution of rains, soil type and elevation above sea level.

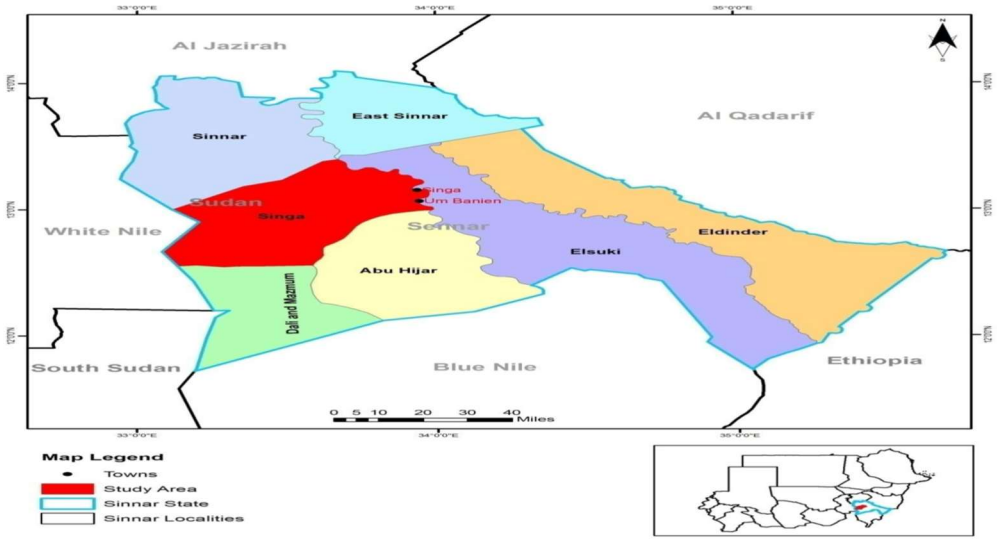

Figure1. The location and localities of Sinnar state, Sudan. Source (ARC, 2017)

Data collected

The data consisted of 113 lambs born from 65 ewes and two rams. The distribution of these lambs according to sex and type of birth subclass is shown in Table 1. The lambs were ear-tagged immediately after birth, then monthly weights were taken from birth to 12 months of age (in days) using a digital scale, with (52) records of male and (61) of female animals.

Table 1. Distribution of number of *Watish* lambs by sex × type of birth

	Male	Female	Total
Single	13	3	16
Twin	39	58	97
Total	52	61	113

Statistical analysis

The following Brody's function (1945) was used to estimate the parameters of growth curve for each animal:

$Y_t = A\ (1\text{-}Be^{-kt}) + \varepsilon_t$

Where:

Y_t = weight (kg) at t^{th} days of age.

A= asymptotic mature weight i.e. weight when age (t) approaches infinity.

B= proportion of mature weight gained after birth.

K= maturing rate (kg gain per kg live weight per day).

E= Napier's base for natural logarithm.

t= age of lamb in days.

ε_t= random residual error term of t^{th} age.

The above-mentioned Brody's function was fitted to weight (kg) – age (days) data of each lamb using nonlinear (NLIN) procedures of the statistical analysis system (SAS, 2000). Stop The estimated growth curve parameters (A, B and K) were analyzed by least squares procedure using model 2 that contained cross-classified non-interacting random sire effect and fixed effects of sex (male and female) and type of birth (single and twin) on *Watish* sheep lambs (Harvey, 1988). Furthermore, heritability, product-moment genetic and phenotypic correlations of growth curve parameters were also computed using Maximum Likelihood Procedure of Harvey Least Square and Maximum Likelihood Computer Program (1988).

RESULTS AND DISCUSSION

Overall means of growth curve parameters

The results of the analysis of variance and least square means for the different parameters of the growth curve are shown in Table (2). The overall means of the asymptotic mature weight (A) of (31.55kg) is heavier than (29.1kg) which was reported by Waheed *et al,* (2011) in Beetal goats and also heavier than (26.033kg) cited by Gautam *et al*, (2018) in Sonadi Sheep using Brody's function. However, the value reported in the current study is lower than (42.75kg) noted by Ali *et al.*, (2020) in Kajli sheep and (37.6kg) which was mentioned by Abegaz *et al*, (2010) in Horro sheep, A point to mention here is that both of these contrasting studies used Brody's function also.

The overall mean of the proportion of weight gained after birth (B) in the current study was 0.88. This result in agreement with those mentioned by Abegaz *et al.* (2010) in Horro sheep (0.88), Gautam *et al*, (2018) in Sonadi Sheep (0.872) and Ali *et al.* (2020) in Kajli sheep (0.891).

Table 2. Analysis of variance for parameters of growth curve of *Watish* lambs

Source variation	Total number	A		B		K	
		LSM	SE	LSM	SE	LSM	SE
sex							
Male	52	33.17	4.3	0.87	0.006	0.0062	0.002
Female	61	30.99	4.4	0.88	0.007	0.0029	0.002
L.S		ns		ns		**	
Type of birth							
Single	16	32.7	4.9	0.87	0.10	0.004	0.002
Twin	97	31.5	4.1	0.88	0.04	0.006	0.001
L.S		ns		ns		ns	
Overall mean	113	31.55	1.04	0.88	0.039	0.0051	0.007

LSM= least square mean, SE= standard error of mean, L.S= level of significance, ns= not significant, **= P≤0.01.

A noteworthy point is that Waheed *et al.* (2011) reported a slightly higher estimate parameter B (0.916) using Brody's function in Beetal goats.

The overall mean of the parameter K obtained in the current study ($0.51 \cdot 10^{-2}$) is higher than the results of Abegaz *et al*, (2010) in Horro sheep, Gautam *et al*. (2018) in Sonadi Sheep, Ali *et al.*, (2020) in Kajli sheep and Waheed *et al.* (2011) in Beetal goat who reported K values of 0.27×10^{2}, 0.16×10^{-2}, $0.39 \cdot 10^{-2}$ and 0.11×10^{-2} kg, respectively. According to Gbangboche, (2007) the Brody's function was the most suitable model for drawing growth curve of male and female growth curve and also appropriate for drawing different age groups together.

Effect of sex

The results in Table 2 show that sex of *watish* lamb had a non-significant effect on both growth curve parameters A and B but it had a highly significant effect (P≤0.01) on parameter K. This result shows that the maturing rate (K) of the males (0.0062) is greater than that of the females (0.0029). The growth curve of the males and females predicted by Brody's function are drawn on

Fig 2. However, these results did not agree with those of Abegaz *et al*. (2010) who used Brody's function on growth curve of Horro sheep and found that the effect of sex on parameters of growth curve were highly significant (P≤0.01) on parameters A and B but it was not significant on K. Also Ali *et al*. (2018) using Brody's function on growth curve of Arabian Tahr found sex of kid had a significant effect (P≤0.05) on parameter A and B but not significant on K.

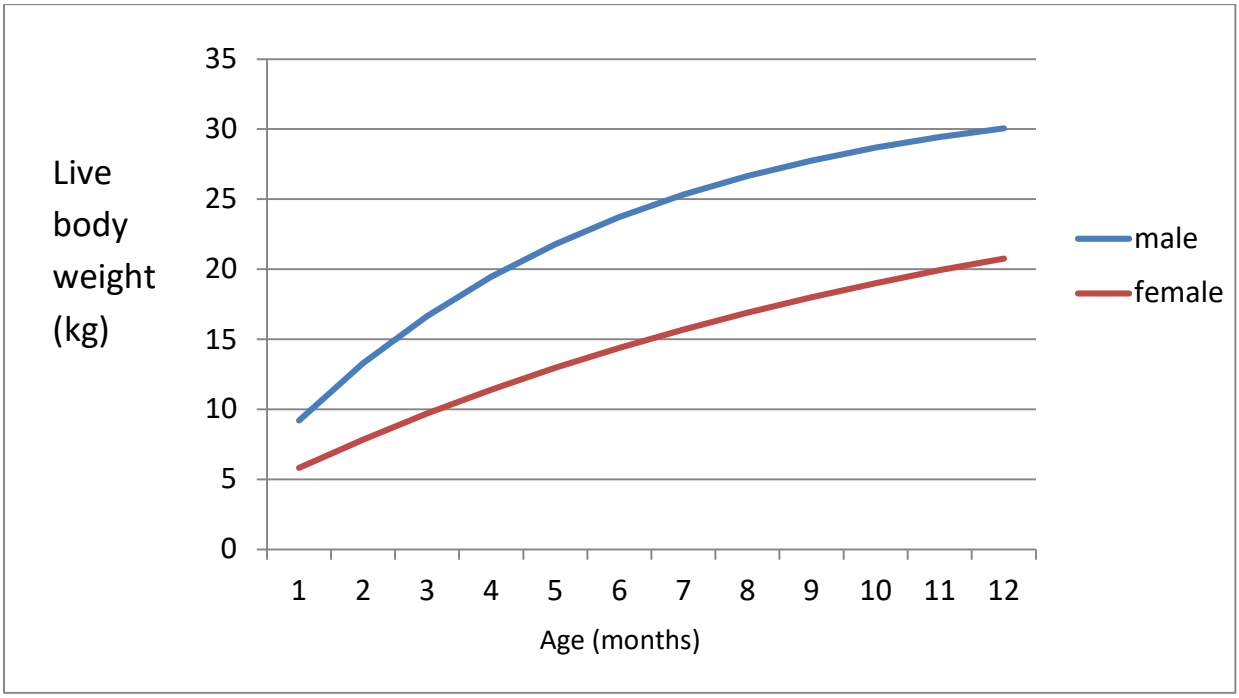

Figure 2. Effect of sex on growth curve of *Watish* lambs from first to twelve months of age

Effect of type of birth

The results in Table 2 show that the type of birth of *Watish* sheep lambs had a non-significant effect on all parameters A, B and K. The result of this study agree with the finding of Abegaz *et al*. (2010) who reported that type of birth had a non-significant effect on parameter A and Kin Horro sheep using Brody's function. In the current study, type of birth of *Watish* lambs had a non-significant effect on parameters B. This result disagree with the finding reported by Abegaz *et al*. (2010) who mentioned that type of birth had a significant effect on parameter B in Horro sheep.

Heritability

Heritability in a broad sense (h^2) is defined as the proportion of phenotypic variance that is due to genetic diversity. Correlations quantify the levels of linkage and pleiotropy existing among genetic loci determining the performances of two different traits (Mekuriaw and Haile, 2014). The heritability of parameters A and K were 0.61 and 0.12 respectively (Table 3). This heritability was high for A and low for K. The heritability estimate of asymptotic mature weight (0.61) was higher than the sheep values of 0.29, 0.29 and 39 which were reported by Abegaz *et al.* (2010) in Horro sheep, Waheed *et al.* (2011) in Beetal goats and Ghavi, (2015) in Guilan sheep, respectively.

The heritability of estimate of the rate of growth parameter (K) was 0.12 in the current study. This value was almost similar to that reported by Waheed, *et al*. (2011) who estimated a heritability of predicted rate of growth (k) of 0.108 applying Brody's function on weight of lambs. The heritability of parameter estimate of K (0.12) obtained in the current study was higher than the value of 0.039 reported by Ghavi, (2015) in Guilan sheep but it was lower than the value of 0.14 which was reported by Abegaz *et al*. (2010) in Horro sheep.

It is noticeable in this study that the heritability of the parameter of proportion of mature weight attained after birth (B) was not estimable and this may be due to diminishing or little genetic variability coupled with small number of rams.

Genetic correlation

The genetic correlation between the asymptotic mature weight × kg gain per kg live weight per day (A × K) and proportion of weight gained after birth × kg gain per kg live weight per day (B × K) was -0.29 and -0.68, respectively (Table 3). These genetic correlations were both negative but the former was low and the latter was high correlation.

The genetic correlation between the parameter A×K in the current study was higher than the estimate of Abegaz *et al.* (2010**)** in Horro sheep (-0.07). Bathaei and Leroy (1998) working on Mehraban Iranian fat-tailed sheep, estimated genetic correlation among growth curve parameters of 0.03, -0.07 and -0.12 for A×B, A×K and B×K, respectively. On the other hand, Mavrogenis and Constantinou, (1990) reported higher estimates of these correlations in values of 0.25, −0.40 and 0.55, respectively.

Table 3. Heritabilities and genetic and phenotypic correlations of some growth curve parameter using Brody's function[1]

Source	A	B	K
A	0.61	0.00	-0.29
B	0.80	0.00	-0.68
K	-0.53	0.00	0.12

[1]Heritability on the diagonal, genetic correlations are above the diagonal and phenotypic correlations are below the diagonal, parameter A=asymptotic mature weight, B= proportion of weight gained after birth, K= kg gain per kg live weight per day. Heritability and genetic and phenotypic correlations pertaining to parameter B were not estimable.

Phenotypic correlation

The phenotypic correlation between A×B and A×K were 0.80 and -0.53, respectively. These correlations are both considered high with one negative value (Table3). Specifically, the former phenotypic correlation (0.8) between A×B was higher than that reported by Abegaz *et al*. (2010) of Horro sheep (0.04) and also higher than that (0.23) of Mavrogenis and Constantinou, (1990) using Brody's function on growth curve in Chios sheep.

The phenotypic correlation between A × K (-0.53) was higher than that reported by Abegaz *et al*. (2010) of Horro sheep (-0.36) and in absolute term it was higher than that (0.33) reported by Mavrogenis and Constantinou, (1990) in Horro sheep.

CONCLUSION AND RECOMMENDATIONS

The parameter of growth curve of *W*atish lambs A, B and K were 31.55kg, 0.88 and 0.51×10^{-2}, respectively. These parameters were estimated using Brody's function. Males had significantly higher K values (0.0062) than females (0.0029). The type of birth had non-significant effect on all the parameters of growth curve. The heritability of parameter A was high (0.61) while that of K was low (0.12). The high heritability of parameter A could be a useful tool in developing selection indices for improvement purposes. The genetic correlation between A × K and B × K were -0.29 and -0.68. The phenotypic correlation between A × B and A × Kwere 0.80 and -0.53. The Brody function was an easy tool in describing growth curve of small ruminants.

Based on findings of this study the following recommendations are made:

1- Comparative study contrasting Brody's function against other linear and non-linear function on parameters of *Watish* growth curve using more data set.
2- A study comparing growth curve of different breeds of sheep using the model with the best fit as achieved above using more data set.

REFERENCES

Abdalla, S. M. A. (2020). Relationship between body measurements, live body weight and parity number in *Watish* females in Sinnar state Sudan. M.Sc, thesis, University of Sinnar.

Abdallah. R. A. (2019). Phenotypic characterization, reproductive traits and lactation performance of Kenana caws at um-benein livestock research station, Sinnar State, Sudan. M.Sc. thesis university of Sinnar. Sudan.

Abegaz, S., Van WYk, J. B. and Olivier, J. J. (2010). Estimation of genetic and phenotypic parameters of growth curve and their relationship with early growth and productivity in Horro sheep. *Archiv Tierzucht 53, 85-94*.

Ali, A., Javed, K., Zahoor, I. and Anjum, K. M. (2020). Determination of the best non-linear function to describe the growth of Kajli sheep.*South AfricanJournal of Animal Science 2020, 50* (*No. 3*) page no 457.

Ali, T. E., Idris, A. M. K., Arabi, H. A. and Arras, P. (2018). Estimation of parameter of growth curve of Arabian Tahr (using Brody's function). *Sudanese Journal of Agricultural sciences* 4, 11-22.

ARC. (2017). Agricultural Research Corporation. Archive of land evaluation department. Digital soil mapping report.

Bathaei, S. S. and Leroy P. L. (1998). Genetic and phenotypic aspects of the growth curve characteristics in Mehraban Iranian fat-tailed sheep. *Small Ruminanr Research.29, 261-9.*

Brody's. (1945). Bioenergetics and Growth. Reinhold Publishing Corp, NY, USA.

Devendra, C. and Mcleroy, G. B. (1982). Goat and sheep production in the tropics. Common wealth Agricltural, Bureau, UK.

Eisen, E. J. (1976). Result of growth curve analysis in mice and rats. *Journal of Animal Science 42, 1008-1023.*

Elnagi. A. H. (2014). Selected morphological, productive and reproductive characteristics of kenana cattle Breed, Sinnar State, Sudan. M.Sc. thesis (2014), University of Gezira. Sudan. England.

Gautam, L., Kumar, V., Waiz, H. and Nagda, R. (2018). Estimation of Growth Curve Parameters Using Non-Linear Growth Curve Models in Sonadi Sheep. *International Journal of Livestock Research,* 8(9), 104-113. doi: 10.5455/ijlr.20180131044656.

Gbangboche, A. B, Glele, K. R., Salifou, S., Albuquerque, L. G. and Leroy, P. L. (2007). Comparison of non-linear growth models to describe the growth curve in West African Dwarf sheep. Article *in* animal. July 2008. https://www.researchgate.net/ publication/ 221972496

Ghavi, H. Z. (2015). Estimation of genetic relationships between growth curve parameters in Guilan sheep *Journal of Animal Science and Technology* (2015) 57:19. DOI 10.1186/s40781-015-0052-6.

Harvey, W. R. (1988). Mixed Model Least squares and Maximum Likelihood Computer Program PC-1 Version.Ohio State University (mimeo).

Jenkins, T. G. and Leymaster K. A. (1993). Estimating of maturing rates and masses at maturity for body components of sheep. *Journal of Animal Science 71, 2952-2957.*

Kor, A., Baspinar, E., Karaca, S. and Keskin, S. (2006). The determination of growth in Akkeci (White goat) female kids by various growth models. *Czech Journal of Animal Science 51, 110-116.*

MARF. (2020). Ministry of Animal Resources and Fishiers. National estimation of livestock in Sudan. Department of Statistics and information. Khartoum.

Mavrogenis, A. P. and Constantinou, A. (1990). Relationships between pre-weaning growth, post-weaning growth and mature body size in Chios sheep. Animal Production 50, 271-5.

Mc Leroy, G. B. (1961). The sheep of the Sudan. 2. Eco-types and tribal breeds. *Sudan Journal of Veterinary Science and Animal Husbandry*. 2:101-151.

Mekuriaw, S. and Haile, A. (2014). Genetic parameter estimates for growth andreproductive trait of sheep for genetic improvement and designing breedingprogram in Ethiopia: a review. *Open Access Library Journal*, e589. Retrieved May19, 2015, from http://dx.doi.org/10.4236/oalib.1100589.

Nasholm, A. (1990). Mature weight of ewe as a trait in sheep breeding. In: Proc. 4th World Congress on Genetics Applied to Livestock Production, Genetics and Breeding Fiber, Fur and Meat Quality, Edinburgh, 154, 88-91.

Nasholm, A. and Danell, O. (1990). Growth and mature weight of Swedish Fine wool Landrace ewes. I. Growth curves and estimation of individual mature weight. Acta Agricultural Scan 40, 71-81.

SAS. (2000). Institue Incorporation. What‘s New in SAS® Software for Release 8.1,: SAS Institute Incorporation.

Sulieman, A. H., Sayers, A. R. and Wilson, R.T. (1990). Evaluation of Shugar, Dubasi and Watish sub ecotypes of Sudan desert sheep at El Huda National Sheep Research station, Gezira Province, Sudan. ILCA Research report, No. 18, Addis Ababa Ethiopia, P: 30.

Waheed, A., Khan, M. S., Ali, S. and Sarwar, M. (2011). Estimation of growth curve parameters in Beetal goats.Archive *Animal Breed*. 54(3), 287-296. https://doi.org/10.5194/aab-54-287-2011.

الملخص

تقدير معالم النمو المكافئ الوراثي ومعامل الارتباط الوراثي والظاهري لهذه المعالم لحملان ضأن الوتيش بولاية سنار ـ السودان

تم تنفيذ هذا البرنامج البحثي بمحلية سنجة وأم بنين. كان الهدف الأول لهذه الدراسة هو تقدير معالم النمو باستخدام دالة برودي غير الخطية والهدف الثاني هو تقدير تأثير جنس المولود ونوع ولادته (فرد أو توأم) على منحنى نموه. أما الهدف الثالث فهو تقدير المكافئ ومعامل الارتباط الوراثي والظاهري لمعالم منحنى النمو. العدد الكلي للحيوانات هو 113 رأس من حملان الوتيش مقسمة لعدد 52 ذكر و61 أنثى مولوده من 65 جعدة. وقد تم تنفيذ هذا البحث في عامي 2021 و2022م. وكان كل سجل من سجلات الحملان يحوي على رقم الحمل، رقم الأم، رقم الأب، التاريخ التقريبي لميلاد الحمل، جنس الحمل، نوع ولادته (فرد أو توأم) ووزنه عند الميلاد وبعد ذلك يوزن كل 30 يوم لغاية 360 يوم. لقد تم استخدام الدالة غير الخطية بواسطة برنامج SAS لحساب معالم نمو الحملان و تشتمل هذه المعالم على A (وزن الجسم الناضج عندما لا نهاية)، B (نسبة وزن الجسم المكتسب بعد الميلاد)، K (وزن الجسم المكتسب/ وزن الجسم الكلي/ يوم). تمت إضافة هذه المعالم إلى سجل المواليد وبعد ذلك تم التحليل الإحصائي لهذه المعالم باستخدام المعادلة الثانية في برنامج هارفي والتي تشتمل على تأثير أب المولود (عشوائي) وتأثير كل من جنس المولود (ثابت) ونوع ولادته (ثابت) بالإضافة إلى الخطأ العشوائي. كان المتوسط العام لكل من A، B وK هو 31.55kg و 0.88 و$0.51x10^{-2}$ على التوالي. كان تأثير جنس المولود معنوياً على المعلم K لدرجة عالية جداً وكان المكافئ الوراثي للمعالم A، B وK هو 0.61 و 0.00 و 0.12 على التوالي. كما كان تقدير معامل الارتباط الوراثي فيما بين معالم منحنى النمو هو 0.29- و 0.68- لكلٍ من AxK وKxB على التوالي علماً بان كلاهما كان سلبيا. و يعتبر معامل الارتباط الأسبق أقل من نظيره الأخير أما بالنسبة لمعامل الارتباط الظاهري فانه 0.80 و0.53 لكل من AxB و AxK على التوالي و يعتبر أن هذان الارتباطان عاليان مع كونهما إيجابيين.