Effects of some factors on growth of lambs and the determination of growth curve models

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Received: 15-08-2017 Accepted: 09-11-2017 DOI: 10.18805/ijar.B-815

ABSTRACT
The aims were to identify the body weight of the several age groups in Norduz lambs and its correlations between these traits were to determine the best non-linear growth curve models for the growth performance of the Norduz sheep breed. A total of 91 male and female of Norduz lambs were evaluated under extensive system conditions. The least square means for weights at birth and at 15, 30, 45, 60, 75, 90, 105, 120, 135, 150, 165, 180, 195 and 210 days of age periods were 4.51±0.56, 9.28±0.25, 11.14±0.29, 14.99±0.37, 18.21±0.43, 22.54±0.54, 22.33±0.25, 23.59±0.54, 25.58±0.55, 28.07±0.58, 29.45±0.60, 29.98±0.84, 32.44±0.61, 32.03±0.59 and 31.45±0.57 kg, respectively. There were differences in favor of lambs of four-year old dams at 15 days of age and also lambs born single at 90 days of age for the body weight. The effect of weight of dam at birth, 30, 45, 60 days of age was significant (P< 0.05-P<0.01) and the birth weight in lambs importantly effected the weights at 15, 30, and 45 days of age.

All correlations between the body weights of several age periods were significant as statistical (P<0.01). As for the growth models, distinguished models were compared using the coefficient of determination and mean square error for both sexes. As a result, we concluded that von Bertalanffy model were the best model in comparison with the other models for biological growth curves in Norduz male and female lambs.

Key words: Body weights, Growth, Lamb, Norduz, Sheep.

INTRODUCTION
Sheep breeding is an important socio-economic activity for small producers of Turkey. In spite of its importance, small ruminant production in Turkey has not improved and it has usually a traditional production structure for markets, and the most of sheep genotypes consist of native breeds, which are low for quality and quantity of carcass compared to intensified sheep genotypes. In Turkey, sheep production is usually managed in village and migratory systems. These systems are both extensive and the feeding is mainly based on natural vegetation with a little supplementary feeding. There are a few cases for intensive sheep production in Turkey. In the intensive systems, sheep are usually managed in barns and fed commercially concentrate mixtures (Ertürk ve Özen, 1996; Ertugrul ve Cengiz, 1997).

In order to provide an effective sheep production increase, it is important to develop the adequate improvement and selection methods for the current sheep breeds raised in Turkey. For an effective animal improvement, growth curve models can provide a contribution to estimate the adequate parameters for growth pattern and thus, these parameters estimated can be used in animal improvement and selection process (sireli, 2002; Bilgi ve Esenboga, 2003; Kor ve ark., 2006; Koncagül et al., 2013; Lupi et al., 2015; Makovický et al., 2017).

In this study we aimed to find the growth characteristics from birth of time to the age of 210 days and to detect the correlations among body weights at that age. Also the aim of this study was to determine the best non-linear growth curve models for the growth performance of the Norduz sheep breed.

MATERIALS AND METHODS
The experiment was conducted at the research farm of the Yuzuncu Yil University, Van, Turkey (38°29′39″N, 43°22′48″W). A total of 91 male and female lambs of Norduz genotypes were evaluated under extensive system conditions. Within the 12 hours after the birth, lambs were weighted with a 10-gr sensitive bascule and each of them was tagged with a plastic ear number. Also, they were recorded for the age of dam, the type of birth and the sex. The body weight of each lamb was measured biweekly with the use of a 100-gr sensitive scale until an average 210 days of age after the birth.

The lambs were accustomed to animal feed after two weeks after birth and they lived with their dams in the barn. During this period, they were provided with fresh water.
and ground clover or dried grass and barley. After their dams were released to the pasture, the lambs were separated from their mothers in the daytime and in the evenings there were again brought together with their mothers. The lambs weaned and separated from their mothers, when they were three months old on average, were released to the pasture in a separate flock.

**Statistical analysis:** Recorded data were statistically analyzed using the least-squares method (SAS, 2010). The systematic environment factors were the age of dam at lambing, sex, and litter size, the body weight of dam in lambing and the age of lamb. The following model was used for statistical calculations:

\[ Y_{ijkl} = \mu + a_i + b_j + c_k + b_l(x_{ijkl} - \bar{x}) + \epsilon_{ijkl} \]

- \( Y_{ijkl} \) = measured trait
- \( \mu \) = overall mean
- \( a_i \) = effect of \( i^{th} \) age of dam
- \( b_j \) = effect of the \( j^{th} \) litter size
- \( c_k \) = effect of \( k^{th} \) sex
- \( b_l \) = regression
- \( \epsilon_{ijkl} \) = residual error

The means and standard errors for live weights at birth, at 15, 30, 45, 60 days of age and at weaning as depending upon the particular effects, are as follows:

\[ Y_{ijkl} \text{, t} \text{. indicates the body weight (kg) observed during monthly age, parameter a indicates the body weight of the each animal- a parameter estimated for all models, which is the asymptotic limit of the weight when time tends to infinity. Parameter b indicates proportion of the body weight to the maturation body. Parameter k represents the relative growth rate (rate of exponential growth). High values for this parameter shows animals with precocious maturity, whereas low values for parameter indicate a delayed maturity (Akbas, 1995; Lupi et al., 2015).} \]

Brody: \( Y = A(1 - Be^{kt}) \)

Gompertz: \( Y = Aexp(-Be^{kt}) \)

Logistic: \( Y = A(1 + Be^{kt}) \)

von Bertalanffy: \( Y = A(1 - Be^{kt})^2 \)

**RESULTS AND DISCUSSION**

The means and standard errors for live weights at birth, at 15, 30, 45, 60 days of age in Norduz lambs were presented in Table 1.

The means and standard errors for live weights at 75, 90, 105, 120 days of age in Norduz lambs were presented in Table 2.

The means and standard errors for live weights at 135, 150, 165, 180, 195, 210 days of age in Norduz lambs were presented in Table 3.

Values of Table 1, 2 and 3 for BWs clearly shows that effect of sexing in Norduz lambs was statistically significant for weights from the 105th and to 210th days on body weight except for 135th days (P<0.05-P<0.01). Similarly, the single lambs were heavier than the twin lambs throughout all the studied periods for body weights. The mean weight of the single lambs until the 105th day, was higher than the twin lambs (P<0.01). However, the differences between single and twin lambs for body weight were not significant between 120th-210th days. In addition, we founded

| Table 1: Means, standard errors for live weights at birth, at 15, 30, 45, 60 days of age and at weaning as depending upon the particular effects. |
|-----------------|--------|--------|--------|--------|--------|--------|
|                 | n     | BW 0   | BW 15  | BW 30  | BW 45  | BW 60  |
| Overall         | 91    | 4.51±0.56 | 9.16±0.14 | 10.99±0.15 | 14.87±0.22 | 18.10±0.29 |
| Age of dam      |       |        |        |        |        |        |
| 3               | 20    | 4.10±0.15 | 8.55±0.37 | 10.52±0.41 | 14.29±0.60 | 17.34±0.74 |
| 4               | 32    | 4.33±0.11 | 8.94±0.27 | 10.61±0.30 | 14.26±0.44 | 17.62±0.55 |
| 5               | 33    | 4.23±0.10 | 8.68±0.25 | 10.41±0.27 | 14.09±0.40 | 17.32±0.53 |
| 6               | 6     | 4.18±0.23 | 7.81±0.56 | 9.25±0.61 | 12.73±0.89 | 15.47±1.08 |
| Gender          |       |        |        |        |        |        |
| Male            | 48    | 4.38±0.10 | 8.76±0.25 | 10.41±0.28 | 14.19±0.40 | 17.45±0.50 |
| Female          | 43    | 4.04±0.10 | 8.22±0.27 | 9.98±0.30 | 13.49±0.44 | 16.43±0.55 |
| Birth type      |       |        |        |        |        |        |
| Single          | 70    | 4.72±0.08 | 9.36±0.20 | 11.22±0.22 | 15.22±0.33 | 18.69±0.42 |
| Twin            | 21    | 3.70±0.14 | 7.63±0.40 | 9.18±0.44 | 12.45±0.64 | 15.19±0.78 |
| Regression      |       |        |        |        |        |        |
| The weight of dam (kg) | 0.02±0.01 | 0.04±0.02 | 0.08±0.03 | 0.13±0.04 | 0.12±0.05 |
| Weight at birth (kg) | 0.84±0.26 | 0.75±0.29 | 0.85±0.42 | 0.61±0.53 |
| Age of lamb (days) | 0.17±0.02 | 0.20±0.02 | 0.23±0.03 | 0.24±0.03 |

*: P<0.05, **:P<0.01, a,b: means in the same column with different superscripts differ significantly (P < 0.05).
Table 2: Means, standard errors for live weight at 75, 90, 105, 120 days of age and at weaning as depending upon the particular effects.

<table>
<thead>
<tr>
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<th>N</th>
<th>BW 75</th>
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<th>BW 105</th>
<th>BW 120</th>
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<tr>
<td>Genel</td>
<td>72</td>
<td>22.37±0.38</td>
<td>22.09±0.41</td>
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<td>Age of dam</td>
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<td>3</td>
<td>20</td>
<td>21.77±0.92</td>
<td>21.56±1.00</td>
<td>22.52±0.97</td>
<td>24.47±1.02</td>
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<td>4</td>
<td>23</td>
<td>21.90±0.74</td>
<td>22.29±0.81</td>
<td>23.39±0.76</td>
<td>25.60±0.81</td>
</tr>
<tr>
<td>5</td>
<td>23</td>
<td>21.91±0.75</td>
<td>21.09±0.82</td>
<td>23.05±0.77</td>
<td>25.40±0.81</td>
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<tr>
<td>6</td>
<td>6</td>
<td>20.63±1.35</td>
<td>20.16±1.48</td>
<td>21.13±1.38</td>
<td>23.32±1.45</td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Male</td>
<td>30</td>
<td>22.28±0.67</td>
<td>21.96±0.73</td>
<td>23.38±0.69</td>
<td>25.60±0.73</td>
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<tr>
<td>Female</td>
<td>42</td>
<td>20.82±0.68</td>
<td>20.59±0.73</td>
<td>21.66±0.69</td>
<td>23.80±0.73</td>
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<td>Birth type</td>
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<td>Single</td>
<td>**</td>
<td>23.20±0.57</td>
<td>23.90±0.63</td>
<td>32.23±0.47</td>
<td>31.85±0.47</td>
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<tr>
<td>Twin</td>
<td>20</td>
<td>19.90±0.96</td>
<td>19.65±1.04</td>
<td>21.04±0.98</td>
<td>23.59±1.04</td>
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<td>Regression</td>
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</tr>
<tr>
<td>The weight of dam (kg)</td>
<td>0.25±0.04</td>
<td>0.20±0.05</td>
<td>0.24±0.04</td>
<td>0.25±0.05</td>
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<tr>
<td>Weight at birth (kg)</td>
<td>0.64±0.70</td>
<td>0.53±0.77</td>
<td>0.69±0.71</td>
<td>0.73±0.76</td>
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<tr>
<td>Age of lamb (days)</td>
<td>0.29±0.05</td>
<td>0.27±0.05</td>
<td>0.28±0.06</td>
<td>0.26±0.05</td>
<td>0.25±0.05</td>
</tr>
</tbody>
</table>

*: P<0.05, **: P<0.01.

Table 3: Means, standard errors for live weight at 135, 150, 165, 180, 195, 210 days of age and at weaning as depending upon the particular effects.

<table>
<thead>
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<th>N</th>
<th>BW 135</th>
<th>BW 150</th>
<th>BW 165</th>
<th>BW 180</th>
<th>BW 195</th>
<th>BW 210</th>
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<tbody>
<tr>
<td>Overall</td>
<td>67</td>
<td>27.85±0.41</td>
<td>29.19±0.47</td>
<td>29.82±0.50</td>
<td>32.23±0.47</td>
<td>31.85±0.47</td>
<td>31.29±0.46</td>
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<tr>
<td>Age of dam</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>18</td>
<td>26.78±1.00</td>
<td>28.32±1.14</td>
<td>29.87±1.24</td>
<td>31.44±1.14</td>
<td>31.22±1.15</td>
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</tr>
<tr>
<td>4</td>
<td>21</td>
<td>28.48±0.80</td>
<td>30.08±0.89</td>
<td>30.27±0.98</td>
<td>33.79±0.94</td>
<td>32.23±0.91</td>
<td>31.87±0.93</td>
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<tr>
<td>5</td>
<td>22</td>
<td>27.72±0.80</td>
<td>29.19±0.91</td>
<td>29.86±0.97</td>
<td>32.01±0.90</td>
<td>31.76±0.91</td>
<td>31.76±0.89</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
<td>26.33±1.41</td>
<td>28.17±1.60</td>
<td>29.26±1.75</td>
<td>31.69±1.61</td>
<td>31.44±1.63</td>
<td>30.80±1.58</td>
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<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>*</td>
<td>28.25±0.71</td>
<td>30.05±0.81</td>
<td>31.42±0.88</td>
<td>34.24±0.83</td>
<td>33.09±0.82</td>
<td>32.76±0.81</td>
</tr>
<tr>
<td>Female</td>
<td>**</td>
<td>26.40±0.71</td>
<td>27.83±0.80</td>
<td>28.21±0.86</td>
<td>30.21±0.80</td>
<td>30.24±0.81</td>
<td>29.76±0.79</td>
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<tr>
<td>Birth type</td>
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<tr>
<td>Single</td>
<td>47</td>
<td>28.37±0.62</td>
<td>29.50±0.70</td>
<td>30.29±0.77</td>
<td>32.87±0.71</td>
<td>32.62±0.72</td>
<td>31.69±0.69</td>
</tr>
<tr>
<td>Twin</td>
<td>20</td>
<td>26.28±1.02</td>
<td>28.38±1.16</td>
<td>29.34±1.25</td>
<td>31.60±1.17</td>
<td>30.70±1.16</td>
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<td>Regression</td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<tr>
<td>The weight of dam (kg)</td>
<td>0.11±0.08</td>
<td>0.14±0.09</td>
<td>0.09±0.10</td>
<td>0.09±0.09</td>
<td>0.14±0.09</td>
<td>0.09±0.09</td>
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<tr>
<td>Weight of lamb (kg)</td>
<td>0.79±0.74</td>
<td>1.00±0.83</td>
<td>0.94±0.91</td>
<td>0.99±0.84</td>
<td>0.95±0.85</td>
<td>1.28±0.83</td>
<td></td>
</tr>
<tr>
<td>Age. lamb (days)</td>
<td>0.29±0.05</td>
<td>0.27±0.05</td>
<td>0.28±0.06</td>
<td>0.24±0.05</td>
<td>0.26±0.05</td>
<td>0.25±0.05</td>
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</tr>
</tbody>
</table>

that the weight of dam at birth affected the weights at 30, 45 and 60 day of age (Table 1) (P<0.05-P<0.01). However, it was not significant for body weights in the other age periods (P>0.05). Just the linear effect of the birth weight on the BW 15 (P<0.01), BW 30 (P<0.01) and BW 45 (P<0.05) were significant statistically. At the same time, the age of lamb affected the body weights for all age periods. Additionally, it was found that the correlations among body weights for the different age periods in Norduz lambs were positive and statistically very important (P<0.01). Fig.1 and Fig. 2 shows that results for all the growth models investigated were very close to each other. At the same time, regardless of the sex factor, the von Bertalanffy became the most compliant model with determination coefficients of 99.8 % and 99.87 % and with error squares means of 1.248 and 0.8372, respectively. In male and female Norduz lambs, the von Bertalanffy was the most compliant model with 99.86 % of coefficient of determination and with 0.9667 error squares means. In the meantime, the Brody model having the smallest error squares means value was too close to the von Bertalanffy model in terms of coefficient...
of determination. Parameter a indicating the maturation body weight was highest in Brody model and lowest in logistic model in all situations. Parameter k indicating the relative growth rate was lowest in Brody model, whereas it was the highest in logistics model. Growth curves with von Bertalanffy and Brody models are shown in the Fig.1 and Fig.2. In fig 1 and fig 2, it was observed that the rapid growth in both sexes was highest between the 0-90 days of age and there was a linear increase during that period.

In agreement with several studies (Ekiz and Altinel, 2006; Karakus, 2007; Ürüsan and Emsen, 2010), the birth weight in Norduz lambs was 4.51 kg. The differences between male and female for birth weight were 4.38 kg and 4.04 kg, respectively (P<0.01). Especially, effect of sexing in Norduz lambs was statistically significant for weights from the 105th and to 210th days on body weight (P<0.05-P<0.01). Similarly, the single lambs were heavier than the twin lambs throughout all the studied periods for body weights. The mean weight of the single lambs until the 105th day was higher than the twin lambs (P<0.01). However, the differences between single and twin lambs of body weight were not significant between among 20th-210th days. In the present study, the findings for lamb’s sex and birth type were in agreement with several studies (Saghi et al., 2007; Ozder et al., 2009; Koncagül et al., 2013; Aktas ve Dogan, 2014; Lalit et al., 2016).

There were some studies indicating that the age of the dam has significant effects on both the birth weights of the lambs and their weights at different age periods (Dangi and Poonia, 2006; Sezenler et al., 2009; Ceyhan et al., 2010; Momani et al., 2010). However, Ekiz and Altinel (2006) and Ünal et al. (2008) reported that the effect of the dam age was not significant for growth performance of the lambs. In the current study we detected that the lambs of the 4-year-old dams had a higher growth performance, while the lambs of the 6-year-old mothers had a lower rate of performance. The differences between lambs of the 4-year-old mothers and the lambs of the 6-year-old mothers were statistically significant (P<0.05). Similarly, the weight of dam at birth affected the weights at 30, 45 and 60 day of age in Norduz lambs (P<0.05-P<0.01). However, it was not significant for body weights in the other age periods (P>0.05). Just the linear effect of the birth weight on the BW 15 (P<0.01), BW 30 (P<0.01) and BW 45 (P<0.05) were statistically significant. At the same time, the age of lamb affected the body weights for all age periods.

In the current study, BWs in Norduz lambs at day 120 which had average of 25.34 were lower those reported by Koyuncu et al. (2002), where BWs in F1 and F2 crossing lambs of Lincoln, Dorset Down, Hampshire Down, Border
Leicester and Black-headed German rams with Merinos sheep at day 120 were at 33.12-37.52 kg. However, it is higher than those reported by Isik (2010), which had an average weight of 15.93 for Bafram lambs (Isik, 2010). Similarly, the average body weights of the Norduz lambs at day 150 and day 180 (29.19 kg and 32.23 kg) was higher than those reported by Isik (2010) for Bafram lambs. However, the BW of Norduz lambs at day 210 (31.29 kg) is lower than those reported by Colakoglu and Özbekay (1999) for Malya and Akkaraman (37.96 and 41.60 kg).

At all age periods studied (birth, 15th, 30th, 45th, 60th, 75th, 90th, 105th, 120th, 135th, 150th, 165th, 180th, 195th, 210th days), the phenotypic correlations between the body weights were positive and significant statistically (P<0.01). Additionally, we found that the correlations between birth weight and the body weights at other age periods were changing between 0.31-0.52. The highest correlation was between the birth weight and BW at day 15 (0.52), whereas the lowest is between the birth weight and BW at day 165 (0.31). This finding was in agreement with values reported for Dorper and Mehraman lambs (Gamasaei et al., 2010).

As for the growth models, we attained the similar results related to coefficient of determination in models of growth curves of Norduz male and female lambs. We detected that von Bertalanffy model had better compliance from the other models investigated, because it had higher determination coefficient in Norduz male and female lambs. Similarly, Simanca et al (2016) also reported that von Bertalanffy model was the best model for Santa InesxCreole sheep. By contrast Daskiran et al (2010) stated that there was a difference between the males and females in terms of growth rate, but no difference in terms of type of birth. In that study, the best model was Logistic model in comparison with the other models. Nonetheless, Kum et al (2010) reported that the most suitable model for growth in Norduz lambs was Gompertz model in the determination of the best nonlinear growth model during the period from birth up to 180th day. Emsen and Köycegiz (2004) showed that the most suitable model for Awassi and Morkaraman female lambs were Gompertz and Brody models during 11-month period. In another study, it was observed that the best nonlinear growth model for Morkaraman lambs until 360th day was Gompertz model, whereas it was Bertalanffy model for Awassi lambs (Topal et al., 2004). Using 15 different model, Akbaş et al (1999) observed that the body weight changes in Kivircik and Daglıç male lambs until 420th day. They founded that the most suitable model is Brody model and the second is Bertalanffy model within five models. In that study, the least suitable model was Logistic model.

In the current study, very close results were attained in terms of coefficient of determination by the growth curves models. In terms of error means square, the lowest models were Brody and Bertalanffy models. However, the von Bertalanffy model had a higher coefficient of determination, showing that this was more compliant. But, there were studies stating that the Brody model is more compliant with sheep growth curves in literature. That the Brody model is one of the most compliant models with the data used in this study in terms of error squares means, is a sign which plays a supporting role for this finding.

REFERENCES


