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AN ANALYSIS OF THE FACTORS AFFECTING BIRTH WEIGHT AND ACTUAL MILK YIELD IN SWEDISH RED CATTLE USING REGRESSION TREE ANALYSIS

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ABSTRACT

Performance records (birth weight and actual milk yield) on 206 Swedish Red cattle maintained at private organic diary cattle enterprise in Kelkit district of Gümüşhane province, in Turkey, were analyzed through regression tree method to determine the effects of some factors affecting birth weight and actual milk yield. The birth weight of calves averaged as 41.034±4.218 kg. Out of total calves born, twin born calves were 2.9 %. Single born calves were heavier (41.185±3.840 kg) than twin born (36.000±10.545 kg). The results revealed that the most significant variable affecting birth weight was birth type, followed by birth season, sex and body condition score (BCS2) of the dam during birth. Lactation period and peak milk yield were important variables affecting the actual milk yield in the dairy herd under investigation.

Key Words: Swidish Red cattle, birth weight, milk yield, regression tree

INTRODUCTION

The major objective of dairy cattle enterprises is to increase milk yield and obtain one calf in a year with regular intervals. Like other quantitative traits, milk yield is under the influence of environmental effects besides genotype. For any genetic improvement programme of farm animals, knowledge of genetic parameters is very important. For estimation of genetic parameters it is necessary to estimate the magnitude of various environmental factors influencing the traits under investigation (Javed *et al.*, 2007; Kuthu *et al.*, 2007). Therefore, for genetic improvement of dairy animals to increase milk yield, the influence of different factors affecting milk yield must be precisely determined. The effects of these two factors (environment and genotype) can be classified either with linear and non-linear models or with regression tree analysis.

Least squares regression analysis is generally used to determine the functional relationship between a dependent variable and one or more independent variables and, based on this functional correlation, to analyses the effects of independent variables on the dependent variable. In the least squares method, the dependent variable should fit the normal distribution. If a dependent variable is a nominal scale variable, then logistic regression analysis can be applied. The regression tree method is a nonparametric alternative to the least squares method and logistic regression methods, and does not contain the assumptions required for the regression analysis. In regression tree analysis, dependent and independent variables can be continuous, nominal or ordinal (Doğan and Özdamar, 2003). Regression tree is a nonparametric partitioning method, which identifies the interaction between the independent and dependent variable.

The literature contains only a limited number of studies using regression tree analysis in animal production, particularly in birth weight and milk yield. In a previous study, carried out on Norduz and Karakaş sheep in Turkey (Eyduran *et al.*, 2008), the regression tree method was used to determine the effects of race, sex, birth type, year of birth and mother's age on birth weight. Doğan (2003) analyzed the factors affecting the milk yield of Holstein cattle.

Domecq *et al.* (1997) used multiple linear regression and principal component analysis; Roshe *et al.* (2006) used mixed models; Waltner *et al.* (1993) used multiple linear and nonlinear regression models; and Berry *et al.* (2007) used linear and nonlinear regression models to determine the relationship between body condition scores and milk yield in Holstein cattle. Akçay *et al.* (2007); Yaylak and Kumlu (2005); Türkyılmaz *et al.* (2005) and Petrovic *et al.* (2009) used analysis of variance; Ray *et al.* (1992) used analysis of variance and regression analysis to determine the lactation number and calving seasons in Holstein cattle.. Previous studies used analysis of variance to analyze the effects of calving season, sex, birth type and number of birth on birth weight in Holstein, Simmental and Brown Swiss calves (Kaygısız, 1998; Koçak *et al.*, 2007; Tilki *et al.*, 2008; Aksakal and Bayram, 2009).

Regression tree analysis has various advantages over other statistical method such as multiple regression, analysis of variance, logistic regression, log-linear models, linear discriminate analysis and survival models (Timofeev, 2004; Yohannes and Hoddinott, 1999). These advantages include the following: (1) Regression tree is a nonparametric method, which does not have to fulfill assumptions; (2) Regression trees can be applied to continuous, nominal and ordinal dependent variables; (3) Regression trees are invariant under transformations of independent variables; (4) The structure of the regression tree algorithm includes the most important variables explaining the dependent variable and eliminates insignificant variables; (5) Interactions within the data set can be determined and the graphical interpretation of complex results containing the interactions is easier; (6) The model has the capability of overcoming missing values in the dependent and independent variables.

In general, previous studies used analysis of variance and regression analysis methods to determine the factors affecting milk yield and birth weight in cattle. The present study aimed to determine and classify the factors affecting birth weight and milk yield in Swedish Red cattle using the regression tree method.

MATERIALS AND METHODS

Data on birth weight, milk yield records and body condition scores measured at different periods of Swedish Red cattle raised in a private organic diary cattle production enterprise in the Kelkit district of Gümüşhane province of Turkey were used in the present investigation. Within this enterprise, matters such as care, nutrition, accommodation and veterinary interventions are carried out in accordance with the "Regulation Pertaining to the Principles and Implementation of Organic Agriculture", issued by the Ministry of Agriculture and Village Affairs on various dates (Anonymous, 2005). Daily rations of the cows in lactation contained 60% rough feed and 40% concentrate feed. In addition, with the permission of the controlling institution, the percentage of concentrate feed can increase to 50% in postpartum cows for a period of three months. In case of shortage of organic feed, 10% of total annual feed requirements can be supplied from conventional enterprises. This percentage was reduced to 5% in the year 2008.

Mainly, concentrate feeds such as corn, barley, vicia sativa, lentil flour and organic concentrated milk feed; and rough feeds such as corn silage, organic clover and herbage are used in the enterprise. The cows are milked twice a day. Daily milk yield was automatically recorded on a computer via transponders carried by each cow. Characteristics such as actual milk yield, peak milk yield and lactation period were calculated from computer-records. The average dry period in the enterprise was 2 months.

Swedish Red cattle were brought to the enterprise as heifers during 2005. Since the 3rd lactation of the majority of the cattle continued, only the records of the cows in 1st and 2nd lactation were used. All of the tested cows were individually scored using a 5-item scoring system developed by Edmonson *et al.* (1989). Animals were tested on the following dates: one month before calving (BCS1), during calving (BCS2) and in the 1st month of lactation (BCS3). In this system, the scoring interval was 0.25 and the scores varied between 1 (emaciated), 2 (thin), 3 (moderate), 4 (stout) and 5 (obese).

This study analyzed the effects of variables which were thought to affect birth weight (birth type, sex, birth order and body condition BCS1 and BCS2) and actual milk yield (lactation period, lactation number, calving season, peak milk yield and body condition score recorded in 3 different periods). Regression tree analysis was performed using the SPSS statistical package program (SPSS 13.0 for Windows).

Regression tree modeling is a nonparametric approach which can explain the response of a dependent variable among independent continuous or categorical variables. Using a variance-minimizing algorithm, regression tree models repeatedly partition the data to determine increasingly homogenous sub-groups, based on partition criteria of the independent variable (Zheng *et al.*, 2009). The objective of regression tree analysis is to derive a structure, according to the independent variable, which produces the most homogenous nodes (Larsen and Speckman, 2004). Dependent variable data is split into a series of left and right child nodes derived from the primary nodes. When the split is terminated, child nodes are determined as terminal nodes.

The homogeneity of the nodes can be described in terms of impurity. The impurity value of fully homogenous models is zero and, as the homogeneity of the nodes decrease, impurity value increases. Maximum homogeneity of the groups corresponds to minimum impurity. Numerous splitting criteria may be used, according to the type of independent variable (De'ath and Fabricius, 2000). If the dependent variable is numerical, the residual sum of squares method is used for regression tree analysis and impurity is defined as the sum of squares of response values (observations) around each node (Questier *et al.*, 2004). Splits are selected on the principle of minimizing the sum of the squared deviations from the mean in each node and observation. The related function can be summarized as follows:

$$D(T) = \sum_{i=1}^{n}(y_i - \bar{y})^2$$

where, $\bar{y}$; is the mean of observations in T node and y_i is the value of the ith. observation (Larsen and Speckman, 2004; Questier *et al.*, 2004). The parent node contains all of the observations. At each stage, the parent node is split into two child nodes, (Node T) left (T_{left}) and right (T_{right}). During the split (Larsen and Speckman, 2004):

1. If the χ_i independent variable is continuous, left and right child node

$T_{left}=\{i \in T: \chi_i \le t\}$ and $T_{right}=\{i \in T: \chi_i > t\}$, t constant value

2. If the χ_i independent value is ordinal, left and right child node

$T_{left}=\{i\in T: \chi_i \leq t\}$ and $T_{right}=\{i\in T: \chi_i > t\}$

3. If the χ_i independent variable is k level categorical, there are 2^{k-1}-1 splits.

RESULTS

A regression tree diagram of the factors which are expected to affect birth weight and actual milk yield in Swedish Red cattle is given in Figures 1 and 2. Descriptive values of the birth weight are given in the main node of the regression tree (Figure 1). Average birth weight ± Standard Deviation in Swedish Red calves were found to be 41.034 ± 4.218 kg. The primary node was divided into two nodes by the birth type variable, which indicates that birth type is the most influential variable on birth weight. It was found that the cattle in birth type node 1 had a total of 200 calves; average birth weight of these calves was 41.185 ± 3.840 kg. The twin born calves within the enterprise were 2.9% and birth weight was 36.000 ± 10.545 kg. Node 1 was further split into two child nodes (Node 3 and Node 4) according to calving season. The regression tree diagram indicates that calving season is the secondary variable affecting the birth weight of the calves. It was found that average birth weight of the calves born in summer and winter were 41.594 ± 3.874 kg, average birth weight of the caves born in autumn were 39.550 ± 3.258 kg respectively. Node 3 was further split into 2 nodes by the sex variable. In Node 5, average birth weight of female calves was 40.725 ± 3.253kg;. In node 6, average birth weight of male calves was 42.462 ± 4.254 kg. Node 5 was split into a child node according to BCS2 score. It was found that in node 7, 50 calves were born from the cattle having a BCS2 score of 3.15 or lower; average birth weight of these calves was 41.300 ± 3.105 kg. It was found that, in node 8, the percentage of the calves born from the cattle having a BCS2 value higher than 3.15 was 14.6%; average birth weight of these calves were found to be 39.767 ± 3.319 kg, respectively.

Table 1 shows the significance level of independent variables included or not included in the regression tree structure affecting birth weight. The improvement based importance value of each variable indicates the surrogate for the primary splitting variable. Surrogate variables result in similar splits in both nodes, like the primary variable. The importance value indicates the influence, on the dependent variable, of variables whose effect was masked by other variables on the regression tree. Relative importance values are calculated as a proportion of the importance of each value to the first importance value. Thus, relative importance value indicates the influence of each variable on the dependent variable when each variable is used to replace the most importance variable.

Table 1.Significance of the independent variables affecting birth weight

Independent Variable	Importance	Relative Importance (%)
Birth type	0.760	100.0
Calving Season	0.658	86.6
Sex of Calf	0.586	77.1
Lactation number	0.571	75.2
BCS2	0.283	37.2

It is evident from Table 1, that the most important variable affecting birth weight is birth type, followed by calving season, sex of calf, birth order and BCS2. However, as the importance of birth order was masked by other variables, it is not contained in the regression tree structure.

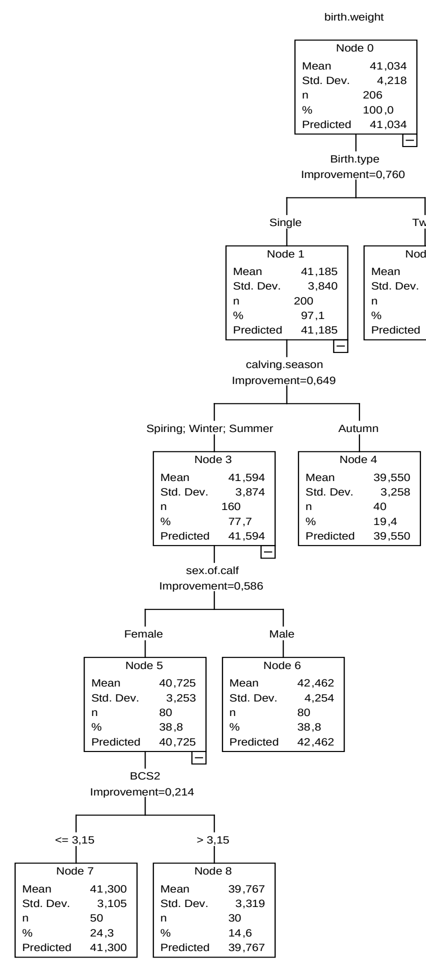

Figure 1. Regression tree analysis of the factors affecting birth weight of Swedish Red calves

Figure 2 shows a regression tree diagram of the independent variables affecting actual milk yield in Swedish Red cattle. It is evident that the independent variable primarily affecting actual milk yield was lactation period, followed by peak milk yield. Lactation period was split into two nodes, below or above 298 days. It was found that average actual milk yield of the cows with a lactation period of 298 days or less were 5262.433 ± 1563.022 kg. Average actual milk yield of the cows having a lactation period of more than 298 days were found to be 7243.527 ±1786.734 kg, respectively. Node 1 and 2 were split into two child nodes according to peak milk yield. In node 3, peak milk yield was 34.76 kg or lower; average actual milk yield and the share in total were found to be 4311.404 ± 1262.491 kg and 23.3% respectively. In node 4, peak milk yield was higher than 34.76 kg; average actual milk yield and the share in total were found to be 6213.462 ±1223.426 kg and 23.3%, respectively. Node 3 and node 4 were terminal nodes. Terminal nodes do not split according to an independent variable. It was found that, in node 5 (cattle having a lactation period of more than 298 days and a peak milk yield of 34.710 kg or lower), average actual milk yield and the percentage in total of the were 6463.919 ± 1466.991 kg and 30.6%, respectively. In node 6, where peak milk yield was more than 34.71 kg, the average actual milk yield and the percentage in total of the cows were 8288.534 ±1647.983 kg and 22.8%, respectively. In addition, node 5 was further split into two child nodes according to lactation period. The corresponding values In node 7 were 6128.102 ± 1219.329 kg and 25.2%, respectively. In node 8, average actual milk yield and the percentage in total of the cattle were found to be 8051.418 ± 1549.741 kg and 5.3%, respectively. According to these results, the increase of lactation period and peak milk yield led to significant increases in actual milk yield of the cattle.

Table 2 indicates the importance level of all independent variables, used or not used in, the regression tree structure; and the influence, on the dependent variable, of variables whose effect was masked by other variables in the regression tree. As indicated in the regression tree diagram lactation duration and peak milk yield were the most important variables in terms of actual milk yield, followed by lactation order, BCS3, BCS1, VBCS2 and season.

DISCUSSION

It is important to estimate the effects of independent variables particularly in specific hypothetical studies related to the effects of independent variables or variable groups on a dependent variable. Various statistical analysis methods can be used for this purpose. In this study, as an alternative to general methods, regression tree method was used to determine the effects of various factors on actual milk yield of cows and birth weight of calves,.

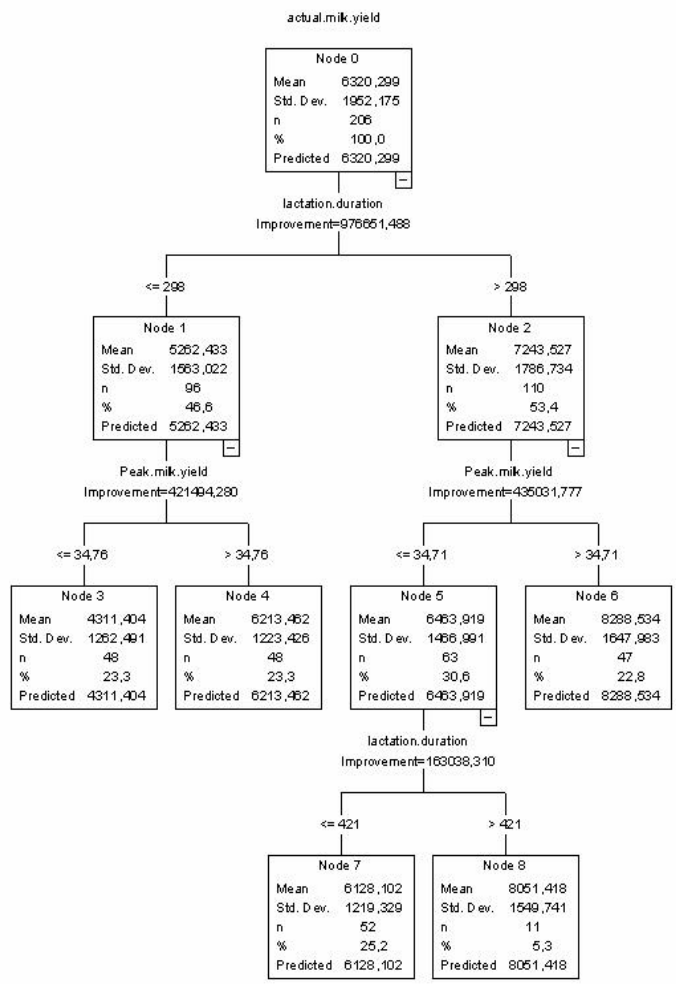

Figure 2. Regression tree analysis of the factors affecting milk yield in Swedish Red cattle

Table 2: Importance level of independent variables affecting actual milk yield

Independent Variable	Importance	Relative Importance (%)
Lactation period	1424450.061	100.0
Peak milk yield	1339024.129	94.0
Lactation number	184036.348	12.9
BCS3	96723.651	6.8
BCS1	90033.198	6.3
BCS2	88023.376	6.2
Calving Season	83578.118	5.9

The most important advantage of regression tree analysis over other methods is that it does not include assumptions, as it is a nonparametric method.

According to the regression tree diagram created for birth weight birth type was the most influential variable on birth weight, followed by calving season, sex of the calf and body condition score (BCS2) during calving. The percentage of twin births within the enterprise was found to be 2.9%. Twin calves had a mean birth weight of 5.185 kg (14.4%) lower than single born calves. Within the same enterprise, Aksakal and Bayram (2009) reported this variation as 6.26 kg for Holstein cattle. Bakır *et al.* (2004) and Kertz *et al.* (1997) reported that, among diary cows, twin calves had a birth weight of approximately 11.2% or 15.9% lower than those of single born calves.

In the present study, the second most important variable affecting the birth weight of calves was found to be calving season. Calves born in autumn were found to have a birth weight of 2.044 kg lower than those born in other seasons. Previous studies, (Akbulut *et al.*, 2001; Koçak *et al.*, 2007) also reported that season had a significant effect on birth weight. Male calves were found to have 1.737 kg higher birth weight than females, so sex was found to have a significant effect on birth weigh. In a previous study carried out in the same enterprise on Holstein Friesain cattle (Aksakal and Bayram, 2009), this value was found to be 2.69 kg. In parallel to the results obtained in this study, previous studies (Kertz *et al.*, 1997; Akbulut *et al.*, 2001; Bakır *et al.*, 2004) reported that male calves had 1.3 to 3.6 kg higher birth weight than females.

Body condition score (BCS2) also affected birth weight in Swedish Red calves. It was found that the birth weight of calves born to cows with lower body condition score (BCS2 <=3.15) was 1.533 kg higher than those born to cows with high condition. Body condition score is a subjective evaluation method giving information about the nutritional balance and energy reserves of the cow, based on its physiological condition. Birth weight of fetus increases as a result of good nourishment of fetus during pregnancy period and weight of cow decreases during calving. Eyduran *et al.* (2008) carried out a study using regression tree modeling, and reported that birth type and sex affected birth weight in Noduz and Karakaş sheep.

In organic Swedish Red cattle, the most important variable effecting actual milk yield was found to be lactation period, followed by peak milk yield. Average actual milk yield of the cows with a lactation period longer than 298 days (7243.527 kg) was found to be higher than those with a lactation period of less than 298 days (5262.433 kg). With the increase in peak milk yield an increase in actual milk yield was recorded (Figure -2). It was observed that, in child nodes where both lactation durations were split according to peak milk yield, the actual average milk yield was high where the peak milk yield was high. The highest actual milk yield was obtained from the cattle in the group with a lactation period greater than 298 days and peak milk yield higher than 34.71 kg (8288.534 kg). It can be suggested that longer lactation period and high peak milk yield increase actual milk yield in cattle. Lactation number (parity), BCS3, BCS1, BCS2 and calving season had a significant effect on actual milk yield; however, as the effects of these variables were masked by other variables in the regression tree analysis, these variables are not indicated in the regression tree diagram. Similar results were obtained in previous studies. Domecq *et al.* (1997) reported that, in Holstein Friesain cows, body condition scores, lactation number and calving season had a significant effect on milk yield of the cow at the 120th day of lactation. Roshe *et al.* (2006), Waltner *et al.* (1993) and Berry *et al.* (2007) reported that, in Holstein Friesain cows, there was a significant linear relationship between body condition scores and milk yield. Akçay *et al.* (2007) reported that, in Holstein cattle, lactation number and calving season had a significant effect on milk yield at 305 days. Ray *et al.* (1992) observed that lactation number and calving season had a significant effect on milk yield, and that the highest milk yield was obtained from cows calved in spring and winter seasons. It was further remarked that milk yield increased with advancing lactation number. Petrovic *et al.* (2009) reported that calving season and lactation number had a significant effect on milk yield in Simmental cattle; the higher milk yield was obtained from cows calved in winter and spring seasons; and that the cows in their 3^{rd}, 4^{th} and 5^{th} lactation had higher milk yield than other lactations. Similar findings have been reported in Holstein cattle (Türkyılmaz *et al.*, 2005). Cows in 4^{th}, 5^{th} and 6^{th} lactation had higher milk yield whereas cows calved in winter and spring seasons also had higher average milk yield than those calved in other seasons. On the other hand, Yaylak and Kumlu (2005) reported that calving season, lactation number and body condition score had a significant effect on milk yield in Holstein cattle. The researchers found that the milk yield of cattle in 3^{rd} and 4^{th} lactation was higher than those in other lactation periods; cattle born in spring and autumn seasons had higher milk yield; and milk yield increased with the increase of body condition score prior to calving.

Conclusions: In conclusion, regression tree modeling can be used to analyze the effect of other variables on a particular variable in farm animals. Only a limited number of studies have used regression tree analysis in studies of farm animals. Since it is a nonparametric method, regression tree analysis does not include the assumptions required for test. The method has important advantages for application to continuous, categorical and grading measurement scale and easy interpretation of the results. Using this method, the significance of the factors affecting economic characteristics such as birth weight and actual milk yield were determined, and the method served as a guide for future improvement studies for these two characteristics.

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