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The Prediction of Prolificacy Using Linear Body Parameters and Craniometric Analysis in Etawah-Grade Does

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ABSTRACT

Etawah-grade goat is a graded up line between Kacang and Etawah goats, which well adapted to Indonesia's humid tropical climate. In order to fulfill national meat requirement, it is necessary to increase the population by increasing prolificacy. This study was aimed to determine whether the body and head measurements of the Etawah-grade does can be used as selection criteria for indirect selection of the litter size. The use of does at 3-4 years old (I_3 dental condition) from BPTU-HPT Pelaihari and Cordero farms (51 and 55 does, respectively) were based on their specific geographical location characteristics. The body variables were withers height, hip height, body length, chest width, chest depth, thurl width, rump length, chest girth, and cannon circumference, whereas for head variables were *acrocranion–prosthion*, *basion–prosthion*, **lower jaw length, head height,** *tuber facial* **left-right,** *nasion–rhinion*, *entorbitale* **left-right,** *euryon* **left-right,** *supraorbitale* **left-right. Bergmann methods were applied for measuring the differences of body and head parameters followed by the principal component, Fisher's discriminant, and principal component regression analyzes. All regression coefficients of linear body measurementss were highly correlated to the litter size (P<0.01), with the equation was $Y= 0.015X_{1b} + 0.011X_{2b} + 0.025X_{3b} - 0.002X_{4b} + 0.022X_{5b} + 0.010X_{6b} + 0.022X_{7b} + 0.030X_{8b} + 0.026X_{9b}$. The chest girth was the most elastic body size measurement to the litter size. The increasing of 1 cm of doe's chest girth would result in the increase of litter size, each of 0.0545 and 0.0417 heads born^{-1} at BPTU-HPT Pelaihari and Cordero farms. Differences in head size and head shape due to the morphometric adaptations cannot be used to predict litter size.**

Keywords: ***craniometric, Etawah-grade goat, linear body parameters, litter size, principal component***

INTRODUCTION

Increased populations of Etawah-grade goat (dual purpose) are required to support the fulfillment of national meat requirements. The wide distribution of Etawah-grade goats in various regions in Indonesia indicates that the Etawah-grade goat can well adapted to Indonesia's humid tropical climate. Mudawamah *et al.* (2014) stated that Etawah-grade goat as one of the local goats of Indonesia had adapted to local conditions.

Directorate General of Livestock and Animal Health Services (2017) reported that the number of goat in Indonesia increased from 18,500,321 heads in 2013, to 18,639,533 and 19,012,794 heads in 2014 and 2015, respectively, and decreased to 17,847,197 heads in 2016 and increased again to 18,410,379 heads in 2017. Chevon production decreased from 65,169 tons in 2013, to 65,142 and 64,948 tons in 2014 and 2015, respectively, but increased to 67,845 and 70,024 tons in 2016 and 2017, respectively. The spread of goats in Indonesia is from the highland to the lowland, even goats can utilize swamp forages in South Kalimantan (Rostini *et al*., 2014).

Kacang goat was domesticated in order to produce meat, skin, and prolificacy (Batubara *et al.*, 2006), while Etawah goat which was domesticated for meat and milk, originated from Chakkar Nagar area in Etawah District, Uttar Pradesh (Rout & Dass 2015). Etawah grade goat is a result of grading up line between Kacang and Etawah goats, which well adapted to Indonesia's humid tropical climate. Wibowo *et al*. (2013) stated that sperm morphometry of Etawah-grade goat has a high similarity with Kacang goat compared to Kejobong and Jawarandu goats. Hasan *et al.* (2014) state that Etawah-grade goat is a local goat for producing meat and milk (dual purpose). However, Sutama (2009) reported that farmers in Indonesia utilized Etawah-grade goats mainly for meat production. Batubara *et al.* (2016) reported that the number of Etawah-grade goat in Indonesia was approximately 9%-10% of the total goat population, which was the second largest number after Kacang goat.

Increasing the population of Etawah-grade goat can be done through direct selection of litter size. However, the selection progress will be slow because its low heritability. In Indonesia, research on heritability estimation of goat reproduction is still very limited, even for litter size does not exist yet. Menezes *et al.* (2016) reported that estimated heritability of litter size on Boer goats in Brazil was close to zero, while on Markhoz goats in Iran was 0.01 (Rashidi *et al.*, 2011). Linear body and head parameters can be used to increase the litter size because some of the body size and head size parameters highly correlate with litter size. Haldar *et al.* (2014) found that doe with chest girth more than 60.90 cm more likely to produce twin than single births, while the doe with chest girth more than 62.29 cm tended to produce triplet. Baranowski *et al.* (2009) observed partial and semi partial correlations to determine the association between craniometric traits and litter size on a rabbit-like *Chinchilla laniger*. It is suggested that statistically significant inheritance of parietal and semi-parietal correlations for nuchal plane selected of skull from a rabbit-like *Chinchilla laniger* is useful in craniometric research, and for the determination of litter size at birth in case of suspecting the value of craniometric traits in animals which have high litter size. These selection methods are easy and cheap to be applied by rural breeder because they do not require advanced equipment. The purpose of this study was to determine which of the linear body and head parameters that is related to the litter size of Etawah-grade does. The Etawah-grade goat in both farms originated from Kaligesing in Purworejo, Central Java as the main source of Etawah-grade goat farm in Indonesia. The use of BPTU-HPT Pelaihari and Cordero farm based on the specific geographical condition differences. BPTU-HPT Pelaihari in Pelaihari, South Kalimantan and Cordero Farm in Bogor, West Java are located in different latitudes. BPTU-HPT Pelaihari is located close to the beach at lower latitudes so it has a warmer temperature, whereas Cordero Farm is located in hillside area at higher latitudes so it has a cooler temperature. The purpose of this study was to determine whether the body and head measurements of the Etawah-grade does can be used as selection criteria for indirect selection of the litter size.

MATERIALS AND METHODS

The experiments were conducted at BPTU-HPT Pelaihari in South Kalimantan and Cordero farm in West Java from November 2014 to January 2015. The total number of does observed at BPTU-HPT Pelaihari were 51 heads, while at Cordero Farm were 55 heads. The 3-4 years old (dental condition I_3) does used in this experiment were selected by using purposive sampling method, with due consideration to the difficulty of obtaining complete data on the does' reproduction records in the field, such as parity and the previous litter size. In that condition, does were assumed to be in the same physiological state where the growth of its body's skeleton and its head's skeleton had ceased.

Etawah-grade does at BPTU-HPT Pelaihari and Cordero farms could be already adapted morphometrically as were reflected by the differences in linear body parameters due to different thermoregulation. Does at Cordero farm were maintained in comfortable temperature zones, which different from BPTU-HPT Pelaihari (Table 1). According to Maia *et al.* (2016), goat comfort zone occurred when the respiratory rate, latent heat loss, rectal, skin, and hair temperatures were unchanged and occurred at a temperature of 22-26 °C. It was explained that goats maintained a balance of body temperature mainly by evaporation through skin and evaporative heat loss, when the ambient temperature exceeded 30 °C. The thermoregulation process of Etawah-grade does at BPTU-HPT Pelaihari was regulated by maintaining body temperature at normal temperature through balance in maintaining body heat at its body volume and releasing body heat load from the surface of its body. According to Trevor *et al.* (2015), a shift in basal metabolic rate and thermal conduction was an important adaptation mechanism of mammals to maintain body temperature. The body temperature is regulated by balancing heat production rate and heat loss. Ray (2016) states that the animal's body size is related to thermoregulation in response to endothermic animals in maintaining body temperature. Based on Bergmann's rules, larger animals that occupy larger latitudes tend to have a lower surface-to-body ratio and the organism's body size is determined by thermoregulation processes.

Cordero farm is located at the southern latitudes higher than BPTU-HPT Pelaihari which has cooler air and lower air humidity but higher rainfall (Table 1). This condition affects the quality of the forage feed type, as a result of the differences in soil nutrient content due to high rainfall. Differences in quality and type of forage could affect the linear body sizes of does observed. Based on the proximate analysis (Table 2), higher water content in various types of forage at Cordero farms could be due to the higher rainfall resulting in a lower content of ash, fat, protein, carbohydrate, and crude fiber than that at BPTU-HPT Pelaihari. According to Trevor *et al.* (2015), larger animals are more suitable to live and survive at cooler environment than smaller animals and vice versa. Yom-Tov & Geffen (2006) stated that the amount of water available for feed plants was determined by a combination of rainfall, temperature, and other environmental factors that affected evaporation such as solar and wind radiation, and a combination of these factors. Sepu'lveda *et al.* (2013) stated that not only latitude and temperature could explain variations in body size but also longitude and availability of food.

Experimental Procedure

Linear body parameters recorded for these does were withers height (X_{1b}), hip height (X_{2b}), body length (X_{3b}), chest width (X_{4b}), chest depth (X_{5b}), thurl width (X_{6b}), rump length (X_{7b}), chest girth (X_{8b}), and cannon circumference (X_{9b}), whereas head parameters recorded were *acrocranion–prosthion* (X_{1h}), *basion–prosthion* (X_{2h}), lower jaw length (X_{3h}), head height (X_{4h}), *tuber facial* left-right (X_{5h}), *nasion–rhinion* (X_{6h}), *entorbitale* left-right (X_{7h}), *euryon* left-right (X_{8h}), and *supraorbitale* left-right (X_{9h}).

Litter size was recorded when the last kid was born. The measurements of spots and areas of body and head were presented in Figure 1.

Statistical Analysis

Data were analysed descriptively for each measurement variable of body and head of Etawah-grade does, using principal component analysis, Fisher's discriminant and principal component regression analyzes that were derived from the covariance matrix (Gaspersz, 1992). The mathematical model of principal component analysis was derived from a covariance matrix according to Gaspersz (1992):

$Y_{1b}= a_{11}X_{1b} + a_{21}X_{2b} +...+ a_{91}X_{9b}$; $Y_{2b}=a_{12}X_{1b} + a_{22} X_{2b} +...+ a_{92} X_{9b}$

$Y_{1h}= a_{11}X_{1h} + a_{21}X_{2h} + ... + a_{91h}$; $Y_{2h}= a_{12}X_{1h} + a_{22}X_{2h} + ... + a_{92}X_{9h}$

Description: Y_{1b} or Y_{1h} = the first principal component of body or head sizes, Y_{2b} or Y_{2h} = the second principal component of body or head shapes, $a_{11} – a_{91}$ = eigen vector for body size or head size equations, $a_{12}– a_{92}$ = eigen vector for body shape or head shape equations.

The clustered diagram of Etawah-grade does' body and head measurements were performed based on the first principal component scores (size scores) as the X axis and the second principal component scores (shape scores) as the Y axis obtained based on the body and head size and shape equations.

The body and head morphometrics differences based on body and head variables between Etawah-grade does at BPTU-HPT Pelaihari and Cordero farms were analyzed by T^2-Hotelling according to Gaspersz (1992). Fisher's discriminant equations between farms were obtained by using the Fisher' s discriminant analysis to determine the discriminant variables.

Spearman correlation (O'Mahony, 1986) was used to determine whether there was a correlation between body size or body shape and litter size, as well as between head size or head shape and litter size. The principal component regression analysis was performed if the Spearman's correlation (O'Mahony 1986) was significant (P<0.05).

The principal component regression analysis model used based on Gaspersz (1992):

$$Y= W_0 + W_1K_1 + ... + W_9K_9$$

Table 1. Environmental conditions at BPTU-HPT Pelaihari and Cordero Farms

Environmental conditions	Pelaihari	Cordero
Latitude	3.64062–3.99204 °S*	6°18' 6°47'10 S**
Longitude	114.642–114.872 °E*	106°23'45–107° 13'30 E**
Altitude	25 m*	500 m **
The area location	Close to the beach	Mountains
Temperature	24–31 °C*	26 °C**
Humidity	60%-95%*	76%**
Precipitation	2,376 mm year^{-1}*	3,500–4,500 mm year^{-1} **
Feed	2 types of concentrates and gamal (*Gliricidia sepium*)	1 type of concentrate and soybean pulp and natural forage (grass and legume)
Production system	Intensive	Intensive

Note: *BMKG (2014), ** BMKG (2015).

Table 2. Results of proximate analysis of forage used at BPTU-HPT Pelaihari and Cordero farms

Nutrient contents	Pelaihari (%)	Cordero (%)
Water	12.25	80.51
Ash	8.62	1.95
Fat	1.34	0.47
Protein	21.51	5.05
Carbohydrates	56.63	11.59
Crude fiber	1.83	0.24

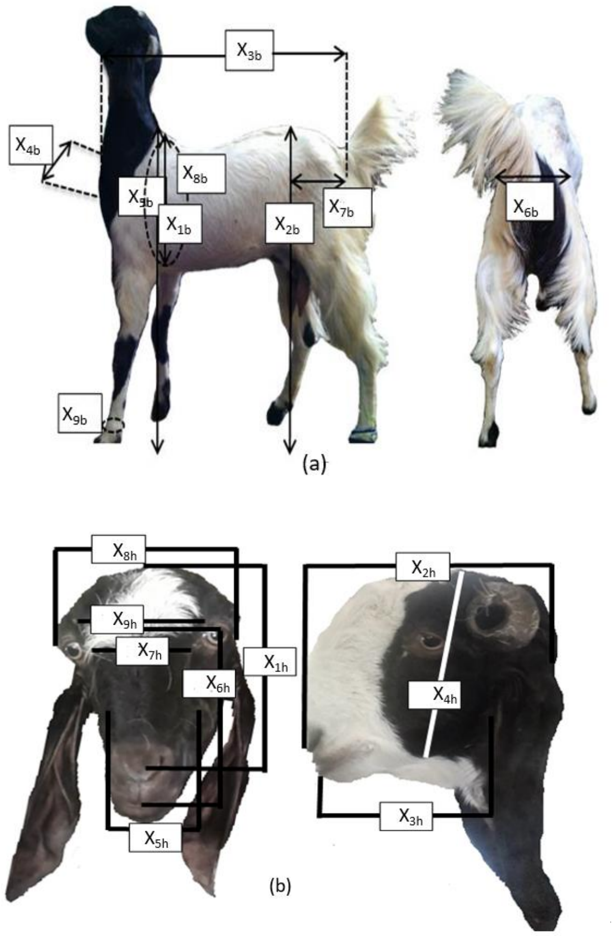

Figure 1. (a) Schematic of linear body parameters of Etawah-grade does observed (X_{1b}: withers height, X_{2b}: hip height, X_{3b}: body length, X_{4b}: chest width, X_{5b}: chest depth, X_{6b}: thurl width, X_{7b}: rump length, X_{8b}: chest girth, and X_{9b}: cannon circumference. (b) Schematic of head measurements of Etawah-grade does observed (X_{1h}: acrocranion–prosthion, X_{2h}: basion–prosthion, X_{3h}: lower jaw length, X_{4h}: head height, X_{5h}: tuber facial left-right, X_{6h}: nasion–rhinion, X_{7h}: entorbitale left-right, X_{8h}: euryon left-right, and X_{9h}: supraorbitale left-right).

Description: Y= litter size, K_1-K_9= observed variables, W_0= constant, $W_1, W_2, ..., W_9$= regression coefficients.

How far the body size, body shape, head size, and head shape of Etawah-grade does affected the litter size was determined using the following elasticity value (Gaspersz, 1992):

$$E_i = b_i \left(\frac{X_i}{\overline{Y}}\right)$$

Description: E= the average elasticity of the litter size to observed variables, b_i= regression coefficient of each observed variable, X_i= average value of each observed variable, $\overline{Y}$= average value of litter size.

RESULTS

Linear Body Parameters and Litter Size

The linear body parameters of Etawah-grade does at Cordero farm were larger except for hip height and chest width (Table 3) when compared to those at BPTU-HPT Pelaihari. The hip height and chest width of goat at BPTU-HPT Pelaihari were larger and more uniform. The diagram of the cluster of linear body parameters was formed based on the body size and body shape scores, which each of its equation was presented in Table 4. The discriminator of body size and body shape were determined by the value of the eigenvector (Table 4). The discriminator of Etawah-grade does' body size in this study was chest girth, while does' body shape were body length, hip height, and withers height (Table 4). The individual data cluster of Etawah-grade does at BPTU-HPT Pelaihari was more centered and relatively smaller in size than that at Cordero farm (Figure 2). The differences in the clustered data were supported by Fisher's discriminant analysis with the equation was Y= $-0.103X_{3b} + 1.065X_{5b} + 1.333X_{7b} + 0.243X_{8b} + 0.012X_{9b}$ resulting body length, chest depth, hip length, chest girth, cannon circumference were the discriminant variables (P<0.05).

Table 5 presents the litter size of Etawah-grade does. Litter size of Etawah-grade does at BPTU-HPT Pelaihari was higher than that at Cordero farm. Spearman correlation showed that only body size of goat PE affecting litter size (P<0.05). The result of principal component regeression analysis showed that

Tabel 3. Linear body parameters of Etawah-grade does at BPTU-HPT Pelaihari and Cordero farms (cm)

Variables	Pelaihari (n=51 heads)	Cordero (n=55 heads)	Total (n=106 heads)
Withers height (X_{1b})	74.85±3.34	75.82±3.62	75.36±3.51
Hip height (X_{2b})	79.38±2.99	79.20±3.63	79.28±3.32
Body length (X_{3b})	74.39±3.31	79.19±6.38	76.88±5.65
Chest width (X_{4b})	19.39±1.51	18.85±1.80	19.11±1.68
Chest depth (X_{5b})	29.35±2.35	34.97±2.03	32.27±3.56
Thurl width (X_{6b})	18.26±1.16	19.42±2.35	18.86±1.95
Rump length (X_{7b})	12.27±1.36	15.26±1.39	13.82±2.03
Chest girth (X_{8b})	75.12±3.41	86.24±6.56	80.89±7.67
Cannon circumference (X_{9b})	7.81±0.69	9.00±0.70	8.43±0.91

Table 4. Equations of body size and body shape of Etawah-grade does

Equations	Total variation (%)	λ
Body size= $0.182X_{1b} + 0.125X_{2b} + 0.476X_{3b} - 0.012X_{4b} + 0.274X_{5b} + 0.068X_{6b} + 0.154X_{7b} + 0.784X_{8b} + 0.080X_{9b}$*	62.8	86.87
Body shape = $0.453X_{1b}$** + $0.483X_{2b}$** + $0.564X_{3b}$** + $0.072X_{4b} - 0.167X_{5b} + 0.026X_{6b} - 0.062X_{7b} - 0.452X_{8b} - 0.031X_{9b}$*	14.6	20.2

Note: *X_{1b}= withers height; X_{2b}= hip height; X_{3b}= body length; X_{4b}= chest width; X_{5b}= chest depth; X_{6b}= thurl width; X_{7b}= rump length; X_{8b}= chest girth; X_{9b}= cannon circumference; **= discriminator; λ= eigen value.

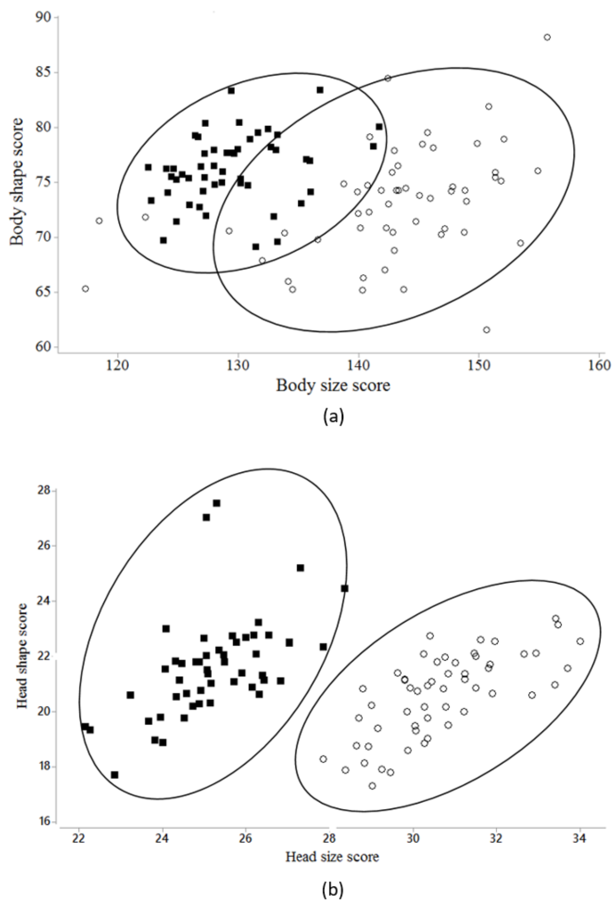

Figure 2. The clustered data of body (a) and head (b) parameters based on size and shape scores of Etawah-grade does at BPTU-HPT Pelaihari (■) and Cordero farm (o).

Table 5. Litter size of the last birth of Etawah-grade does at BPTU-HPT Pelaihari and Cordero farms

Location	Total (heads)	Means of litter size (heads birth^{-1})
Pelaihari	51	1.71±0.57
Cordero	55	1.53±0.61
Average	106	1.62±0.60

all regression coefficients of linear body parameters of Etawah-grade does were highly correlated to the litter size (P<0.01). The equation of principal component regression analysis with Y as litter size was $Y=0.015X_{1b} + 0.011X_{2b} + 0.025X_{3b} - 0.002X_{4b} + 0.022X_{5b} + 0.010X_{6b} + 0.022X_{7b} + 0.030X_{8b} + 0.026X_{9b}$. The largest elasticity was found for the chest girth (Table 6). Table 6 showed that if chest girth of Etawah-grade doe increased by 1%, then it was predicted that the doe had a litter size that was 2.378% higher than the average population.

Linear Head Parameters and Litter Size of Etawah-Grade Does Observed

The head paraemters of Etawah-grade does at BPTU-HPT Pelaihari and Cordero farms (Table 7), were calculated based on the principal component analysis and then visualized in the form of a clustered diagram (Figure 2). Table 8 presented the head size and head shape equations of Etawah-grade does observed. *Basion-prosthion* was the size discriminator of the head of Etawah-grade does observed, while *acrocranion-prosthion* was the discriminator of head shape (Tables 8).

The differences in the data cluster were supported by Fisher's discriminant analysis with the equation was $Y= 2.890X_{2h} - 5.244X_{5h} + 3.814X_{8h} + 3.743X_{9h}$ resulting that *basion-prosthion*, *tuber facial* left-right, *euryon* left-right, *supraorbitale* left-right were discriminant variables (P<0.05) that were larger in Etawah-grade does at Cordero farm (Table 7). The Spearman correlation analysis showed that the litter size was not related to head size or head shape, so that the principal component regression equation could not be established.

Table 6. Elasticity of litter size to linear body parameters of Etawah-grade does

Variables	Regression coefficient	Mean (cm)	Elasticity	Rank
Withers height (X_{1b})	0.015	75.36	1.106	3
Hip height (X_{2b})	0.011	79.28	0.854	4
Body length (X_{3b})	0.025	76.88	1.881	2
Chest width (X_{4b})	–0.002	19.11	–0.035	9
Chest depth (X_{5b})	0.022	32.27	0.674	5
Thurl width (X_{6b})	0.010	18.86	0.172	8
Rump length (X_{7b})	0.022	13.82	0.268	6
Chest girth (X_{8b})	0.030	80.89	2.378	1
Cannon circumference (X_{9b})	0.026	8.43	0.177	7

Tabel 7. Linear head parameters of Etawah-grade does observed at BPTU-HPT Pelaihari and Cordero farms (cm)

Variables	Pelaihari (n=51 heads)	Cordero (n=55 heads)	Total (n=106 heads)
Acrocranion–prosthion (X_{1h})	23.52±1.43	23.87±1.36	23.70±1.40
Basion–prosthion (X_{2h})	21.76±1.36	25.86±1.52	23.88±2.51
Lower jaw length (X_{3h})	15.52±2.00	14.69±0.56	15.09±1.50
Head height (X_{4h})	13.97±0.81	14.58±0.67	14.29±0.80
Tuber facial left-right (X_{5h})	5.30±0.70	4.02±0.47	4.64±0.87
Nasion–rhinion (X_{6h})	12.60±0.81	12.37±1.21	12.48±1.04
Entorbitale left-right (X_{7h})	5.23±0.67	4.78±0.56	5.00±0.65
Euryon left-right (X_{8h})	7.55±0.56	9.67±0.70	8.65±1.24
Supraorbitale left-right (X_{9h})	5.77±0.71	8.36±0.74	7.11±1.49

DISCUSSION

Linear Body Parameters and Litter Size

Differences in body size and body shape scores of Etawah-grade does resulted in clustered diagram (Figure 2). Everitt & Dunn (1998) suggested that body size represented the first principal component, while body shape represented the second principal component in animals. According to Porter & Kearney (2009), size and shape of endothermic animal determine the thermal niche through the interaction of animal with core temperature, insulation, and environmental conditions, thereby determining thermoneutral zone (TNZ), i.e., the condition of body heat released and minimized water expense. Body size is the volume or weight of animal body, while body shape is the ratio of body length and body width like sphere *vs.* ellipsoid. Al-Dawood (2017) stated that thermoneutral zone was the temperature at which the animal did not require additional energy to maintain body temperature.

The individual data cluster of Etawah-grade does at Cordero farm that have a greater variation reflected a greater variation of body size than thosein BPTU-HPT Pelaihari. The higher uniformity of smaller body size data centered at Pelaihari BPTU-HPT reflected that natural selection acted on a warmer environment, but the body size selection of the does at Pelaihari BPTU-HPT toward a smaller size had also been performed when the does were introduced. This was done based on the consideration that the condition of the maintenance environment at BPTU-HPT Pelaihari was much different from those at the origin source of Etawah-grade goat

Table 8. Equations of head size and head shape of Etawah-grade does

Equations	Total variation (%)	λ
Head size= $0.215X_{1h} + 0.798X_{2h}^{**} - 0.118X_{3h} + 0.108X_{4h} - 0.167X_{5h} - 0.040X_{6h} - 0.043X_{7h} + 0.330X_{8h} + 0.389X_{9h}^{*}$	55	9.42
Head shape= $0.626X_{1h}^{**} + 0.238X_{2h} + 0.491X_{3h} - 0.053X_{4h} + 0.219X_{5h} - 0.216X_{6h} + 0.090X_{7h} - 0.246X_{8h} - 0.381X_{9h}^{*}$	17.4	2.98

Note: *Acrocranion–prosthion (X_{1h}); basion–prosthion (X_{2h}); lower jaw length (X_{3h}); head height (X_{4h}); tuber facial left-right (X_{5h}); nasion–rhinion (X_{6h}); entorbitale left-right (X_{7h}); euryon left-right (X_{8h}); supraorbitale left-right (X_{9h}); **=discriminator; λ = eigen value.

at Kaligesing. This difference could affect the development of the goat, so that only limited Etawah-grade does with certain body size range that could survive at BPTU-HPT Pelaihari. Thermoregulation of Etawah-grade does at BPTU-HPT Pelaihari occured by releasing the body's heat load to reduce heat stress effects. The does consume more water in order to keep the body temperature at the homeostatic zone, thus reducing feed consumption. Metabolic energy was partly used to release heat load, and partly for growth. This condition could result in a smaller body size of Etawah-grade does at BPTU-HPT Pelaihari, but had a higher total surface area to body volume ratio, which was shown by a larger hip height and chest width relating to the body surface (Table 3). The thermoregulation process required by Etawah-grade does at BPTU-HPT Pelaihari to release the heat load through its body surface is by evaporation. In general, linear body parameters of Etawah-grade does at BPTU-HPT Pelaihari were smaller due to the differences in latitude from Cordero farm, but had larger hip and chest height that related to body surface area (Table 3). The results found in this study correspond to the Bergmann's rule (Ray, 2016).

The thermoregulation of does at Cordero farm was occurred by consuming more feed to be converted into energy through the Krebs cycle. Energy produced was used to produce body heat and energy used to release heat was minimized and diverted to be used for growth. This mechanism could affect the volume of the body of Etawah-grade does and become larger except for the hip height and chest width (Table 3). The smaller size of these variables could be related to the body surface area. The results found in this study correspond to the Bergmann's rule (Ray, 2016). The similarity of linear body parameters were withers height, hip height, chest width, and hip width (based on Fisher's discriminant analysis) since Etawah-grade does observed in this study originated from the same population source in Kaligesing. The results of this analysis were consistent with the results of principal component analysis that the withers height and hip height (Table 4) were the characteristics of Etawah-grade does, which according to Everitt & Dunn (1998), animal body shape was very interested for taxonomists. Kendall (1984) defined that the shape as a whole was a fixed geometric information at the same time when the location, scale, and rotation were altered. The genetic factors of Etawah-grade does observed had more influence on the body shape than body size. Hip height and chest width were not discriminant variables (based on Fisher's discriminant analysis).

Litter size of Etawah-grade does at BPTU-HPT Pelaihari was higher than that at Cordero farm (Table 5). This result supported the results reported by Tokolyi *et al.* (2014) stating that the specific effect of environmental variabilities affected body size and litter size of mammals. Mammals that live in a cooler environment at higher latitudes, had larger body sizes with smaller litter size so the annual fecundity was smaller than those live in the lower latitudes. The latitude of BPTU-HPT Pelaihari is lower than that of Cordero. The average litter size of Etawah-grade does observed was 1.62 heads birth^{-1}. Average litter size of Etawah-grade does at BPTU-HPT Pelaihari was larger than that at Cordero (Table 5). Praharani *et al.* (2016) reported that the litter size of goat PE was 1.46±0.09 heads birth^{-1}. According to Schai-Braun *et al.* (2017), animals that occupied a low latitude, have a large number of litter size with small size of litter, and *vice versa*. Smaller size of litter of Etawah-grade does at BPTU-HPT Pelaihari showed smaller volume with larger body surface area so that the ratio of surface area to its body volume was greater to release the body's heat load, whereas opposite case was occurred at Cordero farm where the surface area of litter was smaller to the body volume. The results of this study correspond to the Bergmann's rule (Tokolyi *et al.*, 2014; Ray, 2016).

The result in this study showed that the chest girth was the most elastic body size parameter to the litter size of Etawah-grade does observed (Table 6). Therefore, it is suggested that the selection strategy could be performed by selecting the chest girth in order to increase the litter size. Selection of chest girth of Etawah-grade does that highly correlated with litter size is recommended because of it easiness to be performed. The result of this study was consistent with the experimental result of Haldar *et al.* (2014) that reported the chest girth was the best discriminant factor for identifying productive goats of litter size, when compared to the abdominal circumference, neck length, spacing between major trochanter and udder bones, wide pelvic triangle area, shoulder height, and ear length. Martojo (2015) stated that indirect selection is conducted when direct selection of other trait is more difficult to be performed. Selection response per generation of litter size was small because it was a reproductive trait with has low heritability (h^2) value. The variation of litter size was low that caused this trait to be difficult to measure and select directly.

If chest girth of Etawah-grade doe observed increased by 1%, it is predicted that the doe will has a litter size 2.378% higher than the average population (Table 6). It means that if chest girth of the doe increased by 1 cm, it is predicted that the doe had a higher litter size of 0.0476 heads birth^{-1} than the average population. When chest girth selection of Etawah-grade does is conducted at BPTU-HPT Pelaihari and Cordero farm, then an increase 1 cm of chest girth resulted in an increase of 0.0545 and 0.0417 heads birth^{-1} in litter size of the does from the population average, respectively. Differential selection of litter size was due to selection of chest girth of Etawah-grade does observed at BPTU-HPT Pelaihari will be larger than that at Cordero farm, because the average litter size is larger. This selection strategy is in consistent with results reported by Haldar *et al.* (2014). The chest girth is positively correlated with body weight (Mule *et al.*, 2014). An increase in chest girth followed by increased body weight would simultaneously increase uterus volume to support an increase in the number and size of the litter, which in this study is specifically different at each farm because of geographical differences. The same statement was expressed by Hosseini *et al.* (2016) that the differences in morphology and differences between Turkoman, Kurdish and Caspian horses showed adaptation to different environments through phenotypic characterization and body biometric in 23 traits.

Linear Head Parameters and Litter Size

The head was part of the body of an animal that is less desirable by Etawah-grade goat breeder. Nevertheless, Baryshnikov & Puzachenko (2011) reported that studies of craniometric variability via multivariate approaches were conducted to determine the morphological similarity or inequality in animal taxa, so that animals could be grouped by the size of the head. According to Gomes & Valente (2016), the morphology of skull reflected the characteristics of population/individual, genetic distance, environmental influences and growth factors, so craniometric analysis was an important tool for such studies. The head is not important trait, however it has an important role because it related to body weight. Olopade & Onwuka (2008) suggested that physiological adaptation affected the measurement of osteometric skulls in Red Sokoto goats in Nigeria. The craniometric observation on Kejobong, Kacang, and Etawah-Grade goats was conducted by Suryani *et al.* (2013) through multivariate analysis (principal component and discriminant analyses). The result showed that the Kejobong goat was closer to Kacang goat than to Etawah-Grade goat. In this study, only one variable was found to be higher and more uniform at Pelaihari BPTU's does i.e., *nasion–rhinion* (Table 7) that could be associated with the respiratory process i.e., the inlet passage of the air through the nose. The other three variables of the linear head parameters i.e., lower jaw length, *tuber facial* left-right, and *entorbitale* left-right were larger but not as uniform as those at the Cordero farm (Table 7). These results indicated that the head size of Etawah-grade does at Cordero farm were more uniform.

The clustered data of head parameters of Etawah-grade does at BPTU-HPT Pelaihari were separated from those at Cordero farm (Figure 2). The difference occurred could be due to the artificial selection and natural selection that accompanied it. The Cordero farm was a commercial farm that requires a large-sized Etawah-grade does, which also had a larger head size than that at BPTU-HPT Pelaihari. Different geographical locations also supported indirect selection of head size. Katz *et al.* (2016) suggested that significant associations were found between the morphometric distance of the skull and the distance of ecological insignificance. Measurement of cranial vault breadth (the skull part occupied by the brain) showed a large linear relationship with climate.

The difference of head data clusterred of Etawah-grade does in Figure 2 is due to the determinant variables consisting of *basion-prosthion*, *facial tuber* left-right, *euryon* left-right, and *supraorbitale* left-right (based on Fisher's discriminant analysis). These discriminant variables were found to be larger in Etawah-grade does at Cordero farms, except for *tuber facial* left-right with more diverse conditions (Table 7) making it more likely to be selected toward larger sizes by nature at BPTU-HPT Pelaihari. It was selected by nature for larger size in Etawah-grade does at Pelaihari BPTU-HPT, which, along with *nasion-rhinion* and *entorbitale* left-right, lied in the corresponding areas to release the body's heat load through respiration (Table 7). The head size of Etawah-grade does at BPTU-HPT Pelaihari were smaller than those at Cordero farm (Figure 2), but had a higher head surface-to-head volume ratio, shown larger in *tuber facial* left-right, *nasion-rhinion,* and *entorbitale* left-right (Table 7) which is suggested related to the surface area of the Etawah-grade does'head. The thermoregulation process requires Etawah-grade does at BPTU-HPT Pelaihari to release the heat load through the surface of the head via respiration. The lower jaw length of Etawah-grade does at BPTU-HPT Pelaihari was also found to be larger, but not as a discriminant variable (based on Fisher's discriminant analysis). Warmer environmental conditions also requires Etawah-grade does of BPTU-HPT Pelaihari to have larger mandibular length because of the crude fiber content of gamal (*Gliricidia sepium*) consumed (Table 2). The result of Spearman correlation analysis between head's size score and litter size and between head's shape score and litter size were not significant. It was concluded that the linear head measurements was not related to litter size.

CONCLUSION

The Etawah-grade does at BPTU-HPT Pelaihari has smaller body size and head size and higher litter size than those at Cordero farm. In order to increase the litter size, chest girth can be used as an indirect selection criteria. The linear head measurements do not relate to the litter size of Etawah-grade does, but these associate with morphometric adaptations in each farm.

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