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Body Conformation Analysis through Biometric Traits in Borgou Cattle Breed Reared in on Station Conservation Farm in Northern Benin

Research Article

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ABSTRACT

With the view to study the body conformation in Borgou cattle breed, sixteen morphometric measurements were taken on 108 adult Borgou cattle reared at the Okpara breeding farm. The measured body parts were then subjected to a principal component analysis with Varimax rotation of the transformation matrix. The phenotypic correlation coefficients, mostly positive and significant, varied from -0.03 (canon perimeter and rump length) to 0.89 (back height and heigth at sacrum). Three components explaining 83% of the total variation were extracted. The first component explaining 35% of the total variation consisted of back height, height at withers, tail length, head width, rump length, pelvic width, head length, thurl width and canon perimeter in Borgou cattle. The second component (26% of the total variation) was influenced by hip width, body length and chest girth while the third component (22% of the total variation) highlighted the height at sacrum, shoulder width, distance between head until the ischium and chest width. The high values of the communalities (0.73 to 0.93) showed that the measurements strongly contributed to explain body conformation in Borgou cattle. The extraction of these three components can provide the basis for breeding and genetic improvement programs in Borgou cattle.

KEY WORDS cattle, morphometry, Okpara, principal component analysis, selection.

INTRODUCTION

The low productivity of local species is one of the fundamental reasons that often lead to crossbreeding with other breeds deemed more productive. However, these local species are likely to have morphological features which can be taken into account in selection and genetic improvement. The genetic improvement of native animal species is important given their adaptation to hard climatic conditions and their ability to resist disease (mainly trypanosomosis). They can also be valuable experimental animals in basic research and a potential reservoir of unique genes, which can be useful when environmental concerns require changes in the production system (Khargharia *et al.* 2015). In Benin, the Borgou breed is a taurine breed reared under four farming systems and one of these systems is represented by the Okpara Farm in the north of the country pertaining to the conservation and the genetic improvement of that breed (Worogo *et al.* 2019a). These cattle are particularly known for having combinations of genes and special adaptation characters such as resistance to diseases, adaptation to environmental conditions and also the promotion of poor quality fodder (Youssao *et al.* 2013; Worogo *et al.* 2019b). This breed constitutes an animal genetic heritage of Benin whose improvement in production potential is likely to increase the contribution of livestock farming to agricultural gross domestic product (GDP). But the lack of knowledge on the specific features of local breeds is considered as one of the main limits for their sustainable management (Mwai *et al.* 2015). In line with this, the study of body measurements through principal component analysis (PCA) is gradually perceived as an important selection tool for in-depth knowledge and genetic improvement purposes in animals (Congo *et al.* 2019; Silva-Jarquin *et al.* 2019; Putra *et al.* 2020). Morphometric measurements have been used to assess the characteristics of different animal breeds and could provide first-hand information on the animals' aptitude for selection (Yakubu, 2010; Banerjee *et al.* 2014; Popoola, 2015) and for other characterization studies using modern methods of molecular biology. Linear body measurements have become very useful in livestock research, since alternative body measurements and indices estimated from various combinations of conventional and unconventional body parameters provide not only a superior guide for weight but also serve as indicators of type and function in domestic animals (Pundir *et al.* 2011; Verma *et al.* 2015). Even if the analysis of variance and correlations are widely used to characterize the phenotypic and genetic relationships between animal body measurements, the analysis of the principal components is a precious refinement. This analysis transforms an original group of variables into another group, the principal components, which are linear combinations of the original variables. The direct goal of component analysis is to reduce a set of data so that it can be described and used easily. From the point of view of animal genetics and improvement, the principal components simultaneously consider a group of attributes that can be used for breeding purposes (Yakubu *et al.* 2009; Pundir *et al.* 2011; Boujenane, 2015). Similarly, the analysis of the principal components of zoometric measurements provides useful information for the racial diagnosis, the determination of somatic states, or to determine the sexual dimorphism of a breed, among others (Parés, 2009). It is noteworthy that there is no study pertaining to the use of morphometric features in the process of conservation and improvement of the Borgou cattle breed in its cradle and especially in on-station farm in Benin. Thus, this study aims to apply the PCA on Borgou cattle reared at the Okpara Breeding Farm in north Benin to explain their body conformation.

MATERIALS AND METHODS

Study area

This study was carried out at the Okpara breeding Farm (2˚ 39' and 2˚ 53' East longitude, 9˚ 6 'and 9˚ 21' North latitude) in the commune of Parakou, Republic of Benin. The climate is continental sudanian type with an alternation of rainy season (June to September) and dry season (December to March).

The transition from one season to the next is marked by a transition period (April to May and October to November). Annual precipitations averages range from 857.9 to 1413.9 mm.

Average temperatures (25.3 and 30.5 ˚C) vary very little during the year: high in March and April, low in December and January. The vegetation is characterized by wooded or shrubby savannas and old fallows overgrown by graminaceous formations.

Data collection

The data consisted of 16 different body measurements on 108 adult Borgou cattle (>48 months) reared at the Okpara breeding farm from November 2019 to January 2020. The age of the animals was determined from ear-tags and registration data available on the farm. No ethics approval was required when collecting data. Only adult Borgou cattle were included in this study to prevent the effect of age and gender (Pundir *et al.* 2011; Verma *et al.* 2015). Appropriate precautions were taken to avoid measuring unhealthy animals and pregnant females. When recording, special care was taken to measure the animal in a vertical position on the flat surface. All measurements were recorded by the same recorder to avoid effects between recorders. The circumference measurements were taken using a flexible "BAHCO" tape rule while the other measurements were taken using a measuring stick. Morphometric traits were recorded following the FAO (2011) guidelines to phenotypic characterization of animal genetic resources. The recorded traits were: back height (BH), height at withers (HW), tail length (TL), height at sacrum (HS), head length (HdL), rump length (RL), shoulder width (SW), pelvic width (PW), hip width (HipW), distance of head until the ischium (DHI), body length (BL), chest width (CW), head width (HdW), thurl width (TW), canon perimeter (CP), and chest girth (CG).

Statistical analysis

The main statistical values (mean, standard deviation and coefficient of variation) of each measurement were calculated. Correlation coefficients and variance-covariance values were also determined. From the variance-covariance matrix, data for the PCA were generated. The Kaiser-Meyer-Olkin (KMO) test on the adequacy of sampling and the Bartlett's test of sphericity were computed to establish the validity of the data set (the measure of KMO determines whether the model of common factor is appropriate). The KMO value greater than 0.5 is proved to be useful for a satisfactory analysis while the Bartlett test assesses whether the correlation matrix is an identity matrix or not (Parés-Casanova *et al.* 2013; Vohra *et al.* 2015).

The eigenvalues were obtained by spectral decomposition of the data matrix and classified in descending order of the corresponding eigenvalues, which is equivalent to the variance of the components. Thus, the first component has the greatest variance. To extract the number of components for the analysis, we applied the Kaiser rule (Johnson and Wichern, 1982) which stipulates that only the components having an eigenvalue greater than 1 are retained. Varimax rotation was used for the rotation of the main components by transforming the components to approximate a simple structure. The estimate of the communalities for each variable measures the proportion of variance of this variable explained jointly by all the other factors. All analyses were performed with R.3.6.2 software (R Core Team, 2019).

RESULTS AND DISCUSSION

Body measurements and phenotypic correlations in adult Borgou cattle

The body measurements recorded in adult Borgou cattle are presented in Table 1. The values of correlation coefficients between the biometric variables are reported in Table 2a and Table 2b.

The coefficients of variation observed on the biometric measurements varied from 7% (height at the sacrum, CG) to 20% (SW). The correlation coefficients varied from -0.03 (CP and RL) to 0.89 (BH and the HS). A total of 120 correlations were estimated and most of the variables were positively and significantly correlated ($P<0.01$; $P<0.001$) except correlations between SW and RL ($r=0.08$) and between CP and the RL ($r=-0.03$).

Principal component analysis

The measures of the adequacy of the sampling associated with the data (Kaiser-Meyer-Olkin test) was 0.91 and the Bartlett's test for sphericity was significant ($P<0.001$). The eigenvalues, the proportions of variance and rotated components obtained after the varimax rotation are presented in Table 3 and the scree plot is presented in Figure 1.

After the varimax rotation, three components were generated with a cumulative variance of 83%. The first component, which explained 35% of the total variance, included measurements such as BH, HW, TL, HdW, RL, PW, HdL, TW and CP. The second component combined HipW, BL and CG and explained 26% of the total variance. As for the third component, it highlighted HS, SW, DHI and CW while totaling 22% of the total variance. Estimates of the communalities were high and varied from 0.73 to 0.93.

Body measurements

The body traits observed in this study revealed that Borgou cattle reared in the Okpara breeding farm are small and compact. Measurements of BH (118.81 cm), HW (119.31 cm) and slightly lower than that of HS (122.43 cm), showing a rectilinear tendency of the part between the withers and the sacrum. Its head is much longer (42.08 cm) than it is wide (20.37 cm). It can be qualified as a dolichocephalic animal. The means of the measurements such as the HdL, HdW, BL are lower than those recorded on Borgou cattle by Traoré *et al.* (2015) who obtained values 42.08, 20.37 and 119.85 for these traits respectively. The mean value of the CG recorded in this study (154.78 cm) is higher than that obtained value of 142.0 cm by Traoré *et al.* (2015). The RL obtained in this study is similar to that obtained by these same authors on the Borgou breed. Furthermore, the measurements obtained in this study are lower than those reported by Traoré *et al.* (2016) for HdL (52.8 cm), HdW (23.4 cm), BL (135.3 cm), HW (123.1 cm), CG (162.2 cm) and the RL (44.1 cm) on the same breed in Benin. The values obtained for tail length in this study are higher than those obtained (93.0±5.8cm) by Traoré *et al.* (2015) on the Borgou breed in a traditional environment in Benin. However, these values are similar to those of Zebu Peul cattle (84.8±2.6 cm) with regard to the same authors. For this same measurement, the values obtained in this study on the Borgou breed are lower than those of the Gourounsi (94.1±2.0 cm), Lobi (87.3±3.2 cm) and Sanga (93.5±3.1 cm) breeds but higher than those of Zébu Azawak cattle. (74.8±5.3), Zebu Mbororo (74.8±4.3), N'Dama (61.7±4.4 cm) and Lagunaire (52.2±3.4 cm) according to these same authors.

The values obtained in this study for BL, HW and CG in Borgou cattle are lower than those reported by Pundir *et al.* (2011) on Kankrej cows with values 123.44 ± 7.46 cm; 124.49 ± 5.64 cm and 162.56 cm ± 11.29 respectively for the mentioned traits. Borgou cattle also present a shorter head than Kankrej cattle (42.08±4.06 *vs.* 44.09±2.01 cm) but have a larger head than Kankrej cattle (20.37±1.80 cm *vs.* 15.91±1.05 cm).

Compared to the values reported on adult Gojri buffaloes by Vohra *et al.* (2015), adult Borgou cattle have smaller measurements for HW (119.31±11.28 cm *vs.* 128.66±0.32 cm), BL (119.85±9.82 cm *vs.* 195.91±0.67 cm), CG (154.78±11.40 cm *vs.* 213.91±1.34 cm), HdW (20.37±1.80 cm *vs.* 22.33±0.09 cm) and HdL (42.08±4.06 cm *vs.* 48.58±0.11 cm). Compared to Pasundan cows (Putra *et al.* 2020), Borgou cattle have similar values for HW (119.31±11.28 cm *vs.* 119.55±8.37 cm), BL (119.85±9.82 cm *vs.* 120.82±14.79 cm) and CW (30.35±2.45 cm *vs.* 29.26±3.67 cm). In contrast, Borgou cattle have a larger chest than Pasundan cows (154.78±11.40 cm *vs.* 136.67±10.76 cm), a longer rump (38.33±4.99 cm *vs.* 31.26±4.99 cm) and a larger rump (41.06±4.49 cm *vs.* 32.95±4.44 cm).

Table 1 Descriptive statistics of body measurements in Borgou cattle

Body measurement	Mean (cm)	SD	CV (%)
BH	118.81	10.71	9
HW	119.31	11.28	9
TL	84.69	6.66	12
HS	122.43	9.05	7
HdW	20.37	1.80	9
RL	38.33	4.99	13
SW	62.56	12.59	20
PW	21.94	2.68	12
HipW	41.06	4.49	11
DHI	151.61	17.65	12
HdL	42.08	4.06	10
CW	30.35	2.45	8
BL	119.85	9.82	8
TW	51.46	4.26	8
CP	17.95	2.45	14
CG	154.78	11.40	7

HW: height at withers; BH: back height; HS: height at sacrum; TL: tail length; DHI: distance of head until the ischium; BL: body length; RL: rump length; HdL: head length; SW: shoulder width; CW: chest width; HipW: hip width; TW: thurl width; PW: pelvic width; HdW: head width; CG: chest girth; CP: canon perimeter; SD: standard deviation and CV: coefficient of variation.

SD: standard deviation and CV: coefficient of variation.

The coefficients of variation varied from 7% (HS and CG) to 20% (SW) in this study and the majority of measurements showed low variability, which indicates that Borgou cattle are almost similar in body size and this could be attributed to a low degree of environmental effects (drought, climate change…) and the same condition of all animals. The greater variability observed for shoulder width could be due to the fact that this measurement is much more influenced than other measurements by management practices such as traction. In fact, the Borgou cattle present at the Okpara breeding farm come from populations of the Borgou breed initially raised in extensive farming system. In this system, it's well known that these cattle are very often used for animal-drawn cultivation (Youssao *et al.* 2013; Worogo *et al.* 2019a) and during this activity the shoulders are more subject to the impact of the plough. Observations related to variation in body traits have been reported by Vohra *et al.* (2015) who observed a greater variability for horn length (19.41%) and the distance between pin bone (17.05%) in buffaloes.

Phenotypic correlations

The highest positive correlation between body measurements in Borgou cattle was recorded between BH and HS (0.89), while the lowest positive correlation was observed between SW and the RL. On the other hand, the only negative and non-significant correlation was observed between the CP and RL. The differences in correlation estimates between body measurements could be attributed to the fact that body development does not take place proportionately in all organs of the body.

These observations differ with regard to the breeds and the measurements taken into account according to the authors. For example, Vohra *et al.* (2015) observed a greater positive correlation between the height at withers and body length (0.77) and a lower negative correlation between tail length and the Paunch girth (-0.58). Regarding Verma *et al.* (2015), the correlations varied from -0.15 (ear length-Pin to pin distance) to 0.98 (wither heigth-paunch girth). The present study highlighted that most (approximately 98%) of the correlations between body measurements were positive and significant in Borgou cattle. Authors such as Pundir *et al.* (2011), Verma *et al.* (2015) and Vohra *et al.* (2015) also observed that a large proportion of the correlations (more than 75%) between measurements were positive and significant respectively in Kankrej cows, local hill cattle and adult Gojri buffaloes.

Principal component analysis

In this study, we obtained a KMO value of 0.91. This value fits with the acceptable threshold criterion of KMO (>0.5) before proceeding with a PCA analysis. This value highlighted the degree of variance in the sixteen body traits in Borgou cattle with regard to the components. The value of the KMO test obtained in this study (0.91) is higher than that obtained by Vohra *et al.* (2015) who reported a value of 0.74 on Gojri buffaloes in India. On the other hand, Pundir *et al.* (2011) reported similar estimates of sampling adequacy (0.89) in Kankrej cows as well as Yakubu *et al.* (2009) who reported estimates of sampling adequacy of 0.90 and 0.92 in age groups 1.5 to 2.4 and 2.5 to 3.6 years in White Fulani cattle.

Table 2a Correlations among biometric traits

Item	HW	BH	HS	TL	DHI	BL	RL	HdL
HW	1.00	-	-	-	-	-	-	-
BH	0.86***	1.00	-	-	-	-	-	-
HS	0.86***	0.89***	1.00	-	-	-	-	-
TL	0.64***	0.61***	0.61***	1.00	-	-	-	-
DHI	0.81***	0.84***	0.85***	0.51***	1.00	-	-	-
BL	0.66***	0.62***	0.65***	0.39***	0.76***	1.00	-	-
RL	0.42***	0.56***	0.51***	0.66***	0.53***	0.48***	1.00	-
HdL	0.72***	0.81***	0.80***	0.63***	0.77***	0.67***	0.62***	1.00
SW	0.74***	0.63***	0.61***	0.54***	0.57***	0.26**	0.08	0.48***
CW	0.59***	0.56***	0.54***	0.63***	0.54***	0.34***	0.58***	0.53***
HipW	0.88***	0.84***	0.86***	0.68***	0.83***	0.68***	0.43***	0.82***
TW	0.67***	0.55***	0.61***	0.70***	0.58***	0.47***	0.54***	0.58***
PW	0.79***	0.67***	0.72***	0.55***	0.66***	0.57***	0.31**	0.59***
HdW	0.80***	0.77***	0.75***	0.58***	0.83***	0.73***	0.56***	0.70***
CG	0.83***	0.81***	0.82***	0.54***	0.84***	0.63***	0.44***	0.73***
CP	0.73***	0.56***	0.57***	0.43***	0.54***	0.38***	-0.03	0.40***

HW: height at withers; BH: back height; HS: height at sacrum; TL: tail length; DHI: distance of head until the ischium; BL: body length; RL: rump length; HdL: head length; SW: shoulder width; CW: chest width; HipW: hip width; TW: thurl width; PW: pelvic width; HdW: head width; CG: chest girth and CP: canon perimeter.
*** (P<0.001).
SD: standard deviation and CV: coefficient of variation.

Table 2b Correlation among biometric traits

Item	SW	CW	HipW	TW	PW	HdW	CG	CP
SW	1.00	-	-	-	-	-	-	-
CW	0.50***	1.00	-	-	-	-	-	-
HipW	0.77***	0.59***	1.00	-	-	-	-	-
TW	0.58***	0.63***	0.72***	1.00	-	-	-	-
PW	0.71***	0.42***	0.81***	0.65***	1.00	-	-	-
HdW	0.59***	0.55***	0.82***	0.65***	0.76***	1.00	-	-
CG	0.64***	0.54***	0.85***	0.54***	0.68***	0.73***	1.00	-
CP	0.82***	0.31**	0.73***	0.39***	0.74***	0.62***	0.62***	1.00

SW: shoulder width; CW: chest width; HipW: hip width; TW: thurl width; PW: pelvic width; HdW: head width; CG: chest girth and CP: canon perimeter.
*** (P<0.001).

After the varimax rotation of the matrix of the components, three factors (with eigenvalues greater than 1) with a variance ratio of 83% were extracted for Borgou cattle breed in this study. This shows that for Borgou cattle, taking these three factors into account is largely sufficient to identify the groups of variables necessary to improve the genetic performance of this breed. A view of the literature shows that the number of components extracted in the description of conformation in cattle varies depending on the studies. For example, Pundir *et al.* (2011) extracted three components with a cumulative variance of 66.02% in Kankrej cows; Parés-Casanova *et al.* (2013) extracted two components with a cumulative variance of 65.8% in Pallaresa cows while Vohra *et al.* (2015) extracted four components from Gojri buffaloes in India for a cumulative variance of 70.9%.

In this study, the large communalities which represents the proportion of variance of each of the 16 variables were high (0.73-0.93) in Borgou cattle. These communalities are obtained from the correlation matrix and they indicate that a large number of variances were shared by the variables, allowing the PCA to classify them. These values also indicated that the measurements effectively contributed to explain body conformation in Borgou cattle. These variations are higher than those observed by Boujenane (2015) on Oulmes-Zaer cattle (0.28 to 0.82) and Tidili cattle (0.25 to 0.79). These communalities are also higher than those reported by Pundir *et al.* (2011) on Tolenkhomba *et al.* (2012) in local cows in Manipur.

In the present study, the variables loaded most heavily on the first component were BH, HW, TL, HdW, RL, PW, HdL, TW and CP.

Table 3 Variances explained by the factors and rotated component (RC)

Component initial eigenvalues loading				Rotated component (RC) after the varimax rotation				
Factors	Eigenvalues	Variance	CumVar	Traits	RC1	RC2	RC3	Communality
1	10.59	66.21	66.21	BH	0.62	0.61	0.37	0.89
2	1.62	10.13	76.34	HW	0.72	0.40	0.38	0.83
3	1.08	6.74	83.08	TL	0.73	0.43	0.36	0.85
4	0.57	3.55	86.63	HS	0.26	0.31	0.80	0.80
5	0.43	2.67	89.30	HdW	0.82	0.35	0.29	0.88
6	0.33	2.08	91.38	RL	0.88	0.10	0.13	0.80
7	0.27	1.70	93.08	SW	0.51	-0.27	0.75	0.89
8	0.22	1.37	94.45	PW	0.74	0.21	0.45	0.79
9	0.21	1.29	95.75	HipW	0.17	0.89	0.30	0.91
10	0.19	1.16	96.91	DHI	0.22	0.25	0.79	0.73
11	0.12	0.77	97.68	HdL	0.63	0.61	0.40	0.93
12	0.10	0.63	98.32	CW	0.28	0.38	0.71	0.74
13	0.09	0.56	98.88	BL	0.48	0.68	0.27	0.77
14	0.08	0.51	99.38	TW	0.70	0.42	0.37	0.80
15	0.07	0.43	99.81	CP	0.69	0.49	0.28	0.80
16	0.03	0.19	100.00	CG	0.29	0.90	0.03	0.89
				SS loadings	5.57	4.13	3.59	-
				PropVar	0.35	0.26	0.22	-
				CumulVar	0.35	0.61	0.83	-
				PropExpl	0.42	0.31	0.27	-
				CumProp	0.42	0.73	1.00	-

BH: back height; HW: height at withers; TL: tail length; HS: height at sacrum; HdW: head width; RL: rump length; SW: shoulder width; PW: pelvic width; HipW: hip width; DHI: distance of head until the ischium; HdL: head length; CW: chest width; BL: body length; TW: thurl width; CP: canon perimeter and CG: chest girth.

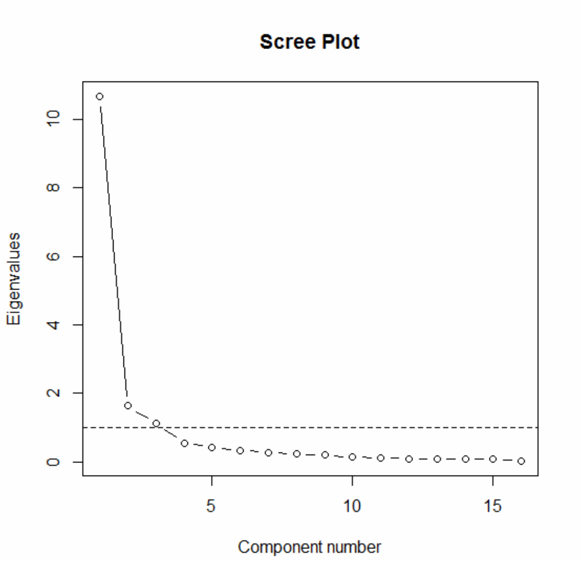

Figure 1 Scree plot of components and eigen values

On the second component, it was HipW, BL and CG and the third component was influenced by HS, SW, DHI and CW in Borgou cattle. Regarding the PCA classification, the main extracted components grouped on both sides the measurements of size and shape in Borgou cattle. The improvement of body traits related to shape and size may be more efficient in the selection criteria within Borgou cattle.

For other authors (Yakubu *et al.* 2009; Pundir *et al.* 2011; Boujenane, 2015), the first component most often reflects the general body size.

For Pundir *et al.* (2011), the second factor explains the morphology of the head and the third factor explains the posterior part in Kankrej cows. Boujenane (2015) reported that in Oulmes-Zaer Tidili cattle, components 2 and 3 described the shape of the body and the size of the head, respectively.

In Vohra *et al.* (2015), the first factor was linked to the size of the Gojri buffalo, the second factor highlighted Hip bone, the length of the tail and the length of the ears; the third factor was closely linked to Paunch girth, Pin bone distance and Tail length up to switch; and a fourth factor described the characteristics of the tail. These differences show that each breed has its own characteristics and the selection measures must take into account the specificity of each breed.

CONCLUSION

In general, the use of PCA in this study allowed to explore the interdependence in the originally considered sixteen body traits in Borgou cattle through a simultaneous analysis. Based on our findings, the use of the first three main components derived from PCA may be more reliable in explaining body conformation in adult Borgou cattle instead of considering the body traits individually. Thus, these components could be exploited in the evaluation and comparison of animals and provide criteria to select animals on the basis of a small group of characters rather than individual characters. The characterization of Borgou cattle breed in this study will be a useful tool to scientists and cattle farmers in the process of conservation and improvement of this local breed which undergoes severe cross-breeding in its cradle.

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