World Journal of Biology Pharmacy and Health Sciences
eISSN: 2582-5542
Cross Ref DOI: 10.30574/wjbphs
Journal homepage: https://wjbphs.com/

(RESEARCH ARTICLE)

Check for updates

Phenotypic Diversity and Production Characteristics of Bali Cattle in Bali Province

Olivia Gidi Ika Putri [1], Dewi Ayu Warmadewi [1,*], Hary Suhada [2], I Nyoman Agus Aryawan [1], Inggita Leli Murtika [1] and Ni Putu Yundari Melati [1]

[1] *Faculty of Animal Husbandry, Udayana University, Bali, Indonesia.*
[2] *Animal Breeding and Genetics Division, Ministry of Agriculture, Republic of Indonesia.*

World Journal of Biology Pharmacy and Health Sciences, 2026, 25(02), 315-324

Publication history: Received on 09 January 2026; revised on 21 February 2026; accepted on 23 February 2026

Article DOI: https://doi.org/10.30574/wjbphs.2026.25.2.0116

Abstract

This study aimed to examine the phenotypic diversity and production trait characteristics of Bali cattle in Bali Province across three regencies/cities. Observations were conducted on qualitative traits, including head shape, muzzle, hooves, leg color, body color, dorsal stripe, tail switch hair color, and horn characteristics. Quantitative production traits body length, shoulder height, and chest girth were measured directly in both females and males. Animals were grouped by age into I0 (6–12 months), I1 (>12–18 months), I2 (>18–24 months), and I3 (>24–36 months). Results showed low to moderate coefficients of variation for quantitative traits, ranging from 5.21% to 11.35% in females and 3.59% to 13.32% in males, indicating a relatively homogeneous population with limited genetic variation, possibly influenced by restricted gene flow, inbreeding, and farmer selection practices. Qualitative traits were consistent with typical breed characteristics. Females were predominantly reddish across all age groups, while males exhibited a color transition from reddish-brown at younger ages to blackish at maturity. Additional characteristic features included a distinct black dorsal stripe (more prominent at younger ages), white coloration on all four lower legs, black tail switch hair, grayish-black horns, and a compact head shape, conforming to the Indonesian National Standard (SNI) 7651-4:2023. Overall, the observed population retains the phenotypic characteristics of purebred Bali cattle and remains suitable for breeding purposes.

Keywords: Bali cattle; Coefficient of variation; Characteristics; Phenotypic; Production traits

1. Introduction

Bali cattle are the result of domestication of the indigenous Indonesian banteng (*Bos javanicus*) and have been officially recognized as one of Indonesia's native animal genetic resources [1]. They represent an important national genetic asset that must be conserved and sustainably developed. Bali cattle have been widely acknowledged for their adaptive ability to tropical environments and their contribution to the national beef supply. This breed is also reported to possess several production advantages, including high reproductive efficiency [2], favorable carcass percentage reaching 46–50% [3,4], and good meat quality [5]. These characteristics make bali cattle highly valuable for both breeding and meat production systems in Indonesia.

Despite these advantages, recent reports indicate a decline in bali cattle population in Bali Province. Official data show that the cattle population decreased from 558,463 head in 2021 to 380,559 head in 2023, representing a decline of 31.8% [6]. In addition to population decline, indications of genetic deterioration have been reported, including increasing difficulty in finding individuals with slaughter weights exceeding 500 kg [7]. Such conditions may be associated with uncontrolled selection, repeated use of related breeding stock, and restricted gene flow.

* Corresponding author: Dewi Ayu Warmadewi.

Phenotypic characterization, including both qualitative and quantitative traits, plays a fundamental role in livestock breeding and conservation programs. Accurate morphometric evaluation following national standards is essential to determine the production potential of breeding stock [8]. Previous studies have demonstrated that morphometric traits, particularly chest girth and body length, are strongly associated with growth performance and body weight [9–11]. However, comprehensive and updated information regarding phenotypic diversity and production characteristics of bali cattle across age groups in Bali Province remains limited.

Therefore, this study was conducted to examine the phenotypic diversity and production trait characteristics of bali cattle in Bali Province across different age classes and sexes as a scientific basis for structured breeding and conservation strategies.

2. Materials and Methods

2.1. Study Area and Duration

The study was conducted from May to July 2025 in three administrative regions of Bali Province, Indonesia: Karangasem Regency, Tabanan Regency, and Denpasar City. These regions were selected purposively to represent areas with high, medium, and low bali cattle populations within the province, respectively.

2.2. Study Population and Sampling Design

The study population consisted of bali cattle raised in Bali Province. A multi-stage sampling approach was applied. First, regencies were selected using purposive sampling based on official cattle population data to represent different population densities. Second, sub-districts with relatively high bali cattle populations were selected within each regency. Third, quota sampling was used to determine the number of animals sampled proportionally to the population size in each selected sub-district.

The required sample size was calculated using the Slovin formula:

$$n = \frac{N}{(1+Ne^2)}$$

where:
n = sample size
N = total population
e = margin of error

Animals were classified based on sex (male and female) and age group determined by dentition as follows:

I0 (6–12 months)
I1 (>12–18 months)
I2 (>18–24 months)
I3 (>24–36 months)

2.3. Data Collection

Quantitative Traits: Primary data were obtained through direct morphometric measurements under field conditions. The production traits measured included:

Body length (cm)
Shoulder height (cm)
Chest girth (cm)

Measurements were performed on standing animals positioned on level ground. Body length was measured from the point of the shoulder (scapula) to the pin bone using a flexible measuring tape. Shoulder height was measured vertically from the highest point of the withers to the ground using a measuring stick. Chest girth was measured circumferentially just behind the forelegs using a measuring tape. All measurement procedures followed the standards described in SNI 7651-4:2023 (Bali Beef Cattle Breeding Standard) [2].

Qualitative Traits: Qualitative phenotypic traits were assessed through direct visual observation and recorded systematically. The observed characteristics included:

- Head shape
- Body coat color
- Leg color
- Presence and clarity of dorsal stripe
- Tail switch hair color
- Horn color and morphology
- Qualitative criteria were evaluated in accordance with breed standards described in SNI 7651-4:2023.
- Supporting Data

Additional information regarding management practices was collected through structured questionnaires administered to cattle owners to ensure relative uniformity of management conditions across sampled animals.

2.4. Research Variables

- Age group was treated as the independent variable.
- Dependent variables included:
- Body length
- Shoulder height
- Chest girth
- Qualitative phenotypic characteristics
- Coefficient of variation

Sex was used as a grouping factor in the descriptive analysis. Management practices were considered as control variables, and feeding systems were assumed to be relatively similar based on field verification.

2.5. Statistical Analysis

Data were grouped according to sex and age class (I0–I3). Statistical analysis was performed descriptively.

For each production trait within each sex and age group, the following parameters were calculated:

- Number of animals (N)
- Mean ($\bar{X}$)
- Standard deviation (SD)
- Coefficient of variation (CV)

The mean was calculated using the formula:

$$\bar{X} = \frac{\sum X}{n}$$

Where:
$\bar{X}$ = mean value
$\sum x$= total observed values
N = number of animals

The coefficient of variation was calculated as:

$$CV = \frac{S}{X} \times 100\%$$

The analysis aimed to describe phenotypic variability and production trait characteristics across age and sex groups. No inferential statistical tests were applied, as the objective of the study was population characterization rather than hypothesis testing.

2.6. Ethical Considerations

This study was designed as a non-invasive field-based observational study involving only external morphometric measurements and visual phenotypic assessments of bali cattle. No experimental treatments, invasive procedures, biological sampling, or physical interventions were performed.

The research was conducted under official institutional authorization issued by the university and formally addressed to the respective Regional Agricultural and Livestock Offices in Bali Province. Field activities were carried out in coordination with designated government livestock officers who supervised and assisted the data collection process to ensure compliance with regional livestock regulations and standard animal handling practices.

Prior to measurement, verbal consent was obtained from cattle owners. All procedures were conducted in accordance with established principles of animal welfare and good livestock management practices. Under these conditions, formal approval from an institutional animal ethics committee was not required.

3. Results and Discussion

3.1. Quantitative Production Traits

The descriptive statistics of body length, shoulder height, and chest girth of bali cattle in Bali Province are presented in Table 1 (female) and Table 2 (male).

3.2. Female Bali Cattle

Table 1 Coefficient of variation of morphometric traits of female bali cattle by age group

Morphometric traits	**Age Structure**							
	I0		I1		I2		I3	
	N	CV (%)	N	CV (%)	N	CV (%)	N	CV (%)
Body length (cm)	40	7.37	47	7.04	26	6.29	58	7.24
Shoulder height (cm)		9.78		6.21		6.34		5.21
Chest girth (cm)		5.54		11.35		6.88		5.81

Footnote: N = Livestock number; CV = Coefficient of variation; I0 = 6-12 month; I1= <12-18 month; I2= <18-24 month; I3= <24-36 month

The coefficient of variation (CV) of quantitative traits in female bali cattle ranged from 5.21% to 11.35%, indicating low to moderate variability. According to genetic variability classification, CV values below 15% reflect a relatively homogeneous population structure [10]. Similar morphometric variability has been reported in bali cattle breeding centers, where dispersion values were also categorized as moderate [9].

Among the measured traits, chest girth showed relatively higher variability compared to body length and shoulder height. Greater standard deviation indicates higher phenotypic dispersion, which may provide better opportunity for selection response within the population [11]. Chest girth is widely recognized as a strong predictor of body weight and growth performance in beef cattle [18], making it an effective selection parameter in female breeding stock.

Table 2 Mean and standard deviation of morphometric traits of female bali cattle by age group

Morphometric traits	Age Structure											
	I0			I1			I2			I3		
	N	X	SD	N	X	SD	N	X	SD	N	X	SD
Body length (cm)	40	103.5	7.62	47	110.55	7.78	26	117.5	7.39	58	118.79	8.60
Shoulder height (cm)		98.52	9.64		107.61	6.68		112.73	7.14		115.58	6.03
Chest girth (cm)		125	6.92		141	16.01		151.76	10.45		156.41	9.09

Footnote: N= Livestock number; X = Mean; SD = standard deviation; I0= 6-12 month; I1= <12-18 month; I2= <18-24 month; I3 = <24-36 month

Mean values of body length, shoulder height, and chest girth increased consistently across age groups, indicating normal skeletal growth patterns. All average measurements exceeded the minimum standards established in the national breeding guidelines for bali cattle [8]. This finding suggests that the observed female population meets phenotypic requirements for breeding purposes. Stable growth until physiological maturity in bali cattle has also been previously documented [12]. Furthermore, shoulder height and chest girth are closely related to carcass yield and body capacity [13], supporting the productive potential of the female population observed in this study.

The relatively low variability observed in female cattle may be associated with restricted gene flow and structured conservation policies implemented in Bali Province to preserve breed purity [16]. While such policies protect genetic identity, limited introduction of new breeding stock may increase the probability of inbreeding in closed populations [13]. Molecular studies have also reported relatively narrow genetic diversity in bali cattle populations [15], which is consistent with the homogeneous morphometric patterns identified in this study.

Nevertheless, despite limited variability, the morphometric performance of female bali cattle remained above national standards [8], indicating maintained genetic potential and good adaptation to local environmental conditions.

3.3. Male Bali Cattle

Table 3 Coefficient of variation of morphometric traits of male bali cattle by age group

Morphometric traits	Age Structure							
	I0		I1		I2		I3	
	N	CV (%)	N	CV (%)	N	CV (%)	N	CV (%)
Body length (cm)	30	7.96	36	8.59	22	5.51	23	3.97
Shoulder height (cm)		6.77		7.19		5.06		3.59
Chest girth (cm)		8.48		8.69		13.32		10.03

Footnote: N = Livestock number; CV= Coefficient of variation; I0= 6-12 month; I1= <12-18 month; I2 = <18-24 month; I3= <24-36 month

The coefficient of variation (CV) of quantitative traits in male bali cattle also ranged within low to moderate categories, indicating relatively limited phenotypic variability within the male population. CV values below 15% are generally classified as low variability and reflect a relatively homogeneous population structure [10]. This pattern suggests that the observed male population exhibits a uniform morphometric profile.

Similar to females, chest girth in males showed relatively higher variability compared to body length and shoulder height. Greater dispersion in chest girth indicates the presence of measurable differences in body capacity among individuals. Since chest girth is strongly correlated with body weight and growth performance in beef cattle [18], this trait may serve as an effective selection criterion in identifying superior breeding bulls. Even within a relatively homogeneous population, variation in chest girth provides an opportunity for within-breed improvement.

Table 4 Mean and standard deviation of morphometric traits of male bali cattle by age group

Morphometric traits	Age Structure											
	I0			I1			I2			I3		
	N	X	SD	N	X	SD	N	X	SD	N	X	SD
Body length (cm)	30	103.06	8.20	36	105.58	9.07	22	121.5	6.69	23	124.43	4.94
Shoulder height (cm)		104.43	7.07		110.11	7.92		123.77	6.26		127.34	4.57
Chest girth (cm)		133.26	11.30		145.19	12.63		154.54	20.59		162.65	16.32

Footnote: N = Livestock number; X= Mean; SD= standard deviation; I0= 6-12 month; I1= <12-18 month; I2= <18-24 month; I3= <24-36 month

Mean values of body length, shoulder height, and chest girth in males increased progressively across age groups, reflecting normal skeletal and muscular growth patterns. As expected, absolute morphometric values in males were consistently higher than in females of corresponding age classes, indicating normal sexual dimorphism. Testosterone plays a key role in stimulating skeletal growth and muscle development, resulting in larger body dimensions in males [23]. Similar findings regarding greater morphometric measurements in male bali cattle have been reported in other production regions [20–22].

All average measurements of male bali cattle exceeded the minimum requirements specified in the national breeding standards [8], indicating that the evaluated male population fulfills phenotypic criteria for breeding stock. Stable growth patterns toward physiological maturity have also been reported in previous studies of Bali cattle [12], supporting the consistency of the current findings.

The relatively low variability observed in males may be influenced by restricted gene flow and breeding management practices in Bali Province. Conservation regulations aimed at preserving breed purity limit the introduction of external genetic material [16]. While such policies protect genetic identity, restricted breeding systems may increase the probability of inbreeding in closed populations [13]. Molecular studies have also reported relatively narrow genetic diversity in Bali cattle populations [15], which aligns with the morphometric homogeneity identified in the male population.

Nevertheless, despite the relatively limited phenotypic variability, morphometric performance remained above national standards [8], indicating that the male population retains favorable production potential and adequate adaptability under local environmental conditions.

The low phenotypic variability observed in both sexes may be linked to structural and regulatory factors. The Province of Bali enforces regulations restricting the introduction of external cattle to preserve genetic purity, including Governor Regulation Number 45/2004 and Regional Regulation Number 10/2017 concerning bali cattle conservation.

While these policies aim to protect bali cattle as a national genetic resource, they also limit gene flow. [13] explained that restricted gene flow increases the probability of inbreeding in closed populations. Molecular studies by [15] reported relatively narrow genetic variation and reduced heterozygosity in bali cattle populations, supporting the possibility that long-term population isolation contributes to limited phenotypic dispersion.

In addition, traditional farmer-based selection without pedigree recording may result in repeated use of closely related breeding stock, further narrowing genetic diversity [9]. These structural and management factors likely explain the relatively homogeneous morphometric traits observed in this study. Nevertheless, despite low variability, morphometric values remain above national standards, indicating that genetic potential and adaptation to the local environment remain favorable.

3.4. Qualitative Phenotypic Characteristics

3.4.1. Female Bali Cattle

The qualitative characteristics of female bali cattle (Table 5) showed strong conformity to breed standards. Reddish body color was dominant and increased with age, while brown coloration decreased. All animals displayed clear dorsal stripes, white lower-leg markings, black tail switch hair, compact head conformation, and horn presence.

Table 5 Percentage distribution of qualitative traits in female Bali cattle by age group

Qualitative Trait	**Age Structure**			
	I0	I1	I2	I3
Coat color (%)				
Brick red	67.5	80.9	84.6	86.6
Dark brown	32.5	19.1	15.4	13.4
Dorsal line (%)				
Present	100%	100%	100%	100%
Absent	-	-	-	-
Lower leg color (%)				
White (socks)	100%	100%	100%	100%
Not white	-	-	-	-
Tail switch color (%)				
Black	100%	100%	100%	100%
Brown	-	-	-	-
Head shape (%)				
Proportional	100%	100%	100%	100%
Small	-	-	-	-
Dewlap (%)				
Present	100%	100%	100%	100%
Absent	-	-	-	-

Footnote: I0= 6-12 month; I1= <12-18 month; I2= <18-24 month; I3= <24-36 month

Qualitative traits in female Bali cattle were highly consistent with breed standards. Reddish coat color was dominant across all age groups and became more intense with increasing age. This characteristic aligns with classical descriptions of Bali cattle phenotypes [23].

Limited variation in coat color expression may be associated with restricted gene flow and strong conservation practices [15,16]. The uniformity of qualitative traits observed confirms that the female population retains phenotypic characteristics consistent with official breed descriptors.

Other distinctive features such as a clearly defined dorsal stripe, white coloration on the lower legs, black tail switch hair, greyish-black horns, and proportional head conformation were consistently expressed. These findings further support the maintenance of phenotypic integrity in the observed female population.

3.5. Male Bali Cattle

In male bali cattle (Table 6), coat color exhibited clear age-related transformation. Younger males (I0) predominantly showed brown or reddish coloration, similar to females. From I1 onward, black coloration became dominant (83.3% in I1 and 87% in I3).

Table 6 Percentage distribution of qualitative traits in male bali cattle by age group.

Qualitative Trait	**Age Structure**			
	I0	I1	I2	I3
Coat color (%)				
Brick red	46.7%	-	5.6%	-
Dark brown	53.3%	16.7%	22.2%	13%
Black	-	83.3%	72.2%	87%
Dorsal line (%)				
Present	100%	100%	100%	100%
Absent	-	-	-	-
Lower leg color (%)				
White (socks)	100%	100%	100%	100%
Not white	-	-	-	-
Tail switch color (%)				
Black	100%	100%	100%	100%
Brown	-	-	-	-
Head shape (%)				
Proportional	100%	100%	100%	100%
Small	-	-	-	-
Dewlap (%)				
Present	100%	100%	100%	100%
Absent	-	-	-	-

Footnote: I0= 6-12 month; I1= <12-18 month; I2= <18-24 month; I3= <24-36 month

Male bali cattle demonstrated a distinct age-related coat color transformation. Younger males exhibited reddish-brown coloration, which gradually changed to predominantly black at maturity. This transformation is a well-documented characteristic of Bali cattle and is attributed to androgen-mediated stimulation of melanin production [23].

The clear differentiation in coat color between young and mature males supports its use as an indicator of sexual maturity and hormonal development. Similar qualitative patterns have been documented in previous morphometric studies of bali cattle populations [20–22].

Other qualitative characteristics, including dorsal stripe presence, white lower-leg markings, black tail switch hair, horn color, and compact head shape, were consistently observed across male age groups. The stability of these traits indicates strong breed conformity and suggests that the male population remains phenotypically pure and aligned with national standards [8,16].

The findings demonstrate that bali cattle in Bali Province:

- Exhibit low but sufficient phenotypic variability.
- Maintain morphometric values exceeding national breeding standards.
- Show consistent sexual dimorphism patterns.
- Retain strong conformity to breed-specific qualitative characteristics.

Although regulatory protection may contribute to reduced genetic variability, the population still displays favorable growth performance and breed integrity. Therefore, structured within-breed selection, particularly targeting chest girth

due to its higher variability and strong correlation with body weight, may enhance productivity while preserving genetic identity.

4. Conclusion

The present study confirms that bali cattle in Bali Province exhibit low to moderate phenotypic variability in quantitative traits, reflecting a relatively homogeneous population likely influenced by restricted gene flow and closed breeding systems. Despite limited variability, morphometric measurements consistently met or exceeded national breeding standards, indicating maintained production potential.

Qualitative characteristics remained highly consistent with established breed descriptors, including typical coat color patterns, dorsal stripe, white leg markings, horn characteristics, and head conformation. These findings demonstrate that the population retains strong phenotypic integrity as pure bali cattle.

Overall, the documented uniformity and conformity to breed standards highlight the continued viability of bali cattle in their native region as a valuable genetic resource. The population remains suitable for structured within-breed selection and sustainable conservation programs aimed at preserving and improving this indigenous cattle breed.

Compliance with ethical standards

Acknowledgments

The authors would like to express their sincere gratitude to the Rector of Universitas Udayana for the opportunity and institutional support provided to conduct this research. Profound appreciation is also extended to the Dean of the Faculty of Animal Husbandry, Universitas Udayana, for granting permission and facilitating the implementation of this study. The authors further acknowledge the valuable support of the Livestock Services of Tabanan Regency, Karangasem Regency, and Denpasar City, including their livestock officers, for administrative assistance, coordination, and direct involvement in field data collection and measurement activities. The authors also sincerely thank all farmers and other parties who directly or indirectly contributed to the successful completion of this research.

Disclosure of conflict of interest

We declare that there is no conflict of interest with any financial organization related to the material discussed in this paper.

References

[1] DGLS. National report on animal genetic resources Indonesia. Jakarta: Directorate General of Livestock Services; 2003.

[2] Gunawan A, Ronjali E. Improvement of quality and population of Bali cattle to support national food security. Prosiding Seminar Nasional ISMAPETI; 2010.

[3] Payne WJA, Rollinson DHL. Bali cattle. World Anim Rev. 1973;7:13–21.

[4] Antara M. The phenomenon of declining cattle population in Bali. Prosiding Seminar Nasional; Universitas Udayana; 2013.

[5] Payne WJA, Hodges J. Tropical cattle: origin, breeds and breeding policies. Oxford: Blackwell Science; 1997.

[6] Badan Pusat Statistik Provinsi Bali. Livestock population by regency/city and livestock type in Bali Province. Denpasar: BPS Provinsi Bali; 2024.

[7] Oka IGL. The advantage of artificial insemination in improving productive performance of Bali cattle. Proceedings of the International Conference on Biotechnology for a Sustainable Future; 2009.

[8] Badan Standardisasi Nasional. Beef cattle breeding stock – Part 4: Bali cattle (SNI 7651-4:2023). Jakarta: BSN; 2023.

[9] Islamiati FS, Susari NNW, Sampurna IP. Diversity and correlation of body girth dimensions in Bali cow dams. Buletin Vet Udayana. 2023;15(1):68–74.

[10] Noor RR. Livestock genetics. 6th ed. Jakarta: Penebar Swadaya; 2010.

[11] Hardjosubroto W. Application of animal breeding in the field. Jakarta: PT Grasindo; 1994.

[12] Gunawan A, Sumantri C, Jakaria. Estimation of genetic parameters of growth traits in Bali cattle. Media Peternakan. 2011;34(2):93–98.

[13] Soeparno. Meat science and technology. Yogyakarta: Gadjah Mada University Press; 2005.

[14] Warmadewi DA, Oka IGL, Ardika IN. Effectiveness of body dimension selection in Bali cow dams as a basis for breeding stock determination. Majalah Ilmiah Peternakan. 2017;20(1):16–19.

[15] Sutarno, Setyawan AD. Genetic diversity of local cattle breeds in Indonesia. Biodiversitas. 2015;16(2):327–354.

[16] Badan Standardisasi Nasional. SNI 7651.1:2017 – Bali cattle breeding stock. Jakarta: BSN; 2017.

[17] Andilah, Muhsinin, Maskur. Correlation between body weight and body measurements of young male Bali cattle. J Ilmu Teknol Peternakan Indonesia. 2021;7(2):68–75.

[18] Mahmudi M, Siregar AR, Hasanuddin. Body measurement characteristics of male Bali cattle aged 18–30 months in Aceh Province. J Agripet. 2019;19(1):15–22.

[19] Saputra DA, Maskur M, Rozi T. Morphometric characteristics of Bali cattle under semi-intensive management system in Sumbawa Regency. JITPI. 2019;5(2):67–75.

[20] Domili A, Gobel Z, Datau F, Fathan S, Laya NK, Dako S. Qualitative performance and correlation analysis of body measurements in male Bali cattle. Jambura J Anim Sci. 2021;4(1):46–52.

[21] Gushairiyanto, Depison. Quantitative characteristics of Bali cattle using principal component analysis. J Sain Peternakan Indonesia. 2021;16(1):74–79.

[22] Lestiyanto A, Prasetyo H, Wibowo R. Morphometric characteristics of male Bali cattle from East Nusa Tenggara in Samarinda City. J Peternakan Nusantara. 2024;10(1):45–53.

[23] Talib C. Bali cattle in breeding source areas and their development prospects. Wartazoa. 2002;12(3):100–107.