



Comparative Morphological Assessment of Swamp Buffalo (*Bubalus bubalis*) Populations in East Java, Indonesia: A Case Study of Tuban and Pacitan Districts

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INFO ARTICLE

Article history
Received 28/09/2025
Received in revised 28/12/2025
Accepted 25/01/2026
Published online 29/04/2026

Keywords

Domestic ruminant
Genetic conservation
Indonesian buffalo
Phenotypic variation
Tropical biodiversity

ABSTRACT

The swamp buffalo (*Bubalus bubalis*) is a critical domestic ruminant in Indonesia. Continuous morphological evaluation is vital for conserving this genetic resource. This study characterized qualitative and quantitative traits of swamp buffalo populations in Tuban and Pacitan districts, East Java, Indonesia. Using purposive sampling, 64 adult buffaloes (32 per district) were assessed. Buffalo samples aged more than 25 months, regardless of sex. Qualitative analysis identified regional variation in body stature and coloration between populations. Quantitative metrics included chest girth, body length, height, head length, neck length, tail length, horn length, and estimated body weight. Tuban buffaloes exhibited a chest girth of 182.31 ± 24.76 cm, body length of 148.94 ± 22.34 cm, height of 119.56 ± 12.48 cm, head length of 46.63 ± 7.80 cm, neck length of 42.88 ± 7.70 cm, tail length of 76.63 ± 9.15 cm, horn length of 14.44 ± 3.98 cm, and estimated body weight of 1045.49 ± 401.51 kg. Pacitan buffaloes displayed higher averages, including a chest girth of 194.44 ± 24.49 cm, body length of 152.25 ± 23.83 cm, height of 122.13 ± 16.81 cm, head length of 49.88 ± 5.28 cm, neck length of 44.31 ± 8.24 cm, tail length of 77.69 ± 10.24 cm, horn length of 13.63 ± 3.90 cm, and estimated body weight of 1208.98 ± 415.66 kg. Despite these differences, one-way ANOVA revealed no statistically significant divergence ($p > 0.05$) in quantitative traits between populations. These findings provide critical baseline data for conserving East Java's swamp buffaloes.

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ABSTRAK

Kerbau rawa (*Bubalus bubalis*) merupakan ruminansia domestik penting di Indonesia yang memainkan peran krusial dalam produksi pangan, pertanian tradisional, dan praktik sosio-budaya. Evaluasi morfologis secara berkelanjutan diperlukan untuk menjaga kelestarian sumber daya genetik ini. Penelitian ini mengkarakterisasi ciri kualitatif dan kuantitatif populasi kerbau rawa di Kabupaten Tuban dan Pacitan, Jawa Timur, Indonesia. Menggunakan metode purposive sampling, sebanyak 64 ekor kerbau dewasa (32 ekor per kabupaten) dievaluasi. Sampel kerbau berusia lebih dari 25 bulan, tanpa memperhatikan jenis kelamin. Analisis kualitatif mengidentifikasi variasi regional pada postur tubuh dan warna tubuh antar populasi. Parameter kuantitatif meliputi lingkaran dada, panjang badan, tinggi badan, panjang kepala, panjang leher, panjang ekor, panjang tanduk, serta perkiraan berat badan. Kerbau Tuban

memiliki lingkaran dada $182,31 \pm 24,76$ cm, panjang badan $148,94 \pm 22,34$ cm, tinggi badan $119,56 \pm 12,48$ cm, panjang kepala $46,63 \pm 7,80$ cm, panjang leher $42,88 \pm 7,70$ cm, panjang ekor $76,63 \pm 9,15$ cm, panjang tanduk $14,44 \pm 3,98$ cm, dan perkiraan berat badan $1045,49 \pm 401,51$ kg. Kerbau Pacitan menunjukkan rata-rata lebih tinggi, yaitu lingkaran dada $194,44 \pm 24,49$ cm, panjang badan $152,25 \pm 23,83$ cm, tinggi badan $122,13 \pm 16,81$ cm, panjang kepala $49,88 \pm 5,28$ cm, panjang leher $44,31 \pm 8,24$ cm, panjang ekor $77,69 \pm 10,24$ cm, panjang tanduk $13,63 \pm 3,90$ cm, dan perkiraan berat badan $1208,98 \pm 415,66$ kg. Meskipun terdapat perbedaan, uji ANOVA satu arah menunjukkan tidak terdapat divergensi yang signifikan secara statistik ($p > 0,05$) pada ciri kuantitatif antar populasi. Temuan ini memberikan data dasar yang kritis untuk menyusun strategi konservasi dan pengelolaan berkelanjutan kerbau rawa di Jawa Timur.

INTRODUCTION

The swamp buffalo (*Bubalus bubalis*) is a critical ruminant livestock species in Indonesia. These animals serve diverse roles, including as traditional plowing animals for rice fields, sources of meat and milk, raw materials for leather industries, and historical modes of transportation. Compared to cattle, swamp buffaloes exhibit distinct advantages: they efficiently convert low-protein, high-fiber feed into high-quality meat and milk, demonstrate lower susceptibility to diseases and parasites, and thrive in resource-limited environments (Rodas-González *et al.*, 2023; Yusnizar *et al.*, 2024). However, Southeast Asian swamp buffalo populations have declined by 4.92% over the past two decades, primarily due to agricultural mechanization (FAOSTAT, 2018; Pineda *et al.*, 2021).

Mirroring regional trends in Southeast Asia, Indonesia's swamp buffalo population

continues to decline overall, though certain areas maintain stable populations. Notable declines have been documented in the Pacitan and Tuban districts of East Java Province. According to BPS-Statistics of East Java (2022), Tuban District experienced a 23.96% population decline between 2020 and 2021. In contrast, according to BPS-Statistics of East Java (2024) and BPS-Statistics of East Java (2025) Pacitan District hosts a significantly smaller population, with annual fluctuations ranging from 1.65% to 7.56% during the same period, followed by a sharp decline in 2023 and 2024 (Figure 1). This limited population size increases susceptibility to inbreeding, posing a risk to genetic diversity.

The availability of comprehensive information and data is fundamental to implementing livestock development and animal health programs. Morphological characteristics, which encompass observable

physical traits, serve as foundational data for designing buffalo breeding strategies (Food and Agriculture Organization [FAO], 2012). Conducting morphological characterization across regional buffalo populations is a prerequisite for assessing genetic diversity and informing conservation efforts. This study focuses on the morphological characterization

of swamp buffaloes in Pacitan and Tuban districts to document phenotypic diversity within and between populations. These findings will directly support localized breeding programs, particularly when integrated with molecular methodologies to ensure holistic genetic management (Rahmawati *et al.*, 2023).



Figure 1. Population trends of swamp buffalo (*Bubalus bubalis*) in Tuban and Pacitan districts, East Java, Indonesia (2017–2024) (BPS-Statistics of East Java, 2022; BPS-Statistics of East Java, 2024; BPS-Statistics of East Java, 2025)

METHODS

This study employed a survey methodology utilizing purposive sampling. Tuban and Pacitan Districts were selected as sampling locations to represent the northern and southern coastal regions of Java Island, respectively. The selection of these regencies was conducted randomly within each coastal zone, with the objective of capturing regional phenotypic variation rather than focusing on a specific local population.

Buffaloes selected for inclusion exceeded 25 months of age, consistent with the Indonesian National Standard 7706-1:2020

(National Standardization Agency, 2020). A total of 64 individuals were sampled, with 32 from Tuban District and 32 from Pacitan District. Tuban District spans longitudinal coordinates 111°30'–112°35' and latitudinal coordinates 6°40'–7°18', while Pacitan District lies between 110°55'–111°25' longitude and 7°55'–8°17' latitude (Figure 2) (Government of Pacitan District, 2021; Government of Tuban District, 2018). In this study, swamp buffaloes of both sexes were included. Sex was not used as a classification variable, as the analysis focused on general phenotypic variation of the

population rather than sex-specific morphological differences.

Morphological data collection followed FAO (2012) guidelines for assessing qualitative and quantitative traits in swamp buffaloes. Qualitative characteristics included body stature (classified as stocky, stout, or lean), body color (recorded as black, gray, white, or other observed hues), eye color (black, brown-black, or red-black), and horn morphology (wide or pointed curvature). Quantitative measurements comprised chest girth, body length, height, head length, neck length, tail length, horn length, and estimated body weight. All linear measurements were recorded in

centimeters using a PROHEX® tape measure. Body weight (W, in kilograms) was calculated using the Schaeffer formula: $W = G^2 \times L / 300$, where G represents chest girth in inches and L denotes body length in inches from the shoulder to the hip bone (Khan *et al.*, 2003; Riaz *et al.*, 2018). Data were analyzed via descriptive statistics and one-way analysis of variance (ANOVA) using Microsoft Excel 2013 (Microsoft Corporation, 2018; Warner *et al.*, 2001). Prior to statistical analysis, data were tested for normality and homogeneity of variances. Since the comparison involved only two groups, post hoc analysis was not conducted.



Figure 2. Sampling sites

RESULTS AND DISCUSSION

Morphological characterization encompassing both qualitative and quantitative traits plays a critical role in assessing biodiversity and advancing genetic management strategies for livestock industries globally (Suhardi *et al.*, 2023). Despite its importance, research on the morphological

traits of East Javan swamp buffaloes remains limited, highlighted by the omission of local buffalo data from East Java in recent meta-analyses (Saputra & Anggraeni, 2023). To address this gap, this study organizes its analysis sequentially, first detailing qualitative traits (Figures 3–5) followed by quantitative metrics (Tables 1–2), thereby providing a

structured framework for evaluating phenotypic diversity and informing conservation strategies.

Qualitative Morphological Traits

Observational data on qualitative traits revealed morphological variation in body stature (Figure 3) and body color (Figure 4) across Tuban and Pacitan swamp buffalo populations, though no variation was detected in eye color or horn morphology. In Tuban District, body stature comprised equal proportions of stocky and lean individuals (50%

each), whereas Pacitan District’s population was predominantly lean (74.93%), with the remainder classified as stocky. This contrasts with the predominantly stocky stature reported in Kudus District, Central Java (Lathifah, 2016). Such phenotypic divergence is likely influenced by genetic variation, environmental conditions, and management practices, particularly disparities in feed quantity and quality.

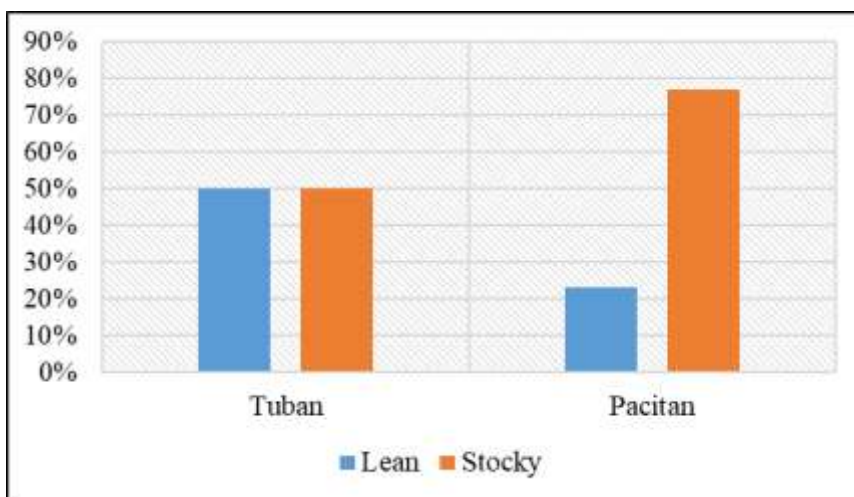


Figure 3. Profile of the body stature of buffalo populations in the Tuban and Pacitan districts

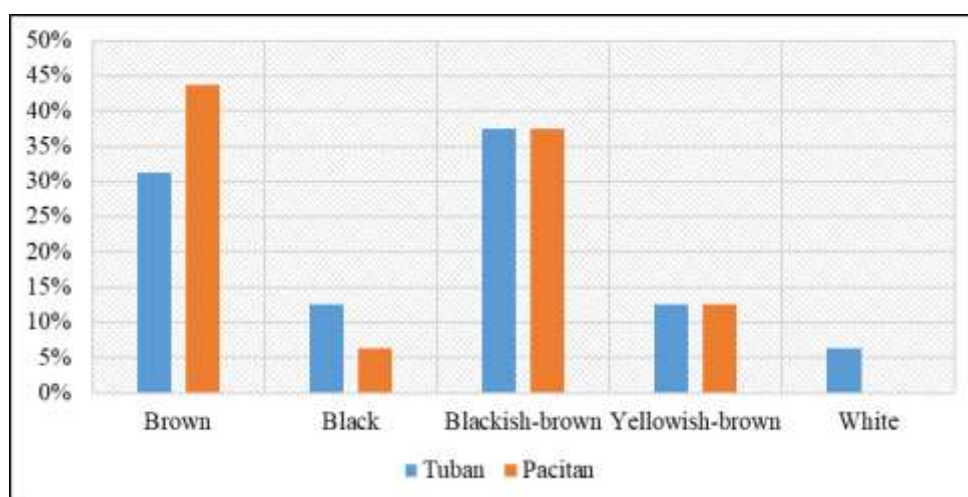


Figure 4. Profile of the body color of buffalo populations in the Tuban and Pacitan districts

Body coloration in both swamp buffalo populations was predominantly brown and

blackish-brown, with additional hues of yellowish-brown and black. Notably, the Tuban

population exhibited rare white or albino phenotypes (Figure 4). Swamp buffalo body color exhibits considerable regional variation. For example, Lathifah (2016) documented predominantly black and grayish individuals in Kudus District, Central Java, while Nur *et al.* (2018) reported black, dark gray, and light gray morphs in Guosobokerto Village, Jepara

District, Central Java. Similarly, Ciptadi *et al.* (2018) identified dark gray, light gray, reddish, and albino variants in the isolated Kangean Island population (East Java). Suhardi *et al.* (2022) further described color diversity in Kalimantan’s *kalang* buffaloes, including black, dark gray, gray, and albino individuals.

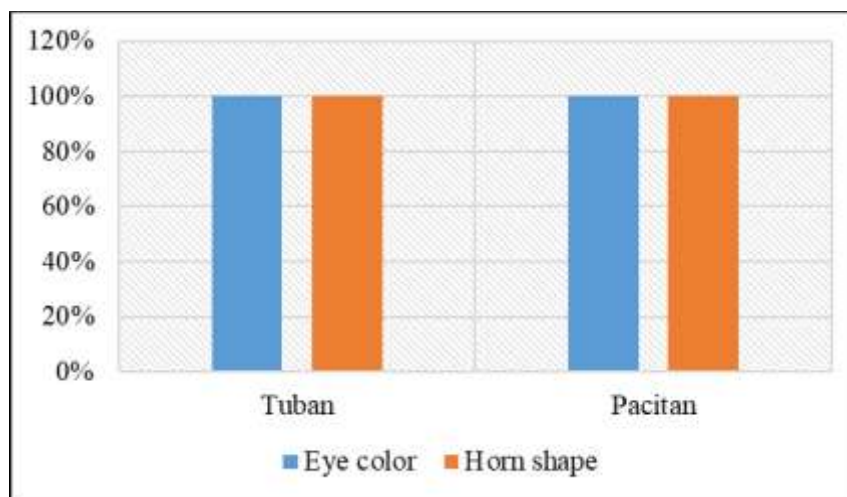


Figure 5. Profile of the eye color and horn shape of buffalo populations in the Tuban and Pacitan districts

No variation in eye color or horn morphology was observed in the Tuban and Pacitan swamp buffalo populations (Figure 5). All individuals exhibited uniformly black eye coloration and wide-based horn curvature. This contrasts with buffalo populations in Kudus District, Central Java, which shared the uniform black eye color but displayed horn shape diversity, including upward-curving and backward-curving morphologies (Lathifah, 2016). Similarly, Sukri *et al.* (2016) documented phenotypic variation in horn shape such as slight downward and upward curvatures in Central Lombok District, West Nusa Tenggara. These findings underscore regional differences in horn morphology despite

conserved eye coloration across Indonesian swamp buffalo populations.

Quantitative Morphological Traits

Chest girth exhibited the highest principal component loading, indicating its dominant contribution to morphological variation in principal component analysis (PCA), underscoring its utility as a key metric for buffalo phenotyping (Saputra & Anggraeni, 2023). The Tuban population displayed a smaller mean chest girth of 189.4 ± 8.2 cm compared to Pacitan’s 195.6 ± 7.5 cm. Both populations surpassed the 176.11 ± 24.72 cm average chest girth of buffaloes aged >4 years in Central Lombok District, West Nusa Tenggara (Sukri *et al.*, 2016) but fell below the

203 ± 6.56 cm average reported for 3.5–7-year-old swamp buffaloes at BPTU Siborongborong (Hidayat *et al.*, 2012).

Table 1. The Average and Coefficient of Variation of Each Quantitative Character in Buffalo Populations in The Tuban and Pacitan Districts

Character	District			
	Tuban		Pacitan	
	$\bar{X} \pm SD$	CV	$\bar{X} \pm SD$	CV
Chest girth (cm)	182.31 ± 24.76	13.58%	194.44 ± 24,49	12.59%
Body length (cm)	148.94 ± 22.34	14.99%	152.25 ± 23,83	15.65%
Body height (cm)	119.56 ± 12.48	10.44%	122.13 ± 16,81	13.76%
Head length (cm)	46.63 ± 7.80	16.71%	49.88 ± 5,28	10.58%
Neck length (cm)	42.88 ± 7.70	17.96%	44.31 ± 8,24	18.59%
Tail length (cm)	76.63 ± 9.15	11.94%	77.69 ± 10,24	13.18%
Horn length (cm)	14.44 ± 3.98	27.56%	13.63 ± 3,90	28.61%
Predicted body weight (kg)	1045.49 ± 401.51	38.40%	1208.98 ± 415.66	34.38%

Abbreviation: \bar{X} = mean; SD = standard deviation; CV = coefficient of variation.

Table 2. A One-Way ANOVA Test on Each Quantitative Character Grouped by Buffalo Population Origin

Character	SV	SS	df	MS	F	P-value
Chest girth (cm)	Between groups	1176.13	1	1176.13	1.94	0.17
	Within groups	18197.38	30	606.58		
	Total	19373.50	31			
Body length (cm)	Between groups	87.78	1	87.78	0.16	0.69
	Within groups	16001.94	30	533.40		
	Total	16089.72	31			
Body height (cm)	Between groups	52.53	1	52.53	0.24	0.63
	Within groups	6573.69	30	219.12		
	Total	6626.22	31			
Head length (cm)	Between groups	84.50	1	84.50	1.91	0.18
	Within groups	1329.50	30	44.32		
	Total	1414.00	31			
Neck length (cm)	Between groups	16.53	1	16.53	0.26	0.61
	Within groups	1909.19	30	63.64		
	Total	1925.72	31			
Tail length (cm)	Between groups	9.03	1	9.03	0.10	0.76
	Within groups	2829.19	30	94.31		
	Total	2838.22	31			
Horn length (cm)	Between groups	5.28	1	5.28	0.34	0.56
	Within groups	465.69	30	15.52		
	Total	470.97	31			
Predicted body weight (kg)	Between groups	213813.40	1	213813.40	1.28	0.27
	Within groups	5009727.76	30	166990.93		
	Total	5223541.17	31			

Abbreviation: SV = source of variation; SS = sum of squares; df = degrees of freedom; MS = mean square; F = F-statistic; P-value = probability value

The Indonesian National Standard stipulates a minimum chest girth of 172 cm for

male and 165 cm for female superior swamp buffalo breeds aged >25 months (National

[Standardization Agency, 2020](#)). Both Tuban and Pacitan populations met or exceeded these thresholds, with mean chest girths surpassing the national benchmarks. Similarly, populations in Central Lombok District and BPTU Sidorongborong align with these standards ([Sukri et al., 2016](#); [Hidayat et al., 2012](#)). Chest girth demonstrates strong positive correlations with all measured quantitative traits, such as body length and height ([Khan et al., 2003](#); [Riaz et al., 2018](#)), solidifying its role as a critical variable in body weight estimation formulas for swamp buffaloes.

The mean body length of Tuban swamp buffaloes was shorter than that of the Pacitan population. Both populations, however, exceeded the 133.00 ± 8.49 cm average body length for males and 127.33 ± 9.29 cm for females reported for buffaloes in Kabanjahe Subdistrict, Karo District, South Sumatra ([Sembiring et al., 2013](#)). These findings align with the Indonesian National Standard for swamp buffalo breeds aged >25 months, which specifies minimum body lengths of 116 cm for males and 113 cm for females ([National Standardization Agency, 2020](#)). The Tuban and Pacitan populations met or surpassed these benchmarks, highlighting their compliance with national zootechnical criteria.

The mean body height of Tuban swamp buffaloes was shorter than that of the Pacitan population. Both populations met or exceeded the Indonesian National Standard minimum body height of 116 cm for males and females aged >25 months ([National Standardization Agency, 2020](#)). Similarly, the average head length of Tuban individuals was shorter than

that of Pacitan buffaloes. Despite this, both populations exhibited longer head lengths of 44.33 ± 3 cm compared to buffaloes aged >4 years in Central Lombok District, West Nusa Tenggara ([Sukri et al., 2016](#)).

The mean neck length of Tuban swamp buffaloes was shorter than that of the Pacitan population. Both populations exhibited marginally shorter neck lengths of 44.44 ± 8.5 cm than buffaloes aged >4 years in Central Lombok District, West Nusa Tenggara ([Sukri et al., 2016](#)). Notably, no significant sexual dimorphism in neck length was observed in Central Lombok buffaloes ([Purwanti et al., 2021](#); [Sukri et al., 2016](#)). Similarly, Tuban buffaloes displayed shorter tail lengths than Pacitan individuals. However, both populations exceeded the 62.78 ± 14.23 cm mean tail length of Central Lombok buffaloes aged >4 years ([Sukri et al., 2016](#)), suggesting regional phenotypic divergence in this trait.

The mean horn length of Tuban swamp buffaloes exceeded that of the Pacitan population. However, both populations fell below the globally reported horn length range of 25–80 cm for swamp buffaloes ([Yusnizar et al., 2024](#)). Similarly, Tuban buffaloes exhibited higher estimated body weights than Pacitan individuals. These values surpassed the 462.17 ± 43.67 kg average body weight documented for 3.5–7-year-old swamp buffaloes at BPTU Sidorongborong ([Hidayat et al., 2012](#)) and Guosobokerto Village (Jepara District, Central Java) ([Nur et al., 2018](#)), underscoring regional variability in growth performance.

Although descriptive analyses revealed variation in quantitative traits between the

Tuban and Pacitan swamp buffalo populations, one-way ANOVA results indicated no statistically significant morphological differences (Table 2). The test yielded a p-value exceeding the alpha threshold of 0.05, leading to rejection of the null hypothesis that quantitative traits differ significantly between populations. This lack of divergence may reflect genetic homogeneity, suggesting shared ancestry or similar environmental pressures shaping phenotypic expression in both populations.

Furthermore, the absence of significant morphological divergence between the two populations suggests comparable environmental conditions and husbandry practices. However, the smaller population size in Pacitan District increases susceptibility to inbreeding relative to Tuban District's population. Inbreeding negatively impacts morphological performance, viability, and morbidity rates in buffaloes. To mitigate these risks, periodic monitoring of the Pacitan population—integrating morphological assessments with molecular analyses—should be prioritized to conserve locally adapted genetic resources (Pineda *et al.*, 2021; Rahmawati *et al.*, 2023). Future studies incorporating larger sample sizes, genetic analyses, and controlled management variables are recommended to better disentangle these effects.

CONCLUSION AND RECOMMENDATIONS

Morphological variation was observed in two qualitative traits body stature and coloration between the Tuban and Pacitan

swamp buffalo populations. While descriptive differences in quantitative traits, including chest girth, body length, height, head length, neck length, tail length, horn length, and estimated body weight, were noted between populations, one-way ANOVA revealed no statistically significant differences ($p > 0.05$). Based on the findings of this study, it is recommended that periodic monitoring of the swamp buffalo population be prioritized in Pacitan District and expanded to other regions across East Java to facilitate early conservation measures for buffalo populations. Additionally, the integration of morphological and molecular approaches is recommended for more holistic management of buffalo genetic resources.

ACKNOWLEDGEMENT

The authors express their gratitude to Prof. Dr. agr. Mohamad Amin, S.Pd., M.Si. and Dr. Umie Lestari, M.Si. (Biology Department, Mathematics and Natural Sciences Faculty, Universitas Negeri Malang) for his expert guidance and supervision throughout this research project.

CONTRIBUTION STATEMENT

Abdul Basith (AB) and Laily Isnaini Rahmawati (LIR) contributed equally to the research and writing of this study. AB and LIR were responsible for designing the research framework, collecting and analyzing the data, verifying the accuracy of the data analysis, developing the manuscript, and critically reviewing and revising the manuscript. In addition, AB was responsible for managing the submission process and handling the

correspondence with the journal's editorial team.

REFERENCES

- BPS-Statistics of East Java. (2022). Agricultural indicators of East Java Province 2021 [Indikator pertanian Provinsi Jawa Timur 2021]. <https://jatim.bps.go.id/publication/2022/11/23/4d83bdf2d0dc48790ea1b18f/indikator-pertanian-provinsi-jawa-timur-2021.html>
- BPS-Statistics of East Java. (2024). East Java Province in figures 2024 [Provinsi Jawa Timur dalam Angka 2024]. BPS-Statistics East Java Province. <https://bit.ly/api-bpsjatim2024-download>
- BPS-Statistics of East Java. (2025). East Java Province in figures 2025 [Provinsi Jawa Timur dalam Angka 2025]. BPS-Statistics East Java Province. <https://bit.ly/api-bpsjatim2025-download>
- Ciptadi, G., Mudawamah, M., Nurgiartiningsih, V. M. A., Wahjuningsih, S., Listiani, R. F., Susiati, ... & Budiarto, A. (2018, October). Reproduction performance and phenogram analysis of local swamp buffalo in East Java with a case of inbreeding based on phenotypic and DNA-RAPD characteristics. In *AIP Conference Proceedings* (Vol. 2021, No. 1, p. 070009). AIP Publishing LLC. <https://doi.org/10.1063/1.5062807>
- FAOSTAT. (2018). Live animals, data on buffaloes. <http://www.fao.org/faostat/en/#data/TA>
- Food and Agriculture Organization. (2012). Phenotypic characterization of animal genetic resources: FAO animal production and health guidelines No. 11. FAO. <https://www.fao.org/4/i2686e/i2686e00.pdf>
- Government of Pacitan District. (2021). Geography [Geografis]. <https://pacitankab.go.id/geografis/>
- Government of Tuban District. (2018). Geography [Geografi]. <https://tubankab.go.id/page/geografi>
- Hidayat, G., Serge, H., & Dauly, A. H. (2012). Morphological characteristics of Murrah and swamp buffalo body size at BPTU Siborongborong [Karakteristik morfologi ukuran tubuh kerbau murrah dan kerbau rawa di BPTU Siborongborong]. *Jurnal Peternakan Integratif*, 1(3), 276–287. <https://doi.org/10.32734/jpi.v1i3.2687>
- Khan, H., Zamin, S., Rind, M. M., Rind, R., & Riaz, M. (2003). Use of Shaeffer's formula for the prediction of body weight of slaughtering cattle. *Journal of Animal and Veterinary Advances*, 2(3), 176–178. <https://makhillpublications.co/files/publicshed-files/mak-java/2003/3-176-178.pdf>
- Lathifah, A. S. (2016, April). Genetic variation identification of Kudus buffalo based on microsatellites as blended learning material for TABM courses [Identifikasi variasi genetik kerbau Kudus berbasis mikrosatelit sebagai bahan ajar blended learning pada matakuliah TABM]. Proceeding of the 1st National Conference of Biology Education and Science and Technology, Surakarta, Central Java, Indonesia. <https://proceedings.ums.ac.id/snpbs/article/view/693/681>
- Microsoft Corporation. (2018). Microsoft Excel. <https://office.microsoft.com/excel>
- National Standardization Agency. (2020). Indonesian national standard (SNI) 7706-1:2020, buffalo seeds – Part 1: Swamp [Standar Nasional Indonesia (SNI) 7706-1:2020, Bibit kerbau – Bagian 1: Lumpur]. <https://repositoripeternakan.ditjenpkh.pertanian.go.id/public/uploads/1688611703.pdf>
- Nur, E. A., Nugroho, H., & Kuswati. (2018). Phenotypic characteristics of swamp buffalo (*B. bubalis carabensis*) in the buffalo development center of Guosobokerto Village, Welahan Subdistrict, Jepara District [Karakteristik fenotip kerbau rawa (*B. bubalis carabensis*) di wilayah sentra

- pengembangan kerbau Desa Guosobokerto, Kecamatan Welahan, Kabupaten Jepara]. *Ternak Tropika*, 19(2), 156–166. <https://doi.org/10.21776/ub.jtapro.2018.019.02.10>
- Pineda, P. S., Flores, E. B., Herrera, J. R. V., & Low, W. Y. (2021). Opportunities and challenges for improving the productivity of swamp buffaloes in Southeastern Asia. *Frontiers in Genetics*, 12, 629861. <https://doi.org/10.3389/fgene.2021.629861>
- Purwanti, N., Sampurna, I., & Susari, N. (2021). The growth rate of length dimension of swamp buffalo in Central Lombok Regency. *Buletin Veteriner Udayana*, 13(2), 187–195. <https://doi.org/10.24843/bulvet.2021.v13.i02.p11>
- Rahmawati, L. I., Basith, A., & Lestari, F. (2023). Genetic profile of local buffalo (*Bubalus bubalis*) populations in Pacitan and Tuban, East Java, Indonesia measured by the molecular marker of INRA032 locus. *Jurnal Riset Biologi dan Aplikasinya*, 5(1), 37–42. <https://doi.org/10.26740/jrba.v5n1.p37-42>
- Riaz, R., Tahir, M. N., Waseem, M., Asif, M., & Khan, M. A. (2018). Accuracy of estimates for live body weight using Schaeffer's formula in non-descript cattle (*Bos indicus*), Nili Ravi buffaloes (*Bubalus bubalis*), and their calves using linear body measurements. *Pakistan Journal of Science*, 70(3), 225–232. <https://doi.org/10.57041/pjs.v70i3.233>
- Rodas-González, A., & Huerta-Leidenz, N. O. (2023). Water buffalo versus cattle under similar rearing condition. I. Growth and carcass performance. *Animal Frontiers*, 13(6), 32–41. <https://doi.org/10.1093/af/vfad060>
- Saputra, F., & Anggraeni, A. (2023). Morphometric diversity of swamp buffaloes in Indonesia: A meta-analysis. *Buffalo Bulletin*, 42(1), 89–95. <https://doi.org/10.56825/bufbu.2023.4214116>
- Sembiring, F., Hamdan, & Mirwandhono, E. (2013). Morphometric analysis of swamp buffalo (*Bubalus bubalis*) in Karo District, North Sumatra [Analisis morfometrik kerbau lumpur (*Bubalus bubalis*) Kabupaten Karo, Sumatera Utara]. *Jurnal Peternakan Integratif*, 1(2), 132–145. <https://doi.org/10.32734/jpi.v1i2.2657>
- Suhardi, S., Sumppunn, P., Duangjinda, M., & Wuthisuthimethavee, S. (2022). Buffalo (*Bubalus bubalis*) phenotypic diversity characterization reveals the need for improved performance based on quantitative and qualitative characteristics. *Buffalo Bulletin*, 41(3), 373–390. <https://doi.org/10.56825/bufbu.2022.4133711>
- Sukri, A., Fitriyani, H., & Supardi. (2016). Morphological characteristics of local buffalo (*Bubalus bubalis*) in Central Lombok, West Nusa Tenggara [Karakteristik morfologi kerbau lokal (*Bubalus bubalis*) Lombok Tengah, Nusa Tenggara Barat]. *Jurnal Biologi dan Pembelajarannya*, 3(1), 1–7. <https://doi.org/10.29407/jbp.v3i1.444>
- Warner, C. B., & Meehan, A. M. (2001). Microsoft Excel as a tool for teaching basic statistics. *Teaching of Psychology*, 28(4), 295–298. https://doi.org/10.1207/S15328023TOP2804_11
- Yusnizar, Y., Ilham, M., Rizal, M., & Sumantri, C. (2024). Buffalo, a forgotten potential livestock [Kerbau, ternak potensial yang terlupakan]. PT Duta Pustaka Indonesia. Unpublished.