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Productivity of different farm sizes in commercial ewe-lamb production systems in Central Java Province, Indonesia

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ABSTRACT

This study evaluated the productivity and identified factors influencing ewe-lamb production in 40 commercial sheep farms across Central Java Province. A survey method with stratified sampling was employed. At the first level, districts/cities were selected based on three population density categories (high, medium, and low). At the second level, sheep farms within these districts/cities were purposively sampled based on the following criteria: operational for at least two years, maintaining a minimum of 25 ewes, and having at least one lactating ewe. At the third level, individual ewes were purposively selected if they had given birth at least twice and were nursing lambs younger than five months. The results indicate that commercially managed ewe-lamb farms in Central Java Province produced an average of 227.29 ±67.67 weaned lambs per 100 ewes per year. The average lambing interval, pre-weaning mortality, and twin birth percentage were 9.22 ±2.49 months, 14.71 ±16.29%, and 36.00 ±27.62%, respectively. Farm size and age did not significantly affect ($P > 0.05$) reproductive performance. Variations in lambing interval, pre-weaning mortality, and twin birth rate contributed 18.6% to the number of weaned lambs per 100 ewes per year ($Y = 8.832 + 12.641X_1 + 0.562X_2 + 0.962X_3$; $R^2 = 18.6\%$). In conclusion, commercial ewe-lamb farming in Central Java Province demonstrates satisfactory performance, with lambing interval, pre-weaning mortality, and twin birth rates reaching optimal levels.

Introduction

Productivity is a key performance indicator in ewe-lamb production systems. Low productivity reflects inefficiencies in the production system, often stemming from ineffective management practices. One of the primary causes of reduced productivity is poor breeding management, which leads to low pregnancy rates (Jan *et al*., 2023). Additionally, inadequate feeding and sanitation management can result in diseases in pre-weaning lambs or lactating ewes, increasing mortality rates (Nuraini *et al*., 2020). Given these challenges, evaluating productivity through reproductive performance is essential for identifying weaknesses in production system management.

Ewe-lamb farms commonly experience low weaning rates due to poor breeding management, with problems occurring at every phase of the reproductive cycle. In the pre-mating phase, farmers' limited understanding of estrus detection can lead to pregnancy failures and extended lambing intervals (Dewi *et al*., 2023; Prastyaningrum *et al*., 2023; Rama *et al*., 2022). During pregnancy, inadequate ewe nutrition may result in low birth weights and prolonged postpartum mating periods (Kenyon *et al*., 2009; Jenkinson *et al*., 2012; Khanal and Nielsen, 2017). In the lambing phase, dystocia and postpartum infections—often due to young maternal age and poor sanitation can contribute to high mortality and extended postpartum mating (Green and Morgan 1994; Ibrahim and Abdelgadir 2017; Bruce *et al*., 2021). During lactation, nutritional deficiencies can reduce weaning weights due to decrease milk production and prolong postpartum mating due to an increased risk of metabolic diseases in ewes (Yendraliza, 2013; Thomas *et al*., 2014; Astuti *et al*., 2022). If left unmanaged, these challenges across all reproductive phases from pre-mating to lactation can significantly prolong lambing intervals and increase pre-weaning lamb mortality, ultimately reducing the weaning rate.

Sheep productivity in different regions and production systems has been reported by a number of researchers. Moloney *et al*. (2023) reported a weaning rate of 133.5% on sheep farms in New Zealand. Farrell *et al*. (2022) reported a weaning rate of sheep at a breeding center in Ireland of 0.97-1.55% for litter sizes of 1.3-2.3. Hudori *et al*. (2022) reported a lambing interval of 10.21 ±0.69 months from sheep farms in East Java managed under a natural mating system. So far, information about productivity and problems of commercial sheep farming in Central Java is not widely available. This study aimed to evaluate productivity from a breeding management perspective and identify factors influencing productivity at each stage of the reproductive cycle in ewe-lamb farms in Central Java Province. The findings are expected to assist farmers to improve breeding management practices.

Materials and methods

This study was conducted from November 2023 to March 2024 in nine districts/cities within Central Java Province using a quantitative survey method. Multistage purposive sampling was employed to select commercial ewe-lamb production farms and individual ewe samples. Data were collected through interviews with farm owners both for farm and individual livestock sampling. The data were then analyzed descriptively and using multiple linear regression to assess reproductive performance and the factors influencing its outcomes.

Research Object

A total of 40 commercial sheep farms in Central Java Province were selected through multistage purposive sampling (Figure 1). The study covered nine districts/cities, categorized based on sheep population density which were low density (<10,000 heads), medium density (10,000–50,000 heads), and high density (>50,000 heads). Within each district/city, commercial sheep farms were purposively selected based on the minimum criterion of having 25 ewes. From these farms, 189 pregnant

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ewes and 345 suckling ewes were purposively sampled.

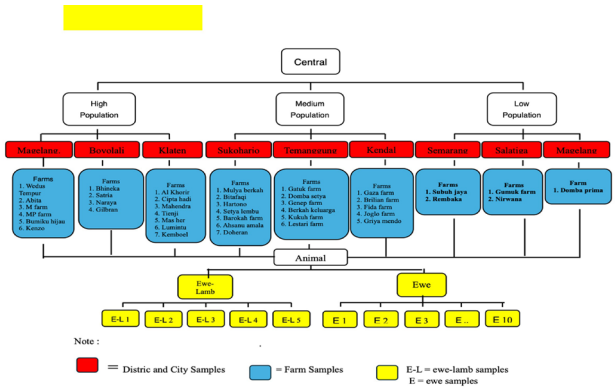

Fig. 1. Multistage Sampling Technique

Variables and Measurement Methods

This study measured several variables related to reproductive performance, including lambing interval, age of first mating, age of first pregnancy, age of first lambing, postpartum mating, days open of ewe, twin births, pre-weaning mortality and the number of weaned lambs. Each variable was assessed through interviews using individual samples of selected lambs and ewes.

Number of weaned lambs (heads) was calculated by summing the number of lambs under one year old during the study period, adding the number of lambs sold, and subtracting the number of weaned lambs that died within the year. The productivity of weaned lambs per 100 ewes per year was determined using the formula of Sodiq (2010).

Number of ewes (heads per year) was calculated as the sum of ewes present during the study, plus replacement ewes sourced externally and internally, minus the number of ewes slaughtered, sold, or deceased between November 2022 and November 2023.

Lambing interval (months) refers to the period between the birth of a lamb currently being suckled and the birth of the previous lamb (Pranoto *et al.*, 2016).

Pre-weaning mortality (%) was calculated as the number of pre-weaning lamb deaths divided by the total number of lambs born, multiplied by 100% (Mangun *et al.*, 2024).

Percentage of twin births (%) was calculated using the Mangun *et al.* (2024) formula, where the number of twin births in one year is divided by the total births in the same year, then multiplied by 100%.

Age at first mating (months) was determined by subtracting the ewe-lamb's gestation period and the number of days required for conception or repeated mating from its current age at the time of the interview. For ewes, this calculation subtracted the weaning period, the first pregnancy duration (5 months), and the number of days needed for initial conception or repeated mating in cases of failed pregnancies.

Age of first pregnancy (months) was calculated as the ewe's age at the time of the interview minus its gestation age and the number of days required for conception or repeated mating. For ewes, the age of first pregnancy was determined by subtracting gestation age, the number of days required for the second pregnancy or repeated mating, weaning time, first pregnancy period (5 months), and the number of days required for first conception or repeated mating from the ewe's age at the time of the interview.

Age at first lambing (months) was calculated by subtracting gestation age, the number of days required for the second pregnancy or repeated mating, and weaning time from the ewe's age at the time of the interview.

Postpartum mating (days) was defined as the number of days required for mating that occur after lambing. This data was collected through farmer interviews based on individual livestock samples or by reviewing farm records (if available).

Days open (days) referred to the period between the last lambing and the next pregnancy. Data were collected through direct interviews with farmers based on individual livestock samples or by examining farm records (if available).

Data Analysis

The collected data were analyzed using descriptive analysis, analysis of variance (ANOVA), and multiple regression. Descriptive analysis was used to evaluate sheep farm productivity. ANOVA was applied to assess the influence of livestock population and farm age on productivity. Multiple regression analysis was conducted to identify factors affecting sheep farm productivity.

Results

The performance of commercially managed ewe-lamb farms in Central Java Province was found to be good in terms of both reproductive efficiency and the effectiveness of breeding management applied by farmers. The results show that the average production of weaned lambs was 227.29±67.67 heads per 100 ewes per year (Table 1). The best performance of these farms is supported by effective breeding governance, as reflected in the average age at the first mating (8.91±1.74 months) and postpartum mating period (2.52±0.23 months) (Table 2). Although the overall reproductive performance is relatively good, further improvements are theoretically possible by reducing the lambing interval and selecting prolific ewes. These two variables can still be optimized based on findings from previous studies.

Table 1. Performance of Commercial Ewe-Lamb Farms in Central Java Province.

Farm Category	∑ Weaned Lambs/100 Heads of Ewe/ Year ^{ns} (Heads)	*Lambing intervals*^{ns} (Moths)	Pre-Weaning Mortality^{ns} (%)	Twin Birth Rate^{ns} (%)
Farm Size (heads)				
25 – 150	231.16 ±64.22	9.4 ±1.47	16.63±16.93	32.25 ±26.67
151 – 300	211.49 ±90.05	8.96 ±0.81	8.84 ±15.15	40.00 ±30.98
>300	218.95 ±77.95	8.06 ±1.39	6.56 ±6.49	66.67 ±11.54
Average	227.29 ±67.67	9.22 ±2.49	14.71 ±16.29	36.00 ±27.62
Farm Age (Years)				
2 – 5	215.39 ±62.53	9.21 ±1.55	20.11 ±18.96	31.57 ±25.22
6 – 10	233.44 ±65.37	8.96 ±1.04	12.96 ±13.62	33.84 ±28.73
>10	245.56 ±85.42	9.37 ±1.59	4.72 ±6.04	50.00 ±30.23
Average	227.29 ±67.67	9.22 ±2.49	14.71 ±16.29	36.00 ±27.62

ns = non-significant (P>0.05)

Table 2. Reproductive Performance of Ewe Lambs and Ewes at Commercial Farms in Central Java Province.

Ewe Group	Variables	Number of Ewes (Heads)	Average Values (Months)
First Pregnant Ewes	The first age of mating	189	8.91 ±1.74
	The first age of pregnancy	189	9.14 ±1.81
Second Pregnant Ewes	The first age of mating	345	8.98 ±1.45
	The first age of pregnancy	345	9.32 ±1.48
	The first age of lambing	345	14.32 ±1.48
	Post partum mating	345	2.52 ±0.23
	Days open	345	2.87 ±0.37

The study also identified both positive and negative aspects of reproductive management (Table 2). Positive factors included earlier ewe mating, shorter postpartum mating intervals, and reduced days open, which can extend the productive lifespan (longevity) of ewes and shorten the lambing interval. However, negative factors were also observed, particularly the risk of reduced productivity (both in the number and quality of weaned offspring). In the short term, this was linked to low fertility in young ewes mated too early. Meanwhile, in the long term, it was associated with diminished reproductive capacity due to suboptimal growth of lambs and low maternal ability resulting from short postpartum mating intervals and days open.

Table 3. Multiple Linear Regression Analysis of Weaned Lamb Productivity, Lambing Interval, Pre-Weaning Mortality, and Twin Birth Rate in Ewe-Lamb Farms in Central Java Province.

Predictors	Constants and Regression Coefficients	Significance Value
Constants	8.83	0.33
Lambing Interval (X_1)	12.64	0.10
Preweaning Mortality (X_2)	0.56	0.40
Twins Birth (X_3)	0.96	0.06

Note: R2=18.6%; r=0.431.

The results of the multiple linear regression analysis showed that lambing interval, pre-weaning mortality, and twin birth percentage had a correlation coefficient (r) of 0.431 and collectively contributed 18.6% (R^2) to the number of weaned lambs per 100 ewes per year. Among these variables, pre-weaning mortality had the highest correlation (0.483) with weaned lamb productivity. However, none of the independent variables were found to have a significant effect (P > 0.05) (Table 3). Findings suggest that other factors play a crucial role in determining weaned lamb production in sheep farms in Central Java Province. This also indicates that simply shortening the lambing interval, reducing pre-weaning mortality, except increasing the twin birth rate will not be sufficient to enhance weaning lamb production.

Discussion

The number of weaned lambs produced by commercial ewe-lamb farms in Central Java Province was generally good, averaging 227.29±67.67 heads per 100 ewes per year. This achievement was consistent across farms with flock sizes ranging from 25 to over 150 heads and farms operating for 6 to over 10 years. For comparison, the lambing rate, weaning rate, and mortality rate of intensively raised Pelibuey purebred sheep at the second parity in Mexico were 2.31 heads/ewe, 1.94 heads/ewe, and 16.22%, respectively (Macedo and Hammel, 2006). Additionally, the lambing interval of native sheep in Langkat, North Sumatra, Indonesia, was reported to be 8–10 months (Kurniawan *et al*., 2023). In Brebes Regency, Central Java Province, the average reproductive index of fat-tailed sheep (DEG) was 2.14 heads/ewe/year or 214 heads/100 ewes/year (Sodiq, 2010). Similarly, the reproductive index of local Sumatran sheep was found to be 2.2 weaned lambs/ewe/year (Sitepu, 2022). Theoretically, the lambing interval for sheep is 8 months (Wati and Saili, 2014; Najmuddin and Nasich, 2019; Prastowo, 2018). These findings indicate that ewe-lamb farms in Central Java Province have efficiently utilized inputs such as ewes, rams, and feed, demonstrating effective livestock management (AHDB, 2024; Jan *et al*., 2023). The reliable performance observed in this study also reflects effective disease control and breeding management, particularly in suckled lambs, which has helped reduce mortality rates and increase the number of weaned lambs (Diwyanto *et al*., 2005; Hidayat *et al*., 2015; García-Pérez *et al*., 2021). Moreover, the number of weaned lambs is influenced by litter size, which can be improved through the selection of ewes with a history of twin births (Tugistan, 2024). The productivity of ewe-lamb farms in Central Java Province compares favorably with previous research. This outcome is undoubtedly shaped by various interdependent factors, highlighting the importance of continuous evaluation and management to maintain or improve the number of weaned lambs produced.

The lambing interval in commercial ewe-lamb farms of varying sizes and operational ages showed no significant difference (P > 0.05). In Central Java Province, the lambing interval in ewe-lamb farms averaged 9.22 ±2.49 months. A 9-month lambing interval is considered good in farming practices. However, theoretically, it can be reduced to 8 months (Wati and Saili, 2014; Najmuddin and Nasich, 2019; Prastowo, 2018). The duration of the lambing interval is significantly influenced by mating and feeding management, particularly in relation to farmers' ability to detect estrus cycles accurately and ensure adequate nutrient intake for ewes. Nutritional adequacy supports ewes in regaining an optimal body condition score (BCS) for mating (Rama *et al*., 2022; Sumaryadi *et al*., 2018). The observed trend of a decreasing lambing interval with increasing farm size suggests that larger farms have better reproductive management. This includes grouping ewes ready for mating, maintaining a balanced ewe-to-ram ratio, ensuring adequate nutrition, and providing proper health management. Conversely, an increase in farm operation age without corresponding improvements in lambing intervals indicates a lack of evaluation and intervention to enhance reproductive, feeding, and environmental management (Prihtyiantoro *et al*., 2023). The results suggest that the lambing interval in this study could be shortened to 8 months through improved reproductive and feeding management, enabling ewes to maximize production.

The mortality rate of pre-weaning lambs in farms of varying sizes and operational ages showed no significant difference (P > 0.05). In Central Java Province, the pre-weaning mortality rate averaged 14.71 ±16.29%. This rate falls into the low category compared to previous studies: Dwyer (2008) a pre-weaning mortality rate of 10–30%, Flinn *et al*. (2020) reported 15-20%, and Rusdiana and Adiat (2020) reported 20%. The low mortality rate of pre-weaning lambs in Central Java Province indicates effective disease control, adequate maternal nutrition during lactation, and improved lamb health and strength (Khotijah *et al*., 2021; Sirat *et al*., 2021; Purwantini *et al*., 2023; Alhuur *et al*., 2023). These findings suggest that farmers have successfully implemented disease control and feeding management strategies, contributing to lower pre-weaning mortality in the studied sheep farms.

The percentage of twin births in farms of different sizes and operational ages also showed no significant difference (P > 0.05). The average twin birth rate in ewe-lamb farms in Central Java Province was 36.00 ±27.62%. This percentage is lower than previous studies, where Inounu *et al*. (2006) reported a 43.4% twin birth rate in crossbred sheep, and Sodiq (2010) reported 52.17% in Thick-Tailed Sheep. The twin birth rate can be improved through selective breeding of prospective ewes (Setiawan *et al*., 2023; Sutiyono *et al*., 2010) and enhanced feeding management, particularly during pre-mating (flushing) and pregnancy (Saputri *et al*., 2022; Suhardiani *et al*., 2021; Kardaya, 2022). Flushing is a nutritional strategy designed to enhance ewe reproductive performance by providing nutrient-rich feed before and after mating, typically 2–3 weeks before and during mating (Socheh *et al*., 2011). This practice helps maintain optimal body condition scores (BCS) in ewes (Inounu *et al*. 2006; Sumaryadi *et al*., 2018; Sodiq, 2010) and has been shown to increase twin birth rates.

The productivity (weaning rate) of ewe-lamb farms in Central Java Province in this study was relatively satisfactory, averaging 227.29±67.67 heads per 100 ewes per year. No significant difference (P > 0.05) was found in productivity between farms of varying sizes and operational ages. The results of this study are higher than those reported by Macedo and Hammel (2006); Sodiq, (2010), and Sitepu (2022). This high reproductive performance (number of weaned lambs) is largely attributed to the low pre-weaning mortality rate compared to previous studies (14.71±16.29%) (Dwyer, 2008; Flinn *et al*., 2020; Rusdiana and Adiat, 2020). However, the

contributions of lambing interval and twin birth rate remain suboptimal, with values of 9.22±2.49 months and 36.00 ±27.62%, respectively. The lambing interval can theoretically be shortened to 8 months (Wati and Saili, 2014; Najmuddin and Nasich, 2019; Prastowo, 2018), and the twin birth rate can be increased through selective breeding of prolific ewes and feeding management (flushing) before mating and during pregnancy to maintain optimal body condition scores (BCS) in ewes (Inounu *et al*. 2006; Sumaryadi *et al*., 2018; Sodiq, 2010).

Most replacement stock of lambs in this study were mated at a premature age (8.98 months), leading to pregnancy and first lambing at an early age (9.32 and 14.32 months, respectively) (Table 2). While lambs can reach puberty at 5–6 months (Ely and Aaron, 2018), they should ideally be mated when they have achieved optimal body growth, usually at 10–12 months (Utomo and Rasminati, 2012: Sudarmono and Sugeng, 2011). Breeding usually occurs when lambs are 10–12 months old (Zein and Rahmatullah, 2022), with the ideal first lambing age ranging from 15 to 18 months (Marisa *et al*., 2023; Nuschati *et al*., 2010). Based on these findings, it is evident that prospective ewes in commercial sheep farms in Central Java were mated too early.

The postpartum mating duration and days open in ewe-lamb farms in Central Java were found to be relatively short, averaging 2.52±0.23 months and 2.87±0.37 months, respectively. Ideally, postpartum mating should last 2–3 months (Sitepu, 2021), while days open should not exceed 120 days (approximately 4 months) (A'ini *et al*., 2021; Ashari *et al*., 2018). This recommendation is based on the fact that uterine involution in sheep is completed within 35 days postpartum, allowing time for the lamb to be ready for weaning (Riady *et al*., 2015; Hudori *et al*., 2022). The short time of postpartum mating and days observed in commercial sheep farms in Central Java Province may be attributed to early postpartum mating (average 2.52 months), leading to rapid postpartum pregnancy (average 2.87 months).

The short postpartum mating interval and days open have both positive and negative impacts that must be considered in the reproductive management of commercial ewe-lamb farms in Central Java Province. The positive impact is a shorter lambing interval, which increases the annual number of weaned lambs. Theoretically, the lambing interval is influenced by postpartum estrus, postpartum mating, service per conception (S/C), and days open (Harahap *et al*., 2021; Parasmawati *et al*., 2013). A longer postpartum mating period and days open lead to a longer lambing interval, while a higher S/C value also extends the lambing interval (Ashari *et al*., 2024; Sodiq, 2010). However, the negative impact of short postpartum mating and days open is the risk of reduced weaning lamb quality due to poor maternal care of lamb because of too early weaned. The lamb-ewe production system requires a short rest interval to allow ewes to be re-mated sooner, but reducing the interval below 40–50 days can significantly lower ewe fertility (Dwitarizki, 2021). Additionally, ewes that are still nursing their offspring and become pregnant too soon may experience a decline or cessation in milk production (Hermadi, 2015), leading to slower growth rates and lower weaning weights of lambs due to insufficient milk supply (Jarmuji, 2014). Based on these findings, although the postpartum mating duration and days open in sheep farms in Central Java Province are within an acceptable range, strategies must be implemented to mitigate the risk of reducing weaned lamb quality. The short time of postpartum mating and days open may negatively impact maternal ability, necessitating further reproductive management improvements.

Lambing interval is generally a key determinant of the number of weaned lambs produced, its contribution in this study was relatively small, making it ineffective as a primary strategy for productivity improvement. Theoretically, a shorter lambing interval increases the number of birth cycles per unit time, with ewe-lamb farms following an 8-month lambing interval capable of producing three birth cycles within two years (Sodiq, 2010; Nurkholis *et al*., 2023; Tugistan, 2024). However, findings from sheep farms in Central Java Province suggest that shortening the lambing interval would not significantly increase weaned lamb production. This conclusion is further supported by the observed lambing interval of 9.22 months, which is already shorter than those reported by Najmuddin and Nasich (2019) (9.96 months) and Hudori *et al*. (2022) (10.55 months). Therefore, efforts to shorten the lambing interval can be deprioritized for the time being.

Pre-weaning mortality has been widely reported as a factor influencing the number of weaned lambs in sheep farming. However, in this study, no significant impact was detected, suggesting that further efforts to reduce the current mortality rate may not effectively improve productivity. Magalhães *et al*. (2017) reported that pre-weaning mortality reduces the number of lambs produced within a given period. Similarly, García-Pérez *et al*. (2021) found that pre-weaning mortality in extensive and semi-extensive production systems in Colima, Mexico, significantly affected weaned lamb numbers. Additionally, Ceyhan and Kozakl (2023) reported a direct effect of pre-weaning mortality on lamb production in Awassi sheep. In contrast to these findings, this study did not detect a significant contribution of pre-weaning mortality to weaned lamb numbers. This discrepancy is likely due to the already low pre-weaning mortality rate (14.7%) observed in this study, compared to previous reports of 10–13% (Dwyer, 2008), 15-20% (Flinn *et al*., 2020), and 20% (Rusdiana and Adiat, 2020). Based on these findings, further reductions in pre-weaning mortality are unlikely to substantially impact weaned lamb production, as the current mortality rate is already relatively low.

Conclusion

The findings of this study indicate that the productivity of commercial ewe-lamb farming is optimal. This performance is influenced by several key variables, including lambing interval, pre-weaning mortality, twin birth percentage, age at first pregnancy, and days open. However, early lambing poses a long-term risk of reduced productivity, while excessively short days open may compromise the quality of weaned lambs. The percentage of twin births can still be optimized through the selection of prospective ewes, although its contribution to the total number of weaned lambs is not highly significant. Farmers can increase productivity in the long run by delaying the first mating of ewes, allowing enough time for days open, and selecting ewes that can potentially bear twins for replacement.

Conflict of interest

The authors have no conflict of interest to declare.

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