Comparative Reproductive Performance of Crossbred Cows in Tanah Miring, Merauke, South Papua

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Abstract : Reproductive performance is an important determinant of cattle productivity, yet differences among crossbred cattle groups remain a concern for improving breeding efficiency under local farming conditions. Identifying crossbreeding combinations with superior reproductive traits is therefore essential for developing effective breeding strategies. This study aimed to compare the reproductive performance of five crossbred cattle groups raised in Tanah Miring District, Merauke, South Papua. Data were collected from 152 cows comprising Taurus × Local (n = 24), Indicus × Local (n = 38), Indicus × Indicus (n = 23), Indicus × Taurus (n = 44), and Taurus × Taurus (n = 23). Four reproductive parameters were evaluated: service per conception (S/C), age at puberty, age at first mating, and postpartum mating interval (PPM). Differences were analyzed using the Kruskal–Wallis test, followed by pairwise Mann–Whitney U tests. All parameters differed significantly among groups ($P < 0.05$). Taurus × Local cows exhibited the lowest S/C (1.58 ± 1.38), earliest puberty (15.96 ± 1.55 months), youngest age at first mating (19.67 ± 2.87 months), and shortest PPM (49.58 ± 13.98 days). These findings suggest that mating Bos taurus sires with local cows may improve reproductive efficiency and should be considered in breeding programs in the study area.

Keywords : Crossbred Cows, Reproductive Performance, Service Per Conception, Postpartum Mating Interval, Merauke

Abstrak : *Kinerja reproduksi merupakan faktor penting yang menentukan produktivitas ternak sapi, tetapi perbedaan kinerja reproduksi antar kelompok sapi hasil persilangan masih menjadi tantangan dalam meningkatkan efisiensi pembibitan pada kondisi peternakan lokal. Oleh karena itu, identifikasi kombinasi persilangan dengan karakteristik reproduksi yang lebih unggul diperlukan untuk mengembangkan strategi pembibitan yang efektif. Penelitian ini bertujuan membandingkan kinerja reproduksi lima kelompok sapi hasil persilangan yang dipelihara di Distrik Tanah Miring, Merauke, Papua Selatan. Data dikumpulkan dari 152 ekor sapi betina yang terdiri atas kelompok Taurus × Lokal (n = 24), Indicus × Lokal (n = 38), Indicus × Indicus (n = 23), Indicus × Taurus (n = 44), dan Taurus × Taurus (n = 23). Empat parameter reproduksi yang dievaluasi meliputi jumlah perkawinan per kebuntingan (service per conception/S/C), umur pubertas, umur kawin pertama, dan interval perkawinan setelah beranak (postpartum mating interval/PPM). Perbedaan*

antarkelompok dianalisis menggunakan uji Kruskal–Wallis, dilanjutkan dengan uji Mann–Whitney U untuk perbandingan berpasangan. Seluruh parameter menunjukkan perbedaan yang signifikan antarkelompok (P < 0,05). Sapi kelompok Taurus × Lokal memiliki nilai S/C terendah (1,58 ± 1,38 kali), umur pubertas paling dini (15,96 ± 1,55 bulan), umur kawin pertama termuda (19,67 ± 2,87 bulan), dan interval perkawinan setelah beranak terpendek (49,58 ± 13,98 hari). Temuan ini menunjukkan bahwa perkawinan pejantan Bos taurus dengan sapi betina lokal berpotensi meningkatkan efisiensi reproduksi sehingga dapat dipertimbangkan dalam program pembibitan sapi di wilayah penelitian.

Kata kunci : *Sapi Hasil Persilangan; Kinerja Reproduksi; Jumlah Perkawinan per Kebuntingan; Interval Perkawinan Pascaberanak; Merauke*

INTRODUCTION

Cattle production plays an important role in meeting the growing global demand for animal protein and supporting rural livelihoods, particularly in developing countries where livestock contributes to household income and food security (Barendse, 2017; Widyas et al., 2022). Reproductive efficiency is a key determinant of cattle productivity because it influences calving frequency, herd replacement, and the economic sustainability of livestock production systems (Cooke et al., 2020; de Sá Filho & Vasconcelos, 2011). In tropical regions, improving reproductive performance remains challenging because genetic potential interacts with environmental conditions, nutritional availability, and management practices (Chenoweth, 1994; Oosthuizen et al., 2019). Therefore, understanding the factors influencing reproductive performance is essential for developing appropriate breeding strategies under local production conditions.

Reproductive performance in cattle is commonly evaluated using several indicators, including age at puberty, age at first mating, service per conception (S/C), and postpartum mating interval (PPM) (Hariyono et al., 2025; Pramadani et al., 2026). Age at puberty indicates the onset of reproductive maturity, whereas age at first mating reflects the timing of entry into the breeding program. Service per conception represents the number of mating or insemination services required to achieve conception, while PPM refers to the interval between calving and subsequent mating. These parameters provide complementary information for assessing reproductive efficiency and identifying potential constraints to herd productivity (de Sá Filho & Vasconcelos, 2011; Oosthuizen et al., 2019). Earlier reproductive maturity, fewer services per conception, and a shorter PPM may contribute to increased lifetime calf production. Nevertheless, reproductive outcomes are also affected by nutrition, body condition, environmental stress, and reproductive management (Cooke et al., 2020; Severino-Lendechy et al., 2020). Consequently, evaluating these indicators collectively is important when selecting breeding combinations for specific production environments.

Breed composition is another important factor influencing cattle productivity and reproductive traits. *Bos taurus* cattle are generally associated with favorable growth and production characteristics, whereas *Bos indicus* cattle possess physiological adaptations that support survival and productivity under tropical conditions, including greater tolerance to heat and certain parasites (Barendse, 2017; Chenoweth, 1994). Differences between these genetic groups also occur in reproductive physiology, including ovarian function, estrous behavior, and the timing of puberty (Cooke et al., 2020; Sartori et al., 2010). In general, *Bos indicus* females tend to reach puberty later than *Bos taurus* females, although the magnitude of this difference depends on genetic background, nutritional status, and management (Nogueira, 2004; Cooke et al., 2020). Crossbreeding therefore offers a potential strategy for combining desirable production characteristics with environmental adaptability. However, the benefits of crossbreeding depend on appropriate breed combinations

and the suitability of the resulting animals for their production environment (Bunning et al., 2019; Widyas et al., 2022).

In Indonesia, crossbreeding has been widely practiced to improve cattle production, but the absence of well-structured breeding programs and reliable pedigree records can make it difficult to identify the genetic composition and performance of crossbred animals (Widyas et al., 2022). Tanah Miring District is one of the areas with a substantial cattle population in Merauke Regency, South Papua. Cattle farming in this district involves several crossbred groups resulting from the use of *Bos taurus* and *Bos indicus* sires on local cows (Nurcholis et al., 2024). Farmers and extension workers must select suitable breeding combinations despite constraints such as limited local semen availability, the economic value of crossbred male calves, and incomplete records of breeding histories. These conditions create uncertainty regarding the comparative reproductive advantages of different crossbred groups and may limit evidence-based breeding decisions.

Previous studies have documented differences in reproductive physiology between *Bos taurus* and *Bos indicus* cattle (Sartori et al., 2010; Nogueira, 2004), the role of reproductive management in tropical beef production (de Sá Filho & Vasconcelos, 2011; Oosthuizen et al., 2019), and the importance of genetic improvement and structured breeding strategies for Indonesian local cattle (Widyas et al., 2022). Research has also demonstrated that nutritional supplementation can influence the age at puberty in crossbred heifers raised under tropical conditions (Severino-Lendechy et al., 2020). Nevertheless, comparative evidence on age at puberty, age at first mating, S/C, and PPM across multiple crossbred cattle groups under the specific production conditions of Tanah Miring District remains limited. This gap restricts the availability of locally relevant evidence for selecting suitable breeding combinations. The novelty of the present study lies in the simultaneous evaluation of four reproductive parameters across five crossbred cow groups within a single local production setting. Therefore, this study aimed to compare the reproductive performance of Taurus × Local, Indicus × Local, Indicus × Indicus, Indicus × Taurus, and Taurus × Taurus cows raised in Tanah Miring District, Merauke, South Papua. The findings are expected to provide an evidence base for selecting appropriate breeding combinations, improving reproductive management, and supporting more efficient and sustainable cattle production in the region.

METHOD

This study employed an observational comparative design to evaluate reproductive performance among five crossbred cow groups raised under local farming conditions. The study was conducted in Tanah Miring District, Merauke Regency, South Papua, Indonesia, from August to September 2026. A total of 152 cows were classified into five groups according to their reported parental breed composition: Taurus × Local (n = 24), Indicus × Local (n = 38), Indicus × Indicus (n = 23), Indicus × Taurus (n = 44), and Taurus × Taurus (n = 23). The distribution of cows and the corresponding parental breed compositions are presented in Table 1.

Table 1. Crossbred groups and number of cows

Group	Parental composition	*n*
Taurus × Local	*Bos taurus* × local cattle	24
Indicus × Local	*Bos indicus* × local cattle	38
Indicus × Indicus	*Bos indicus* × *Bos indicus*	23
Indicus × Taurus	*Bos indicus* × *Bos taurus*	44
Taurus × Taurus	*Bos taurus* × *Bos taurus*	23

The research procedures involved identifying the study animals, classifying them according to parental breed composition, collecting reproductive performance data, and organizing the data for statistical analysis. Four reproductive parameters were evaluated: service per conception (S/C), defined as the number of mating or insemination services required to achieve conception; age at puberty, defined as the age at first observed estrus and expressed in months; age at first mating, expressed in months; and postpartum mating interval (PPM), defined as the interval between calving and the first subsequent mating and expressed in days. The same definitions were applied

across all five groups to maintain consistency in the comparison. Descriptive statistics were used to summarize the reproductive parameters, with results presented as mean ± standard deviation (SD). Because the data were not normally distributed, differences among the five crossbred groups were analyzed using the Kruskal–Wallis test (Febrianti et al., 2022). When a statistically significant overall difference was detected, pairwise comparisons were conducted using the Mann–Whitney U test, with the significance level set at $P < 0.05$. Pairwise comparisons were not adjusted for multiple testing; therefore, results close to the significance threshold were interpreted with caution.

RESULTS AND DISCUSSION

All four reproductive parameters differed significantly among the crossbred groups (Table 2). The Taurus × Local group showed the most favorable values for S/C, age at first mating, and PPM, and was among the earliest to reach puberty.

Table 2. Reproductive performance of five crossbred cow groups (mean ± SD)

Group	*n*	S/C (times)	Age at puberty (months)	Age at first mating (months)	PPM (days)
Taurus × Local	24	1.58 ± 1.38^{a}	15.96 ± 1.55^{a}	19.67 ± 2.87^{a}	49.58 ± 13.98^{a}
Indicus × Local	38	2.16 ± 1.59^{ab}	16.32 ± 1.79^{a}	21.92 ± 3.05^{b}	65.79 ± 24.01^{b}
Indicus × Indicus	23	2.17 ± 1.37^{b}	17.96 ± 3.52^{ab}	21.91 ± 3.29^{b}	55.65 ± 13.43^{ab}
Indicus × Taurus	44	1.84 ± 0.99^{ab}	19.98 ± 3.45^{b}	21.82 ± 3.68^{ab}	55.91 ± 21.38^{ab}
Taurus × Taurus	23	2.65 ± 1.80^{b}	15.87 ± 3.31^{a}	20.00 ± 2.71^{ab}	53.04 ± 9.74^{ab}
P-value		0.023	<0.001	0.004	0.043

S/C = service per conception; PPM = postpartum mating interval. Values with different superscript letters within the same column differ significantly (P < 0.05; Mann–Whitney U test).

Service per conception

Taurus × Local cows needed the fewest services per conception (1.58 ± 1.38), significantly fewer than Indicus × Indicus (2.17 ± 1.37) and Taurus × Taurus cows (2.65 ± 1.80) (Figure 1). Indicus × Local and Indicus × Taurus cows were intermediate and did not differ from the other groups. The high SD relative to the mean in all groups shows that S/C varied widely among individual cows within each group. Significant variation may be attributed to the farmers' level of education; a good or adequate level of education influences how farmers respond to questions regarding the actual conditions of their farms (Salamony et al., 2025). The highest S/C in the Taurus × Taurus group may be related to the lower heat tolerance of *Bos taurus* in the tropical lowlands, but this was not measured in the present study and should be tested further. The level of the S:C value is influenced by the livestock breed and the animal's ability to adapt to the environment (Adyantono et al., 2024; Tophianong et al., 2023). High adaptability accelerates reproductive performance via the endocrine system (Fernandez-Novo et al., 2020).

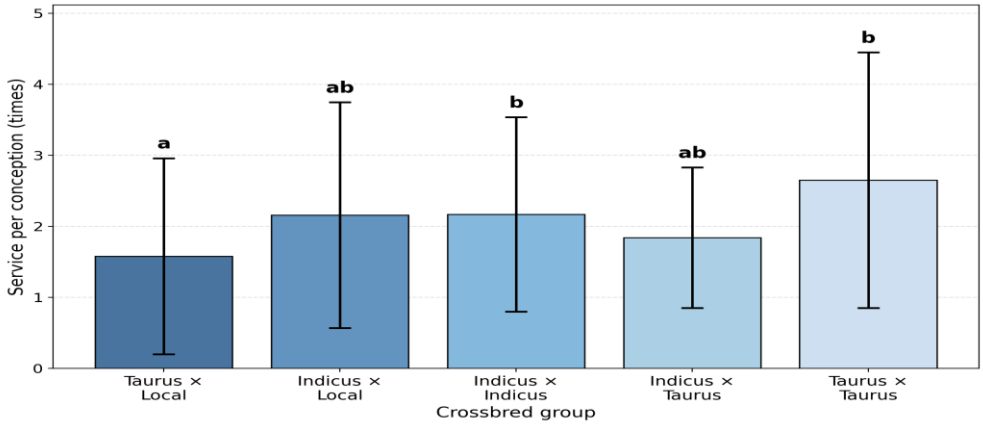


Figure 1. Service per conception (S/C) of the five crossbred groups. Bars show the mean and error bars show SD. Different letters indicate significant differences ($P < 0.05$).

Age at puberty

Age at puberty differed most clearly among groups ($P < 0.001$). Indicus × Taurus cows were the latest to reach puberty (19.98 ± 3.45 months), about four months later than Taurus × Local (15.96 ± 1.55), Indicus × Local (16.32 ± 1.79), and Taurus × Taurus cows (15.87 ± 3.31), which did not differ from one another (Figure 2). Indicus × Indicus cows were intermediate (17.96 ± 3.52). Crossbred Iindicus and Taurus cattle have higher heat production than purebred cattle (Moura et al., 2021), making them more susceptible to heat stress and affect to age of puberty. The early puberty of the Indicus × Local group shows that later maturity cannot be attributed to *Bos indicus* breed alone; feeding and management, which were not controlled here, may also play a role. The effect of stress on reproduction and reproductive technologies in beef cattle (Nurcholis et al., 2024; Sumiyanti et al., 2023)

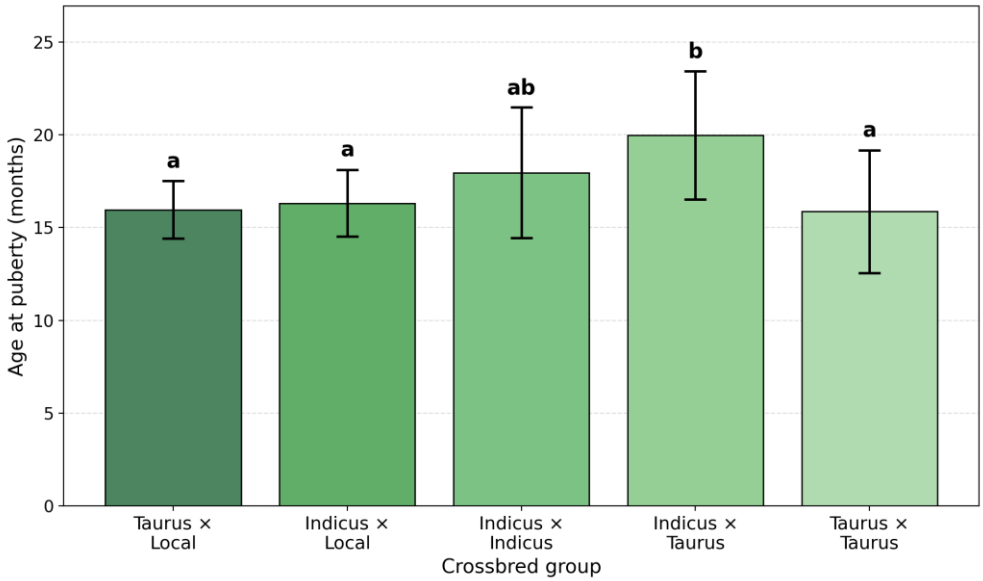


Figure 2. Age at puberty of the five crossbred groups. Bars show the mean and error bars show SD. Different letters indicate significant differences ($P < 0.05$).

Age at first mating

Taurus × Local heifers were mated for the first time at the youngest age (19.67 ± 2.87 months), roughly two months earlier than Indicus × Local (21.92 ± 3.05) and Indicus × Indicus heifers (21.91 ± 3.29). Indicus × Taurus and Taurus × Taurus heifers did not differ from the other groups. The gap between puberty and first mating was largest in Indicus × Local cows (about 5.6 months, compared with about 3.7 months in Taurus × Local), which suggests that the timing of

first mating is also influenced by farmers' decisions, such as waiting for a certain body size, and not only by biological readiness. Furthermore, delayed initial breeding is also attributable to traditional extensive rearing systems (Daoed et al., 2024), which are constrained by fluctuating forage availability and compounded by low monitoring intensity due to subestrus (silent heat) phenomena (Akriono et al., 2017; Sumiyanti et al., 2023).

Postpartum mating interval

The shortest PPM was found in Taurus × Local cows (49.58 ± 13.98 days), compared with 65.79 ± 24.01 days in Indicus × Local cows, a difference of about 16 days. The other groups were intermediate and did not differ from either. Because this difference was only just significant (P = 0.043) and pairwise tests were not adjusted, it should be regarded as an indication rather than a firm conclusion. Bos taurus cattle generally exhibit a shorter postpartum mating (PPM) interval or postpartum recovery period compared to Bos indicus cattle, owing to a history of intensive genetic selection for precocity and reproductive efficiency (Lucy, 2019; Mansur, 2025; Solehudin & Hasibuan, 2020).

Overall interpretation

Taken together, the Taurus × Local group had the most consistently favorable reproductive profile. This may reflect hybrid vigor combined with the adaptation of local cattle to the environment, although this study was not designed to separate those effects. In contrast, the same genetic background did not guarantee good results: the Taurus × Taurus group reached puberty early but needed the most services per conception. The findings come from field data in which feeding, health, season, and management were not controlled, and group sizes were unequal, so the results should be read as a comparison under actual farm conditions.

DISCUSSION

The results showed that all four reproductive parameters, namely service per conception (S/C), age at puberty, age at first mating, and postpartum mating interval (PPM), differed significantly among the five crossbred cattle groups. These findings indicate variation in reproductive performance among cattle groups with different breed compositions under the farming conditions of Tanah Miring District, Merauke, South Papua. Overall, the Taurus × Local group exhibited the most consistently favourable reproductive profile, particularly in terms of the lowest S/C, youngest age at first mating, and shortest PPM, together with a relatively early age at puberty. Nevertheless, these differences should be interpreted in the context of the fact that reproductive performance is influenced not only by genetic composition but also by nutritional status, body condition, health, environmental conditions, and husbandry practices. Budiyanto et al. (2020) reported variations in reproductive performance according to breed, parity, and age in beef cattle, whilst Salman et al. (2021) demonstrated that ovarian dysfunction and repeat breeding were associated with reduced reproductive success. These findings reinforce the view that cattle reproductive performance should be evaluated by considering animal characteristics and management factors simultaneously.

Service per conception differed significantly among the groups ($P = 0.023$). The Taurus × Local group had the lowest S/C value, at 1.58 ± 1.38 services, which was significantly lower than those of the Indicus × Indicus group (2.17 ± 1.37) and the Taurus × Taurus group (2.65 ± 1.80). Meanwhile, the Indicus × Local and Indicus × Taurus groups exhibited intermediate values and did not differ significantly from the other groups. A lower S/C indicates that conception can be achieved with fewer mating or insemination services, potentially improving reproductive efficiency and reducing breeding or insemination costs. This finding is consistent with Budiyanto et al. (2020), who reported variation in reproductive performance among different beef cattle groups. In addition, Salman et al. (2021) showed that reproductive disorders, including ovarian hypofunction and repeat breeding, may be associated with reduced conception success. Thus, the differences in S/C observed in the present study may reflect interactions between animal characteristics and reproductive management conditions.

The lower S/C value in the Taurus × Local group may indicate that this genetic combination possesses characteristics favourable to reproductive success under local farming conditions. However, the present study did not directly measure genetic heterosis, physiological characteristics, or the degree of environmental adaptation; therefore, this apparent advantage cannot be

conclusively attributed to crossbreeding. Conversely, the highest S/C in the Taurus × Taurus group may be associated with several unmeasured factors, including body condition, accuracy of oestrus detection, mating timing, semen quality, or reproductive health status. Harmayani et al. (2023) investigated the relationship between body condition score (BCS) and S/C in Bali cattle, highlighting the importance of considering body condition when evaluating reproductive success. Furthermore, the relatively large standard deviations for S/C across all groups indicate substantial individual variation. This suggests that cattle within the same crossbred group do not necessarily exhibit uniform reproductive success. Therefore, alongside the selection of appropriate crossbreeding groups, improvements in oestrus detection, mating-history recording, reproductive health examinations, and body-condition assessment should form part of strategies to improve reproductive efficiency.

Age at puberty showed the strongest statistical evidence of differences among the five groups ($P < 0.001$). The Indicus × Taurus group reached puberty at the oldest mean age, at 19.98 ± 3.45 months, whereas the Taurus × Taurus group had the youngest mean age, at 15.87 ± 3.31 months. The Taurus × Local and Indicus × Local groups reached puberty at 15.96 ± 1.55 and 16.32 ± 1.79 months, respectively, whilst the Indicus × Indicus group showed an intermediate value of 17.96 ± 3.52 months. These findings indicate that the timing of puberty varied among the crossbred groups and did not follow a simple pattern based solely on the presence of a particular cattle breed. Instead, reproductive development may be influenced by interactions between genetic composition and growth conditions. Allen et al. (2017) demonstrated that energy intake and body-weight gain during the growth phase were associated with metabolic and endocrine processes governing the onset of puberty in beef heifers. Cardoso et al. (2014) also showed that nutritional management during growth could influence reproductive development and the timing of puberty in heifers. These findings support the importance of considering growth and nutritional status when interpreting differences in age at puberty among the cattle groups in the present study.

The relatively early onset of puberty in the Indicus × Local group indicates that the presence of *Bos indicus* ancestry is not necessarily associated with delayed reproductive maturity. Conversely, the Indicus × Taurus group exhibited the oldest age at puberty, although this group did not show the poorest overall values for S/C, age at first mating, or PPM. This pattern suggests that individual reproductive parameters may respond differently to breed combinations and husbandry conditions. Copley et al. (2022) reported that environmental variation, including cumulative heat load and growth-related factors, was associated with reproductive outcomes and the likelihood of reaching puberty in beef cattle under tropical conditions. Thammahakin et al. (2024) also demonstrated that heat stress could affect reproductive responses in crossbred dairy cattle under tropical conditions. Nevertheless, environmental temperature, humidity, heat exposure, and physiological indicators of heat stress were not measured in the present study. Heat stress should therefore be regarded only as a possible explanatory factor and cannot be identified as the direct cause of delayed puberty in the Indicus × Taurus group. From a practical perspective, these findings emphasise the importance of monitoring growth, body weight, body condition, and the occurrence of oestrus when determining the reproductive readiness of heifers, rather than relying solely on breed classification or chronological age.

Age at first mating also differed significantly among the groups ($P = 0.004$). The Taurus × Local group had the youngest mean age at first mating, at 19.67 ± 2.87 months, compared with 21.92 ± 3.05 months in the Indicus × Local group and 21.91 ± 3.29 months in the Indicus × Indicus group. The Indicus × Taurus and Taurus × Taurus groups exhibited intermediate values and did not differ significantly from the other groups. These findings indicate that Taurus × Local heifers entered the breeding programme earlier than those in the Indicus × Local and Indicus × Indicus groups. Although age at puberty represents an indicator of biological reproductive maturity, age at first mating may also be influenced by farmers' decisions, the availability of bulls or semen, body condition, body weight, and the husbandry system. Allen et al. (2017) demonstrated that growth and adequate energy intake during development were associated with the attainment of reproductive maturity. Thus, the differences in age at first mating observed in this study cannot be explained solely by age at puberty; management factors and the animals' readiness for breeding must also be considered.

A descriptive comparison between mean age at puberty and mean age at first mating revealed differences in the time elapsed between these two events among the groups. The difference between the mean ages was approximately 3.71 months in Taurus × Local cows, 5.60 months in Indicus × Local cows, 3.95 months in Indicus × Indicus cows, 1.84 months in Indicus × Taurus cows, and 4.13 months in Taurus × Taurus cows. These values represent differences between group means rather than individual-level intervals that have been statistically tested. Nevertheless, the pattern suggests that the timing of first mating is not determined solely by the onset of puberty. In the Indicus × Local group, for example, the longer interval may be associated with farmers delaying mating until the heifers attain a particular body condition or size. Conversely, the shorter interval in the Indicus × Taurus group does not automatically indicate greater reproductive efficiency, because this group also exhibited the oldest mean age at puberty. Therefore, mating decisions should be based on a combination of age, growth, body condition, and reproductive readiness. Recording the dates of first observed oestrus and first mating is also necessary to distinguish delayed biological maturity from delayed breeding management.

Postpartum mating interval differed significantly in the overall analysis ($P = 0.043$). The Taurus × Local group had the shortest mean PPM, at 49.58 ± 13.98 days, whereas the Indicus × Local group had the longest interval, at 65.79 ± 24.01 days. The difference between these two group means was approximately 16 days. The Indicus × Indicus, Indicus × Taurus, and Taurus × Taurus groups exhibited intermediate values of 55.65 ± 13.43, 55.91 ± 21.38, and 53.04 ± 9.74 days, respectively. According to the pairwise comparisons, the Taurus × Local group differed significantly from the Indicus × Local group, whereas the other groups did not differ significantly from either of these groups. These findings indicate variation in the timing of mating after calving, which may be associated with reproductive recovery and husbandry practices. Rutter and Randel (1984) demonstrated that nutrient intake and body condition after calving were associated with reproductive function and the timing of first oestrus in beef cattle. This provides a physiological basis for considering nutritional status and body condition when evaluating postpartum reproductive intervals.

In addition to nutritional factors, environmental conditions may influence postpartum reproductive recovery. Avendaño-Reyes et al. (2009) investigated the relationship between heat exposure, body condition, and reproductive parameters in Holstein dairy cows under hot environmental conditions. Thammahakin et al. (2024) also reported an effect of heat stress on reproductive responses in crossbred dairy cattle under tropical conditions. Although these studies provide a basis for considering environmental influences, their contribution to PPM in the present study cannot be determined because temperature, humidity, body condition, lactation status, and postpartum ovarian activity were not directly measured. A shorter PPM in the Taurus × Local group may facilitate more efficient reproductive scheduling, but it cannot be interpreted directly as evidence of a shorter calving interval or greater annual calf production. Successful conception, maintenance of pregnancy, and calf survival also determine reproductive productivity. Furthermore, the overall *P*-value of 0.043 was relatively close to the 0.05 significance threshold, and the pairwise comparisons were not adjusted for multiple testing. Consequently, the PPM findings should be interpreted cautiously and confirmed in studies involving larger samples and more comprehensive reproductive records.

Overall, the Taurus × Local group exhibited the most consistently favourable reproductive profile across the four parameters evaluated. This group had the lowest S/C, the youngest age at first mating, and the shortest PPM, together with a relatively early age at puberty. These findings suggest that mating *Bos taurus* sires with local cows may represent a promising option for breeding programmes in Tanah Miring District. However, the present study cannot establish whether this pattern resulted from heterosis, local adaptation, or associated management factors. This is illustrated by the Taurus × Taurus group, which had the youngest mean age at puberty numerically but the highest S/C. Thus, an advantage in one reproductive parameter does not necessarily correspond to advantages in all other parameters. The evaluation of replacement females and the selection of breeding strategies should consider several reproductive indicators simultaneously, together with growth, health, adaptability, productivity, and maintenance costs. For farmers and extension workers, recording mating histories, services per conception, age at first mating, calving

dates, and postpartum mating dates may provide a practical means of improving decision-making. At the breeding-programme level, regular assessment of the reproductive performance of each group could help determine whether the observed advantages remain consistent across different herds and production seasons.

Several limitations should be considered when interpreting these findings. First, the observational design allows comparisons of reproductive performance under actual farming conditions but cannot establish a causal relationship between breed composition and reproductive parameters. Secondly, the number of animals differed among groups, and factors such as age, parity, body condition, nutrition, reproductive health, oestrus detection, and husbandry practices were not experimentally controlled. Thirdly, classification according to parental breed composition may not accurately represent the genetic proportions of individual animals where pedigree records or genetic testing are unavailable. Fourthly, the pairwise comparisons were not adjusted for multiple testing, meaning that the possibility of false-positive findings should be considered, particularly for results with *P*-values close to 0.05. Finally, the study was conducted in a single district, and its findings should therefore be generalised to other cattle production systems with caution. Nevertheless, this study provides empirical evidence of variation in reproductive performance among five crossbred cattle groups under local farming conditions and establishes a basis for further investigation. Future studies should involve larger and more balanced samples, more accurate pedigree records, and measurements of body condition, nutrition, health, and environmental exposure. Multivariable analyses could also be used to assess the contribution of breed composition after accounting for other factors associated with reproduction. Longitudinal monitoring of pregnancy rates, calving intervals, calf survival, and lifetime reproductive productivity would help determine whether the favourable reproductive profile observed in the Taurus × Local group translates into sustained improvements in herd productivity and economic efficiency.

CONCLUSION AND RECOMMENDATIONS

Reproductive performance varied among the five crossbred cow groups in Tanah Miring, indicating differences in reproductive efficiency associated with crossbreeding combinations. Taurus × Local cows exhibited the lowest service per conception (S/C), the youngest age at first mating, and the shortest postpartum mating interval (PPM), suggesting a more favourable reproductive performance under the conditions of this study. In contrast, Indicus × Taurus heifers attained puberty at a later age, while Taurus × Taurus cows required the highest number of services per conception. These findings suggest that Taurus × Local crossbreeding may be a promising option for improving reproductive efficiency; however, breed selection should be considered alongside nutritional adequacy, animal health, and overall herd management.

Future research should involve larger sample sizes and longitudinal observations across different environmental and management conditions to validate these findings and clarify the effects of genetic composition on reproductive performance. Researchers should also incorporate nutritional intake, body condition score, health status, and environmental variables to distinguish genetic influences from management-related effects. In practice, farmers and livestock practitioners should prioritise appropriate feeding strategies, regular reproductive monitoring, and timely identification of reproductive problems, particularly in heifers that attain puberty later. At the policy level, livestock development programmes should promote evidence-based crossbreeding strategies supported by extension services, improved feeding management, and reproductive health interventions, while ensuring that breeding recommendations are adapted to local production systems and environmental conditions.

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