



Bull Mating Load and Its Effects on Conception Outcomes: A Case of TALIRI Mpwapwa Farm

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Abstract

Cattle production underpins livelihoods, food security, and household income in Tanzania, where the improved Mpwapwa breed—developed for high productivity and tropical adaptation—is widely disseminated to upgrade local herds. However, shared communal use often subjects Mpwapwa and crossbred bulls to extreme mating loads of 40 - 60 cows per season, far exceeding temperate-region recommendations, while locally validated guidelines for optimal cow-to-bull ratios remain absent. This study evaluated how mating load, breed, and age influence conception performance using 10 breeding seasons of secondary farm records (2019-2023) from 33 eligible bulls selected from a population of available bulls, each allocated to one of the breeding groups at different mating loads ranging from 1:16 to 1:77, and retained with their assigned groups for the full three-month duration of each breeding season at the Tanzania Livestock Research Institute Mpwapwa station. Data were analyzed via binomial generalized linear models incorporating interaction terms between mating load, breed, and age. Results showed a significant inverse relationship: conception probability declined as dam numbers per bull increased (OR = 0.985, $p = 0.001$). Mpwapwa bulls were most resilient to higher loads (OR = 1.012, $p < 0.0001$), while older bulls were more adversely affected (OR = 0.9998, $p < 0.0001$). The highest conception rates—35.6% for Mpwapwa, 31.2% for Danish Red, and 30.6% for crossbred bulls—occurred at 16 dams per bull, with performance falling sharply beyond this threshold. These findings provide the first empirical breed-specific benchmarks for Tanzania, confirming that universal ratios are unsuitable. Recommended allocations are 16 dams for Mpwapwa bulls, 12 - 14 for exotic and crossbred types, with further reductions for animals over six years old. Adopting these guidelines will preserve fertility, improve reproductive efficiency, and support sustainable genetic improvement across tropical smallholder and research systems.

Subject Areas

Mating Load - Conception Outcomes

Keywords

Mpwapwa Bull, Mating Load, Conception Rate, Cow-to-Bull Ratio, Reproductive Efficiency

1. Introduction

Like most countries in East Africa, Tanzania depends heavily on cattle production to support livelihoods, household income, and food security, with the sector dominated by smallholder and agro-pastoral systems. The national cattle population comprises indigenous breeds—primarily the Tanzania Short Horned Zebu (TSZ) and its variants—and improved breeds, most notably the Mpwapwa, developed by the Tanzania Livestock Research Institute (TALIRI) during the 1960s [1] [2]. The Mpwapwa is a composite breed derived from 19% TSZ, 32% Red Sindhi, 8% Ayrshire, 11% Boran, and 30% Sahiwal, and was selected for high productivity—with milk yields three to four times greater than local breeds and faster growth rates—alongside adaptation to tropical environments, disease resistance, and the ability to perform on low-quality forage [3]. Since its development, Mpwapwa bulls and their crosses have been widely disseminated to upgrade local TSZ populations, particularly in central Tanzania's Dodoma and Singida regions, making it one of the country's most successfully adopted improved breeds [4]. While demand for Mpwapwa breeding bulls is high, communal sharing across villages and herds leads to extremely heavy mating loads, often reaching 40 - 60 cows per bull per breeding season—far exceeding recommended levels reported from other production systems [5].

In connection to this, reproductive performance is universally recognized as the primary determinant of productivity, profitability, and long-term sustainability in both dairy and beef production systems worldwide [2] [6]. Herd productivity depends on timely conception, short calving intervals, high calf survival, and consistent output—all of which directly influence economic returns and household food security. Among the many factors affecting reproductive efficiency, bull fertility and management, particularly the mating load or bull-to-cow ratio, are especially critical. Because a single bull serves multiple females, his reproductive capacity directly impacts the performance of the entire herd [7]-[10]. Bull fertility is defined as the ability to successfully impregnate females through natural mating or artificial insemination, resulting in viable pregnancy; it encompasses physical soundness, mating drive, semen quality, sperm production capacity, and overall health status [7]-[11]. Deficiencies in any of these traits, or overuse beyond biological limits, reduce conception rates, extend calving intervals, and cause substantial economic losses [7] [12]. For instance, excessive mating pressure often

leads to a decline in semen quality—including concentration, motility, morphology, and volume—which forms the biological basis of successful fertilization. Without sufficient fertile semen, even healthy, cycling females will fail to conceive, regardless of other management practices [13]. Consequently, maintaining optimal bull fertility is central to reproductive efficiency at the farm level. Unlike female infertility, which affects only individual animals, reduced fertility or overuse of a single bull impacts every female he mates with, making sound bull management a high priority for overall herd productivity.

On the other hand, reproductive efficiency can also be compromised by disorders affecting both sexes. In cows, common issues include ovarian cysts, metritis, anestrus, and early embryonic loss; in bulls, testicular degeneration, orchitis, hypoplasia, physical injury, or poor body condition can severely impair reproductive function [11].

In contrast to many tropical regions, extensive research in North America, Europe, and Australia has established evidence-based guidelines for mating loads, supported by standardized Breeding Soundness Evaluations (BSE)—a procedure that is either mandatory or strongly recommended prior to each breeding season [14]. BSE involves physical examination, structural assessment, measurement of scrotal circumference, and laboratory analysis of semen, allowing bulls to be classified as satisfactory, deferred, or unsatisfactory breeders. Bulls rated satisfactory typically achieve pregnancy rates of 85% - 95%, while untested bulls reduce these rates by 6% - 12%, and up to 20% are found to be subfertile or infertile [15]. Recommended ratios vary by age and maturity: young bulls (18 - 30 months) should be mated at 1 cow per 15 - 25 females; mature bulls (30 - 60 months), with a scrotal circumference of at least 34 cm, may serve 25 - 50 females; and older bulls (>6 years) are limited to 20 - 30 females per season [14].

To estimate maximum breeding capacity and prevent overuse while preserving fertility, the Auburn formula, as described by [14], provides a practical framework. Under single-sire management, the recommended cow-to-bull ratio is determined by age for bulls under 36 months, and by scrotal circumference for bulls aged 36 months or older. In multiple-sire systems, the required number of bulls can be calculated using the equation: $B = 1 + [(T - N)/(0.5 \times N)]$, where N is the single-sire capacity, and T is the total number of females in the group. This standardized approach allows farmers to align bull allocation with herd size to maintain consistent reproductive performance. [15] confirmed that under good conditions, fertile bulls that pass BSE perform similarly across ratios of 1:25, 1:44, and 1:60, indicating that inherent fertility status is more influential than ratio alone. However, when ratios exceed 1:60 or 70 cows per bull, conception rates drop by 10% - 18% and semen quality declines within 4 - 6 weeks of continuous use [15]. In intensive dairy systems, more conservative ratios of 1:20 - 1:30 are advised to minimize physiological stress; in extensive beef systems, ratios up to 1:50 are acceptable only if bulls are BSE-verified, well-nourished, and maintained in low-disease environments [12].

In comparison, studies from Latin America, South Asia, and sub-Saharan Africa show much greater variability in recommended ratios, due to differences in breed type, climate, nutrition, and limited adoption of BSE [16]. Tropical breeds such as Zebu, Sahiwal, and Boran, as well as their crosses, exhibit superior heat tolerance and disease resistance but typically produce less sperm, have lower libido, and reach smaller mature scrotal circumferences than temperate breeds [17]. For mature tropical bulls, recommended ratios range from 1:15 to 1:30—markedly lower than those used in temperate zones—and conception rates decline sharply when ratios exceed 1:35 - 1:40 [18]. Additional stressors, including high ambient temperatures, seasonal feed shortages, and endemic diseases such as Trypanosomiasis, further reduce breeding capacity to just 1:10 - 1:20 under traditional management systems [16]. Key findings from developing regions highlight three consistent patterns: 1) crossbred bulls show intermediate capacity but often reduced fertility due to poor environmental adaptation, while indigenous breeds have lower but more stable performance; 2) fewer than 10% of bulls undergo BSE, leading to widespread use of sub-fertile animals and conception rates of only 40% - 60%, compared with 75% - 90% in well-managed herds; and 3) underfeeding reduces semen quality and libido by 20% - 40%, while shared breeding bulls increase both disease transmission risk and the likelihood of overuse [16] [17]. In neighbouring countries including Ethiopia, Kenya, and Uganda, ratios above 1:25 reduce pregnancy rates by 12% - 25%, and the absence of locally validated guidelines means farmers often apply temperate-region recommendations that are unsuited to tropical conditions [18].

Notably, BSE remains the only standardized tool available to reliably predict mating capacity and conception outcomes [9] [10]. Bulls classified as satisfactory typically achieve 15% - 20% higher pregnancy rates than untested or unsatisfactory bulls and can be utilized at the upper end of recommended ranges; bulls rated deferred require reduced mating loads (1:15 - 1:20) or are unsuitable for single-sire use. While BSE is a routine practice in developed livestock sectors, its near absence in developing regions represents a major barrier to efficiency, as farmers cannot distinguish high- from low-fertility bulls prior to the breeding season [7] [14].

Despite its importance, scientific research specifically addressing the reproductive performance of Mpwapwa bulls—particularly regarding optimal cow-to-bull ratios—remains limited. [9] [10] reported that Mpwapwa bulls with a body condition score of 3.5 - 4.0 (on a 1 - 5 scale) and scrotal circumference ≥ 34 cm exhibit the highest fertility, though these findings were derived from a study with a small sample size. To date, no study has empirically determined the maximum or optimal number of cows per Mpwapwa or crossbred bull required to maximize conception rates, nor has there been an assessment of how this capacity interacts with age, nutrition, season, or management practices under Tanzanian conditions.

Available data from Tanzania and East Africa further highlight three critical challenges: 1) under traditional management, conception rates range from only 45% - 65%, compared with 70% - 85% achieved at research stations and well-man-

aged farms—a gap attributed to untested bulls, overuse, and inadequate nutrition; 2) BSE is rarely performed, and bulls are selected solely on physical appearance rather than fertility potential; and 3) seasonal variation is pronounced, with conception falling by 15% - 20% during the dry season due to weight loss and heat stress, which further reduces breeding capacity [3] [4]. Unlike in developed countries where breed-specific, standardized ratios are available, Tanzanian farmers and extension workers lack locally validated guidelines for Mpwapwa cattle and must rely on external recommendations that do not account for the breed's unique genetic makeup, adaptive traits, or production environment. This knowledge gap leads to excessive use of valuable improved bulls, diminished genetic progress, and unnecessary economic losses [5].

More importantly, the dissemination of Mpwapwa bulls is a core component of Tanzania's national livestock improvement strategy, but current sharing practices and unregulated mating loads undermine the breed's full genetic and economic potential. Excessive mating pressure directly reduces semen quality, lowers sperm production, and diminishes libido—resulting in poor conception rates, extended calving intervals, and slower herd growth, which negates the breed's intended advantages [12]. While a substantial body of literature exists on this topic globally and within tropical regions, no scientific evidence currently defines the optimal cow-to-bull ratio for Mpwapwa or crossbred bulls, nor how BSE outcomes can be used to refine recommendations under local conditions. This retrospective study therefore aims to evaluate the conception performance of Mpwapwa bulls and their crosses under varying mating loads, identifying the optimal predicted number of females per bull required to maximize reproductive efficiency. The findings will provide evidence-based guidelines for farmers, extension services, and national breeding programs, helping to preserve genetic quality, improve reproductive performance, and enhance the profitability and sustainability of beef cattle production in Tanzania and similar tropical regions.

2. Methodology

2.1. Study Area

This retrospective study was carried out at the TALIRI Mpwapwa farm, situated in Mpwapwa District, Dodoma Region. The district sits at an elevation of roughly 1100 meters above sea level and has a semi-arid climate, with two distinct seasons: a dry period extending from May to December, and a rainy season occurring between December and April. Daily temperatures in the area typically range from 24°C to 29°C, and the region receives an average annual rainfall of approximately 720 millimeters.

2.2. Study Animals and Their Management

The study used Mpwapwa cattle and their crossbreeds reared at TALIRI Mpwapwa farm. Animals graze daily from 07:30 to 15:00 on natural pastures dominated by *Panicum maximum*, *Cenchrus ciliaris*, and *Chloris gayana*. Herd size has been

kept below 1000 head since 1999. Supplementary feed is provided routinely, and hay produced on-farm is offered during periods of forage shortage. Culling is performed based on milk yield and lactation length; cows producing ≥ 10 L/day are classified as elite. Calves are managed under restricted suckling and weaned at three months. Standard health practices including dipping, vaccination, and deworming are conducted regularly. Breeding weights of bulls and cows are recorded before and after mating, with all data stored in the farm records unit.

2.3. Data Collection

Since the study was retrospective, it utilized secondary data from farm records at TALIRI Mpwapwa farm, covering ten consecutive breeding seasons (two in a year), spanning five years (2019-2023). Detailed records were maintained for every mating event, including the number of dams assigned to each bull, mating dates, and pregnancy diagnosis results. Breeding weights of bulls and cows were measured before and after mating using a calibrated scale to assess body condition. Conception status was determined via rectal palpation performed 90 days after mating in each season.

2.4. Sample Size and Selection

This retrospective study was carried out at TALIRI Mpwapwa farm over a five-year period (2019-2023). The study population comprised Mpwapwa and Danish Red x Mpwapwa bulls maintained for natural mating purposes. Bulls were purposively selected for inclusion based on the following criteria: a proven reproductive history, absence of prior reproductive disorders, and age between 2 and 10 years-representing breeding males with established fertility. The 33 eligible bulls were enrolled and selected from a population of the available bulls, each allocated to one of the mating groups at different mating loads ranging from 1:16 to 1:77, and retained with their assigned group for the full three-month duration of each breeding season. For female animals, cows were randomly sampled from the eligible herd, defined as individuals exhibiting postpartum estrus. All male and female animals recruited for mating across all 10 seasons throughout the 5-year study were included in the final analysis.

2.5. Data Analysis

The primary objective of this retrospective study was to evaluate the population-averaged association between bull mating load and conception success, rather than quantifying variance attributable to individual bulls or breeding seasons. Breeding season effects were incorporated by deriving mating load metrics aggregated per season; bull breed and age were included as fixed effects to adjust for systematic inter-bull variation.

Given the binary nature of the outcome variable (conception status: 1 = conceived, 0 = not conceived), a generalized linear model (GLM) with binomial error structure was selected as the appropriate analytical framework. The number of

dams allocated to each bull within a breeding season was designated as the primary explanatory variable. Bull breed and age (in months) were included as covariates to control for heterogeneity arising from animal-specific characteristics. Additionally, interaction terms between mating load and breed, and between mating load and age, were included to evaluate whether the relationship between mating load and conception success varied by breed or age.

For categorical predictors, the Mpwapwa breed was specified as the reference group. Continuous age values were centred at their respective mean values to facilitate straightforward interpretation of main and interaction effects. All statistical analyses were implemented in the R environment using the glm function with the binomial link function. Model adequacy was assessed via inspection of residual deviance and fitted probabilities to identify and rule out complete separation. Regression coefficients were exponentiated to yield odds ratios (ORs), and statistical significance was defined at a threshold of $p < 0.05$.

The final model retained the main effects of mating load, breed, and age, alongside the two interaction terms, enabling simultaneous estimation of the direct effect of mating load and its modification by bull-specific attributes. Predicted conception probabilities were computed across the empirically observed range of mating load values for each breed, holding age constant at its mean, and visualized graphically using a line plot.

3. Results

1) Descriptive statistics of predicted probabilities of conception

Overall, predicted probabilities of conception varied between 0.13 and 0.36, with a mean of 0.26 and a median of 0.26. The first and third quartiles were 0.19 and 0.32, respectively. Detailed values are presented in [Table 1](#).

Table 1. Descriptive statistics of predicted probabilities of conception.

Statistic	Predicted Probability
Minimum	0.1327
1st Quartile	0.1930
Median	0.2586
Mean	0.2560
3rd Quartile	0.3231
Maximum	0.3558

2) Effect of mating load, bull breed, and age on conception probability

Conception success was significantly influenced by mating load, bull breed, and bull age. Increasing mating load was associated with a significant reduction in conception probability, with the odds of conception declining by 1.5% for each additional dam allocated (OR = 0.985, 95% CI: 0.977 - 0.993, $p = 0.00106$). The effect of mating load varied significantly by breed: relative to Mpwapwa bulls (the

reference group), which maintained relatively better performance under increasing mating load, Danish Red and Mpwapwa × Danish Red crossbred bulls experienced more pronounced declines; however, the difference in response to mating load between crossbred Mpwapwa × Danish Red and Mpwapwa bulls was not statistically significant ($p = 0.87$). Additionally, there was a significant interaction between mating load and age, indicating that the adverse effect of increasing mating load on conception was significantly stronger in older bulls compared to younger animals (OR = 0.9998, 95% CI: 0.9997 - 0.9999, $p < 0.0001$).

Overall, predicted conception probabilities ranged from 13.3% to 35.6%, with a mean of 25.6%, varying according to breed, age, and number of dams per bull. By breed, predicted values ranged as follows: Danish Red bulls 14.9% - 31.2%, Danish Red × Mpwapwa crosses 13.3% - 30.6%, and Mpwapwa bulls 31.3% - 35.6%—the latter showed consistently higher probabilities across all mating loads.

Across all breed groups, the highest predicted conception probability occurred at the lowest mating load examined in this analysis (16 dams per bull). This represents the minimum load tested, not a statistically derived or empirically confirmed optimum; no mating loads below 16 dams per bull were assessed in this study. At this tested minimum load, Mpwapwa bulls had the highest predicted conception probability (35.6%), followed by Danish Red bulls (31.2%) and Danish Red × Mpwapwa crossbred bulls (30.6%). Full model-derived estimates are presented in **Table 2**.

Table 2. Inferential statistics from Binomial GLM model.

Predictor	Estimate (β)	Std. Error	z value	p-value	Odds Ratio
Intercept	-0.543200	0.237800	-2.285000	0.022320	0.580886
Mating load	-0.015570	0.004757	-3.274000	0.001060	0.984551
Mating load * (Danish red × Mpwapwa bull breed)	-0.001753	0.011080	-0.158000	0.874330	0.998249
Mating load X Mpwapwa bull breed	0.012410	0.003037	4.086000	0.000044	1.012487
Mating load * Bull age (centered)	-0.000239	0.000060	-3.964000	0.000074	0.999761

4. Discussion

This study evaluated how mating load, bull breed, and bull age influence conception probability in Mpwapwa and crossbred Mpwapwa cattle. The findings confirm that mating load exerts the strongest influence, with each additional female assigned to a Mpwapwa bull reducing conception odds by approximately 1.5%. **Figure 1** clearly illustrates the inverse relationship between mating load and predicted conception probability across all three breed groups, showing consistently higher performance for Mpwapwa bulls at every stocking rate and parallel declines

as dam numbers increase. While overall breed-related differences in the effect of mating load were detected, direct comparison showed no meaningful difference in conception response between Mpwapwa and Danish Red $\times$ Mpwapwa cross-bred bulls. The adverse effect of higher mating load was also amplified in older bulls, indicating age-related variation in reproductive resilience. These results provide important insight into reproductive management for smallholder and improved cattle production systems in the region, and are interpreted alongside existing evidence and practical implications as discussed below.

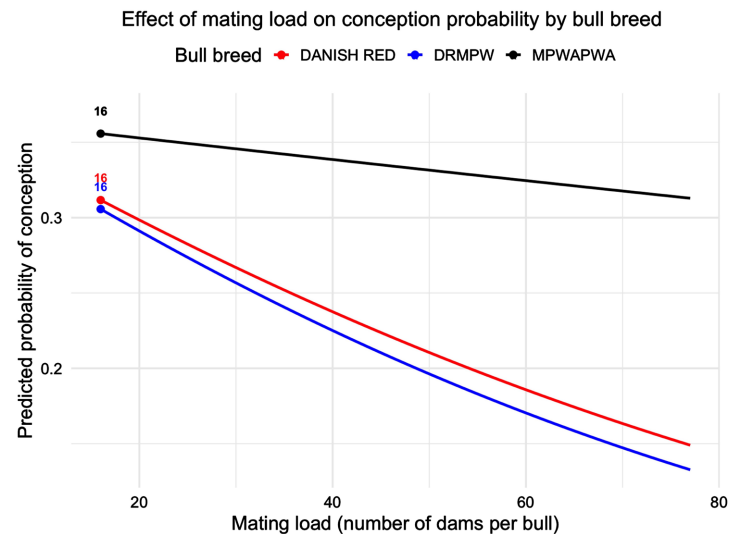


Figure 1. Predicted probability of conception in Mpwapwa cattle in relation to mating load (number of dams per bull), shown separately for three bull breeds. Estimates are derived from a binomial logistic regression model including interactions between mating load, breed, and mean-centered bull age. Lines show predicted probabilities across the observed range of mating loads; plotted points mark the highest predicted conception rate (at the lowest mating load of 16 dams per bull) for each breed. Predictions were generated with bull age held constant at its mean value.

Mating load—defined as the number of dams assigned to a bull—exerts a significant influence on conception success in Mpwapwa cattle, highlighting the critical trade-off between maximizing bull usage and maintaining optimal reproductive efficiency. The analysis revealed a clear inverse relationship: as the number of dams per bull increased, the probability of conception declined significantly (odds ratio [OR] = 0.99, $p = 0.001$). This reduction is most likely attributable to physiological stress, physical fatigue, or deterioration in sperm quality and quantity resulting from excessive mating frequency. These findings align closely with [14], who similarly reported that higher mating loads reduce fertility, noting that over-utilization exceeds the bull's physiological capacity to sustain high-quality semen production and mating activity. Such declines are not unique to this population; studies across different cattle breeds and production systems consistently identify mating load as one of the most influential management factors determining reproductive outcomes [8] [19].

Beyond the main effect of mating load, this study confirms that bull breed and age play substantial modifying roles, in agreement with established reproductive physiology literature [20] [21]. Mpwapwa bulls exhibited distinctly greater tolerance to increasing numbers of dams, with a positive interaction term indicating a slight but consistent advantage ($OR = 1.012$, $p < 0.0001$) compared to Danish Red bulls and their crosses. This resilience likely stems from the breed's genetic background and long-term adaptation to tropical environments, where they have evolved to maintain reproductive function under conditions of high ambient temperature, limited nutrition, and higher workloads. [1] [3] similarly observed that indigenous and adapted breeds often outperform exotic or crossbred animals under heavy mating pressure, attributing such differences to better thermoregulation, superior testicular function in hot climates, and greater stamina. In contrast, Danish Red bulls and their crosses showed a steeper decline in conception rates as mating load increased, indicating lower adaptive capacity and greater sensitivity to over-utilization. These results reinforce the view that reproductive performance under natural mating systems is not uniform across genotypes, and that one management standard cannot be applied equally to all breeds [16] [18].

Age was another critical factor modifying the impact of mating load. Older bulls were significantly more susceptible to the adverse effects of increased dam numbers ($OR = 0.99$, $p < 0.001$), with conception probabilities declining more rapidly compared to younger adults. This pattern is well-documented: [20] [21] explained that advancing age is associated with gradual reductions in sperm quality, decreased testosterone production, diminished testicular efficiency, and lower physical endurance—factors that collectively reduce the ability to sustain high mating frequencies without fertility loss. In the present study, bulls aged 3 - 8 years were included, and the results showed that even within this prime breeding age range, older individuals require more conservative mating allocations to maintain acceptable conception rates. This contrasts with younger mature bulls, which can often serve more dams before performance declines, a finding consistent with reports by [19] on age-related changes in reproductive capacity.

The study also identified mating densities that differ by breed. For all animal types, the best chance of conception came at the lowest rate tested: 16 females per male. However, since we did not test groups smaller than this, 16 should not be treated as the proven best ratio. At this level, Mpwapwa bulls achieved a maximum predicted conception rate of 35.6%, while Danish Red and Danish Red $\times$ Mpwapwa bulls reached 31.2% and 30.6%, respectively. Beyond 16 dams, reproductive success declined progressively, confirming that excessive mating load compromises fertility regardless of breed, though the rate of decline varies. This value is comparable to recommendations from [14] [20], who suggested that under natural mating in tropical environments, bulls should not serve more than 15 - 20 cows per breeding season to maintain high fertility. However, the present data demonstrate that while the upper limit is similar, the *efficiency* within that range differs markedly: Mpwapwa bulls remain effective closer to the upper end, whereas exotic

breeds and crosses show performance drops even at moderate loads. This supports the argument by [16] [18] that recommended bull-to-cow ratios must be adjusted according to breed, age, and environmental conditions rather than applying universal figures.

Notably, the wide range of effective mating loads observed in Mpwapwa bulls offers practical advantages for breeding programs. Their ability to sustain conception rates across a broader spectrum of dam numbers allows farmers and breeders to maximize genetic contribution of superior sires without sacrificing reproductive output—an important consideration for improving herd genetics in smallholder and research farm settings [1] [8]. This finding also highlights the danger of using general management guidelines: applying the same mating load to all breeds will inevitably lead to sub-optimal results for adapted genotypes or excessive fertility loss for less-tolerant breeds. Consequently, the study strongly advocates for context-specific management protocols that explicitly account for breed characteristics and age groups.

In conclusion, this study demonstrates that mating load significantly affected the conception probability in Mpwapwa breed cattle and their crossbreds; with each additional dam per bull reduces conception odds by approximately 1.5%. This effect, however, is strongly mediated by breed and age. Mpwapwa bulls exhibited significantly greater resilience to increased mating pressure compared to Danish Red and Mpwapwa × Danish Red crossbred bulls, whereas older bulls experienced disproportionately steeper declines in fertility with increasing mating loads. Conception rates were highest at the minimum tested mating load of 16 dams per bull, with consistent declines observed at higher loads—an outcome with important implications for optimizing both genetic progress and economic returns in tropical production systems. Because the present study evaluated mating loads starting from 16 dams per bull and did not examine lower stocking rates, breed- or age-specific optimum mating thresholds cannot be definitively established from these data. Further research is therefore required to identify the precise mating-load optima or thresholds for Mpwapwa bulls and their crosses.

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Author Contributions

Conceptualization and methodology, Joel Mahugija Malagira and Mwemezi Lutakyawa Kabululu; formal analysis, Mwemezi Lutakyawa Kabululu; writing—original draft preparation, Joel Mahugija Malagira; writing—review and editing,

Kabuni Thomas Kabuni, Deogratias Fidelis Masao, Felista Perfect Nicolaus, Janeth Frank Nkinda, and Neema Vicent Nyoni. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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