

Field effectiveness and reproductive outcomes of Synchromate-based estrus synchronization and artificial insemination in smallholder dairy cattle in Gondar Zuria District, northwestern Ethiopia

Tsegaye Asredie Kolech

Gondar Agricultural Research Center

Dejen Asaye Mengistu

dejuvet2002@gmail.com

Bahir Dar University

Alayu Kidane Solomon

Gondar Agricultural Research Center

Yosef Amsalu Abitew

Gondar Agricultural Research Center

Tamrat Degefa Geleto

Debre Zeit Agricultural Research Center

Solomon Abegaz Guangul

Debre Tabor University

Yeshimebet Chanyalew Getahun

Ethiopian Biotechnology Institute

Research Article

Keywords: Artificial insemination, Estrus synchronization, Gondar Zuria district, Smallholder dairy cattle, Synchromate

Posted Date: October 21st, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-11085019/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations: No competing interests reported.

Abstract

Background

Estrus synchronization combined with artificial insemination (AI) is used to disseminate improved dairy genetics in smallholder systems. This study evaluated the field effectiveness of a Synchromate-based estrus synchronization protocol and identified factors associated with estrus response and pregnancy in the Gondar Zuria district, northwestern Ethiopia.

Methods

In a prospective, longitudinal, field-based intervention study (2019–2020), 423 of 690 presented smallholder dairy cows and heifers met eligibility criteria (based on age, postpartum interval, presence of corpus luteum, and clinical reproductive status) and received a first Synchromate injection; eligible non-responders were re-treated with a second injection. Estrus was detected by behavioral observation and confirmed by a trained AI technician; pregnancy was diagnosed by rectal palpation at 90 days post-AI. Data were analyzed using multivariable logistic regression, adjusting for relevant animal- and herd-level factors, with results expressed as adjusted odds ratios (AORs) and 95% confidence intervals (CIs).

Results

Of 690 animals presented, 423 met the eligibility criteria and received the first synchromate injection. Estrus was detected in 165 (39.0%) animals after the first injection, and they were inseminated. Of the 112 eligible non-responders, which received the second injection, 71 of them expressed estrus, and they were inseminated. Overall, 236/423 (55.8%) animals were inseminated, and 50 (21.2%) were diagnosed pregnant. High body condition score was positively associated with estrus response (AOR = 1.80, 95% CI: 1.02–3.20; $P = 0.043$), whereas breed was not significant. Crossbred cattle had higher odds of pregnancy than indigenous cattle (AOR = 3.24, 95% CI: 1.37–7.69; $P = 0.008$), while animals responding to the second injection had lower odds of pregnancy (AOR = 0.12, 95% CI: 0.025–0.55; $P = 0.007$).

Conclusion

Synchromate-based synchronization was implementable under the studied smallholder field conditions, although the overall pregnancy outcome was limited. Adequate body condition, accurate estrus detection, timely artificial insemination, competent technical service, and post-breeding management are important for improving reproductive performance.

Introduction

Dairy production is an important component of Ethiopia's livestock sector and contributes substantially to household nutrition, income, and rural livelihoods (1). However, the productivity of the dairy sector remains constrained by low the genetic potential of indigenous cattle, inadequate nutrition, animal health problems, and weaknesses in reproductive management and service delivery. Improving reproductive efficiency is therefore essential for accelerating genetic improvement, increasing the availability of improved dairy animals, and enhancing milk production and farm profitability (2, 3).

Genetic improvement of Ethiopian dairy cattle has largely relied on crossbreeding indigenous cows with exotic dairy breeds and the use of artificial insemination (AI) to disseminate improved genetic material. Although these approaches provide important opportunities for increasing the productive potential of smallholder dairy cattle, their success depends heavily on effective reproductive management (4). Poor body condition and nutrition, postpartum reproductive disorders, inadequate estrus detection, limited access to timely AI services, inadequate technical capacity, and weaknesses in breeding records can substantially reduce reproductive performance and the effectiveness of genetic improvement programs. These constraints are particularly relevant under smallholder production systems, where continuous observation of animals and timely access to skilled reproductive services may be difficult (2, 3, 5).

Estrus synchronization (ES) is an important reproductive management technology that manipulates the estrous cycle to induce estrus in a group of females within a relatively predetermined period. When appropriately implemented, ES can facilitate the efficient use of AI, improve the dissemination of superior genetic material, reduce dependence on prolonged estrus detection, and facilitate more organized reproductive management (6, 7). However, successful synchronization requires appropriate animal selection, adequate nutritional and health status, functional ovarian activity, effective estrus detection, and timely AI. Consequently, animal-related, management, nutritional, technical, and environmental factors can substantially influence the reproductive outcomes of synchronization programs (2, 8).

Prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) and its synthetic analogues, including cloprostenol, are widely used for estrus synchronization in cattle because they induce luteolysis of a functional corpus luteum (CL), resulting in a decline in progesterone concentration and subsequent return to estrus (8, 9). Therefore, $PGF_{2\alpha}$ -based synchronization is most effective in cycling animals possessing a functional CL and is less effective in anestrus animals or animals lacking responsive luteal tissue (9, 10). The response to $PGF_{2\alpha}$ may also vary according to ovarian status, stage of the estrous cycle, parity, body condition, nutrition, and management conditions. In field practice, $PGF_{2\alpha}$ -based programmes may involve a single injection followed by estrus detection and AI, whereas animals not responding to the initial treatment may receive a second injection after an appropriate interval. Recent evidence from Ethiopia demonstrates the continued use of single- and sequential $PGF_{2\alpha}$ -based protocols under field conditions, although reproductive outcomes vary among production systems and animal populations (9–11).

In Ethiopia, ES combined with AI has been promoted as an important reproductive biotechnology for accelerating the dissemination of improved dairy genetics. Nevertheless, the effectiveness of

synchronization and mass AI programmes under smallholder conditions has frequently been limited by inappropriate selection of animals, poor body condition and feed availability, inadequate estrus detection, inappropriate timing of insemination, insufficient technical skills, inadequate recording systems, and inconsistent availability of reproductive inputs and services (2). Recent Ethiopian evidence also demonstrates substantial variation in estrus response and conception among breeds, body condition categories, parity groups, and synchronization protocols (11). Furthermore, a recent review of cattle breeding in Ethiopia emphasized the continuing importance of reproductive management, systematic breeding practices, record keeping, nutrition, and access to appropriate breeding services for improving cattle production and reproductive efficiency (3).

Evidence on the field performance of prostaglandin-based estrus synchronization in smallholder dairy systems remains variable, and information from Gondar Zuria District is limited. In particular, the proportion of eligible animals responding to an initial injection, the additional response obtained after re-treatment, and the subsequent pregnancy and calving outcomes have not been adequately documented in this setting.

Therefore, this study aimed to evaluate the field implementation of a synchromate-based estrus synchronization program followed by artificial insemination among indigenous and crossbred dairy cattle in the Gondar Zuria district.

Materials and Methods

Study Area

The study was conducted in Gondar Zuria District, Central Gondar Zone, Amhara Regional State, Northwestern Ethiopia, approximately 45 km southeast of Gondar town (Fig. 1). Seven kebeles, namely Tsion, Chinchaye, Degola, Maksegnit, Tach Teda, Minziro, and Burbuax, were included. Four kebeles were enrolled in 2019 and three in 2020. The district is located between 12.42° N latitude and 37.61° E longitude, with an elevation ranging from 1,500 to 3,200 m above sea level. The mean annual temperature in the district ranges from 13.6°C to 32°C. Annual rainfall ranges from 641 to 1,678 mm, with a mean annual rainfall of approximately 1,052 mm. The district has an estimated cattle population of 324,897 head.

Study Design and Study Population

A prospective field-based implementation study was conducted during 2019 and 2020 among smallholder farmers in seven purposively selected kebeles of Gondar Zuria District. Farmers were invited through meetings to present their cows and heifers for screening. The seven kebeles with potential for their improved dairy production were purposively selected based on their relatively good access to infrastructure, milk collection centers, major markets, motivated farmers, and livestock reproductive services.

The study population comprised indigenous and crossbred dairy cows and heifers kept by smallholder farmers in the selected kebeles. Animals were screened for eligibility based on age, postpartum interval, body condition, clinical reproductive status, and presence of a functional corpus luteum (CL). Eligible animals were enrolled in the synchromate-based estrus synchronization program and followed through estrus detection, artificial insemination, and pregnancy diagnosis.

Farmer Training, Technology Popularization, and Knowledge Transfer

A technology popularization and field-day event was organized to demonstrate the practical application and potential benefits of estrus synchronization followed by artificial insemination. The field day brought together participating and non-participating farmers, district animal-resource officers, district and kebele animal-breeding experts, artificial insemination technicians, researchers, and district communication personnel. The activity provided an opportunity to demonstrate the advantages of synchronization technology for improving the production capacity of local animals under smallholder production conditions, as well as the production capacity of local animals and its outcomes under local smallholder production conditions, and to facilitate interaction among farmers, technical experts, and researchers.

To support dissemination of the technology, educational leaflets describing the estrus synchronization technology were prepared and distributed to field-day participants. The demonstration emphasized the practical application of the technology and its potential contribution to the production of crossbred calves through synchronization-assisted artificial insemination. At the end of the field day, facilitated discussions were conducted with participants to obtain their views, questions, experiences, aberrations or misunderstandings, and feedback regarding the technology and its implementation under local farming conditions.

Study Animal Selection and Eligibility Criteria

The study animals comprised indigenous local breeds and HF x local zebu crossbred dairy cows and heifers kept under farmers' extensive management conditions in the selected study kebeles. A total of 690 cows and heifers were presented by participating farmers, comprising 447 animals in 2019 and 243 in 2020. Before enrollment in the synchronization program, all animals were evaluated for body condition score (BCS) using a 1–5 scale, based on the overall assessment of fat cover and flesh deposition over the ribs, loin, and tail-head regions. Animals with a $BCS \geq 2.5$ were subjected to further reproductive examination. General health status, pregnancy status, and the reproductive tract were assessed by transrectal palpation before hormone administration by breeding experts and researchers. Only healthy, cyclic, non-pregnant animals that were more than 60 days postpartum and had no obvious reproductive-tract abnormalities were considered eligible for synchronization. The reproductive organs were further examined to assess reproductive status and, where applicable, the presence of a mature corpus luteum (CL) before initiation of the synchronization protocol. Based on these eligibility criteria, 423 animals (269 in 2019 and 154 in 2020) were selected for the initial synchromate-based synchronization intervention.

Thus, 267 animals were excluded at screening due to poor BCS, health status, and reproductive abnormalities.

First Synchromate Administration and Estrus Monitoring

Animals fulfilling the predefined eligibility criteria and considered suitable for synchronization received 2 ml Synchromate (0.263 mg of cloprostenol sodium per 1 ml of solution, equivalent to 0.250 mg of cloprostenol; Synchromate® 0.25 mg/ml; Alivira España, Karizoo, Spain) intramuscularly (IM) on Day 0 (Fig. 2). Following administration, animals were monitored for external behavioral and physical signs of estrus, including clear vaginal mucus discharge, mounting other animals, standing to be mounted, and other characteristic signs of estrus. All animals were detected for estrus at 24, 48, 72, 96, 120, and > 120 hours after Synchromate administration, and animals were observed four times daily: in the morning, at noon, in the early evening, and at midnight. Animals expressing estrus were recorded and inseminated with frozen bull semen.

Second Synchromate administration

Animals that did not exhibit detectable estrus after the first injection were not immediately classified as permanently anestrous. On Day 11, they were re-examined by rectal palpation to assess reproductive status, particularly the presence of a functional corpus luteum, before determining eligibility for re-treatment. Only animals meeting the predefined criteria received a second 2-ml intramuscular dose of synchromate. The re-treatment pathway was therefore based on reproductive status and response rather than random assignment. Following the second administration, animals were monitored for estrus, and those expressing standing heat were inseminated 8–12 hours after confirmation (Fig. 3).

Estrus detection and artificial insemination

Estrus was defined as standing to be mounted, with or without additional signs such as mounting other animals, clear vaginal mucus discharge, restlessness, or vulvar swelling. Expression of estrus was assessed by direct observation, and the date and time of first detection were recorded. Following Synchromate injection, cows and heifers were monitored at 24, 48, 72, 96, and 120 hours, and thereafter when applicable (> 120 hours). The interval from hormone administration to onset of estrus was documented for each animal. Animals expressing estrus after either the first or second injection were considered eligible for artificial insemination. Insemination was performed 8–12 hours after confirmation of standing estrus by trained technicians using frozen semen. Semen was stored in liquid nitrogen and thawed according to the manufacturer's instructions (37°C for 30 seconds). Technician identity, semen bull, and insemination date and time were recorded. The reproductive outcome was subsequently assessed, and conception rate was calculated as the proportion of inseminated animals that became pregnant among those that expressed estrus and received AI.

Pregnancy Diagnosis and Reproductive Outcome Assessment

Pregnancy status was assessed 90 days after artificial insemination by transrectal palpation performed by experienced technicians in each kebele. Farmers were revisited or contacted to record subsequent reproductive outcomes, including abortion and calving. A live-calving outcome was defined as delivery of a live calf. Among inseminated cows and heifers, pregnancy and subsequent outcomes were documented to evaluate the performance of the estrus synchronization and AI protocols. Of 50 pregnancies with complete follow-up, 46 resulted in live calves and 4 ended in abortion. The number of pregnancies lost to follow-up was also recorded.

Data Management and Statistical Analysis

Field data were checked for completeness and consistency before entry into Microsoft Excel. Each animal was assigned a unique identification code, and variables including year, study village, category, breed, parity, body condition score, synchrodate pathway, estrus response, time to estrus, insemination details, technician identification, pregnancy status, and birth outcome were coded for analysis. The dataset was reviewed for missing, duplicate, inconsistent, and out-of-range values, and discrepancies between field records and summary tables were reconciled prior to statistical analysis. Missing values were described for each variable. Complete-case analysis was applied in regression models, with the number of observations reported for each. Animals with incomplete records were excluded only from analyses requiring the missing variable, but not from the overall study dataset. The final dataset comprised verified individual animal records corresponding to the study population and reproductive outcomes. Data were analyzed using IBM SPSS Statistics version 22.0. Categorical variables were summarized using frequencies and percentages, while continuous and ordinal variables were described using measures of central tendency and dispersion. Estrus response and pregnancy status were treated as binary outcomes, with primary estrus outcomes defined as (1) response after the initial injection, (2) response among animals receiving the re-treatment injection, and (3) cumulative response after completion of the synchronization sequence. Pregnancy was defined as a positive diagnosis among inseminated animals, and the calving outcome was assessed among pregnancies with documented follow-up. Initial associations between reproductive outcomes and explanatory variables, including breed type, animal category (cow/heifer), body condition score, parity, study year, study village, and synchronization pathway, were explored using Pearson's chi-square or Fisher's exact tests, as appropriate. Variables selected a priori based on biological plausibility, study objectives, or evidence of association in the initial analysis were subsequently evaluated using multivariable logistic regression. Separate models were developed for cumulative estrus response and pregnancy, with potential confounders retained irrespective of statistical significance where relevant. Results were reported as crude and adjusted odds ratios (ORs) with 95% confidence intervals (CIs). Time to estrus was summarized according to recorded observation intervals, and statistical significance was set at $P < 0.05$.

Results

Participation of farmers and implementation of the intervention

A total 373 participants including 342 farmers from the seven selected kebeles, 19 district experts, 5 AITs, and 7 invited researchers participated in the training about synchronization before implementation. The training covered estrus synchronization technology, synchronization hormones, handling and management of cows and heifers before and after hormonal treatment, artificial insemination, identification of estrus signs, feeding, isolation of bulls before and after artificial insemination, and calf management. The training incorporated both theoretical and practical components, with participation from researchers, animal-breeding experts, and artificial insemination technicians. A technology popularization field day was organized one year after the synchronization work (conducted in 2021) and was attended by 176 participants, comprising 143 farmers, 18 district experts, 6 researchers, 4 AITs, and 5 support staff (Table 1). Of these, 149 (85.5%) were male and 27 (14.5%) were female. Educational leaflets were prepared and distributed, and participants had the opportunity to observe newborn crossbred calves produced following the estrus-synchronization intervention. At the end of the field day, there was an opportunity to obtain participants' feedback on the synchronization technology.

Table 1
Participants for farmer training and technology popularization field day

Participant category	Participants for farmer training			Field-day participants conducted in 2021		
	Year		Total	Male	Female	Total
	2019	2020				
Farmers	202	140	342	127	16	143
District experts	11	8	19	11	7	18
AITs	3	2	5	02	02	04
Researchers	2	5	7	6	0	6
Supporting staff				3	2	5
Total	218	155	373	149	27	176

Synchromate Administration and Estrus Response

A total of 690 cows and heifers were presented for estrus-synchronization program, comprising 447 animals in 2019 and 243 in 2020. Of these, 423 animals (61.3%) fulfilled the predefined eligibility criteria and received the first synchromate injection, including 269 (60.2%) in 2019 and 154 (63.4%) in 2020. Animals that did not express estrus following the first injection but remained eligible for second shot based on the predefined criteria were subsequently re-examined and received a second synchromate injection. Overall, 112 animals (26.5% of those receiving the first injection) received the second injection, with 56 animals in each study year (Table 2).

Among the 423 animals receiving the first synchromate injection, 165 (39.0%) expressed estrus and were subsequently inseminated following the first injection, including 129 (48.0%) in 2019 and 36 (23.4%) in 2020. Among the 112 animals receiving the second injection, 71 (63.4%) expressed estrus and were subsequently inseminated, including 37 (66.1%) in 2019 and 34 (60.7%) in 2020. Thus, a total of 236 animals were inseminated, comprising 166 in 2019 and 70 in 2020. Overall, 236 of the 423 animals that received the first synchromate injection (55.8%) expressed estrus and were subsequently inseminated, while the remaining 187 initially treated animals did not proceed to AI following the synchronization sequence (Table 2).

Table 2

Synchromate administration, estrus expression, and subsequent artificial insemination by study year

Variables	Year		Total
	2019	2020	
Cows/heifers presented	447	243	690
Received first synchromate injection	269 (60.2%)	154 (63.4%)	423 (61.3%)
Received subsequent second synchromate injection	56 (20.8%)	56 (36.4%)	112 (26.5%)
Expressed estrus and inseminated after 1st injection	129 (48.0%)	36 (23.4%)	165 (39.0%)
Expressed estrus and inseminated after 2nd injection	37 (66.1%)	34 (60.7%)	71 (63.4%)
Total expressed estrus and inseminated	166	70	236 (55.8%)

Factors Associated with Estrus Response

Among 423 animals that received the first synchromate injection, 236 (55.8%) expressed estrus and were subsequently inseminated following either the first or the second synchromate injection. Of these, 165 animals (39.0%) expressed estrus following the first injection, while 71 of the 112 animals (63.4%) that received the subsequent second injection expressed estrus and were subsequently inseminated. In the multivariable logistic regression analysis, body condition score was associated with estrus response. Compared with animals with low body condition scores, animals with a high body condition score had greater odds of expressing estrus (AOR = 1.80, 95% CI: 1.02–3.20; $P = 0.043$). Animals with moderate body condition scores also had higher odds of estrus response, although the association was not statistically significant (AOR = 2.04, 95% CI: 0.90–4.63; $P = 0.087$). Heifers had lower odds of expressing estrus than cows, but the difference was not statistically significant (AOR = 0.63, 95% CI: 0.39–1.03; $P = 0.064$). Similarly, crossbred animals had slightly lower odds of expressing estrus than indigenous animals, although this association was not statistically significant (AOR = 0.88, 95% CI: 0.54–1.42; $P = 0.593$) (Table 3).

Table 3
Multivariable logistic regression analysis of factors associated with estrus response

Predictor	Category	Adjusted OR (AOR)	95% CI	P-value
Breed	Indigenous	1.00 (Ref.)	—	—
	Crossbred	0.88	0.54–1.42	0.593
Animal Category	Cow	1.00 (Ref.)	—	—
	Heifer	0.63	0.39–1.03	0.064
Body Condition Score (BCS)	Low	1.00 (Ref.)	—	—
	Moderate	2.04	0.90–4.63	0.087
	High	1.80	1.02–3.20	0.043

AOR = adjusted odds ratio; CI = confidence interval

Time to Detected Estrus

Among 236 animals with recorded time-to-estrus data, the overall median interval from synchronization treatment to detected estrus was 72 h (range: 24–120 h). Specific interval distribution showed that 33 (19.9%), 40 (24.1%), 38 (22.9%), 15 (9.0%), and 40 (24.1%) animals expressing estrus at 24, 48, 72, 96, and 120 h post-injection, respectively. Animals responding following the first-shot pathway expressed estrus earlier than those requiring the subsequent second-shot pathway (median: 48 vs. 120 h; Mann–Whitney U test, $P < 0.001$) (Table 4).

Table 4
Interval (hours) from synchromate injection to onset of detected estrus by synchronization pathway

Synchronization Pathway	Sample Size (N)	Mean Time (hours)	Median Time (hours)	Range (hours)
First-shot pathway	166	60.7	48.0	24–120
Second-shot pathway	70	105.3	120.0	48–120
Overall	236	70.4	72.0	24–120

Artificial Insemination and Pregnancy Outcome

Among the 236 inseminated animals, 50 (21.2%) were diagnosed pregnant, while 186 (78.8%) were not pregnant. Pregnancy outcomes varied according to breed and synchronization pathway. Crossbred animals had a higher pregnancy rate than indigenous animals (34.4% vs. 16.3%), corresponding to a crude odds ratio (COR) of 2.60 (95% CI: 1.24–5.45; $P = 0.012$). Similarly, animals inseminated following the initial synchromate injection had a higher pregnancy rate than those requiring the subsequent second injection (27.2% vs. 9%; COR = 0.15, 95% CI: 0.034–0.645; $P = 0.011$). Adjusted associations were subsequently evaluated using multivariable logistic regression (Table 5).

Table 5

Artificial insemination and pregnancy outcome according to breed and synchronization pathway

Characteristic	Category	Inseminated (n)	Pregnant n (%)	Crude OR (95% CI)	P-value
Overall pregnancy outcome	Pregnant		50 (21.2)	—	—
	Not pregnant		186(78.8)	—	—
Breed	Indigenous	172	28 (16.3)	1.00 (Ref.)	—
	Crossbred	64	22 (34.4)	2.60 (1.24–5.45)	0.012
Synchronization pathway	First-shot pathway	165	47 (28.5)	1.00 (Ref.)	—
	Second-shot pathway	71	3 (4.22)	0.15 (0.034–0.645)	0.011
Total		236	50 (21.2)		

Factors Associated with Pregnancy

Among the 236 inseminated animals with recorded outcomes, 50 (21.2%) were diagnosed pregnant. In the multivariable logistic regression analysis, breed, synchronization pathway, and study village (kebele) were significantly associated with pregnancy outcome. Crossbred animals had more than three times higher odds of pregnancy compared to indigenous animals (AOR = 3.24, 95% CI: 1.37–7.69; $P = 0.008$). Conversely, animals inseminated following the second-shot pathway had significantly lower odds of pregnancy than those inseminated after the first-shot pathway (AOR = 0.12, 95% CI: 0.025–0.55; $P = 0.007$). Pregnancy odds also varied significantly by location: animals in kebele 3 (AOR = 4.44, 95% CI: 1.34–14.67; $P = 0.015$) and kebele 4 (AOR = 3.66, 95% CI: 1.04–12.84; $P = 0.043$) showed significantly greater odds of pregnancy compared to the reference kebele 1. Animal category (heifer vs. cow) and body condition score were not significantly associated with pregnancy outcome ($P > 0.05$) (Table 6).

Table 6

Table 6: Multivariable logistic regression analysis of factors associated with pregnancy outcome following artificial insemination

Predictor	Category	Adjusted OR (AOR)	95% CI	P-value
Breed	Indigenous	1.00 (Ref.)	—	—
	Crossbred	3.24	1.37–7.69	0.008
Animal Category	Cow	1.00 (Ref.)	—	—
	Heifer	0.73	0.29–1.84	0.506
Synchronization Pathway	First-shot pathway	1.00 (Ref.)	—	—
	Second-shot pathway	0.12	0.025–0.55	0.007
Body Condition Score (BCS)	Low	1.00 (Ref.)	—	—
	Moderate	0.99	0.38–2.60	0.986
	High	1.24	0.43–3.55	0.692
Study Kebele	Kebele 1	1.00 (Ref.)	—	—
	Kebele 2	2.18	0.60–7.95	0.238
	Kebele 3	4.44	1.34–14.67	0.015
	Kebele 4	3.66	1.04–12.84	0.043

Pregnancy Outcome Following Artificial Insemination

Among the 236 inseminated animals across both study years, 50 animals were diagnosed pregnant, yielding an overall pregnancy rate (conception rate) of 21.2%. Pregnancy rates varied considerably across the seven study kebeles. The highest pregnancy rate was recorded in Maksegnit (12/34; 35.3%), followed by Degola (13/45; 28.9%), Chinchaye (8/38; 21.1%), Teda (6/30; 20.0%), Burbuax (5/29; 17.2%), and Tsion (6/49; 12.2%). No pregnancy was recorded among the 11 inseminated animals from Minziro (0%) (Table 7).

Table 7
Pregnancy outcome (Conception rate) across study kebeles

Study village (Kebeles)	Kebeles Identification	Inseminated (n)	Pregnant, n (%)
Tsion	Kebele 1 (K1)	49	6 (12.2)
Chinchaye	Kebele 2 (K2)	38	8 (21.1)
Degola	Kebele 3 (K3)	45	13 (28.9)
Maksegnit	Kebele 4 (K4)	34	12 (35.3)
Teda	Kebele 5 (K5)	30	6 (20.0)
Minziro	Kebele 6 (K6)	11	0 (0.0)
Burbuax	Kebele 7 (K7)	29	5 (17.2)
Total		236	50 (21.2)

Pregnancy Outcome by Breed and Animal Category

Pregnancy rates varied according to cattle breed and animal category across the total 236 inseminated animals. Crossbred animals achieved a higher pregnancy rate than indigenous breeds (22/64, 34.4% vs. 28/172, 16.3%). When evaluated by animal category, cows demonstrated a higher pregnancy rate than heifers (37/156, 23.7% vs. 13/80, 16.2%) (Table 8).

Table 8
Pregnancy outcome by breed and animal category

Variable	Category	Inseminated (n)	Pregnant, n (%)
Breed	Indigenous	172	28 (16.3)
	Crossbred	64	22 (34.4)
Animal category	Cow	156	37 (23.7)
	Heifer	80	13 (16.2)
Total		236	50 (21.2)

Pregnancy Outcome by Synchronization Pathway and Study Year

Pregnancy outcomes varied according to the synchronization pathway and study year. Among the 165 animals inseminated following the one-shot pathway, 47 (28.5%) were diagnosed pregnant, compared with 3 of 71 animals (4.2%) inseminated following the subsequent two-shot pathway. By study year, animals inseminated in the first year (2019) achieved a higher pregnancy rate than those inseminated in 2020 (39/166, 23.5% vs. 11/70, 15.7%) (Table 9).

Table 9
Pregnancy outcome following artificial insemination according to synchronization pathway and study year

Variable	Category	Inseminated (n)	Pregnant n (%)
Synchronization Pathway	One-shot pathway	165	47 (28.5)
	Two-shot pathway	71	3 (4.2)
Study Year	2019	166	39 (23.5)
	2020	70	11 (15.7)
Total		236	50 (21.2)

Birth and Reproductive Outcomes

Among the 50 animals diagnosed pregnant, 46 (92.0%) had a documented calving outcome, whereas 4 (8.0%) aborted based on the scheduled follow up and farmers' report. The proportion of pregnancies resulting in a recorded calf was 92.3% (36/39) in 2019 and 90.9% (10/11) in 2020. Correspondingly, abortion occurred in 3 (7.7%) pregnant animals in 2019 and 1 (9.1%) in 2020 (Table 10). Overall, most confirmed pregnancies progressed to a recorded calving outcome, with no substantial difference in the proportion of pregnancies resulting in calves between the two-implementation years.

Table 10
Birth and reproductive outcomes among inseminated animals by study year

Reproductive outcome	2019, n (%)	2020, n (%)	Total, n (%)
Animals inseminated	166	70	236
Pregnant	39 (23.5)	11 (15.7)	50 (21.2)
Calves born among pregnant animals	36 (92.3)	10 (90.9)	46 (92.0)
Abortion among pregnant animals	3 (7.7)	1 (9.1)	4 (8.0)
Total pregnancies with recorded outcome	39 (100)	11 (100)	50 (100)

Discussions

The farmer-training and technology-popularization component complemented the field intervention by strengthening farmer knowledge and participation. A total of 342 farmers participated in training activities, and 172 participants attended the subsequent field day. Training covered synchronization and AI, animal selection, estrus detection, feeding, pre- and post-treatment management, bull management, and calf care. Such coordinated participation is important for successful synchronization and AI under smallholder conditions, where limited awareness, inadequate estrus detection, poor stakeholder communication, and insufficient technical training remain important constraints in different parts of Ethiopia (2).

The overall estrus response of 55.8% (236/423) observed in the present study indicates a moderate response to the synchromate-based synchronization program under smallholder field conditions. This response was lower than the 62.4% (286/458) reported in a field study conducted in the Debre Birhan milk-shed area of the Amhara Region, Ethiopia, (12); 91.2% reported by (13) in South Ari District, southern Ethiopia; 90.8% reported by (11) in Dalocha District, Ethiopia. The difference may reflect variation in animal selection, reproductive status, body condition, nutritional management, estrus detection, timing of observation, semen quality, and field-level implementation of synchronization and artificial insemination. These factors are particularly relevant under Ethiopian smallholder conditions, where improper selection of cows and heifers, feed shortages, inadequate estrus detection, inappropriate timing of insemination, limited AI-technician capacity, and inadequate service infrastructure have been identified as important constraints affecting the effectiveness of estrus synchronization and AI programs (2).

The 39.0% estrus response among animals responding after the first synchromate injection was lower than the 63.4% response among animals that subsequently received the second injection, which is consistent with findings reported in a previous study (11). Prostaglandin $F_{2\alpha}$ and its analogues induce luteolysis in cattle with a functional corpus luteum; therefore, the response to $PGF_{2\alpha}$ -based treatment depends substantially on the reproductive status and stage of the estrous cycle at the time of treatment. Repeated treatment after an appropriate interval may increase the likelihood that animals not responsive to the first treatment reach a responsive luteal stage. The relatively higher response following the second treatment in the present study therefore supports the practical value of sequential re-treatment, particularly under field conditions where animals may be at different stages of the estrous cycle at the time of the initial $PGF_{2\alpha}$ administration.

The overall median interval from treatment to detected estrus was 72 h, with animals in the first-shot pathway expressing estrus significantly earlier than those in the second-shot pathway (median: 48 vs. 120 h; $p < 0.001$). The peak estrus expression between 48 and 72 h in the first-shot group aligns closely with standard physiological response intervals documented in zebu and crossbred cattle following prostaglandin-induced luteolysis (14). The delayed median response (120 h) in the second-shot group is attributable to the slower follicular wave emergence and variable luteal regression kinetics in animals recovering from sub-clinical anestrus or possessing immature dominant follicles at the time of injection (15, 16).

Multivariable analysis demonstrated that body condition score (BCS) was associated with estrus response in the present study. Cattle with moderate to high BCS (≥ 2.5) had significantly higher odds of expressing estrus (AOR = 1.80, $p = 0.043$) compared to those with low BCS (< 2.5). Nutritional status and body energy reserves are well-established endocrine regulators of the hypothalamic-pituitary-ovarian (HPO) axis in cattle (17, 18). Under unfavorable nutritional conditions or low BCS, reduced circulating concentrations of metabolic signals suppress the pulse frequency of luteinizing hormone (LH), impair dominant follicle maturation, and ultimately cause anovulation or behavioral silent estrus (19, 20). The strong positive association between adequate BCS and estrus expression observed in this study is

consistent with ((21–25) highlighted BCS as the primary driver of hormonal responsiveness at field synchronization trials across Ethiopia in zebu and crossbred cattle under smallholder management. Furthermore, our findings are consistent with results reported by (11) in central Ethiopia, who observed that cows with $BCS \geq 2.5$ achieved significantly higher estrus detection rates (62.5%) compared to thin cows (35.0%). However, the overall estrus response observed in our low-BCS cattle was notably lower than the 73.3% response reported by (26) in peri-urban dairy herds in south-western Ethiopia, where strategic concentrate supplementation buffered against energy deficits. Conversely, our findings showed higher responsiveness in moderate-BCS cattle than the 42.1% response reported by (27) in rural smallholder herds of southern Ethiopia, where severe seasonal feed scarcity and high parasite loads compromised baseline metabolic status. These comparisons demonstrate that while hormonal regimens like synchromate provide the requisite endocrine signal, metabolic adequacy remains a prerequisite for overt estrus expression (28).

Parity also influenced estrus expression, with heifers exhibiting lower odds of behavioral estrus compared to multiparous cows (AOR = 0.63), although this difference did not reach statistical significance ($p = 0.064$). The lower numerical response in heifers is consistent with national field evaluations in Ethiopia (14, 29), where pubertal delay, sub-optimal growth velocity, and nutrient partitioning toward bodily growth impair cyclic reactivity relative to multiparous cows with established cyclic activity ((30, 31)). While multiparous cows often show higher baseline cyclic reactivity following hormonal treatments, young heifers under low-input smallholder management frequently remain in prepubertal anestrus, suppressing their responsiveness to hormonal synchronization (32). Similarly, breed was not significantly associated with estrus response in the present study (AOR = 0.88, 95% CI: 0.54–1.42; $P = 0.593$). This finding is consistent with an Ethiopian study of Boran and Boran–Holstein crossbred cattle in which breed did not significantly affect the response to $PGF_{2\alpha}$ -based estrus synchronization (33). More recently, a study of Boran cattle in southwestern Ethiopia also found no significant effect of breed-related reproductive grouping or synchronization protocol on estrus response, emphasizing the importance of physiological status in determining responsiveness to $PGF_{2\alpha}$ (8). In contrast, other Ethiopian field studies have reported differences in estrus response among breeds, suggesting that the effect of breed may vary with nutritional status, reproductive status, management system, and environmental conditions rather than acting independently (2, 11, 34). Therefore, the absence of a significant breed effect in the present study suggests that, under the conditions of this pre-scaling-up program, animal physiological and nutritional status may have been more important determinants of estrus response than breed type alone under the conditions of this field program. The genetic makeup of the animals may not have differed substantially in terms of blood hormone levels and response, despite the breed difference between local and local $\times$ Holstein-Friesian crosses, which they were kept under the same management system. The significant association between high BCS and estrus response further supports the importance of selecting animals in adequate body condition and providing appropriate nutritional and reproductive management before synchronization.

The overall pregnancy rate following AI was 21.2% (50/236). This rate was considerably lower than 48.3% conception rates reported by (11) in the Dalocha district following single- and double-shot

cloprostenol protocols, 43% conception rate reported by (26) in southwestern Ethiopia following prostaglandin-based synchronization and AI, 60.4% conception rate reported by (27) following estrus synchronization in Dale district, southern Ethiopia. The relatively lower pregnancy rate observed in the present study may reflect the field-based pre-scaling-up nature of the intervention, differences in animal reproductive status and body condition, estrus detection and timing of AI, semen handling, technician performance, and post-insemination management even though the practical effectiveness of synchromate-based synchronization. There is also substantial difference among studies in animal selection, synchronization protocols, management conditions, and definitions and timing of pregnancy assessment. In Ethiopian smallholder systems, multiple interacting technical and management constraints can reduce the reproductive outcome of synchronization and AI programs even when an acceptable proportion of animals express estrus.

Breed and synchronization pathway were significantly associated with pregnancy in the present study. Crossbred animals had higher adjusted odds of pregnancy than indigenous animals (AOR = 3.24, 95% CI: 1.37–7.69; $p = 0.008$). This finding is consistent with (11) in the Dalocha district with the conception rates of 64.8% in crossbred compared with 40.8% in local cattle. The higher pregnancy likelihood among crossbred animals may reflect differences in reproductive performance, management, nutritional status, and genetic background, although breed effects should not be interpreted independently of these management factors. In contrast, animals inseminated following the second-shot pathway had substantially lower adjusted odds of pregnancy than those inseminated following the first-shot pathway (AOR = 0.12, 95% CI: 0.025–0.55; $p = 0.007$). This outcome likely reflects the absence of randomization, as the second-shot group consisted of animals that failed to express estrus after the first injection. Thus, the reduced pregnancy rate may be attributed to biological differences in reproductive status or underlying responsiveness among animals expressing estrus after the initial treatment. This finding further supported by (2) showing that single- and double-dose PGF₂ α protocols can produce comparable conception outcomes when appropriately managed, despite differences in the timing and pattern of estrus response.

Among the 236 animals inseminated following estrus synchronization, 46 (19.5%) subsequently gave birth to live calves and 4 (1.7%) abortion. When considered only among the 50 animals with confirmed pregnancy, 46 (92.0%) progressed to live birth, indicating that most established pregnancies were maintained to calving. The 19.5% birth outcome among all inseminated animals was lower than the 51% calving rate from all AI services reported in a national assessment of the artificial insemination delivery system in Ethiopia (35), the 55.9% calving rate reported among AI-receiving animals in intensive dairy farms in central Ethiopia (36). The lower proportion in the present study may reflect differences in the intervention context, including the smallholder production system, animal selection, synchronization response, AI timing, technician performance, follow-up, and post-insemination management. More importantly, the present study evaluated a synchronization-based field intervention. Therefore, the 19.5% birth outcome should be taken as the overall proportion of inseminated animals that ultimately produced a recorded live calf, while the 92.0% figure demonstrates the relatively high proportion of confirmed pregnancies that progressed successfully to birth. The latter finding indicates that once pregnancy was

established, pregnancy maintenance to calving was generally favorable under the field study conditions in smallholder farmers.

Collectively, the findings suggest that synchromate-based estrus synchronization could be implemented as a practical reproductive-biotechnology intervention under smallholder dairy conditions, but its effectiveness depends on more than the hormonal treatment itself. The overall 55.8% estrus response (236/423) demonstrates that a substantial proportion of eligible animals responded sufficiently to proceed to AI, while the higher response among animals receiving sequential treatment indicates the potential value of re-treatment of appropriately selected non-responders. However, the subsequent pregnancy outcome demonstrates that achieving estrus is only one stage of a successful breeding program. Effective pre-scaling-up therefore requires appropriate animal selection, adequate body condition and nutrition, systematic estrus monitoring, timely AI, competent technicians, proper semen handling, reliable reproductive records, and coordination among farmers and service providers. These requirements are consistent with the major constraints identified in Ethiopian smallholder synchronization and AI programs. Thus, future scaling-up should prioritize an integrated service-delivery model rather than focusing exclusively on increasing the number of hormonally treated animals.

Limitations of the Study

This study has several limitations. First, since there was no untreated or alternative-protocol comparison group, the uncontrolled field design precludes the causal attribution of reproductive results to synchromate. Second, kebeles and farmers were purposively selected, and participation was voluntary, which may limit generalizability. Third, the exclusion of presented animals before treatment may have introduced selection bias. Fourth, entry into the re-treatment pathway was determined by prior response and reproductive status; therefore, comparisons between initial- and re-treatment pathways are observational and vulnerable to confounding by indication. Finally, the number of pregnancy events was limited relative to the number of candidate predictors, and pregnancy and calving follow-up should be interpreted in light of any missing records.

Conclusion

Synchromate-based estrus synchronization, followed by AI, was implemented among selected smallholder dairy cattle under the field conditions of the Gondar Zuria district. The cumulative estrus response reflected the contribution of both initial treatment and re-treatment, but the overall pregnancy outcome was limited. Adequate body condition was associated with greater estrus response, while animals entering the re-treatment pathway had lower pregnancy odds than those responding after the initial injection; this comparison is not causal because pathway assignment was nonrandom. Improvement of animal selection, nutrition, estrus detection, AI timing, semen handling, technical supervision, and reproductive follow-up is needed. Future studies should use multi-site designs with standardized protocols, adequate control groups, clustering adjustment, and economic evaluation.

List of Abbreviations

AI Artificial Insemination

AOR Adjusted Odds Ratio

BCS Body Condition Score

CL Corpus luteum

HPO Hypothalamic-Pituitary-Ovarian axis

LH Luteinizing hormone

PGF2 α Prostaglandin F2 α

Declarations

Ethics Approval and Consent to Participate

Ethical approval was obtained from the Ethical Review Committee of the Gondar Agricultural Research Center (GARC-RERC), Gondar, Amhara, Ethiopia (Approval Ref. No. GARC/RERC/312/08/19), on 16 August 2019. Informed verbal consent was obtained from all participating animal owners before enrollment. All procedures, including clinical examination, hormone administration, artificial insemination, pregnancy diagnosis, and follow-up, were performed by trained veterinary or animal-health personnel in accordance with institutional and national animal-welfare requirements.

Consent for Publication

Not applicable. This manuscript does not contain any person's data in any form.

Competing Interests

The authors declare that they have no competing interests.

Funding

Not applicable.

Author Contribution

TAK: Conceptualization, study design, data collection, statistical analysis, software, writing (original draft), manuscript drafting, writing (review), and editing. DAM: Data collection, statistical analysis, software, draft writing, manuscript drafting, writing and editing the manuscript. AKS and YAA, TDG, and YCG: Conceptualization, study design, data collection, draft writing, review and editing. SAG: Study design, Resource management, and Supervision. All authors review and approved the manuscript.

Acknowledgement

The authors express their sincere gratitude to Amhara Agricultural Research Institute (ARARI) for their support. The authors extend their special thanks to the Central Gondar Zone Administration Office, the Central Gondar Zone Livestock and Fisheries Resource Development Office, and the Gondar Zuria District Livestock Resource Office for their institutional support and administrative collaboration. Finally, the authors gratefully acknowledge the field veterinary professionals, kebele administrators, and smallholder livestock farmers for their invaluable cooperation and dedicated assistance during the field trials.

Data Availability

The datasets generated and analyzed during this study are available from the corresponding author upon reasonable request.

References

1. Shapiro BI, Gebru G, Desta S, Negassa A, Negussie K, Aboset G et al. Ethiopia livestock master plan: Roadmaps for growth and transformation. 2015.
2. Abebe B, Alemayehu M. Challenges and opportunities on estrus synchronization and mass artificial insemination in dairy cows for smallholders in Ethiopia. *Int J Zool*. 2021;2021(1):9914095.
3. Mohammed Ali T. A review on underestimated; but pertinent challenges of cattle breeding: the Ethiopia perspective. *J Appl Anim Res*. 2024;52(1):2375246.
4. Gebreyohanes G, Yilma Z, Moyo S, Okeyo Mwai A. Dairy industry development in Ethiopia: Current status, major challenges and potential interventions for improvement. 2021.
5. Leggesse G, Gelmesa U, Jembere T, Degefa T, Bediye S, Teka T et al. Ethiopia national dairy development strategy 2022–2031. 2023.
6. Lidder P, Sonnino A. Biotechnologies for the management of genetic resources for food and agriculture. *Adv Genet*. 2012;78:1–167.
7. Mercadanteab VR, Evena F, Tabatabaia N, Vidlunda T. Recent developments in estrus synchronization programs. 2024.
8. Dodicho AA, Gebeyehu ST, Kidane ZY. Evaluating single and double doses of prostaglandin (PGF_{2α}) injection on estrus induction and conception rate in Boran cattle breed in Southwestern Ethiopia.

- Cogent Food Agric. 2024;10(1):2420851.
9. Bihon A, Assefa A. Prostaglandin based estrus synchronization in cattle: A review. *Cogent Food Agric.* 2021;7(1):1932051.
 10. Lopez-Gatius F. Ovarian response to prostaglandin F2 α in lactating dairy cows: A clinical update. *J Reprod Dev.* 2022;68(2):104–9.
 11. Haile SM, Abebe BK, Tesfa TW. Efficiency evaluation of two estrus synchronization protocols in estrus response and conception rate of dairy cows in the Dalocha district, Ethiopia. *Heliyon.* 2023;9(1).
 12. Demis C, Zewudie T, Aydefruhim D, Terefe W. On farm trial of prostaglandin based estrus synchronization protocols in selected milk-shed areas of Amhara Region, Ethiopia. *Anim Prod.* 2022;24(3):120–6.
 13. Aydaiso W, Chebo C, Mohammed N. Evaluation of Oestrus Synchronization Program on Dairy Cattle in South Ari District, South Omo Zone, Southern Ethiopia. *Omo Int J Sci.* 2020;3(2):13–29.
 14. Gizaw S, Tesfaye Y, Mekuriaw Z, Tadesse M, Hoekstra D, Gebremedhin B, et al. Oestrus synchronization for accelerated delivery of improved dairy genetics in Ethiopia: Results from action research and development interventions. International Livestock Research Institute; 2016.
 15. Bó GA, de la Mata JJ, Baruselli PS, Menchaca A. Alternative programs for synchronizing and resynchronizing ovulation in beef cattle. *Theriogenology.* 2016;86(1):388–96.
 16. Stewart JL, Stella S, Cunha LL, Dias NW, Canisso IF, Mercadante VRG, et al. Administration of nerve growth factor- β to heifers with a pre-ovulatory follicle enhanced luteal formation and function and promoted LH release. *Theriogenology.* 2020;148:37–47.
 17. Hess B, Lake S, Scholljegerdes E, Weston T, Nayigihugu V, Molle J, et al. Nutritional controls of beef cow reproduction. *J Anim Sci.* 2005;83(suppl13):E90–106.
 18. Fernando L-G. Ovarian response to prostaglandin F 2 α in lactating dairy cows: A clinical update. *J Reprod Dev.* 2022;68(2):104–9.
 19. Wiltbank M, Lopez H, Sartori R, Sangsritavong S, Gümen A. Changes in reproductive physiology of lactating dairy cows due to elevated steroid metabolism. *Theriogenology.* 2006;65(1):17–29.
 20. Sartori R, Prata A, Figueiredo A, Sanches B, Pontes G, Viana J, et al. Update and overview on assisted reproductive technologies (ARTs) in Brazil. *Anim Reprod (AR).* 2018;13(3):300–12.
 21. Tegegne A, Hoekstra D, Gebremedhin B, Gizaw S. History and experiences of hormonal oestrus synchronization and mass insemination of cattle for improved genetics in Ethiopia. From science to developmental impact; 2016.
 22. Milkias T, Chebo C, Worku A. Status of On-Farm Artificial Insemination Services and Effectiveness of Oestrus Synchronization in Dairy Cattle Under Small-Scale Dairy Farming System. *Veterinary Med Sci.* 2026;12(4):e71035.
 23. Getabalew M, Alemneh T. Status of artificial insemination; Its constraints and estrous synchronization in Ethiopia. *SM J Reproductive Healthand Inferfility.* 2019;4(1):1008.

24. Gatew H, Zewde T, Kassa G, Chanyalew Y, Gazu L. Factors influencing the success of on-farm estrus synchronization of dairy cattle in North Shewa Zone, Amahara Region, Ethiopia. *Int J Livest Prod*. 2018;9(1):9–16.
25. Goodluck SJ, Nguluma AS, Wilson S, Chenyambuga ZCN, Lugeye S, Kabululu ML et al. Effect of body condition score on reproductive performance of crossbred dairy cows in the Tanga region, Tanzania. *Ovozoa: Journal of Animal Reproduction*. 2025;14(3):159 – 70.
26. Masho W, Foato A, Begna R. Breeding practices and evaluation of hormonal estrus synchronization and mass artificial insemination of dairy cattle in southwest Ethiopia. *J Agric Food Res*. 2024;16:101167.
27. Legesse D. Assessment of breeding practice and evaluation of estrus synchronization of dairy cattle in Sidama Zone. Southern Ethiopia: Hawassa University; 2016.
28. Cardoso Consentini CE, Wiltbank MC, Sartori R. Factors that optimize reproductive efficiency in dairy herds with an emphasis on timed artificial insemination programs. *Animals*. 2021;11(2):301.
29. Kibre D, Ashebir G, Gebrekidan B, Fesseha H. Study on factors affecting estrus synchronization in smallholder dairy farming systems of Tigray, Northern Ethiopia. *Veterinary Med Int*. 2022;2022(1):2435696.
30. Rhodes F, McDougall S, Burke C, Verkerk G, Macmillan K. Treatment of cows with an extended postpartum anestrous interval: Review. *J Dairy Sci*. 2003;86(6):1876–94.
31. Morotti F, Lorenzetti E, Seneda MM. Artificial insemination program in cattle. *Sustainable Agriculture Reviews 54: Animal Biotechnology for Livestock Production 1*: Springer; 2021. pp. 1–53.
32. Piñeyrúa JTM, Fariña SR, Mendoza A. Effects of parity on productive, reproductive, metabolic and hormonal responses of Holstein cows. *Anim Reprod Sci*. 2018;191:9–21.
33. Yilma T. Estrus Response of Boran and Boran-Holstein Crossed Cattle to pgf2 α and Pregnancy Rates to Sexed and Conventional Semen, Holeta, Ethiopia. Addis Ababa: Addis Ababa University; 2020.
34. Ayanie TD, Wassie AT, Kebede EM, Mekonnen TY, Geleto TD, Biru AL. Ovarian response and conception rate in Boran and Boran* Holstein cows treated by Gonadotrophin-realizing hormone and ProstaglandinF2 α with and without exogenous progesterone. *BMC Vet Res*. 2023;19(1):75.
35. Melesse K. The performance of artificial insemination delivery system in Amhara, Oromia, SNNP and Tigray Regions of Ethiopia. *Int J Livest Prod*. 2020.
36. Tschopp R, Gemechu G, Wood JL. A longitudinal study of cattle productivity in intensive dairy farms in Central Ethiopia. *Front Veterinary Sci*. 2021;8:698760.

Figures

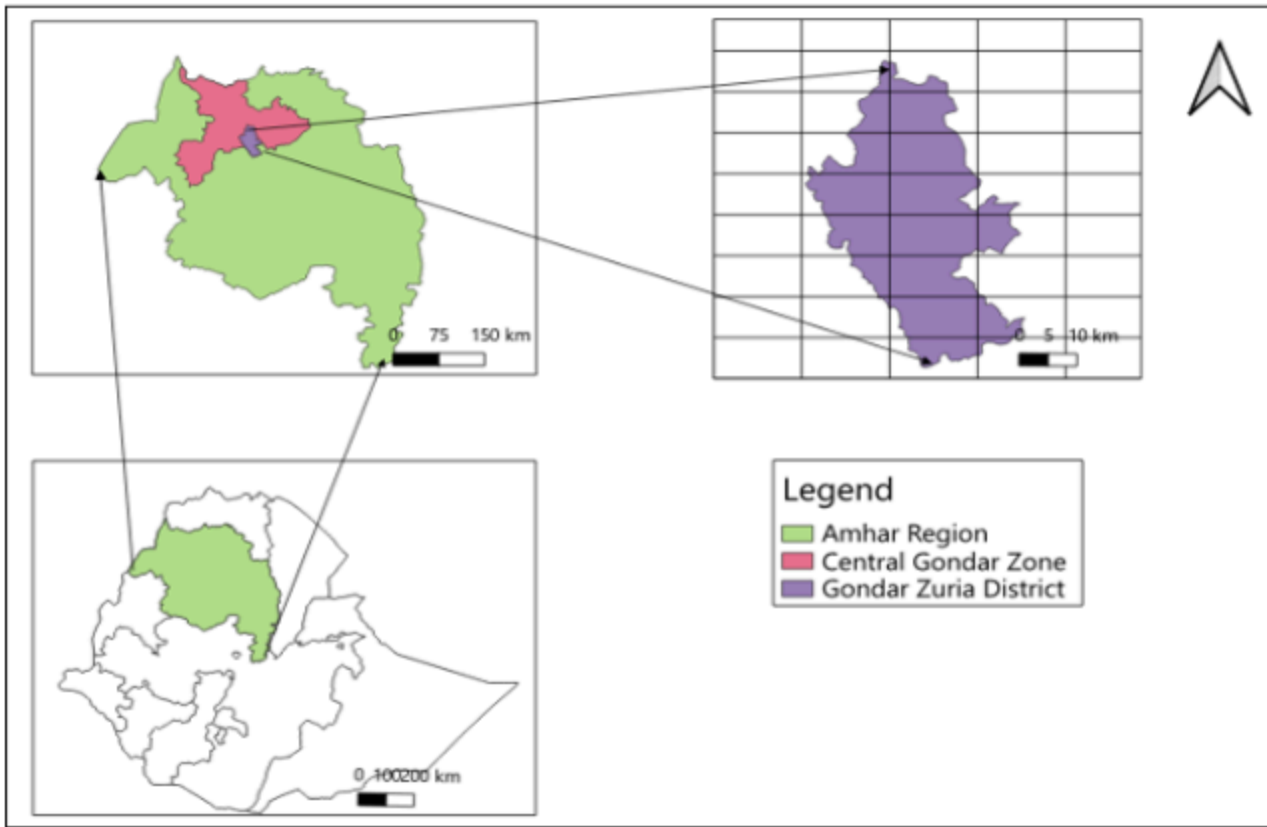


Figure 1

Map of the Study Area

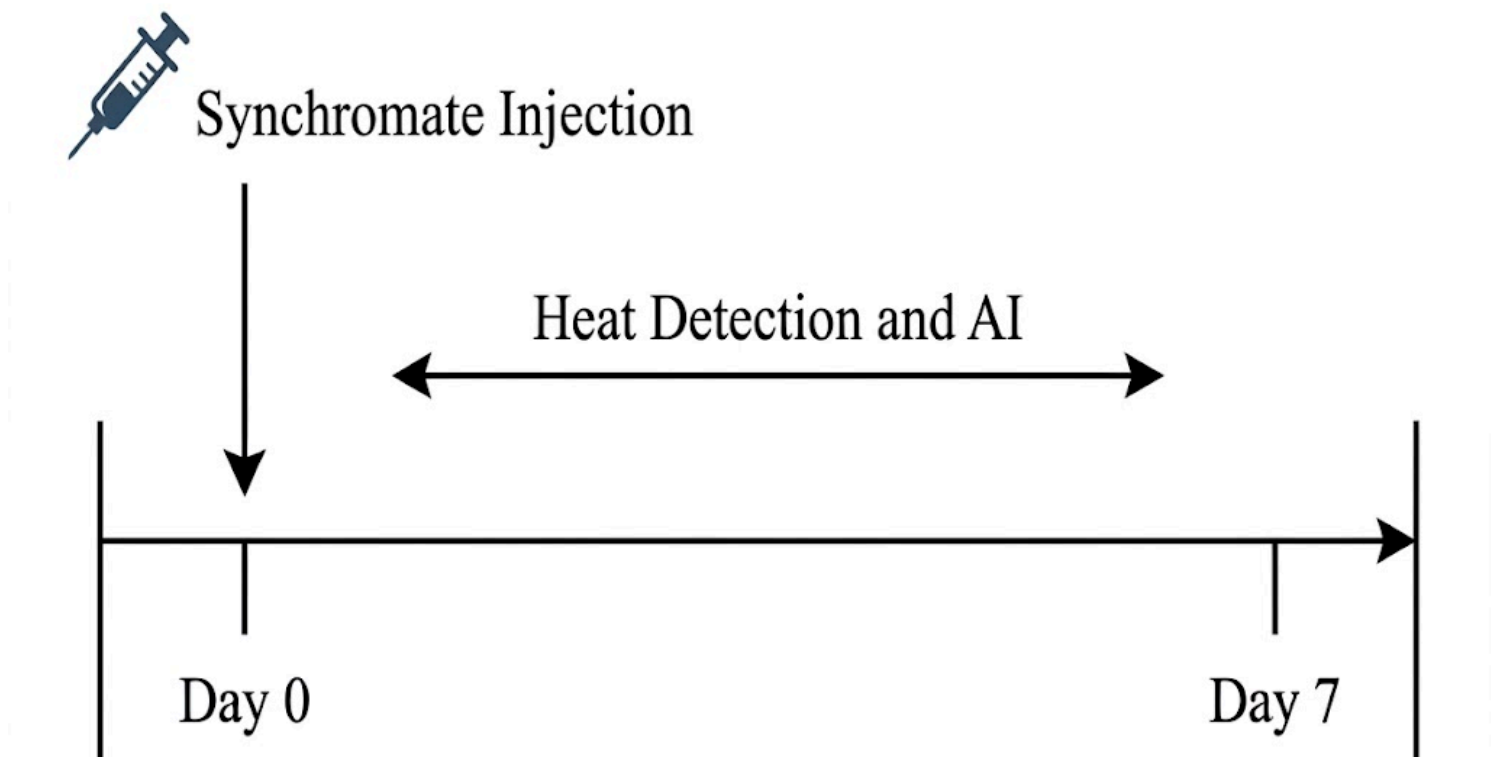


Figure 2

Schematic of the reproductive management protocol following a single synchromate injection.

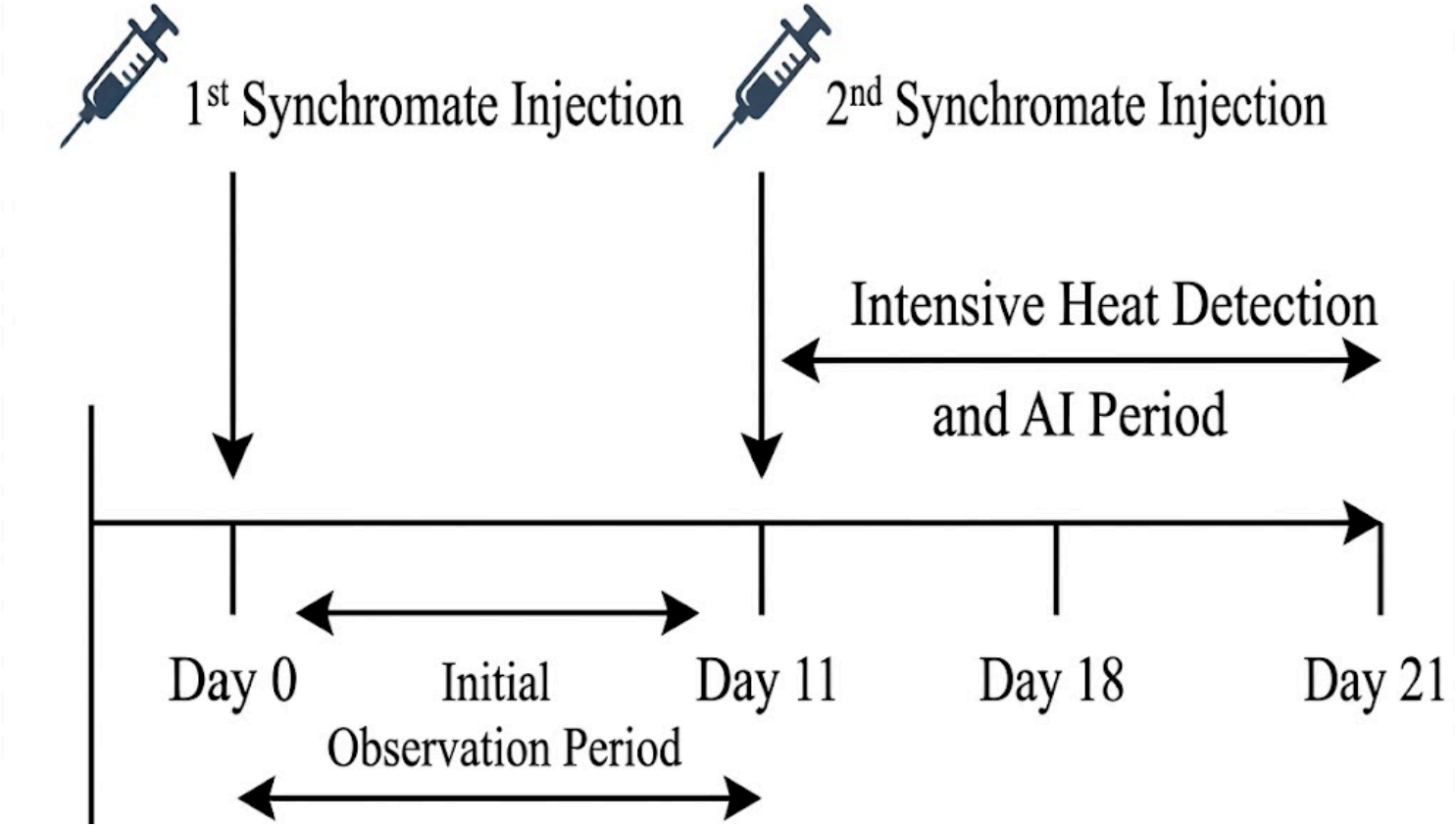


Figure 3

Schematic diagram of the Second synchromate Injection Protocol at Day 0 & Day 11.