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Oestrus synchronization for accelerated delivery of improved dairy genetics in Ethiopia: Results from action research and development interventions

Oestrus synchronization for accelerated delivery of improved dairy genetics in Ethiopia: Results from action research and development interventions

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Executive summary

Oestrous synchronization is the manipulation of the oestrous cycle or induction of oestrus to bring a large percentage of a group of females into oestrus at a short, predetermined time. The first field trial on hormonal oestrous synchronization regime and mass artificial insemination was conducted by the Improving Productivity and Market Success (IPMS) project in Tigray and Southern Nations, Nationalities, and Peoples' Region (SNNP) regions. The objective was to improve access to improved dairy genetics by smallholder farmers and to kick-start market-oriented smallholder dairy development in Ethiopia. Following the field trial, the synchronization technology was adopted and scaled up by the Ministry of Agriculture (MoA) and regional Bureaus of Agriculture (BoAs) in collaboration with international development partners (IPMS and Livestock and Irrigation Value Chains for Ethiopian Smallholders (LIVES) projects of International Livestock Research Institute (ILRI)) and the national research system. Performance of the scaled up project was inconsistent in the application of the technology and the results achieved. The LIVES project thus initiated action research activities to appraise the performance of the technology at a larger scale and introduce state of the art technologies to improve the performance of oestrous synchronization. The studies were conducted by four LIVES-sponsored MSc projects in the four highland regions of Ethiopia. This working paper synthesizes results of action research activities and performance of the technology at larger scale, discuss implications of the results and draw recommendations for effective and sustained application of the technology in Ethiopia. The results of the four studies in the four highland regional states showed that farmers' breeding methods have significantly shifted to Artificial Insemination (AI). However, availability, regularity and effectiveness/efficiency of the service is below expectation of farmers and the current studies indeed showed that conception rates are low. Hormonal synchronization of oestrus is well adopted by farmers who had the access to the service. However, farmers expressed low satisfaction with the service, although evaluation of the technology by farmers is confounded with low conception rates which may also result mainly from low efficiency in the AI practice. This argument could be supported by the data generated in this study that oestrous response rate per se was very high, but conception rates were very low. AI technicians' skill on identification of functional corpus luteum (CL) and AI skill are important determinants of successful oestrous synchronization and pregnancy. A comparison of results from action research activities and the regular synchronized AI service indicated that there is a possibility to improve the service; oestrous response can be increased by18.2% and conception rate by 46.6%. However, a strict follow up of activities, skill upgrading and consideration of the factors affecting oestrous response and successful pregnancy presented in this paper and elsewhere in the literature need to be considered for a successful oestrous synchronization and AI service. Choice of technically right and practically feasible protocol is essential for a successful breeding program. Based on the results, it can be recommended that single dose and heat detection could be a more feasible protocol than the double dose protocol for Ethiopia. Further challenges to the oestrous synchronization and AI program are embryo loss (which was found to be high in the current study), incidence of missed AI opportunity due to failure to detect heat and wrong insemination of non-oestrous cows, and pregnancy diagnosis through rectal palpation which could be intrusive and could not be done earlier than 60 days post AI. Technological aides that use progesterone profiling (e.g. using Hormonost®) could be a solution for all the above challenges.

1. Introduction

Odde (1990) described synchronization of oestrus as the manipulation of the oestrous cycle or induction of oestrus to bring a large percentage of a group of females into oestrus at a short, predetermined time. Instead of females being bred over a 21-day, synchronization can shorten the breeding period to less than five days. Because the cow has a 21-day oestrous cycle, cows could have three opportunities to be bred in a 45-day breeding season with synchronization of oestrus at the beginning of the breeding season, whereas a 63-day breeding season would be required for three breeding opportunities without synchronization of oestrus.

The advantage of oestrous synchronization and mass artificial insemination (OSMAI) in the Ethiopian context relates largely to the challenges faced by the AI service system in the country. Efficiency of AI service in Ethiopia was found to be very low with conception rate to first service being 27.1% (Desalegne et al. 2009). Furthermore, the number of AI services provided per AI technician over a given period of time is expected to be low. This is because of the challenges associated with providing services to individually occurring heats over geographically dispersed cows. Azage et al. (1989) listed the advantage of using oestrous synchronization under smallholder context to be, among others, production of large number of dairy animals in a short period of time, matching calving with feed availability and market demand for dairy products and to improving the effectiveness and efficiency of the AI service. The major problems with the AI system include technical limitation, lack of transport facility, poor quality of semen, poor heat detection, lack of incentive, and unavailability of the service off-working hours (Azage et al. 2012).

Studies on oestrous synchronization in dairy cattle in Ethiopia was initiated in the late eighties (Azage et al. 1989; Mukasa-Mugerwa et al. 1989; Mutiga et al. 1993). The first field trial was conducted by the IPMS project in Tigray and SNNP regions (Azage et al. 2012) with the objectives of testing a simple hormonal oestrous synchronization regime and mass insemination under on-farm condition to improve access to improved dairy genetics by smallholder farmers and to kick-start market-oriented smallholder dairy development in selected sites. Following the field test, the synchronization technology was adopted and scaled up by the MoA and regional BoAs in collaboration with international development partners (IPMS and LIVES projects of ILRI) and the national research system. Performance of the scaled up project was inconsistent in the application of the technology and results achieved. The LIVES project thus initiated action research activities to appraise the performance of the technology at a larger scale and introduce state of the art technologies to improve the performance of OSMAI in Ethiopia through LIVES-sponsored MSc projects in the four highland regions of Ethiopia. The current paper synthesizes results of action research activities and performance of the technology at larger scale, discuss implications of the results and draw recommendations for effective and sustained application of the technology in Ethiopia.

2. Source of study materials

This study compiles and analyzes five MSc theses conducted on hormonal synchronization and mass artificial insemination (OSMAI) in dairy cattle in 2015 (Destalem 2015; Tadesse 2015; Bainesagn 2015; Samuel 2015; Debir 2015). The theses were sponsored by the LIVES project as part of its action research projects. The study also briefly reviews performance of oestrus synchronization in Ethiopia and elsewhere from the literature. The MSc research projects were conducted in Oromia (Ada berga, Ejere and Metarobi districts), Amhara (Bahir Dar Zuria, Mecha and Yilmanadensa districts), Tigray (Laelay Mychew, Adwa and Ahferom districts by Destalem (2015) and Kilte-awlaelo, Atsibiwenberta and Ganta-afeshum districts by Tadesse (2015)) and SNNP (Arbegona, Bensa and Bona zuria districts) states in Ethiopia. Three activities were conducted in each state: assessment of farmers breeding practices and opinions on OSMAI, evaluation of OSMAI program of the Bureau of Agriculture in each state, and action research on OSMAI. The methods followed are described below.

Assessment of farmers' breeding practices and perceptions

A total of 180 respondents were sampled for questionnaire survey. Twenty households from each of nine rural kebeles in each of the three districts in each regional state were purposively selected for questionnaire administration. Questionnaire surveys and discussions with focus groups and key informants were conducted to assess dairy producers' practices and perceptions.

Evaluation of BoA synchronization and mass AI

The performance of synchronization and mass artificial insemination program of the BoA in each state were assessed using secondary data from records of AI centers on synchronized, inseminated and conceived cows in 2012 and 2013. The protocol followed by the BoA was treatment of cows/heifers with single shot of prostaglandin, heat detection and AI. Data on 701, 225, and 883 cows in Tigray, Amhara and SNNP, respectively, were used for the study. The dependent variables evaluated were oestrus response, conception rate and number of service per conception. AI technician efficiency, sire and dam breed, body condition, parity and year were included as independent variables. The BoA results were compared with results from action research activities conducted in Amhara, Tigray and SNNP.

Action research on oestrous synchronization and mass AI

Performance of hormonal oestrous synchronization was evaluated in five action research activities, one in each of the three states (Oromia, Amhara and SNNP) and two in Tigray (Destalem 2015 and Tadesse 2015). In each of the experiments, 126–130 cows/heifers were selected based on presence of receptive corpus luteum and absence of pregnancy upon rectal palpation. Four protocols varying in the frequency of hormone administration and AI were evaluated:

Protocol 1: One injection of Prostaglandin, heat detection and AI

Protocol 2: Double injection of Prostaglandin at 14 days interval, heat detection and AI

Protocol 3: Double injection of Prostaglandin at 14 days interval, fixed AI at 48–72 hrs. post injection

Protocol 4: Double injection of Prostaglandin, AI after each prostaglandin injection. Cows/heifers that were not detected in heat and not bred after the first injection received a second prostaglandin injection and bred after heat detection (The cows/heifers were observed for signs of oestrus by the farmers and inseminated within 8–12 hrs after first oestrus behaviors were detected).

The hormone used was $PGF_{2\alpha}$ (33.5 mg of dinoprost tromethamine per 5 ml of solution, equivalent to 25 mg of $PGF_{2\alpha}$; Lutalyse®; Pharmacia and Upjohn Company, Pfizer, New York, USA) except in Tadesse (2015) experiment where Synchromate was used. Data on name of AI technician, breed, body condition (score of 1–5), and parity were collected. Evaluation of the performance of synchronization was based on oestrus response rate and conception rate.

Cow cyclicity, pregnancy and embryo mortality were determined based on milk progesterone profiles using Hormonost® Micro-Lab FarmersTest, a newly introduced technology by the LIVES project. Though there was some variation in the approaches followed by the four experiments in progesterone profiling, the basic approaches were similar. Progesterone profiling on day 0 was conducted to detect presence of functional corpus luteum (CL) responsive to hormonal treatment; a concentration of progesterone higher than 3 ng/ml of milk was considered indicative of presence of functional CL. Progesterone profiling on day 1 (insemination day) was conducted to check if inseminated cows were indeed in heat or if heat is missed by visual observation for oestrous behaviors. A progesterone concentration of ≤3.2 ng/ml of milk indicates oestrus. Analysis of progesterone on day 18–24 was made to diagnose pregnancy (>16 ng/ml indicates pregnancy), and thereafter at three days interval to determine embryo/foetal mortality where concentration below 16 ng/ml indicates embryo loss. In the Oromia experiment, milk sampling (20–30 ml from each cow) and progesterone profiling was conducted on day 0 (hormone treatment) on 53 lactating cows involved in the oestrus synchronization activity, on 26 cows on day 10–12, 18 and 21 post AI for early pregnancy determination based on progesterone concentration. After day 18–21 post AI, 20 lactating cows (which were pregnant) were continued for milk sample progesterone determination to detect embryonic loss until day 45 post AI at the interval of three days. In SNNP, Tigray and Amhara, progesterone profile was recorded on 20 pregnant cows 3 times per week at day 19, 22, 25, 28, 31, 34, 37, 40, 43, 46, 49, 52, 55 and 58 post inseminations. Detailed methods of the progesterone profiling technique can be found in Debir (2015), Destalem (2015), Samuel (2015) and Bainesagne (2015).

3. Delivery of improved dairy genetics

3.1 Farmers' breeding practices

The strategy adopted for genetic improvement in dairy breeding in Ethiopia is crossbreeding of the local dam breeds with exotic sire breeds, mainly Holstein-Friesian and Jersey breeds. Breeding programs for improving the milk production merits of the local breeds through within-breed selection does not exist. Two approaches have been followed to deliver improved genetics to smallholders, namely production of crossbred heifers and bulls in public genotype multiplication centers and dissemination to smallholders; and local production and importation of semen and AI services by the National Artificial Insemination Centre (NAIC) and regional AI centers. The former approach has largely been inefficient and the major suppliers of crossbred heifers are small- and medium-scale private heifer producers. Currently the major improved genetics delivery mechanism adopted by the government is the AI program.

The current studies in four regional states (Oromia, Tigray, Amhara and SNNP) showed that about 36.0, 39.3 and 27.5% of the farmers surveyed used natural mating largely using crossbred bulls, AI and a combination of bull and AI service, respectively (Table 1). Specifically, the farmers in the study areas used either or any combinations of the following breeding methods: natural mating with bulls, AI with natural heat detection, and AI with oestrous synchronization. Natural mating using bulls can be controlled where heat detection is carried out by the farmer and each cow is mated once or twice during each heat period or uncontrolled/free mating where cows are mated in communal grazing areas by any one of the bulls in the village (Table 1). Different methods of breeding could be used in a single heat period of a cow. For instance, if a cow fails to conceive to an AI service, it could be mated to a bull or AI could be repeated. Farmers commonly select the best bulls in controlled mating system, the selection criteria being milk yield of the bulls' daughters based on subjective assessment of their milk yield. However, it is highly likely that the best bulls could be sold for beef or castrated to be used for ploughing since no pedigree or performance recording is practiced. Farmers also do not have any information on the genetic merits of the AI bulls apart from the type of breed.

It should be mentioned that the percentage of farmers using hormonal synchronization of oestrus presented in Table 1 may not be representative and could be biased upwards since sampling of farmers for the study was purposive to include farmers who had access to the technology. Thus the data presented may not be valid for inferences outside the project areas or at national level. For instance, the level of use of oestrus synchronization technology presented here may not show the national picture. However, the data presented here could still be valid for comparison of the different breeding methods and the variations between production systems within the sampling districts. Notwithstanding the limitations of the current study, the current results are comparable to a previous study in Ethiopia (Lijalem et al. 2014) where 39% of the respondents used AI and 32% of the respondents used oestrous synchronization for AI. The reasons given by the farmers for not using oestrous synchronization when the service is available included heat detection (28% of respondents) and pregnancy diagnosis problems (22% of respondents). The difficulty of diagnosing early pregnancy through rectal palpation is a major challenge for OSMAI since administration of hormone to pregnant cows induces abortion. The respondents included in the study cited above reported that AI has advantage over natural mating since AI accelerates introduction of new genetics (42%), entails less cost (23%), avoids the need for bull management (19%), and limits disease transmission (16%).

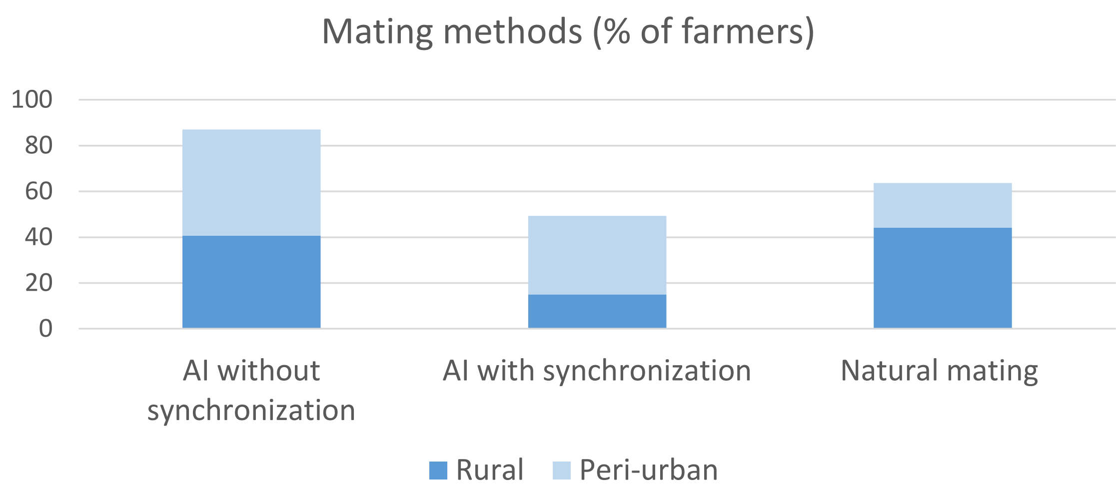
The use of oestrus synchronization technology varies with production system. The Tigray study (Destalem 2015; Figure 1) shows that AI and AI with synchronization were used more frequently in peri-urban areas than rural areas. This study also revealed that 19.4% of peri-urban farms and 44.2% of rural farms depended on natural mating system. In general, there was a tendency that farmers' breeding practices have shifted from natural mating to improved mating system in the study areas.

Table 1: Percentage of respondents (N = 180 per region) who used different mating/breeding methods across four regional states in Ethiopia

Mating/breeding method	Oromia	Tigray	SNNP	Amhara	Overall
Natural mating (uncontrolled)	33.9	35.0	29.0	24.9	30.7
Natural mating (controlled)	12.2		48.3	68.8	43.1
AI without synchronization	48.3	42.8	68.0	14.6	43.4
AI with synchronization	3.3	22.2	56.7		27.4
AI with and without synchronization	1.1		97.0		49.0
Natural mating + AI with synchronization	1.1		53.9		27.5

Source: Debir (2015), Destalem (2015), Samuel (2015), Bainesagne (2015).

Figure 1: Methods of breeding in rural and peri-urban dairy systems. Source: Destalem (2015).



3.2 AI service delivery

AI service providers and farmers' access

AI service is primarily provided by the government, which accounts for 99.1% of the insemination service in West Shoa zone of Oromia state (Table 2). Semen production is exclusively operated by the NAIC and regional artificial insemination centers, though a small amount of exotic semen is imported by a private breeding service called Addis Livestock Production and Productivity Improvement Service (ALPPIS). The government AI service is provided mainly by the woreda offices of the regional Livestock Production and Health Agencies. However, various institutions such as research centers and livestock projects provide AI services for research purpose and scaling up of livestock breeding technologies, albeit with a very limited coverage.

The efficiency and effectiveness of AI service and field AI operations was evaluated in terms of regularity of service. According to farmers in three districts in West Shoa, only 4.5% of the respondents reported to receive regular AI service, the remaining either received irregular service (90.4%) or do not practice AI (5.1%). The reasons for the inconsistent AI provision was unavailability of the service on weekends and holidays (5.8%), shortage of AI technicians (7.2%), shortage of inputs (2.4%) and a combination all the above reasons (88.0%). Access to regular services and reasons for irregular service or complete absence of service vary across woredas depending on their geographic locations which determine the level of infrastructure development. Where and when there is irregular AI service, farmers either revert to natural mating or skip the mating period and wait for the next oestrous cycle. These options are adopted by about 53.7% and 41.1% of farmers according to data from West Shoa of Oromia (Bainesagne 2015). While most of the farmers interviewed in Oromia (60.5%, Table 2) use AI service at AI stations, 68.6% of farmers in the Tigray study use on-call service (Destalem 2015).

Table 2: Breeding service providers, regularity of service, alternative breeding options and means of accessing service in West Shoa zone study districts

Service providers and % of farmers using service		Regularity of service and reasons for interruptions (% farmers)		Alternative breeding options and means of accessing services (% farmers)	
Government AI technician	75.9	Receiving regular service %	4.5	Fate of in-heat cows on off days:	
Private AI	0.9	Reasons for interruption		Pass estrous period (%)	41.1
Private bull service	15.2	Unavailable on off-days (%)	2.4	Use natural mating (%)	53.7
Research (RC) AI	4.5	Shortage of AITs (%)	7.2	Means of access to AI service	
RC AI + bull service	1.8	Shortage of inputs (%)	2.4	Visit by AIT (%)	2.8
Gov't, RC AI & bull	1.8	All of the above (%)	88	Call service (%)	36.7
				Service at AI station (%)	60.5

Source: Compiled from Bainesagne (2015). AIT: artificial insemination technician.

Farmers' perceptions on AI

Farmers' awareness on the importance of appropriate timing of AI was assessed through their common practice of heat detection and AI. Nearly 42% of the respondents reported that they seek insemination of their cows in the same morning heat signs were observed. Similarly when heat signs were detected in the afternoon, 46.7% of farmers seek AI service in the same afternoon (Table 3). This could indicate lack of awareness among farmers as the right time for effective AI would be within 8 to 14 hours after standing heat is manifested. This is because ovulation occurs 10 to 14 h after the cessation of behavioral signs of estrus (Allrich 1993). Data collected in the SNNP study on time of first estrus observed, time of AI and non-return rate showed that the best time for AI would be 9–14 hrs after heat detection and AI after the 19th hr would result in significantly ($P<0.05$) low pregnancy rate (Table 3).

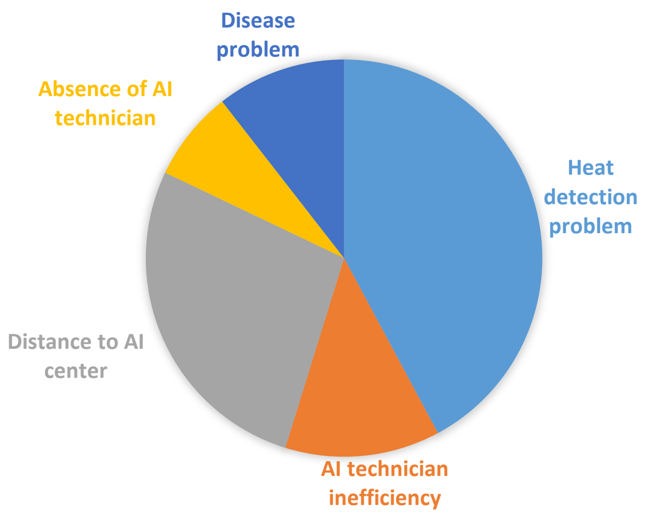
Table 3: Farmers' practice of timing of AI and effect of time of AI on conception rate in SNNP

Farmers AI practice			AI time and pregnancy	
Time of insemination	Heat detected in the morning (%)	Heat detected in the afternoon (%)	Time of insemination (hr.)	Pregnancy (%)
Afternoon of same day	38.3	46.7	4 to 9	59.6
Morning of same day	41.7	33.3	>9 to 14	71.6
Afternoon of next day	6.7	6.7	>14 to 19	57.3
Morning of next day	6.7	5.0	>19 to 24	12.5
When AIT available	5.0	3.3		
Use bull immediately	1.6	5.0		

Source: Debir (2015).

Farmers' satisfaction with the current AI service is low. About 47.2% of farmers interviewed in SNNP were not satisfied with the service, whereas 18.9% of the respondents expressed satisfaction. Similarly, as a result of dissatisfaction with delivery of AI service and low conception rates, 60.6% of the respondents preferred to use natural mating rather than AI (Debir 2015). However, most of the farmers surveyed in Tigray (78.8%) were satisfied with the current AI service (Destalem 2015). Farmers in Amhara (Samuel 2015) identified heat detection problem (37.4%) and distance to AI center (24.2%) as the main reasons for failure of the AI service (Figure 2).

Figure 2: Farmers' perceived reasons (% of farmers) for failure of AI.



Source: compiled from Samuel (2015).

3.3 Use of oestrous synchronization technology

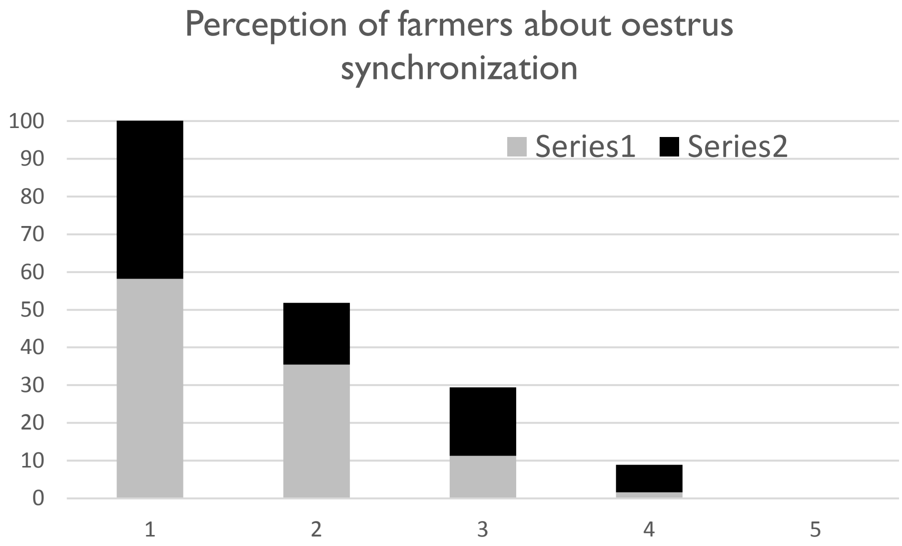
Focus group discussions with farmers in Oromia, SNNP and Tigray (Table 4) indicated that farmers' perception/satisfaction with hormonal oestrous synchronization technology is determined by the conception/pregnancy rates achieved rather than by the rate of response to hormone treatment. This is to be expected since the ultimate product for a farmer is a viable calf crop and not an intermediate outcome of induced oestrus. Accordingly, the overall farmers' perception/satisfaction was medium to low with some proportion of the farmers reporting very good or complete satisfaction. The major reasons given by the farmers for the low performance included feed problem, inappropriate season, semen problem, failure to detect heat, poor semen quality/problem in semen handling, performance of the inseminator and low awareness of farmers on the technology (taking hormone injection for insemination and providing sterile and non-cyclic animals for PGF2α treatment). On the other hand, farmers' perception on oestrous synchronization technology vary with production systems or geographic locations. Farmers in peri-urban area had better perception than rural farmers (Figure 3).

Table 4: Farmers' perception of and satisfaction with hormonal oestrous synchronization in the study area

	Oromia	SNNP	Tigray
Farmers' perception/satisfaction (%)			
Low	42.9	55.7	54.7
Medium	6.2	31.9	26.5
Good	4.0	-	14.5
Very good/satisfied		12.4	4.3
Not using technology	46.9	-	-
Preferred method of breeding			
AI with synchronization	28.0	-	
AI only	60.6	39.4	
Natural mating	11.4	60.6	

Source: Bainesagne (2015), Debir (2015), Destalem (2015).

Figure 3: Perception of farmers (% of respondents) towards oestrus synchronization in rural and peri-urban areas. Source: Destalem (2015).



4. Performance of oestrus synchronization

4.1 Performance under research versus development intervention

Methods of evaluating synchronization systems include estrous response (percentage of females showing estrus of those treated), synchronized conception rate (percentage of females conceiving of those inseminated), synchronized pregnancy rate (percentage of females conceiving of the total treated), and pregnancy rate at various stages of the breeding season (Odde 1990). In the current study, performance of hormonal oestrus synchronization was evaluated primarily based on oestrus response to hormonal treatment of cycling cows/heifers with functional corpus luteum. However, since the ultimate outcome expected in animal breeding is the number of calves born, conception rate (percentage of females conceiving of those inseminated) and eventual successful pregnancy until 60 days post AI were also considered as evaluation criteria. Successful calf production in hormone-synchronized oestrus and artificial insemination breeding system is determined by identification of cycling cows/heifers with functional corpus luteum, accurate heat detection (standing heat), timely and correct insemination procedure, and avoiding factors causing embryo and fetal mortality.

In general, oestrous response rate to hormone treatment, measured as the percentage of cows/heifers that showed oestrus out of the total treated, under development intervention by the regular extension service of the regional BoA was comparable to the results obtained under the conditions of the action research reported here. However, there was variation in the performance of oestrous synchronization across the regions (Table 5). Oestrus response was in general high, particularly under research condition. The average oestrous responses were 77.0% under the regular service and 89.3% under research condition.

However, there was high variation between conception rates under the action research and the regular development intervention. The average conception rates across regions were 39.3% and 59.2% under the regular service and research condition, respectively. The conception rates were consistently below 50% for the regular service and above 50% for the action research across the two experiments in the regional states.

Reasons for the higher oestrous response and conception rate under research condition included intensive follow-up on animal selection for hormone treatment, minimizing stress conditions on the cow, heat detection by farmers and timely insemination. On the other hand, there was little opportunity for a close follow-up under the regular service due to the work load on the AI technicians who had to treat and inseminate a large number of cows. Furthermore, lack of skill to detect functioning corpus luteum results in inappropriate time of hormone administration and hence low rate of oestrus response.

Table 5: Oestrous response and conception rate results from single shot hormonal oestrous synchronization by the regular extension service and LIVES action research

	Development intervention			Action research		
	No. of cows/heifers	Oestrus response (%)	Conception (%)	No. of cows/ heifers	Oestrus response (%)	Conception (%)
Amhara	225	66.2	36.3	126	88.9	60.3
SNNP	883	87.9	42.2	126	89.7	58.4

Source: Debir (2015), Samuel (2015).

4.2 A literature review of performance

Oestrus response rates obtained in the action research project (Table 5) was compared with results from the literature (Odde 1990; Table 6). Oestrous rate in 18 trials reported in the literature ranged from 77 to 100% with an average of 92%. The conception rate to 1^{st} service (% of females conceiving of those inseminated) ranged from 33 to 68% (average = 48.8%), while the average pregnancy rate five days post breeding (% of females conceiving of the total treated) was 44.6% with a range of 30–64%. The corresponding average values for the control groups without hormone treatment were 24.2, 61.1 and 15.1%, respectively.

The literature results clearly show the effectiveness of hormone treatment in inducing a high percentage of cattle to oestrus soon after treatment. The fertility of this oestrus, however, was variable, the conception rate ranging from 33 to 68%. The differences in conception rate across trials may be due in part to level of cyclicity. These results clearly show that results obtained in the action research reported in this paper are in conformity to the literature results. The results from the current action research are also comparable with the original oestrous synchronization experiment in Ethiopia (Tegegne et al. 2012).

Table 6: A literature review on the use of syncro-mate for synchronization of oestrus in cattle (Source: Extracted from Odde 1990)

References	Trial	Treatment	No	5-d oestrous rate (%)	1st service Conception rate (%)	5-d pregnancy rate (%)
Wiltbank and Gonzala-Padilla 1975	1	Treated	16	94	57	50
		control	14	0		
	2	Treated	77	79	56	43
		control	81	6		4
	3	Treated	78	100	33	33
		control	77	27	54	14
	4	Treated	98	98	63	63
		control	95	27	63	10
	5	Treated	56	98	56	55
		control	53	28	60	15
	6	Treated	39	85	38	31
		control	39	10	63	5
	7	Treated	99	96	49	43
		control	99	26	45	15
	8	Treated	99	96	45	43
		control	99	26	45	15
	9	Treated	97	77	40	30
		control	89	16	52	4
Miksch et al. 1978	1	Treated	44	93	39	36
		control	29	38	56	16
	2	Treated	23	100	39	39
		control	21	33	62	28
	3	Treated	50	94	34	32
		control	48	25	72	18
	4	Treated	77	93	68	64
		control	71	25	84	20
	5	Treated	33	82	60	48
		control	38	13	69	8
Spitzer et al. 1981	1	Treated	114	98	48	47
		control	110	26	70	22
	2	Treated	54	83	35	30
		control	45	44	58	22
	3	Treated	48	100	63	63
		control	53	40	49	21
	4	Treated	56	91	56	52
		control	68	25	75	19
	Average	Treated	64	92.06	48.83	44.56
	Range	Treated		77–100	33–68	30–64
	Average	control	63	24.17	61.06	15.06
	Range	control		0–44	45–84	4–28

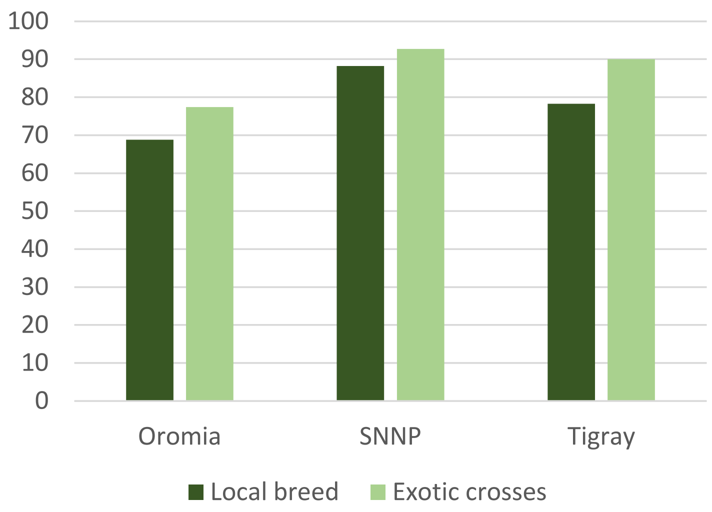
4.3 Factors affecting performance of synchronization

Variation among breeds

Oestrus response of cows/heifers to hormonal treatment varied with breeds (Figure 5). On the average, a higher percentage of exotic crossbred cows/heifers (86.7%) than local cows/heifers (78.4%) responded to treatment. The differences in oestrus response between breed groups was statistically non-significant (P>0.05) in all the three studies in Oromia, SNNP and Tigray. For local cows/heifers, the oestrus response rate varied form 68.8% in the West Shoa, Oromia action research to 88.2% in the SNNP action research. Similarly, the highest response rate (92.7%) for exotic crosses was in SNNP and the lowest (77.4%) in Oromia. This could be due to the fact that oestrus duration in exotic breeds is longer, so response to hormone treatment is higher. Plasse et al. (1970) reported that duration of sexual receptivity in B. taurus females varied from 4 to 48 hrs with means reported between 13.60 and 19.30 hrs, while in B. indicus cows the mean duration of estrus was short (6.70 hrs) which also vary from 2 to 22 hrs.

However, conception rates of oestrus-synchronized and inseminated cows/heifers did not vary much across breeds. In the Amhara experiment, conception rate of hormone treated and inseminated Holstein-Friesian, Jersey crosses and local cows/heifers was 70.4, 78.2 and 71.5%, respectively. Similarly, conception rates of Holstein-Friesian, Begait local and a non-descript local cows/heifers in the Tigray experiment were 38.4, 39.7 and 37.7%, respectively. However, in the Oromia experiment, the local cows/heifers had higher (77.4%) conception rates than the exotic crossbred cows (68.8%), whereas in the SNNP experiment exotic crosses had higher (68.4%) than local cows/heifers (53.3%).

Figure 4: Effect of breed on oestrus response to hormonal treatment.



Effect of body condition, AIT and parity

Performance of oestrus synchronization and artificial insemination programs could also be influenced by body condition of cows selected for hormonal treatment and skill of AI technicians. In the Oromia experiment, cows/heifers with body condition score of 3 and 4 had higher rate of oestrus response (92.3% and 84.2%, respectively) compared to cows/heifers with body condition score of 2 (76.3%), though these differences were not significant (P>0.05). Optimal body condition for maximum conception rate appears to be around a body condition score of 4.5 in the Amhara study (Figure 5), and 6 in SNNP, 4 in Tigray and 2 in the Oromia study. These variations could be due to variation in body scoring scale adopted or due to variation in the breeds in the different studies. Synchronized pregnancy rate was reduced in beef heifers that were greater than condition score of 6, suggesting that having cattle too fat also may be detrimental (Andersen et al. 1987).

There was great variation in terms of skill of technicians in detecting presence of functional corpus luteum for hormone administration and effective AI. There was a variation of up to 27.5% in oestrus response rate among cows palpated by different AIT (Table 7). The variation in efficiency or failure of insemination ranged from 24.0% in Amhara to 28.9% in Tigray. Effect of parity on rate of response to hormone treatment and conception rate is depicted in Figure 6.

Table 7: Effect of AI technician on oestrus response and conception rate (CR) in hormone-treated cows/heifers

	Oromia				Tigray		Amhara	
AIT	No. treated	Oestrus (%)	No. AI	CR (%)	No. AI	CR (%)	No. AI	CR (%)
T1	18	66.7	12	66.7	125	53.6	341	40.0
T2	52	61.5	32	43.8	48	31.3	152	23.0
T3	16	87.5	14	64.3	80	25.0	402	25.9
T4	39	84.6	33	63.6	89	24.7	260	28.1
T5	5	60	3	66.7	234	38.9	280	17.1
T6					125	40.8	156	16.0

AIT: artificial insemination technician.

Figure 5: Effect of body condition on conception rate. Source: Samuel (2015).

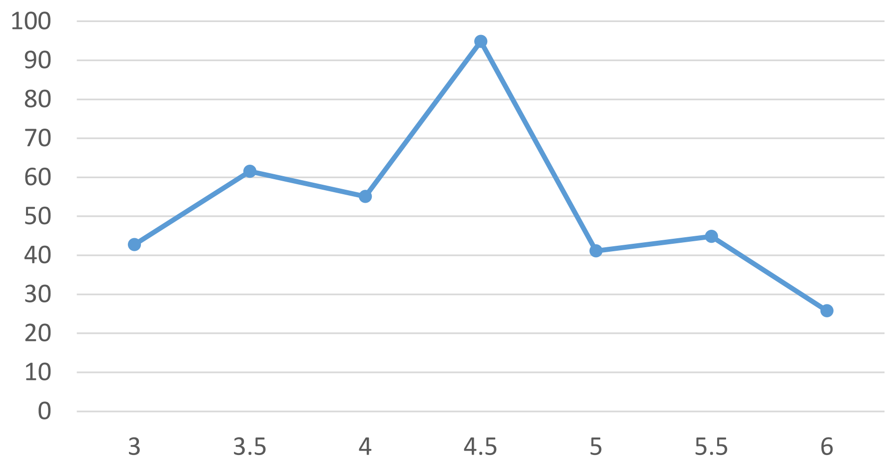
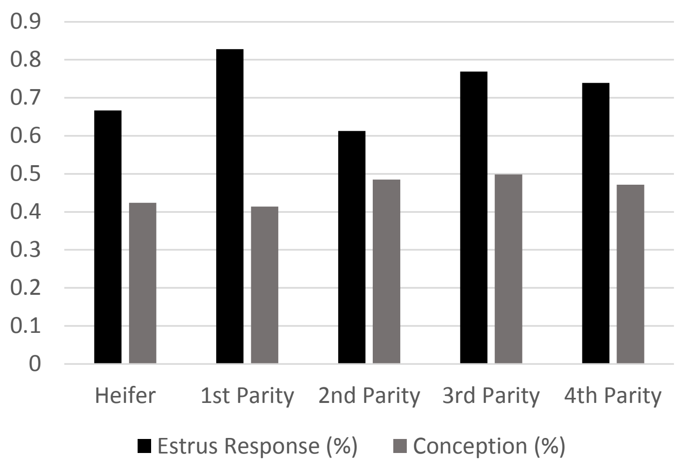


Figure 6: Average effect of parity on oestrus response (Oromia) and conception (average of four experiments).



4.4 Comparison of alternative protocols

Oestrus response rate

Comparison of single and double injection of $PGF_{2\alpha}$ showed that a higher percentage of oestrus response was obtained among cows and heifers that received double injection (Table 8). The advantages of double over single dose protocols in rates of oestrous responses were 9.1% for Protocol 2 (Tadesse 2015), and 13.5% (Destalem 2015) and 11.5% (Bainesagne 2015) for Protocol 4 (comparing response from 1st injection with overall 1st + 2nd injections). For Protocol 2 (Tadesse 2015), the odds of oestrous response in cows and heifers that received double injection was 2.6 times more likely compared with females that received single injection; however, this difference was not statistically significant ($P>0.05$).

The result of this study (Tadesse 2015) also showed that, from 61 heifers and 119 cows synchronized using both protocols of $PGF_{2\alpha}$ injection, 77.0% and 92.4%, respectively, showed oestrus. The odds of estrus response in cows was 3.6 times more than heifers, and this difference was statistically significant ($P<0.01$). The estrus manifestation rate of the local and cross breeds treated with single injection of PGF2α were 78.3% and 90.0%, respectively (odds ratio=2.48; $P>0.05$). However, there was no difference between the breed groups in oestrus response under the double dose protocol.

Table 8: Oestrous response rates under four single and double PGF2α dose synchronization protocols

Experiment	Protocol*	No. treated	Oestrus response (%)
Tigray (Tadesse 2015)	1	120	84.2
Tigray (Tadesse 2015)	2	60	93.3
Tigray (Tadesse 2015)	3	60	-
Tigray (Destalem 2015)	4		
Oestrus response to 1st injection		126	84.9
Oestrus response to 2nd injection		19	89.5
Oestrus response to 1st + 2nd injection		126	98.4
Oromia (Bainesagne 2015)	4		
Oestrus response to 1st injection		130	72.3
Oestrus response to 2nd injection		36	41.7
Oestrus response to 1st + 2nd injection		130	83.8

* Protocols:

Protocol 1: One Injection of Prostaglandin, heat detection and AI

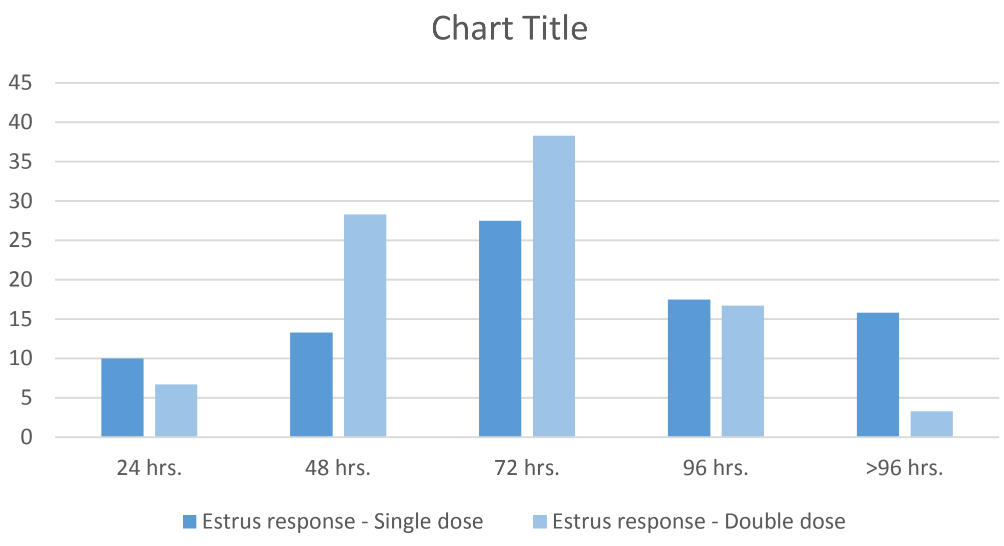
Protocol 2: Double Injection of Prostaglandin at 14 days interval, heat detection and AI

Protocol 3: Double Injection of Prostaglandin at 14 days interval, Fixed AI at 48–72 hr. post injection

Protocol 4: Double Injection of Prostaglandin, AI after each prostaglandin injection. Cows/heifers that were not detected in heat and not bred after the first injection received a second prostaglandin injection and bred after heat detection

Among cows/heifers placed under single shot $PGF_{2\alpha}$ injection, 10% of the cows and heifers manifested heat at 24 hrs, 13.3% at 48 hrs, 27.5% at 72 hrs, 17.5% at 96 hrs and 15.8% at >96 hrs (Figure 6). There was no significant difference ($p>0.05$) between the different time intervals of heat manifestation on conception rate of the local and cross breed cattle. Among cows/heifers that received double dose of PGF2α, 6.7% of the cows/heifers manifested heat at 24 hrs, 28.3% at 48 hrs, 38.3% at 72 hrs, 16.7% at 96 hrs and 3.3% cows at >96 hrs from the last administration of PGF2α. The results showed that a larger proportion of the animals from both single and double dose protocols manifested heat after 72 hrs of hormonal treatment.

Figure 7: Time (hours) of oestrus response (% of cows) after single and double prostaglandin injection. Source: Tadesse (2015).



Conception rate

Conception rate under Protocol 1 was found to be lower by 8.9% than Protocol 2 (Table 9), indicating the advantage of double hormone injections and AI with heat detection after the second injection. However, although cows/heifers in Protocol 2 seemed to be 47% more likely to conceive compared to those under Protocol 1 (odds ratio = 1.475), the differences were not statistically significant (*P*>0.05). Furthermore, double injection with fixed AI (Protocol 3) was inferior in conception rate than the single injection protocol (Protocol 1). AI at detected oestrus was found to be 2.3 times more likely to result in conception than fixed time AI (odds ratio=2.27; P<0.05).

Under protocol 4 (Table 9), advantage of overall conception (from AI after the first and second hormone administration) over conception from AI after the first injection alone varied with experiments. The advantages were 7.3% in Tigray experiment and 5.1% in the Oromia experiment. The lower value from the double dose protocol in the Oromia experiment was due to lower conception rate following the second injection. The oestrous response to the second injection was also low in the Oromia experiment (Table 8).

Table 9: Conception rate under single and double PGF2α dose synchronization protocols

Experiment	Protocol*	No. inseminated	Conception (%)
Tigray (Tadesse 2015)	1	99	59.6
Tigray (Tadesse 2015)	2	54	68.5
Tigray (Tadesse 2015)	3	47	48.9
Tigray (Destalem 2015)	4		
Conception (1st injection)		107	51.4
Conception (2nd injection)		17	52.9
Overall Conception (1st + 2nd injection)		74	58.7
Oromia (Bainesagne 2015)	4		
Conception to 1st injection		109	57.4
Conception to 2nd injection		-	-
Conception to 1st + 2nd injection		109	52.3

* Protocols:

Protocol 1: One Injection of Prostaglandin, heat detection and AI

Protocol 2: Double Injection of Prostaglandin at 14 days interval, heat detection and AI

Protocol 3: Double Injection of Prostaglandin at 14 days interval, Fixed AI at 48–72 hr. post injection

Protocol 4: Double Injection of Prostaglandin, AI after each prostaglandin injection. Cows/heifers that were not detected in heat and not bred after the first injection received a second prostaglandin injection and bred after heat detection

5. Determination of cyclicity, oestrus, pregnancy and embryonic mortality using progesterone

Progesterone profiling for hormone administration

The protocol adopted for synchronizing oestrous cycles of dairy and beef cattle in Ethiopia involves the administration of a PGF2α (commonly Lutalyse) that shortens the normal life span of the corpus luteum. Oestrous-cyclic females can respond to injections between days 7 and 16 of the oestrous cycle in the presence of a functional corpus luteum. However, anoestrous cows and prepubertal heifers will not respond to an injection of PGF2α since no CL exists.

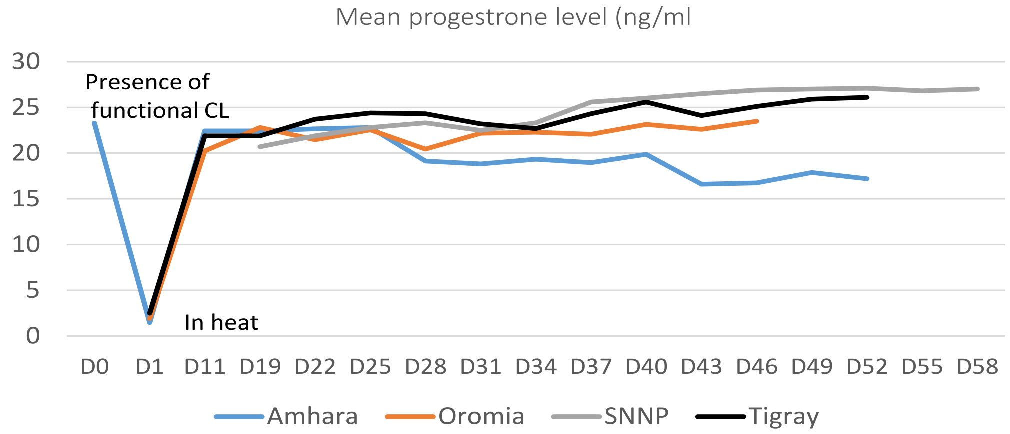
In the regular oestrus synchronization and AI program of the BoAs, presence of a functional CL is determined through rectal palpation by AITs. Identification of responsive CL by AIT has proved a challenging task as it requires skill and lack of such skills among some AIT could be a factor for low oestrous response in some cases. In the current action research project, presence of functional CL was determined based on milk progesterone level on the day of hormone administration (day 0) using Hormonost® MicroLab FarmersTest. In the Amhara experiment, the mean progesterone level was 23.4±0.8 ng/ml, which indicated accurately the presence of responsive CL for the application of $PGF_{2\alpha}$ (Figure 8).

Progesterone profiling for heat detection

Efficiency of AI service in Ethiopia has been found to be low (Desalegne et al. 2009). One of the major reasons for the low efficiency is the difficulty of heat detection and timely insemination. Short duration, low intensity and poor expression of estrus signs in Ethiopian Zebu cattle could be the cause of most estrus detection failures (Tegegne et al. 1989; Mukassa-Mugerwa et al. 1989; Bekele et al. 1991).

The current study confirmed the difficulty of heat detection based on visual observation for behavioral signs of oestrus, resulting in low efficiency of the AI program due to wrong insemination of anoestrous cows. In the Tigray experiment (Destalem 2015), out of 33 cows which were inseminated after heat detection based on behavioral signs, only 25 of the cows had progesterone concentration ≤3ng/ml (an indication of oestrus) as determined by progesterone profiling on day 1 (insemination day). The progesterone concentration in the remaining eight cows was above 3.2 ng/ml, an indication that the cows were not in heat. The level of false oestrus detection in this study was 24.2%. Similarly in the Oromia experiment (Bainesagne 2015), milk samples were collected from 53 lactating cows out of 130 cows/heifers treated with prostaglandin for progesterone profiling on the day of AI (day 1). Out of the 53, the progesterone concentrations of 33 of the cows were less than 3ng/ml. However, only 26 of the cows/heifers were inseminated, but the remaining seven cows/heifers were not inseminated due to failure to detect heat by the farmers/AITs. These results showed the magnitude of false heat detection and missed heat in the AI program. The results also provided evidence to the usefulness of technological aids (i.e. progesterone profiling with Hormonost®) to improve efficiency of AI.

Figure 8: Average progesterone level of experimental cows from day 0 to day 58.



Source: Plotted based on Destalem (2015), Bainesagne (2015), Debir (2015), Samuel (2015). Pregnancy diagnosis and embryonic mortality

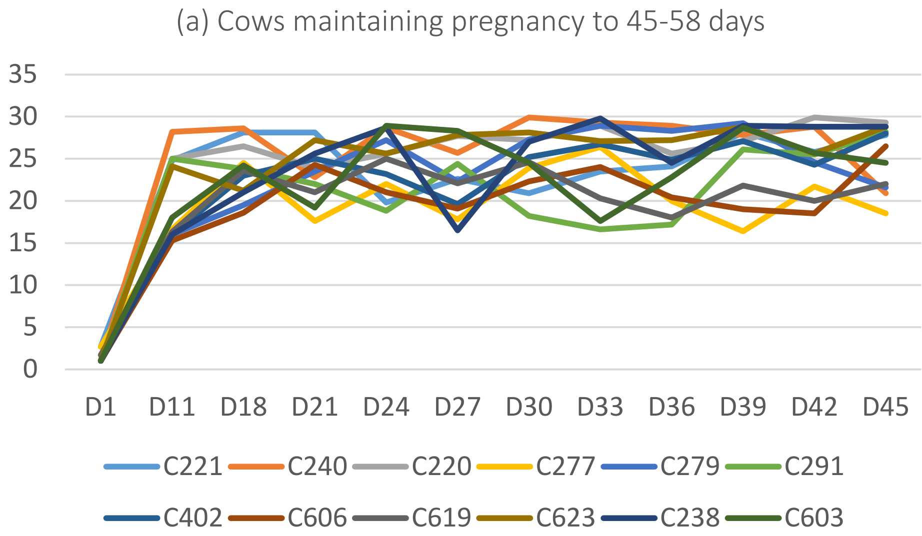
Early pregnancy was diagnosed using milk progesterone concentration on day 18–21 post AI. Embryonic mortality was determined based on progesterone profiling every three days from day 24 to 58 post AI. The progesterone concentration in cows that maintained pregnancy was above 16 ng/ml which increased with increasing gestation period, whereas the concentration in cows that lost their embryo was below 16 ng/ml (Figure 9). The pregnancy status and embryo mortality determined by progesterone profiling was consistent with the final pregnancy results confirmed by rectal palpation on day 60 post AI. Embryo losses of 15, 25, 40 and 30% were determined in the Tigray, Amhara, Oromia and SNNP experiments, respectively (Table 10). Out of the total loss of 22 embryos across the four experiments, 19.1, 38.1, 23.8, 14.3 and 4.8% of the losses occurred on the 21–24th, 27–30th, 33th, 42nd and 46th day post AI.

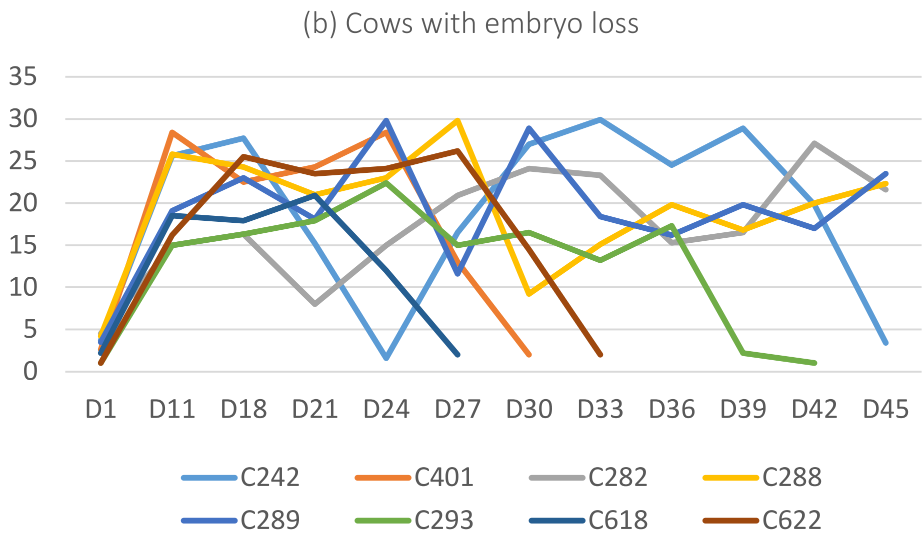
The results obtained in the current experiments on pregnancy diagnosis based on progesterone profiles using Hormonost® could be a solution to the invasive rectal palpation to diagnose pregnancy which farmers disliked. Progesterone profiling could also increase reproduction (reduce calving interval) and milk production through early pregnancy diagnosis/determination of embryo mortality and re-breeding of cows.

Table 10: Pregnancy diagnosis and embryonic loss determination based on progesterone profile

	No. cows profiled	No. pregnant (≥16 ng/ml on day 18–24)	No. non-pregnant (<16 ng/ml on day 18–24)	No. embryo loss (<16 ng/ml on day 21–51)
Tigray	33	20	13	3
Amhara	20	20	0	5
Oromia	26	20	6	8
SNNP	20	20	0	6

Figure 9: (a) Progesterone concentration from day 1 (AI day) to day 45 post AI in 12 cows that maintained pregnancy to 46–58 days and (b) eight cows that lost embryo. Source: Extracted from Bainesagne (2015).





6. Implications of results and conclusions

Farmers' mating practices are shifting to AI

The results of the four studies in the four highland regional states showed that farmers' breeding methods have significantly shifted to AI, where this service is available. Farmers also expressed willingness to pay for AI service. However, availability, regularity and effectiveness/efficiency of the service is below expectation of farmers. AI service efficiency as low as 27% has been reported (Desalegne et al. 2009) and the current studies also reported low conception rates.

Performance of synchronization by the regular service is low

Hormonal synchronization of oestrus is well adopted by farmers who had the access to the service. However, farmers expressed low satisfaction with the service. It is obvious that farmers evaluate the technology based solely on successful breeding leading to calf production. A successful pregnancy depends on many factors including selection of appropriate cows/heifers at the right stage of the oestrous cycle, presence of responsive corpus luteum, heat detection, appropriate insemination practice and choice of the right environmental condition and management practice to maintain pregnancy to term. All these factors are determined by AIT and farmers' skill. Particularly, AIT skill on identification of functional CL and AI skill are important determinants of successful oestrous synchronization and pregnancy. The current results showed that oestrous synchronization per se was very high, but conception rates were very low. Low conception rates, which are largely determined by efficiency of AI (assuming conception rates in artificially induced heat and natural heat are comparable), would undermine performance of oestrous synchronization technology.

Action research results indicate opportunity for improving performance of synchronization

A comparison of results from action research activities and the regular synchronized AI service indicated that there is a possibility to improve the service. From the data presented in this study, oestrous response could be improved by about 18.2% and conception rate by 46.6%. However, a strict follow up of activities, skill upgrading and consideration of the factors affecting oestrous response and successful pregnancy presented in this paper and elsewhere in the literature need to be considered for a successful oestrous synchronization and AI service.

Single dose hormonal treatment with AI on detected heat protocol recommended

There are a variety of protocols for synchronizing oestrus in cattle. The choice of relevant protocols depends on the oestrous response rates and feasibility of application of the protocol in the specific situation under consideration. According to the current results, double administration of prostaglandin at an interval of 14 days with AI on heat detection or AI after each hormone administration could result in higher oestrus response than the single shot protocol. However, the differences are not statistically significant. Moreover, the requirements of the double dose protocol in terms of time, logistics, costs and convenience to farmers may not justify its use, especially under smallholder conditions. Fixed-timed AI was also found to result in less conception rate. Thus the single dose protocol with heat detection could be a feasible option for Ethiopia.

Similar argument regarding feasibility of double dose protocol for rural Ethiopia has been made by Tadesse (2015). The single dose protocol of PGF2α synchronization has also advantages of lower cost and that cattle are only handled once (Islam 2011).

Use of modern technologies improves determination of pregnancy and embryonic mortality

A high rate of embryo death was recorded in the studies synthesized here. The loss ranges from 15 to 40%. Embryo mortality could be difficult to detect since expression of oestrous behavior presumed to be pregnant base on known AI could be taken as false heat. These studies also showed that incidence of missed AI opportunity due to failure to detect heat and wrong insemination of non-oestrous cows is considerable. Lastly, pregnancy diagnosis through rectal palpation could be intrusive and could not be done earlier than 60 days post AI. Technological aides that uses progesterone profiling (e.g. using Hormonost®) could be a solution for all the above challenges.

7. References

Allrich, D.R. 1993. Estrous behavior and detection in cattle. *Veterinary Clinics of North America* 9: 249–262.

Andersen, K.J., Brinks, J.S., LeFever, D.G., Asbury, W.C., Schafer, D.W. and Moon, J.L. 1987. Re*productive performance of Angus heifers*. Colorado State Univ. Beef Program Rep., p 71. Fori Collins.

G/Medhin, D., Bekana, M., Tegegne. A. and Blihu, K. 2009. Status of artificial insemination service in Ethiopia. *A paper presented at the 17th Annual Conference of the Ethiopian Society of Animal Production (ESAP), September 24–26, 2009*, held at the Headquarters of the Ethiopian Institute of Agricultural Research (EIAR), Addis Ababa, Ethiopia, pp. 87–104.

G/Michael, D. 2015. *Breeding practice and estrus synchronization evaluation of dairy cattle in central zone of Tigray, northern Ethiopia* . MSc thesis, Jimma University, Ethiopia.

Gugssa, T. 2015. *Effects of prostaglandin administration frequency, artificial insemination timing and breed on fertility of dairy cows and heifers in eastern zone, of Tigray regio*n, Ethiopia. MSc thesis, Mekelle University.

Legesse, D. 2015. *Assessment of breeding practices and evaluation of mass estrus synchronization of dairy cattle in sidama zone, southern Ethiopia*. MSc thesis, department of animal and range science, Hawassa college of Agricuture, school of graduate studies, Hawassa University, Hawassa, Ethiopia.

Lijalem, T., Abebe, M., and Haile, B. 2014. Breeding Technology Assessment at Small Holder Dairy Cattle Production Level in Selected Districts of Hadya zone, Southern Ethiopia. *Advances in Life Science and Technology*, Vol.34, 2015. www.iiste.org.

Miksch, E.D., LeFever, D.G., Mukembo, G., Spitzer, J.C. and Wiltbank, J.N. 1978. Synchronization of estrus in beef cattle. 11. Effect of an injection of norgestomet and an estrogen in conjunction with a norgestomet implant in heifers and cows. *Theriogenology* 10:201.

Odde, K.G. 1990. A review of synchronization of estrus in postpartum cattle. *Journal of Animal Science* 68: 817–830.

Plasse, P., Warnick, A.C. and Koger, M. 1970. Reproductive behavior of B. indicus females in a subtropical environment. Length of estrous cycle, duration of estrus, time of ovulation, fertilization and embryo survival in grade Brahman heifers. *Journal of Animal Science* 30: 63–72.

Shiferaw, S. 2015. *Assessment of breeding practices and evaluation of estrus synchronization and mass artificial insemination techniques in dairy cattle in west West Gojjam zone*. MSc thesis, Bahir Dar University College of agriculture and environmental sciences, graduate program, Ethiopia.

Spitzer, J. C., Mares, S.E. and Peterson, L.A. 1981. Pregnancy rate among beef heifers from timed insemination following synchronization with a progestin treatment. *Journal of Animal Science* 53:l.

Tegegne, A., Estifanos, A., Tera, A. and Hoekstra, D. 2012. Technological options and approaches to improve smallholder access to desirable animal genetic material for dairy development: IPMS Experience with hormonal ooestrus synchronization and mass insemination in Ethiopia. Paper presented at the conference on *Resilience of agricultural systems against crises,* Tropentag, September, 19–21, 2012, Göttingen.

Wiltbank, J.N. and Gonzalez-Padilla, E. 1975. Synchronization and induction of estrus in heifers with a progestagen and estrogen. *Ann. Biol. Anim. Biochim. Biophys.* 15:255.

Worku, B. 2015. *Assessment of breeding practices and evaluation of estrus synchronization and mass insemination technique in dairy cattle in West Shoa zone*. MSc thesis, Haramaya University, Haramaya, Ethiopia.

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Livestock and irrigation value chains for Ethiopian smallholders project aims to improve the competitiveness, sustainability and equity of value chains for selected high-value livestock and irrigated crop commodities in target areas of four regions of Ethiopia. It identifies, targets and promotes improved technologies and innovations to develop high value livestock and irrigated crop value chains; it improves the capacities of value chain actors; it improves the use of knowledge at different levels; it generates knowledge through action-oriented research; and it promotes and disseminates good practices. Project carried out with the financial support of the Government of Canada provided through Foreign Affairs, Trade and Development Canada (DFATD). lives-ethiopia.org

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