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SUMMARY

Smallholder dairy farming in developing countries plays a crucial role in poverty alleviation and food security. Therefore, tremendous efforts have been made to increase dairy productivity through rapid genetic improvement of dairy herds through different approaches including the use of artificial insemination (AI) technology. However, there is information gap on its adoption and effectiveness of artificial insemination in resource limited settings. Therefore, the aim of this study was to assess the factors affecting adoption of AI Technology by small dairy production systems. Semi-structured questionnaire was used to collect data from 656 smallholders, and 91 AI technicians (AITs) in seventeen administrative districts of eleven regions located in four major geographical zones of Tanzania. Results shows that 89% of the respondents acknowledged AI as an effective breeding method for increased milk yield, prevention of sexually transmitted diseases (82%), bulls were used as an alternative when AI failed (51%). However, irregularity in getting AI services, unreliable liquid nitrogen supply, and unavailability of reliable transport were major obstacles to AI services provision. Furthermore, mobile phone was a major means of communication (93%) between farmers and AIT, and 65% of the AITs use private transport while the rest uses public transport. Since majority of the small scale dairy producers acknowledge the importance of AI, strategic interventions on the identified obstacles and promoting enabling environment for AI service provision is likely to improve and facilitate a much wider adoption and delivery of AI services.

Keywords: Cow; Technology Breeding; Farmers, Semen, Reproduction

INTRODUCTION

Tanzania has one of the fastest growing human populations in the world with about 50 percent agriculture households depending upon livestock enterprises as major means of income generation (Msalya *et al.*, 2017). Although Tanzania has approximately 33.94 million cattle which accounts for 11% of the African and 1.4 percent of global cattle population, livestock related activities contribute only 7.4% to Tanzania's agriculture gross domestic product (GDP) with about 2% of the GDP coming from dairy sector (URT, 2021). Similarly, with an expected 4% annual GDP growth and 5% annual urbanization rate, Tanzania is projected to have a vast shortage of milk in the following years because the country's dairy value chain isn't keeping up.

The ever-increasing population and consumption growth will put pressure on the demand of perishable products such as milk not only in Tanzania, but also in East and

Southern Africa (Godfray *et al.*, 2010).

In order to reduce the gap between supply and demand, it is necessary for dairy industry to change the manner in which livestock are reared to increase the productivity of animals (Ojango *et al.*, 2019; Mrode *et al.*, 2021). The use of modern breeding technologies such as artificial insemination (AI) coupled with best management practices may facilitate the realization of the goal of improving productivity of dairy cows in small holder farming systems.

Smallholder dairy farming is an important agricultural sector providing income, and main producers of milk supplied in many developing countries (Howley *et al.*, 2012; Rathod *et al.*, 2017). Although this type of farming system is widespread in different parts of Tanzania and other developing countries where the climate is appropriate, there are variety of factors limiting its growth including keeping of low-producing dairy

cattle breeds, poor management practices, limited forage and feed, poor animal health, and accessibility of affordable extension or veterinary services (Kanuya *et al.*, 2000; Mwatawala *et al.*, 2002; Msangi *et al.*, 2005; Kivaria *et al.*, 2006; Ngou and Kashoma, 2015).

To enhance productivity, robust and practical germplasm delivery technologies such as AI and selective bull mating are widely used. The use of AI in dairy cattle industry has been of great economic benefit through genetic improvement for milk production, control of other undesirable conditions that may limit the efficiency of bull usage (Vishwanath, 2003; Lamb *et al.*, 2016). However, since 1950's when AI services was introduced in Tanzania, the technology has faced low adoption rate as compared to other countries (Mwanga *et al.*, 2019). Consequently, majority of the cows are bred by natural mating practices, using bulls of poor quality, and thus slow genetic improvements of animals (Kashoma *et al.*, 2010). The low adoption and success of AI technology is influenced by many factors which can be divided into demographic, socio- economic and location factors (Woldu *et al.*, 2011; Ingabire *et al.*, 2018; Mwanga *et al.*, 2019).

MATERIALS AND METHODS

Description of the study area

The study was authorized and conducted in accordance with Sokoine University of Agriculture research regulation and guidelines. The study was conducted in seventeen administrative districts from eleven regions located within four major geographical zones of Tanzania. The zones and their respective regions in bracket are Lake (Kagera and Mwanza), Northern (Tanga, Arusha and Kilimanjaro), Eastern (Morogoro, Dar es Salaam and Pwani), and Southern zone (Njombe, Iringa and Mbeya) (Figure 1). The respective administrative districts were purposely selected based the availability of dairy cattle farmers, and AI services. The districts involved in this study were Morogoro (Morogoro urban), Dar es salaam (Temeke, Kigamboni, Kinondoni and Ubungo), Pwani region (Kibaha), Tanga (Tanga), Kilimanjaro (Moshi and Hai), Arusha (Arusha and Arumeru), Iringa (Iringa), Njombe (Njombe), Mbeya (Mbeya urban), Mwanza (Ilemela and Nyamagana),

The adoption of appropriate breeding method is critical for improvement of dairy productivity, and efforts have been made to improve genetic potential of dairy animals including the involvement of parastatal and non-governmental to improve genetic traits of dairy animals through AI and distribution of improved bulls and crossbred (F1) dairy heifers (Msangya *et al.*, 2014; URT, 2016; Chawala *et al.*, 2019). These programs were not successful.

The adoption and success of new technologies including AI is influenced by many factors ranging from social, economic, price of AI services, availability of extension agents, AI services, education, and intensification level of farming (Kanuya *et al.*, 2014; Mugisha *et al.*, 2014; Rathod *et al.*, 2017). In addition, the level of understanding and satisfaction of farmers on AI delivery system in small-scale dairy enterprises of are critical but not clearly known. Therefore, the objective of this study was to assess the farmers' perception and attitude, efficiency of AI services and identify the challenges encountered by with AI technicians while delivering AI service in seventeen administrative districts of eleven regions of Tanzania.

and Kagera (Bukoba).

Study population and study design

Dairy cattle farmers as well as artificial insemination technicians (AITs) in each study district were randomly chosen from the list of farmers maintained at the respective District Livestock and Fisheries Office. Farmers included were those who keep 2–10 dairy cattle (Swai *et al.*, 2010). AITs were either public servants or private providing both stationed (animal health center) and mobile services. The sample size was purposely set to 50 for farmers, and AITs for each of the selected district by engaging individuals who were willingly available to participate in the study after being briefed about the objective of the study. This was a cross-sectional study that was conducted using semi-structured questionnaire, and was conducted from September 2020 to February 2021.

Socio-demographic (personal information, gender, age, occupation, family size,

educational level) of the respondents, and farm specific information (herd size, type of breeding whether natural or AI, reason for adoption of a particular service system, knowledge of AI services, availability and accessibility of AI services, methods and time of heat detection, number of inseminations per conception, satisfaction to AI services) were recorded. For AITs, the information collected were demographic data, mode of communication with farmers, transport means, outstanding signs of estrous before insemination, number of animals inseminated per month, average number of services per conception, and satisfaction with the AI practice.

Data Management and Statistical Analysis

Data collected during the study period were stored into Microsoft Excel. The data were cleaned, coded and analyzed using Statistical Package for Social Sciences (SPSS) version 20.0. Descriptive statistical analysis including frequency, percentage, mean and standard deviation were used to examine socio-economic characteristics of respondents, animal management practices, and AI service delivery. Chi-square and multiple logistic regressions were used to compare the association of dependent variable (AI adoption by farmers) with independent variables (level of education, AI technology awareness, availability of AITs, and cost of AI services). In all the analyses, confidence level was held at 95% and value less than 0.05 was considered as significant.

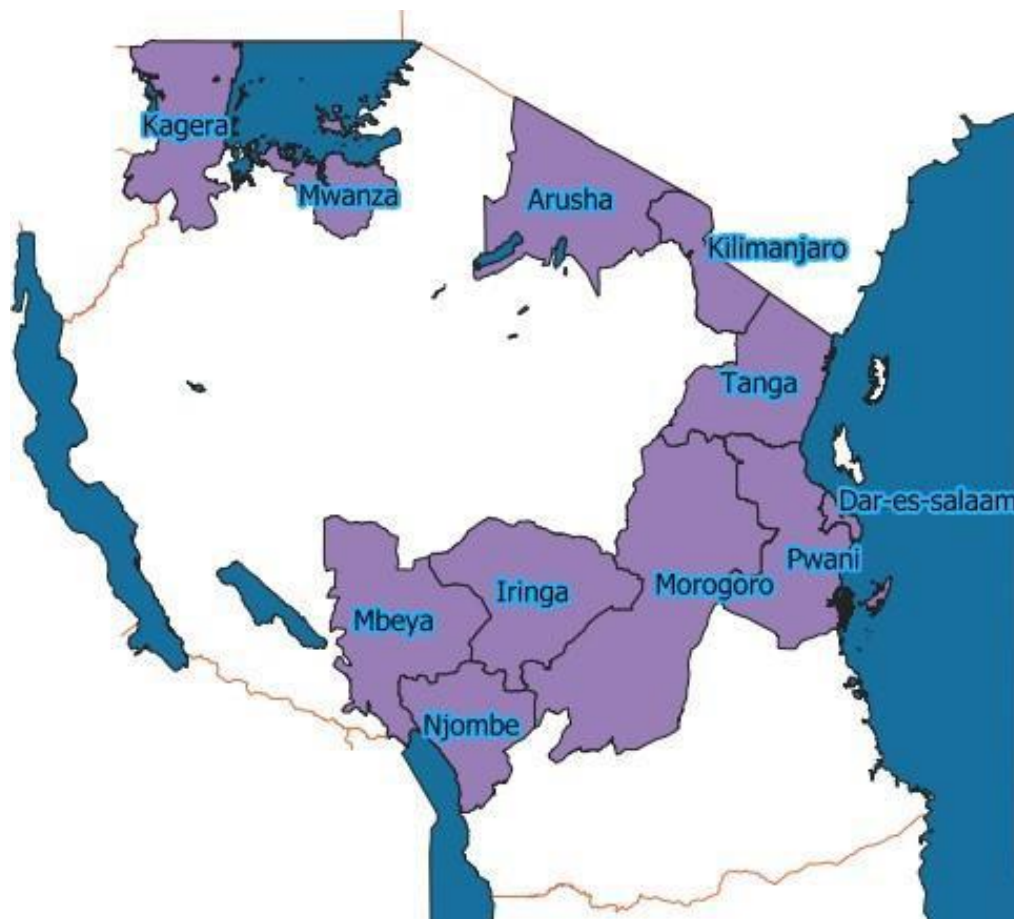


Figure 1: A Map of Tanzania indicating the study regions

RESULTS

Socio-demographic characteristics of respondents

Socio-demographic characteristic findings revealed that males were more (68.4%) involved in dairy cattle activities than female (31.6%). Minority (4.4%) of respondents had

informal education while majority (95.6%) had formal education of either primary education (42.4%), secondary education (26.2%) or college/university education (27.0%). Moreover, the highest percentages (71.8%) of AI users had experience of over 5 years in dairy keeping, and 56.4% of farmers

keep dairy cattle as their primary source of income (56.4%), and 16.9% keep for supplementary source of income. Experience in dairy keeping and level of education were likely to have significant impact on record keeping (odds ratio of 7.99; $p = 0.003$), and frequency of using AI (odds ratio of 8.02; $p = 0.003$).

Animal types, management and interaction with extension service providers

Smallholder dairy farmers in study districts kept different types of dairy cattle breeds with majority rearing crossbreed cattle (51.2%). Pure breed kept and the respective proportion include: Friesian (39.3%), Ayrshire (7.9%) and Jersey (1.7%). However, in Southern highland farmers had pure Friesian ($p < 0.05$) than other breeds of cattle. In addition, respondents keeping less than 10 animals preferred to keep few animals under intensive system (75%) while those keeping more than 10 animals preferred semi-intensive (18.9%) or extensive (5.2%) system. Most of the respondents (59.2%) admitted to give supplements to lactating, and pregnant animals than other classes in the herd.

When the respondents were asked if they had farm herd health management records, a significant ($P > 0.05$) difference was observed in record keeping. Majority 56.2% of farmers in Eastern zone admitted having complete records, whereas 52.5% in Northern zone had incomplete records, 44.8% in Southern zone had no records and majority of farmers in lake zone had variable responses (complete 38.0%, incomplete 32.2% and no data keeping 29.8%). The odds of keeping records was significantly higher in farmers with intensive management system as compared to semi-intensive or extensive management systems ($OR = 2.25$; $P = 0.011$). Based on herd size, odds of perfect observation of signs of oestrous was significantly lower in medium and large-sized herds as compared to small-sized herds ($OR = 0.38$; $P = 0.02$), whereas there was no significant difference in animal supplementation between zones. In this study farmers reported to interact with extension service providers only when there is a need (79.4%), and fewer (20.6%) respondents interacted with extension service providers on regular basis.

Specific estrous signs and timing of insemination

Herdsmen were largely responsible for observing and reporting signs of oestrous (48.2%). Observation for oestrous signs several times in a day was the preferred method of tracking oestrous signs (52.7%) than observing either in the evening during milking (3.7%), afternoon (5.2%) or morning hours (38.4%). 48.2% of dairy farmers reported to depend on their herds men and minority (5.3%) depending on any member of family to observe the animals for signs of oestrous. The signs of oestrous observed before reporting for insemination were statistically significant different ($P = 0.003$). The observed signs include clear vulva mucus discharge (31.1%), mounting others (20.5%), reduced appetite and milk production (17.6%), bellowing (16.6%), and swelling of vulva (14.2%). The perception of on the timing of insemination revealed that, most of the respondent (59.1%) preferred their animals to be inseminated between 7 and 12 hours after observing signs of estrous whereas 27.3% preferred to have their animals inseminated no more than 6 hours since estrous signs were first observed. Furthermore, (64.1%) of the respondents reported to inseminate their animal two to three months after calving, 19.8% give their cows 4 months of resting before inseminated while 16.2% inseminate at any time once the cow shows oestrous after calving.

Farmer's knowledge and attitude toward AI technology

Knowledge is a key determinant of the farmers to adopt and continuous use of any new technology to improve household income. In this study, significantly higher percentage (82.6%) of farmers received the AI service from extension officers, while a small percentage (17.4%) of farmers were informed by other stakeholders of livestock industry. According to Table 1, most of respondents (88.9%) significantly ($p < 0.05$) acknowledged that AI technology is efficient and effective breeding method for upgrading animals as compared to natural mating, whereas minority either opposed the statement (5.3%) or were not certain (5.8%) of the technology's benefits of upgrading animals. Generally, farmers showed positive attitude ($P > 0.05$) towards the AI as they either breed their animals using AI only (48.6%) or start with AI

and when animal fail to conceive introduce bulls (51.4%). However, significant differences ($p < 0.05$) were observed on breeding methods in use across zones with great number ($n=150$; 75%) of farmers in Northern zone reported to depend on AI while majority of farmers in Southern highland zone ($n=82$; 70.7%) and Lake zone ($n=85$; 70.2%) depending both AI and natural mating.

Perception towards to benefits of using artificial insemination services

Results in Figure 2 revealed that improved milk production ranked first in terms of proportion among the other reported benefits including improvement of animal genetic, prevention of venereal disease as well as to avoid the cost of keeping bulls in the head. Increase in milk production was more perceived ($p < 0.05$) reason for continuing using AI whereas avoidance of cost of keeping breeding bull was least mentioned reason. However, there was no statistically significant ($P = 0.213$) difference in other AI-related benefits across the study zones (Figure 2).

Dairy cattle farmer's satisfaction with AI services

Majority of respondents (about 79.0%) had been using AI services for less than 6 years while minority (21.0%) had experience of using AI for more than six years (Table 2). There were statistically significant ($P > 0.05$) satisfaction of AI services provided. Generally, 79% of farmers were satisfied with the AI services provided. However, when asked on the costs of AI services offered, there was no statistically significant difference among districts/zone (P value > 0.005). Generally, 47.0%, 34.0% and 19.0% of the respondents reported moderate, high, and extremely high AI costs, respectively. When the respondents were asked to rank on the competency of AITs, satisfaction with NAIC semen and recommend to other fellows, most (80%) were satisfied with the AITs, NAIC semen (55.0%) and could recommend to others (86.0%) on the AI services. However, there was no statistically significant difference among districts/zones ($P > 0.005$).

Table 1: Farmers' knowledge and awareness toward artificial insemination technology

Parameter		Zones				Total ($n=656$)
		Eastern ($n=219$)	Northern ($n=200$)	Southern Highland ($n=116$)	Lake ($n=121$)	
		%	%	%	%	%
Introduced to AI Technology by extension officers	Yes	89.0	83.5	67.2	84.3	82.6
	No	11.0	16.5	32.8	15.7	17.4
AI as effective breeding method	Yes	97.3	81.5	78.4	95.9	88.9
	No	0.9	2.5	20.7	3.3	5.3
For upgrading animals	Not certain	1.8	16.0	0.9	0.8	5.8
	AI	24.7	52.0	49.1	53.7	42.7
The effective breeding method in terms of pregnancy rate	Natural	55.7	18.0	15.5	38.8	34.0
	Not sure	19.6	30.0	35.3	7.4	23.3
Breeding method currently in use	AI only	45.2	75.0	29.3	29.8	48.6
	AI and bull	54.8	25.0	70.7	70.2	51.4

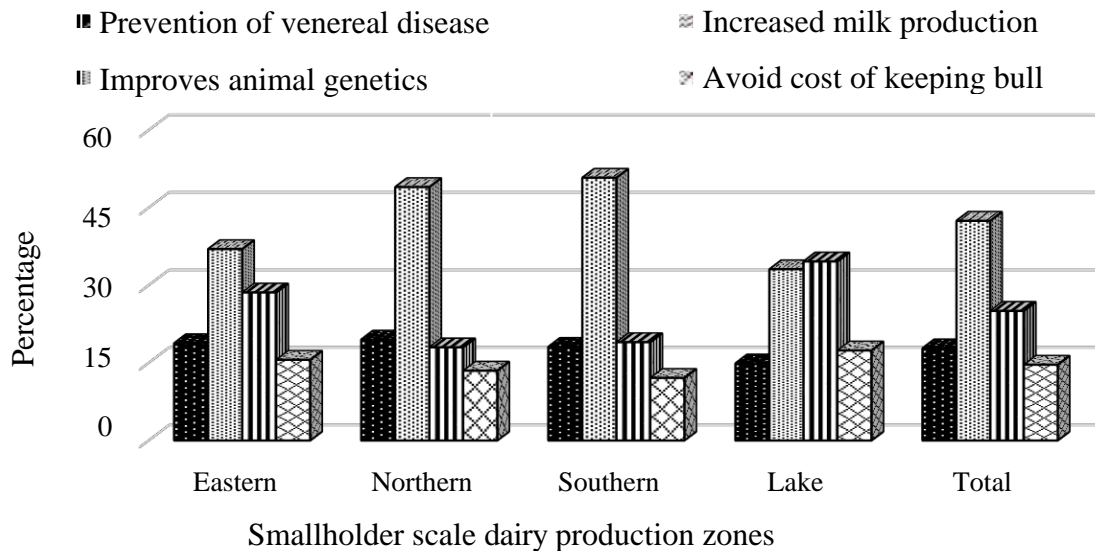


Figure 2: Farmers' perception on the benefits of using Artificial Insemination

Table 2: Dairy farmers' attitude and satisfaction with Artificial Insemination services

Parameter		Eastern	Northern	Southern	Lake	Total
		(n=219)	(n=200)	Highland (n=116)	(n=121)	(n=656)
		%	%	%	%	%
Duration of using AI services (years)	1 – 3	39.7	50.0	50.9	55.4	47.7
	4 – 6	38.4	21.5	46.6	19.8	30.9
	7 – 10	14.6	18.5	0.9	7.4	12.1
	Above 10	7.3	10.0	1.7	19.0	9.3
Whether AI service provider offers best semen you needed	Yes	75.8	85.0	63.5	83.5	78.8
	No	22.4	12.0	36.2	4.1	18.3
	No option	1.8	3.0	0	12.4	2.9
Farmers' opinions on the cost of AI services	Extremely high	21.5	27.5	7.8	12.4	19.2
	High	39.3	46.0	20.7	14.9	33.5
	Moderate	39.3	26.5	71.5	72.7	47.3
Ranking the competence of AI service provider	Excellent	31.1	37.0	36.2	20.7	31.9
	Best	64.8	36.0	62.1	57.9	54.3
	Moderate	4.1	27.0	1.7	21.5	13.9
Whether satisfied with semen from NAIC	Yes	55.7	65.0	32.8	56.2	54.6
	No	22.4	9.0	6.0	11.6	13.4
	No option	21.9	26.0	61.2	32.2	32.0
Recommend use of AI to fellow farmers	Yes	92.7	80.0	88.8	81.8	86.1
	No	7.3	20.0	11.2	18.2	13.9

Major AI service delivery problems identified in the study area

Out of 656 dairy cattle owners, 288 (43.9%) experience difficulty in getting AI services, 231 (35.2%) experience difficulties in receiving the services, while 137 (20.9%) of the respondents receive AI service regularly and with some interruption. In relation to problems encountered, the cattle owners identified delayed insemination (55.8%), unavailability of AITs (23.6%) and conception failure (20.6%) as common problems. However, there was no statistically significant ($P > 0.05$) differences between districts, regions or zones regarding the AI service delivery problems. Minority (27.6%) of farmers⁷ acknowledged to have a single insemination to their animals and get pregnancy whereas majority of farmers admitted to have either two (36.4%), three (26.7%) or more than three (9.2%) inseminations before their animals get pregnancy. Among the reasons mentioned for increased number of inseminations per conception included inaccurate/poor heat detection (10.7%), untimed inseminations (25.6%), incompetency of inseminators (7.8%) and cows' problems (9.9%) as well as unknown reasons (15.7%).

Major dairy cattle reproductive disorders

According to information obtained (Figure 3), the major animal reproductive problems reported ranged from retention of fetal membranes (31.08%), infertility/conception failure (26.78%), endometritis/metritis (18.70%), abortions (16.95%) to neonatal deaths (6.58%). Nevertheless, there was statistically significant ($p < 0.05$) variations in prevalence of specific animal reproductive disorders between zones. It was noted that

conception failure and retention of fetal membrane were significantly ($P < 0.05$) reported in Northern and Southern zones while conception rate was less reported in Eastern zone.

Responses from Artificial Insemination Technicians

From the 91 AITs interviewed, 90.0% were males and the minority 10.0% were females. 53.8% of the respondents had either diploma in animal discipline or secondary education with AI short course (29.7%) while minority (16.5%) had University education with AI sort course. There was no statistically significant difference

Majority (45.1%) had 1 to 5 years of AI service provision, and 25.5% had 5 to 10 years of experience. 50.5% of respondents who received calls from farmers requesting for AI services inquired more information before deciding when to inseminate. The heat sign that was of practical importance and used by AITs is mucus discharge from the vulva (59.3%), followed by standing still to be mounted, and mount other animals (23.1%). The average numbers of cows being covered by AITs ranged from 16 to 60 per month. 42% of the AI cases attended by AITs required two inseminations for the animal to conceive. Irregular and interruption supply of Liquid Nitrogen and other AI consumables (56.0%), irresponsibility of farmers on observation of signs of estrous (28.6%), unavailability of reliable transport (34.1%), low pregnancy rate (13.2%) after AI, and low purchasing power of farmers to AI services provided (22.0%) as the main limiting factors for effective AI service delivery.

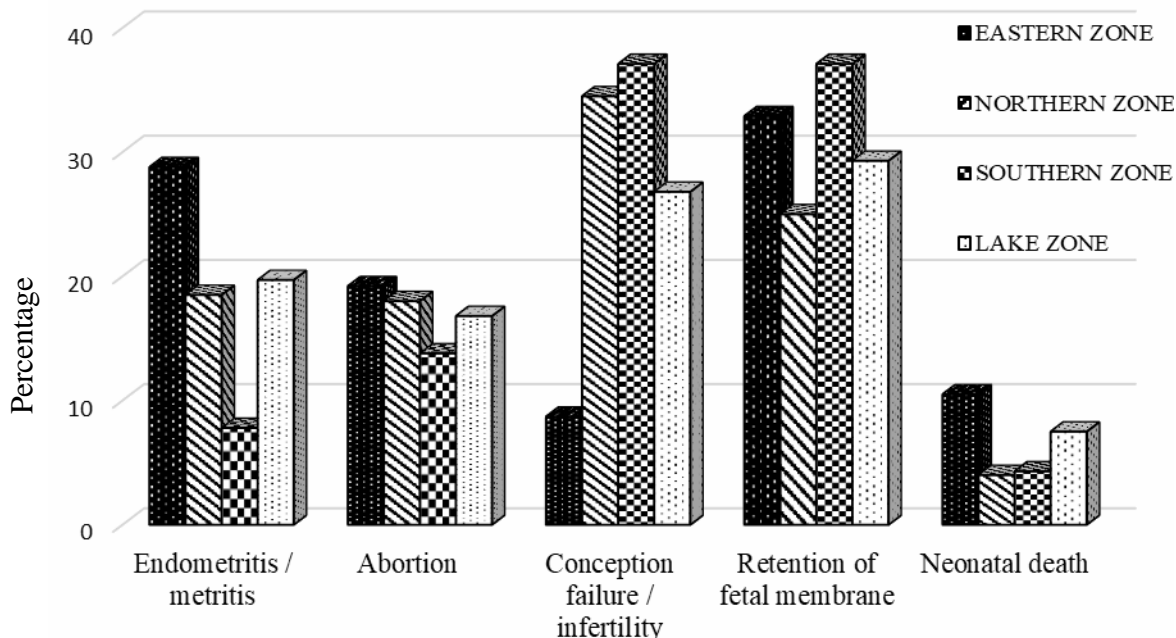


Figure 3: Major dairy cattle reproductive disorders reported in four zones of TZ, 2020/2021

DISCUSSION

The adoption and success of artificial insemination in any areas is greatly influenced by multiple factors including awareness, social-economic factors, and management practices. From the socio-demographic point of view, majority (68.4%) of the respondents interviewed were males, having formal education (from primary to tertiary education), more than 5 years in farming experience (72%), and keeping animals as main enterprise (73%). High proportion of males involved in dairy farming reported in this study is similar to the findings observed in Kenya (Ingabire *et al.*, 2018; Lochampa, 2019; Mekonnen and Berhe, 2020) however, low proportional of males had been reported in Ethiopia (Girma and Marco, 2014). Farmers engaged in AI having formal education is in agreement with reports from elsewhere (Girma and Marco, 2014; Ingabire *et al.*, 2018).

Education level was found to significantly influence the adoption of any new technology as is believed that education enables farmers to perceive, interpret and respond to new information quicker than uneducated farmers. Indeed, this study identified farming experience and level of education to have a significant impact on record keeping (odds ratio of 7.99; $p = 0.003$) and frequency of using AI (odds ratio of 8.02; $p = 0.003$). Similar results with respect to AI was reported by Ingabire *et al.* (2018) in Rwanda. Other forms of education specific for AI services are likely to be obtained through short term

training offered by extension agents. The higher frequency of contacts with extension agents is likely to help farmers to get new technical skills and gain self-confidence on managing dairy production in a sustainable manner. In this study almost (80%) farmers received extension services when there was a need while 10% getting regular extension services at least once a month, same report has been pointed out by Temba, (2011) in the study conducted in Kinondoni district, Dar es salaam. However, this is contrary to what was reported in neighboring countries such as Uganda (Mugisha *et al.*, 2014; Ahikiriza *et al.*, 2021), Rwanda (Ingabire *et al.*, 2018), Kenya (Lochampa, 2019) and Ethiopia (Abraha *et al.*, 2020) where regular contacts with extension agents is more common, and facilitated farmers to access information about new dairy technologies (Kaaya *et al.*, 2005; Gillespie *et al.*, 2014; Warriach *et al.*, 2018).

Apart from education, management practices and herd size is likely to influence the adoption of AI. In the current study, majority of farmers (64%) own small herds (1-5 animals) with adoption of both intensive (76%) and semi-intensive (19%) management systems similar to the finding reported previously for Urban and peri-urban dairy farming in East Africa (Gillah *et al.*, 2012). Intensive management system allows sufficient time to monitor for oestrous signs, and 52.7% of the dairy farmers had no specific time (observing estrous signs several

times a day). The practices of multiple observation for signs of heat is likely to improve heat detection whereas poor heat detection leads to prolonged calving interval, long lactation, low milk yield, few calves, and loss due to repeated breeding expenses (Gaude *et al.*, 2021; Madkar *et al.*, 2021). The need for a successful AI with the goal of increasing animal productivity as reported in this study and Gaude *et al.* (2021) is likely to be the incentive to do multiple observations to track signs of heat. Other studies supporting these findings include that of Chawala *et al.* (2019), and Abraha *et al.* (2020) who observed that farmer in smallholder dairy farming systems prefer to use AI for genetic improvement of animals and minimizes the risk of diseases transmission to their dairy cows.

Interestingly, 55% of the respondents using AI services in the studied regions of Tanzania were satisfied with the quality of semen supplied from National Artificial Insemination Centre, and 86% would recommend to others. However, delayed inseminations (56%), unavailability of services (24%) and poor conception rate (21%) were problems frequently highlighted by respondents using AI services. The challenges are likely to reduce the adoption of AI services and have been reported in Rwanda (Rugwiro *et al.*, 2021) and Ethiopia (Woretaw *et al.*, 2015; Kebebew and Bekele, 2018).

Several factors can cause poor conception rate ranging from poor AI practices, quality of semen, timing of insemination and infertility related to poor health status of the animal among others. This study could not establish the cause of poor conception rate after AI. However, the overall incidences of endometritis/metritis, abortion, infertility, retained fetal membranes and neonatal deaths were 20%, 17%, 26%, 29% and 8% in the studied zones, each of the condition is capable of causing infertility and reduction of conception rate. This finding is not uncommon in developing countries under small holder production systems, and is consistent with other study reports from other countries (Haile *et al.*, 2014; Mekonnin *et al.*, 2015; Nguyen-Kien *et al.*, 2017; Tolosa *et al.*, 2021). Furthermore, the overall retained fetal membrane (RFM) prevalence rate of 29% obtained in this study is higher than

previously reported in different farms in Tanzania (Swai *et al.*, 2005; Kashoma and Ngou, 2021) as well as in other countries (Sheetal *et al.*, 2015; Simeneh and Moges, 2019). The reasons for variation in the incidences of RFM across studies is not known, however may be due to variations of predisposing factors such as breed variation, nutritional status of animals and management systems. Compared to 46-70% reported previously (Kashoma and Ngou, 2021), reports of clinical endometritis/metritis were found to be lower at 19.7%. However, the lower cases of endometritis is consistent with other study conducted in Rwanda by Nyabinwa *et al.*, (2020).

On the other hand, abortion rate of 13.2% to 19.2% obtained in this study is higher than that of 1.0% to 5.3% reported in Ethiopia dairy cattle (Gashaw *et al.*, 2011; Getachew and Nibret, 2014; Tolosa *et al.*, 2021). Differences in types of breeds, geographical location, and differences in management practices could be the reasons for the differences pending verification by researchers. The differences across other studies was also recorded in the observed proportion of repeat breeders in which ranged from 8.7% to 37.2% which is in line with findings in Ethiopia (Hunduma, 2013; Alemselem *et al.*, 2015; Tolosa *et al.*, 2021), but higher than that reported by Getachew and Nibret, (2014), and Haile *et al.* (2014). Some of the reasons brought forward as the cause of repeat breeding include deficiency of minerals in the diet, improper insemination, and poor managements in terms of estrous detection as previously stated elsewhere (Yusuf *et al.*, 2010; Walsh *et al.*, 2011; Aruna *et al.*, 2021).

The overall most outstanding challenges of AI service delivery outlined by AITs and farmers such as irregular and interruptions supply of liquid nitrogen and other AI consumables, unreliable transport, poor herd management, inability of farmers to pay for the services, and poor semen quality appear to be common with some other countries but not a universal. For example, irregularity in supply of liquid nitrogen and other AI consumables has also been reported as a serious problem in AI service delivery in Rwanda (Rugwiro *et al.*, 2021) but it is not the case in Ethiopia (Woretaw *et al.*, 2015; Feyera and Tegenu, 2016; Belete *et al.*, 2018; Ephrem, 2019;

Mekonnen and Berhe, 2020) and Kenya (Omondi *et al.*, 2017) where the challenges included dystocia, and shortage of AITs. Nevertheless, this study and others highlighted above provide an insight on the existing obstacles limiting AI service provision and which may require interventions in order for the farmers to realize the full potential benefits of AI technology. Although the study was conducted in a limited geographical areas and the results may not be generalized due to

geographical and biological differences of animals across regions in Tanzania and other developing countries, it provides the basis for further exploration of other regions, and other limiting factors with the aim of documenting and providing comprehensive information that can facilitate more understandings of the constraints of AI service delivery and adoption, and consequently designing specific, and or tailor made interventions for specific region or country.

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CONFLICT OF INTERESTS

The authors declare that they have no financial or personal relationships which may have

inappropriately influenced them in writing this article.

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