REDUCING SYNCHRONIZING PROSTAGLANDIN F2α DOSAGE IN DAIRY GOATS FOR ENHANCED GOAT ARTIFICIAL INSEMINATION UPTAKE IN KENYA

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DECLARATION

This thesis is my original work and has not been presented in any university for any degree.

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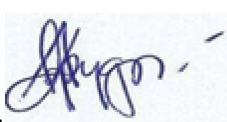
Signature……………  ………… Date…31/10/2022………………………

DEDICATION

To my husband, my sons and siblings.

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I thank God for the strength he gave me to pursue the degree. I also recognize the religious prayer partners who consistently prayed for me.

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LIST OF ACRONYMS

AI	Artificial insemination
AV	Artificial Vagina
ANOVA	Analysis of variance
CIDR	Control Internal Drug Releasing Device
CKL	Cooper Kenya Limited
CL	Corpus Luteum
DGAK	Dairy Goat Association of Kenya
FAO	Food and Agriculture Organization
FGA	Flurogestone Acetate
Fig	Figure
FTAI	Fixed time artificial insemination
Freq	Frequency
FSH	Follicle Stimulating Hormone
GHG	Green House Gas
GnRH	Gonadotrophic releasing hormone
IM	Intramuscular
IGAD	Inter Governmental Authority on Development

IVEP	In vitro embryo transfer
KCSAP	Kenya Climate Smart Agricultural Project
KNBS	Kenya National Bureau of Statistics
LSD	Least Significant Difference
MOET	Multi ovulation and embryo transfer
MPA	Medroxyprogesterone Acetate
MAP	Methyacetoxy progesterone
NGO	Non-Governmental Organization
PGF2α	Prostaglandin F2α
SDGs	Sustainable Development Goals
SCNT	Somatic cell nuclear transfer
TAI	Timed Artificial Insemination

ABSTRACT

Dairy goat farming is rising globally as an alternate climate smart livestock. This rise is attributed to its high drought and heat resilience, less methane emission and better disease resistance. According to KNBS (2019), the goat population in Kenya stands at 15 million with close to 400,000 being dairy goats mainly bred using rotation bucks thus predisposing them to reproductive challenges. This study was carried out to determine farmers attitudes and perception on artificial insemination (AI) in goats and to determine the optimal dose of prostaglandin ($PGF_2\alpha$) required for estrous synchronization in goats. A baseline survey was undertaken on 200 goat rearing households in Mukurwe-ini Sub County in Nyeri County using a structured questionnaire. This was followed by a controlled experiment at the Ol Magogo sheep and goat farm which involved 45 healthy cycling, non-pregnant dairy goats aged 1.5 to 3 years using a control randomized block. They were randomly allocated into three groups of 5 goats each, the control group received 500µg, group 2 received 250µg and group 3 received 125µg of Cloprostenol (estroPLAN) intramuscularly (IM) replicated three times. Double injection protocol of 11 days apart was used. The heat response, onset, intensity and duration were observed and recorded. Questionnaire data were analyzed using R software version 4.03 and comparisons done using Pearson chi-square test at 95% confidence interval. Experimental data were analyzed using two-way analysis of variance (ANOVA) using R software and means separated using least square differences (LSDs). The results revealed that a majority of farmers use natural mating (98%) and a significant (p-<0.05) number of farmers were willingness to pay for AI. 71.4% of farmers though willing to pay, perceived this technology to be expensive. Whereas the heat response for group 1 and 2 were similar, a majority of group 2 goats had milky vaginal mucus between 60 and 72 hours and highest pregnancy rates (84.6%). It is concluded that goat rearing Goat rearing in Nyeri was through small scale practice involving 2-5 goats and most farmers were not members of goat associations. Breeding was done through rotation bucks and this practice was leading to inbreeding and reproductive venereal diseases. Goat AI practice was significantly low and mostly practiced by younger generation. Lowered dosage of PGF2α by half (250µg) was effective and efficient in synchronizing goats. It is recommended that Farmers be encouraged to join the goat associations for better management of goat farming. It is suggested that farmers do away with the use of rotation bucks to decrease venereal diseases and in breeding in goat farming. The other suggestion is that synchronizing of goats be done using 1ml (250µg) instead of 2 ml of PGF2α. It is suggested that the results of this study be used to inform policy that allows lower synchronizing dose be applied for synchronizing goats across the country and also to be part of the protocol to be integrated within the goat AI Centre in Ndomba for enhanced delivery of goat AI services in Kenya and beyond.

Key words: Artificial inseminations, goats, prostaglandins, synchronization

CHAPTER ONE

1.0 INTRODUCTION

Agriculture plays a significant role in sustaining the developing countries´ economy and attaining food security. Livestock sector in developing countries accounts for more than one third of Global Agricultural GDP (Alston and Pardey, 2014). This sector employs more than one billion people in the world of which 60% are from rural households (Ingabire *et al.*, 2018). In Kenya, livestock contributes approximately 12% of the country's GDP where goats form an essential component (Ndeke *et al.*, 2015). The use of technologies in the livestock sector enhances productivity, reduces threats of diseases and ensures environmental sustainability in productive areas (Ingabire *et al.*, 2018).

The world goat population was about 850 million in 2007 with 245 million of these found in Africa (Solaiman, 2010). Kenya has approximately 27.7 million in Kenya (KBNS 2009; out of which 400,000 are dairy goats (Kikwatha *et al.*, 2020a). Goats too have become popular in recent years as a pathway out of poverty in Kenya due to its critical socio-economic role through meat, milk, and skin production (Ahuya *et al*., 2009). Goat breeds reared in Kenya are either local, exotic or their crosses with the majority being the indigenous found in the arid and semi- arid areas. The local breeds include the Small East Africa goat (SEAG) and Galla whereas the exotic breeds introduced to Kenya are Toggenburg, British and German Alpine, and Saanen (Kiema *et al*., 2020; Ndeke *et al.*, 2015). The distribution of the local goat breeds in Kenya assumes some pattern with counties in the north having predominantly Galla goats while those in the rest of the country having the SEAGs. The exotic breeds are mainly concentrated around Mount Kenya region.

In recent years, goat farming has gained popularity as it's seen to be a pathway of poverty eradication especially through the sale of milk and meat (Kiema *et al.*, 2020). Despite this rise, goat farming system today is faced with many problems, key among them being poor breeding methods, poor nutrition and high disease and parasite burden. However, their rapid growth translates into quicker investment returns which makes this enterprise attractive amongst the youth and women.

This study aimed to determine the factors affecting the uptake of artificial insemination technology by testing the hypothesis that there are no factors affecting the uptake of artificial insemination in goat farming. The study also established through control experiments the optimal doses of PGF2α required for effectively synchronizing goats as a cost saving measure since this information is not readily available.

1.1 Statement of Problem and Justification

Goat milk has high nutritional value and medicinal advantages over the cow milk thus good for the children, the elderly, and those with terminal diseases like HIV. Producer prices of livestock products are expected to increase by 19% in 2027 from the year 2015 in response to the increasing world demand for animal products (Miller and Lu, 2019). This current situation of increased livestock pricing products, increased pressure on land resources, hunger, poverty and changing climatic conditions driven by international and domestic consumer demand present unpredicted development challenges in the developing countries. This has elicited the need for adoption of reproductive technologies like AI and synchronization that have been improved and are relatively cheaper to reduce the cost of production. However, in Kenya there is low uptake of AI in goats by dairy goat farmers which prompted the need to find out the factors affecting this uptake. The other theory is that the amount of pgf2a dose used for synchronizing goats is similar to what is used in cows thus being costly. With the reduction of the synchronization cost, then the adoption of goat AI technology stands a higher chance of uptake leading to improved dairy goat practice in the country. Improving dairy goat practice will enhance improved nutrition and food security thereby achieving the Kenya 2030 vision and the UN SDGs one, two, five and thirteen (Abubakar and Saeed, 2015).

1.2 Study Objectives

1.2.1. General Objective

To determine the factors affecting uptake of artificial insemination technology and establish the minimum dose of prostaglandin F 2α (PGF2α) required for synchronizing dairy goats.

1.2.2 Specific Objectives

1. To establish the factors affecting the uptake of artificial insemination, an assisted reproductive technology amongst smallholder dairy goat farmers.

2. To assess the willingness of smallholder dairy goat farmers on their willingness to adopt and pay for the assisted reproductive technologies.

3. To test and recommend the minimum effective dose of PGF2α required for optimal synchronization to achieve heat stimulation in goats.

1.3 Research Hypothesis

1. The uptake of artificial insemination technology amongst smallholder dairy farmers is low (Ho)

2. Smallholder dairy goat farmers are not willing to adopt for assisted reproductive technologies due to high cost (Ho)

3. A reduced dose of PGF2α is not effective in synchronization of goats for optimum estrous achievement (Ho)

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Historical Background of Goats

Goats were first domesticated about 10,000 years ago (Solaiman, 2010). These domesticated goats (*Capra hircus*) have since then been involved in many human aspects including cultural, religious, traditions, nutrition and economic purposes. World goat population has shown an increase since the year 2000 with Asian having the largest population followed by Africa. In African, Nigeria has the largest goat population followed by Somalia and Kenya respectively (Bampidis, 2021). Goats are mainly kept for milk, meat, fiber and skins. Goat meat among these products is extensively consumed followed by milk which is consumed mainly in developing countries while in developed countries milk and its products are sold commercially (Miller and Lu, 2019; Solaiman, 2010).

In Kenya a majority of the goats are indigenous and adapt naturally to diverse climate conditions. They are kept mainly for meat, milk and socio-cultural activities among a majority of the communities in the marginal parts of Kenya. The exotic breeds are mostly found in areas of high rainfall and with agropastoral activities. They were introduced into the country primarily for milk as they are good milk producers (Mburu *et al.*, 2014).

2.2. Dairy Goat Industry in Kenya

Currently there is a rapid global expansion of the goat dairy industry in the world (Miller and Lu, 2019). Kenya has not lagged behind in this as the demand for dairy goats by farmers is increasing very fast (Okoti and Lengarite, 2018). However, there is need for upgrading goats (Kiema *et al.*, 2020) especially among the pastoralists for fast growth and increased production of milk. This is because the milk sold in Kenya more than 70% is from cows and less than 1% from the dairy goats (Kikwatha *et al.*, 2020b). Though research has been done on cross breeding as a strategy to improve production (Waineina *et al.*, 2020), local breeds still need a lot of improvement to carb the challenge of milk and meat shortages.

The cross bred dairy goat population in the country have vastly increased from 20,000 in 1991, to 160,000 in 2005 (Mburu *et al.,* 2014). The aim of upgrading was mainly for milk production and the fact that goats have small land requirements, need less management facilities but reproduce faster making it a good adventure for women and youths in terms of investment returns (Kiema *et al.,* 2020; Mbuku *et al.*, 2015; Peacock *et al.,* 2010).

2.2.1 Dairy Goat Trends in Kenya

In Kenya there is a widespread use of exotic dairy goats among the small holder goat production systems for breeding programmers (Mbuku *et al.*, 2015). The dairy sub sector which was introduced in 1950s by British settler farmers in the Kenya highlands picked in the 1980s and 90s (Kikwatha *et al*., 2020; Miller and Lu, 2019). The Government of Kenya in partnership with Farm Africa and GTZ introduced upgrading programs for dairy goats in potentially medium to high areas (Kiema *et al.*, 2020). These non-governmental organization encouraged projects that were geared to improving the local breeds using the exotic breeds for improved milk production and adaptability. (Peacock *et al.,* 2010) Toggenburg, the German Alpine and the Saanen have been introduced in various parts of the country by non-governmental organizations (NGO). There has been no particular criterion for introduction of these breeds into the country but has majorly been NGO dependent.

The German Technical Cooperation (GTZ) introduced German Alpine in Embu, Nyeri and Kirinyaga in the early 1980s to central Kenya where it is being promoted by Dairy Goats Association of Kenya (DGAK). Today, it is found predominantly in Nyeri, Embu, Kirinyaga, Murang'a, Kiambu, Vihiga and Nakuru counties. Toggenburg was introduced by FARM Africa an NGO in Ethiopia and Kenya rural areas of Meru and Kitui (Ndeke *et al.,* 2015). They are also reared in Tharaka-Nithi, Makueni, Nakuru, Kiambu and Nairobi Counties. The Saanen breed was introduced to the country in 1990s by the Heifer

International to South Nyanza. South Nyanza Goat Breeders Association which is based at Rongo is promoting the breed in the region. This breed is also in small populations in Central Rift.

2.2.2. Characteristics of Kenya Dairy Goat Breeds

There are more than 1,153 goat breeds listed by Food and Agriculture Organization (FAO) in the database of animal diversity (Solaiman, 2010). Classification of goat breeds are mainly based on geographical origin, productivity and their region while others consider shape and size of horns and some primary product of the goats which is mostly used in the developing countries (Solaiman, 2010).

Dairy goats are primarily selected for productivity which is based on milk quantity, percentage of milk fat, production efficiency and longevity. For morphological traits, large capacity body and angularity are normally considered while milk composition is key criteria for making cheese (Solaiman, 2010).

In Kenya, there are two main indigenous goat breeds and a number of exotic breeds that were imported into the country. Exotic dairy goat breeds in Kenya are the Toggenburg, Alpine, and Saanen, while indigenous breed is the Galla goat which is also reared for meat.

The Alpine goat breed originated from Switzerland. They have large well shaped udders and excellent in milk production. French Alpine goat breed descended from Swiss Alpine. The mature bucks weigh 77kg and the does weigh about 61kg. They are either polled or horned and short haired. They have no distinct color but chamoisee color is mostly common. Have been larger were selected for their uniformity, large size, and high milk production. They are adapted to a variety of climate.

British Alpine is a Swiss Alpine that was imported to Great Britain in 1903.The breed is both horned and polled and medium to a heavy milk producer. It’s a breed suited for the temperate climate (Mburu *et al.*, 2014; Solaiman, 2010).

Saanen breed is known as the queen of dairy goats as it's the most reputable dairy breed. It's a native breed of Saanen Valley in Switzerland. This breed is heavy in milk production with average content of butterfat. The doe weighs around 68kg whereas the buck weighs 80 to 91 kg. The breed is polled and has white or a light cream color**.** It's the most widely dairy goat breed distributed worldwide for local goat upgrading to increase milk production (Okoti and Lengarite, 2018; Solaiman, 2010)**.**

Toggenburg breed originated in Toggenburg Valley, northeastern Switzerland. It's the oldest dairy breed among these Swiss dairy breeds**.** It's the smallest breed among the Alps breeds. The does weigh around 54kg whereas the bucks weigh 91 kg or more. The color ranges from light fawn to dark chocolate and have white stripes running down the face. They ate best suited for cooler environments (Ahuya *et al*., 2009; Solaiman, 2010) (Mburu *et al.,* 2014; Solaiman, 2010).

Galla goat breed also known as the Somali or Boran is an indigenous breed of the northern Kenya areas but also found in Somalia, Ethiopia, Djibouti and Eritrea. Its origin is Arabian Peninsula (Kenya Livestock Breeds Catalogue, 2019). They have white hair coat and black skin, feet, under tail and nose. Does weigh up to 55kg whereas bucks around 70kg. There are two sub-types of this breed, Degyir that is reared for meat and Degeun which is kept for milk production (Kenya Livestock Breeds Catalogue, 2019).

Small East African breed is prominent across Kenya. Their size is relatively small with characteristic short hair and erect ears that are short too (Kenya Livestock Breeds Catalogue, 2019) and vary in color coats. They are reared mainly for their meat and sometimes for skins. The breed is early maturing but with low twinning rates. Adults weigh approximately 30 kg too (Kenya Livestock Breeds Catalogue, 2019).

2.3 Dairy Goats' Climate Smart Livestock

Dairy goats are considered climate smart livestock due to a number of reasons. They provide nutritious and wholesome milk and its products as well as sustainable livelihoods more so in areas with limited resources. More so goats are consistent producers at all times, lesser nutritional requirements, fast breeders, good in browsing and diet selection and market price (Gonzalez *et al.*, 2013). These goats if well managed benefits the environment in weed controlling as they are good browsers and they also maintain biodiversity and mitigation of climate effects such as reduction of greenhouse gas emission (Miller and Lu, 2019).

Global Greenhouse gas emissions (GHG) from sheep and goats is about 20 - 25 % that of dairy and beef cattle. Existing mitigation methods for these emissions in dairy goats consist of high-quality forage utilization, protein supplementation in case where forage quality is low, fat inclusion in diet among others. Methane inhibitors such as probiotic have also been used. Effective systems for manure management can also reduce these gases (Miller and Lu, 2019).

Dairy goat farming can be an important tool in achieving the UN Agenda 2030 for Sustainable Development. Its shifting from focusing on production in itself to the broader way of its contribution to the 17 sustainable development goals (SDGs). These include gender equality, human nutrition and environmental protection. The dairy goat farming is important in achievement of these goals, because of goat milk importance in diet of the poor children and the strong role of women management and ownership of dairy goats (Peacock *et al.,* 2010).

2.4. Reproductive Physiology of Goats

Goats have good adaptation to various condition of the environment (Simões *et al.,* 2021). They also exhibit distinctive reproductive seasonality (Simões, 2016). Their reproductive activity is controlled by hypothalamic-pituitary-gonadal axis (Luo *et al.,* 2019).

Female goats reach puberty at age of 4-6 months but sexual maturity is closely related to their body weight than age (Kubkomawa *et al.,* 2017). Breeding occurs between 7-10 months based on body weight. Nutrition, health and breed influence puberty onset (Tsuma *et al*., 2015). The length and onset of mating season depends on climate, latitude, nutritional status, photoperiod, male effect, management and physiological stage (Pehlivan *et al.,* 2017). Photoperiod acts through control of melatonin secretion by pineal gland in darkness whereas seasonality is observed in goats raised in high attitudes, more than 35°C and in temperate regions (Pehlivan *et al*., 2017).

2.4.1 Estrous Cycle in Goats

Estrous cycle is the length in days defined by two consecutive estrous periods (Tsuma *et al.,* 2015). Estrous behavior is regularly repeated at intervals except when interrupted by diseases, nutritional factors or pregnancy (Joshi and Khanal, 2021; Tsuma *et al*., 2015). A doe in health state will normally last between 20 - 21 days, but can vary between individuals and breeds. This cycle is normally divided into two phases namely the follicular phase and the luteal phase (Abecia *et al.*, 2011).

The follicular phase is dominated by Follicle Stimulating Hormone (FSH) released from the anterior pituitary gland and stimulates synchronous growth of cohort follicles. Luteal phase is predominated by the corpus luteum (CL) and begins from around day 3 of estrous to day 16. The CL develops from follicular cells after ovulation and consists of small and large lutein cells. The life span of the CL is characterized by luteal development, maintenance and luteolysis (regression) (Malik, 2019). Progesterone is the principal hormone produced by the CL and its decrease in concentration in synergistic action with raising of estrogen levels results in behavioral estrous (Joshi and Khanal, 2021). This understanding will enable the manipulation of the productive cycle with the aid of reproductive technologies.

2.4.2 Hormonal Control of the Estrous Cycle

At puberty, the hypothalamus located in the brain of the doe sends a signal to the follicle located in ovary to commence egg development every three weeks. The signal from the hypothalamus is through releasing of the hormone, Gonadotropin Releasing hormone (GnRH) (Esteves *et al.,* 2013). This GnRH stimulates pituitary gland located in the brain base for production of gonadotropin hormones that is, Luteinizing Hormone (LH) and Follicle Stimulating Hormone (FSH). Follicle stimulating hormone is responsible for initiating development of follicles in the ovary which are initially small pinhead structures in size to fluid-filled of about half -inch diameter (Tsuma *et al*., 2015). This growing follicle increases in size with fluid accumulation in the cavity and secretion of estrogen hormone into the blood for circulation. Estrogen secretion is greatest when the follicle has attained its maximum in terms of size**.** High circulating levels of these hormone act on brain of the doe affecting the nervous system thus resulting in behavior the change of the doe described as the heat signs. Once this estrogen levels reach a particular threshold, they stimulate LH surge. This surge causes mature follicle or follicles to undergo some changes that eventually result into rupture of the follicle and releasing of the ova or egg normally known as ovulation.

After ovulation, changes begin in the cells of ruptured follicle by beginning to growth and undergoes changes known as luteinization under LH influence to form a yellow body which is a gland structure called Corpus Luteum (CL).the CL is responsible for progesterone production which maintains pregnancy in early gestation, but if there is no fertilization, destruction of the CL occurs at about 16 days later after heat and progesterone production ceases (Maia *et al.,* 2017).Prostaglandin F2α (PGF2α) produced in the walls of the uterus is responsible the lysis of the CL. The drop of progesterone is followed consequently by an increase in FSH and LH resulting in development of the follicles and release of the ova and heat recurring at around 20 or 21 days after previous heat (Tsuma *et al.,* 2015).

2.4.3 Heat in Goats

Heat is the period when a doe that has attained puberty desires or stands to be bred by a buck (Joshi and Khanal, 2021) and may last for 24 to 48 hours. This depends on season, availability of a male and breed. Goats on heat manifest heat signs which include, continuous bleating, inflammation of the vulva, clear and stringy mucus discharge from the vulva, urine secretion increases and moving of the tail (Dávila et al., 2018; Tsuma *et al.,* 2015).

2.4.4 Heat Detection Techniques

In goats, estrous detection techniques include having the buck in a closer proximity to does. The does will be easily identified if on heat due to intense heat signs such as pacing around restlessly trying to get to the bucks (Tsuma *et al.,* 2015). Time for heat observation is also a factor as these does have a tendency of being more active sexually during cooler times which is either early in the morning or late in the evening (Faigl *et al*., 2012). This is a perfect time and is more facilitated by housing or grouping the does together so that they can interact. This way you are able to notice if a doe is on heat based on their behavior.

Using of teaser buck is the other method and has been used widely more so in experimental designs. This is where a buck that cannot impregnate the doe due to various preparation methods is used to identify these does on heat. The teaser buck can either be an entire male or deviation of whole penis. The buck can also be vasectomized thus cannot deposit spermatozoa in the does reproductive tract. System (Tsuma *et al.,* 2015).

2.4.5. Follicular Waves in Goats

Follicular wave dynamics in goats have been shown to have received lesser attention in comparison to cattle and sheep (Sharma *et al.,* 2020). This follicular development is divided into gonadotropin independent phase were LH and FSH are involve. In this phase there is growth of follicle from primordial stage to antral stage of follicle. The other phase is dependent on the FSH and the LH, where in this phase the follicle reaches ovulation as a result of the amplitude of the LH pulse (Sharma *et al.*, 2020). Follicular development begins during embryogenesis and continues through the neonatal and postnatal stages of the doe. The primordial follicles which develop during the postnatal period grow to become primary, secondary and tertiary (antral) follicles (Malik, 2019). Female goats at puberty produce one or more follicles from the pool of antral follicles which become dominant and proceed to ovulated as the reminder naturally regressing at various intervals (Malik, 2019; Tsuma *et al.*, 2015).

There are 5-10 follicles at any given day of estrous cycle measuring not more than 3mm ovarian diameter and the follicles normally ovulate when the diameter is between 6 to 9mm. Onset of each follicular wave and interval of the inter wave vary highly because of the variation in number of the follicular waves. The diameter of dominant follicle in the anovulatory wave is between 6-6.7mm in diameter whereas for ovulatory follicle it's up to 8. 2mm. Goats normally experience between 2-6 follicular waves in estrous synchronized or naturally cycling goats (Vázquez *et al.*, 2010). However, 4- wave pattern has been observed in many goats (Sharma *et al.*, 2020).

2.5 Assisted Reproductive Technologies

Assisted reproductive technology is a technique and practice applied to ensure genetic improvement in livestock (Omontese, 2018; Paramio and Izquierdo, 2014). These technologies in include artificial insemination (AI) estrous synchronization, in vitro and in vivo embryo production (IVEP), multi-ovulation and embryo transfer (MOET and somatic cell nuclear transfer (SCNT) (Abecia *et al.*, 2011; Tsuma *et al.*, 2015)). Utilization of artificial reproductive technologies among goat farmers in dissemination of superior genetics however is still seen as a challenge (Kahi and Wasike, 2019).

Assisted reproductive technologies through its advancement in the recent years has given a window for the manipulation of the reproductive physiology revolutionization of animal agriculture in the world (Verma *et al.*, 2012).

2.5.1 Artificial Insemination in Goats

Artificial insemination (AI) in goats is the process in which collected semen from the buck is processed, preserved and introduced artificially into the doe reproductive tract for conception (Dávila *et al.*, 2018). AI is an important tool for genetic improvement (Maia *et al.*, 2017). AI practice in reproduction of animals was initially introduced for control of disease but later it was recognized as a tool of dissemination of valuable genes (Faigl *et al.*, 2012). AI following estrous synchronization in goats has been carried out successfully in the past years (Mehmood *et al.*, 2015; B. O. Omontese *et al.*, 2016). However, AI and estrous synchronization has widely been used in dairy cattle breeding compared to goat dairy farming.

Semen quality for AI depends on collection and storage procedures (Dávila *et al.*, 2018). Semen can either be used fresh or preserved, though fresh semen has demonstrated a higher conception rate compared to frozen semen in goats (Gore *et al.*, 2021). Preservation methods include refrigeration of semen under 4ºC, which requires to be used within 24 hours while frozen semen can be stored for a very long period.

Artificial insemination has numerous advantages which include, use of superior males, increased milk production, genetic improvement, control of venereal diseases brucellosis, trichomoniasis and vibriosis, elimination of dangerous and expenses of keeping a buck, and ease of semen transportation than buck transportation (Omontese, 2018; Tsuma *et al.*, 2015). Disadvantages of AI include the need for technical skills and well-trained personnel to undertake semen collection, storage, transportation and insemination (Abubakar and Saeed, 2015). Artificial insemination can also lead to the fast spread of undesirable traits in case of fewer donor bulls from where semen is collected thus resulting in inbreeding.

2.5.1.1 Semen Collection

Semen collection from desired buck with quality traits can be done using various methods, but there are two main methods. Artificial vaginal (AV) is one of the methods which involves use of a teaser doe to stimulate the buck and be able to mount her. AV components which include inner and outer rubber, cone, collecting tube and rubber band are sterilized by autoclaving. Semen collected is proper labelled and stored (Joshi and Khanal, 2021). In Kenya, the Kenya Agricultural Resource Center is does the semen collection tough a majority of semen is imported into the country. Disadvantage of this method is that the buck must have been trained in advance to ejaculate.

The other method is electro-ejaculation method where an electro ejaculator is used. This method however, is less tolerated by bucks and reduces spermatozoa's ability to survive during preservation. After semen collection, sperm motility and morphology, including its concentration in the extenders are checked critically (Faigl *et al.*, 2012).

Sexing of sperm to control sex of the offspring has been a major goal for livestock IA industries. There has been establishment of several methods attempting to realize this goal. However, a majority proved ineffective and impractical but recent years flow cytometry has been Most of these proved impractical or ineffective, but in recent years, flow cytometry method has been established (Parkinson and Morrell, 2019). Sperm sexing through flow cytometry with high speed is utmost significant new technology developed for the 20th century for artificial insemination in livestock. It has a wide commercial application in the dairy cattle industry (Maxwell and Evans, 2006). Along with this new technology of sexing there is need to develop better processing and storage techniques and adapt.

Limitations related to sexed semen include high cost, slow processing rate and lack of portability

2.5.1.2. Storage of Semen

There are two main methods for liquid storage of semen. One of these methods is Cooled semen using simple diluents. Initial this method involved seminal plasma removal by washing with a simple buffer diluting it citrate egg yolk and utilized at 5°C (Maxwell and Evans, 2006). Use of skimmed milk as an extender is another alternative since you don't remove seminal plasma which consumes a lot of time and results in loss of the total spermatozoa numbers (Parkinson and Morrell, 2019). However effective spermatozoa lifespan when skimmed milk is used as an extender is comparatively short and can only be used for approximately 12 hours. Freezing of semen causes cryoinjury however, chilling (to 5° C) is advantageous as it reduces the sperm death numbers. Chilled liquid semen retains acceptable fertility only for about 24 hours for intra cervical inseminated but afterwards fertility reduces unless intrauterine insemination is performed (Maxwell and Evans, 2006). Prolongation of the life of semen that is chilled has been done through addition of antioxidants which have extended the chilled semen fertilizing life to about 14 days for intrauterine insemination. Optimum longevity and viability of sperm during storage and after insemination is paramount (Kharche *et al.,* 2013). This however favours intrauterine insemination more than cervical insemination because of time limitation.

The other method utilizes diluents of ambient temperatures thus there is no need of egg yolk which is responsible for prevention of cold shock when spermatozoa is cooled to less than15°C (Parkinson and Morrell, 2019). This method utilizes skimmed milk diluent and commercial soya which is lipid-based also as a diluent. These diluents maintain sperm viability between 15° and 22°C for around 24 hours.

Cryopreservation or frozen stored semen uses egg yolk or skimmed milk extenders though use of soy lecithin as an extender is gaining popularity. The utmost effective cryoprotectant is glycerol. If spermatozoa are washed, an extended with 14% glycerol is added when semen is at 4°C (Parkinson and Morrell, 2019). However, if spermatozoa being used is unwashed glycerol addition is done when semen is at 30°C. Semen may be frozen in two methods, the pellet method where it's on the solid surface of carbon dioxide and in paillettes suspended over liquid nitrogen vapour.

Frozen stored semen can only be used for intrauterine insemination via laparoscopy with acceptable results as cervical insemination cannot produce consistently acceptable fertility. With this, little progress has been made and thus the need to develop improved methods for semen processing for cryopreservation (Kharche *et al.,* 2013; Maxwell and Evans, 2006).

2.5.1.3. Process of Artificial Insemination in Goats

AI process in goats involves the technician first ensuring the doe being presenting is on heat and restrained with hind quarters held up to allow ease of access to reproductive tract (Ericksen and Crane, 2018; Tsuma *et al.,* 2015). The AI equipment should be clean including the perineum region of the doe by wiping with paper towel. Semen in straws should be stored in the Liquid nitrogen tank that has a measuring stick for monitoring the levels of liquid nitrogen in the tank. Measuring of liquid nitrogen should be at least done weekly. Other equipment needed include a straw tweezers. For semen straw retrieval from the nitrogen tank and thawing bath. **A s**traw cutter which cuts the straw and a lubricant which is non-spermicidal and sterile to lubricate the vaginal speculum before its inserted into the vagina. A kit for semen thawing with a thermos flask, water thermometer and a timer are also essential for proper semen thawing at right temperatures (Tsuma *et al.,* 2015).

The doe is restrained as early described and a lubricated speculum is inserted into the vagina to check intensity of the mucus. Cloudy mucus is the best time for insemination as clear is too early and cheesy too late. The doe is bred again should it show heat signs 12 hours later after being inseminated (Maia *et al.,* 2017). After semen is loaded in the AI gun a lubricated speculum and a source of light is inserted to visualize the cervix. And insert the loaded gun through the cervix rings and deposit the semen into the uterine body or cervix by slowly pushing the plunger and finally removing the speculum and the AI gun (Tsuma *et al.,* 2015).

2.5.1.4 Methods of Artificial Insemination

Artificial insemination techniques performed in goats are transcervical and laparoscopy (Maia *et al.,* 2017). Transcervical technique can either be the standard AI method where a speculum and insemination gun are used to deposit semen in the cervix or the deep carnual insemination where a catheter within a catheter is used to deposit semen in the uterine horn or uterine body (Dávila *et al.,* 2018; Anakkul *et al.,* 2014). This method is successful in nearly 60 to 70% of does when frozen semen is used.

Laparoscopy entails semen deposition directly into the horns of the uterus with the use of local anesthesia during endoscopy. This technique was earlier used in the 80s by Australian researchers in sheep. Pregnancy rates with this method is about 80% with fresh diluted semen and 50-80% for frozen semen (Dávila *et al.,* 2018). The dairy goat industry still needs an improved method of semen processing to increase the success rates of cervical insemination (Maxwell and Evans, 2006).

2.5.1.5 Status of Artificial Insemination of Dairy Goats in Kenya

Currently dairy goat artificial insemination is still low compared to dairy cow industry globally mainly due to lack of trained personnel and economic resources (Dávila *et al.,* 2018). Presently it is stated that for every 2 goats inseminated 10 cows are inseminated.

The low proportion of inseminated goats to that of cattle has caused limited genetic progress in goats (Dávila *et al.,* 2018). In Kenyan artificial insemination of goats is not well documented as there are few records. The dairy industry is also faced with challenges of inbreeding as organizations such as DGAK (Ndeke *et al.,* 2015) have not imported other goats for breeding since the importation of the 11 breeding goats over 16 years ago. (Witjaksono *et al*., 2021) Goat AI has been faced with challenges of high cost, unavailability of trained AI providers among others. AI adoption is still not well documented as minimal research has been done in dairy goat farming compared to dairy cattle industry (Witjaksono *et al.,* 2021).

2.5.1.6. Pricing of Artificial Insemination in Goats

The slow adoption of AI use in Kenya is not because of its potential to enable genetic improvement but it's the cost in comparison with short-term realizable benefits. AI was calculated as 3 times more than natural breeding in Australia (Maxwell and Evans, 2006). This however could be due to cost of equipment for AI including liquid nitrogen and also increased labor needed for detection of heat and insemination performance (Kifaro *et al.,* 2008). However, the benefits gained by AI such as quick genetic gains outweigh these disadvantages. Moreover, the high cost of artificial insemination can be lowered through improving detection methods such as use of lowered doses of hormones to detect heat thus minimizing labor requirements.

Currently goat artificial insemination in the country on average is 1500 Kes which is similar to the price dairy cow insemination. This price however can be higher depending on the type of breed and source of semen (Khainga *et al.,* 2018).

2.5.2 Synchronization of Estrous in Does

Synchronization is an essential technique in reproduction and management of goat breeding programs (Sunil *et al*., 2018) since goats are seasonal breeders (Holtz *et al.,* 2011).

It is the manipulation of estrous cycle to bring large numbers of females to estrus within a short time through management of light hours, the male effect or the use of hormones (Pal and Rayees, 2020). Hormonal synchronization primarily includes the use of PGF2α and progestogens (Cinar *et al.,* 2017).

Utilization of synchronization will lead to a more cost-effective management of time and resources (Pal and Rayees, 2020). The technique however should ensure a reasonable fertility in synchronized cycle and more research carried out to establish optimal dose and agents used (Hashemi and Safdarian, 2017).

2.5.2.1 Estrous Synchronization by use of Male Effect

This involves introducing a buck to a group of does which have had no contact with the males for a minimum of three weeks (Mobini, 2019). This presents of the male leads to induction of hormonal surge in the does that results in ovulation in three days (Paramio and Izquierdo, 2014). The pheromones from the buck are responsible for this pulsative triggering of the GnRH leading to LH secretion (Sakamoto *et al.,* 2013). The doe endocrine and ovulation responses from buck exposure are influenced by factors such as intensity of bucks' sexual behavior, separation period of both sexes previously and extend of familiarity with the bucks (Mobini, 2019). Male effect is also influenced by male to female ration where more than 30 females for a buck result in lower estrous stimulation and 20 is the optimum number required (Gallego-Calvo *et al.,* 2015). Other factors that can influence this stimulation of the male effect include breed, nutrition, anestrus depth in the does and postpartum stage (Mobini, 2019). This manipulation can however be improved by combining it with hormonal therapies when breeding during the out of season.

2.5.2.2 Light Control for Estrous Synchronization

Artificial light control can be used to manipulate goats in the breeding season and can also carried out in out of breeding season when combined with hormonal therapy (Mobini,

2019) The goats are subjected to artificial light for a longer period per day for around 2 months then are subjected to normal light where males are then introduced in six weeks and estrous occurs later in about 10 to 20 days (Mobini, 2019). Bucks that are photo stimulated are also known to have increased libido and are able to reactivate gonadotropin axis leading to GnRH/LH secretion in does resulting in ovulation.

2.5.2.3 Hormonal Estrous Synchronization

This involves the use of exogenous hormones to manipulate the physiological activities of the sexual cycle. Luteal phase in does is more responsive and longer in duration compared to follicular phase making it more appropriate for manipulation (Holtz *et al.*, 2011). These hormones function by controlling the CL, follicular stimulation development and regulates ovulation (Omontese, 2018).

Hormones for estrous synchronization can either be used during the out of season, transitional period or during breeding season in does that are cycling. Hormones that are used during breeding season include $PGF_{2\alpha}$ administration to induce luteolysis from day three of estrous cycle (Mobini, 2019). Progestogens are also used during this season, which are administered either intravaginally, parenterally, orally or implant. For shorter length of progesterone administration, luteolytic drug like $PGF_{2\alpha}$ is required (Romanio, 2021).

Transitional period utilizes progesterone for estrous synchronization. Hormones used during out of season breeding include melatonin implants, and progesterone which are combined with gonadotropin such as equine Chorionic Gonadotropin (eCG). However repetitive eCG use results in antibody production against eCG in some goats, consequential leading to modification in ovulation time hence reduction in fertility especially if fixed time AI is to be done fixed (Romanio, 2021).

2.5.2.4 Synchronization Protocols

Although there are several synchronization protocols for goats, preference should be on simple, reliable and economical protocols that farmers can easily adopt (Hashemi and Safdarian, 2017). Currently adopted protocols utilizes the use of progesterone, prostaglandins and its analogues or their combination among other hormones (Abecia *et al.*, 2011).

2.5.2. 5 Progesterone based Protocols

Progesterone control estrous cycle by mimicking corpus luteum functions through prevention of hormonal activity (Tsuma *et al.*, 2015). It involves usage of natural progesterone or its synthetic analogues (Omontese, 2018). Synthetic analogues include Flurogestone acetate (FGA), norgestomet, Medroxyprogesterone acetate (MPA)) and Methyacetoxy progesterone (MAP) which are administered as intravaginal sponge or as an ear implant (Omontese et al., 2016). The natural progesterone includes silicone implants and control internal drug releasing device (CIDR) made from silicone elastomer inserted intravaginal (Omontese, 2018). The progestogens are applied for a period of 5-14 days then a luteolytic agent, preferably prostaglandins F2 α (PGF2α) followed by 24 hours to its removal with additional application of either equine chorionic, gonadotropin releasing hormone or estradiol 36 hours to removal to synchronize ovulation (Dávila *et al*., 2018).

2.5.2.6 Prostaglandins and Prostaglandin-based Protocols.

Prostaglandin is a primary luteolytic agent used for the lysis of the corpus luteum and subsequently causes induction of follicular phase of estrous cycle (Dávila *et al.*, 2018). The choice of prostaglandins over progesterone is because prostaglandins are rapidly metabolized in lungs hence reduced hormonal residues making it safe to be administered throughout the year (Omontese *et al.*, 2016). Progesterone has animal welfare issues since it can cause vaginitis and sometimes results in sponge retention (Esteves *et al.*, 2013). This hormone also has public health implications as residues of the hormone are traced in food from animals treated with it making it a less preferred option (Abecia *et al*., 2011).

Protocols utilizing prostaglandins include the single and double dose of PGF2α. The main objective of the double dose protocol is to have high percentage of goats in diestrus at the time second injection is administered (Wildeus, 2000; Biradar *et al.*, 2019)). Goats with mature CL will regress after PGF2α jab and come on heat around 3 days post administration. Second injection administered day 7, 11 or 14 later will bring the remaining animals in heat. Opportunities still remain for the improvement of this protocol.

The other protocols are Ovsysch, NCSynch, Co-synch and select synch. These protocols have been widely used in goats with great success (Simões, 2016). Ovsynch protocol synchronizes ovulation in goats by use of GnRH injected day 0 and day 9 and PGF2α injected day 7 and timed AI done 16-20 hours later after the second GnRH injection. NCSynch a modification of Ovsysch has administration of PGF2α for lysis of existing CL and beginning of a uniform follicular phase (Simões, 2016) as demonstrated below.

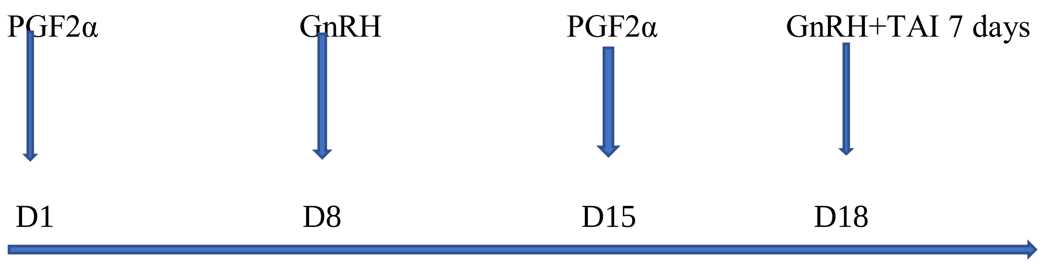

Figure 1: Schematic NCSynch-TAI protocol representation in goats (Simões, 2016)

Co-synch Protocol is also a modification of Ovsynch where insemination takes place at the same time with the administration of the last dose of GnRH (Abubakar and Saeed, 2015). However, in this method conception rates are low. Select Synch GnRH is administered day 0 and PGF2α day 7 and the goat is then observation for heat an insemination done at an appropriate time (Abubakar and Saeed, 2015).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Study Area

The study was carried out in two phases namely questionnaire survey and experimental phase. The survey was conducted in Mukurwe-ini sub-County, Rugi and Mukurwe-ini Central Wards, Nyeri County. Mukurwe-ini sub-County was purposively selected because of its high population of dairy goats. Mukurwe-ini Central had 7,726 households and eight locations, while Rugi had 5,806 households and six locations (KNBS, 2019). Figure 2 shows a map of the study area.

This sub-County lies on a latitude 0̊ 25′12.47" N and longitude 36° 56' 51.32" E. The climate is warm with annual temperature range of between 12.8 and 20.8 °C. It experiences a bimodal rainfall with long rains in March to May ranging from 1200 -1600 mm and short rains between October and December ranging from 500 -1500 mm. The main cash crops are tea, coffee and pyrethrum. Dairy cattle farming is also a major source of livelihood in Mukurwe-ini sub-County.

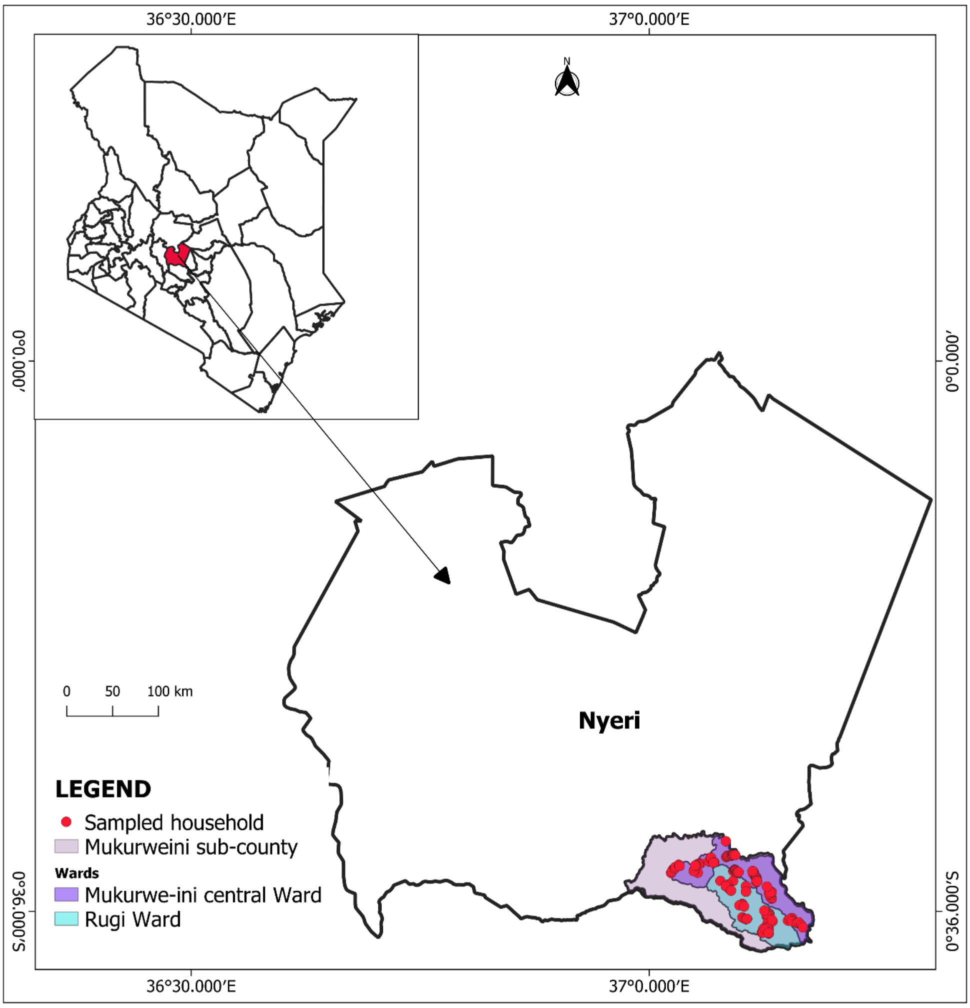

Figure 2: Map of Nyeri County showing Rugi and Mukurwe-ini central wards in Mukurwe-ini Sub County.

The experimental study was conducted at Ol'Magogo sheep and goat farm located in Naivasha sub county, Nakuru County. Naivasha is 76 km from Nairobi city and 63km from Nakuru town. It lies on 2084m above sea level and on 00 43' 0" S, 360 26' 0" Rainfall pattern at Ol'Magogo is bimodal and ranges between 200-700mm whereas temperature ranges from 20-30^{o}c. The long rainy season falls between March and August and the short rains falls between November and December. The main economic activities in Naivasha are flower farming, high value fruits like water melons, livestock production which include goats, sheep and indigenous cattle rearing and tourism

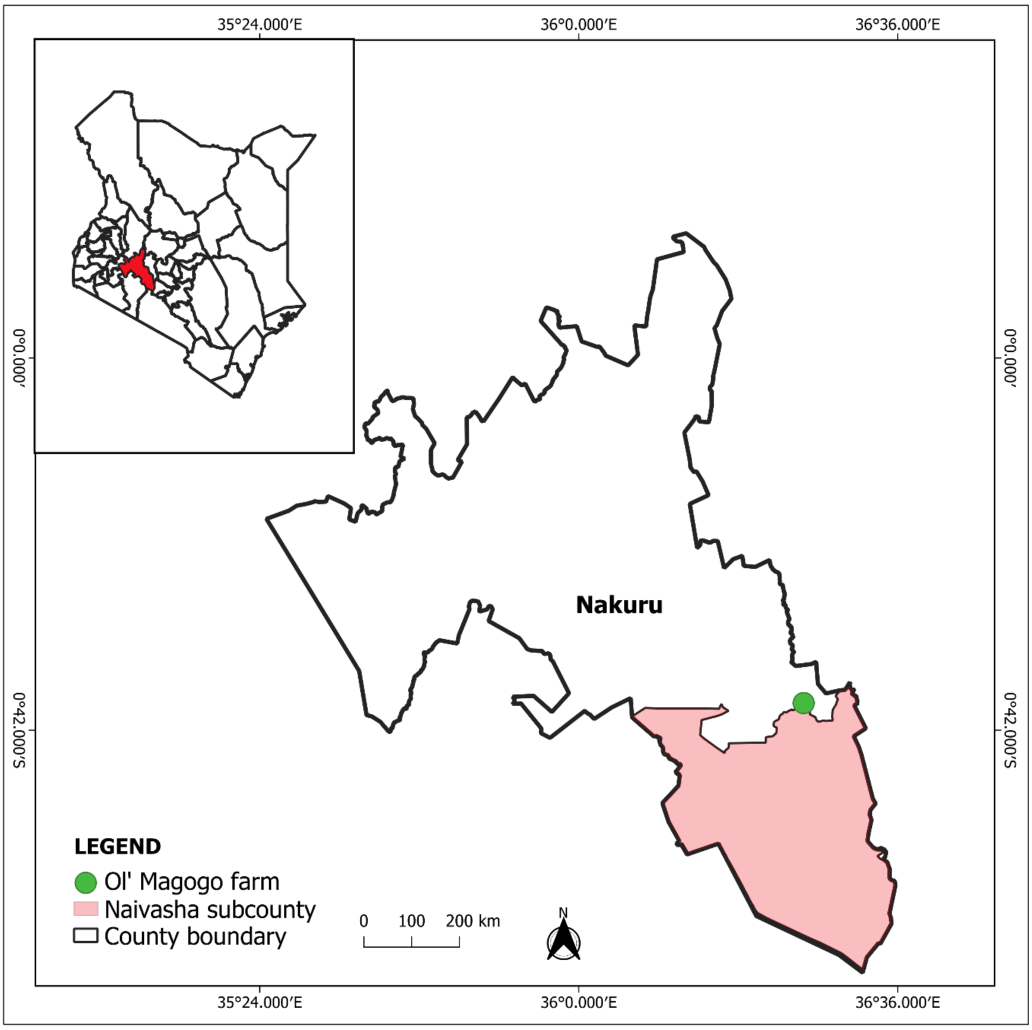

Figure 2: Map of Nakuru County showing OL Magogo farm, Naivasha sub-County

3.2 Study Design

3.2.1. Study Design and Sampling for the Questionnaire

A cross sectional survey was carried out between February to March 2021 for the questionnaire survey. A structured questionnaire was developed and used as a data collection instrument. The questionnaire included farm demographics, goat herd sizes and structure, source of breeding goats, production systems, goat breeds, breeding practices and benefits and challenges accruing from adoption of AI. The questionnaire was pretested and finally administered to 200 selected goat farmers in the two Wards selected through simple random sampling.

The sample size for each Ward was computed using Proportionate population size (PPS) sampling method using Yamane, (1967) formula below;

$$n = \frac{N}{1 + N(e)^2}$$

to determine the overall sample for the two targeted Wards.

Where;

n = Sample size

N = Population size

e = Level of precision

The Yamane formula was used to determine the overall sample for the two targeted Wards. The sampling frame for the two Wards was determined from KNBS population census of 2019. Using this formula, a total of 200 farmers were selected from the two wards of Mukurwe-ini sub-County. One hundred (100) households were picked from each Ward and divided among the locations in the respective Ward. However, 194 questionnaires were analysed as six of them were removed during data cleaning.

3.2.2. Study Design for the Experiment

The study was a complete randomized block design and conducted during the breeding season in the month of March to June 2021. The experiment utilized 45 health cycling goats.

3.2.3 Inclusion Criteria

The goats before entering into the study were aged using dentition (Umar *et al.*, 2018; Famakinde et al., 2017) to ensure they meet the required age criterion for entry. Only goats aged between 1.5 years and 3 years were included in the experiment (Sun *et al.,* 2019). Thereafter, the selected goats were subjected to physical examination for any health abnormalities. Their reproductive tracts visually examined for abnormal discharges before they were checked for pregnancy using a speculum and ultrasound scanner, respectively. Only non-pregnant does which were free from genital tract infections were recruited. Similarly, each goat was weighed using hanging digital weighing scale and only those which weighed 20kg and 30kg were included into the experiment.

3.2.4 Randomization and Treatment with Different Doses of PGF2α

The recruited goats were randomly assigned into three groups of 5 experimental goats each as described by (Begashaw and Lemma, 2017) (Table 1). This was replicated three times for each group at an interval of one week totaling to 15 goats for each treatment and a total of 45 does for the overall experiment. Commercial PGF2α, Cloprostenol, marketed as estroPLAN®, Parnel PTY LTD, Australia, which is a synthetic prostaglandin analogue was used to artificially induce heat. The goats in group 1 were treated with 500µg of PGF2α, those in group two with 250µg of PGF2α and those in group three with 125µg of PGF2α and observed for onset of heat. All treatments were administered intramuscularly.

Table 1: Experimental layout by groups and treatment administered.

Groups	**No. Goats**	**Cloprostenol dose** (µg)	**Route of administration**
Group 1	5	500	IM
Group 2	5	250	IM
Group 3	5	125	IM
Total	15		

Each goat received a double injection administered 11 days apart as described by (Omontese *et al.*, 2016). Briefly, each goat was injected in the neck muscle on day 0 and day 10 by a qualified and registered veterinarian. All treated goats were observed for heat between 6 am and 8 am in and between 4 am and 6 pm in the evening for three consecutive days following each treatment of PGF2α. Onset of estrous was recorded in hours from the last treatment time to the time the signs of a doe on heat were observed. Two main behavioral characteristics observed were tail wagging and standing to be mounted by other does. The duration of estrous was calculated in hours from the time the first heat sign was observed to the time it ended. End of heat was considered when the doe did not allow the buck or other females to mount. Those without the above signs were deemed not to have come on heat. Goats on heat were hand mated. Pregnancy diagnosis was done from day 30 using ultra sound scanner.

3.2.5 Management of Experimental Goats

Experimental goats were housed and grazed separately from the rest of the goats throughout the period of the trial. However, other routine practices including health care and optimum nutrition were not altered. The goats were observed every morning before being released to graze from 8am until around 4pm when they were returned to their enclosed night boma structures. Salt blocks (CKL blocks) from coopers Kenya weighing 5kg each were strategically hanged in goat shelters where the goats could access and lick freely. Water was provided adlib both at the grazing fields where they had water troughs and in the night shelters.

Experimental goats were managed by three skilled animal handlers recruited by the project who grazed them as an animal heath assistant took care of their health during the entire four-month period of the experiment. The farm routinely houses and grazes the bucks separately so there was no interaction between the does on experiment and bucks.

3.3 Data Management and Analysis

Questionnaire data were entered in an excel sheet and descriptive statistics including frequencies, percentages carried out using web-based R software version 4.03. and proportions on number coming on heat and pregnancy for those mated derived using Pearson chi-square (χ^2) and comparisons for differences in proportions done at $p<0.05$. Below is the chi-square equation model

$$x_c^{\ 2} = \sum \frac{(O_i - E_i)^2}{E_i}$$

Where O_i is observed value, E_i expected value and c is degree of freedom

The data on effect of different doses of PGF2α on heat (estrous) response, onset time, duration and pregnancy were also analyzed using R software version 4.03. Similarly, two-way analysis of variance and means were calculated for the time it took before heat onset and duration of the heat after detection were calculated and separated using least significant difference (LSD) whenever there was a statistical significance at $p<0.05$).

CHAPTER FOUR

4.0 RESULTS

4.1 Farm Demographic Description

The survey involved a total of 194 farmers with 95 of these coming from Mukurwe-ini central and 99 from Rugi wards. Farmers interviewed in Mukurwe-ini had a mean age of 52.4 years with age range from 30 years to 83 years whereas in Rugi the farmers had a mean of 49.1 years with age range from 22years to 80 years. In Mukurwe-ini central ward, about half of the farmers interviewed were of either gender while in Rugi ward about two thirds of those interviewed were female farmers (Table 2).

Table 2: Results of farm demographics

	Ward				
Variable	**Mukurwe-ini Central**		**Rugi**		
	%	**n**	**%**	**n**	**χ2 (p-Value)**
Gender					0.719 (0.396)
Female	49.5	47	55.6	55	
Male	50.5	48	44.4	44	
Total	100	95	100	99	
Education					0.172 (0.918)
College	17.9	20	20.2	20	
Primary	48.4	47	47.5	47	
Secondary	33.7	32	32.3	32	
Total	100.0	99	100	99	
Farmers affiliated to any goat association					0.013* (0.911)
No	93.5	87	93.9	93	
Yes	6.5	6	6.1	6	
Total	100	93	100	99	
If no give reason					13.118 (0.157
Unaware	47.1	32	43.5	27	
Not Interested	30.9	21	29.0	18	
Left the group	14.7	10	4.8	3	
No group to join	5.9	4	4.8	3	
Other commitments	1.5	1	6.5	4	
New	0	0	4.8	3	

resident/farmer				
Too old	0	0	1.6	1
To join soon	0	0	1.6	1
Poor Leadership	0	0	1.6	1
Financial constraints	0	0	1.6	1
Total	100	68	100	62

*Significantly different at $p<0.05$

In both wards, literacy levels were fairly high with all the interviewees having at least primary level education. In both wards, affiliation to goat associations by farmers was very low with about 94% of those interviewed reporting no association with any goat association. The main reasons for not being affiliated included lack of awareness about the existence of such associations, having no interest in becoming members and some actually exited from such groups as reasons.

4.2 Goat Herd Size and Structure

In both Mukurwe-ini ward and Rugi ward, farmers interviewed owned on average two goats, majority of which were female goats (Table 3). Farmers in both wards rarely owned male goats.

Table 3: Goat herd size (mean±SD) and structure in Mukurwe-ini central and Rugi wards, in Nyeri County, Kenya 2020

Variable	Mukurwe-ini Central		Rugi	
	Size	n	Size	n
Total goats	2.02.0	94	1.7 ± 1.4	99
Male goats	0.3±0.5	94	0.2 ± 0.5	99
Female goats	1.7±01.8	95	1.5 ± 1.3	99
Milking goats	0.8±1.3	95	0.8 ± 0.9	99

Source: Survey Data

4.3 Source of Breeding Goats, Production System and Goat Body Condition Scores

Farmers sourced breeding goats from different places with farmers from Mukurwe-ini ward preferring purchase of the goats from the market while those from Rugi ward preferring sourcing goats from local farmers. The differences in source of breeding goats between the two wards was significant ($p<0.05$) (Table 4). Other less preferred sources for breeding goats were goats paid as dowry, goats sourced associations or those received as donations.

Over three quarters of the farmers in Mukurwe-ini Central ward and slightly over two thirds of those in Rugi ward preferred the semi-intensive production system for raising their goats (Table 4). The intensive production was similarly practiced with slightly over two fifth of the farmers in Mukurwe-ini ward and about one third in Rugi ward using it to raise their goats. Extensive was the least preferred production system.

Table 4: The table present results of source of breeding goats, production system and body conditions.

Variable	**Mukurwe-ini Central Ward**		**Rugi Ward**		
	%	**n**	**%**	**n**	**χ^2 (p-Value)**
Source of goats					15.535 (0.04*)
Dowry	7.6	5	2.6	2	
Group association	3.0	2	3.9	3	
Group donation	3.0	2	0.0	0	
Local farmers	39.4	26	69.7	53	
Market	47.0	31	23.7	18	
Total	100.0	66	100.0	76	
Production system					5.798 (0.055)
Intensive	24.2	16	30.7	23	
Extensive	0.0	0	6.7	5	
Semi intensive	75.8	50	62.7	47	
Total	100.0	66	100.0	75	
Body score					1.157 (0.561)
Thin	22.7	15	26.7	20	
Ideal	62.1	41	53.3	40	
Fat	15.2	10	20.0	15	
Total	100.0	66	100.0	75	

*Significantly different at $p<0.05$

In both wards, the vast majority of goats in the farms surveyed had an ideal body condition. However, farmers in Mukurwe-ini had slightly more goats with ideal body state compared to those from Rugi.

4.4 Dairy Goat Breeds and Breeding Practices

In both Mukurwe-ini and Rugi, the preferred dairy goat breed was Toggenburg with dairy crosses as the least preferred (Table 5). Other exotic goat breeds reared included the Alpine and Saanen. Goat breeding was predominantly done through natural mating with only one farmer practicing AI. Breeding bucks were obtained from amongst the rotational buck serving a group of farmers on rotational basis and also own bucks. In some instances, dairy goat farmers used both rotational and own bucks for breeding.

Awareness about synchronization as a technique to promote breeding in goats was low. Only half of the farmers interviewed at Mukurwe-ini Ward and about a third of those interviewed at Rugi Ward had an idea about the method. Those who knew about synchronization reported that it was done by keeping the buck together with does (male effect). Only four farmers in each Ward knew about hormonal use. Although AI in dairy goats had not been widely adopted in both study areas, more than two thirds of the farmers interviewed expressed their willingness to adopt and pay for the AI service. Respondents in Mukurwe-ini reported that they paid on average pay KES 288 per insemination while those in Rugi paid KES 168. More than half of the respondents from both counties preferred the County subsidized goat AI scheme with only one person from Mukurwe-ini Central Ward who preferred AI from private practitioners. A fifth of the farmers were undecided on what to use.

Table 5: Dairy goat breeds and breeding methods.

Variable	**Mukurwe-ini Central**		**Rugi**		
	%	**n**	**%**	**n**	**χ^2 (p-Value)**
Goat breeds					11.481 (0.22)
Toggenburg	48.3	29	61.6	45	
Alpine	33.3	20	20.5	15	
Saanen	21.7	13	24.7	18	
Crosses	11.7	7	1.4	1	
Total	100.0	60	100.0	73	
Breeding method					4.301 (0.231)
AI	0	0	1.0	1	

Natural mating	100	95	99.0	98	
Total	100.0	95	100.0	99	
Source of buck					
Rotational buck	53.7	51	65.7	65	
Own buck	15.8	15	10.1	10	
Both	30.5	29	23.2	23	
Total	100.0	100.0	99.0	98	
Synchronization awareness					3.994 (0.046*)
Yes	54.7	52	40.4	40	
No	45.3	43	59.6	59	
Total	100.0	95.0	100.0	99	
Synchronization technique used					4.143 (0.126)
Natural (male effect)	50.5	48	36.4	36	
Hormonal	4.2	4	4.0	4	
N/a	45.3	43	59.6	59	
Total	100.0	95	100.0	99	
Willingness to pay for AI					8.426 (0.015*)
N/A	22.1	21	14.1	14	
No	0.0	0	7.1	7	
Yes	77.9	74	78.8	78	
Total	100.0	95	100.0	99	
Preferred source of AI by farmers if AI was adopted					4.723 (0.317)
County subsidized	60.0	57	50.5	50	
Group organization	4.2	4	3.0	3	
Individual	1.1	1	0.0	0	
Undecided	20.0	19	21.2	21	
Private Service	14.7	14	25.3	25	
Total	100.0	95	100.0	99	

*Significantly different at $p<0.05$

4.5 Benefits and Challenges of using Artificial Insemination in Goats

The farmer perceived challenges, benefits and solutions are displayed in Table 6. About 70% of the farmers in both wards perceived that if they adopted AI as a method of breeding their goats would be able to have increased milk production. This was closely followed by those who reported by slightly over two thirds of the respondents in both Mukurwe-ini and Rugi wards who thought AI would result in upgrading of existing goat breeds for better productivity. Other benefits which can be achieved by adopting AI for breeding include control of reproductive diseases, reduced chances of inbreeding, timely breeding services and reduced cost of production by only keeping and feeding female goats and not bucks.

On the perceived challenges of adopting AI as a breeding method, high cost was cited as the main challenge with slightly more than three quarters of the respondents in Rugi ward and two thirds' respondents in Mukurwe-ini ward reporting this. Other challenges which were reported included repeat breeding, lack of trained AI providers, poor heat detection and inadequate knowledge.

Table 6: Farmer perceptions on the benefits and challenges of adopting use of artificial insemination for breeding goats.

Variable	**Mukurwe-ini Central Ward**		**Rugi Ward**		
	%	**n**	**%**	**n**	**χ^2 (p-Value)**
Benefits of using AI					4.690 (0.584)
Improved breeds	66.3	53	60.5	49	
Increased milk production	68.8	55	69.1	56	
Disease control	46.3	37	55.6	45	
Control inbreeding	40.0	32	34.6	28	
Timely service	41.3	33	49.4	40	
Reduced cost of production	36.3	29	28.4	23	
Challenges					9.565 (0.144)
High cost	66.3	53	76.5	62	
Poor heat detection	46.3	37	46.9	38	
Limited semen variety	31.3	25	28.4	23	
Repeat breeding	55.0	44	54.3	44	
Lack of trained AI providers	53.8	43	64.2	52	
Inadequate knowledge	46.3	37	28.4	23	
Potential solutions					9.213 (0.162)
Affordable cost	66.3	53	76.5	62	
Train on heat detection	45.0	36	46.9	38	
Gynecology examination	31.3	25	28.4	23	
Farmer sensitization	55.0	44	55.6	45	
Train AI providers	55.0	44	64.2	52	
Avail a variety of semen	46.3	37	28.4	23	

On solutions to the perceived challenges of using AI, ensuring the AI service is accessible and affordable to the small-scale farmers was listed as the most important. About three quarters of the respondents in Rugi ward and two thirds in Mukurwe-ini ward expressed their fears on the high cost and thus the need to make the service affordable to small-scale farmers. It was also reported that training for animal health providers need to be conducted for them to be able to provide the service as well as conduct farmer sensitization on the use of this technology for breeding goats. Other solutions cited included training farmers on heat detection, ensuring female goats are regularly examined for reproductive diseases which can compromise conceptions and ensuring a variety of semen for insemination is easily available and accessible.

4.6 Goat Response to Treatment with Varying Doses of PGF2α

Experimental goats treated with three different doses of PGF2α had varied heat and pregnancy responses (Table 7). Heat response in the three groups of experimental goats was generally low after administering the first injection of PGF2α compared to the response after the second injection. Goats treated with 250µg had the highest (66.7%) after the first injection whereas after the second injection both 250ug and 500 µg had the highest heat response (86.7%). The group treated with 125 µg had the least (53.3%) after the first injection and (66.7%) heat response after the second PGF2α injection. The observed heat responses were not statistically different ($p>0.05$). The mean onset varied with interval of injection with those after the first injection having an overall mean of 44.4±3.3 and after the second injection a mean of 42.8±2.7 hours. The observed differences in time of estrous onset between the three experimental groups were not statistically different ($p>0.05$).

Table 7: Mean heat response, onset time, duration and pregnancy response for goats treated with three different doses of PGF2α using double injection protocol.

Groups	No. goats	Heat response (%)		Mean onset time SEM (hours)		Mean duration SEM (hours)		Pregnancy rates (%)
		1st	2nd	1st	2nd	1st	2nd	

Group 1 (500ug)	15	60.0	86.7	45.4±4.5	45.4±2.1	33.6±4.5	33.8±4.0	76.9
Group 2 (250ug)	15	66.7	86.7	43.0±4.3	39.4±2.2	39.4±3.2	33.9±2.8	84.6
Group 3 (125ug)	15	53.3	66.7	44.7±10.5	42.8±2.7	28.0±4.0	36.3±6.7	80.0

Similarly, duration of estrous for the three treatments was not influenced by the dose but the injection interval with those after the first injection having a shorter duration compared to those after the second injection. Group 2 had the highest both at first injection (39.4±3.2) hours and second (33.9±) hours. However, the differences in duration length were not significant ($p>0.05$).

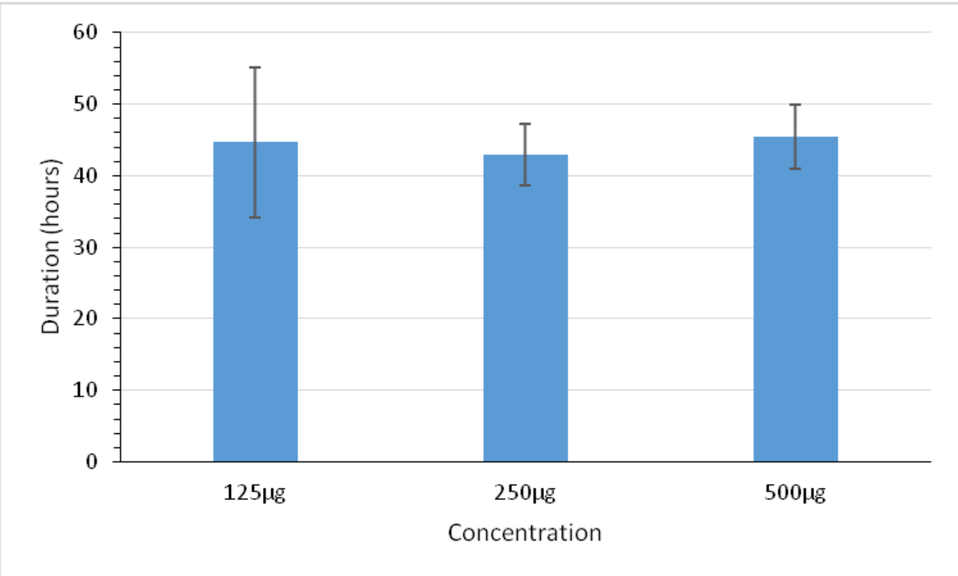

Figure 3: Estrous onset after the first PGF2α injection

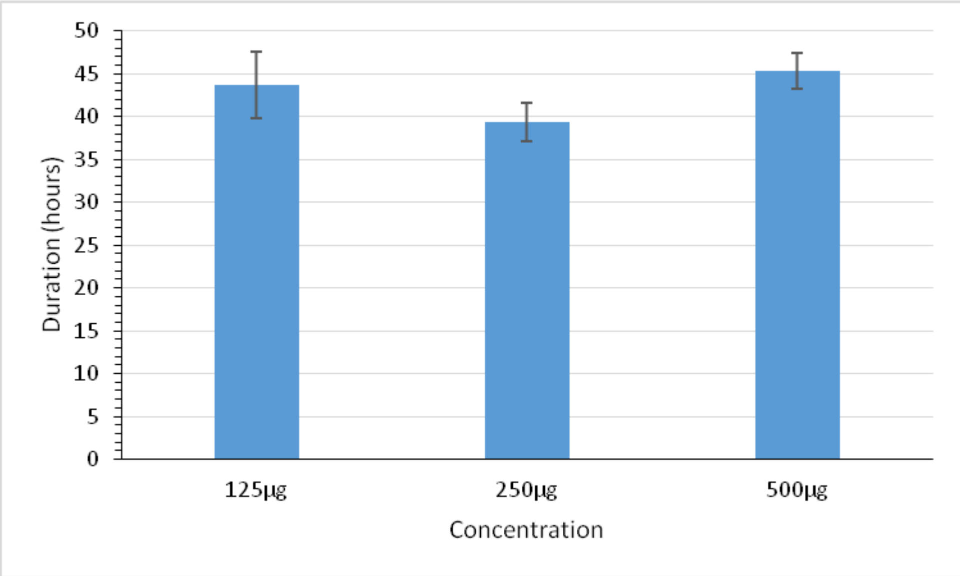

Figure 4: Estrous onset after the second pgf2a administration.

For the two injections the mean time for onset of heat was highest for group 1 receiving 500ug and least for group 2 receiving 250ug (fig. 4 and fig. 5). However, the difference within a group in terms of heat onset was greatest in group 3 receiving 125ug (fig. 4) after the first injection of pgf2a. However, for heat duration, this difference was highest in group 3 after second injection (fig. 7) followed by group 1 after first injection (fig.6)

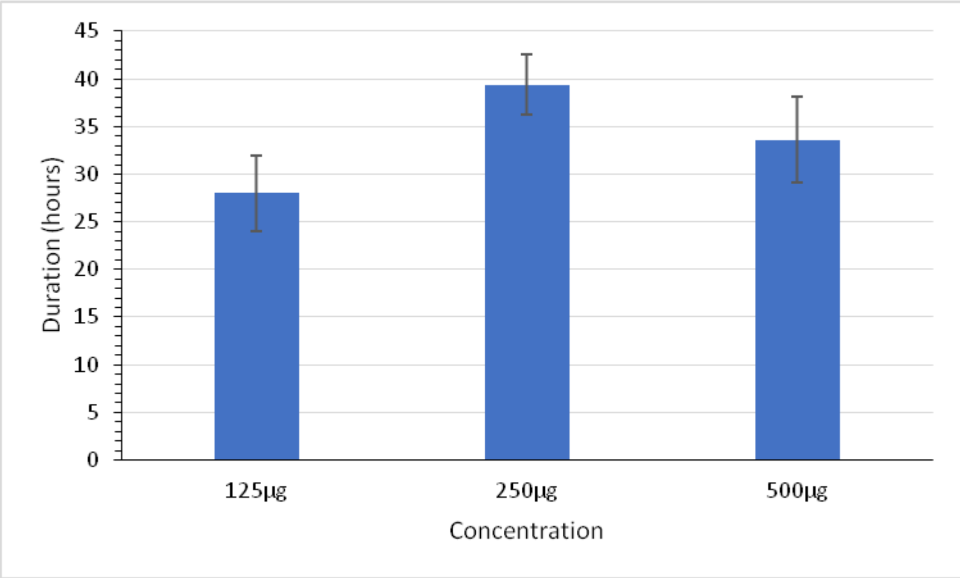

Figure 5: Estrous duration after the first estrous injection

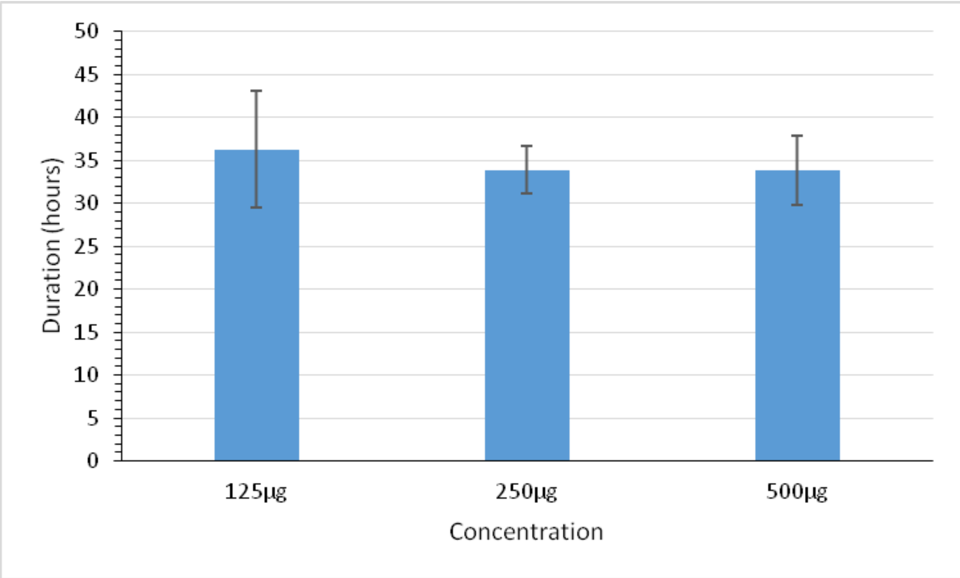

Figure 6: Estrous duration after the second estrous injection.

After inseminating all the goats which came on heat after treatment with PGF2α, the highest (84.6%) pregnancy rates were observed amongst the group which were treated with 250µg followed by the ones which received the lowest dose with a pregnancy rate of 80%

and those with highest dose only registering 76.9% (Table 7). The differences were not statistically significant (p>0.05).

4.7 Mucus Intensity

Goats in the three treatments registered highest proportion of goats with clear mucus discharge after 60 hours and highest milky discharge at 72 hours (Table 8). Clear mucus intensity was higher 40% in group 2 at 48 hours and group 3 at 60 while group 3 at 48 hour and group 1 and 2 at 72 hours registered the least 6.7% (Table 8). Group 2 had higher (66.7%) proportion of does with milky discharge 72 hours post treatment. For group 1 and 3 had no goat showed milky discharge at 48 hours.

Table 8: Mucus intensity for the three doses at 48, 60 and 72 hours after the second PGF2α administration

Group (treatment)	**No. goats**	**48 hours**		**60 hours**		**72 hours**	
		Clear Mucus %	**Milky mucus %**	**Clear mucus %**	**Milky Mucus %**	**Clear mucus %**	**Milky mucus %**
Group 1 (500ug)	15	26.7	0	46.7	13.3	6.7	53.3
Group 2 (250ug)	15	40.0	6.7	53.3	13.3	6.7	66.7
Group 3 (125ug)	15	6.7	0	40.0	6.7	13.3	40.0

CHAPTER FIVE

5.0 DISCUSSION

The findings of this study revealed that farmers aged above 50 years were engaged in goat farming in both Mukurwe-ini and Rugi wards, this finding is lower than the Africa mean farmer age, which stands at 60 (Afande *et al.*, 2015) but is consistent with a report by Bwanawoy and Maitho, (2017). Age is considered a key factor in technology awareness and willingness to adapt. In this study, farmers awareness of AI and synchronization technologies was influenced by age as reported previously that the older a farmer is the more reluctant, they become in uptake of technology (Ojango *et al*., 2010; Bwanawoy and Maitho, 2017). This was the case in our study as AI adoption was low due to a majority of farmers being older. Despite this, the youth who are techno savvy are not willing to embrace these technologies as they are limited by the cost thus the low uptake of these technologies. Thus, the study sought to improve the existing synchronization technology through reduction of the cost to entice the youth to embrace agriculture as a livelihood source and hence a boost in uptake of new farming technologies.

Majority of goat keeping farmers in our study were women. The finding agreed well with those of Ndeke *et al.,* (2015) but contrasted the findings by Kikwatha *et al.,* (2020b). Other studies have reported a higher involvement of women in agriculture (Karunakaran *et al.,* 2015). The fact that women were the most involved in goat rearing can be interpreted to mean many issues. Firstly, goat rearing requires less resources and so it becomes more convenient for the women to be involved in this enterprise. Kiema *et al*., (2020) reported less initial capital to purchase starting goat breeding stock required compared to the capital one needs to invest in cattle rearing. This becomes easier for women to invest in such an enterprise. The other reason why women in this study were keeping dairy goats is due to the nutritional benefits associated with goat milk (Ahuya and Okeyo, 2000). Waithanji *et al*.,

(2015) in their study found that women are more likely to be owners of small than large livestock. Although women are responsible for many livestock husbandry tasks, especially in dairy systems, they also face barriers to adopting improved practices (Ericksen and Crane, 2018) as they barely get time to go for farmer trainings. This negatively has contributed to the low adoption of AI technology in our study. More so women have the attitude of being less risk takers and slow in adoption of technologies (Ojango *et al.*, 2010 such as AI and synchronization. However, the study hopes that lowering of the cost of AI will encourage women to consider uptake of these technology.

The study revealed a majority of the respondents were not affiliated to any goat association. Farmer groups and other farmer aggregation platforms are commonly encountered in areas where poverty levels are high (Mburu *et al.,* 2014). This was not the case for this study because Nyeri is considered one of the counties in Kenya with the highest income levels. Farmers with resources at their disposal are able to manage their own affairs without the need to form farmer groups. Another reason is that Nyeri County has a well-developed cooperative movement thus farmers have no reason to farmer groups for activities and functions the cooperative societies can do. However, Waithanji *et al.,* (2015) in their study found that farmers who were members of Meru Goat Breeders Association (MGBA) were more knowledgeable than non-members. This was the case in our study as those who have never been members of any association or group had no idea of AI and synchronization techniques. The collapse of this associations may thus necessitate conducting proper sensitization to encourage farmers to join farmer groups (Wainaina *et al.,* 2020) and creation of more diverse activities within the groups as also noted by Mbindyo *et al.*, (2017). Dissemination of information more so for reduced synchronizing dose which eventually reduces cost of AI in instances were synchronization is applied is made possible by existence of an association.

The goat herd sizes per household surveyed were on average 2 meaning this enterprise is practiced as a smallholder. A study on dairy goats in Embu showed the herd size per household was 4 which was comparatively higher than we found (Kiema *et al.,* 2020). This difference could have been due to land sizes where Nyeri county is known to have small land size (Birch, 2018). When land size is small, farmers tend to intensify their productivity by keeping fewer animals. However lowered production and reproduction due to small land size and lack of utilization of reproductive technologies will ultimately have implications on sustainability of flock productivity (Ojango *et al*., 2010). As is expected when the size of land is small, the practice is to keep more female animals than male and incorporate reproductive technologies such as AI and synchronization. This was confirmed by this study since it was reported that most buckling's born in their herds were sold off to earn the household some income. In some rare cases the males are left in the herd to mature and are slaughtered during festive seasons or for socio-cultural functions (Fafa *et al.,* 2021). Males were also sold at a younger age to control inbreeding and cut down on production cost as feeding. This showed the urgency of AI introduction in the region with the use of synchronization as there are few males for either mating or detecting heat in the does. Majority of the female goats in the surveyed households were lactating which agreed with results by Wainaina *et al*., (2020). The milking goats were considered valuable not only for reproduction and milk but because their milk has nutritional value and fetches better prices compared to cow milk (Waithanji *et al.,* 2015)

The main source of breeding bucks was markets as farmers had fewer alternative sources. This practice of buying breeding goats from markets was also reported by another study (Wainaina *et al.,* 2020). This is disadvantageous since people dispose goats mainly through culling when they are sick, old, low productivity or with poor breeding traits (Karunakaran *et al.,* 2015). Such animals are not appropriate for breeding purposes and may become a risk in terms of disease spread to the healthy animals in the herd. Because dairy goats not easily available, other farmers take advantage of this and act as brokers by selling low quality animal claiming they are pure breeds (Mburu *et al.*, 2014). The best solution for this farmer as per the study to gap this is to embrace AI with synchronization due to the authenticity and are guarantee of the breed type they require. Lowering synchronization cost will eventually encourage AI as bucks for heat detection are no longer required.

It is clear from our findings that there were few farmers who practiced extensive production system. This is because in the area studied there is pressure on land with the available land supporting other enterprises mainly tea and coffee; the two main cash crops in the area. In the circumstance, livestock is intensively reared in total agreement with the practices around Thika (Wainaina *et al.,* 2020). In order to optimize productivity, surveyed farmers tended to have preference for the exotic dairy breeds including the Kenyan Alpine followed by Toggenburg, Saanen over the local breeds because of their perceived high milk production. This agreed with the study of Ndeke *et al*., (2015) and Wainaina *et al.,* (2020). The Alpine was the preferred breed in the region due to its high milk production and the factor that it adapts well in sub humid to humid climate that has long, cold and wet seasons (Mburu *et al.,* 2014; Wainaina *et al.,* 2020). Even then, Toggenburg was the second preferred among the exotic dairy breeds because it's perceived to be resilient, has short inter-kidding interval and possess high productive capabilities under local conditions (Ndeke *et al.,* 2015; Peacock *et al*., 2010). This breed is shown to be gaining popularity in the region mainly because of the above reasons. With the availability of semen from these exotic breeds compared to buck availability, thus necessitates the use of AI which the study intended increase uptake through reduced synchronization cost.

Under the intensive production system, livestock are heavily supplemented which may have an effect on their body condition scores. The use of commercial concentrates or feeding animals on high nutrient fodders rich in nutrients is likely to result in animals of good body conditions (Mburu *et al.,* 2014). This observation was consistent with our findings. It should be noted the issue of body condition is of critical importance especially for breeding bucks. Breeding buck with less than 2 may not have sufficient stamina and vigor to breed while more than 4 lack sexual desire, while for lactating below 2 can lead to anestrous and low milk production (Ghosh *et al*., 2019). The study done by Debele *et al.,* (2013) a majority of goats had a body score slightly lower than ours. Animals with good body conditions are ideal for the synchronization and AI as their cyclicity is not influenced. This encourages the use of AI with lowered synchronizing dose.

Breeding of goats in our study was predominantly through natural mating with only one farmer practicing AI. This finding was in agreement with the study by Gore *et al.,* (2021). This can be explained due to the fact that most farmers in Mukurwe-ini are members of Dairy Goat Association of Kenya (DGAK) hence have been involved in buck rotation (Mbindyo *et al.,* 2017). On the contrary some goat keepers use own bucks for breeding purposes (Wainaina *et al.,* 2020). It ought to be noted that natural mating has the disadvantage of increasing the risk of spreading transmissible venereal diseases such *Brucella meltensis*, *Chlamydia abortus* and herpes virus (Underwood *et al.*, 2020) and also result in inbreeding particularly from use of own buck (Mbindyo *et al*., 2017; Wainaina *et al.,* 2020). Because breeding was mainly through natural mating, the awareness on synchronization technique was correspondingly low. Surprisingly some farmers were aware that keeping a buck in a herd of female goats resulted in some coming on heat. In the absence of the buck, it should be noted that the use of hormones is more effective in enhancing reproductive efficiency (Omontese, 2018). Despite the low uptake of AI as at the time of the survey, it is worth noting that many farmers expressed their willingness to not only uptake AI services if availed but also pay for the same. The interviewed farmers however quoted comparatively lower insemination prices compared to what the same service goes for in cattle. Perhaps their judgement of cost of insemination in goats was made on the basis of the small size of the goat compared to a cow. The KES 1500 farmers pay for inseminating cows was considered too high (Khainga *et al*., 2018). Generally, the high cost of AI in Kenya is mainly attributed to the AI equipment, logistical challenges and the fact that performing AI requires well trained and skilled personnel (Tsuma *et al*., 2015). This study also revealed that lack of trained AI providers echoed by the key informant posed a challenge in adoption of AI. The key informant was in agreement with the farmers on the need to train AI providers to effectively carry out these activities (Gunaseelan *et al.,* 2018; Kharche *et al.,* 2013).

Despite the fact that AI as a breeding method in goats had not been widely adopted, surveyed farmers though it can help them increase milk productivity in their goats if adopted as a breeding method. Mbindyo *et al*., (2017) reported that utilization of genetically proven buck semen and improved breeds resulted in increased milk production. The farmers also perceived that AI in goats was likely to upgrade the existing breeds. This seemed to corroborate findings in other reports that AI is cheaper way of obtaining good breeds and a much more effective way than importing bucks (Kifaro *et al*., 2008). Venereal disease control is the other advantage of AI since semen are collected from quality bucks free from this transmissible venereal disease (Tsuma *et al.*, 2015). Similarly timely breeding will be done as time wasted looking for a buck is reduced or transportation from one place to another (Dávila *et al*., 2018). With the ban of importation of live animals (Mburu *et al.,* 2014) IA can only be used to improve the existing breeds to a pedigree level and get animals that are well adapted to a particular region.

Farmers often fail to adopt a new technology because of various barriers. The constraints identified in our study should the farmers take up the technology which was also echoed by the stake holders included high cost of AI which was cited by a majority of farmers, repeat breeding, lack of trained AI providers, poor heat detection and inadequate knowledge on these technologies. Repeat breeding require the input of the farmer and AI providers as management practices at farm level, proper examination of reproductive health, proper chain of semen storage, transportation and proper AI timing are needed. For reproductive health examination, this needs trained animal health providers (Arrebola *et al.,* 2013). Poor heat detection by farmers necessitated farmer training not only on AI awareness and heat detection but also on hormonal estrous synchronization which will help minimize labor on heat detection (Omontese *et al.,* 2016). The farmers interviewed noted that other key barrier to more AI use are limits on the number of trusted providers, particularly given the need for AI to happen at the precise moment in a goat's cycle.

The findings of this study clearly demonstrated that PGF2α had an effect on inducing heat in treated goats. PGF2α being a primary luteolytic agent induces luteolysis of potential corpus luteum resulting in rapid growth of the dominant follicle for ovulation from the existing follicular wave (Gupta *et al*., 2018). These findings agreed well with other past studies, (Maia *et al.,* 2017; Omontese *et al.,* 2016). It ought to be noted that there was a slightly lower heat response of goats following the first PGF2α injection due to lack of a responsive corpus luteum to be lysed by the exogenous prostaglandins. The proportion of goats exhibiting heat response was higher amongst those that were treated with 250ug and500ug of PGF2α and least amongst those which were administered with 125ug.This variation in heat responses based on the dose of PGF2α administered has also been reported by Omontese *et al.,* (2016) who reported 84% heat response in red Sokoto goats administered with 7.5mg of dinoprost while Biradar *et al*., (2019) reported 100% heat response in Malabari goats administered with 125ug Cloprostenol which was higher than what this study observed. In another study involving Salem black goats administered with double injection of PGF2α using a dose of 125ug, the proportion of treated goats which achieved heat was lower for on station does as it was 36% (Bekahegn, 2019; Dávila *et al.*, 2018). Whitley and Jackson, (2003) recorded a response of 100% for 250ug and 87.5% for 125ug with double injection protocol. This variation on estrous response as noted above is not only dose dependent but is also influenced by the administration interval, season, breed and parity (Omontese *et al*., 2016; Simões, 2016). It is suspected PGF2α treatment for goats in luteal phase may not show overt heat signs because of silent heat or high stress levels in case of nulliparous females (Maia *et al*., 2017).

Onset of heat was not influenced by the dose but the interval of injection and individual goats. However, onset of heat helps to determine the appropriate time for insemination. Variation on the response to PGF2α within treatments is related to differences in ovarian status among the does as day of cycle in which PGF2α is given influences estrous onset interval (Mehmood *et al.,* 2015). These findings agreed with the findings of Atmoko *et al.,* (2020). Comparatively, our findings were slightly lower compared to the work done on Etawah crossbred does (Andrabi, 2015). On the contrary, our findings differed with the findings by Famakinde *et al*., (2017). Onset of estrous is mostly influenced by breed, age, season, presence of male and protocol used.

Heat duration in the current study was higher after the second injection of PGF2α than the first injection. These findings were generally in agreement with the observation of reported in other studies (Biradar *et al.,* 2019). Gupta *et al.*, (2018) recorded higher mean duration of 50±1.23 hours. A study on West Africa dwarf goats reported heat onset lower 31.11 hours which was in agreement with the heat onset patters observed after the first injection of experimental goats with PGF2α (Oyeyemi *et al.,* 2012). It is important to note that heat which lasts on average between 12 hours and36 hours is vital for the determination of appropriate time to undertake AI (Tsuma *et al.,* 2015).

The study revealed a higher percentage of goats with clear mucus discharge at 48 and 60 hours for group 2 and 3 respectively and milky discharge at 72 in group 2 for the double Cloprostenol injection. This makes those receiving 250ug of Cloprostenol good for estrous synchronization and timed artificial insemination to be carried out. From the findings of this study, mucus initially is clear and small in quantity but later the quantity and viscosity increase. Mucus amount increased from 24-36 hours in the findings of Atmoko, *et al.*, (2020). In the current study however, mucus increased from 48-72 hours with changes noticed after every 12 hours. Cervical mucus undergoes changes from the onset of estrus to the end of the estrous and ovulation (Fonseca *et al.,* 2019). Cervical mucus observed in goats presenting estrus may range from watery (clear) to caseous (geese) like. Clear or watery mucus is the first marker of estrus, appearing before the first acceptance of the mounting though may not be noticed as the quantities are small. Mucus suitable for AI execution is milky or striated and striated/caseous (Fonseca *et al*., 2019, 2012) Later the mucus become caseous at the time of ovulation and it's not a good time for AI. Insemination is best before ovulation to give enough time for the sperm to be fully capacitated and fertilization to occur at the most appropriate time.

This study revealed a higher pregnancy rate for treatment group 2 (250ug) and least for treatment group 1 (500ug). Pregnancy rate indicated by Biradar *et al.,* (2019) in their study was 69.23% with dinoprost and 66.6% with Cloprostenol. Agossou and Koluman, (2018) in their study recorded a higher percentage 93.5%. This showed that pregnancy rate depends on factors such as breed, method of breeding, dose of PGF2α, and location (Gupta *et al*., 2018). It's also possible that embryo loss can occur at a time which natural luteolysis could not be evoked thus lowering the pregnancy rates (Maia *et al.,* 2017). Exogenous PGF2α can cause lower secretion of progesterone (P4), weakened effect and life span of dominant follicle growing during mid-luteal phase thus a defective preovulatory follicle

(Maia *et al*., 2017). Lower P4 during the first days after ovulation can lead to embryo loss as P4 from the lutein cells plays an important role in embryo development before the uterine secretion of P4 (Vázquez *et al*., 2010). Appropriate dose and protocol need to be sort to ensure that not only estrous is stimulated but also the amount of progesterone for maintenance of early pregnancy is sufficient. Fertility appeared to decrease with an increase in PGF2α doses with seemingly lower conception rate and number born per bred doe (Whitley and Jackson, 2003). This is in agreement with the current study where 500ug recorded a lower rate but also lower doses recorded lower pregnancy rates.

CHAPTER SIX

6.0 Conclusions and Recommendations

6.1 Conclusions

From the findings of the study it can be concluded that: -

1. Goat rearing in Nyeri was done through small scale practice involving 2-5 goats.
2. Most farmers were not members of goat associations.
3. Breeding was done through rotation bucks.
4. Buck rotation practice was leading to inbreeding and reproductive venereal diseases.
5. Goat AI practice was significantly low and mostly practiced by younger generation.
6. Lowered dosage of PGF2α by half (250µg) was effective and efficient in synchronizing goats.

6.2 Recommendations

From the study conclusion the following can be recommended: -

- Farmers need to join the dairy goat associations for better management of their goats and its husbandry
- Farmers are encouraged to avoid rotation buck practice of breeding to decrease in breeding and reduce prevalence of venereal diseases
- Synchronization protocols for goats adopt use of 1ml (250µg) of instead of 2 ml (5000µg) of PGF2α for lowered costs
- Results of this study be utilized to inform policy on dairy goat synchronization protocols and integration of the same by the goat AI Centre in Ndomba for enhanced delivery of goat AI services in Kenya and beyond

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APPENDICES

Appendix 1: Questionnaire

Interviewer: Dr. Ascah Jesang a postgraduate student from University of Nairobi, undertaking a Master of Veterinary Theriogenology Degree Programme. She also works at the **Veterinary Science Research Institute-KALRO** under the Kenya Climate Smart Agriculture Project with focus on goat reproductive technologies.

The purpose of this study is to carry out a survey on general knowledge and awareness of the goat reproductive technologies and management practices for good productivity. The findings from this study will be for research academic only.

RESPONDENTS CONSENT AGREEMENT:

I…………………………………………………………hereby agree to participate in this study with my full consent and conscious and declare that to the best of my Knowledge the information that I have provided is true, accurate and complete.

Signature................ Date …............/2021

Question 1-9 To be filled by farmers, questions 2,5,6,7,8,&9 to be filled by artificial insemination providers, questions 2,3,4,5,6,8,&9 to be filled by the sub county animal production officer, questions 2,3,4,5,6,8,&9 to be filled by the Kenya Agricultural Resource Center and Ahiti Ndomba officers in charge of artificial insemination station.

1. BIODATA

A) Personal details

(a) Interviewee Name....................................... (b) Age [ ] years

(c) Gender 1. Male [ ] 2. Female [ ] (d) Level of Education Codes..................

B). Location details: County.................................... District/Sub County..................................... Location.................. Sub location................... Nearest shopping centre...................

GPS reading: ……………………………………………………….

2. a) Are you affiliated to any goat association? Yes /___/ 2. No /___/

- o If yes, name
- o If no, why

b) What are the benefits of this association?

c) What are the challenges of the association?

3. What goat breeds do you keep and how many are they? (List, why the preference, how you obtained, gender, body condition, number of lactating goats)

4. a) What type of breeding method do you practice?

- o centralized rotational buck breeding
- o home kept buck
- o artificial insemination

b). If artificial insemination, how was it supported?

- o Through the county government.
- o Through the association
- o Self-sourcing
- o Private artificial insemination service provider?

5. a) What are the existing challenges of artificial insemination service in goat farming?

b) What are the benefits of artificial insemination?

c). How can we improve artificial insemination?

6.) Are you aware of any other technologies that would enhance and support artificial insemination and how was it done? (Tick the appropriate)

Technology		**How it was done**
synchronization	Male effect	○ Community mobilization ○ Individual efforts ○ Non-governmental organization
	hormonal	
Embryo transfer		○ Community mobilization ○ Individual efforts ○ Non-governmental organization
none		

7. a) What is the cost of artificial insemination?

b) Is it affordable? Yes /___/ 2. No /___/

8. a) Are you willing to pay for artificial insemination and synchronization if availed? Yes /___/ No /___/

b) If yes, at what cost?

c) How do you want it carried out? (Tick the appropriate choice)

- ○ County subsidized
- ○ Group organization
- ○ Private Service
- ○ Individual farmer efforts

9. a) What are the perceived benefits of these technologies in order to achieve good productivity?

b) What are the perceived challenges of these practices?

c) What are the perceived solutions to these challenges?