Animal reproduction strategies for sustainable livestock production in the tropics

D Hufana-Duran and P G Duran
Reproduction and Physiology Section, Philippine Carabao Center, Science City of Munoz, Nueva Ecija 3120 Philippines
E-mail: dhufanaduran@pcc.gov.ph

Abstract. Animal reproduction is an integral component for a sustainable livestock production. Enhancing the reproduction potential of animals without compromising the welfare would lead towards sustainable animal production. Careful attention adopting technological interventions would result to efficient performance and guarantees profit and sustainability. In the tropical environment, the effect of heat stress, food and water scarcity during summer affects the reproduction performance in most livestock species. Low expression of estrus, poor libido, incidence of abortion especially during prolonged exposure to direct sunlight, and embryonic death are among the problems that compromised reproductive efficiency. Through advance reproductive biotechnologies and management innovations and interventions, these problems could be controlled. The application of reproductive biotechnology tools such as estrus synchronization (ES), artificial insemination (AI), embryo transfer (ET) through multiple ovulation and in vivo collection of embryos, in-vitro embryo production (IVEP) and cryopreservation, somatic cell nuclear transfer (SCNT) to produce the desired breed and sex of animal, and other reproductive biotechnologies that enhances reproduction potential are important innovations that can address specific needs and purpose for animal reproduction. The strategies, innovations, and important practices in the application of these reproductive tools and interventions are presented and discussed considering the welfare of the animals for a sustainable livestock production in a tropical environment.

1. Introduction
Animal reproduction is an integral component of sustainable livestock production. It needs to be given attention and strategies in order to improve efficiencies. Enhancing the reproduction potential and performance of animals without compromising the welfare would mean the production of a new generation that would lead towards a sustainable animal production. Careful attention to animal reproduction and adopting technological interventions and strategies would result in efficient performance and guarantee profitability and sustainability.

It is expected that global demand for livestock products will be doubled by 2050 because of the improvement in the worldwide standard of living. The United Nations [1] expected that human population would increase to 9.6 billion that implies demand for agricultural products and a need for intensive livestock production. The livestock sector contributes to the livelihoods of one billion of the poorest population in the world and employs close to 1.1 billion people [2]. In the developing countries, there is a rapid growth in the demand for livestock products [3]. On top of the livelihood
and food-related concerns, livestock production is likely to be adversely affected by climate change, competition for land and water, and food security at a time when it is most needed [4].

In tropical countries, climate change is a threat to livestock production because of the impact on the availability of water and food that eventually aggravate animal diseases affecting reproduction, compromising biodiversity and a profound effect on overall livestock productivity. The predicted negative impact of climate change on agriculture would adversely affect livestock production by aggravating the feed and fodder shortages [5]. These developments posed challenges to livestock raisers, technicians, researchers, policymakers, and field practitioners. Optimizing the reproduction potential and the production performance of the animals is inevitable to cope up these challenges.

2. Reproduction in tropical environment

2.1. Puberty

In a tropical environment, puberty in livestock is a bit delayed than the livestock in temperate countries. Most heifers reared in the tropics are subjected to low-quality forages and suffer from protein, energy and/or mineral deficiencies. Therefore, most of these animals cannot reach puberty until two years of age; while those in a temperate climate reach puberty around 9 to 12 months of age [6]. Puberty is the period when sexual maturity is attained, and the animal becomes capable of reproduction. In females, it is the time when the heifers first ovulate and show an estrus or heat period, and which can support pregnancy. The process involves sensitivity to hormones and receptors in the brain (specifically the hypothalamus) and the ovaries in females and testis in males. In heifers, first ovulation is triggered when the hypothalamo-pituitary axis loses its sensitivity to the negative feedback effect of oestradiol-17β, allowing an LH surge to occur. It is now known that puberty and first ovulation are not necessarily synonymous. In fact, after first ovulation, some time is needed before the reproductive system “drives itself in” [7]. This stage is usually attained when the animals reached a certain age and body weight. Table 1 presents the age when puberty is reached in some livestock species.

Nutrition, genetics, environment, and social conditions affect the onset of puberty. Calves that are given colostrum, dewormed, managed, and fed properly attain puberty at a younger age with improving and uniformity of performance.

| Species     | Male     | Female    |
|-------------|----------|-----------|
| Bovine      | 11 mo (7-18) | 11 mo (9-24) |
| Bos taurus  | 17 mo (12-24) | 25 mo (16-40) |
| Bos indicus | 7 mo (6-9)  | 7 mo (4-14)  |
| Ovine       | 7 mo (5-8)  | 6 mo (5-7)   |
| Porcine     | 14 mo (10-24)| 18 mo (12-19) |
| Equine      | 13 yr     | 12 yr      |

2.2. Estrus observation

Estrus detection is an important factor affecting the reproductive performance of an AI program and overall livestock production. Failure to detect cows in estrus or misdiagnosis of estrus can result in significant economic losses [8]. Various methods of estrus detection are being used such as tail painting, use of pedometers, chin-ball markers, heat-mount detectors, devices that measure vaginal or milk temperature, and devices that measure the electrical impedance of the genitalia or vaginal mucus, and presence of cornified cells in vaginal epithelial cells [9]. Although some of these aids can increase the efficiency of estrus detection when used in combination with visual observation, their efficiency
and accuracy may be less effective than desirable when used alone. The observation of vaginal epithelial cells is efficient in small-scale livestock raising but not in the big herds because of the time needed to check the status of the cells under a microscope.

For animals in an open pasture, estrus detection using radiotelemetry (HeatWatch® or HW; DDx Inc., Denver, CO) or visual observation can be an effective means. The efficiency and accuracy of estrus detection were 97.6% to 98.4 for visual observation and 91.7 to 100% for HeatWatch® detection [10]. Conception rate was similar for AI after estrus detection with HeatWatch® (65.8%) and after visual observation (65.0%). The highest conception rate was obtained when AI was carried out between 12 and 18 h after the first mount. Visual observation was carried out for about 20 min before the morning and afternoon milking and was aided by a strip of paint applied over the tailhead.

In view of the silent nature of estrus in water buffalo, a non-invasive approach of estrus detection was developed based on the pheromone compound [11]. It is a color reaction test for urine where after adding the kit solution, a no color developed in urine (i.e., positive reaction) means that the female is in estrus. By contrast, pale and/or dark pink color developed in urine (i.e., negative reaction) of a female is from the proestrus and diestrus buffaloes, respectively. These technologies can be adopted in tropical areas to aid estrus detection and improve the reproduction performance of livestock.

2.3. Breeding for reproduction
The type of breeding strategy followed in the tropics primarily depends on the environment and level of management. Introduction of exotic animals has been practiced to improve production performance of livestock. Live animals, semen, or embryos were imported for use in breeding activities. However, most of the breeds of livestock in the tropic, even when kept under optimal managerial conditions, are small, probably indicating that the environment is such that it cannot support larger animals. Taylor and Murray [12] indicated that small breeds have an advantage over larger breeds under conditions of food shortage. It would thus be unwise to select for growth rate or body mass above a certain optimum level, which might result in animals’ adaptive capacity to the prevailing conditions.

It was indicated [13] that the only breeding strategies to be followed in tropical and subtropical areas appear to be pure breeding with indigenous breeds in the harsh and undeveloped areas and terminal crossbreeding in the more developed areas. Terminal crossbreeding is highly advantageous and increases the efficiency of animal production because fertility and calf viability of crossbred cows were higher than that of the best parental breed.

| Table 2. Recommended age to breed. |
|-----------------------------------|
| Species                      | Age                             |
| Heifer, Cattle                | 15 months (65% mature weight)   |
| Heifer, buffalo               | 18 months (300 kg)              |
| Bull                         | 15 natural mating, 12 months AI |
| Filly                        | 2-3 years old                   |
| Colt                         | 2 years                         |
| Boar                         | 9 months                        |

With these realities, any effort to improve livestock production should be strongly directed towards the improvement of management, education, and nutrition of the people. The introduction of exotic breeds for breeding and production improvement alone will not address a sustainable livestock production if feed resources are not provided accordingly. It is necessary that all the animal welfare requirements are provided, and manpower is technically equipped on care and management of livestock before breeding with exotic breeds are to be carried out.

2.4. Care and management of pregnant animals
Pregnancy is a major objective in reproduction, but this can be affected by several factors that may cause early embryonic death. In a tropical environment, excessive exposure under direct rays of the
sun and work or exercise is detrimental. Excessive feeding with legumes rich in estrogen and prostaglandins such as flax and Chromolaena morii [14] and Lycopodium saururus, Carachipita [15] may cause abortion. Other plants known to cause abortion include Enterolobium contortisiliquum, E. gummiferum, Stryphnodendron coriaceum, S. obovatum, and S. fissuratum, Aspidosperma pyrifolium, Ateleia glazioviana, Tetrapterys acutifolia, and T. multic glandulosa result in abortion and neonatal mortality in cattle and sheep, and the same signs have been experimentally observed in goats [16]. Poisonous plants that impair normal reproductive functions in livestock include Veratrum californicum Durand, lupines, ponderosa pine (Pinus ponderosa Dougl.), broom snakeweed (Gutierrezia sarothrae) (Pursh) Britt. & Rusby), locoweeds (Astragalus and Oxytropis spp.), selenium-containing forages, phytoestrogenic plants, endophyte-infected grasses and others [17]. Panter et al. [17] indicated that certain lupines (Lupinus spp.) contain quinolizidine and piperidine alkaloids that are fetotoxic and when grazed by pregnant cattle during specific stages of gestation induce skeletal birth defects and cleft palate, "crooked calf disease." Poison-hemlock (Conium maculatum) and some Nicotiana spp. contain similar alkaloids and induce identical birth defects in cattle, pigs, goats, and sheep when ingested at certain stages of gestation. Locoweeds (species of the Astragalus and Oxytropis genera containing the indolizidine alkaloid swainsonine) interfere with most processes of reproduction when grazed for prolonged periods of time. Ponderosa and lodgepole pine needles (Pinus spp.) cause abortion in cattle when grazed during the last trimester of gestation. The specific chemical constituents responsible for the abortions belong to a class of compounds called labdane resin acids, including isocupressic acid (ICA), succinyl ICA, and acetyl ICA [17]. Basic management recommendations to reduce reproductive losses to poisonous plants include: (1) know what poisonous plants grow on ranges and understand their effects; (2) develop a management plan to provide for alternate grazing in poisonous plant free pastures during critical times (3) integrate an herbicide treatment program to reduce poisonous plant populations or to maintain clean pastures for alternate grazing; and, (4) manage the range for maximum forage production.

Pregnant animals should be watched with care, particularly during the last stages of pregnancy to avoid abortion due to physical trauma and must be guarded against milk fever. Mineral and vitamin deficiencies have a serious adverse effect on the newborn calf. Hence, feeding trace mineralized salt plus recommended amounts of calcium and phosphorus is usually enough to avoid these problems. Care, however, is needed as calcium and phosphorus should not be taken in excessive amounts. During the last few weeks of pregnancy, constipation may cause prolapse of the vagina. Balanced and laxative rations should be fed to maintain the normal tone of the reproductive tract. Enough mineral, especially calcium by a bone meal in daily diet is beneficial. During the last month of pregnancy, parturition signs must be watched carefully such as udder enlargement and becoming distended, a hollow or depressed appearance on either side of the tail head, enlargement of the vulva, and discharge of thick mucus from the vulva and uneasiness of the animal. During the day of parturition, milking should be avoided as this can delay the parturition for several hours.

Pregnant animals are isolated and monitored 8-10 days before the expected date of calving and keep in a clean, well-bedded, dry, and disinfected maternity place with forage grasses fed ad libitum. A good calving environment reduces the exposure of cows and newborn calves to infectious disease. A clean and comfortable area that provides cows with good footing minimizes the potential for injuries. Calving areas should be landscaped to allow for adequate drainage and under a shade.

2.5. Calving and post calving management

During parturition, disturbances are not good for the animal. In most of the tropical system, calves are usually born without assistance. Any abnormality in their presentation that requires immediate attention is given by the livestock raiser himself or by a competent person to correct the position of the calf so that it can be delivered. Strict sanitation is observed during assistance. After removal of the calf, the dam is milked to facilitate and help in removal of placenta. The placenta is normally expelled within 2 to 6 hours after calving. Placenta failed to expel within 12 hours is considered retained placenta where veterinarians are called for its removal. The animals are closely watched for health
problems, feed intake, and milk production. Animals having health problems are treated accordingly, whereas healthy animals can join the general population or allowed to graze 3 to 4 days postpartum. Observation of the first sign of estrus three months after calving is the usual practice with involution checked to ensure that the animal is ready for breeding.

3. Factors affecting reproduction

3.1. Environmental condition

Tropical environments are extremely rich in diversified livestock species, but due to climate change, they are being threatened. The effect of heat stress, food, and water scarcity during summer affects the reproduction performance in most livestock species. In large ruminants, low expression of estrus, poor libido, the incidence of abortion, especially during prolonged exposure to direct sunlight, and embryonic death are among the problems that hindered and compromised reproductive efficiency.

The most striking deleterious effects of the environment on the livestock reproduction raised in the tropics is the seasonal shortage of fodder and nutritional imbalances. Animals submitted to under-nutrition management results in a low body score condition (BSC). The body condition score (BCS) seems to affect the fertility of female livestock directly since females that calved with a BCS < 2.5 show delayed postpartum ovulation, weak estrus symptoms and more service per conception compared with animals with a BSC between 3-4 [18]. The offering of fodder has great importance in the puberty, calving interval, service period, and fertility in general.

In dairy animals, reproductive activity was related closely to the magnitude of their milk production as well as receiving climatic influence. This may mean that tropical climate possibly influences the reproductive performance of dairy cows by two routes, directly and indirectly through its effect on milk production, and, therefore, the effects of lactation and climate on reproduction [19].

Vale [20] reported that in tropical areas like in Brazil, the light seems to have a minimal effect or no effect on the reproductive cues however the nutrition and heat stress measured throughout temperature and humidity indexes (THI) play an important role in the reproductive functions, and it was suggested that THI>75 has a negative effect on reproductive performances. THI accounts for the combined effects of environmental temperature and relative humidity and is a useful and easy way to assess the risk of heat stress. Research has identified THI values above which heat stress begins (Fig. 1). These THI values vary between the different livestock species of interest and within the same species, they vary for the different classes of animals. Normally THI is used in cattle breeding, both in dairy and in meat cows. Cows are indeed very delicate animals, which suffer a lot of heat stress with serious consequences on their productivity and on the quality of their final output. This happens because a large part of the energy deriving from food is used to maintain constant body temperature and it is therefore not destined for other activities (milk production, growth, pregnancy, fattening, etc.).

The THI value indicated in Figure 1 provides a set of categories that indicate the heat stress of animals. For its interpretation, however, it is necessary to know the predominant climate conditions in the area of concern, as well as relative humidity and how it is used to differentiate the discomfort category according to the type of heat: dry, typical of semi-arid climates or moist heat. The microclimatic changes that are taking place on the planet, global warming and pollution will have a significant impact on the stress tolerance of cows that the table will change again and adapt to the new standards.

Due to the increased milk production and feed intake, the cows at present times are much more susceptible to heat stress than the cows of the 1950s. Vitali [21] showed that modern cows become heat-stressed, starting at an average THI of 68 with the levels of stress increase with increasing THI values. When the THI exceeds 72, cows are likely to begin experiencing heat stress, and therein calf rates are affected. When the THI exceeds 78, cows’ milk production is seriously affected. When the THI rises above 82, very significant losses in milk production are likely, and cows show signs of severe stress and may ultimately die. This was confirmed by the reports of Somporn et al [22]
indicating that the use of temperature-humidity indexes (THI) is an important tool to study the thermal stress in cattle and buffalo and determine the welfare of the species. According to them, livestock managers recognize four livestock welfare categories for environmental management decisions. A THI ≤ 74 generally does not cause safety problems for healthy animals. Under alert conditions (THI = 75–78), producers can expect some decrease in the rate of weight gain. A danger conditions (THI = 79–83), animals show noticeable decreases in weight gain and, when handled, transported or overcrowded, may be severely affected. Under emergency conditions (THI ≥84) without management intervention, animal mortality can occur, especially when such conditions are prolonged. Given these realities, it is important to provide countermeasures in order to overcome these harmful effects of the environment on reproduction.

| Temp | Relative Humidity (%) |
|------|-----------------------|
| 77   | 25.0                  |
| 78   | 25.6                  |
| 79   | 26.1                  |
| 80   | 26.7                  |
| 81   | 27.2                  |
| 82   | 27.8                  |
| 83   | 28.3                  |
| 84   | 28.9                  |
| 85   | 29.4                  |
| 86   | 30.0                  |
| 87   | 30.6                  |
| 88   | 31.2                  |
| 89   | 31.7                  |
| 90   | 32.2                  |
| 91   | 32.8                  |
| 92   | 33.3                  |
| 93   | 33.9                  |
| 94   | 34.4                  |
| 95   | 35.0                  |
| 96   | 35.6                  |
| 97   | 36.1                  |
| 98   | 36.7                  |
| 99   | 37.2                  |
| 100  | 37.8                  |
| 101  | 38.3                  |
| 102  | 38.9                  |
| 103  | 39.5                  |
| 104  | 40.0                  |
| 105  | 40.6                  |
| 106  | 41.2                  |
| 107  | 41.8                  |
| 108  | 42.4                  |
| 109  | 43.0                  |
| 110  | 43.6                  |
| 111  | 44.2                  |
| 112  | 44.8                  |
| 113  | 45.4                  |
| 114  | 46.0                  |
| 115  | 46.6                  |
| 116  | 47.2                  |
| 117  | 47.8                  |
| 118  | 48.4                  |
| 119  | 49.0                  |
| 120  | 49.6                  |
| 121  | 50.2                  |
| 122  | 50.8                  |
| 123  | 51.4                  |
| 124  | 52.0                  |
| 125  | 52.6                  |
| 126  | 53.2                  |
| 127  | 53.8                  |
| 128  | 54.4                  |
| 129  | 55.0                  |
| 130  | 55.6                  |
| 131  | 56.2                  |
| 132  | 56.8                  |
| 133  | 57.4                  |
| 134  | 58.0                  |
| 135  | 58.6                  |
| 136  | 59.2                  |
| 137  | 59.8                  |
| 138  | 60.4                  |
| 139  | 61.0                  |
| 140  | 61.6                  |
| 141  | 62.2                  |
| 142  | 62.8                  |
| 143  | 63.4                  |
| 144  | 64.0                  |
| 145  | 64.6                  |
| 146  | 65.2                  |
| 147  | 65.8                  |
| 148  | 66.4                  |
| 149  | 67.0                  |
| 150  | 67.6                  |
| 151  | 68.2                  |
| 152  | 68.8                  |
| 153  | 69.4                  |
| 154  | 70.0                  |
| 155  | 70.6                  |
| 156  | 71.2                  |
| 157  | 71.8                  |
| 158  | 72.4                  |
| 159  | 73.0                  |
| 160  | 73.6                  |
| 161  | 74.2                  |
| 162  | 74.8                  |
| 163  | 75.4                  |
| 164  | 76.0                  |
| 165  | 76.6                  |
| 166  | 77.2                  |
| 167  | 77.8                  |
| 168  | 78.4                  |
| 169  | 79.0                  |
| 170  | 79.6                  |
| 171  | 80.2                  |
| 172  | 80.8                  |
| 173  | 81.4                  |
| 174  | 82.0                  |
| 175  | 82.6                  |
| 176  | 83.2                  |
| 177  | 83.8                  |
| 178  | 84.4                  |
| 179  | 85.0                  |
| 180  | 85.6                  |
| 181  | 86.2                  |
| 182  | 86.8                  |
| 183  | 87.4                  |
| 184  | 88.0                  |
| 185  | 88.6                  |
| 186  | 89.2                  |
| 187  | 89.8                  |
| 188  | 90.4                  |
| 189  | 91.0                  |
| 190  | 91.6                  |
| 191  | 92.2                  |
| 192  | 92.8                  |
| 193  | 93.4                  |
| 194  | 94.0                  |
| 195  | 94.6                  |
| 196  | 95.2                  |
| 197  | 95.8                  |
| 198  | 96.4                  |
| 199  | 97.0                  |
| 200  | 97.6                  |
| 201  | 98.2                  |
| 202  | 98.8                  |
| 203  | 99.4                  |
| 204  | 100.0                 |

Figure 1. The temperature and humidity index (THI) chart (Source: Australian Livestock Export Corporation [23])

3.2. Heat stress and counter measures

Heat stress is caused by a combination of temperature, relative humidity, solar radiation, air movement, and precipitation. Garcia [24] indicated that the impact of the heat stress on the female could be observed on the sexual behavior, low manifestation of estrous, low conception rate, high embryonic dead rates and reduction in the reproductive efficiency. In hot tropical climate conditions, it is necessary to introduce management practices suitable for better sustainability of the livestock production systems. The incorporation of trees together with the grazing pasture areas, including the planting of new forage species, is highly recommended. Such system increases the local biodiversity providing multiple areas of shading, protection and resting for the animals, reducing the direct
incidence of solar radiation on the animals, increasing the comfort and well-being of the herd, and consequently positive impacts on the productive and reproductive efficiency of the livestock herds. Physiological adaptation to extremes of heat and cold is different among livestock species. For example, buffalo is remarkably versatile but has less tolerance than the various breeds of cattle [25]. Nevertheless, buffalo skin is covered with the thick epidermis, the basal cells of which contain many melanin particles that give the skin surface its characteristics black color, that forms natural protection and attenuates the harmful effect of the environment in the tropical areas [26].

High milk production animals require a high feed intake that leads to higher metabolic heat production. High yielding animals thus have a disadvantage over lower-yielding animals and need more cooling facilities. The following points are guidelines to have in mind when giving advice on management: 1) the feeding, watering, and milking place should always give shade and protection from heavy rains, either by trees or by a roof. 2) Cool water either from a clean river or served in an earthen pit helps the animals to maintain temperature. Water trough should always be placed in the shade. 3) A paddock with trees gives very cheap and effective protection from the sun. However, the trees may need to be protected from the buffaloes. Also, 4) provide shelter for even a simple construction with only a roof. In tropical areas, it is better not to have walls as walls may lead to inadequate ventilation and thereby favoring bacteria and growth of mold making the stable unhygienic. 5) Allow the animals to wallow on rivers or any improvised wallowing area or 6) Showering off the buffaloes with cool water for 3 minutes twice a day has proven to be an efficient way for them to get rid of excess heat.

On the other hand, the breed of the animal is an important factor to consider in managing reproduction. Reproductive inferiority of imported breeds compared with native ones, and even the crossbreds with foreign breeds is common [27]. Heat stress has been proven to reduce the conception rate of lactating cows by impairing the ovarian follicular development during an estrous cycle [28,29] and increasing the rate of early embryo death due to the elevation of body temperature [30]. In dairy buffalo, Qureshi et al. [31] reported an inverse relationship between milk progesterone levels and atmospheric temperature and that fertility was the lowest during summer associated with the lowest progesterone levels and the highest incidence of silent ovulations. The cause of depression of fertility as in this case is due to the disturbance of the function of hypothalamo-hypophysial-gonadal system due to the elevated air temperature. Gwazdauskas et al [32] demonstrated that there were significant inverse relationships between conception rate and uterine temperature on the day of insemination, and between the rate and ambient (maximum, minimum and average) temperature on the day after insemination. High ambient temperature during only one or two days after the insemination could induce embryo death enough. Eminent seasonal changes in the rates of estrus occurrence and successful insemination in the purebred indicate the presence of definite effects of hot climate on the reproductive activity of this breed, even under the protection of electric fans and water sprinklers. Forced ventilation by electric fans and water sprinklers were effective enough to protect the reproductive ability of imported purebred and crossbred animals from the adverse effects of a hot climate [19]. By feeding them higher quality rations, their heat susceptibility has been covered and their good productive and reproductive abilities displayed as much as possible.

In males, it is known that gametogenesis is unable to occur at temperatures characteristic of the body core – heat stress as little as 12 hours disrupts spermatogenesis in the bull [18]. Ohashi et al [33] reported that heat stress is the main cause for the disruption in sperm production of male buffalo, which lead to a testicular degeneration that affects the semen pattern that includes a decrease in the sperm number, decreased sperm motility and increased number of abnormal sperm in the ejaculated semen and affect the sexual libido. It is well known that bull testes must be 2-6°C cooler than core body temperature for fertile sperm to be produced. Therefore, increased testicular temperature results from thermal stress could change in seminal, and biochemical parameters lead to infertility problems in bulls. The significant seasonal difference in semen characteristics was reported by several studies [34]. Cardozo et al [35] reported seasonal effects on changes in testicular volume, hormonal profiles, sexual behavior, and semen quality that affect the reproductive performance of males. Balic et al [36]
studied the seasonal influence on 19 Bos taurus (Simmental) bulls and found summer heat stress declined semen quality parameters. They also reported that younger bulls are more sensitive to elevated air temperatures during the summer seasons.

In a tropical environment, heat stress reduces the length and intensity of estrus besides increases the incidence of anestrus and silent heat in farm animals [37]. Heat stress affects the fertility and reproductive livestock performance by compromising the reproductive physiology tract, through hormonal imbalance, decreased oocyte quality and poor semen quality, and decreased embryo development and survival [38]. It increases Adrenocorticotropic hormone and cortisol secretion [39] and blocks estradiol-induced sexual behavior [40]. Roth et al. [41] reported that developed follicles suffer damage and become non-viable when the body temperature exceeds 40°C. FSH secretion is elevated under heat stress condition probably due to reduced inhibition of negative feedback from smaller follicles that ultimately affect the reproductive efficiency of dairy animals [42]. In goats, when females are exposed to 36.8°C and 70% relative humidity for 48 h, follicular growth to ovulation suppresses, and this is accompanied by decreased LH receptor level and follicular estradiol synthesis activity. Reduced granulosa cells aromatase activity and viability also contributed to poor estradiol secretion [43]. In water buffalo, low estradiol secretion suppresses signs of estrus, gonadotropin surge, ovulation, transport of gametes, and ultimately reduced fertilization [44]. A temperature rises of more than 2°C caused negative impacts due to low or desynchronized endocrine activities, particularly pineal-hypothalamo-hypophyseal-gonadal axis altering respective hormone functions. Upadhyay et al [45] indicated that low estradiol level on the day of estrus during the summer period might be the likely factor for the poor expression of estrus in Indian buffaloes.

Conception rates dropped from about 40% to 60% in cooler months to 10-20% or lower in summer, depending on the severity of the thermal stress [46]. About 20-27% drop in conception rates [47] or decrease in 90-day non-return rate to the first service in lactating dairy cows were recorded in summer [48]. Moreover, in severe heat stress, only 10-20% of inseminations and in normal pregnancies were also reported [41]. Oocytes of cows exposed to thermal stress lose their competence for fertilization [49] and development to the blastocyst stage [50]. Recently, Lacerda and Loureiro [51] also reported heat stress decreases fertility by diminishing the quality of oocytes and embryos through direct and indirect effects.

Embryonic growth and survival also affected during thermal stress in dairy animals. Heat stress causes embryonic death by interfering with protein synthesis [52], oxidative cell damage [44], reducing interferon-tau production for signaling pregnancy recognition and expression of stress-related genes associated with apoptosis [53]. Low progesterone secretion limits endometrial function and embryo development [42]. Exposure of lactating cows to heat stress on the 1st day after estrus reduced the proportion of embryos that developed to the blastocyst stage on the day 8th after estrus [54]. Further, exposure of post-implantation embryos (early organogenesis) and fetus to heat stress also leads to various teratologies [41]. The deleterious effects of heat stress in the embryo are most evident in the early stages of its development. However, embryos subjected to high temperatures in vitro or in vivo until day 7 of development (blastocyst) showed lower pregnancy rates at day 30 and higher rates of embryonic loss on day 42 of gestation [35]. Fetal malnutrition and eventually, fetal growth retardation under thermal stress were also reported [55].

3.3. Nutrition and feed resources
Increasing temperatures and decreasing rainfall in tropical climate reduce yields of rangelands and contribute to their degradation. Higher temperatures tend to reduce animal feed intake and lower feed conversion rates [56]. In fact, climatology characteristics such as ambient temperature and rainfall patterns have a great influence on pasture and food resources availability cycle throughout the year, and types of disease and parasite outbreaks among animal populations and this affect animal reproduction performance [57]. Livestock generally expends more energy and increase their voluntary feed intake in order to maintain their core temperature, resulting in lower feed efficiency, high incidence of delayed and less pronounce estrus, long service period, and calving interval [58].
Preparations to save feed resources for feeding during the time of scarcity is necessary to ensure reproductive function among livestock.

With the increasing incidence of global warming, heat stress and food scarcity are the big threats in livestock reproduction in the tropics. Proper programming of reproduction in livestock is important to optimize the reproduction potential and performance to counteract these threats. The use of advanced reproductive biotechnologies is necessary to overcome these threats.

4. Assisted reproductive biotechnologies

Through advance, reproductive biotechnologies and some management innovations and interventions, the problems posed by climate change, particularly, the heat stress and food scarcity on reproduction of livestock could be controlled and resolved. This is through the production of heat-tolerant animals, programming the reproductive function during the time when the animals are not vulnerable to heat stress, and when the season is favourable due to abundance of feeds and grasses for the nutrition of the animals. The application of reproductive biotechnology tools such as estrus synchronization, artificial insemination, early detection of pregnancy, embryo transfer through multiple ovulation and in vivo collection of embryos, in vitro embryo production and cryopreservation, somatic cell nuclear transfer to produce the desired breed and sex of animal, and other reproductive biotechnologies that enhances reproduction potential are important innovations that can address specific needs and purpose for animal reproduction.

4.1. Estrus synchronization

Seasonal anestrus is a normal phenomenon in the outbreeding season especially during summer times when environmental condition is hot in the tropical areas; however, the anestrus can be overcome by the use of hormone to synchronize heat and ovulation [20].

In water buffalo, it is well known that the estrus manifestations declines during the warmest hours of the day and in animals with heat stress. The reproductive behavior of female buffaloes and other livestock is feeble during the hot season. A herd of livestock had almost equal incidences of ovulation in hot (May-October) and the colder (November-April) seasons. However, estrus detection is more frequent and stronger in the colder season, which is accomplished by changes in the seasonal patterns of progesterone (P4) and estradiol and the number and amplitude of the luteinizing hormone (LH) pulses that was greater in the colder season [26].

Estrus synchronization has been accomplished using several methods with varying degrees of success [60]. In Bos indicus, several restricted suckling or weaning procedures (temporary or permanent), and hormonal treatments have been used to induce ovulation and cyclicity in postpartum cows [61]. Most hormonal treatments are based on progesterone/progestogen (P4) releasing devices associated with estradiol benzoate (EB), or a combination of GnRH/PGF(2alpha)/GnRH (Ovsynch). Treatments with GnRH/PGF(2alpha)/GnRH has presented inconsistent results, probably due to the variable number of cows in anestrous. Treatments using P4 devices and EB have resulted in apparently more consistent results than Ovsynch programs in Bos indicus cattle; however, pregnancy rates are low in herds presenting high anestrous rates and moderate to low body condition.

Prostaglandin F2-alpha has been used to cause regression of the corpus luteum to recruit a new wave of follicles to grow. Sponges that are impregnated with either native progesterone or an analog and then inserted into the vagina for a given period of time have also been used. In most instances, the synchronized animal will exhibit estrus within a 2 to 3 d after sponge removal. The controlled internal drug release (CIDR) device has been developed in New Zealand and been applied and adopted in tropical areas, and it consists of a nylon core surrounded by a silicone elastomer that is impregnated with progesterone [62]. The CIDR device works similarly to that of the sponges. The CIDR device has
been compared with various other progesterone-releasing devices and has been found to have a better-sustained release of progesterone over time. Both PGF2-alpha and CIDR devices have been shown to be effective for synchronizing estrus in goat [63], hair sheep ewes [64], in dairy cattle [61] and in buffaloes [65].

The use of estrus synchronization is a good strategy to overcome breeding problems during the summer months. By estrus synchronization, it is possible to program the breeding of the animals so that it could be scheduled when the time is favorable to the animal both from environmental, nutrition, and from health factors and success of reproduction is achieved. In dairy animals where income from milk is the major concern of the livestock raisers that breeding needs to be done even during the vulnerable times; the Ovsynch method of estrus synchronization is a good alternative for enhancing conception rates [66]. In this method, the results of conception rate were similar in animals raised in floodplain areas, and the animal raised in other regions were seasonal pattern play a role in the sexual activity.

4.2. Artificial insemination

Artificial insemination (AI) is an important reproductive biotechnology that can be employed to facilitate genetic gain in a tropical environment. The AI is reproductive biotechnology that maximizes the use of a genetically superior bull allowing it to breed a large number of females from its single ejaculate without moving it from place to place. This technology is the most adopted one as AI technicians can travel by motorcycle and penetrate even the most remote areas where livestock raisers need their female animals to be bred.

The world's bovine herd is mostly found in tropical regions. Due to their adaptation to the climate and management conditions, the Bos indicus and the Bubalus bubalis predominates. The reproductive performance of these animals is affected by the incidence of anestrus, which is the main factor that negatively affects reproductive performance of animals bred in these regions of the globe. Several factors affect postpartum anestrus, including suckling and maternal-offspring bond, and pre- and postpartum nutritional status. The short duration of estrus and the tendency to show estrus during the night, greatly affect the efficiency of artificial insemination (AI) programs in this livestock managed in tropical areas.

Artificial insemination used in conjunction with estrus synchronization would provide livestock raisers in the tropics access to genetic material not available locally. The use of AI could provide a means for exchanging genetic material and increasing the genetic base of the local livestock population within a breed without having to transport livestock. It would also allow crossbreeding programs to be developed using breeds that are not adapted to the climate of the tropics but are of superior genetics. The offspring would benefit from hybrid vigor and have the potential to increase the quantity and quality of milk and meat produced by local producers. This is reproductive biotechnology that can indeed make livestock reproduction in the tropics sustainable and profitable.

In carrying out AI, bull farm operation is necessary where bulls are raised, and semen is collected for screening and processing for cryopreservation. Collection of semen from a genetically superior bull during the best season of the year when semen quality is not affected by the adverse climatic condition and use it for AI is a good strategy to sustain livestock production and increase profit. It has to be noted, however, that the effect of the adverse climatic condition on bull semen is manifested not only during the exposure of stress but at least eight weeks thereafter [67]. This is because the effect of heat stress is more distinct on spermatogenesis when the sperm cells are at growing and developmental stage.

The perfect time of AI is crucial in order to achieve pregnancy. As the incidence of silent estrus is prominent during summer when the animals are exposed to extreme of hot environmental condition, the time of AI could be delayed, and efficiency could be compromised resulting to long calving interval. In order to sustain livestock production and promote a profitable operation, estrus observation, or prediction of the perfect time for AI is inevitable. Livestock raisers need to take the
estrus detection a priority concern in order to address the problems of long calving interval and loss of profit.

4.3. Embryo transfer

Embryo transfer is a technology that increases the reproductive ability of female animal as well as the bull of genetic merit. This technology involves the production of an embryo in vivo; through superovulation, AI and in vivo collection of the embryos, or in vitro; through ovum pick-up and in vitro maturation and fertilization of oocytes and culture of embryos to the preimplantation stage. The in vivo or in vitro production of embryos can be done from genetically superior animals during the perfect time of a year when there is no heat stress and transferring it at desired schedule would allow bypassing all the environmental and management challenges that affect reproduction potential and increase reproductive efficiency. Application in tropical areas is promising.

The embryo transfer is a matured technology and is routinely adopted in the propagation of genetically superior animals in cattle that is already on a commercial level. In water buffalo, live calves were born from in vivo collected and transferred embryos [68], but the application was limited by the poor superovulation response in water buffalo. Production of live calves from in vitro produced vitrified embryos [69–71] and cloned embryos [72–75] after embryo transfer were also achieved. However, application and adoption of this technology require technical expertise. Nevertheless, the technology is in place, and service providers are available.

Embryo transfer technology includes several consecutive stages: 1) Selection of the donor of embryos that is genetically superior and with normal reproduction. 2) Selection of recipients that is of low genetic but with high reproductive ability. 3) Hormonal treatment of the donors for the induction of superovulation. 4) Artificial insemination of the donors. 5) Embryo recovery from the donors and evaluation of embryos recovered and embryo transfer to the recipients by non-surgical methods, which would complete the pregnancy and give birth to a calf. Recipients of embryos are also prepared by synchronizing their estrus to commence during the collection of embryos. While each stage is simple and usually a matter of common sense, it must be carried out properly in coordination with all preceding and subsequent steps; otherwise, failure will result.

In the in vitro production of embryos, oocytes can be retrieved from the ovaries of a dead animal or through ovum pick-up from the live animal through ultrasonography-guided ovum pick-up. Oocytes are matured and fertilized in vitro and develop the embryos to the preimplantation stages in the laboratory. Resultant embryos can be transferred fresh to the recipient animals or can be cryopreserved in a liquid nitrogen tank for future use. The cryopreservation of both the in vivo and in vitro produced embryos makes it possible to transfer it at the time when breeding is favorable to the recipient animal and considering the production need of the livestock raiser. This technique exploits the genetic potential of females to accelerate the multiplication of superior animals for milk, meat, and as breeding stocks. In swamp buffalo dominated countries; this technique is an alternative to produce purebred dairy buffaloes in a shorter period of time.

4.4. Early detection of pregnancy

Early detection of pregnancy is an important component of the reproduction process in a tropical environment. Since heat stress could lead to early embryonic death, early detection of pregnancy is necessary in order to apply the needed management interventions to avoid abortion. Grunert et al [76] observed that the blood flow in the heat-stressed female animals increased in the proximity of the superficial vessels in detriment of the deep vessels whereas such change in the deep circulatory flow affects the circulation and nutritive supply at the uterus and ovaries causing impairment in its normal physiology. Such problem has been well documented in either milk of beef or cows managed at tropical and sub-tropical areas of the southern USA where the magnitude of the depression in the conception rate is proportional to the degree of hyperthermia. The disruption in the establishment of pregnancy is severe if heat stress occurs around the time of ovulation or early pregnancy as heat stress altered the oocyte or the reproductive tract so that normal embryonic development is compromised.
Additionally, a period of high-temperature results to increase secretion of endometrial PGF-2α, thereby threatening pregnancy maintenance and can even lead to infertility [78].

Pregnancy can be detected in cows as early as 30 days using ultrasound and blood tests. For cows to be identified as pregnant utilizing the palpation method, cows often need to be at least 35-50 days pregnant. Experience of the person palpating can make a significant difference in how early in this range that pregnancy can be detected. Producers should realize that stress to heifers and cows early in pregnancy can result in loss. Research has shown a pregnancy loss of 1-3.5% when palpation or ultrasound are used for pregnancy diagnosis at 40 - 75 days of gestation.

Table 3. Methods of pregnancy testing.

| Method                | When pregnancy can be detected, days | Age of calf | Sex of calf | Experienced technician needed | Cost per cow, $ | When results known |
|-----------------------|--------------------------------------|-------------|-------------|-------------------------------|-----------------|--------------------|
| Blood                 | 28-30                                | No          | No          | Yes                           | 3-5             | 2-4 days           |
| Ultrasonography       | 30                                   | Yes         | Potentially | Yes                           | 7-15            | On the spot        |
| Palpation per Rectum  | 35-50                                | Yes         | No          | Yes                           | 3-10            | On the spot        |

There are several ways to detect pregnancy; 1) palpation per rectum, 2) ultrasonography, and through 3) blood analysis (table 3). Traditionally, livestock raisers relied on veterinarians to palpate cows after 35 d of gestation or use ultrasound after day 28. The accuracy of these conventional methods depends on the practitioner’s experience, the gestational stage, the age of the animal, and its body condition score [79]. While these techniques have served the producers well over the years, they all require that a veterinarian visit the farm. Other methods such as detection of specific placental proteins by blood analysis appeared promising as a complement to the conventional methods.

The ability to identify open cows quickly and re-inseminate them as soon as possible, allows producers to increase their profitability. Therefore, the frequency and accuracy of pregnancy diagnosis methods have a direct impact on livestock management.

5. Other important practice

5.1. Record keeping

Women are often the traditional record keepers of animal performance and pedigree and are knowledgeable about these issues. It is, therefore, a sensible choice to involve them in record-keeping. Literacy rates among women are usually lower than among men, which need not be a problem, however, if recording methods are designed accordingly. It is important to record the date of AI, date of calving, and date when estrus is observed in order to carry out the needed actions to shorten calving interval.

6. Conclusion and recommendation

The growing human population and its increasing affluence would increase the global demand for livestock products. But the expected big changes in the climate globally will affect directly or indirectly the animal productivity and health and the sustainability of livestock-based production systems, especially in tropical areas. Under the climate change scenario, elevated temperature and relative humidity will definitely impose heat stress on all the species of livestock and will adversely affect their reproductive ability. Extended periods of high air temperature compromise the ability of livestock to dissipate excess body heat which affects feed intake, milk production, and reproductive efficiency. The loss of electrolytes via skin secretions must be minimized by the improvement of housing and cooling of the animals. Increase pregnancy rate of heat stress livestock could be achieved by improving various management conditions. To be able to minimize the effect of the mentioned adverse factors in farm animal productivity, it is essential to design mitigation strategies at the local,
regional, national, and transnational level. It is vital that such strategies would focus on the study and use of local genetic resources showing a high level of adaptation to the most significant issue for that specific region, either climate, disease, or nutrition-induced. Such studies have necessarily to be directed towards the full comprehension of the local breed’s genetic background and production ability, as well as the search for markers of tolerance to those limiting factors. Such markers would be of great importance and use in the definition of selection strategies and objectives to increase livestock productivity, with special reference to tropical countries.

Fortunately, proven strategies exist to mitigate some effects of heat stress on animal reproduction. These include housing animals in facilities that minimize heat stress, use of timed AI protocols to overcome poor estrus detection, implementation of embryo transfer programs to bypass damage to the oocyte and early embryo caused by heat stress, and early detection of pregnancy to address long calving interval and employ management interventions to avoid early embryonic death. Attempts should be made to identify effective hormonal regimes for good conception rate on animals in tropical areas. Management alternatives, such as the strategic use of shade, wind protection, sprinklers, and ventilation in the summer, also need to be considered to help livestock cope with adverse conditions. Further research and exploration on climate-resilient animal agriculture is the need of the hour for sustainability in livestock farming system, especially in the tropical region.

References
[1] United Nation 2013 World population projected to reach 9.6 billion by 2050 (United Nations Department of Economic and Social Affairs: http://www.un.org/en/development/desa/news/population/un-report-world-population-projected-to-reach-9-6-billion-by-2050.html)
[2] Hurst P, Termine P and Karl M 2005 Agricultural workers and their contribution to sustainable agriculture and rural development (Rome: Sustainable Development Department, FAO SD Dimensions)
[3] Wright I A, Tarawali S, Blümmel M, Gerard B, Teufel N and Herrero M 2012 Integrating crops and livestock in subtropical agricultural systems J. Sci. Food Agric. 92 1010–5
[4] Thornton P K 2010 Livestock production: recent trends, future prospects Philos. Trans. R. Soc. B Biol. Sci. 365 2853–67
[5] Kebede D 2016 Impact of climate change on livestock productive and reproductive performance Livest. Res. Rural Dev. 28 12
[6] Fajerssson P, Barradas H V, Roman-Ponce H and Cook R M 1991 The effects of dietary protein on age and weight at the onset of puberty in Brown Swiss and Zebu heifers in the tropics Theriogenology 35 845–55
[7] Moran C, Quirke J F and Roche J F 1989 Puberty in heifers: a review Anim. Reprod. Sci. 18 167–82
[8] Senger P L 1994 The estrus detection problem: new concepts, technologies, and possibilities J. Dairy Sci. 77 2745–53
[9] Duran P G, Corpuz H L V, Gaspar D C A, Misola C M, Munar M P and Hufana–Duran D 2015 Non-invasive clinical diagnosis of estrus for AI synchronization using vaginal cytology in three bubaline breeds in the Philippines J. Pharm. Biol. Chem Sci 6 562–7
[10] Xu Z Z, McKnight D J, Vishwanath R, Pitt C J and Burton L J 1998 Estrus detection using radiotelemetry or visual observation and tail painting for dairy cows on pasture J. Dairy Sci. 81 2890–6
[11] Muthukumar S, Muniasamy S, Srinivasan M, Ilangoivan A, Satheshkumar S, Rajagopal T, Ramesh Saravana Kumar V, Sivakumar K and Archunan G 2018 Evaluation of pheromone-based kit: A noninvasive approach of estrus detection in buffalo Reprod. Domest. Anim. 53 1466–72
[12] Taylor C S and Murray J 1987 Inter-breed relationships of birth weight and maternal and paternal weight in cattle Anim. Sci. 44 55–64
[13] Scholtz M M, Roux C Z and Lombard P E 1990 Breeding strategies for beef cattle in the
subtropics and tropics: Terminal crossbreeding 4th World Congress on Genetic Applications in Livestock Production pp 361–4

[14] Groenewald E G and Van der Westhuizen A J 1997 Prostaglandins and related substances in plants Bot. Rev. 63 199–220

[15] Ciganda C and Laborde A 2003 Herbal infusions used for induced abortion J. Toxicol. Clin. Toxicol. 41 235–9

[16] Riet-Correa F, Medeiros R M T and Schild A L 2012 A review of poisonous plants that cause reproductive failure and malformations in the ruminants of Brazil J. Appl. Toxicol. 32 245–54

[17] Panter K E, James L F, Gardner D R, Ralphs M H, Pfister J A, Stegelmeier B L and Lee S T 2002 Reproductive losses to poisonous plants: influence of management strategies J. Range Manag. 55 301–8

[18] Vale W G 2004 Recent advances in the male buffalo reproduction VII World Buffalo Congress. Makati City, Philippines pp 105–15

[19] Pongpiachan P, Rodtian P and Ōta K 2003 Effects of tropical climate on reproduction of cross-and purebred Friesian cattle in Northern Thailand Asian-australasian J. Anim. Sci. 16 952–61

[20] Vale W G 2007 Effects of environment on buffalo reproduction Ital. J. Anim. Sci. 6 130–42

[21] Vitali A, Segnalin M, Bertocchi L, Bernabucci U, Nardone A and Lacetera N 2009 Seasonal pattern of mortality and relationships between mortality and temperature-humidity index in dairy cows J. Dairy Sci. 92 3781–90

[22] Somparn P, Gibb M J, Markvichitr K, Chaiyabutr N, Thummabood S and Vajrabukka C 2004 Analysis of climatic risk for cattle and buffalo production in northeast Thailand Int. J. Biometeorol. 49 59–64

[23] Australian Livestock Export Corporation 2019 Veterinary Handbook for Cattle, Sheep and Goats. Animal Health Information for Veterinarians and Stock People in the Livestock Industries (http://www.veterinaryhandbook.com.au)

[24] Garcia A R 2007 Influência de fatores ambientais sobre as características reprodutivas de búfalos do rio (Bubalus bubalis) Rev. Cien. Agr 45 1–13

[25] Bhat P N 1999 BUFFALOES In: An introduction to animal husbandry in the tropics ed W J Payne and R T Wilson (Oxford: Blackwell Science Ltd) pp 325–404

[26] Shafie M M 1994 Environment effects on water buffalo production World Anim Rev 77 21–5

[27] Humbert J M, Chantaraprateep P, Singhajan S, Sekasiddhi P, Songsasen P, Lohachit C, Chabeuf N, Suparattanawon S and Planchenaut D 1990 Control of reproductive disorder and monitoring of herd! health programme for improvement of dairy production in Thailand J. Heal. Res. 4 11–32

[28] Trout J P, Mc Dowell L E E R and Hansen P J 1998 Characteristics of the estrous cycle and antioxidant status of lactating Holstein cows exposed to heat stress J. Dairy Sci. 81 1244–50

[29] Wilson S J, Marion R S, Spain J N, Spiers D E, Keisler D H and Lucy M C 1998 Effects of Controlled Heat Stress on Ovarian Function of Dairy Cattle. 1. Lactating Cows1 J. Dairy Sci. 81 2124–31

[30] Putney D J, Mullins S, Thatcher W W, Drost M and Gross T S 1989 Embryonic development in superovulated dairy cattle exposed to elevated ambient temperatures between the onset of estrus and insemination Anim. Reprod. Sci. 19 37–51

[31] Qureshi M S, Habib G, Nawab G, Siddiwqui M M, Ahmad N and Samad H A 2000 Milk progesterone profiles in various reproductive states in dairy buffaloes under field conditions Proceedings-National Science Council Republic of China Part B Life Sciences vol 24 (Citeseer) pp 70–5

[32] Gwazdauskas F C, Thatcher W W and Wilcox C J 1973 Physiological, environmental, and hormonal factors at insemination which may affect conception J. Dairy Sci. 56 873–7

[33] Ohashi O M, Sousa J S and Vale W G 1988 Aspecto reprodutivo do macho bubalino Bubalinos: fisiologia e patologia da reprodução (Sao Paulo: Fundacao Cargill) pp 69–86

[34] Bhakat M, Mohanty T K, Gupta A K and Abdullah M 2014 Effect of season on semen quality of
crossbred (Karan Fries) bulls Adv. Anim. Vet. Sci 2 632–7

[35] Cardozo J A, Fernández-Juan M, Forcada F, Abecia A, Muíño-Blanco T and Cebrián-Pérez J A 2006 Monthly variations in ovine seminal plasma proteins analyzed by two-dimensional polyacrylamide gel electrophoresis Theriogenology 66 841–50

[36] Balić I M, Milinković-Tur S, Samardžija M and Vince S 2012 Effect of age and environmental factors on semen quality, glutathione peroxidase activity and oxidative parameters in simmental bulls Theriogenology 78 423–31

[37] Kadokawa H, Sakatani M and Hansen P J 2012 Perspectives on improvement of reproduction in cattle during heat stress in a future Japan Anim. Sci. J. 83 439–45

[38] Krishnan G, Bagath M, Pragna P, Vidya M K, Aleena J, Archana P R, Sejian V and Bhatta R 2017 Mitigation of the Heat Stress Impact in Livestock Reproduction Theriogenology vol 8 (InTech) pp 8–9

[39] Singh M, Chaudhari B K, Singh J K, Singh A K and Maurya P K 2013 Effects of thermal load on buffalo reproductive performance during summer season J. Biol. Sci 1 1–8

[40] Hein K G and Allrich R D 1992 Influence of exogenous adrenocorticotropic hormone on estrous behavior in cattle J. Anim. Sci. 70 243–7

[41] Roth Z, Meidan R, Braw-Tal R and Wolfenson D 2000 Immediate and delayed effects of heat stress on follicular development and its association with plasma FSH and inhibin concentration in cows J. Reprod. Fertil. 120 83–90

[42] Khodaei-Motlagh M, Shahneh A Z, Masoumi R and Derensis F 2011 Alterations in reproductive hormones during heat stress in dairy cattle African J. Biotechnol. 10 5552–8

[43] Ozawa M, Tabayashi D, Latief T A, Shimizu T, Oshima I and Kanai Y 2005 Alterations in follicular dynamics and steroidogenic abilities induced by heat stress during follicular recruitment in goats Reproduction 129 621–30

[44] Wolfenson D, Roth Z and Meidan R 2000 Impaired reproduction in heat-stressed cattle: basic and applied aspects Anim. Reprod. Sci. 60 535–47

[45] Upadhyay R C, Ashutosh A and Singh S V 2009 Impact of climate change on reproductive functions of cattle and buffalo Global Climate Change and Indian Agriculture ed P K Anggarwal (New Delhi: ICAR) pp 107–10

[46] Cavestany D, El-Wishy A B and Foote R H 1985 Effect of season and high environmental temperature on fertility of Holstein cattle J. Dairy Sci. 68 1471–8

[47] Chebel R C, Santos J E P, Reynolds J P, Cerri R L A, Juchem S O and Overton M 2004 Factors affecting conception rate after artificial insemination and pregnancy loss in lactating dairy cows Anim. Reprod. Sci. 84 239–55

[48] Al-Katanani Y M, Webb D W and Hansen P J 1999 Factors affecting seasonal variation in 90-day nonreturn rate to first service in lactating Holstein cows in a hot climate J. Dairy Sci. 82 2611–6

[49] Gendelman M and Roth Z 2012 Seasonal effect on germinal vesicle-stage bovine oocytes is further expressed by alterations in transcript levels in the developing embryos associated with reduced developmental competence Biol. Reprod. 86 1–8

[50] Gendelman M and Roth Z 2012 In vivo vs. in vitro models for studying the effects of elevated temperature on the GV-stage oocyte, subsequent developmental competence and gene expression Anim. Reprod. Sci. 134 125–34

[51] Lacerda T F and Loureiro B 2015 Selecting thermotolerant animals as a strategy to improve fertility in Holstein cows Glob. J. Anim. Sci. Res 3 119–27

[52] Edwards J L and Hansen P J 1996 Elevated temperature increases heat shock protein 70 synthesis in bovine two-cell embryos and compromises function of maturing oocytes Biol Reprod 55 340–6

[53] Fear J M and Hansen P J 2011 Developmental changes in expression of genes involved in regulation of apoptosis in the bovine preimplantation embryo Biol. Reprod. 84 43–51

[54] Ealy A D, Drost M and Hansen P J 1993 Developmental changes in embryonic resistance to
adverse effects of maternal heat stress in cows *J Dairy Sci* 76 2899–295

[55] Tao S and Dahl G E 2013 Invited review: heat stress effects during late gestation on dry cows and their calves *J. Dairy Sci.* 96 4079–93

[56] Rowlinson P 2008 Adapting livestock production systems to climate change–temperate zones *Livestock and global change* (Hammamet, Tunisia: Cambridge University Press) pp 61–3

[57] Lamy E, van Harten S, Sales-Baptista E, Guerra M M M and de Almeida A M 2012 Factors influencing livestock productivity *Environmental stress and amelioration in livestock production* (Springer) pp 19–51

[58] Council N R 1981 *Nutrient Requirements of Goats* (Washington, DC: Nat. Academy Press)

[59] Raizada B C and Pandey M D 1981 Reproductive status of buffalo cows during summer. *Indian J. Anim. Sci.* 5 1025–7

[60] Scaramuzzi R J and Martin G B 1984 Pharmacological agents for manipulating oestrus and ovulation in the ewe *Reproduction in sheep: Australian Wool Corporation technical publication/supervising editors, DR Lindsay and DT Pearce* ed D R Lindsay and D T Pearce (New York: Cambridge University Press,) pp 316–25

[61] Baruselli P S, Reis E L, Marques M O, Nasser L F and Bó G A 2004 The use of hormonal treatments to improve reproductive performance of anestrous beef cattle in tropical climates *Anim. Reprod. Sci.* 82 479–86

[62] Hamra A H, McNally J W, Marcck J M, Carlson K M and Wheaton J E 1989 Comparison of progesterone sponges, cronolone sponges and controlled internal drug release dispensers on fertility in anestrous ewes *Anim. Reprod. Sci.* 18 219–26

[63] Nogueira D M, Lopes Júnior E S, Peixoto R M de, Christilis M, Martins S R and Monte A P 2011 Using the same CIDR up to three times for estrus synchronization and artificial insemination in dairy goats *Acta Sci. Anim. Sci.* 33 321–5

[64] Godfrey R W, Gray M L and Collins J R 1997 A comparison of two methods of oestrous synchronisation of hair sheep in the tropics *Anim. Reprod. Sci.* 47 99–106

[65] Haider M S, Hassan M, Khan A S, Husnain A, Bilal M, Pursley J R and Ahmad N 2015 Effect of timing of insemination after CIDR removal with or without GnRH on pregnancy rates in Nili-Ravi buffalo *Anim. Reprod. Sci.* 163 24–9

[66] Baruselli P S and Carvalho N A T de 2005 Biotecnologias da reprodução em bubalinos (Bubalus bubalis) *Rev. Bras. Reprodução Anim.* 29 4–17

[67] Staub C and Johnson L 2018 Review: Spermatogenesis in the bull *animal* 12 27–35

[68] Cruz L C, Venturina H V, Jha S S, Adriano F, Duran P G, Serra P, Smith O F, Faylon P S and Lorenzo N 1991 Successful transfer of Murrah buffalo embryos into Philippine Swamp buffalo recipients *Proc. 3rd World Buffalo Congress* (Varuna, Bulgaria) pp 586–90

[69] Hufana-Duran D, Pedro P B, Venturina H V, Hufana R D, Salazar A L, Duran P G and Cruz L C 2004 Post-warming hatching and birth of live calves following transfer of in vitro-derived vitrified water buffalo (Bubalus bubalis) embryos *Theriogenology* 61 1429–39

[70] Hufana-Duran D, Pedro P B, Salazar A L, Venturina H V, Duran P G and Cruz L C 2007 River buffalo calves (2n=50) delivered to term by swamp buffalo recipients (2n=48) out of in vitro-derived vitrified embryos *Livest Sci* 107 99–104

[71] Hufana-Duran D, Pedro P B, Salazar Jr A L, Venturina H V, Duran P G, Takahashi Y, Kanai Y and Cruz L C 2008 Twin calf production in water buffaloes following non-surgical transfer of in vitro-produced-vitrified embryos *Philipp. J. Sci.* 137 99–104

[72] Shi D, Lu F, Wei Y, Cui K, Yang S, Wei J and Liu Q 2007 Buffalos (Bubalus bubalis) cloned by nuclear transfer of somatic cells *Biol. Reprod.* 77 285–91

[73] Yang C Y, Li R C, Pang C Y, Yang B Z, Qin G S, Chen M T, Zhang X F, Huang F X, Zheng H Y and Huang Y J 2010 Study on the inter-subspecies nuclear transfer of river buffalo somatic cell nuclei into swamp buffalo oocyte cytoplasm *Anim. Reprod. Sci.* 121 78–83

[74] Shah R A, George A, Singh M K, Kumar D, Chauhan M S, Manik R, Palta P and Singla S K 2008 Hand-made cloned buffalo (Bubalus bubalis) embryos: comparison of different media
and culture systems *Cloning Stem Cells* **10** 435–42

[75] Tasripoo K, Suthikrai W, Sophon S, Jintana R, Nualchuen W, Usawang S, Bintvihok A, Techakumphu M and Srisakwattana K 2014 First cloned swamp buffalo produced from adult ear fibroblast cell *animal* **8** 1139–45

[76] Grünert E, Birgel E H, Vale W G and Birgel Júnior E H 2005 Patologia e clínica da reprodução dos animais mamíferos domésticos: ginecologia *Patol. e clínica da reprodução dos animais mamíferos domésticos Ginecol.*

[77] Hansen P 2003 Fatores naoinfecciosos associados com a baixaconcepcão e perda embrionaria em vacas de leite. VII. Curso novos enfoques na producao e reproducaode bovinos *Proc., Uberlandia* 9–26

[78] Bilby T R, Baumgard L H, Collier R J, Zimbelman R B and Rhoads M L 2008 Heat stress effects on fertility: Consequences and possible solutions *the Proceedings of the 2008 South Western Nutritional Conference*

[79] Youngquist R C 2007 Pregnancy diagnosis *Current Therapy in Large Animal Theriogenology* ed R C Youngquist and W R Threlfall (Saunders: St-Louis) pp 294–303