TEMPORAL VARIATION OF TEMPERATURE AND RELATIVE HUMIDITY AND THE RESPONSES BY THE FRIESIAN X BUNAJI CROSS BREED COWS IN SHIKA ZARIA, KADUNA STATE, NIGERIA.

BY

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A DESERTATION SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES, AHMADU BELLO UNIVERSITY, ZARIA, IN PERTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER DEGREE IN GEOGRAPHY

DEPARTMENT OF GEOGRAPHY,
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APRIL, 2015

DECLARATION

I hereby declare that this thesis titled "Temporal variation of temperature and relative humidity and the responses by the Friesian X Bunaji cross Breed cows in Shika Zaria, Kaduna State, Nigeria." is a record of my own research work under the supervision of Dr. B.A. Sawa and Dr. P.P. Barje. All information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis has been previously presented for another degree or diploma at any university.

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Mungwa Cletus CHAFA Date

CERTIFICATION

This thesis titled "Temporal variation of temperature and relative humidity and the responses by the Friesian X Bunaji cross Breed cows in Shika Zaria, Kaduna State, Nigeria" by Mungwa Cletus CHAFA, meets the regulations governing the award of degree in Master of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This thesis is dedicated to the memory of my father, Sir Alexander Alibo Chafa.

ACKNOWLEDGEMENT

First and foremost, I give all the honour and thanksgiving to the Blessed Trinity-the author of my life with whom all things are possible.

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ABSTRACT

Heat stress or Hyperthermia occurs when the metabolic heat produced by the cow in combination with heat from the environment exceeds the cow's ability to lose heat to the environment. During periods of heat stress, cows are unable to dissipate this additional metabolic heat produced, especially in areas of high temperature and humidity. As a result, cows voluntarily reduce dry matter intake (DMI), thus limiting milk production. The aim of this research is to identify and assess the effect of heat stress factors (temperature and relative humidity) on milk yield of Friesian X Bunaji cross breed cows in National Animal Production Research Institute (NAPRI) Samaru Zaria for the period of ten years (2001-2010). The objectives of the study include; characterisation of the environmental conditions in the study area (temperature and relative humidity), examining the variation in temperature, examining milk production level, assessing the temperature and seasons at which dairy cows start experiencing heat stress, examining the relationship between temperature, relative humidity and milk yield and finally to determine the temperature humidity index (THI) values at which cows are stressed. The study was conducted using secondary data. Daily temperature , relative humidity and milk yield record per cow from 2001 to 2010 were sourced from National Animal Production Research Institute (NAPRI) and Institute for Agricultural Research Samaru Zaria. Data were analysed using Microsoft excel, time series analysis, and temperature humidity index. Data were presented using line graphs, charts, and simple bar graphs. The study revealed that air temperature surrounding dairy cows in the study area is above the thermonutral zone (2-20°C) or comfort zone where cows are expected to produce best. Time series analysis showed that high temperature alternates with low temperature. It was observed that these alternating temperatures weaken the cows and upset their thermostat. Relating milk yield with season further shows that high volume of milk is recorded during cool dry and cool wet season than hot dry and hot wet seasons when both temperature and relative humidity are at their peak. Finally, relating the calculated temperature humidity values with the revised temperature humidity chart shows that all cows in the study area are stressed. The study concluded that the environmental temperature of dairy cows is above the critical thermonutral zone which has a negative influence on milk produced by dairy cows. If dairy cows in this environment must meet their full potential for milk yield, action therefore must be taken to improve the living conditions of these dairy cows.

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CHAPTER ONE: INTRODUCTION

1.1 Background to the Study

The ability of animals to withstand tropical conditions vary considerably between different breeds. Environmental conditions directly affect the mechanism and rates of heat gain or loss by all animals (NRC, 1981). Lack of prior conditioning to weather events most often results in catastrophic losses in the domestic livestock industry. When environmental temperatures move out of the thermoneutral zone (comfort zone), dairy cattle begin to experience either heat stress or cold stress. Either stress requires the cow to increase the amount of energy used to maintain the body temperature and there is less energy available for milk production.

Thermoneutral zone is the range of environmental temperatures where normal body temperature is maintained and heat production is at the basal level. Thermoneutral zone depends on the age, breed, feed intake, diet composition, previous state of temperature acclimatization, housing and stall conditions, tissue insulation, external (coat) insulation, coat colour and the behaviour of the animal (NRC, 1981).

According to the U.S. Department of Agriculture, (2007), dairy cattle are cattle (adult females) that have the ability to produce large quantities of milk, from which dairy products are made. Dairy cows generally are of the species *Bos taurus.* In the United States, dairy cattle are divided into six major breeds namely: Holstein-Friesian, Brown Swiss, Guernsey, Ayrshire, Jersey, and Milking Shorthorn (Blaney and Don, 2002).

Friesians are breed of cattle known today as the world's highest-production dairy animals (Duane and Hare, 2010). They are large, black-and-white marked Cows that vary from mostly black to mostly white, or they can also be red and white. Originating in Europe, Friesians were bred in what the Netherlands and more specifically in the two northern provinces of North Holland and Friesland, and northern Germany, more specifically what is

now Schleswig-Holstein. The animals were the regional cattle of the Friesians and the Saxons. The Dutch breeders bred and oversaw the development of the breed with the goal of obtaining animals that could best use grass, the area's most abundant resource (Duane and Hare, 2010). Over the centuries, the result was a high-producing, black-and-white dairy cow. The black and white colour is due to artificial selection by the breeders. Holstein in this instance, and indeed in all modern discussion, refers to animals traced from North American bloodlines, while Friesian refers to indigenous European black and white cattle (DEFRA, 2008).

Historically, there was little distinction between dairy cattle and beef cattle, with the same stock often being used for both meat and milk production. Today, the bovine industry is more specialized and most dairy cattle have been bred to produce large volumes of milk. The United States dairy herd produced 83.9 billion litres of milk in 2007, up from 52.6 billion litres in 1950, (David, 2004). Yet there are more than 9 million cows on U.S. dairy farms—about 13 million fewer than there were in 1950 (Blaney and Don, 2002).

In the central US in 1992, 1995, 1997, 1999, 2005 and 2006, some feedlots operations (intensive cattle feeding operations) recorded losses in excess of 100 heads during severe heat episode. The heat waves of 1995 and 1999, 2005 and 2006 were particularly severe with documented cattle losses in individual states approaching 5,000 head each year (DEFRA, 2008).

The Sudan-Sahel zone of Nigeria is home to a large number of livestock. However, statistics on Nigerian cattle population cannot be said to be reliable, as figures often quoted have been on estimates for 1994 ranging from 13.5 million cattle, 8 million sheep and 24 million goats (IPCC, 2000). The difficulty in ascertaining the exact statistics of Nigerian cattle population has been attributed to the traditional production system (nomadism), on one hand, and the different methods and sources of information used on the other hand (Voh

Jr.,1997). Over 90% of this national cattle herd is in the hands of the nomadic Fulani (FAO/ISCDD, 1975).

The breeds of cattle in Nigeria are Bunaji (White Fulani), Rahaji, Sokoto Gudali, Adamawa Gudali, Keteku, Muturu, Kuri, Wadara, and others of mixed genetic composition – mainly various degrees of crossing within the local breeds and/ or with exotic breeds. The composition of the Nigerian national herds by breed estimated from data from FMA (1981), FAO (1980) and Larmode and Franti (1975) is as follows: Bunaji (White Fulani) 51%, Rahaji (Red Fulani) 14%, Sokoto Gudali 11.5%, Adamawa Gudali 11.5%, Keteku 2.1%, Muturu 0.7%, Ndama 0.2% and others 9%. Milk from cattle reared under the traditional management system accounts for about 50% of the domestic milk supply (FMAO/GRNC, 1981). Although, milk production under modern intensive and semi-intensive systems in Nigeria contributes only to about 3% of the national output of milk and is almost entirely restricted to government and institutional experimental farms. Milk supply from these domestic sources is grossly inadequate in meeting the increasing demand for milk and milk products by the ever-increasing human population. With the demand for milk and milk products being nearly twice the level of domestic production in Nigeria, there is need to boost domestic production through strategic interventions that will help alleviate problems of heat stress in dairy industry. It is on this background that the Bunaji cows were crossed with the Friesian cows to double production in order to meet consumers demand.

Dairy cows are very sensitive to heat stress which has a significant economic impact on the farmer, leading not only to loss of productivity and milk yield but also health related problems (James and McDonald, 2007). A direct effect of heat stress on dairy cattle involves heat exchange between the animal and the surrounding environments that are related to radiation, temperature, humidity and wind speed. Under prevailing climatic conditions, the

inability of animals to dissipate the environmental heat indicates that in many areas in the world, animals suffer heat stress during, at least part of the year.

Yousef, (1985) defined heat stress as the magnitude of forces external to the body which tend to displace its systems from their resting or ground state. In this light, heat stress for the dairy cow can be understood to indicate all high temperature related forces that induce adjustments occurring from sub-cellular to the whole animal level to help the cow avoid physiological disfunction and for it to better fit its environment. Heat Stress can also be defined as the point where the cow cannot dissipate adequate quantity of heat to maintain body thermal balance (Yousef 1985). Thermal environment is a major factor that can negatively affect milk production of dairy cows, especially in animals of high genetic merit. Therefore, Heat stress can be considered as the sum of all the forces acting on the cow to increase body temperature above normal limits (Sartori, R., Sartor- Bergfelt, R., Martens, S.A., Guenther, J.N, Parrish, J.J., and Wiltbank, M.C., (2002).

Climatic environment influences nearly every aspects of animal life, thus animals in the tropics produce less products compared to their temperate counterparts, probably as a result of the extra energy they expend in combating meteorological stress factors of ambient temperature, air humidity, and solar radiation (IPCC, 2000). Increase in air temperature, air movement, humidity and solar radiation all combine to disrupt the thermoregulatory mechanism of farm animals thus, influencing their growth and reproductive functions (Ryan, *et al*; 1992). The deep body temperature of hemeothermic animals is maintained within fairly narrow limits by elaborate thermoregulatory mechanisms which rely on a large number of graded physiological, morphological and behavioural responses which in turn depend on the thermal nature of the environment. (Hansen and Montieth, 1994).

In cold weather, animals' loose heat through channels that depend on a temperature gradient, that is, by radiation, convection and conduction (Mount and Monteith, 1984). These

channels are often termed ‘sensible,’ because the loss of heat through them is a form of energy transfers that can be detected by the sense. Under hot conditions, animals tend to gain heat through these channels and can lose heat to the environment only by evaporation either from their surface (by sweating or by the evaporation of water other than sweat) or by panting (Mount and Monteith, 1984).

The ranges of thermoneutral zone are from lower critical temperature (LCT) to upper critical temperature (UCT) (Yousef, 1985). Lower critical temperature is the environmental temperature at which an animal needs to increase metabolic heat production to maintain body temperature while Upper critical temperature is the environmental temperature at which the animal increases heat production as a consequence of a rise in body temperature resulting from inadequate evaporative heat loss (Yousef, 1985). All animals have a specific range of ambient or environmental temperature termed thermoneutral zone. This is a range of temperature that is conducive to health and performance of the animals. The upper critical temperature is the point at which heat stress effects begin to affect the animal (Ravagnolo, and Misztal, 2002).

One way to think of a cow is as a furnace (Ravagnolo, and Misztal, 2002), **(**Figure 1.1). It burns fuel (carbohydrates, fats, and proteins that are mobilized from body stores and that ultimately are derived from feed stuff's) and the heat produced as a result is lost to the environment. Cows, like other warm-blooded animals, attempt to match the amount of heat produced with that lost to the environment so that body temperature remains constant. For cattle, the body's thermostat is set to about 38.3° to 38.6°C. When it is cold, cows can increase heat production and decrease heat lost to the environment so as to prevent a decline in body temperature. When it is hot, however, cows can increase heat lost to the environment, but the ability to reduce heat production is limited to reducing feed intake. As a result, cows exposed to heat stress often experience increased body temperature (i.e., hyperthermia).

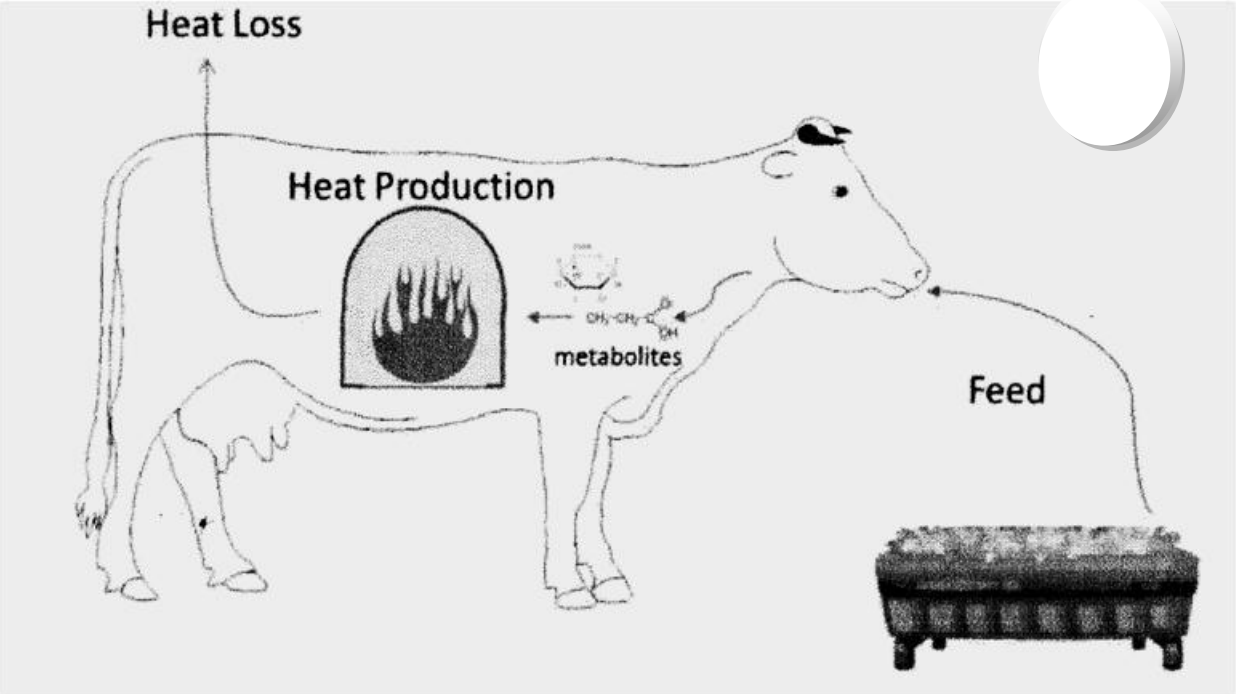


Figure 1.1: How a Cow Burns Fuel In form of Metabolites Produced from Feed. Source: (Ravagnolo, and Misztal, 2002).

A cow burns fuel in the form of metabolites produced from feedstuffs and uses some of the energy in the fuel to do work such as milk synthesis, muscle growth, etc. The heat released from burning metabolites is lost to the environment. When heat stress is a problem, the cow cannot lose all of the heat of metabolism to the environment, and body temperature rises (Ravagnolo, and Misztal, 2002).

There are a number of environmental factors that contribute to heat stress. These include high temperature, high humidity and radiant energy (sunlight). Environment of high temperatures and humidity are detrimental to the productivity of commercial animals (Faquay, 1981)

Farm animals have known zones of thermal comfort (ZTC) that are primarily dependent on the species, the physiological status of the animals, the relative humidity, velocity of ambient air, and the degree of solar radiation (NRC, 1981). Economic losses are incurred by the livestock industries raised in places and seasons where temperature conditions

venture outside the zone of thermal comfort. Heat stress results from a negative balance between the net amount of energy flowing from the animal to its surrounding environment and the amount of heat energy produced by the animal (NRC, 1981). This in-balance is induced by the combinations of changes in environmental factors (sunlight, thermal radiation, air temperature) and thermoregulatory mechanism (conduction, radiation, convection and evaporation).

The importance of heat stress to livestock industries is increasing with time because of the long-term trend shift in the location where dairy animals are primarily located and because animals of better genotype produce more body heat due to their greater metabolic activity (West, 1994).When exposed to heat, domestic animals increase their breathing in an attempt to increase the rate of heat loss by evaporation (West, 1994). Inspit of this, however, the body temperature is likely to rise to an extent determined by the severity of the external conditions, the productivity level of the animal, and its type.. The rapid breathing interferes with eating and even with rumination (Ingram, 1975). It tends to upset the balance between acidic and basic substances in the blood stream; and in itself, increases the work and heat production of the animal. Appetite is lost and if the animal is on open pasture, it may lie down or seek shade in preference to eating (West 1994). If this occurs where the nutritive value of the pasture is low, it may be impossible for the animal to make up in the cooler hours what it loses in the hotter parts of the day (Johnson, 1987). The animal therefore tends to be less well nourished than it would otherwise be; milk production, growth, work capacity, and other types of productivity suffer and fertility may be seriously reduced.

1.2 Statement of the Research Problem

Heat stress is a significant issue for the dairy industry (Moghaddam, Karimi and Pooyanmehr, 2009). Increasing air temperature and humidity makes it more difficult for cows

to cool themselves. It is difficult for a dairy cow in a hot environment to meet her full potentials for either milk yield or fertility. The physiological adjustment the cow makes to prevent body temperature from rising during heat stress helps prevent death from heat stroke but also reduces productivity (Sartori *et al.,* 2002). For example, heat stressed cows experience a decrease in appetite. The advantage to the cow is that her internal heat production is lowered, and regulation of body temperature becomes easier. The disadvantage to the producer especially dairy farmer is that the reduction in appetite caused by heat stress decreases milk yield.

Cows have optimal temperature zones within which no additional energy above maintenance is expected to heat or cool the body (West, 2003). This thermoneutral zone for dairy cattle is estimated to be from 2° to 20°C with an upper critical air temperature of approximately 25°C (West, 2003). Dairy animals become heat stressed when the effective temperature conditions exceed the animal's zone of thermal comfort. Temperature-humidity indices (THI) are frequently used measures of heat stress in dairy cattle and are calculated using the ambient temperature and relative humidity. Heat stress in dairy cattle starts at a THI of 20, which corresponds to 25°C at 100% humidity, 25°C at 50% humidity, or 28°C at 20% humidity (Ravagaolo, Mistztal and Hoogenboom 2000; Jordan, 2003). Lately, even lower thresholds for THI have been identified in high-producing dairy cows, such as 20°C (Collier, Zimbelman, Rhoads and Baumgard, 2011). Heat stress reduces milk production, feed intake and reproduction and increases the risks of lameness and culling.

Dairy cattle are more susceptible to heat stress because of their select inherited ability to ingest vast quantities of dry matter, thus producing greater metabolic heat from rumen fermentation as well as from the process of milk production (Hansen, 1994). Older, heavier, higher milk-producing cows are most susceptible to heat stress (Bucklin and Hahn, 1991; and Drost, 1997). During periods of thermal stress, cows are unable to dissipate this additional

metabolic heat produced, especially in areas of high humidity. As a result, cows voluntarily reduce dry matter intake, thus limiting milk production.

Lactating dairy cows create large quantity of metabolic heat and accumulate additional heat from radiant energy. Heat production and accumulation coupled with compromised cooling capability because of environmental conditions causes heat load in the cow to increase to the point that the body temperature rises, feed intake declines and ultimately the cow productivity declines (Ravagnolo, Misztal and Hoogenboom, 2000).

Climatic conditions in the Northern parts of Nigeria where cattle are mostly dominant are such that hot season is relatively longer than wet season. There is, therefore, intense radiant heat energy for an extended period of time and generally, the presence of high relative humidity (IPCC, 2000). Thus, heat stress is chronic in nature, there is often little relief from the heat during the evening hours, and intense burst of combined heat and humidity further depresses milk yield. The Friesian-Bunaji, though a crossbreed, still possesses traits of the cold environment. Its milk yield and performance could be affected by high temperature and humidity.

Dairy cattle researchers have tended to concentrate on genetic improvement for increase milk production and nutrient supply to the cow during early lactation, devoting little attention to the thermal regulatory ability of the modern cow as her capacity to produce milk has increased (Ravagnolo, Misztal and Hoogenboom, 2000). Much work has been done in most temperate countries to identify the physiological effects of heat stress and the mechanisms by which dairy production is reduced. For example, St-Pierre, Cobanov, Schnitkey, (2003) analyzed the effects of heat stress on dry matter intake, reproduction, and death of both young stock and adult cows. The results indicated that stressed cow's loose appetite, and become very weak which results to the death of both young and old cows.

Similarly, Mount (1984), Bunmi (1994) and Umar (2010) reported that the hot –dry season gave significantly lower pulse rate than the cold dry season. Also, both respiratory rate and rectal temperature were significantly higher during hot –dry season than the cold dry season which affected the normal body function and also reduced the productivity of the cow.

Although a number of studies (Mount and Monteith, 1984; Bunmi, 1994l; 2003, Umar, 2010) have been conducted in the study area to identify the physiological effects of heat stress on cattle and the mechanisms by which dairy production is reduced, none of these studies to the best of the researcher's knowledge has addressed how the environment of dairy cows has affected milk yield and performance of the dairy cattle which primarily could be a function of temperature and humidity. This is a research gap that needs to be filled. The focus of this study, therefore, is to identify, examine the extent to which heat stress affects milk production of the Friesian X Bunaji cross breed cows in National Animal Production Research Institute (NAPRI), Shika Zaria, considering the environment factors of temperature and relative humidity.

The study therefore posed and sought to answer the following research questions:

i. What are the environmental conditions to which Friessian X Bunaji cows are exposed?
ii. What is the variation in temperature?
iii. What is the pattern of milk production per cow and variation between Friesian X Bunaji cows?
iv. At what temperature and season do dairy cows start experiencing heat stress?
v. Is there any relationship between temperature, relative humidity and milk yield?
vi. At what THI do Friessian X Bunaji cows start experiencing heat stress?

1.3 Aim and Objectives of the Study

The aim of this research was to examine how the variation in temperature and relative humidity affects milk production of Friesian X Bunaji cows in National Animal Production Research Institute (NAPRI) Shika. The specific objectives of the study were to:

i. characterize the environmental conditions to which Friessian X Bunaji cows are exposed.
ii. examine the variatin in temperature.
iii. examine the milk production level per cow and variation between cows.
iv. assess the temperature and season at which Friessian X Bunaji cows start experiencing heat stress.
v. examine the relationship between temperature, relative humidity and milk yield.
vi. determine the THI value at which Friessian X Bunaji cows are stressed

1.4 Scope and Delimitation

This research focused on the variation of temperature and relative humidity on milk production of Friesian X Bunaji cows in National Animal Production Research Institute (NAPRI) Shika, of Kaduna State Nigeria. This study covered a period of ten years: from 2001 to 2010.

1.5 Justification of the Study

It is difficult for Friessian X Bunaji cows in a hot environment to meet her full potential for either milk yield or fertility. The physiological adjustment the cow makes to prevent body temperature from rising during heat stress prevents heat stroke but also reduce productivity (Sartorie et al., 2002).

According to (Craig Thomas 2002), all dairy producers are aware that their cows are subject to heat stress on warm summer days. Expert's estimate that heat stress causes $5 to $6

billion in lost of milk production and decreased animal performance in the United States each year. Dairy cows are more sensitive to heat stress than many other mammals because of the high metabolic heat production due to performance in the rumen. Dairy cows experiencing heat stress show higher rectal temperatures, increased respiration rates, decreased feed intake, decreased milk production (volume and components) and other health problems (e.g. decreased reproduction efficiency) As milk production increases, heat production from the rumen increases and makes cows even more susceptible to the unfavourable effects of heat stress.

The Friesian X Bunaji cows, being cross species from the temperate environment where environmental temperature could be as low as -5°C to 20°C, introducing this cows into a new environment (Tropics) which is fairly different from its original environment and allowed to graze freely in an open but semi intensive system with an environmental temperature of 20°C to 35°C, there is no doubt that these temperate cows will be stressed, although, crossbreeding with the local breeds especially the Bunaji, have given rise to a breed that is fairly adapted to the environment.

The fact that no studies on this breed (Friesian X Bunaji) of cows looked at the variation in temperature and relative humidity on milk production of Friesian X Bunaji cows in National Animal Production Research Institute (NAPRI) Shika, considering its immediate environment and how this environment has affected these cows. This makes this study timely and worthwhile.

The hope is that the data generated would constitute an invaluable source of information for future references, especially in the area of managing the Friesian X Bunaji under high temperatures and humidity for improved and sustainable milk production.

CHAPTER TWO: CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

2.1 Sustainable Development

2.1.1 Sustainable milk production

The line of argument is sometimes advanced that it is more economic in underdeveloped countries to grow food crops that can be directly consumed by man than to grow feed for animals which will be at best only particularly consumed by him. In a general way, it may be said that if one acre of land sown to rice will support a family, it will require seven acres to support it on meat, milk and other animal products. No animal converts more than a fraction of the food it consumes in to edible flesh or milk (NRC, 1989). Actually, several factors intrude to compel, or at least to make advisable, the maintenance of a certain proportion of livestock. It is therefore on this background that the Bunaji; a local and low milk producing cow was crossed with a temperate high producing Friesian cow to produce substantial litres of milk that could meet the demand of the present and future population.

2.1.2 Concept of Heat Stress

Pronounced seasonal patterns of milk yield and composition are evident in cattle (Doelger, Thatcher, Wilcox, 1982). These seasonal patterns are largely induced by climatological variables, breed effects and management factors, such as feed quality and reproductive management.

Yousef, (1985) defined heat stress as the magnitude of forces external to the body which tend to displace its systems from their resting or ground state or the point where the cow cannot dissipate adequate quantity of heat to maintain body thermal balance. In this light, heat stress for the dairy cow can be understood to indicate all high or low temperature

related forces that induce adjustments occurring from sub-cellular to the whole animal level to help the cow avoid physiological disfunction and for it to better fit its environment.

According to Sartori *et al.,* (2002) it is difficult for a dairy cow in a hot environment to meet her full potential for either milk yield or fertility. The physiological adjustment the cow makes to prevent body temperature from rising during heat stress helps prevent death from heat stroke but also reduce productivity. For example, heat stressed cows experience a decrease in appetite. The advantage to the cow is that her internal heat production is lowered, and regulation of body temperature becomes easier (Sartori, *et al.,* 2002). The disadvantage to the dairy farmer is that the reduction in appetite caused by heat stress decreases milk yield.

West, (2003) discovered that cows have optimal temperature zones within which no additional energy above maintenance is expected to heat or cool the body. This thermoneutral zone for dairy cattle is estimated to be from 2° to 20°C with an upper critical air temperature of approximately 25°C. Dairy animals therefore become heat stressed when the effective temperature conditions exceed the animal's zone of thermal comfort. Temperature-humidity indices (THI) are frequently used measures of heat stress in dairy cattle and are calculated using the ambient temperature and relative humidity. West, (2003) went further to say that heat stress in dairy cattle starts at a THI of 20, which corresponds to 25°C at 100% humidity, 25°C at 50% humidity, or 28°C at 20% humidity.

Lately, Ravagaolo and Misztal, (2000) and Jordan, (2003) identified lower thresholds for THI in high-producing dairy cows, such as 20°C. Collier, Zimbelman, Rhoads and Baumgard, (2011) reported that heat stress reduces milk production, feed intake and reproduction and increases the risks of lameness, thus culling rate.

According to Collier, Zimbelman, Rhoads and Baumgard (2011), heat stress is caused by a combination of environmental factors (temperature, relative humidity, solar radiation, air

movement, and precipitation). Therefore, several indices combining different environmental factors to measure the level of heat stress have been proposed. However, their usefulness has been limited by non-availability of data. That is why temperature-humidity index (THI) is a single value representing the combined effects of air temperature and humidity associated with the level of thermal stress.

Berman and Wolfensen (2005) developed a weather safety index based on THI to monitor and reduce heat-stress-related losses based on the fact that animal species have different sensitivities to ambient temperature and the amount of moisture in the air. These authors observed that cattle can tolerate much higher temperatures at lower relative humidity than swine, due to the fact that cattle can dissipate excessive heat more effectively by sweating, whereas swine do not have sweat glands. However, during hot and humid weather the natural capability of cattle to dissipate heat load by sweating and panting is compromised, and heat stress occurs at these conditions in cattle much faster than in swine.

Generally, meteorologists use wet bulb temperature (Twb), relative humidity (RH), or dew point temperature (Tdp) to measure water vapour content (Jensen, Burman, and Allen, 1990). The Twb represents the equilibrium temperature of a thermometer covered with a cloth that has been wetted with water. Relative humidity provides information about saturation of the air at a given temperature. Dew point temperature is the temperature to which the air must be cooled for saturation to occur; that is, the temperature at which RH is 100%. Jensen, (1990) compared comfort zone in humans and cattle and revealed that in humans, the effect of Twb on comfort is almost 6 times as large as that of dew point temperature (Tdp), whereas in cattle it is only about twice as large. This difference reflects differences in the capacity for evaporation.

According to Bianca, (1962) humans can dissipate about 190% of their metabolic heat production by evaporation, whereas cattle can dissipate only 105% of their metabolic heat production. Because of the differences in sensitivity to ambient temperature and amount of moisture in the air among species, a range of equations for calculation of THI with different weightings of dry bulb temperature (Tdb) and air moisture have been proposed. Some indices integrate air moisture in the index by Twb (Thom, 1959; Bianca, 1962; National Research Council, 1971); others use Tdp (National Research Council, 1971); Yousef, (1985) or RH (National Research Council, 1971). However, none of the indices has been designed specifically for Holstein cows milking in field conditions.

The impact of heat stress on production of cows is alleviated in many dairies by some kind of heat abatement system such as shades, fans, fog misters, and sprinklers. These systems differ in efficacy of cooling and thus create variation in thermal conditions to which cows are exposed (Ryan, *et al;* 1992). Thermal relief provided by those devices differs significantly between climatic regions.

2.1.3 Breeds

In the United States, David, (2004) observed that dairy cattle are divided into six major breeds. These are the: Holstein-Friesian, Brown Swiss, Guernsey, Ayrshire, Jersey, and Milking Shorthorn. In Rajasthan, David, (2004) also observed that an indigenous breed called Tharparkar exists, named from the Tharparkar District, now in Sindh Pakistan. Another type of dairy cow known as Nagauri from Nagaur District also exist. The bull of which is renowned for its ability to plow fields and run. Traditionally, they used to pull covered wagons, known as rath, and in marriages to transport the newlywed couple. They are now a crutch for thriving agricultural and livestock rearing societies of the Thar Desert.

2.1.4 Cow's Milk Production Levels

According to US Department of agriculture (2007), a cow will produce large amounts of milk over her lifetime. Certain breeds produce more milk than others; however, different breeds produce within a range of around 6,800 to 17,000 litres of milk per lactation. The average for a single dairy cow in the US in 2007 was 9164.4 litres per year, excluding milk consumed by her calves, whereas the same average value for a single cow in Israel was 12,240 litres in 2007. Hutgens and Mike, (1999) went further to say that production levels peak at around 40 to 60 days after calving, prior to the been. Production declines steadily afterwards, until at about 305 days after calving, the cow is 'dried off', and milking ceases. About sixty days later, one year after the birth of her previous calf, a cow will calve again. High production cows are more difficult to breed at a one year interval. Many farms take the view that 13 or even 14 month cycles are more appropriate for this type of cow Hutgens and Mike, (1999).

In a comprehensive analysis, Blaney and Don, (2002) revealed that dairy cows may continue to be economically productive for many lactations. In most cases, 10 lactations are possible. The chances of problems arising which may lead to a cow being culled are high, however; the average herd life of US Holstein is today fewer than 3 lactations. This requires more herd replacements to be reared or purchased. Furthermore, Blaney and Don, (2002) investigated that over 90% of dairy cows are culled for 4 main reasons:

I. **Infertility** – This is the failure of a cow to conceive and reduced milk production. Cows are at their most fertile between 60 and 80 days after calving. Cows remaining "open" (not with calf) after this period become increasingly difficult to breed, which may be due to poor health. Failure to

expel the afterbirth from a previous pregnancy, luteal cysts, or metritis, an infection of the uterus, are common causes of infertility.

II. **Mastitis** – This is a persistent and potentially fatal mammary gland infection, leading to high somatic cell counts and loss of production.

Mastitis is recognized by a reddening and swelling of the infected quarter of the udder and the presence of whitish clots or pus in the milk. Treatment is possible with long-acting antibiotics but milk from such cows is not marketable until drug residues have left the cow's system, also called withdrawal period.

III. **Lameness** – This is a persistent foot infection or leg problems causing infertility and loss of production. High feed levels of highly digestible carbohydrate cause acidic conditions in the cow's rumen. This leads to Laminitis and subsequent lameness, leaving the cow vulnerable to other foot infections and problems which may be exacerbated by standing in faeces or water logged areas.

IV. **Production** – It has been revealed that some animals fail to produce economic levels of milk to justify their feed costs. Knaus, (2009) reported that production below 12 to 15 liters of milk per day is not economically viable. According to Knaus (2009), Cow longevity is strongly correlated with production levels. Low producing cows live longer than high production cows, but may be less profitable. According to Blaney and Don (2002) the stress to which the cow is faced with should affect milk production.

2.1.5 Reproduction

Since the 1950s, artificial insemination (AI) is used in most dairy farms. Advantages of using AI include its low cost and ease compared to maintaining a bull, ability to select from a large number of bulls to match the anticipated market for the resulting calves, and predictable results. Rupam (2010) carried out a study on embryo transfer in dairy cows and reported that embryo transfer enable the multiplication of progeny from elite cows. These embryos are then 'flushed' from the cow's uterus. 7-12 embryos are consequently removed from these donor cows and transferred into other cows who serve as surrogate mothers. The result showed that between 3 and 6 calves were produced instead of the normal single, or rarely, twins.

2.1.5.1 Hormone Use

Hormone treatments are sometimes given to dairy cows in some countries to increase reproduction and to increase milk production. According to a report from the Department of Dairy and Animal Science (2009), the hormones used to produce multiple embryos, are administered at specific times to dairy cattle to induce ovulation. Frequently, for economic considerations, these drugs are also used to synchronise a group of cows to ovulate simultaneously. The hormones Prostaglandin, Gonadotropin Releasing Hormone, and Progesterone are used for this purpose and sold under the brand names Lutalyse, Cystorelin, Estrumate, Estroplan,Factrel, Prostamate, Fertagyl, Insynch, and Ovacyst. The drugs may be administered by injection.

The U.S. Food and Drug Administration (FDA) in 2007 revealed that about 17% of dairy cows in the United States are injected with Bovine Somatotropin also called Recombinant Bovine Somatotropin (rBST), Recombinant Bovine Growth Hormone (rBGH), or artificial growth hormone. The use of this hormone increases milk production from 11%-25%, but also increases the likelihood of cattle developing mastitis, reduction in fertility and

lameness. The U.S. Food and Drug Administration (FDA) in 2007, ruled that rBST is harmless to people. Today, the use of rBST is banned in Canada, parts of the European Union, Australia and New Zealand.

2.1.5.2 Nutrition

Nutrition according to Blaney and Don (2002) plays an important role in keeping cattle healthy and strong. Forages, which refer especially to hay or straw, are the most common type of feed used. Cereal grains, as the main contributors of starch to diets, are important in meeting the energy needs of dairy cattle. Maize is one example of grain that is extensively used around the world. According to Blaney and Don, (2002) Maize is grown in temperate to subarctic climates, and it is transported to those areas lacking the necessary amounts of grain. Although, Dewey (2011) revealed that variations may occur, but in general, Maize is an excellent source of balanced amounts of protein, energy, and fibre.

Ensuring adequate body fat reserves is essential for cattle to produce milk and also to keep reproductive efficiency. However, Richard (2011) discovered that if cattle get excessively fat or too thin, they run the risk of developing metabolic problems and may have problem with calving. Today Scientists have found that a variety of fat supplements can benefit conception rates of lactating dairy cows. Some of these different fats according to Rupam (2010) include oleic acids, found in canola oil, animal tallow, and yellow grease; palmitic acid found in granular fats and dry fats; and linolenic acids which are found in cottonseed, safflower, sunflower, and soybean. It is also important to note that proper levels of fat also improve cattle longevity.

2.1.6 Signs of Heat Stress in Dairy Cattle

McDowell and Hooven, (1976) identified some of the signs of heat stress shown by dairy cattle. Some of these signs are;

i. Restlessness

ii. Crowding under shade or at water tanks

iii. Panting (open-mouthed breathing)

iv. Increased salivation

v. Increased respiration rate (gasping):

- ✓ 80 to 120 breaths per minute moderate heat stress
- ✓ 120 to 160 breaths per minute strong heat stress
- ✓ Over 160 breaths per minute severe heat stress.

vi. Rates of gut and ruminal motility are reduced.

vii. Lethargy

viii. Decreased activity Reduced feed intake:

Under continuous heat stress, lactating cows begin to show a decline in the intake at 25-27°C

ix. Increased sweating

In dairy cows two types of sweating can be distinguished: both of which are involved in heat dissipation: The first type is insensible sweating or perspiration that leaves the body at all times, unless the relative humidity is 100 %. The other type, thermal sweating, occurs as the principle evaporative cooling mechanism of the cow when the ambient temperature rises.

x. Rise of rectal temperature

Rectal temperature is an indicator of thermal balance and may be used to assess the adversity of the thermal environment. In severe cases of heat stress the rectal temperature rise. The effect is increased when the relative humidity is greater than 50%. A rise of 1°C or less is enough to reduce performance in most livestock species (McDowell, Hooven, 1976).

xi. Reduced heart beat

Initial increase in heart beat slows down when the heat stress persists. Reduced heart beat is more typical in heat-stressed cows as it is associated with the reduced rate of heat production as a response to high environmental temperatures.

xii. Declined feed intake

Feed intake in lactating cows begins to decline at the ambient temperatures of 25-26 °C and drops more rapidly above 30 °C. At 40°C, dietary intake may decline by as much as 40% (National Research Council, 1989). Heat stress in high producing lactating dairy cows results in considerable reductions in roughage intake and rumination. The reduction in appetite under heat stress is a result of elevated body temperature and may be related to gut fill (Silanikove, 1992).

xiii. Increased Water Intake

According to McDowell and Hooven, (1976) heat stress increases water consumption by at least five times the normal level in temperate zones. Water and macro-mineral needs, influenced heavily by demands to maintain homeostasis and homeothermy, are altered for lactating dairy cows during heat stress. Milk is about 87% water, and contains large concentrations of the electrolytes Na, K, and CI. Therefore, lactating dairy cows have large turnover of water and these electrolytes.

xiv. Drop in Daily Milk Production and Composition

It is accepted that heat stress is the major cause of reduced production in dairy cattle in hostile regions. Silanikove (1992) reported that decline in the

production of milk and fat is a direct result of high environmental temperatures which may be explained by the negative effects the heat stress has on the secretary function of the udder. Kadzere (2002) suggested that milk production is reduced by 15%, accompanied by a 35% decrease in the efficiency of energy utilization for productive purposes when a lactating Holstein cow is transferred from an air temperature of 18 to 30 °C. Milk fat, solids-not-fat, and milk protein percentage decreased 39.7, 18.9 and 16.9% respectively.

xv. Metabolic Responses

Kadzere, (2002) reported that under heat stress, metabolism is reduced, which is associated with reduced thyroid hormone secretion and gut motility, resulting in increased gut fill. Plasma growth hormone concentration and secretion rate declines during hot temperature (35°C). Ruminal pH is typically lower in heat stressed cattle (Kadzere, 2002). There are also great changes in dietary electrolyte balance and acid/base balance associated with heat stress. The major electrolytes involved in dietary electrolyte balance are Na*, K*, CL and the buffer $HC0_3$. S" is not considered so critical in the equation of dairy cattle. Na*, K*, CL are the main ions involved in sweat (Kadzere, 2002).

2.1.7 Effects of Heat Stress on Dairy Cows

The effects of heat stress according to Hansen, (1994) have proven to be a great hindrance to the efficiency and productivity of cattle, especially dairy cattle. Dairy cattle are more susceptible to heat stress because of their selective inherited ability to ingest vast quantities of dry matter, thus producing greater metabolic heat from rumen fermentation as well as from the process of milk production. Older; heavier, higher-producing cows are most susceptible to heat stress. Bucklin and Hahn, (1991) also reported that during periods of thermal stress cows are unable to dissipate the additional metabolic heat produced, especially

in areas of high humidity. As a result cows voluntarily reduce dry matter intake, thus limiting milk production. Reproduction also suffers as a result of thermal stress on folliculogenesis and oocyte maturation as well as embryonic development and survival. The decrease in productivity and negative reproductive effects render periods of heat stress, and those periods following, less profitable for dairy operations, making heat stress abatement practices cost effective and advantageous. Heat stress brings many challenges (Thatcher and Collier, 1986), but with proper facilities and management heat stress can be alleviated to an acceptable level.

2.1.7.1Effects of Heat Stress on Dietary Electrolyte Balance:

Some of the effects of heat stress on dietary electrolyte balance in dairy cows as enumerated by Thatcher and Collier, (1986) are:

i. Appetite is depressed, there is some indigestibility of feed and gut motility is slowed
ii. Milk yield - at 35°C there is up to 33% depression and at 40°C, as much as 50%.
iii. Loss in milk quality - fat and protein content declines
iv. Loss in body weight
v. Incidence of milk fever increases
vi. Uterine prolapse is more common
vii. Mammary gland infections increase
viii. Uterine infections increase
ix. Fertility is lowered-insemination success rate falls, embryo mortality increases
x. Calves are often premature and small
xi. Growing animals have markedly reduced weight gains

xii. Drinking water intake increases

xiii. Nutrient deficiencies occur in marginally adequate diets (RCI Heat stress in dairy cattle).

2.1.7.2 Water Metabolism

Silanikove (1992) report that the total body water is estimated to range between 75 and 81% of the body weight for lactating dairy cows, and that temperature is among the most important environmental factors controlling water intake in lactating dairy cows. Heat stress simultaneously influences both energy and water metabolism. Under thermal stress, cows tend to have increased water content in the rumen as a result of an accelerated water turnover rate (Silanikove, 1992). Water loss from an animal is a continuous process taking place all the time and increasing during the heat stress because of additional evaporative water loss. Water intake of a dairy cow under heat stress increases significantly.

2.1.7.3Thermoregulation Physiology

All mammals are homeotherm that is they must maintain a constant body temperature of an acceptable level (Hansen, Thatcher, 1994). The normal body temperature in cattle ranges from (24- 26°C) but cold and heat stress can result in an inability of dairy cows to maintain this constant body temperature causing animal health, productivity and efficiency to suffer (Hansen, Thatcher, 1994). The mammalian body is set up to constantly regulate peripheral and internal body temperatures with the assistance of cutaneous sensors and internal temperature sensors (located in the hypothalamus) along with integration of the endocrine system. Robertshaw, (1985) in a study of heat stress in cattle discovered that cattle utilize their respiratory systems to dissipate heat by evaporation. Cattle pant with their mouths closed so heat exchange occurs from the nasal mucosa of the upper respiratory tract near the turbinale hones. The heat is provided by the blood supply to the nasal mucosa and the cool blood drains into the venous sinuses at the skull base, where it joins venous drainage

of the ears and poll. The rete mirabile, a network of small arteries that make up the blood supply to the brain base, functions as a countercurrent heat exchanger with blood supplying the brain being cooled by blood draining the nasal mucosa, the ears, and the poll (Robertshaw, 1985).

All signals received by the Peripheral Nervous System (PNS) according to Bligh, (1985) are relayed to the Central Nervous System (CNS) for processing. Processing of this information occurs in the thermoregulatory region of the hypothalamus in the brain. Through constant monitoring, information is received and processed in the thermoregulatory center and appropriate physiologic and metabolic modifications occur as a result. The Central Nervous System (CNS) integrates and involves the cardiovascular, respiratory, digestive, and endocrine systems in the heat regulatory process. Through changes in these systems heat loss or gain can be regulated accordingly.

Hansen, (1994) came up with a simple formula that could be used to sum up animals body temperature as shown below:

Body Temp= Metabolic Heat ± Conduction ± Convection ± Radiation + Evaporation

According to Hansen, (1994) for a cow to maintain a constant temperature, heat production has to equal heat loss. Although, this concept is complicated by several factors, including environmental temperature and humidity. This can be represented in the simple equations:

Heat Loss = Heat Produced + Environmental Heat, and heat stress results when: HS= (HP + EH) > HL. Animals are most comfortable, productive, and efficient existing in a temperature range known as the Thermoneutral Zone (Hansen, 1994).

Bucklin, (1992) reported that animals are most comfortable, productive, and efficient while existing in a temperature range known as the Thermoneutral Zone (TNZ). The Thermoneutral Zone (TNZ) is considered the range of ambient temperature within which the metabolic rate is at a minimum, and within which temperature regulation is achieved by non-evaporative physical processes alone, aided by autonomic nervous control and behavioral responses. Disregarding humidity, Jacobsen, (1996) proposed that Thermoneutral Zone (TNZ) of cattle will be between 16-25°C. When temperatures therefore exceed the upper limits of the Thermoneutral Zone (TNZ) milk production, reproduction, and overall health suffer.

Several mathematical formulas have been developed to estimate the effects of heat stress on cattle. The most commonly used formula according to Yousef, (1985) is;

$$Tdb - <0.55-(0.55*RH/100)*(T_db-58)$$

Where Tdb = dry bulb temperature in °F and

RH = relative humidity.

This formula utilizes temperature (T) measurement along with an account for humidity using the dew point temperature (Tdp). When the THI is above 72 heat stress occurs.

Bray, Beede, Bucklin and Hahn, (1992) showed that the body temperature of cattle lags behind ambient air temperature by 2 to 5 hrs. Many complex mathematical formulas also exist to estimate the effects of heat on cattle, but regardless of environmental variables a cow's body temperature (rectal or core) is the best indicator of the physiologic response to Heat stress.

2.1.7.4 Nutritional and Dietary Effects of heat stress

Water is considered the most important nutrient during periods of Heat stress (Beede, 1992). Water's high heat capacity provides a thermal buffer by conserving body heat in cold climates and conserving body water in warmer climates. Beede, (1992) reported that milk is approximately 87% water, and inadequate water supply will decrease milk production more rapidly and dramatically than any other nutritional factor. Water intake can also increase by nearly 33% during Heat stress.

2.1.8 Mechanisms of Heat Exchange

Heat exchange with the environment occurs basically through four ways namely: conduction, convection, radiation and evaporation (Fuquay, 1981).

The first is conduction, which occurs when heat is transferred through direct contact with material. The second is convection, which occurs by transfer of heat to surrounding air. Convection is greatly limited by high ambient air temperatures. Radiation is the third method of heat exchange and likely the most important for cattle residing in sub-tropical and tropical climates. Research by Fuquay, (1981) has concluded that black cows absorb more than twice the solar radiation as white cows.

During periods of heat stress, there is generally a net heat gain from radiation in the daytime and a net heat loss from radiation at night with the animal radiating to its relatively cooler surroundings. Facilities should be designed with this in mind. It is thought that cooling cows continuously throughout the day is more beneficial than only cooling during the daylight hours. The fourth and final means of heat exchange is evaporation, which occurs during sweating, panting and when cows are wet. Evaporation allows for the conversion of water from a liquid phase to a vapour or gaseous phase, thus transferring heat from the cow's

body to the surrounding air with the evaporating water. As the ambient temperature rises, evaporative heat loss becomes the major avenue of heat loss because it is not dependent on the thermal gradient, as are conduction and convection.

Environmental factors also have great influence on the ability of a cow to exchange heat with the surroundings (Gebremedhin, 1985). For example, clouds and dust particles in the air as well as grass on the ground can affect heat exchange. Hair coat also has a profound influence on ability to dissipate heat.

2.1.9 Animal Responses to Heat Stress

2.1.9.1 Behavioural Responses

One of the most discussed behavioural responses to heat load is reduced feed intake. For example, a study conducted by Ominiski and Colleagues (2002), where cows were exposed to heat stress in an environmental chamber showed that feed intake was reduced by 3.1 1bs/d, or approximately 5%/d. This change also resulted in a 3.81b reduction in milk yield. Extensively managed cattle also changed grazing times and patterns to cope with heat load. Moreover, Kendall (2006) found that shaded cows used shade during the day and grazed more at the night compared to unshaded cows.

A less discussed change in behavior associated with heat load is an increase in time spent standing (Overton, 2002). Tucker, (2008), found that time spent standing increased by 10% (13 – 15 h/d) when heat load increased by 15% (THI=60-70). Tucker (2008) opined that the cows spend more time standing to increase heat loss by increasing the amount of skin exposed to air flow or wind.

2.1.9.2 Recognizing Heat Stress

Pictured below are cattle displaying increasing levels of heat stress. A description of typical behaviours is associated with each level. Vulnerable animals will show stress symptoms early. Varying stages of stress will be evident throughout the herd as environmental conditions become more intense (Gaughan, et al; 2000). As more animals display signs of increasing heat stress, action should be taken.



Plate 1. Dairy cow exhibiting sign of heat stress.

Armstrong, (1994) discovered that cattle in some areas especially local breeds, have adapted to heat stress with physiologic changes and behavioral responses. Behavioral responses exhibited are seeking out shade, reducing Dry Matter Intake (DMI), increasing water intake, standing rather than lying down, and bathing in ponds or mud. Heat stressed

cattle therefore tend to have increased body temperatures (core and rectal). As a result of Heat stress cattle decrease dry matter intake (DMI) and increase water intake.

Respiration and sweating, according to Bligh, (1985) are both increased in cattle under heat stress. During this period, the skin and respiratory tract of cattle have great capacity to dissipate heat by evaporation, through sweating and panting, respectively. Increased respiratory rates consequently increase daily maintenance energy requirements by 7-25%. Respiratory changes due to heat stress in cattle are also characterized by increased rates and tidal volumes (dead space ventilation), thus increasing evaporative effectiveness, but also results in rapid loss of carbon dioxide leading to respiratory alkalosis(Hansen, 1994).

Cattle compensate for respiratory alkalosis by increasing urinary excretion of bicarbonate (Hansen, 1994). Salivary bicarbonate is also lost, by drooling secondary to panting, thereby decreasing bicarbonate for ruminal buffering. Reduced rumen pH, leading to ruminal acidosis, along with increased standing increase the risk of developing laminits (Hansen, 1994). Bligh, (1985) observed that cows likely stand more during heat stress because it is easier to pant standing rather than lying. Blood flow is also re-directed from internal systems to the peripheral integumentary system.

Most mammalian cells possess the capability to produce what are known as heat shock proteins (HSP) and antioxidants in response to thermal stress, thereby limiting the damaging effects of heat stress (Hansen, 1994). T3 and T4 (thyroxine and tri-iodothyronine) levels decrease to lower heat production, assist in acclimation, and lower dry matter intake. According to Rebhun, (1995) these decreases have negative effects on mammary development and lactogenesis, as well as, likely negative reproductive effects.

2.2 Literature Review

Majority of studies on heat stress in livestock have focused mainly on temperature and relative humidity (Igono, 1985; Igono and Johnson, 1990; Ravagnolo and Misztal, 2000; Bouraoui, *et al*; 2002; St-Pierre, Cobanov and Schnitkey, 2003; West, 2003; Correa-Calderron, Armstrong and Ray, 2004), because data on the amount of thermal radiation received by the animal, wind speed, and rainfall are not publicly available. On the other hand, temperature and humidity records can be usually obtained from a meteorological station located nearby.

2.2.1 Measurement of Heat Stress

2.2.1.1 Temperature-Humidity Index (THI)

Temperature humidity index (THI) is a mathematical formula based on dry bulb temperature and humidity that is used as an estimate of the magnitude of heat stress affecting a cow and to determine when cows would begin to show the symptoms of heat stress (Kibbler, 1964). The most commonly used THI is calculated as follows:

$$Tdb - <0.55-(0.55*RH/100)*(T_db-58)$$

Where Tdb = dry bulb temperature in °F and

RH = relative humidity.

In line with the formula above, Zimbelman, (2009) estimated that milk yield starts to decline when cows are exposed to a minimum THI of 65 or greater. Thus, the author recommended that cooling should be initiated at average THI of 68 to minimize loss of milk due to heat stress. Ravagnolo and Misztal, (2000) reported that milk yield decreased when average THI was 70 or above, and that milk yield was affected by heat stress at a THI lower than the

value of 72, commonly considered as a threshold for heat stress. Ravagnolo and Misztal, (2002) through analysis of non-return rate at 45 days after insemination indicated that heat stress became detrimental at a THI above 70.

A study conducted by Ominiski and Colleagues (2002), where cows were exposed to heat stress in an environmental chamber showed that feed intake was reduced by 3.1 1bs/d, or approximately 5%/d. This change also resulted in a 3.81b reduction in milk yield. Extensively managed cattle also changed grazing times and patterns to cope with heat load. Moreover, Kendall (2006) found that shaded cows used shade during the day and grazed more at the night compared to unshaded cows.

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2.2.1.2 Body Temperature

The accuracy of Temperature humidity index (THI) for estimating the magnitude of heat stress is limited by the fact that THI is not greatly affected by the amount of shade, forced ventilation, and evaporative cooling provided to cows (Kilbber, 1964).

Kilbber, (1964) had observed that average body temperatures of cows did not go above normal until cows experienced dry bulb temperatures and THI well above those usually considered as being characteristic of heat stress (65-72). Probably, cows were cooled more than the THI indicated and -were also somewhat adapted to heat stress because they were exposed to it chronically. To overcome the discrepancy, Ravagnolo and Misztal, (2000) developed a chart

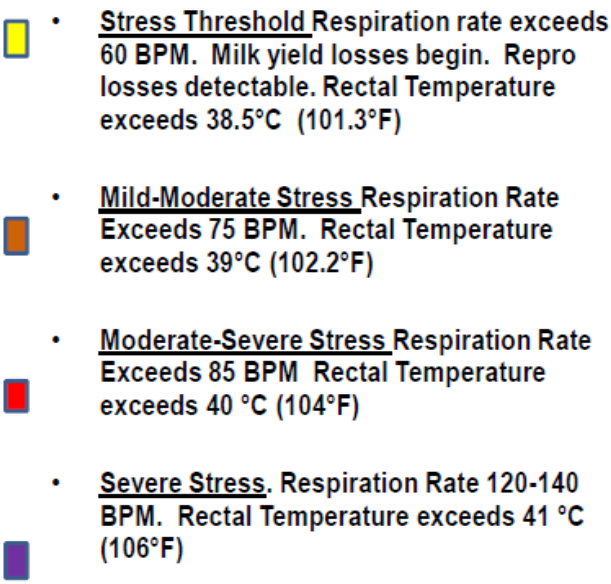
that expressed the intensity of heat stress as a function of temperature and relative humidity. Based on entire analysis of the data, they summarized that a THI of ≥ 72 was when adverse effects of heat stress are seen. There results indicate that a daily THI equal to 68 results in a milk loss of 2.2 litres/day for each 24 hours.

Since THI is often based on retrospective analysis of data, Bernabucci, *et al*; (2010) in their study categorised the effects of THI into mild, moderate and severe as shown in Figure 2.9.

Themperature		% Relative Humidity																				
°F	°C	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
72	22.0	64	65	65	65	66	66	67	67	67	68	68	69	69	69	70	70	70	71	71	72	72
73	23.0	65	65	66	66	66	67	67	68	68	68	69	69	70	70	71	71	71	72	72	73	73
74	23.5	65	66	66	67	67	67	68	68	69	69	70	70	70	71	71	72	72	73	73	74	74
75	24.0	66	66	67	67	68	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75
76	24.5	66	67	67	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75	76	76
77	25.0	67	67	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75	76	76	77
78	25.5	67	68	68	69	69	70	70	71	71	72	73	73	74	74	75	75	76	76	77	77	78
79	26.0	67	68	69	69	70	70	71	71	72	73	73	74	74	75	76	76	77	77	78	78	79
80	26.5	68	69	69	70	70	71	72	72	73	73	74	75	75	76	76	77	78	78	79	79	80
81	27.0	68	69	70	70	71	72	72	73	73	74	75	75	76	77	77	78	78	79	80	80	81
82	28.0	69	69	70	71	71	72	73	73	74	75	75	76	77	77	78	79	79	80	81	81	82
83	28.5	69	70	71	71	72	73	73	74	75	75	76	77	78	78	79	80	80	81	82	82	83
84	29.0	70	70	71	72	73	73	74	75	75	76	77	78	78	79	80	80	81	82	83	83	84
85	29.5	70	71	72	72	73	74	75	75	76	77	78	78	79	80	81	81	82	83	84	84	85
86	30.0	71	71	72	73	74	74	75	76	77	78	78	79	80	81	81	82	83	84	84	85	86
87	30.5	71	72	73	73	74	75	76	77	77	78	79	80	81	81	82	83	84	85	85	86	87
88	31.0	72	72	73	74	75	76	76	77	78	79	80	81	81	82	83	84	85	86	86	87	88
89	31.5	72	73	74	75	75	76	77	78	79	80	80	81	82	83	84	85	86	86	87	88	89
90	32.0	72	73	74	75	76	77	78	79	79	80	81	82	83	84	85	86	86	87	88	89	90
91	33.0	73	74	75	76	76	77	78	79	80	81	82	83	84	85	86	86	87	88	89	90	91
92	33.5	73	74	75	76	77	78	79	80	81	82	83	84	85	85	86	87	88	89	90	91	92
93	34.0	74	75	76	77	78	79	80	80	81	82	83	85	85	86	87	88	89	90	91	92	93
94	34.5	74	75	76	77	78	79	80	81	82	83	84	86	86	87	88	89	90	91	92	93	94
95	35.0	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
96	35.5	75	76	77	78	79	80	81	82	83	85	86	87	88	89	90	91	92	93	94	95	96
97	36.0	76	77	78	79	80	81	82	83	84	85	86	87	88	89	91	92	93	94	95	96	97
98	36.5	76	77	78	80	80	82	83	83	85	86	87	88	89	90	91	92	93	94	95	96	98
99	37.0	76	78	79	80	81	82	83	84	85	87	88	89	90	91	92	93	94	95	96	98	99
100	38.0	77	78	79	81	82	83	84	85	86	87	88	90	91	92	93	94	95	96	98	99	100
101	38.5	77	79	80	81	82	83	84	86	87	88	89	90	92	93	94	95	96	98	99	100	101
102	39.0	78	79	80	82	83	84	85	86	87	89	90	91	92	94	95	96	97	98	100	101	102
103	39.5	78	79	81	82	83	84	86	87	88	89	91	92	93	94	96	97	98	99	101	102	103
104	40.0	79	80	81	83	84	85	86	88	89	90	91	93	94	95	96	98	99	100	101	103	104
105	40.5	79	80	82	83	84	86	87	88	89	91	92	93	95	96	97	99	100	101	102	103	105
106	41.0	80	81	82	84	85	87	88	89	90	91	93	94	95	97	98	99	101	102	103	104	106
107	41.5	80	81	83	84	85	87	88	89	91	92	94	95	96	98	99	100	102	103	104	106	107
108	42.0	81	82	83	85	86	88	89	90	92	93	94	96	97	98	100	101	103	104	105	107	108
109	43.0	81	82	84	85	87	89	89	91	92	94	95	96	98	99	101	102	103	105	106	108	109
110	43.5	81	83	84	86	87	89	90	91	93	94	96	97	99	100	101	103	104	106	107	109	110
111	44.0	82	83	85	86	88	90	91	92	94	95	96	98	99	101	102	104	105	107	108	110	111
112	44.5	82	84	85	87	88	90	91	93	94	96	97	99	100	102	103	105	106	108	109	111	112
113	45.0	83	84	86	87	89	91	92	93	95	96	98	99	101	102	104	105	107	108	110	111	113
114	45.5	83	85	86	88	89	92	92	94	96	97	99	100	102	103	105	106	108	109	111	112	114
115	46.0	84	85	87	88	90	92	93	95	96	98	99	101	102	104	106	107	109	110	112	113	115
116	46.5	84	86	87	89	90	93	94	95	97	98	100	102	103	105	106	108	110	111	113	114	116
117	47.0	85	86	88	89	91	93	94	96	98	99	101	102	104	106	107	109	111	112	114	115	117
118	48.0	85	87	88	90	92	94	95	97	98	100	102	103	105	106	108	110	111	113	115	116	118
119	48.5	85	87	89	90	92	94	96	97	99	101	102	104	106	107	109	111	112	114	116	117	119
120	49.0	86	88	89	91	93	95	96	98	100	101	103	105	106	108	110	111	113	115	117	118	120

Fig 2.1: Revised temperature humidity index for lactating dairy cows

Source: Ravagnolo and Misztal (2000)



Majority of studies published on effects of climate on milk composition and yield have been on the evaluation effects of temperature. However, cattle have been shown to be sensitive to heat stress because of the high metabolic heat production and feed intake associated with rumen fermentation and milk yield. Likewise, for the same reasons, dairy cattle are relatively resistant to cold stress (Berman and Wolfensen, 2005). Berman and Wolfensen, (2005) also pointed out that heat stress in cattle is characterized by increased rectal temperature, elevated respiration rates and decreased feed intake which contributes to the decreased milk yield. They discovered that the environmental temperature range from -5 to 23.9ºC has little impact on milk yield and composition and is referred to as the thermoneutral zone for the lactating dairy cow. However, temperatures above 23.9ºC are known to decrease solids-not-fat (SNF), protein, lactose and fat percentage of milk.

Tucker, (2008) in an experiment, compared the behavior and body temperature of dairy cows when they had no access to shade or free access to shade that blocked 25, 50 or 99% of solar radiation and reported that as average ambient solar radiation increased, total

use of the shade structures increased. Cows with more protection from solar radiation had lower minimum body temperature.

Collier *et al*., (1981); and Spiers *et al*., (2004) indicated that the effects of a given temperature on milk production are maximal between 24 and 48 hours following heat stress. It has also been reported that ambient weather conditions two days prior to milk yield measurement had the greatest correlation to decreases in milk production and dry matter intake (West et al., 2003). It has been shown that the total number of hours when THI is greater than 72 or 80 over a 4-day interval had the highest correlation with milk yield (Linville and Pardue, 1992). Thus avoiding a decline in milk production over a 48-hour period will automatically prevent a decrease in lactation persistency two weeks later (Linville and Pardue, 1992). Utilizing the THI in order to reduce milk production losses has been effective; however the current THI is in need of updating an appropriate time scale with data from higher producing animals. The pattern of stress application is a final component of the THI to be considered (Linville and Pardue, 1992).

Holter *et al*., (1996) reported that minimum THI is more highly correlated with a reduction in feed intake compared to maximum THI:- evaluating test day, milk yields results showed a decrease of 0.2 kg per unit of THI increase above 72 when THI was composed of maximum temperature and minimum humidity.

CHAPTER THREE: STUDY AREA AND METHODOLOGY

3.1 Physiography of the Study Area

3.1.1 Location

The study area "NAPRI" is located 22 kilometres North-West of Zaria along the Zaria- Sokoto road. It lies between 11^{o} 11'N and11^{o} 14 'N and longitude 7^{o} 32'E and 7^{o}36'E (Fig 3.1). The study area is located in Zaria, Kaduna State, Nigeria. Zaria is one of the provinces that make up the Central high plains of Northern Nigeria and it is approximately 670m above mean sea level. NAPRI occupies about 1,150 hectares of land and is located in the Galma plains named after River Galma, of which Shika River is a minor tributary .This stream forms the eastern boundary of the station and flows in northerly direction.

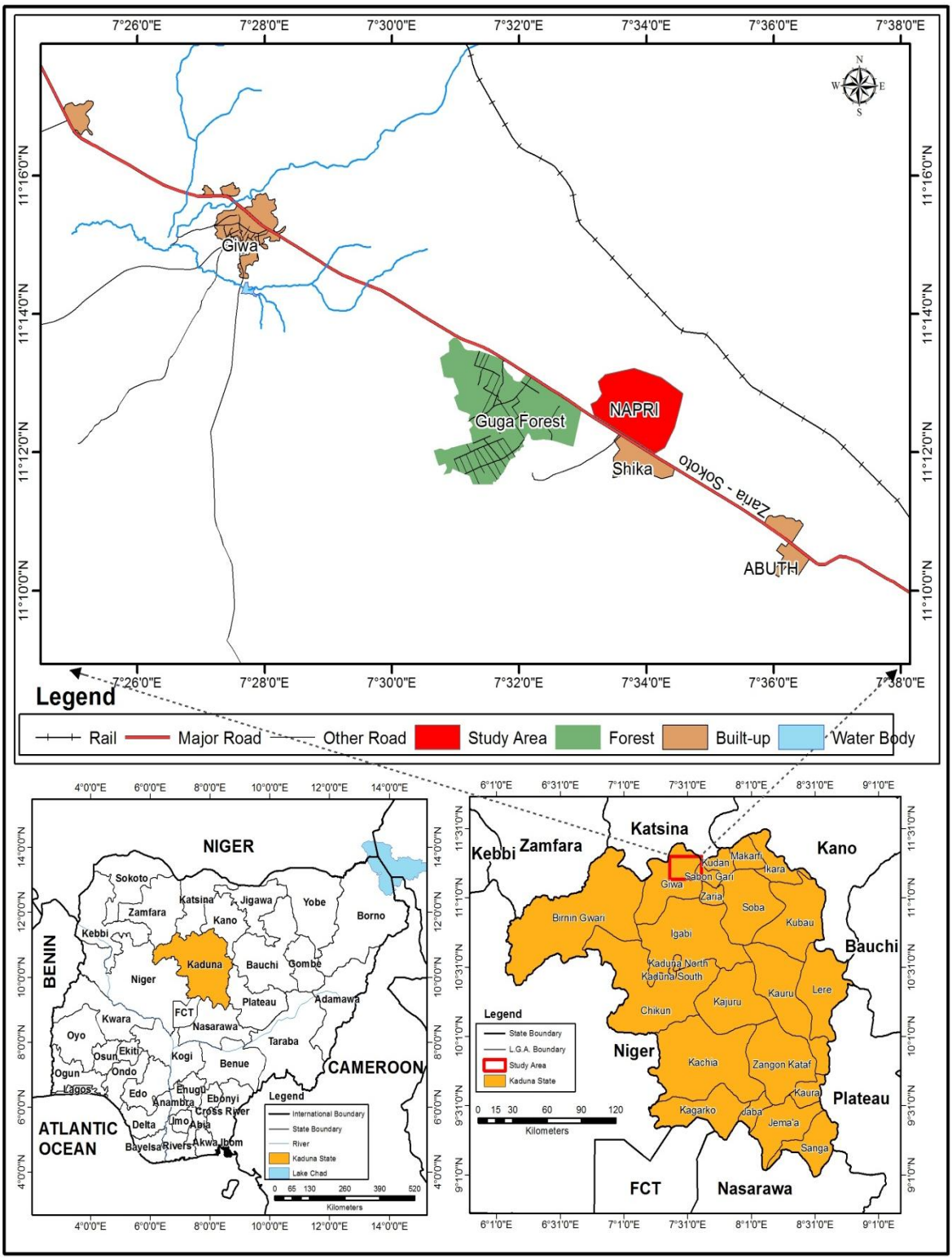


Fig 3.1: The Study Area

Source: Adopted From Administrative Map of Kaduna State

3.1.2 Climate

According to the Thonthwaite's Scheme, the climate of Zaria is the dry sub-humid type (Ogbaji, 2006). The gross features of rainfall pattern in this region, as in other

parts of Nigeria are usually in association with what is often called the inter-tropical discontinuity (ITD) (Nicholson, 1981; Kanote, 1984; Hayward and Oguntoyrnbo, 1987; Oladipo, 1993). The ITD itself is the boundary at the ground between the dry tropical continental (cT) air of northern origin and the cool moist tropical maritime (mT) air of southern origin. These two air masses pass through and are responsible for the seasonal changes in Zaria climate. Sticky hot weather conditions prevail during the northward movement of the ITD because of small diurnal temperature range, high relative humidity with little or scanty showers of rainfall, in the southward movement is associated with dry and cold weather condition because of great diurnal temperature range and low relative humidity with no rainfall (Ogbaji, 2006).

On the basis of these two air masses and their subsequent weather, the year in Zaria is divided into four climatic seasons (Ogbaji, 2006):

i. Dry season ("winter" and harmattan) November – February
ii. Hot season (March to April)
iii. Thunderstorm and rainy season (May to June)
iv. Wet season (July to October).

These are however broadly classified as wet and *dry* seasons. The wet season, lasting from May to October and the dry season, lasing from October to March (Ogbaji, 2006).

The onset of the wet season in May begins with light showers once or twice and between May and June considerable thunderstorm occurs and the rains begin to get steadier. Between July and October the wet season proper comes on (Oshaji, 2000). While May marks the onset of the rain and the end of the hot season, October usually marks the end of the wet season and

the beginning of dry season. With the onset of .the wet season, the daily maximum temperature drops and the diurnal range of temperature becomes low. July and August in Zaria are the months of mildest weather (Oshaji, 2000). The diurnal range of temperatures during this period varies from 6.7°C to 9.4°C. The mean daily maximum temperature range in this period is about 26.7°C to 28.9°C. Cloudiness reaches maximum in August and consequently, the hours of sunshine are at the least. The average duration of sunshine in August varies from 3 to 6 hours. The relative humidity is very high in August (about 70-80 percent (Hore, 1970).

The daily minimum temperature at the beginning of the dry season drops more rapidly than the maximum. Consequently, the diurnal range of temperatures increases rapidly. The sky is mostly clear in November which permits longer hours of sunshine. In early November, morning and nights become cooler and pleasant. Dust haze begins to appear and increases in frequency as the harmattan wind is being introduced. In December to January, the haze and dust layer of the harmattan sometimes creates poor visibility (Hore, 1970).

3.1.3 Relief and Drainage

The study area lies on a Plain land ranging in height from 550-750m. This plain is being drained by River Kubani with its numerous tributaries. This river becomes heavily flooded during the rains and dries up during the dry season. Alluvial soils which occur along this river are used for dry season farming. There are no major high surfaces or inselberges but there are some marshy surfaces and rivers. River Kubani which formed the main focus of the drainage system is a tributary of Galma River which has water throughout the year while River Kubani dries up in the period between January and June (Mortimore and Wilson, 1965).

Zaria is situated on a Plian which is part of the extensive gentle rolling peneplain which extends from Sokoto to Lake Chad, and northwards from south of Kaduna to Tigueddi

Scarp near Agades (Niger Repulic) This embraces most of northern Nigeria and has been correlated with the mid-tertiary African planation surfaces, recognized in other parts of the continent. The plain, which is generally undulating, varies in altitude from about 550km to 740km above the sea level and is dotted with outcrops of rocky inselbergs, with the Kufena hill attaining a height of 820m and flat top lateritic ironstone capped residuals, the Kampagi hill, about 708m above sea level (Iguisi, 1996).

Valley side slopes exhibit a convex-concave form with few rectilinear elements (Ameh, 1966; Ojenya, 1989). Slope angles of the valley sides are generally low between 0.5^{o} and 45^{o}; although relatively steeper slopes have been observed especially adjacent to isolated residuals and erosional scarps (Abubakar, 1966; Bello, 1973). The characteristic slope angle of the valley side slopes is, however, 1^{o} -2^{o} (Ibrahim, 1986; Ojenya, 1986).

The drainage systems of Zaria focus mainly on River Galma. Except for Galma River, all streams in the area are seasonal, although the larger ones have surface water along stretches for much of the year. A very good example is the Kubanni River along Samaru (Mortimore and Wilson, 1965). Du preez and Barber (1965) remarked that the geology of the area gave rise to its characteristic dentritic drainage pattern in the south eastern portion, trellis in the northern portion, where, tributaries of Kubanni, enter the main River at right angle.Due to poor conservation and land use practices like extensive vegetation clearance for agricultural and urban development purposes, intensive grazing, livestock tracks and human footpaths criss-crossing the area, overland flow, rilling and gullying have become the dominant modes of rainwater disposal from the landscape (Ologe, 1971; 1972; Bello, 1973; Iguisi, 1996).

3.1.4 Geology

Zaria is primarily underlain by the Basement Complex Rocks. The region is an area within the Zaria plain, a dissected part of the Zaria - Kano portions, an extensive peneplain,

which had developed on crystalline metamorphic rock, and believed to be overlain by wind drift sediments.

Du preez and Barber, (1965) presented a fairly detailed description of the geology of Zaria region by classifying the basement complex rocks of Zaria into three principal groups:

(i) Younger metasediments found in a north-south trending belt. These younger metasediments include Quartzites (forming ridges), Schists and Phylites.

(ii) A re-mobilized older crystalline Basement Complex made up of Gneisses, Migmatites and ancient metasediments.

(iii) Granites and Granodiorites of late pre-cambrian to lower palaezoic age, which includes groups one and two above.

The geologic materials of the study area are composed mainly of fine-grained biotite gneiss and migmatites, with some coarse-grained granitic outcrops in a few places. The gneisses are moderately to weakly foliated, principally made up of quartz and oligoclase (Du preez and Barber, 1965).

Superficial deposits include young and old laterites, as well as young and old alluvium. Thorough and deep chemical weathering has developed thick lateritic regolith of varying degrees of induration. The laterites are different in morphological character and occur at different levels of the valley sideslope profiles. The massive and hardened laterites form older laterites (vermicular and vesicular types) and occur at high levels on the upland and close to the interfluves as mesas and buttes. As the older laterites are destroyed by erosion, the rubble is transferred to gentle sloping surface at lower levels where it undergoes re-concretion to form what has been described as younger laterites (Pullan, 1970; Ologe, 1972; and Bello, 1973).

The older alluvium is made up of brown to brownish red, fine to medium-grained, fairly indurated sands, clay and gravels. The younger alluvium which are mostly unconsolidated,

are made up of grey-brown sands, silts and clay. Ololobou (1982) observed an excellent site, which occurs about 0.5km upstream from the bridge along Zaria by-pass. Within the Kubanni basin, the presence of younger laterite with recent alluvial deposits along the river are prominent, there exists a crust belt occurring across the Kubanni basin with recent alluvial deposits along the dam impoundment.

3.1.5 Soil and Vegetation

The soil reflects the geology, climate and vegetation of the area. The soils of the area are the leached ferruginous tropical soils, which have well developed texture, B-horizon consisting 30-40 percent clay (Ipinmidun, 1972). The soils of these group are normally heavily worked, drainages being very poor on account of the high percentage of fine materials in the upper layers. It becomes waterlogged with rains and also cracks during rainy season. Alluvial soils occur especially along the rivers and streams (fadamas).

Along the fadamas are found hydromophic soils in the flood plains which allow for the cultivation of sugarcane, cassava, yam and coco-yam. The soil are generally hard to cultivate, hence it requires the use of heavy implements.

The vegetation of the area falls into the guinea savannah belt. Even though there has been so much felling of trees for fuel purposes and bush burning by hunters, there are still patches of savannah woodland with tress rising to heights of between 6-12 meters. There are also shrubs in the area characterized by varieties of grasses. The appearance of vegetation however, changes with season. This is because during the rainy season, the vegetation is usually fresh and green while in the dry season, they appear brownish yellow, looking withered and un-healthy (Rains, 1963; Ologe, 1971). The dominant species are the annual grasses interspaced with shrubs, herbs and deciduous trees.

3.2 Research Methodology

This section discusses the various methods that have been employed in gathering data for the study. This section also highlights the types of data, sources of data and the methods used in data analysis.

3.2.1 Data Types Used

Based on the scope of the study, aim and objectives, the types of data used for this research were as follows:

1. Daily temperature and relative humidity records for 10 years (2001-2010).
2. Daily milk yield (in litres) per cow for 10 years (2001-2010)

3.2.2 Sources of Data

All the data used for this research were of secondary source. Literature was obtained from secondary sources through the consultation of related books, journals, articles, information from the library research, conference papers, on-line publications, and other relevant materials.

3.2.3 Data Acquisition

Ten years (2001-2010) daily temperature and relative humidity data were obtained from the Institute for Agricultural Research (IAR) Meteorological Station, Ahmadu Bello University Zaria.

At the same time, available records on milk yield were collected from different Cows for ten years (in liters per day) from 2001 to 2010 from Dairy research programme herd office at NAPRI which were summed and their monthly averages obtained.

3.2.4 Data Analysis

A total of one hundred and twenty months records of temperature and relative humidity were sourced. Monthly averages of temperature and relative humidity were then derived for each month. After working out the mean temperature and relative humidity for each month, the records were used in finding the annual totals and averages, and

subsequently the mean and totals for the period of study. This made the whole data short and easy to manipulate.

Both descriptive and inferential statistics were used in analyzing the information obtained from the secondary data. Four techniques of data analysis were employed in this research to achieve each of the objectives stated.

Objective one: To characterize the climatic conditions to which dairy cows are exposed, the minimum and maximum mean monthly temperature, annual temperature and relative humidity of the area were computed using Microsoft Excel. Coefficient of variability was also used to determine the deference's between mean annual temperatures and mean annual relative humidity for the period of study. It was achieved using the formula;

$$\text{Coefficient of variability} = \sqrt{\frac{\sum(x_i - \bar{x})}{n-1}}$$

Where x_i = the values of temperature and relative humidity
$\bar{x}$ = mean of temperature and relative humidity
n = number of variables

Objective two: To examine the variation temperature. This was achieved using line graph.

Objective three: To examine the milk production level per cow and variation between cows. Milk production level per cow was achieved using simple bar graph while variation between cows was established using Multiple bar graph.

Objective four: To assess the temperature and seasons at which dairy cows start experiencing heat stress. This was achieved using multiple line graphs. Temperature and milk yield graphs were superimposed to determine the temperature and seasons at which dairy cows start experiencing heat stress.

Objective five: To examine the relationship between temperature, relative humidity and milk yield. Tables were used to present the mean monthly milk produced per cow in litres

and also the average mean monthly temperature and relative humidity for the period of study (2001-2010). Finally, multiple line graphs were used to show the relationship between average monthly temperature, relative humidity and average monthly milk yield in litres for the period of study.

Objective six: To assess the THI value at which cows are stressed. This was achieved using Temperature Humidity Index (THI). Temperature humidity index is a mathematical formula based on dry bulb thermometer and humidity which is used as an estimate of the magnitude of heat stress affecting a cow. Temperature humidity Index (THI) was calculated for all seasons (2001-2010), using the formula developed by Kibler (1964).

Temperature humidity index (THI) was calculated as follows.

$$THI = T_{db} - <0.55-(0.55*RH/100)*(T_{db}-58)$$

Where Tdb = dry bulb temperature in °F and

RH = Mean monthly relative humidity.

However, definitions of these levels and magnitude vary between indices and authors. For instance, Armstrong (1994) identified index below 71 as comfort zone, values ranging from 72 to 79 as mild stress, 80 to 89 moderate stress, and values above 90 as severe stress. But for the purpose of this research, THI values ranging below 65 are considered comfortable periods, while THI values ranging from 65 and above are termed dangerous periods.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Characterisation of Climatic Conditions of the Study Area

4.1.1 Mean Monthly Temperature

The mean monthly and mean annual temperature of the study area for the period under consideration (2001-2010) are presented in Table 4.1

Temperatures were lowest during the months of November, December and January, ranging from 21-25°C. March, April and May were the hottest months over the years with temperatures ranging from 28-31°C.

Table 4.1 Mean Monthly and Mean Annual Temperature (2001-2010)

	MEAN MONTHLY AND MEAN ANNUAL TEMPERATURE OF ZARIA (2001-2010)										
	2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Monthly Average**
Jan	23	21	24	24	22	25	21	21	24	24	**22.9**
Feb	25	26	28	24	28	28	26	24	27	27	**26.3**
Mar	30	30	29	27	31	29	28	29	29	29	**29.1**
Apr	30	31	31	32	31	30	30	29	31	31	**30.6**
May	29	32	31	28	29	28	28	28	28	29	**29**
Jun	27	28	28	26	26	27	26	27	27	27	**26.9**
Jul	26	27	26	25	25	26	25	25	26	25	**25.6**
Aug	26	26	26	25	25	25	25	25	25	25	**25.3**
Sep	26	27	26	29	26	26	26	28	26	26	**26.6**
Oct	26	26	27	28	26	26	27	26	26	26	**26.4**
Nov	25	24	26	27	24	22	34	23	24	25	**25.4**
Dec	25	23	23	25	23	21	23	23	23	22	**23.1**
Annual Average	**26.5**	**26.7**	**27**	**26.6**	**26.3**	**26**	**26.5**	**25.6**	**26.3**	**26.4**	

This pattern is explained by the differences in the factors influencing the temperature during the dry and wet seasons. Wet season temperatures are depressed by a higher rate of evaporative cooling and the reduction in the amount of solar radiation reaching the surface of

the earth as a result of thick cloud cover. The climatic conditions in the northern part of Nigeria exhibit mainly two different seasons, namely, a short wet season and a prolonged dry season. Therefore temperatures during the day time remain constantly high, with little or no cloud cover. There are, however, wide diurnal ranges in temperature (between nights and days) particularly in the very hot months. The mean monthly temperatures during the day exceed 36°C while the mean monthly temperatures at night drop, most times, below 22°C.

4.1.2 Mean Monthly and Mean Annual Relative humidity

The mean monthly and mean annual relative humidity of the study area is presented in Table 4.2.

Table 4.2, shows that mean monthly relative humidity is lowest from November to March (18-29%) and highest from April to October (between 40-79%), except the year 2003 where relative humidity were exceptionally high in January (64%), February (63%), March (59%) and April (70%).

Table 4.2 Mean Monthly and Mean Annual Relative humidity (2001-2010)

	MEAN MONTHLY AND MEAN ANNUAL RELATIVE HUMIDITY OF ZARIA FOR TEN YEARS (2001-2010)										
Yr/M	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**MONTHLY AVERAGE**
JAN	19	20	64	13	15	15	15	17	15	16	**20.9**
FEB	19	16	63	12	17	17	11	11	9	11	**18.6**
MAR	14	26	59	16	21	12	14	17	10	15	**20.4**
APR	43	57	70	42	32	21	39	28	40	32	**40.4**
MAY	62	68	69	54	56	60	61	55	53	62	**60**
JUN	72	80	77	70	69	64	70	64	63	69	**69.8**
JUL	79	89	74	72	75	72	73	74	68	76	**75.2**
AUG	85	90	78	77	79	76	76	78	75	77	**79.1**
SEP	51	90	71	69	69	75	68	72	60	73	**74.4**
OCT	56	77	61	46	50	63	49	56	67	70	**59.5**
NOV	24	66	24	25	24	22	20	22	34	28	**28.9**
DEC	22	52	16	14	15	16	17	20	16	15	**20.3**
TOTAL	592	731	726	510	522	513	513	514	510	544	
ANNUAL AVERAGE	**49.3**	**60.9**	**60.5**	**42.5**	**43.5**	**42.7**	**42.7**	**42.8**	**42.5**	**45.3**	

This abnormal increase in relative humidity in these dry months has resulted to an increase in temperature across the years there by stressing dairy cows in the area. This abnormal increase in relative humidity has the ability to trap the outgoing terrestrial radiation there by worming the earth surface and making the cows uncomfortable.

4.1.3 Coefficient of Variability

4.1.3.1 Variability in Temperature and Relative Humidity

Variability in temperature and relative humidity from 2001-2010 is presented in Table 4.3.

Table 4.3 Coefficient of Variability between Temperature and Relative Humidity

	Coefficient of variability
T° C	0.4733
RH%	8.4825

Table 4.3 presents the coefficient of variability of temperature and relative humidity. The study revealed that temperature varied between 0.4733 and relative humidity 8.4825. It therefore implies that relative humidity is more variable than temperature. This wide variation in relative humidity over temperature has the tendency of upsetting the body thermostat of Friesian X Bunaji cows, drying them and impacting negatively on milk production.

4.2 Variation in Temperature

4.2.1 Variation in Mean Monthly Temperature.

Variation in mean monthly temperature for the period of study is presented in figure 4.1

From figure 4.1, the month of January recorded an average temperature of 23.3°C. Following the standard thermoneutral zone classification scheme by West (2003), January

and December temperatures were normally distributed and falls within the thermoneutral zone of 2 - 20°C over most of the area. The months of February experienced relatively moderate temperatures which later rose to 26°C. March, April and May temperatures on the whole were unusually higher: the months ending with, the most severe hot spell (29 - 30°C). These high temperatures were soon cancelled by subsequent cool rains of June, July, August accompanied with periods of rather heavy precipitation, relieving previous high temperatures in some localities, but not always wholly offsetting them. The influence of rainfall gave rise to a low temperature of 26°C (June to August).

The months of September and October experienced an increase in temperature from 26-27°C**.** Cool weather at the end of October continued into November and December.

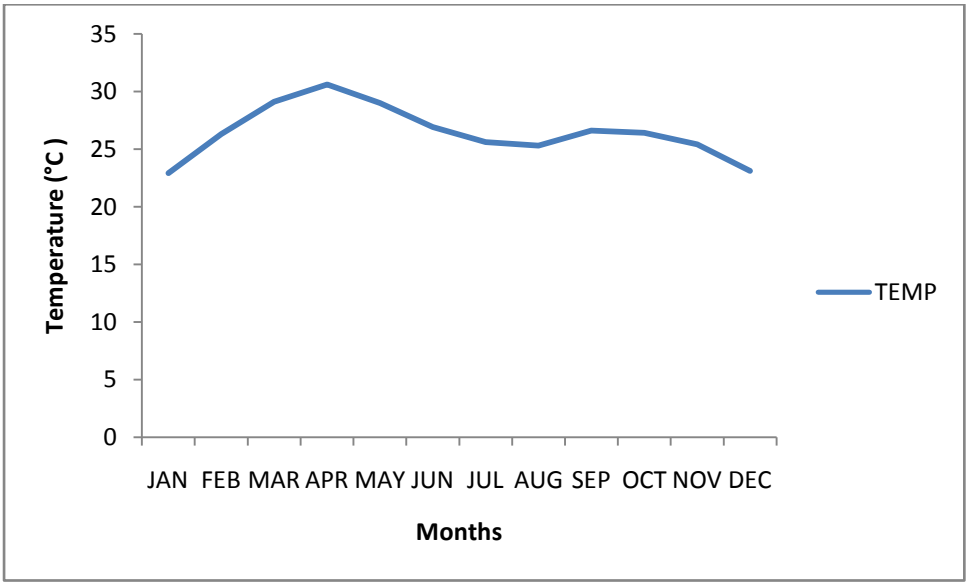


Fig. 4.1 Variation in Mean monthly temperature

4.2.2 Variation in Mean Annual Temperature.

Variation in Mean Annual Temperature from 2001-2010 is presented in figure 4.2.

Temperatures for the last ten years, as shown in Figure 4.2 have been fluctuating. It shows clearly that high temperatures have been alternating with moderate to low temperatures. The

year 2001 to 2003 experienced a relatively high temperature (27°C) indicating that there has been an episode of heat stress. By the year 2004 to 2006, temperature dropped to 26°C. Temperature rose again to 26.6°C in the year 2009 and in 2010, temperatures dropped to 26.4°C. Going by West, (2003) cows have optimal temperature zones within which no additional energy above maintenance is expected to heat or cool the body. This thermoneutral zone for dairy cattle is estimated to be from 2° to 20°C with an upper critical air temperature of approximately 25°C. Based on these facts, dairy cows in the study area are stressed.

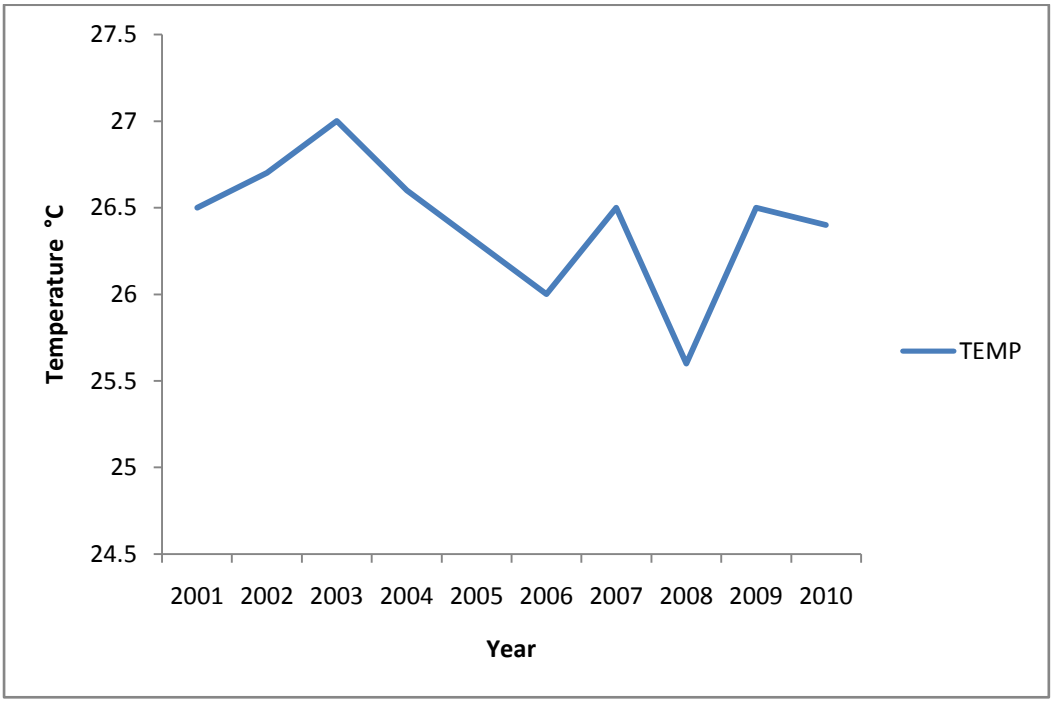


Fig. 4.2 Variation in mean annual Temperature

4.3 Milk Production Level

Figures 4.3 show records of milk produced monthly and annually by Friesian X Bunaji cows. These records are represented graphically to see variations in the volume of milk a cow produces and also see the months that record the highest volume of milk.

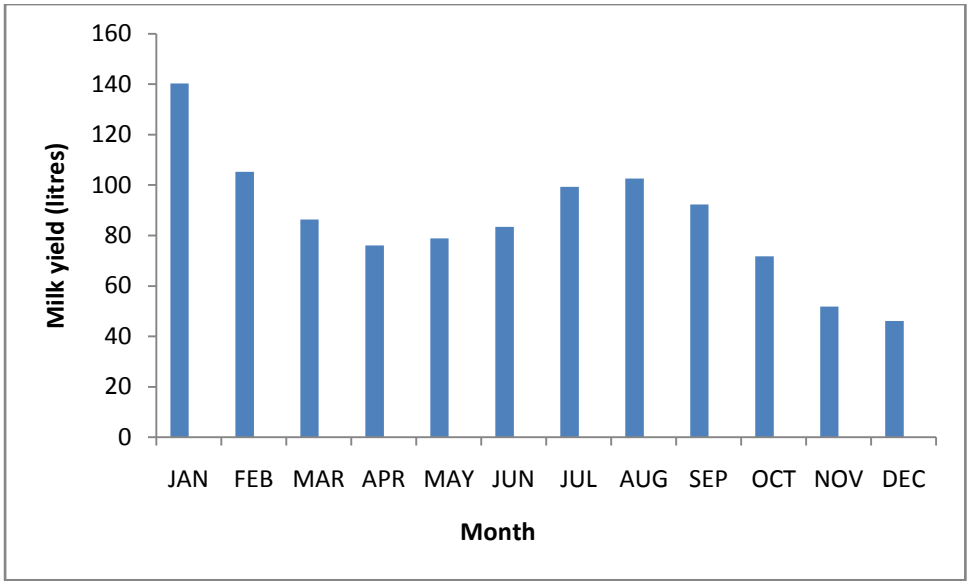


Fig. 4.3 Milk production level

Result shows that the month of January and February recorded highest volume of milk accompanied with cool harmattan weather. This cool weather makes it conducive for cows to cool themselves and expel the excess heat of metabolism there by producing high volume of milk (140 litres). The months of March, April, May and June characterised by high temperature weekend the cows and resulted to decreased milk. The cool rains of July, August and September relieved the cows from high temperature, cooling them and producing more milk. The months of October, November and December accompanied with high temperature led to decrease in milk yield.

In general, result shows that milk production is only favoured in cool months of January, February, July, August and September. Other months, characterised by high temperature and dryness where cows are stressed with elevated metabolic temperature, retard milk production, impacting negatively on Friesian X Bunaji cows.

4.4 Seasonal Variation in Temperature and Milk Yield

Seasonal variation in temperature and milk yield for Friesian X Bunagi cows is presented in figure 4.4

Result shows that dry and relatively hot temperature of November and December (24 ^{o}C**)** gave rise to low milk yield, but the low temperature of January (22^{o}C) accompanied by harmattan relived cows from the heat load there by creating a conducive atmosphere for milk synthesis and production. Low temperature of January, which range within the thermoneutral zone of 2-22^{o}C as shown in fig 4.4 gave rise to 145 litres of milk. In February, as temperature increased, milk production dropped to 100 litres. Hot and dry season of March and April characterised by dryness and absence of rainfall led to a significant drop in milk yield. This shows that cows could not bear the harsh weather condition and could not give out the excess heat of metabolism because of their high surrounding environmental temperature. As such, milk production decreased significantly below 80 litres. But the wet season of May, June and cool wet season of July to October led to a significant increase in milk production. Friesian X Bunaji cows under this condition were able to cool themselves and giving off freely this excess heat of metabolism.

From Fig. 4.4, it can be seen clearly that Seasonal differences in milk production are caused by periodic changes of environment over the year, which has a direct impact on milk production through decreased dry matter intake (DMI) and an indirect effect through fluctuation in quantity and quality of milk. It can be seen that pronounced seasonal patterns of milk yield and composition are evident in cattle. These seasonal patterns are largely induced by climatological variables, breed effects and management factors, such as feed quality and reproductive management.

These result shows that there is a significant relationship between milk production and season where cool dry and cool wet season favoured milk production while on the other hand, hot dry and dry cold season discouraged milk production.

From the analysis above, it can be seen that pronounced seasonal patterns of milk yield and composition are evident in cattle. These seasonal patterns are largely induced by

climatological variables, breed effects and management factors, such as feed quality and reproductive management.

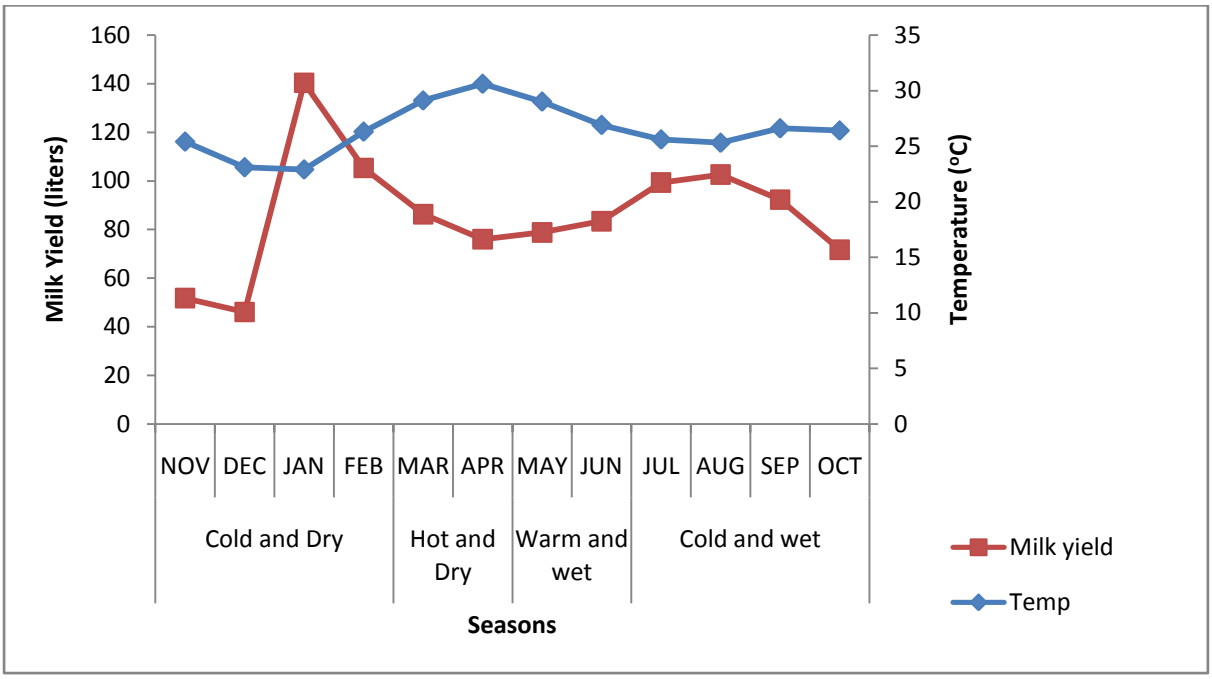


Fig 4.4 Seasonal variation in temperature and Milk yield

4.5 Relationship Between Temperature, Relative Humidity and Milk Yield

Figure 4.5 show changes caused by temperature and relative humidity on milk yield. Mean monthly temperatures, relative humidity and monthly milk yield were derived annually and superimposed on a graph to observe the relationship between them.

Result shows that the month of January and February recorded high milk yield followed by the month of July August and September. It will be interesting to know that months with the highest yield corresponds with month with low temperature while months with low yield correspond with months that records high temperature. January, been the month with the highest yield, characterised by cool and dry weather with temperature below 20 as revealed by west 2003. Under such condition, cows find it easy to give out the excess heat of metabolism there by cooling themselves. Cows like other warm blooded animals

attempt to match the amount of heat produced with that lost to the environment so that body temperature remains constant. When it is cold as in January, cows increase heat production and decrease heat lost to the environment so as to prevent a decline in body temperature. When it is hot as in the case of March and April cows however increased heat lost to the environment, but the ability to reduce heat production is limited to reducing feed intake. As a result, cows voluntarily reduce dry matter intake, lose appetite and finally reduce milk production.

On the other hand, the month of July, August and September experienced a steady rise in milk production due to the influence of cool heavy rains of August and relative humidity which reduced direct insulation there by lowering the temperature of the area. These, led to the increase in milk production in this month's by the Friesian X Bunaji cows. October, November and December, characterised by high temperature and absence of rain fall with temperature above the thermonuetral zone result in decrease milk produced by Friesian X Bunaji cows.

It can therefore be deduced from the entire analysis that temperature and relative humidity have adverse effect on milk production. Generally, the study also revealed that the months with the highest temperatures (March, April, and May) recorded very low volume of milk which is related to the effects of elevated temperature on milk yield; indirect effects are due to photoperiod effects and the negative impact of heat stress. The months of June, July, August and September are months with relatively cool temperature due to the cooling effects of rainfall, but still records temperatures above the cows thermoneutral zone (25°C). The increase in temperature here is due to the effect of cloud cover and high relative humidity which traps the outgoing terrestrial radiation, there by worming the earth surface and also increasing the body temperature of Friesian X Bunagi cows.



Plate 2. Dairy cow exhibiting sign of heat stress.

This increase in temperature therefore weakens the cow, there by loosing appetite and decreasing the quantity and quality of milk a cow will produce. It will be interesting to know that once the environmental temperature of a cow exceeds its thermoneutral zone, such cow experiences severe heat stress with high rectal temperatures, increased respiration rates, decreased feed intake, decreased milk production (volume and components) and other health problems (e.g. decreased reproduction efficiency).

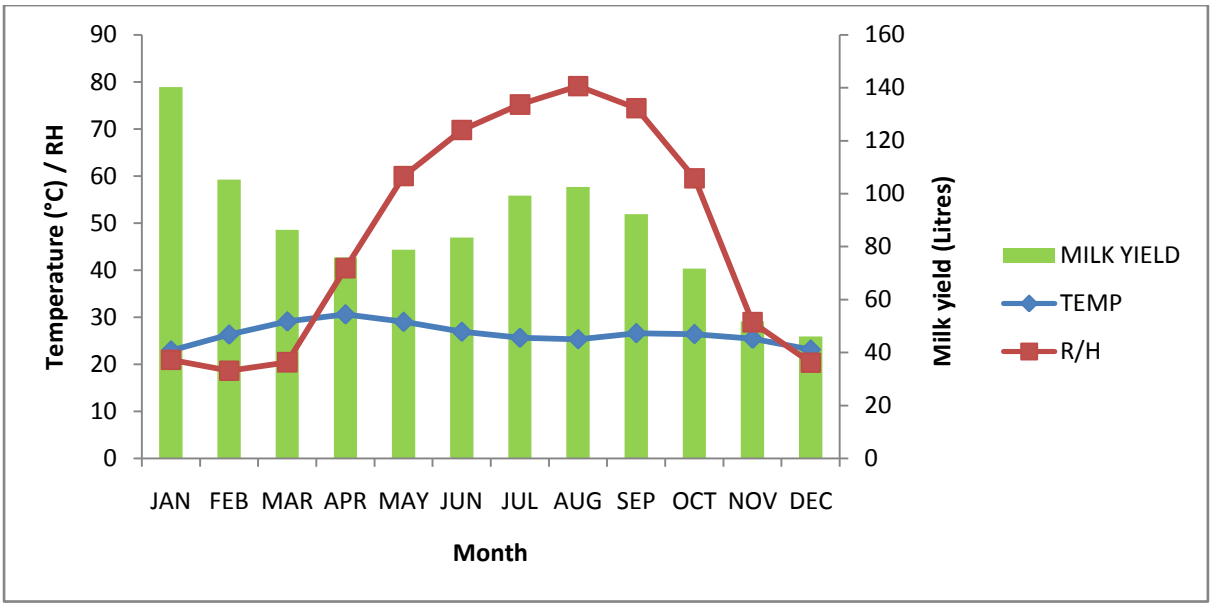


Fig. 4.5 Relationship between temperature, relative humidity and milk yield

According to Sartori *et al.,* (2002) it is difficult for a dairy cow in a hot environment to meet her full potential for either milk yield or fertility. The physiological adjustment the cow makes to prevent body temperature from rising during heat stress helps prevent death from heat stroke but also reduce productivity. For example, heat stressed cows experience decrease in appetite. The advantage to the cow is that her internal heat production is lowered, and regulation of body temperature becomes easier. The disadvantage to the dairy farmer is that the reduction in appetite caused by heat stress decreases milk yield. Therefore, the interplay of high temperature and relative humidity in the hot humid months of April through July makes it difficult for dairy cows to expel the excess heat in them.

From the analysis above, it can be deduced that high relative humidity compromises evaporative cooling, so that under hot humid conditions cows cannot dissipate sufficient body heat to prevent a rise in body temperature. Increasing air temperature, temperature-humidity index and rising rectal temperature above critical thresholds all relates to decreased dry matter intake (DMI), and also reduce efficiency of milk yield.

4.6 Temperature Humidity Index and Heat Stress

4.6.1 Mean Monthly Temperature Humidity Index

Table 4.4 presents calculated THI values for the period of study which is derived from the formula developed by Kibler (1964).

Results from table 4.4 shows clearly that no month throughout the study period recorded THI below 71 except, December 2006, January 2007 and January 2008 which recorded THI at 70, and these months correspond to cool seasons of the year termed comfort periods where cows best produced milk. The calculated THI values throughout the study period ranged from 70 to 101 with minima in January and maxima in May and September which are months with highest temperature and relative humidity. This is a strong indication

that cows in the study area are stressed, because the result of these (THI) is as interplay of air temperature and relative humidity within the environment. Therefore, whatsoever affects the environment of these animals, will directly affect their physiological set up.

Table 4.4 Temperature Humidity Index for Ten Years

	TEMPERATURE HUMIDITY INDEX TABLE FOR 2001-2002									
MONTH	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
JAN	82	71	81	76	72	78	70	70	76	76
FEB	78	79	88	76	84	84	80	76	81	87
MAR	88	89	92	82	91	85	84	89	85	86
APR	92	96	99	96	92	89	91	88	94	92
MAY	93	101	99	89	92	90	90	89	89	93
JUN	89	93	92	86	86	88	79	88	88	89
JUL	87	91	87	83	84	86	84	84	86	84
AUG	88	99	87	84	85	84	84	85	84	84
SEP	100	96	86	94	86	87	86	92	85	87
OCT	85	87	88	88	84	85	86	85	86	89
NOV	79	81	81	83	77	73	97	75	78	79
DEC	79	77	74	77	74	70	74	75	74	72

Considering THI as an indicator of heat stress and assuming heat stress is induced at THI $\geq$ 72, decline of milk production due to heat stress should be detected as from January.

In line with this, Ravagnolo and Misztal, (2000) developed a chart that expressed the intensity of heat stress as a function of temperature and relative humidity (fig 4.6) and classified Temperature - Humidity Index into classes that indicate level of heat stress. However, definitions of these levels vary between indices and authors. For instance, Armstrong (1994) identified index below 71 as comfort zone, values ranging from 72 to 79 as mild stress, 80 to 89 moderate stress, and values above 90 as severe stress. Huhnke et al. (2001) divided THI into 2 categories: 79 $\leq$ THI $\leq$ 83 dangerous situation, and THI $\geq$ 84 emergency situation.

The result of this research is not far from (Ravagnolo and Misztal, 2000) where THI values range between 71 and 101 which is a strong indication that all the cows in this

region are uncomfortable; therefore the cows cannot produce the required volume/ litres of milk they are expected to produce.

Therefore, utilizing the revised temperature humidity index chat in fig. 4.6 which classified heat stress as Mild –Moderate stress, Moderate –Severe stress, Severe stress, indicates that milk yield losses are detectable at THI of 71.

Themperature		% Relative Humidity																				
°F	°C	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
72	22.0	64	65	65	65	66	66	67	67	67	68	68	69	69	69	70	70	70	71	71	72	72
73	23.0	65	65	66	66	66	67	67	68	68	68	69	69	70	70	71	71	71	72	72	73	73
74	23.5	65	66	66	67	67	67	68	68	69	69	70	70	70	71	71	72	72	73	73	74	74
75	24.0	66	66	67	67	68	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75
76	24.5	66	67	67	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75	76	76
77	25.0	67	67	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75	76	76	77
78	25.5	67	68	68	69	69	70	70	71	71	72	73	73	74	74	75	75	76	76	77	77	78
79	26.0	67	68	69	69	70	70	71	71	72	73	73	74	74	75	76	76	77	77	78	78	79
80	26.5	68	69	69	70	70	71	72	72	73	73	74	75	75	76	76	77	78	78	79	79	80
81	27.0	68	69	70	70	71	72	72	73	73	74	75	75	76	77	77	78	78	79	80	80	81
82	28.0	69	69	70	71	71	72	73	73	74	75	75	76	77	77	78	79	79	80	81	81	82
83	28.5	69	70	71	71	72	73	73	74	75	75	76	77	78	78	79	80	80	81	82	82	83
84	29.0	70	70	71	72	73	73	74	75	75	76	77	78	78	79	80	80	81	82	83	83	84
85	29.5	70	71	72	72	73	74	75	75	76	77	78	78	79	80	81	81	82	83	84	84	85
86	30.0	71	71	72	73	74	74	75	76	77	78	78	79	80	81	81	82	83	84	84	85	86
87	30.5	71	72	73	73	74	75	76	77	77	78	79	80	81	81	82	83	84	85	85	86	87
88	31.0	72	72	73	74	75	76	76	77	78	79	80	81	81	82	83	84	85	86	86	87	88
89	31.5	72	73	74	75	75	76	77	78	79	80	80	81	82	83	84	85	86	86	87	88	89
90	32.0	72	73	74	75	76	77	78	79	79	80	81	82	83	84	85	86	86	87	88	89	90
91	33.0	73	74	75	76	76	77	78	79	80	81	82	83	84	85	86	86	87	88	89	90	91
92	33.5	73	74	75	76	77	78	79	80	81	82	83	84	85	85	86	87	88	89	90	91	92
93	34.0	74	75	76	77	78	79	80	80	81	82	83	85	85	86	87	88	89	90	91	92	93
94	34.5	74	75	76	77	78	79	80	81	82	83	84	86	86	87	88	89	90	91	92	93	94
95	35.0	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95
96	35.5	75	76	77	78	79	80	81	82	83	85	86	87	88	89	90	91	92	93	94	95	96
97	36.0	76	77	78	79	80	81	82	83	84	85	86	87	88	89	91	92	93	94	95	96	97
98	36.5	76	77	78	80	80	82	83	83	85	86	87	88	89	90	91	92	93	94	95	96	98
99	37.0	76	78	79	80	81	82	83	84	85	87	88	89	90	91	92	93	94	95	96	98	99
100	38.0	77	78	79	81	82	83	84	85	86	87	88	90	91	92	93	94	95	96	98	99	100
101	38.5	77	79	80	81	82	83	84	86	87	88	89	90	92	93	94	95	96	98	99	100	101
102	39.0	78	79	80	82	83	84	85	86	87	89	90	91	92	94	95	96	97	98	100	101	102
103	39.5	78	79	81	82	83	84	86	87	88	89	91	92	93	94	96	97	98	99	101	102	103
104	40.0	79	80	81	83	84	85	86	88	89	90	91	93	94	95	96	98	99	100	101	103	104
105	40.5	79	80	82	83	84	86	87	88	89	91	92	93	95	96	97	99	100	101	102	103	105
106	41.0	80	81	82	84	85	87	88	89	90	91	93	94	95	97	98	99	101	102	103	104	106
107	41.5	80	81	83	84	85	87	88	89	91	92	94	95	96	98	99	100	102	103	104	106	107
108	42.0	81	82	83	85	86	88	89	90	92	93	94	96	97	98	100	101	103	104	105	107	108
109	43.0	81	82	84	85	87	89	89	91	92	94	95	96	98	99	101	102	103	105	106	108	109
110	43.5	81	83	84	86	87	89	90	91	93	94	96	97	99	100	101	103	104	106	107	109	110
111	44.0	82	83	85	86	88	90	91	92	94	95	96	98	99	101	102	104	105	107	108	110	111
112	44.5	82	84	85	87	88	90	91	93	94	96	97	99	100	102	103	105	106	108	109	111	112
113	45.0	83	84	86	87	89	91	92	93	95	96	98	99	101	102	104	105	107	108	110	111	113
114	45.5	83	85	86	88	89	92	92	94	96	97	99	100	102	103	105	106	108	109	111	112	114
115	46.0	84	85	87	88	90	92	93	95	96	98	99	101	102	104	106	107	109	110	112	113	115
116	46.5	84	86	87	89	90	93	94	95	97	98	100	102	103	105	106	108	110	111	113	114	116
117	47.0	85	86	88	89	91	93	94	96	98	99	101	102	104	106	107	109	111	112	114	115	117
118	48.0	85	87	88	90	92	94	95	97	98	100	102	103	105	106	108	110	111	113	115	116	118
119	48.5	85	87	89	90	92	94	96	87	99	101	102	104	106	107	109	111	112	114	116	117	119
120	49.0	86	88	89	91	93	95	96	98	100	101	103	105	106	108	110	111	113	115	117	118	120

Fig 4.6: Revised temperature humidity index for lactating dairy cows

- **Stress Threshold** Respiration rate exceeds 60 BPM. Milk yield losses begin. Repro losses detectable. Rectal Temperature exceeds 38.5°C (101.3°F)

- **Mild-Moderate Stress** Respiration Rate Exceeds 75 BPM. Rectal Temperature exceeds 39°C (102.2°F)

- **Moderate-Severe Stress** Respiration Rate Exceeds 85 BPM Rectal Temperature exceeds 40 °C (104°F)

- **Severe Stress**. Respiration Rate 120-140 BPM. Rectal Temperature exceeds 41 °C (106°F)

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMENDATIONS

5.1 Summary

The study was conducted to examine how the variation in temperature and relative humidity affects milk production of Friesian X Bunaji cows in National Animal Production Research Institute (NAPRI) Shika, Zaria for the period of study (2001-2010). It was done to characterise the environmental conditions in the study area, examine the variation in temperature, examine milk production level, assess the temperature and seasons at which dairy cows start experiencing heat stress, examine the relationship between temperature, relative humidity and milk yield and finally assess the THI value at which cows are stressed.

Monthly temperature, relative humidity and milk yield data per cow were collected from both National Animal Production Research Institute (NAPRI) in Shika and Institute for Agricultural Research (IAR) Samaru Zaria. Both descriptive and inferential statistics were used in analyzing the information obtained from the secondary data. Four techniques of data analysis were employed in this research to achieve each of the objectives.

Result shows that there were no significant differences in mean annual temperatures over the years but there exist a wide variation between temperature and relative humidity, where temperature varies between 0.4733 and relative humidity 8.4825. The result also shows that there exist wide variations in milk production within the same species of cows where cows failed to produce the expected litres of milk compared to temperate cows where production dropped below 300 litres per annum. Result also shows wide seasonal variation in temperature and milk yield where Friesian X Bunaji cows produced high volume of milk in cool dry and cool wet seasons and low volume of milk in hot dry and hot wet seasons. Finally, calculated temperature humidity index shows that all dairy cows in the study area are stressed where THI values ranged between 70 and 101.

5.3 Conclusion

From the result of this research, it is concluded that Zaria temperature is above the critical temperature value (2-20°C) for Friesian X Bunaji cows to effectively produce the required volume of milk needed, and that the hot dry and humid season in Zaria is relatively longer that severe heat stress occurs majorly for seven months; March to September. These relatively longer hot dry and humid seasons impacted negatively on dairy cows. For example, heat stressed cows experience a decrease in appetite. The advantage to the cow is that her internal heat production is lowered, and regulation of body temperature becomes easier. The disadvantage to the producer especially dairy farmer is that the reduction in appetite caused by heat stress decreases milk yield.

5.4 Recommendations

Our natural environment and the elements therein are by no means beyond our control even though there is a limit to the control man has over them. Heat stress in dairy cattle is one of the leading causes of decreased production and fertility in Friesian X Bunaji dairy cattle during hot season. These losses are apparent in decreased amount of milk produced. Some heat stress is unavoidable, but effects can be minimized if current management practices are followed.

i. Increasing the amount of available water. Recommendations are for one basin of water per 20 head. This may not be enough during extreme heat stress. When the temperature reaches danger levels, add additional sources of water near the feeding area.

ii. Dairy cows should not be allowed roam freely to graze rather there movement should be restricted there by keeping them under intensive management system. This will go a long way in reducing heat stress and reserving the

energy a cow would have lost grazing, there by using the stored energy for milk synthesis.

iii. Shade should be provided for cows so that they can get out of direct sunlight during peak hours. Trees if available are excellent, but should be provided over the feeding area to increase feed intake.

iv. More work can still be done in this area by analysing the economics of heat stress to know how much dairy farmer's loos annually especially when cows are producing below expectation.

vi Finally, the knowledge acquired from this study should not be treated as a mere academic exercise, but should be applied to design a current management schemes for heat abatement.

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Appendix 1: Mean Monthly Temperature of Zaria For Ten Years (2001-2010)

MEAN MONTHLY TEMPERATURE OF ZARIA FOR TEN YEARS (2001-2010)

Yr/M	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Jan	27	21	24	24	22	25	21	21	24	24
Feb	25	26	28	24	28	28	26	24	27	27
Mar	30	30	29	27	31	29	28	29	29	29
Apr	30	31	31	32	31	30	30	29	31	31
May	29	32	31	28	29	28	28	28	28	29
Jun	27	28	28	26	26	27	26	27	27	27
Jul	26	27	26	25	25	26	25	25	26	25
Aug	26	30	26	25	25	25	25	25	25	25
Sep	30	27	26	29	26	26	26	28	26	26
Oct	26	26	27	28	26	26	27	26	26	27
Nov	25	24	26	27	24	22	34	23	24	25
Dec	25	23	23	25	23	21	23	23	23	22
Total	326	325	325	320	316	313	319	308	316	317
Average	27.1	27	27	26.6	26.3	26	26.5	25.6	26.3	26.4

Appendix II: MEAN MONTHLY RELATIVE HUMIDITY % FOR TEN YEARS (2001-2010)

MEAN MONTHLY RELATIVE HUMIDITY % FOR TEN YEARS (2001-2010)

Yr/M	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	AVERAGE	TOTAL
JAN	19	20	64	13	15	15	15	17	15	16	21	209
FEB	19	16	63	12	17	17	11	11	9	11	19	186
MAR	14	26	59	16	21	12	14	17	10	15	20	204
APR	43	57	70	42	32	21	39	28	40	32	40	404
MAY	62	68	69	54	56	60	61	55	53	62	60	600
JUN	72	80	77	70	69	64	70	64	63	69	70	698
JUL	79	89	74	72	75	72	73	74	68	76	75	752
AUG	85	90	78	77	79	76	76	78	75	77	79	791
SEP	97	90	71	69	69	75	68	72	60	73	74	744
OCT	56	77	61	46	50	63	49	56	67	70	60	595
NOV	24	66	24	25	24	22	20	22	34	28	29	289
DEC	22	52	16	14	15	16	17	20	16	15	20	203
TOTAL	592	731	726	510	522	513	513	514	510	544		
AVERAGE	49.3	60.9	60.5	42.5	43.5	42.7	42.7	42.8	42.5	45.3		

Appendix III: MONTHLY MILK YIELD IN LITERS PER COW PER ANNUM

MONTHLY MILK YIELD IN LITERS PER COW PER ANNUM (2001)

	TAG NUMBERS									
	414171	1393	414162	1972	414142	4257	1377	414143	414130	414129
JAN	121	156	138	233	363	136	223	209	151	149
FEB	87	86	79	147	226	84	194	1138	128	98
MAR	73	82	78	125	175	82	151	127	110	68
APR	14	61	104	27	178	41	31	177	283	84
MAY	0	0	0	0	308	0	0	238	143	108
JUN	0	0	0	0	204	0	0	188	88	88
JUL	0	0	0	0	167	0	0	172	82	83
AUG	0	0	0	0	256	0	0	252	93	97
SEP	85	0	192	0	166	0	0	199	37	12
OCT	185	0	126	0	195	0	0	202	0	0
NOV	129	0	129	0	11	0	0	144	0	0
DEC	135	0	210	0	0	0	0	74	0	151

	TAG NUMBERS (2002)									
	1375	414233	431479	1742	313852	414162	414171	414129	151	130
JAN	139	183	193	63	17	165	72	253	84	26
FEB	82	137	124	45	0	118	5	216	88	150
MAR	0	126	144	20	0	94	0	173	85	119
APR	0	139	137	0	0	87	0	184	52	104
MAY	0	168	208	0	0	113	0	234	0	102
JUN	0	0	27	0	0	0	0	209	0	91
JUL	0	0	0	0	0	0	0	297	0	90
AUG	0	0	0	0	0	0	0	278	0	104
SEP	0	0	0	0	0	0	0	222	0	75
OCT	0	0	0	0	0	0	0	89	0	27
NOV	0	0	0	0	0	0	0	0	0	0
DEC	0	0	0	0	0	0	0	0	0	0

TAG NUMBERS
2003

MONTHS	316	314	312	449	317	318	456	326	331	86
JAN	128	79	164	117	58	72	56	162	180	183
FEB	82	45	158	119	49	46	33	160	171	164
MAR	0	0	204	104	0	0	0	121	183	169
APR	0	0	234	105	0	0	0	178	208	200
MAY	0	0	173	87	0	0	0	128	147	156
JUNE	0	49	188	78	0	0	0	134	155	135
JUL	215	296	135	8	0	0	0	145	145	49
AUG	271	218	0	0	0	0	0	78	56	0
SEP	265	190	73	0	0	54	42	3	0	0
OCT	166	127	316	0	0	114	57	55	56	148
NOV	154	128	281	0	0	16	24	0	168	283
DEC	74	129	360	68	0	0	0	0	138	252

TAG NUMBERS
2004

	335	437	313	85	327	312	86	331	320	449
JAN	212	165	53	61	189	405	290	135	145	358
FEB	95	105	25	30	98	275	231	54	37	254
MAR	54	114	23	30	107	250	273	31	46	303
APR	0	107	0	0	18	279	228	0	48	235
MAY	0	91	0	0	0	218	148	0	0	165
JUN	0	22	0	0	0	207	124	0	0	176
JUL	222	0	0	0	0	168	53	0	0	114
AUG	316	0	0	0	0	177	0	0	0	116
SEP	235	0	0	0	0	0	0	0	0	74
OCT	193	45	0	0	0	0	116	76	0	33
NOV	170	177	0	0	0	0	225	130	0	0
DEC	145	184	14	24	21	28	189	108	15	45

TAG NUMBER
2005

	450	890	762	805	314	335	326	86	331	1760
JAN	74	34	22	78	38	95	41	167	44	168
FEB	18	0	0	11	2	57	33	143	32	134
MAR	0	0	0	0	0	1	17	140	1	169
APR	0	0	0	0	0	0	0	106	0	132
MAY	0	36	62	20	0	0	0	153	0	184
JUN	0	172	157	219	34	0	0	140	0	182
JUL	0	228	145	275	165	0	0	124	0	229
AUG	191	177	149	180	180	212	0	64	0	223
SEP	172	151	107	0	122	203	0	0	0	155
OCT	229	217	154	0	139	285	0	0	0	206
NOV	167	144	84	0	82	131	0	0	0	84
DEC	165	121	77	0	55	109	0	80	0	0

TAG NUMBERS
2006

	327	762	890	317	314	450	335	183	895	86
JAN	135	52	80	83	48	164	69	136	124	131
FEB	94	43	45	69	14	150	47	104	83	154
MAR	57	14	17	46	0	190	15	120	104	219
APR	8	0	0	41	0	112	0	69	28	165
MAY	0	0	0	54	0	111	0	66	7	258
JUN	0	0	0	44	0	46	0	68	0	194
JUL	0	0	0	19	0	0	0	44	0	187
AUG	0	0	0	0	0	0	0	5	0	257
SEP	0	0	0	0	0	0	0	0	0	194
OCT	0	0	0	0	0	0	0	0	0	177
NOV	0	0	0	0	0	0	0	0	0	134
DEC	0	0	0	0	0	0	0	0	0	40

			TAG NUMBER 2007		
	304	1394	1747	137	333
JAN	14	30	30	11	8
FEB	9	11	13	1	0
MAR	6	14	14	0	0
APR	0	0	0	0	0
MAY	0	0	0	0	0
JUN	0	0	0	0	0
JUL	0	0	0	0	0
AUG	0	0	0	0	0
SEP	0	0	0	0	0
OCT	0	0	0	0	0
NOV	0	0	0	0	0
DEC	0	0	0	0	0

			TAG NUMBERS 2008
	768	30	24
JAN	75	123	0
FEB	57	122	0
MAR	13	87	57
APR	0	34	243
MAY	0	8	328
JUN	0	0	261
JUL	0	0	234
AUG	0	0	268
SEP	0	0	156
OCT	0	0	213
NOV	0	0	170
DEC	0	0	171

TAG NUMBERS 2009

	24	948	292	86	963	895
JAN	155	119	175	135	110	80
FEB	162	133	187	226	112	66
MAR	157	131	184	259	132	77
APR	128	65	163	226	115	57
MAY	123	74	119	179	113	46
JUN	96	74	110	174	106	0
JUL	0	74	150	187	118	0
AUG	0	5	8	12	83	0
SEP	0	0	0	0	65	0
OCT	0	0	0	0	18	0
NOV	0	0	0	0	0	0
DEC	0	0	0	0	0	0

TAG NUMBERS 2010

	158	697	1095	463	1092	1099	895	911	948	1090
JAN	129	29	55	221	191	53	96	180	193	246
FEB	0	0	0	57	175	0	52	198	219	240
MAR	0	0	0	0	180	0	16	250	283	304
APR	0	0	0	0	125	0	0	260	222	253
MAY	0	0	187	0	32	0	0	231	253	235
JUN	0	0	387	0	0	0	0	184	234	224
JUL	0	0	446	0	0	0	0	9	245	259
AUG	16	0	283	0	0	0	0	0	95	92
SEP	285	0	203	291	267	0	0	50	0	0
OCT	275	0	176	303	233	0	0	25	0	0
NOV	283	0	210	304	204	55	0	0	0	0
DEC	290	125	162	310	174	112	0	0	0	0