FEMALE BUFFALO AND COW DRAUGHT ENERGY PRODUCTION & UTILIZATION IN FARMING SYSTEM

THESIS SUBMITTED TO THE
NATIONAL DAIRY RESEARCH INSTITUTE, KARNAL
(DEEMED UNIVERSITY)
IN PARTIAL FULFILEMENT OF THE REQUIREMENT
FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

IN
ANIMAL PSYSIOLOGY

BY

SOHAN-VIR SINGH

DIVISION OF DAIRY CATTLE PHYSIOLOGY
NATIONAL DAIRY RESEARCH INSTITUTE
(I.C.A.R.)
KARNAL 132001(HARYANA), INDIA

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November 9th, 1992

CERTIFICATE

This is to certify that the thesis entitled '"FEMALE BUFFALO AND COW DRAUGHT ENERGY PRODUCTION AND UTILIZATION IN FARMING SYSTEM" submitted by Mr. SOHAN-VIR SINGH in partial fulfilment of the requirements for the award of degree of DOCTOR OF PHILOSOPHY in DAIRY CATTLE PHYSIOLOGY of the National Dairy Research Institute (Deemed University), Karnal (Haryana), India is a bonafide research work carried out by him under my supervision and guidance and no part of the thesis has been submitted for any other degree or diploma.

RCUpadhyay

(R.C. UPADHYAY)
MAJOR ADVISOR & CHAIRMAN
(GUIDE)

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S.V.

(SOHAN-VIR SINGH)

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LIST OF ABBREVIATIONS

AW	-	After work
AW1	-	After first work
AW2	-	After second work
bpm	-	Beats per minute
BW	-	Before work
CO2	-	Carbon dioxide
d.f.	-	Degree of freedom
DM	-	Dry matter
DNP	-	Dry non-pregnant
EW	-	End of the work
FFA	-	Free fatty acids
GEE	-	Gross energetic efficiency
Hb	-	Haemoglobin
Hct	-	Haematocrit
HR	-	Heart rate
KCal	-	Kilo calories
kJ/min	-	Kilo Joule/min
km/h	-	Kilometers per hour
l	-	Litre
LA	-	Lactic acid
LNP	-	Lactating non-pregant
Load I	-	5 quintals
Load II	-	10 quintals
mg %	-	Milligram per cent
Qtl	-	Quintal
r	-	Correlation coefficient
Rest I	-	After one hour rest
Rest II	-	After two hour rest
RQ	-	Respiratory quotient
RR	-	Respiration rate
RT	-	Rectal temperature
SEM	-	Standard error of means
TDN	-	Total digestible nutrient

GRAPHS

1	-	Before work
2	-	After work
3	-	After one hour rest
4	-	After two hour rest
5	-	After end of the second work

CHAPTER 1

INTRODUCTION

1.0 INTRODUCTION

In most tropical and subtropical countries, chief farm operations and rural transportation are dependant on animal power. At present, developing countries import about 80 million tons of food, which is likely to increase to 100-150 million tons by the end of 2000 A.D. Increased food production from existing land would necessitate use of more energy for ploughing, tillage, irrigation and other farm adjunct works. Though the pace of mechanization of farm sector is very fast, yet it cannot reduce the gaps in energy demand and supply. This shortfall in energy is likely to increase further and the draught animals will keep on sharing the bulk of the energy for farm in most developing countries.

Draught animals produce between 0.4 to 0.8 horse power on a sustained basis. Taking the lower conservative figure of 0.5 HP/ draught animal, the power made available by 300 million animals at work may be of the order of 150 million HP. For purposes of replacement, it is usually assumed that 5 pairs of animals can be replaced by one tractor though it is theoretically possible for a tractor to replace many more pairs. Taking the figure of five pairs, about 30 million tillers and tractors will be required to replace the existing draught animal population. Thus, replacement by mechanized system may need equipment worth any where between 200 to 300 billion dollars. The recurring annual cost towards fuel and spares may also be around 5 billion dollars. It is well known that many countries using draught animals (such as India, Bangladesh, Pakistan, Thailand and Ethiopia etc.) do not have resources of indigenous petroleum sufficient to meet their own needs. In densely populated countries where the average cultivated area is small and number of land holding is very high, mechanization is not profitable and feasible particularly due to socio-economic condition of farmers.

In India, energy for ploughing two-thirds of cultivated area comes from DAP. Tractors and tillers become viable only for holdings above 5 ha. Marginal and small farmers cannot afford the initial cost of these machines. Technical manpower and maintenance facilities of agricultural machineries are inadequate in most developing countries. Animal drawn vehicles are suitable for rural areas under certain conditions, viz. uneven terrain, small loads, short distances and where time is not critical factor. Since 50 per cent of India's villages are not connected by roads, animal drawn carts are the only mode of transport for goods and passengers. Also in India,. two-thirds of rural transport is hauled by 13 million animal drawn vehicles. An estimate of National Commission on Agriculture (1976) for optimum output revealed that energy input to farm has to be doubled in India to enhance farm production. Thus, such a vast quantity of energy cannot be supplied from petroleum-based fuels or other sources of energy only and utility of draught animals will be inevitable and an essentiality particularly in India.

During work, various physiological systems in body interact and bring about series of temporary adjustments in physiological and biochemical processes to meet the body requirements of oxygen and energy and to tackle expeditiously the metabolites produced in the processes. Evidently, the metabolic profiles are altered and the magnitude of these changes can be interpreted to reflect the animals endurance for work. During last decades, several systematic studies have been conducted to measure the draught power, physiological changes in working cattle and buffaloes in order to provide their ability to withstand the stress of environment work. Lately, considerable emphasis has gone to understand the changes in physiological processes during work and to find out the limits of bovine work production. An opinion emerged out from the work carried out at NDRI (Upadhyay and Madan, 1985a; Upadhyay *et al.*, 1987; Upadhyay, 1989) at JCU, Townsville (Martin and Teleni, 1989) and at CTVM, Edinburg (Pearson and Lawrence, 1989) is that "work performance is limited by various factors related to animal structure, environment, thermal stress, radiant heat load and feedings. Work performing capacity may be sustained and improved by selection and modification of animal implements environment system" (Upadhyay, 1989).

The environmental conditions particularly ambient temperature, humidity, solar radiation and other climatic elements affect physiological processes and ultimately limit work capacity. It is not feasible from the existing information to give exact permissible limit in relation to working environment. These limitations depend on the combination of different climatic factors and the duration of work. Under distressful climatic conditions, the body's capacity to store heat most often limit other physiological processes and sustained work output over prolonged hours. Suitable work rest cycle for animals need to be developed for reducing work-environment stress and for proper use of animal power.

In general, bullocks are preferred for light work, like tillage, light carting and other farm allied jobs and buffaloes are used mainly for load transport and occasionally for other works. The use of animals, however, vary to a great extent upon the farmer's socio-economic status and farm size. Male buffaloes are used for pulling heavy loads in northern India, particularly in rice and sugarcane belts. According to an estimate, working bovines in India are about (69.7 million), male buffaloes (5.9 million), cows (2.0 million) and female buffaloes less than one million. An appraisal of the number of working buffaloes, vis-a-vis bullocks indicates that the buffalo power is neither fully utilized nor exploited for its power output, in general and in certain states like Gujarat, Haryana, Himachal Pradesh and Rajasthan in particular.

In India, males are preferentially used for agricultural operations and females are limitedly used. Females constitute only about 6.25 per cent of total DAP (Sharma, 1982). Recent developments in farming systems have necessitated not only to review the objectives and priorities of research but also explore the possibility of uses of females for work. A new concept in farming system has emerged out which emphasize the use of females (buffaloes and cows) for draught purposes. Use of cows has been considered more efficient than bullocks as they contribute in terms of work at farm, , give milk, calf, dung and draught power (Dolbert, 1981; Mathewman *et al.*,1988). Therefore, use of females need to be explored for draught purposes particularly at small and marginal farm levels. In the states of Bihar, Orissa and Karnataka, cows having low milk yield are used for draught purposes. Leaving religious sentiments aside, there is a need for systematic research investigation to highlight the effects of work on milch animals, their reproductive performance, physiological limits for work and extent of work females are capable of doing without any adverse consequences on physiological processes.

Female may perform work, produce milk and rear calves. However, the imposition of work on females may exacerbate the negative impact. Earlier, preliminary experiments carried out on treadmill at NDRI on low producing and long anoestrus cows have indicated that unproductive period of the females may be used for work without adversely affecting their performance. Through the present study, attempts have been made to document the effects of work on some physiological functions and explore the possibility of use and compare the work capacity of buffaloes and cows for field work with following specific objectives.

1. To study comparative performance, energetic efficiency and physiological changes during ploughing in the buffaloes and cows.

2. To develop work-rest cycle for buffaloes and cows.

3. To study and quantify the effect of work and stress on physiological processes.

4. To study the inter-relationship between metabolic hormones and effect of work on reproductive status of animals.

CHAPTER 2

REVIEW OF LITERATURE

2.0 REVIEW OF LITERATURE

Cattle and buffaloes are the integral components of Indian agriculture and of Indian way of life. Advances of science and technology in all human endeavours - atomic energy, electronics, communications, space travels, medicine, etc. have revolutionised man's life. In spite of these spectacular achievements, even today, two billion people in developing countries depend on the draught animal power (DAP). DAP provides energy for cultivation of nearly 50 per cent of world's farm area under cultivation and also for hauling over 25 million carts.

2.1 DAP - AN APPROPRIATE TECHNOLOGY

Draught Animal Power (DAP) refers to the power of draught animals -- cattle, buffalo, horse and mule, donkey and camel, yak and elephant. From technical and economic points of view, DAP is inevitable in certain agro-climatic conditions and it is an appropriate technology for the farmers with limited resources at their disposal. In India, energy for ploughing two-thirds of cultivated area comes from DAP, and tractors and tillers become viable only for holdings above 5 ha. Marginal and small farmers under present socio-economic conditions cannot afford the initial cost of most farm machines and implements. Further, technical manpower and maintenance facilities for these agricultural machineries are inadequate in rural areas. To meet the targets of food production from existing land area for 885 million population, power availability at farms must be improved and both renewable and non-renewable sources of energy need to be used judiciously.

Small farm energy needs may be partly met from animals and for larger needs either petroleum-based or hydroelectric power may be used. Both males and females of bovines could be used as in the cases of horse, elephant, camel and donkey. At present, in India, females of bovines are used very limitedly for farm work, about 6.5 per cent of females (Sharma, 1982). These females are used by small farmers and particularly during peak periods of a cropping season (Mathewman, 1987). However, the cows are used as a source of farm power in South Korea (Anon., 1978), Pakistan (Akhtar, 1981), Philippines (Ranjan, 1983), Sri Lanka (Slangantillake, 1983), Bangladesh (Orskov, 1984), Indonesia (Komarudin-Ma'sum and Teleni, 1991) and in Australia (Teleni *et al.*, 1991).

Energy needs in developing countries were not given an appropriate attention till some of the International organizations pointed out the problem. The developing countries have not shown interest of their own in the development of draught animal power (DAP) till recently. Though DAP problem looks simple, but it needed efforts to upgrade technology and its dissemination. Emphasis on high technology needs to be given whereever appropriate but modernizations and/or introduction to DAP should not longer be neglected.

Studies on Haryana (Mukherjee *et al.*, 1961; Singh *et al.*, 1968a, 1970; Devadattam and Maurya, 1978; Upadhyay and Madan, 1985b; Upadhyay and Madan, 1987; Agarwal and Agarwal, 1992), Sahiwal (Singh *et al.*, 1968a, 1970), crossbred (Georgie *et al.*, 1970; Sastry *et al.*, 1970; Maurya & Devadattam, 1982 ; Rao and

Upadhyay, 1984; Upadhyay and Rao, 1985 ; Upadhyay *et al.*, 1987; Parveen Kumar *et al.*, 1987; Kaur and Rao, 1984; Agarwal and Agarwal, 1992; Anjuli, 1988) and buffaloes (Kapoor, 1985; Upadhyay and Rao, 1985,1988; Nangia *et al.*, 1978; Singh *et al.*, 1980,1981) have been conducted. These studies have used varied methods and criterion for assessment of animals and their responses under varying conditions often may not be comparable.

Draught capacity of different animals and related physiological reactions, viz. rectal temperature, heart rate/ pulse rate, respiration rate, haematological and biochemical parameters have been studied in past and some of these have been correlated to the functional capabilities of animals. The understanding of physiological processes and the adjustment required for performing work, take place in coordinated fashion involving cardio-pulmonary, neuromuscular, thermoregulatory and neuroendocrine functions. Limited experiments have been carried out in past to correlate the physiological processes with graded level of work. In this review, only pertinent literature on draught animals has been reviewed. To correlate the physiological functions with work and environment, the use of data on horses and other mammals, whenever appropriate, have also been reported.

2.2 DRAUGHT CAPACITY

Devnani (1981) and Goe (1983) have reported that draught power developed by an animal is a function of force exerted and speed. Draught animals are capable of producing maximum pull of about 15 to 18 per cent of their body weight for a short period. But during work animal perform with a sustainable pull, which generally is less than 10 per cent of the body weight. Animals under natural conditions often work continuously with these loads for several hours.

Theoretically, the maximum pull animal can develop is near 18 per cent of its body weight (Devnani, 1981). The size, conditions, training, method of hitching and speed of travel of animal affect the maximum pulling capacity. However, the normal draught capacity is approximately one-tenth of its body weight (FAO, 1966).

Rautaray and Srivastava (1983) studied the performance of crossbred (Red Dane x Sahiwal) bullock during tillage in summer under different draft conditions. They observed that these bullocks could negotiate 184.4 kg draft (12.9% of body weight) with speed of 2.55-1.77 km/h for seven hours without any abnormal change. Gorhe (1983) used crossbreds in harrowing, ploughing and carting operations and measured some physiological, haematological responses together with some draught capacity measurements. The study indicated that 1/2 and 3/4 crossbred bullocks were able to perform, almost similar to indigenous bullocks. The study advocated that crossbred bullocks may be used as efficiently as other bullocks with some modifications of work timing for different agricultural operations.

Large variations in draught capacity estimates, from different laboratories, have been reported due to employment of different loading devices and surface conditions, probably in the absence of standard guidelines related to draught capacity measurement systems. Buffaloes, being heavier, can pull greater loads than light bodied oxen, but latter can work for longer periods in adverse climatic conditions, i.e. summer and hot-humid conditions. Studies on Swamp buffaloes have indicated that even though they are slow, heavy and strong but are well suited to work in muddy and submerged fields. Under such conditions they are able to pull heavier loads than cattle (Naumann and Stout, 1969; Rollinson and Nell, 1973). Goe and McDowell (1980) have reported estimates of tractive efforts of different farm animals which vary with body weight and speed of animal at work. Sumadi and Kuncoro (1982) found that working capacity of buffalo pair in Klaten E. Java was 853 m^2 in 180 min in wet rice field or 284 m^2/h. The capacity measurements under forestry indicate that buffaloes can drag the logs (0.2 m^3 to 0.3 m^3) of wood per pair, at a speed of 10 meter/min and can work for 6-7 h/day in winter and 4-5 h a day in summer (Berry, 1982). Ploughing studies have revealed that one pair bullock ploughs around one acre of dry land or one half to three-fourth acre of wet land in 8 h (Sivaiah, 1983).

Studies on the power output of Haryana, Sahiwal x Brown Swiss crossbred, Sahiwal and male buffaloes were conducted at National Dairy Research Institute, Karnal, using a single animal drawn pneumatic tyred cart (Upadhyay, 1982; Parveen Kumar *et al.*, 1987; Kaur and Rao, 1984; Rao and Upadhyay, 1985; Upadhyay and Madan, 1985a,b, ; Upadhyay and Rao, 1986). The loads tested were 2, 5, 10, 15 and 20 quintals. Haryana bullock could work longer and travel faster than crossbred bullocks. Continued work for a prolonged period decreased speed in Haryana but not in crossbred animals. During heavier load pulling over a sustained period of work, crossbred animals showed better endurance while Haryana animals showed a decrease in speed. Haryana bullocks produced 0.91 hp during 10 quintals load pulling operation. Crossbred bullocks also generated about equivalent power (Upadhyay, 1982). Kaur and Rao (1984) reported 0.16, 0.21 and 0.39 hp production during different load pulling operations. Singh *et al.* (1968a, 1970) studied the physiological responses of Haryana and Sahiwal bullocks while working with 3 common agricultural implements, viz. disc plough, harrow and cultivator. The horse power developed by Haryana during disc ploughing, harrowing and cultivation was 0.803, 0.974 and 0.743, respectively. The average horse power developed by a pair of Sahiwal bullocks during disc ploughing, harrowing and tilling was 0.837, 0.627 and 0.703 respectively. During harrowing, the speed and horse power developed by Sahiwal bullocks were significantly lower than those of Haryana bullocks. Devadattam and Maurya (1978) observed that optimum draft for an average pair of Haryana bullocks was about 60 kg.

Ploughing and carting trials on crossbred and nondescript cattle have indicated that the crossbreds were able to perform better than indigenous bullocks in Orissa condition (Acharya *et al.*, 1979). The crossbred bullocks pulled a maximum load of 1,310 kg as against 1,210 kg pulled by the indigenous bullocks. Maurya and Devadattam (1982) conducted carting experiments in summer on two Jersey x Red Sindhi bullocks and reported that animals develop draft between 11 to 18 per cent of their body weight.

Upadhyay (1984) observed that during summer and hot humid seasons both temperatures and humidity limit the performance of crossbred bullocks. The duration of ploughing and carting should not exceed over 2 h if continuous work output is desired. A rest of 10 to 15 min after every 2 h is essential in order to perform optimum work without harmful effects on animals. Upadhyay and Madan (1987) studied the draught capacity and efficiency of crossbred and Haryana bullocks, while working under tropical climate and have indicated that the optimum load for a single animal is 0.5 to 1.0 ton. The work efficiency of Haryana bullock was higher than that of the crossbred and was affected by continuous work.

Extensive studies have been conducted on male buffaloes and cattle but no systematic work has been carried out on the work capacity of female animals. A study on use of cows for draught was conducted by Bhatnagar (1989). Adult cows were exercised on a treadmill at a speed of 2.5 km/h uphill 15.5^{o}. This exercise intensity doubled oxygen consumption, increased cardiac activity and reduced durations of ECG intervals. The milk yield of lactating cows remained unaffected by this intensity of exercise.

Martin and Teleni (1989) carried out experiments on four female Swamp buffaloes on a treadmill at a speed of 2.5 km/h for a maximum of 3 h. Draught load equivalent to either 0, 5, 8 or 11 per cent of their live weight were pulled. The study has indicated that work performance was limited by heat stress. Komarudin Ma'sumtTeleni (1991) conducted an experiment to compare the work capacity of Ongole (*Bos indicus*), Bali (*Bos sondaicus*) and Madura cows.

Females of bovines becuase of their inherent nature and body configuration do not have capacity to sustain hard work for long periods and to exert fully for work, but training and feeding improves their work capacity. Females may be able to produce a maximum pull of at least 10 per cent of their body weights which may be utilized for optimizing production and for efficient utilization at least of unproductive or less productive females. In India, attempts have been made to measure draught power.

2.3 PHYSIOLOGICAL LIMITING FACTORS

Increased metabolic activity in response to work is economical at environmental temperatures which does not stress physiological system and doesnot require additional mechanisms for heat dissipation. Both extreme cold and heat uneconomically utilize available energy for heat production and elimination, respectively, instead of work. A significant difference exists in the mechanism for maintaining increased metabolic activity during work than for maintaining normal activity. The explanation for this difference is in the requirement of muscle at high level of activity. Work during low ambient temperatures do not increase body heat content to the same levels which reach during thermal stress or intense muscular work; under such conditions heat of work is used to maintain body temperature instead of causing stress.

Work lead to adjustments in the various organ systems involved in the work process. Work increase muscle metabolism several folds the resting level, therefore, adjustments take place in the body which concern the uptake and transport of oxygen by the blood and its utilization in muscle tissues. Sustained muscular activity over prolonged hours depend mainly on the aerobic process and oxygen supply may be a limiting factor. During prolonged work, the requirement of oxygen by muscle increases and the significant changes which occur with prolonged work period that seems important in draught animals, similar to marathon runners and horses are increased pulmonary ventilation (Upadhyay and Madan, 1985b) increased cardiac output (CO) through increased heart rate (Upadhyay and Madan, 1986) and stroke volume (Nangia *et al.*, 1980), increased peripheral circulation, increased blood and plasma volume (Upadhyay and Madan, 1988). Increased muscle activity produces greater heat of work, which needs to be eliminated by various thermoregulatory processes to maintain body temperature (Moran, 1973; Nangia *et al.*, 1980; Mathers *et al.*, 1984; Upadhyay, 1987; Pieterson and Ffoulkes, 1985). Sustained muscular activity, besides above factors, is also limited due to inadequate oxygen diffusion from the lung alveoli into the blood (Astrand and Rodhal, 1977), oxygen transport from the blood to muscle tissues and capacity of muscle to use oxygen (Engelhardt, 1977; Upadhyay and Madan, 1985b).

2.4 THERMOREGULATORY PROCESSES

Body heat content during exercise increases in all mammalian species and changes in muscle temperature occur more than rectal temperature. Heat exchange by radiation, conduction and convection also occurs under natural conditions, whereas evaporation is primarily in the form of sweating and panting (Hafez, 1968). Changes in rectal temperature have been considered to be affected by environmental temperature change during work when heat production increase and the animal exerts extra to dissipate the body heat (Murray and Yeates, 1967; Grashaw, 1980).

In working animals, rectal temperature of animals has been considered to be an index of thermoregulatory mechanisms (Harvath *et al.*, 1950; Moran, 1973). Taneja and Bhatnagar (1960) observed an increase (1.76%) in rectal temperature of buffalo calves after half an hour of exercise. A rise of rectal temperature in buffaloes from 38.20°C to 40.08°C after running and upto 39.20°C while carrying load on the back (60 kg) was observed by Sodhi and Singh (1973). Rana *et al.* (1978) reported a rise in rectal temperature from 37.5°C to 38.2°C after 1 h, 40.2°C after 2 h and 41.1°C after 3 h of exercise in buffalo calves. Nangia *et al.* (1980) observed increase in rectal temperature, tympanic temperature, and skin temperature upto 41.8°C, 39.05°C and 39.74°C, respectively from their respective initial values of 37.56°C, 34.07°C and 35.12°C in working buffalo calves. Upadhyay and Rao

(1985) also observed a significant increase in rectal temperature of working buffaloes (38.03° to 41.05°C) during summer season.

Chikamune (1987) studied thermoregulatory functions of Swamp buffaloes. Degree of water loss and heat dissipation through different channels was lower in buffaloes than in cattle in all the seasons, viz. summer, winter and spring.

Martin and Teleni (1989) also observed that work load affects the thermoregulatory system of an animal and the rectal temperature increased with increase in work load. During heavier work load, the mean increase over pre-work value of rectal temperature was approximately 2.4°C. Dang (1990) reported increase in rectal temperature of buffalo heifers from 37.83 $\pm$ 0.18°C to 39.90 $\pm$ 0.12°C after 2 h of work. One hour rest decreased rectal temperature to 39.0 $\pm$ 0.11°C. Another period of exercise raised rectal temperature to 39.55 $\pm$ 0.13°C, which decreased to 39.05 $\pm$ 0.11°C after 1 h rest.

Maurya and Devadattam (1986) observed an increase in body temperature of Jersey x Red Sindhi crosses and in Khillari bullocks. Increase in body temperature has also been observed by Upadhyay and Madan (1985a) in Haryana and crossbred bullock subjected to work under heavy loads in summer. Sreekumar and Thomas (1989) reported change in rectal temperature of working crossbred and Kangayam bullocks. Rectal temperature was recorded before the start of work, immediately after work and after 1 h of rest after work were 38.45 $\pm$ 0.01, 39.73 $\pm$ 0.03, 38.93 $\pm$ 0.02, respectively in Kangayam and 38.70 $\pm$ 0.02, 40.01 $\pm$ 0.03 and 39.21 in crossbred bullocks. Bhatnagar (1989) observed a rise in rectal temperature in cows moving uphill at a speed of 2.5 km/h for 30 min from 38.04 $\pm$ 0.19 to 39.0 $\pm$ 0.14°C and increase in skin temperature from 29.05 $\pm$ 0.00 to 33.13 $\pm$ 1.31°C.

2.5 CARDIOVASCULAR CHANGES

The famous Danish physiologist August Krogh made the classical observations on the capillary circulation of experimental animals. He counted 5 capillaries per square millimeter in the resting muscle, and 190 per square millimeter after stimulation. It was estimated that only 1/20 to 1/50 of the capillary bed is open in the resting state (Krogh, 1922).

As the increase in active capillaries and the bloodflow is approximately the same about 20 times that at rest, it follows that the velocity of flow in the capillary is much the same in the exercise as at rest, and the time each blood corpuscle spends in the capillaries is not much changed by activity. Cardiovascular system, in order to supply adequate amount of oxygen for working muscle and to transport carbon dioxide to lungs and to maintain *internal milieu*, increases its activity several folds during exercise/work. Increased demand of oxygen during exercise is partially met by enhanced oxygen carriage by blood aided by an increased circulation rate (Wiggers, 1955). Heart rate changes during exercise in horses have also been reported (Asheim *et al.*, 1970; Senta *et al.*, 1970; Steel *et al.*, 1976; Hornicke *et al.*, 1977,1983). At the peak demand for oxygen, the heart rate has to increase its output both by speeding up its rate of beating and by increasing the volume of blood pumped at each stroke. According to the available evidences, it appears that under moderate stress the heart may increase either its stroke volume or rate or both (Rushmer, 1961; Rowell, 1974; Sodhi and Singh, 1973; Naughton, 1979). Initially, heart rate increases due to inhibition of parasympathetic control over heart (Hall *et al.*, 1976; Rowell, 1983) but while running, oxygen supply to muscle is mainly achieved by increase in rate than the cardiac output (Bhutani and Nangia, 1976; Nangia *et al.*, 1980).

Buffalo bullocks working under heavy load during summer also showed a significant increase in the heart rate from 58.88 to 97.50 bpm after exercise (Upadhyay and Rao, 1985). Rana *et al.* (1978) reported a significant change in pulse rate of castrated and uncastrated buffalo males while pulling a stone roller at constant speed of about 3 km/h for 3 h.

The increase in heart rate during moderate and submaximal work at normal speed does not go beyond 150 to 160 bpm (Upadhyay, 1987). Pulmonary ventilation increases to only a limited extent during work and this may limit work over prolonged periods in animals as in humans (Bye *et al.*, 1983; Upadhyay, 1989). The reasons relate to inefficiency of gas exchange and respiratory muscle fatigue as a result of inadequate perfusion when respiratory muscle compete for blood flow with working muscle and thermoregulations (Rowell, 1974).

Upadhyay and Rao (1988) reported an increase in heart rate to about 150 to 160 bpm after 30 min of treadmill exercise. The heart rate increased immediately at start to 100 to 120 bpm which stabilized after 4 to 5 min and remained at these levels during exercise. Wachirapakorn and Wanapat (1989) found that pulse rate increased in buffaloes from 43.8 to 67.7 and 77.4 bpm after working for 1 and 2 h, respectively. Pulse rate decreased to normal level within a period of 2 h.

Heart rate changes during work have been studied in bullocks

(Singh *et al.*, 1968a; Rao *et al.*, 1974; Devadattam and Maurya, 1978; Acharya *et al.*, 1979; Upadhyay, 1982; Rao and Upadhyay, 1985; Upadhyay and Madan, 1986; Anjuli, 1988). The increase in heart rate doesnot exceed 150 to 160 bpm. The rise in pulse rate was reported by Rao *et al.* (1974). The effect of roller pulling (Sastry, 1969), loading (Devadattam and Maurya, 1978), treadmill working (Upadhyay and Rao, 1988; Martin and Teleni, 1989) were also similar and rise in heart rate/pulse rate have not been reported to exceed levels of 150 to 160 bpm.

Sreekumar and Thomas (1989) compared the draught capacity of crossbreds with Kangayam bullocks and found that the increase in pulse rate was more in crossbred animals. Pulse rate values were observed to be much higher in crossbred bullock than Haryana bullocks (Agarwal and Agarwal, 1990).

2.6 PULMONARY CHANGES

During exercise, several adaptations occur in respiratory system analogous to those of thermoregulatory and cardiovascular adaptations. During work the energy demands of muscle increase several folds. In order to transport greater volume of oxygen, respiration rate, tidal volume and diffusion rate for oxygen must increase. The ventilation volume increases due to increasing work loads upto the maximal levels. From a resting value of about 6.0 l/min the ventilation increases to 100 and 150, and in extreme cases to 200 l/min (Saltin and Astrand,1967).If pulmonary ventilation is expressed in relation to magnitude of oxygen uptake, it is 20 to 25 l/l oxygen at rest and during moderately heavy work but increases to 30 to 35 l/l oxygen during work. Pulmonary ventilation, which is at rest 25 to 80 l/min in cattle must increase many folds to accommodate for increased requirements. Such increase is brought about by increase in breathing rate coupled with increase or decrease in tidal volume (Brody, 1945).

Increase in respiratory rate (RR) with the increase of air temperature is one of the first prominent and viable physiological response of cattle. Numerous reports have been published indicating increase in respiratory frequency with increase in environmental temperature (Bianca, 1965; Thompson, 1973). Increased respiration rate with increase of relative humidity (Rhoad, 1936; Sheath and Miller, 1946) and decrement in respiration rate with drop of temperature (Kibler and Brody, 1949) have also been reported.

Increased energy demands of muscle during exercise is accompanied by an enhanced pulmonary activity in cattle (Upadhyay, 1982; Martin and Teleni, 1989) and in horses (Brody, 1945; Pearson, 1985; Manohar, 1988).

During agricultural work, respiration rate increases in both native and crossbred bullocks (Mukherjee *et al.*, 1961; Singh *et al.*, 1968a,1970; Sastry, 1969; Rao *et al.*, 1974; Acharya et al 1979; Kaur and Rao, 1984; Upadhyay and Rao, 1986; Bakrie *et al.*, 1987; Anjuli, 1988; Bhatnagar, 1989; Agarwal and Agarwal, 1990). Increase in RR of buffaloes during work/exercise has been reported (Taneja and Bhatnagar, 1960; Moran, 1973; Sodhi and Singh,1973; Alim and Ahmad, 1975; Singh *et al.*,1981,1982; Rao and Upadhyay, 1985; Kapoor, 1985; Bakrie *et al.*, 1987; Upadhyay, 198L,1989; Upadhyay and Rao, 1988; Dang, 1990). Komarudin Ma'sum and Teleni (1991) compared the three breeds of cows and found that respiration rate increased significantly during exercise, the differences were significant between breeds, the highest mean respiration rate was observed in Bali cows while Ongole cows showing the lowest mean values.

Sodhi and Singh (1973) observed a respiration rate of 43.25/min after running and 28.17 after walking with a 60 kg load on the back from a normal value of 27.50 in buffalo calves.

Alim and Ahmed (1975) recorded a respiration rate of 25.92 per minute in buffaloes and observed a significant relationship between body temperature and respiration rate. Kapoor (1985) reported an increase in respiration rate from 13 to 125 per minute after work, indicating a rise of 861 per cent. Upadhyay and Rao (1985) also observed an increase in respiration rate by 934 per cent in buffalo males in response to heavy work.

In order to ensure an adequate supply of oxygen for muscles, the lungs provide more oxygen for haemoglobin saturation and circulatory system attempts to deliver oxygen in proportion to tissue metabolism. Studies on human, cattle, buffalo and horse have indicated that all systems adjust to supply oxygen to working muscle within the physiological limits.

2.6.1 PANTING

Many lower animals have inherent ability to lose heat from the surface of their bodies for two reasons, the surface area usually covered with fur, second the skin of most lower animals is not supplied with sweat glands, which prevents much evaporative loss of heat from the skin. Therefore, a substitute mechanism of panting - which is primarily dead space ventilation, is an important temperature regulating mechanism in many species.

During panting, the respiratory frequency is increased and the tidal volume is decreased so that alveolar ventilation remains constant. This process often protects animals and birds from hyperventilation.

A heat load evokes polypnea in many mammalian and non-mammalian species, and in some the panting is fast enough to account for a major heat loss. Panting is usually accompanied by increased salivary secretion and may cause a considerable increase in respiratory evaporative cooling if the humidity of the inspired air is not too high.

Studies on the panting mechanism in cattle have shown that evaporative cooling occurs in the upper respiratory passage and not from cooling in the lungs. It is clear in the calf and in the sheep that panting is in response to raised environmental temperature and starts before there is an increase in the temperature of the blood supplying the brain (Hales and Webster, 1967). But panting may also be induced at a constant external temperature by a rise in body temperature or by local warming of the anterior hypothalamus (Hales and Bligh, 1969).

Biology and comparative physiology of panting in different animals have been observed by Richards (1970). When cattle were exposed to hot environment, respiratory frequency increased and tidal volume decreased with net rise in respiratory evaporation, especially from upper respiratory passage (Bianca, 1965). Panting is not as effective as sweating in increasing evaporative moisture loss in the heat, and in addition there is the possibility that the effort of panting increases the animal's heat production. Findley and Whittow (1966) observed a 3-fold increase in the respiratory frequency of steers after heating hypothalamus but did not detect any significant increase in oxygen consumption.

In severe heat stress (40/38°C, DB/WB) when body temperature rises continuously, the initial respiratory pattern changes from high frequency and shallow breathing to a deep breathing with low frequency respiration. In such type of breathing, dead space ventilation occurs and respiratory alkalosis develops. This phase of breathing has a very high energy cost and the mixed venous blood has a high lactate values, indicating tissue hypoxia (Hales and Webster 1967; Hales, 1973).

McLean and Calvert (1972) found that increasing the relative humidity from 32 to 72 per cent at an environmental temperature of 35°C reduced respiratory evaporation. In an environment of 35°C, the heat loss is reduced to 38 per cent from 54 per cent at 15°C. Chikamune *et al.* (1987) studied the heat loss in relation to evaporative water loss in Swamp buffalo and Holstein cattle in three different seasons in temperate region. Evaporative water loss both through respiratory and body surface was lower in buffaloes than in cattle in all seasons. Cattle lost a greater per cent of heat through evaporative channels than did buffaloes. Thereby, study suggested that buffaloes were not as efficient as cattle in heat dissipation processes. On the other hand, the lower respiratory volume associated with a high rate of oxygen uptake in buffaloes may indicate the existence of a more efficient energy saving mechanism in buffaloes.

2.7 HAEMATOLOGICAL CHANGES

The blood and lymph are responsible for transportation of material between the different cells and tissues. Various products, by-product and intermediates of metabolism are transported through blood; therefore, the blood circulation has a key role in the maintenance of "internal milieu" and body fluid regulation. During exercise, the tissue demands for oxygen increases several times and blood has to supply oxygen to the tissue, if work is to be sustained for longer periods. In order to fulfil this need, red blood cells are mobilized from the spleen at the time of initiation of work as has been evidenced by red blood cells increase in cattle and buffaloes (Singh *et al.*, 1968; Upadhyay and Madan, 1988).

Haematocrit, red blood cells counts and haemoglobin concentration of buffaloes are negatively correlated with the ambient temperature (Murty and Mullick, 1960; Raghvan and Mullick, 1962). Thermal stress of direct solar radiation caused a decrease in the haemoglobin in buffaloes and cattle (Shafie and Badreldin, 1962). At any environmental temperature, buffalo has greater content of haemoglobin than Egyptian native cattle and temperate cattle crosses with native, but also equal to that of pure dairy shorthorn (Shafie and Badreldin, 1962). Shebaita and Kamal (1973) reported lower values of Hb in mature buffaloes and Friesian cows, 11.18 $\pm$ 0.37 and 9.25 $\pm$ 0.27, respectively. Mullick (1960) reported higher value of Indian buffaloes than Indian cattle, 12.3 and 10.4 g in hot dry weather (33^{o}C, 33% RH) and 10.4 and 9.8 g in less hot humid weather (28^{o}C, 82% RH).

It was observed that in most cases lower values of Hb in cattle (Manresa *et al.*, 1940; Bonsoma *et al.*, 1940; Pal *et al.*, 1945; Spealman *et al.*, 1949). Manresa *et al.* (1940) reported a lower value of Hb in imported temperate breed in comparison to Zebu which was associated with the degree of acclimatisation and conclusively more variations in the Hb concentration in any breed or species due to climate changes indicates lesser capacity of adaptation.

Upadhyay (1982) reported a decrease in Hb and PCV level during work. Continuous work over several weeks may not have enough red blood cells in spleen for mobilization. Decrease in hematocrit and Hb levels from their basic values during load pulling and ploughing operations in Haryana, crossbred and buffaloes have been reported (Upadhyay and Madan, 1988; Sastry *et al.*, 1970; Singh *et al.*, 1968; Upadhyay and Rao, 1985; Rao *et al.*, 1974; Nangia *et al.*, 1978).

These studies indicated that crossbred bullocks appeared to possess a better adaptive mechanism to meet the increased demand for oxygen during work by changing the Hb level in blood than in Sahiwal bullocks (Georgie *et al.*, 1970). Acharya *et al.* (1979) worked on bullocks (crossbred and nondescript indigenous type) and found an increase in Hb per cent, packed cell volume, total red blood cells, white blood cells after work.

Bhatnagar (1989) reported no significant difference in Hb and PCV value either due to exercise or in recovery phase in working cows. Sreekumar and Thomas (1989) also reported significant decreases in the levels of Hb and packed cell volume in crossbred and Kangayam bullocks.

2.8 PLASMA VOLUME CHANGES

Work in hot environment involves another perturbation to cardiovascular system as a result of changes in fluid volume. Evaporative loss in the form of sweat or water from respiratory tract spends several litres of body water/h during work in hot conditions. Extracellular and intra-cellular volume changes occur with other physiological changes which influence thermo-regulation in humans (Senay, 1979). But the changes in ruminants are undoubtedly not the same. The plasma volume rises due to work in the heat as a result of haemodilution in buffaloes and cattle (Upadhyay, 1987). Continuous working over 3 h expends plasma volume to an extent of 16 per cent over the initial volume (Upadhyay, 1982). The magnitude of changes may be even higher in some of the animals. Plasma volume expend greater in summer while performing heavy work at a higher speed. The Haryana bullocks have greater capacity to mobilize their water content and increase plasma volume more than the crossbreds under similar conditions. Some of the bullocks in beginning develop hemo-concentration but continuous work result into haemodilution. Prolonged working produce hyper-volumia to the extent of 15 to 20 per cent depending on load and duration of work. Plasma volume expends to help animal system to transport greater heat of work. Therefore, these changes in plasma volume during work in summer may be regarded as "the single most important mechanism responsible for homeostasis during work in hot environment". Most likely, these changes occur through aldosterone-arginine-vaso-pressin mechanisms to maintain fluid and electrolyte balance. Whether the induced hyper-volumia is an osmotic expension as a result of increased retention of crystalloid within the intra-vascular space or an oncotic expansion as a result of increased retention of colloids is still not clear. In either case, the expansion of the volume must be regarded as a homeostatic response.

2.9 BIOCHEMICAL ADJUSTMENT (ENERGY, DEMAND AND SUPPLY)

The main substrates for skeletal muscle metabolism during exercise and carbohydrates and free fatty acids (Dole, 1956; Newsholme, 1981). Three major sources, namely (i) adipose tissue, (ii) intramuscular triacylglycerols, and (iii) circulatory triacylglycerols supply FFA's for utilization in muscle. Several factors may influence the rate of triacylglycerol synthesis. Insulin is the key hormone for this process. It enhances the entry of glucose into the fat cells (Bjorntorp and Ostman, 1971). To ensure optimum delivery of fuel to exercising muscle endocrine control systems interact and for the most part oppose the actions of *anabolic hormones, primarily insulin as is evidenced by the* decline in pancreatic and gut blood flow (Bell *et al.*, 1983).

Substances elaborated as a result of high sympathetic action by neuro-endocrine organs, particularly catecholamines, glucocorticoids and growth hormone exert anti-insulin effects and provide energy demands of muscle by enhancing assimilation of glucose from blood, glucogenolysis and increased oxidation of fat. To compensate for these changes in glucose homeostasis, hepatic glucose output and FFA metabolization from adipose tissue is augmented. Thus, the energy demands are met in the muscles via endocrine glands after stimulus from hypoxic tissue(s) or/and action of labile humoral substances produced by exercising muscle.

Vinten and Galbo(1983) studied that exercise/training modify the responses of the adipocytes to insulin. Adipose tissue depots are mobilized to provide energy for milk secretion during early lactation and for work. Complete hydrolysis (lipolysis) yields 3 mol non-esterified fatty acids(NEFA) and 1 mol glycerol/ mol triacylglycerol.

Studies on exercising horses (Rose *et al.*, 1977; Lucke and Hall, 1980) and sheep (Leng, 1985) have indicated that FFA's are mobilized from these sources to meet energy needs. About 50 to 60 per cent of the supply is from extra-muscular depots in exercising dogs (Paul and Issekutz, 1967) and man (Havel *et al.*, 1967) and that remaining is contributed by the intramuscular triacylglycerol (Costill *et al.*, 1973; Essen *et al.*, 1977).

During exercise adipose tissue blood flow increases several fold in sheep (Upadhyay and Hales, unpublished), dog (Bullow, 1982) and man (Bullow, 1981). The fatty acids are released from adipose tissues in association with plasma albumin (Bullow, 1983). The increase in blood flow has been demonstrated to enhance the FFA's mobilization during exercise. The association with albumin increases enormously that amount of FFA's that can be transported but since the free concentration is very low, it limits the rate at which FFA's can be taken by muscle (Newsholme, 1981). The fuel availability in Marathon runners has been implicated in the poor performance (Gollnick, 1977; Davies and Thompson, 1979). Studies on fat depleted sheep carrying weight on their back have also revealed that adipose tissue depots are perfused to drive FFA's and depleted animals depend on limited adipose tissue depots for energy during work (Upadhyay and Hales, unpublished). A similar situation is expected in under-fed oxen ploughing fields and covering 40 to 50 km/day in 6 to 8 h continuously and for several weeks in a cropping season. Inadequate feed availability prior to monsoon season leads to poor physical condition of animals. Under such condition, work is performed over prolonged hours on the expenses of adipose tissue depots many and to a lesser degree on stored glycogen (Upadhyay, 1989).

Training has a profund effect of FFA's mobilization in humans (Holloszy and Booth, 1976) and rats (Buckowiecki *et al.*, 1980). Both sex (Despres *et al.*, 1984a) and genetic (Despres *et al.*, 1984b) differences in lipolytic activity have observed and training improves the preferential utilization of FFA's more in males than females (Despres *et al.*, 1984a).

The role of FFA's as an important fuel for muscular work is directly revealed by modern techniques including the use of isotopes (Fritz, 1961). Adipose tissue depots have a large heat store in the adipocytes. At the beginning of exercise there is a drop in the plasma FFA due to an increased uptake in the active muscle. After sometime there is a subsequent rise in the plasma FFA concentration provided that the work is not extremely heavy. This rise is due to an enhanced mobilization of FFA from the adipose tissues which is probably induced by an increased sympathetic activity which is, in turn, levels to a proportionately increased turnover of the FFA (Armstrong *et al.*, 1961).

Studies of Kartiarso *et al.* (1989) on four steers and four buffaloes have suggested that the fatty animals can be worked on their fat resources with minimal nutrient input. These animals would probably do best on a diet of high glucogenic potential. The effect of exercise (work) on female cows was reported by Teleni *et al.* (1991) that there were significant differences between breeds in the value of FFAs. The highest concentration of FFAs was recorded in the Ongole cows while lowest values were observed in Bali cows and Madura cows in between 1.162, 0.765 and 1.130 mM/l, respectively. Physical condition had a significant effect on the plasma concentration of FFAs. Plasma concentration of FFAs was higher in the untrained (1.102 mM) than trained (0.953 mM). Plasma concentration of free fatty acids increased during work period. Kartiarso *et al.* (1987) and Teleni and

Hogan (1989) concluded that increase of plasma free fatty acids and glucose concentrations during work are consistent with the view that these are the two most important energy yielding substrates for the working muscle.

2.10 RESPONSE TO HORMONAL STIMULI

The hormonal effects on lipolysis have been studied in detail *in vitro* as well as *in vivo* (Heindel *et al.*, 1975; Hales *et al.*, 1978). A wide variety of hormones have been found to be lipolytic. These are catecholamines, growth hormone, ACTH, various pituitary hormones and intestinal hormones such as secretin and VIP. In human adipose tissue, only catecholamine and TSH have consistently been found to stimulate lipolysis *in vitro*.

The effect of catecholamines and insulin on lipolysis are brought via receptors located on the adipocyte cell membranes. Hormonal mechanism of importance for the increased lipolytic rate during exercise is the depressed insulin concentration. The decrease in insulin concentration in peripheral plasma is directly related to work intensity (Galbo, 1983). The concentrations of FFAs and glycerol during exercise are higher in fasted and in fat fed animals than in normal animals while insulin concentration is lower (Galbo *et al.*, 1979).

In dog, the essential hormonal changes promoting increased lipolysis during exercise seems to enhance sympatho-adrenal- β - adrenergic stimulation reinforced by the L-adrenergic elicited decrease in circulating insulin concentration. In small mammals, it has been found that thyroidectomy abolishes exercise stimulated lipolysis (Federspil [illegible] 1975). Thyroid function may not be without influence on the lipolytic response during exercise in man. However, there is no evidence that thyroid hormones may be acute regulators of lipolysis and furthermore the concentrations of thyroxine and triiodothyronine do not change during exercise (Galbo, 1983; Bhatnagar, 1989).

Falls (1968) suggested that growth hormone has a physiological role in fat metabolism. Human growth hormone secretion, in turn, is responsive to alterations in glucose metabolism, stimulation being caused by hypoglycemia and suppression by glucose administration.

2.11 ENERGY SUBSTRATES

Muscle preferentially use glucose for energy supply, depending on energy needs in the muscle and oxygen availability. Glucose may be used both aerobically and/or anaerobically, though later process being less economic and efficient in comparison to the former one.

Judson *et al.* (1976) found that in exercising sheep the amount of glucose passing through the glucose pool in the animal increased, and they attributed this increase in extra-gluconeogenesis, however, recycling of glucose undoubtedly occurs to some extent.

Clearly, glucose is a substrate for muscle energy at rest and during work and long chain fatty acids become increasingly important with progression of work. utilization of glucose in muscle is approximately 1.25 mmol/h/kg muscle in fed, non-producing sheep but utilization is reduced in lactating sheep to about 0.3 mmol (Pethick, 1984).

Glucose uptake by muscle increased with exercise (walking 5 km/h) as did the uptake of FFA (Pethick and Chong, 1985). If the muscle mass in a 40 kg sheep is about 25 per cent of body weight (i.e. 10 kg) then muscle accounts for the utilization of 37.5 mg glucose/min (4.5 g/2 h) at rest in a fed animal, 6 mg/min (0.72 g/2h) in a fasted pregnant animal, but as much as 10.5 mg/min (12.6 g/2 h) in a sheep walking on a treadmill at 5 km/h. In these physiological states, glucose passing through the body pool varies from 30 to 100 mg/min (Leng, 1970) and, therefore, the muscle when working uses a high proportion of glucose normally available and the animal must be mobilising glucose from its glycogen resources. As the liver contains about 5 g glycogen/ 100 g and the skeletal muscle 1 to 2 g glycogen/100 g. These resources could be potential sources of the glucose for muscle.

ATP is readily available source of energy which is generated by metabolism of glucose and other intermediates of metabolism. Exercising muscle chiefly depend upon glucose for energy supply hence require more glucose. Changes in the glucose level due to exercise in ruminants do not occur significantly (Upadhyay and Madan, 1988; Nangia *et al.*, 1979; Singh *et al.*, 1980).

Blood glucose in relation to environment and substrates availability has received considerable attention among bovines (Diven *et al.*, 1958; Bianca and Findley, 1962; Raghvan and Mullick, 1962). Tripathi *et al.* (1978) concluded that the effect of climatic variables on blood sugar levels in animals is not always uniform and other factors compound in. A brief review of glucose changes in bovines is presented here.

Murty and Mullick (1960) observed a positive correlation of blood sugar with increase in air temperature, whereas humidity had no effect. Similar thermoglycemic responses during hot and hot humid conditions in Haryana cattle were reported by Bhosrekar and Sadhu (1963) and Singh and Bhattacharyya (1986). On the other hand, Blincoe and Brody (1951) indicated that blood sugar decreased with the increase of environmental temperature.

No significant changes in blood sugar levels of animals have been reported due to rise in environmental temperature (Pal *et al.*, 1945; Brody, 1949; Bianca and Findley, 1962). More recently, Singh and Bhattacharyya (1991) have reported that the blood glucose was significantly ($P < 0.05$) higher at 37^{o}C and 22^{o}C in all crossbred groups at 9 days and in only Brown Swiss animals at 19 days exposure.

Georgie *et al.* (1970) observed among bullocks a decreasing trend in blood glucose level during autumn and winter seasons. In Sahiwal bullocks, blood glucose fell from a resting value of 60.45 to 47.10 mg/100 ml against a fall from a rest value of 57.12 to 37.90 mg per cent in crossbred after second hour of work. Anjuli (1988) observed that 4.65 and 9.34 per cent reduction in blood glucose in growing male crossbred cavles working on a treadmill at different speed and gradient.

Bhatnagar (1989) reported that changes in blood glucose

decreased from pre-exercise value of 43.4 $\pm$ 1.36 mg per cent to 36.2 $\pm$ 0.93 mg per cent after 30 min of exercise on treadmill. The increase of plasma glucose concentration during work has also been observed by Teleni and Hogan (1989). Teleni *et al.* (1991) found that there were significant differences between breeds in values of glucose. The highest concentrations of glucose were recorded in Ongole cows

(3.755 mM) while the lowest values were observed in Bali cows (3.109 mM) and in between Madura cows (3.241 mM). Physical condition had a significant effect on plasma concentrations of glucose in untrained and trained cows.

2.11.1 LACTIC ACID

During exercise, anaerobic breakdown of glycogen steadily increases lactic acid concentration in muscles and blood. Accumulation of lactic acid in muscle causes fatigue and hinders the work performance of the animals.

Limited studies on cattle and buffaloes have revealed that blood lactate concentrations do not increase to very high levels and often the level remains in physiological limits. Contrary to horses and humans where the circulating levels of lactic acid rises to very high levels, which develop acidosis in muscles and affect muscle contractile process.

Normal blood lactic acid concentration varies from 5 to 15 mg per cent in cattle (Georgie, 1969; Rao *et al.*, 1974). Most hyperlactacidemic responses after intense muscular work have been reported in human beings and horses (Takahashi, 1961; Lucke and Hall, 1980), but lowering of blood lactate levels have also been reported by Astrand and Rodhal, 1970; Astrand *et al.*, 1963).

During submaximal exercise, Georgie *et al.* (1970) observed that crossbred bullocks do not increase blood lactate level, most likely due to the bicarbonate buffer capacity which restricts the elevation of lactic acid in blood.

In Haryana and crossbred bullock, increase in lactic acid levels from an initial value of 9.33 to 10.60 mg per cent to 20.30 to 23.20 mg per cent after end of ploughing, respectively have been observed during summer (Rao *et al.*, 1974).

Increase in blood lactic acid levels have been reported while work in cattle and buffaloes. Upadhyay and Madan (1988) reported moderate increase in blood lactic acid levels during work in different work regimes during exercise in bullocks. Anjuli (1988) and Bhatnagar (1989) also reported increase in lactic acid in crossbred bullocks and cows working on treadmill. Sreekumar and Thomas (1989) observed increase in blood lactic acid level from 27.81 ± 0.12, 30.52 ± 0.45 to 40.37 ± 0.19 and 40.73 ± 0.22, respectively in Kangayam and crossbred. Teleni *et al.* (1991) reported the effect of working Ongole, Bali and Madura cows and found a significant difference between breeds in lactic acid levels (0.935, 1.040 and 1.122 mM) respectively in three breeds. The mean lactate concentration in blood plasma of Ongole was the lowest among the breeds. Martin and Teleni (1989) observed an increase in lactic acid in working buffaloes after different work levels.

Studies on working buffaloes have indicated that lactic acid increase in blood and blood bicarbonate levels decreases in response to exercise (Nangia *et al.*, 1978). Singh *et al.* (1980) reported increase in lactic acid from 13.00 to 22.3 mg per cent after 3 h of roller pulling in buffaloes during hot humid season.

2.12 EFFECT OF WORK ON FEMALE FERTILITY AND PRODUCTIVITY

The use of cows for draught varies between countries, regions and places. An estimate of the proportion of draught animal power derived from cows indicate that cows contribute to farm power in India (6.25%), Senegal (27%), Philippines (18.0%) and Thailand (61.0%). According to the Bangladesh Bureau of Statistics (1986), of the 11.78 million draught animals in Bangladesh, 3.4 million or 29 per cent are draught cows. Theoretically, cow can produce draught power more efficiently than oxen when considering efficiency of production in individual ox and cow or when considering the total output from oxen and cows on a farm (Mathewman, 1984).

Thermal stress, particularly in a tropical environment affect female reproduction either directly or indirectly through a reduction in feed intake and through reproductive hormones. The extent to which heat generated during work affects the chain of events leading to ovulation, conception, pregnancy, fetal development and parturition is not known clearly. Therefore, a better understanding of the female reproductive processes is necessary in developing management systems which will not depress life time production in terms of calf crop and milk in a working female.

2.13 THERMAL STRESS AND FERTILITY

Exposure of most animals to elevated ambient temperature results in reduced reproductive performance, particularly in the tropics where thermal stress prevails during most months of year. Although some of the reduced fertility can be attributed to male infertility such as reduced libido and semen quality, much of the infertility is due to the effect of heat stress on female reproduction, particularly from oestrus to implantation (Jainudeen, 1976).

Thermal stress alters the length of oestrus cycle, reduce the duration and the intensity of oestrus, and if the stress is severe, will reduce anoestrus in cows (Bond and McDowell, 1972). High environmental temperature depresses fertility of cows (Stott and Williams, 1962) by increasing the incidence of fertilization failure and embryonic motility. High ambient temperatures at the time of breeding and for 72 h thereafter had a detrimental effect on conception (Dunlop and Vincent, 1971). High atmospheric temperature on the day of and the day after insemination was inversely associated with fertility (Gwazdauskas *et al.*, 1973). An elevated temperature humidity index prior to breeding was associated with a linear decline in fertility (Ingraham *et al.*, 1974). Heat stress reduced fetal growth in late gestation and conceptus function which may have carry over effects on lactation and postpartum reproduction (Collier *et al.*, 1982).

Information on the effects of thermal stress on buffalo reproduction is limited. During summer, when ambient temperature and photoperiod effects were at their maximum prolactin level were highest (Kaker *et al.*, 1982) and plasma progesterone levels were lowest (Rao and Pandey, 1982). About 28 per cent of all reproductive failures in over 12,000 buffaloes under Indian village management were attributed to non-function ovaries, particularly in summer and autumn (Rao and Sreemannarayanan, 1982).

Little experimentation has been carried out on the effect of work on milk yield though there has been speculations about the effects. In well fed animals, the effect may be negligible (Lawrence, 1985; Munzinger, 1982; Rajapurohit, 1979) while under other circumstances there may be a negative effect (Kibria, 1982; Goe, 1983; Jabbar, 1980). Rizwan-ul-Muqtadir, Ahmed and Ahmad, 1975), carried out a trial in Pakistan using cows for 3 h a day for 3 weeks and no significant effect on milk yield or composition.

Mathewman *et al.* (1988) studied to investigate the effect of exercise on twelve pregnant crossbred Hereford/Friesian suckler cows fed to requirement on a diet of known composition for maintenance, growth of concepta, normal exercise and lactation. Exercise reduced milk yield, lactose yield and protein yield but did not reduce yield of milk fat. When animals did not walk, milk yield returned almost to three previous levels. The result demonstrated a negative effect of work on milk yield and composition in animals fed to requirement, and suggest that the supply of glucose precursors is the main limiting factor to milk yield.

Mathewman (1986,1987) suggested that if animals are fed properly. They will suffer no ill effect (i.e. loss of milk or fertility) though there would be adverse effects on animals which are poorly fed.

Experiment was conducted by Agyemang et al (1991) to see the effect of work on reproduction and productive performance of crossbred dairy cows and reported that after the end of second lactation there were no significant differences between draught and non-draught animals for milk production [1.713 ± 57.4 compared with (vs) 1,857 ± 48.1 kg], lactation length (299 ± 20.4 vs 288 ± 18.0 days), calf birth weight (29.6 ± 1.0 vs 29.3 ± 1.0 kg), number of days open (77 ± 14.1 vs 83 ± 12.9), calving interval (385 ± 14.5 vs 358 ± 13.2 days), gestation length (2 78 ± 1.6 vs 274 ± 1.4 days) and number of service per conception (1.21 vs 1.64).

The number of hours walked by each pair of crossbred cows was sufficient to cultivate the average small holder farm of 2.5 ha. However, the work done was spread over a longer time than that required by small holder farmers to cultivate 2.5 ha. It was concluded that low levels of work with improved feeding, management, draught or traction do not have adverse effect on reproductive and productive performance of crossbred dairy cows.

2.14 ENDOCRINE RESPONSE TO EXERCISE, HEAT AND PHOTOPERIODS

High environmental temperature depress body activities and metabolic processes which viewed homeostatically, are biological mechanism for preventing stress of over-heating. Over-heating creates physiological stress that could have conceivable effect on production by promoting unfavourable endocrine balance or/and by changing metabolic processes. The thyroid is involved in the regulation of metabolic activity and its activity is augmented in cold climate and suppressed in hot environment or work. The general hypofunction of the anterior pituitary may be major result of high temperature and exercise (Johnson, 1980). Through hypothalamo-hypophyseal-gonadal axis, most of the animals mediate their physiological processes and respond to environment.

2.14.1 THYROID HORMONES

Muscular exercise changes the concentration of circulating thyroid hormone. Muscular exercise itself increases heat production and this may militate against increasing the rate of utilization of thyroid hormone (Larhof *et al.*,1954). Bogoroch and Timiras (1951) studied that stressing agents which activate the adrenals cause a loss of iodine ions into the urine and a decrease in the activity of iodine concentrating mechanism of the thyroid gland. The latter may be due to a decrease or suppression of thyrotrophic stimulation. Irvine (1967) found that thyroxine fractional turn over rate in race horses increased 265 per cent after 12 weeks of physical exercise. Same worker (Irvine, 1968) further reported that athelets had T_4 degradation rates that were 75 per cent higher than value found 3 h after exercise in sedentary controls.

Terjung and Tipton (1971) found that an increase in total T_4 concentration averaging 11 per cent during exercise was attributed mainly to hemoconcentration that was indicated in the changes in hematocrit values. An average increase in free T_4 concentration of the 20 per cent was found during exercise with a peak response of 35 per cent above the control value. Manson *et al.* (1973) found a small but consistent increase in plasma immunoreactive thyroid stimulating hormone in man, just before they took part in exhaustive exercise on bicycle ergometer. The increase in mean values of 3.1 to 4.0 uU/ml was statistically significant. The conclusion was that physiological stimuli could induce pituitary thyroid activity in man.

Ceralis *et al.* (1977) reported the effect of strenuous dynamic muscular exercise on serum free thyroxine (FT_4) and free triiodothyronine (FT_3) concentration in man and observed a slightly decrease in FT_3 concentration. Increased free thyroxine concentrations developed in subjects who were physically better trained. Refsum and Stremme (1979) reported an increase in triiodothyronine and thyroxine concentration in serum after prolonged heavy exercise. Bosello *et al.*(1983) showed that diet and exercise increased thyroxine significantly.

Limited studies on cattle and buffaloes have been carried out and these indicate that thyroid function is slightly depressed in buffaloes than Friesian cows due to heat stress. The I^{131} uptake per 24 h at 22°C air temperature was 10.13 and 13.75 per cent of dose in buffaloes and Friesians, respectively. At 35°C, the respective values were 8.91 and 9.14, thus, a reduction of only 1.22 of the dose occurred in buffaloes compared to 4.61 per cent reduction in Friesians indicating about 1/10 reduction of activity in buffaloes as compared to 1/3 reduction in Friesians (Kamal *et al.*, 1972). Similarly, responses of the two species were also reported by Ibrahim (1968) under winter and summer conditions (i.e. under Egyptian climatic conditions as well as under controlled air temperature of 14.6, 29.0 and 42°C). Mean serum content of thyroxine in summer and winter in buffaloes have been reported 11.16 $\pm$ 2.04 and 11.36 $\pm$ 1.55 ng/ml, respectively. The respective values of T_3 were 1.01 $\pm$ 0.11 and 0.85 $\pm$ 0.10 ng/ml. These seasonal changes were not significant (Dixit *et al.*, 1982).

Peripheral levels of testosterone and thyroid hormone in male buffaloes, and the temporal variation have also been reported by Agarwal *et al.* (1983). Thyroid levels vary from 20 to 40 ng/ml which increase after work without a change in ratio between T_3 and T_4 throughout the work rest. Agarwal *et al.* (1983) studied the circulatory levels of thyroxine and tri-iodothyronine in blood serum of male buffalo calves from 1-2 months to till maturity. Thyroid hormones were low at early age but attained a peak at puberty followed by a decline at full maturity. T_4 and T_3 ratio more or less constant through all stages of development.

Khurana (1983) observed alterations in T_3 and T_4 values when Haryana and crossbred bullocks were subjected to low (9 quintals) and high (14 quintals) load pulling operations during hot dry and hot humid conditions. T_3 increased from 0.27 to 0.29 ng/ml in Haryana bullocks during hot dry conditions, when subjected to pull 9 quintals of load. There was a decrease in plasma T_3 concentration at 2 and 3 h after work. In crossbred bullocks, the pre-treatment values changed from 0.43 ng/ml 0.20, 0.46 and 0.45 ng/ml after 1, 2 and 3 h of work. Heavy load pulling decreased T_3 from 0.34 ng/ml to 0.22, 0.32 and 0.31 ng/ml at 1, 2 and 3 h of work, respectively in Haryana bullocks. Whereas T_3 increased in crossbred from 0.24 ng/ml to 0.32, 0.35 and 0.35 ng/ml. Under hot humid conditions, plasma T_3 concentrations varied from pretreatment value of 1.06 ng/ml to 1.19, 1.21 and 0.97 ng/ml after 1, 2 and 3 h with high loads in Haryana bullocks. In crossbred bullocks, the respective values changed from 0.95 to 1.06, 1.09 and 1.08 ng/ml after 1, 2 and 3 h treatment.

Under hot humid conditions, the mean circulating plasma T_4 values was 30.95 and 32.23 ng/ml in Haryana and crossbred bullocks, respectively. After 1, 2 and 3 h of work, the values were 35.31, 30.10 and 26.84 ng/ml in Haryana and 23.11, 16.42 and 35.48 ng/ml in crossbred bullocks, respectively.

Under hot humid conditions, mean plasma T_4 concentrations were 80.22 and 100.07 ng/ml in Haryana and crossbred bullocks, respectively. Under 9 quintals loads, the pretreatment T_4 values after 1, 2 and 3 h of treatment were 76.80, 82.16 and 80.40 ng/ml in Haryana and 73.74, 76.25 and 77.85 ng/ml in crossbred bullocks, respectively. Alterations may be due to heat stress which was existing in animals. It was argued that the magnitude of work stress may play secondary role when stress was imposed on the working animals.

Khurana and Madan (1985) also observed that T_4 levels were negatively correlated with milk yield in both cattle and buffaloes, whereas correlations of T_3 were positive in cattle and negative among buffaloes. The relationship between T_3 and T_4, however, was not significant.

Borady *et al.* (1987) studied the seasonal variation in thyroid hormones and reproduction in Egyptian water buffaloes. Anjuli (1988) reported a rise in plasma thyroxine levels of crossbred during treadmill exercise.

Bhatnagar and Upadhyay (1990) studied the effect of gradient walking on T_4 and T_3 hormones in crossbred cows. A significant reduction in T_4 level after 30 min of exercise was observed from a pre-exercise value 45.58 ± 5.13 to 28.2 ± 0.80 ng/ml. Post exercise value of T_4 was 34.4 ± 2.03 ng/ml after 30 min rest. Plasma levels increased after 5 min of exercise from 0.93 ± 0.12 ng/ml but with progress of exercise the value declined to 0.71 T_3 0.11 ng/ml at 30 min. During rest, the level was seen normal at 5, 15 and 30 min post exercise.

2.14.2 INSULIN

The pancreas in addition to its digestive functions secrete two important hormones, insulin and glucagon. Insulin has been associated with blood sugar and it has profound effects on carbohydrate metabolism mainly related to abnormalities of fat metabolism. Therefore, it is clear that insulin affects fat and protein metabolism as much as it does carbohydrate metabolism. According to Vranic and Kawamori (1979), strenuous exercise can enhance the release of long acting insulin from a previously injected subcutaneous site into the circulation or insulin bound to endogenous antibody may associate at an accelerated rate due to altered kinetics that may occur during exercise.

Insulin is well recognized for it's hypoglycaemic effects. For a long time, ruminant tissues have been considered less sensitive to insulin than non-r uminant tissues. The increment in plasma insulin causing 50 per cent reduction in glucose production is 50 to 60 uU/ml (Brockman, 1983a) whereas the comparable value for humans is 30 uU/ml (Rizza *et al.*, 1981). Similarly, the rate of utilization of glucose appears to be less responsive to insulin in ruminant than in non-ruminant. The concentrations of insulin in plasma are positively correlated with food or energy intake (Bassett *et al* 1971). Paradoxically, insulin concentrations are highest in the fed state when glucose production is greatest (Bergman *et al.*, 1970).

However, *in vitro* studies indicate that insulin has at best only small effect on fatty acid synthesis from acetate and glucose in sheep (Vernon, 1982; Broad *et al.*, 1983) and cattle (Yang and Baldwin, 1973).

In lactating animals, particularly hypoglycaemic-ketonaemic animals, insulin secretory responses to glucose and propionate are reduced (Hove, 1978; Lomax *et al.*, 1979; Bair d *et al.*, 1980). The post-prandial rise in insulin is also reduced (Hove and Halse, 1978) and hepatic extraction of lactate is higher than in non-lactating animals. Thus, in lactating animals maximum rates of gluconeogenesis may be attained and smaller quantities of nutrients are taken up by muscle and fat. Mertsching (1981) found no significant changes in insulin levels in lactating cattle exposed to heat.

Blum and Eichinger (1988) reported a decrease in blood insulin levels during walking which rapidly increased afterwards. Blood insulin was affected by work loads.

Bhatnagar and Upadhyay (1990) studied the effect of gradient walking on insulin level in crossbred cows. In order to know the exercise induced insulin changes, six trained lactating crossbred cows were exercised on treadmill at a speed of 2.5 km/h uphill 15.5^{o} for 30 min. Mixed venous blood samples were collected at 5, 15 and 30 min post exercise. Plasma insulin declined from 7.75 ± 2.03 uU/ml to 3.66 ± 1.28 uU/ml after 15 min exercise but at 30 min the values dramatically increased to 10.25 ± 2.33 uU/ml. The insulin levels did not return to normal even after 30 min post exercise. Gradient walking decreased insulin level.

2.14.3 STEROID HORMONES

Seasonal reproduction is a physiological process through which animals not only respond to climatic extremes but also manipulate the survival of the off-spring and their own well beings. Particularly in India, where assured feed and fodder supply is often restricted to hot humid periods, animals exhibit such a phenomenon in a pronounced manner. During summer, in northern India, temperature reach upto $42^{o}C$ for many days during the afternoon and $30^{o}C$ during the night. Day length goes upto 13-14 h.

Seasonality in buffalo breeding has been reported (Rife, 1959; Bhattacharya *et al.*, 1970; Roy *et al.*, 1972). Luktuke *et al.* (1973) found that buffaloes ovaries were least active during extreme climatic conditions. The important seasonal reproductive problems are weak or silent oestrus, and irregular oestrus cycle lengths.

Heat stress has also been shown to reduce the fertility of dairy and beef cows (Stott and Williams, 1962; Dunlop and Vincent, 1971; Ingraham *et al.*, 1974; Gwazdauskas *et al.*, 1979; Mohammed *et al.*, 1981; Bodinga *et al.*, 1985; Gangwar, 1988; Geisert *et al.*, 1988).

The degree of heat stress and its effect on plasma progesterone concentrations is influenced by the length of exposure (Abilay, Johnson and Madan, 1975) and by milk production (Wolft-Vaught *et al.*, 1977). The concentration of progesterone and oestradiol-17 β in the plasma of high milk yielding dairy cows exposed to subtropical summer conditions have been reported (Folman *et al.*, 1979b).

2.14.3.1 Estrogen

The most common estrogenic substance in cows is estradiol. Two other estrogens, estrone and estriol are present in lesser concentrations and are considered to be produced from estradiol (Asdell, 1964). The theca interna cells are considered to be source of estrogen. In addition to causing the behavioural manifestations of estrus, estrogens stimulate blood flow and growth of the tubular genitalia and gonadal hormone levels during different phases of estrus cycle around parturition in cattle and buffaloes have appeared in previous papers and reviews (Christensen *et al.*, 1971; Swanson and Hafs, 1971; Nessan and King, 1981; Prakash and Madan, 1984; Avenell *et al.*, 1985; Yang and Wang, 1988; Agarwal *et al.*, 1989; Eltohamy *et al.*, 1990).

The serum LH levels increased as heifers approached first estrus (Swanson *et al.*, 1972) which coincided with the gradual rise of estradiol, 3 days before estrus suggesting that endogenous estrogen secretion increases (Wettemann *et al.*, 1972). Garverick *et al.* (1974) observed a significant increase in plasma estradiol levels from 2 days pre-partum (292.6 ± 31.7 pg/ml) to higher levels at parturition (544.3 ± 63.3 pg/ml) followed by a precipitous drop after parturition.

Studies carried out by Hunter *et al.* (1970), Edqvist and Johansson (1972), Hoffman *et al.* (1973), Peterson *et al.* (1975), Madan *et al.* (1983) and Prakash and Madan (1984) indicated that estrogens increased at the time of approaching parturition reaching peak levels just before partum, and then show a sharp decline to low values immediately post-partum. However, Edquist *et al.* (1973), Arije *et al.* (1974) and Agthe and Kolm (1975) are specific to point out that under their experimental conditions they did not observe estrogen increase with these hormone almost plateauing upto term and only declining post partum. An important consideration which should be taken in interpreting their observations is the assay system, experimental protocol, specificity and sensitivity of the assay factors which must have obviously contributed to tremendous variability in results. Prakash (1983) reported a gradual rising trend in mean plasma estradiol-17 β in cows on day 30 pre-partum followed by an abrupt rise in the hormone concentration to peak values by day 1 pre-partum.

Agarwal *et al.* (1989) reported serum estrogen levels in repeat breeding cows. Blood samples were collected from 16 cows on day 0 (estrus), 2, 5, 9, 17 and 20 of an oestrus cycle. After mating 8 cows returned to oestrus (repeat breeders) and 8 conceived. In repeat breeders, blood oestradiol concentration 5.70 ± 0.08, 3.60 ± 0.30, 5.90 ± 0.40, 3.60 ± 0.50, 3.50 ± 0.06 and 3.40 ± 0.24 pg/ml. Corresponding figures for cows that conceived were 9.00 ± 1.50, 6.00 ± 1.10, 6.50 ± 1.60, 5.50 ± 0.60, 6.00 ± 1.20 and 4.70 ± 0.55 pg/ml.

Bryner *et al.* (1990) studied the pattern of concentration of oestradiol-17β during an oestrus cycle. Oestradiol-17 β during the follicular phase differed with age ($P < 0.05$). In old cows, an earlier mid-cycle elevation of FSH was associated with an earlier rise and greater concentration of oestradiol ($P < 0.05$) during follicular phase.

Bhatnagar and Upadhyay (1990) studied the effect of gradient working on plasma concentration of oestrogen in working cows and found that gradient walking in cows did not effect circulating level of oestrogen. The values before and after exercise were 10.98 ± 4.11 pg/ml and 10.92 ± 3.85 pg/ml.

Only a few studies have been carried out in case of buffaloes and not many are relevant to present study. Rao *et al.* (1978) observed that the total and free estrogens in serum of three buffaloes from about 60 days post-partum to 4 days post-partum found individual variation in the levels of the estrogen among the three animals with values ranging between 56 to 230 pg/ml at around 51 to 57 days prepartum. Although an increasing trend in hormone level was reported in all three buffaloes from around 2 months prepartum, the results obtained were inconsistent and inconclusive. Concentration of estradiol-17 β on the day of estrus was 19.32 ± 3.75 pg/ml which declined to reach a nadir (5.73 ± 3.68 pg/ml) on the day 2 of the cycle, it again increased during 3 day preceding estrus and attained a peak (35.5 ± 3.48

pg/ml) a day before the onset of next estrus in cycling buffalo heifers (Bachalaus *et al.*, 1979). In addition, estradiol level of 20.31 ± 1.14 pg/ml and lower value of 8.41 pg/ml on the day of estrus and 2 to 18 days post-partum respectively was observed by Arora and Pandey (1982).

Avenell *et al.* (1985) studied the oestradiol concentration in peripheral plasma of 13 mature Swamp buffalo cows at 4 h interval from 36-40 h before until 36-40 h after the onset of estrus. The mean oestradiol-17 β concentration lay in the range 9-13 pg/ml from 36-40 h before until 12-16 h after the onset of estrus and within the range 7-9 pg/ml thereafter.

Madan *et al.* (1983) conducted an experiment on 5 buffaloes and found that plasma oestradiol-17 β concentration increased gradually from 71.00 ± 7.79 pg/ml at 30 days before calving to 174.60 at 2 days before calving. There was a peak of 209 ± 75 on the day before calving. Concentration on the day of calving and the 3 subsequent days averaged 141.65 ± 65.33, 42.13 ± 10.27, 17.09 ± 2.30 and 19.60 ± 2.65 pg/ml.

Prakash and Madan (1984) measured oestradiol-17 β by radio-immunoassay in the maternal jugular venous plasma of pregnant buffaloes on day 30, 15, 5, 2 and 1 pre-partum on the day of parturition at 6 h intervals upto 72 h post-partum and on day 4, 6, 10, 18, 34 and 80 post-partum. The mean plasma oestradiol level rose gradually from day 30 (71 pg/ml) to day 5 pre-partum (100 pg/ml) and then increased to a peak value of 209.75 pg/ml on the day before parturition. The peak levels of the hormone dropped sharply over the first 24-72 h post-partum and remained low during rest of the sampling periods (20-34.2 pg/ml). Kumar and Rattan (1990) reported that plasma oestradiol-17 β level was comparatively high in post-natal calves, significantly low in young calves and maximum 26.06 $\pm$ 3.69 pg/ml in sexually mature heifers.

Eltohamy *et al.* (1990) reported serum concentration of oestradiol-17 β in buffaloes, the level was maximal during pro-estrus, while there was a relatively high concentration of sodium in the cervical mucus.

2.14.3.2 Progesterone

The ovarian hormones that have been identified with the estrus cycle are the oestrogens and progesterone. Progesterone is produced mainly by the corpus luteum. This hormone is essential for the development of the endometrium for implantation and is necessary for the maintenance of pregnancy. From the early post-natal stimulation of gonads by the hypothalamic and pituitary hormone, the progesterone play a key role in change leading to puberty in cattle.

Donaldson *et al.* (1970) observed a fluctuation in plasma progesterone levels towards onset of puberty indicating cyclic ovarian activity before the first observed oestrus in heifers with lowest concentration of 0.44 ng/ml at estrus and increased to a maximum of 6.8 ng/ml about day 14 to 21 of cycle reaching low level on the day of estrus. Smith *et al.* (1973) observed that the hormone level remains high until two days pre-partum (7.6 $\pm$ 0.9 ng/ml) falling to 3.0 $\pm$ 0.7 ng/ml at 1 day pre-partum and to 0.6 $\pm$ 0.1 ng/ml at parturition and remained near this level for 9 days post-partum.

Abiloy et al. (1975) studied the effect of acute heat (45^{o}C) exposure on plasma progesterone response of Zebu and Highland heifers. Plasma progesterone levels increase significantly during exposure in Highland cattle only. The differences in response between breed suggest the active involvement of adreno-ovarian functions in the heat acclimatisation process. Shin *et al.* (1979) collected blood samples from 55 cows every five days from 30 to 5 days before calving and then daily until day of calving. The samples were radioimmunoassayed progesterone concentration ranged from 5.12 to 11.70 ng/ml between 30 and 5 days before calving and fell rapidly from 5.12 $\pm$ 1.07 ng/ml 2 days before calving to 1.48 $\pm$ 0.32 ng/ml 24 h before calving.

Prakash (1983) reported a decline trend in mean plasma progesterone, gradually from day 30 and day 2 pre-partum, the mean values at these two days recorded by 6.32 and 2.59 ng/ml for cows and 1.82 and 1.21 ng/ml for buffaloes respectively. Thereafter the levels fell sharply to low values at calving ($P < 0.05$ ng/ml) in both species.

Wise *et al.* (1988) reported the influence of acute exposure to thermal stress on the secretion of progesterone in lactating dairy cows. Eight cows were maintained through the summer in a refrigerated, air conditioned, tie stall barn, another 8 cows were maintained in outdoor corral with access only to shade cows in the two environments had similar concentration of progesterone. In buffaloes, relative few studies have been conducted. Rao *et al.* (1978) reported progesterone concentration in three buffaloes from around 2 months prepartum to 4 days post-partum. The progesterone concentration varied markedly in the 3 animals with values of 1.6, 5.5 and 2.2 ng/ml being recorded around 50 to 60 days pre-term. The trend observed in three animals was also not similar with a gradual fall in the hormone levels with minor fluctuations being observed from 60 days prepartum in an animal, and high hormone levels being maintained till 4 days pre-partum in the other two animals. No progesterone levels have been reported in these two animals till 3 to 4 days post-partum when lower values were recorded.

However, plasma progesterone level reflected age dependent change occurring in the cyclic corpus luteum in buffalo cows. A higher level of plasma progesterone 4.81 $\pm$ 0.39 ng/ml concentration on day 13 of the cycle among Murrah buffalo, heifers and lower values of 0.14 ng/ml on the day of estrus has been observed by Arora *et al.* (1979).

Rao and Pandey (1982) conducted an experiment during different seasons and reported plasma progesterone concentrations on day of oestrus and also in the luteal phase of cycle which were significantly higher ($P < 0.01$) in the cooler (warm and cold) seasons than in hot and dry, and hot and humid season.

Madan *et al.* (1983) studied anoestrus rural buffaloes and concluded that progesterone level was constantly low (0.14 $\pm$ 0.36 ng/ml). Jainuddin *et al.* (1983) reported that mean concentration of progesterone in plasma of Swamp buffaloes with or without corpus luteum on their ovaries was 1.49 $\pm$ 0.78 and 0.14 $\pm$ 0.09 ng/ml, respectively. Jain and Pandey (1983,1985) reported low level of 0.3 $\pm$ 0.1 ng/ml, with a tendency to increase with advancing age, reaching to 0.8 $\pm$ 0.1 ng/ml in the heifers exhibiting estrus at 30 months of age. Prakash and Madan (1985) studied the periparturient plasma progesterone levels in buffaloes. The mean plasma progesterone concentration decreased gradually from 1.82 ng/ml on day 30 before birth to 1.21 ng/ml on day 2 ($P < 0.05$) falling sharply at parturition to 0.32 ng/ml

(P < 0.05) and remaining low upto the end of the sampling (day 50 postpartum).

Bamualim *et al.* (1987) conducted an experiment on 16 non-pregnant buffaloes and blood samples for plasma progesterone were taken 3 times per week during first four weeks and last four weeks of experiment, and plasma progesterone (PP) used as a measure of ovarian activity. This was categorised as (a) negative (< 0.5 ng PP/ml), (b) doubtful (> 0.5 ng PP/ml) in two or more samples but not in a regular pattern, and (c) positive (if there were regular changes in progesterone concentration typical of normal cyclic ovarian activity). The number of cows showing each pattern of ovarian activity during the first and last 4 weeks of the experiment period, respectively were 2, 3, 3 and 4, 2, 2 as negative, doubtful, and positive respectively.

Jain (1988) studied the progesterone levels in 13 age groups of cycling and non-cycling buffaloes and found that the progesterone concentration ranged from 0.27 ± 0.07 to 0.61 ± 0.15 ng/ml, and was significantly higher in non-cycling heifers aged 811 and 1,260 days than in young animals. Pregnant and non-pregnant buffaloes did not differ significantly in plasma concentration of progesterone upto 22 days after insemination.

Yang and Wang (1988) studied the peripheral plasma level of *progesterone during normal and low breeding seasons in Chinese Swamp buffaloes. Blood concentration of progesterone during the "low" breeding season (February-June)* 0.54 ± 0.22 ng/ml was significantly lower than those in the buffaloes studied during the normal breeding season (0.73 ± 0.71 ng/ml).

Perera *et al.* (1989) studied the effect of supplemental light on growth and progesterone level in water buffalo. Fifty non-pregnant Surti buffalo heifers aged between 17 and 42 months were subjected to normal day light + 4 h supplemental light or natural day light (controls) in a study in Sri Lanka. Ambient temperature and relative humidity during the day time generally were $\succ$ 27^{o}C and RH < 70 per cent, respectively. Light supplemented heifers had 16.2 kg for controls but higher mean progesterone concentration (0.41 vs 0.19 ng/ml, P < 0.06) after 6.5 weeks than control heifers. Older heifers had 39.7 per cent greater body weight, but a net 4.3 per cent weight gain, compared with a 10.1 per cent gain for younger heifers at 10 weeks. Older, light supplemental heifers had higher mean progesterone concentration (0.63 vs 0.19 ng/ml, P < 0.07) than the other groups. These weight and hormonal changes suggest that 4 h supplemental light can alter growth and endocrine function in buffaloes under similar pla nes of nutrition.

Studies in relation to effect of environmental stress or work stress on estrogen and progesterone have not been carried out mainly due to their limited scientific relevance as females are limitedly used for work.

CHAPTER 3

MATERIALS AND METHODS

3.0 MATERIALS AND METHODS

3.1 EXPERIMENTAL ANIMALS

3.1.1 SELECTION OF ANIMALS

Apparently healthy, ten crossbred cows and ten buffaloes were selected from the herd of National Dairy Research Institute (NDRI), Karnal. Among these five animals were dry non-pregnant (DNP) and other five animals were lactating non-pregnant (LNP). The ploughing experiments were carried out on both the groups of buffaloes and cows during summer (hot dry) and winter (cold humid). Only dry non-pregnant animals were used for carting experiments during hot-humid season.

3.1.2 MANAGEMENT OF EXPERIMENTAL ANIMALS

All experimental animals were maintained under identical conditions of feeding and management. Animals were given maintenance ration as per NDRI schedule, and feeds and fodders were fed depending on the availability from time to time, the main fodders being Maize, Jowar and Berseem. All the DNP and LNP animals were offered maintenance allowance during forenoon, but concentrate mixture (both maintenance and production) to LNP animals was offered at the milking time. The average composition of concentrate mixture fed to experimental animals was as follows:

Ingredient	Quantity
	(kg/100 kg)
Groundnut cake	35
Barley/maize	28
Wheat bran	34
Mineral mixture	2
Common salt	1

3.1.3 TRAINING OF ANIMALS FOR PLOUGHING AND CARTING

Before subjecting the animals to actual experimental work, all the animals were trained for ploughing and carting for 2-3 months. In the initial stages, animals were trained for carting without load, and subsequently these were trained for ploughing.

3.2 ENVIRONMENTAL CONDITIONS DURING EXPERIMENTAL PERIOD

The elevation of Karnal is 250 meter above mean sea level, latitude 29.43° and longitude 77°. Minimum temperature falls near freezing point in winter and maximum goes upto 45°C in summer. The annual rainfall is about 70 mm. Maximum and minimum temperature, dry bulb and wet bulb temperature and vapour pressure, intensity of light observed during experiments have been presented in Table 3.1 and climograph in Fig. 3.1.

3.3 EXPERIMENTAL PROTOCOL

Both cattle and buffaloes were subjected to work of ploughing to measure work capacity, efficiency of work and extent

Table 3.1 Climatic variables during experimental period

Season	Temperature (°C)		Dry bulb temp (°C)		Wet bulb temp (°C)		Relative humidity (%)		Vapour pressure (mmHg)		Radiation (W/m^2)	Light intensity (Lux)
	Max.	Min.	I	II	I	II	I	II	I	II	I	
Winter	20.97 ±1.01	7.47 ±1.03	9.50 ±0.93	20.37 ±0.96	8.93 ±0.86	14.97 ±0.85	92.00 ±0.58	55.33 ±1.45	8.77 ±0.35	10.50 ±0.29	457 ± 92	393.17 ±39.94
Summer	36.27 ±1.59	21.27 ±2.36	25.13 ±2.23	35.10 ±1.69	20.73 ±2.05	22.73 ±1.76	67.00 ±6.03	34.33 ±7.69	16.00 ±2.41	13.57 ±2.94	504 ± 36	418.18 ±20.93
Rainy	33.53 ±1.23	24.97 ±1.42	26.96 ±1.27	32.33 ±0.95	25.20 ±0.79	26.97 ±0.20	86.33 ±3.67	65.67 ±4.06	23.07 ±0.89	23.60 ±0.50	353 ± 43	369.36 ±22.79

Fig. 3.1 CLIMOGRAPH

Location : Karnal
Latitude : 20.7°
Longitude : 77°
Sea level : 250 m
Year : 1991

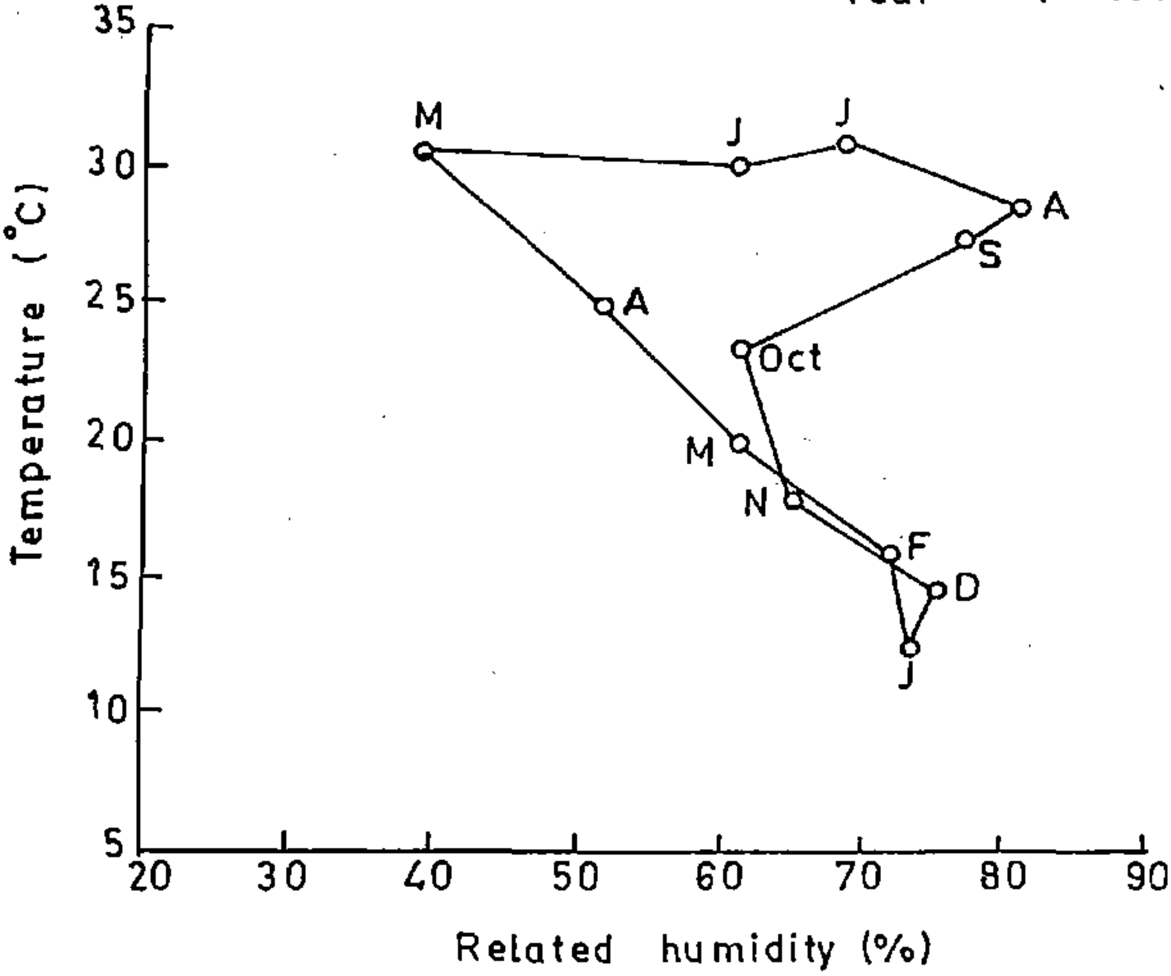
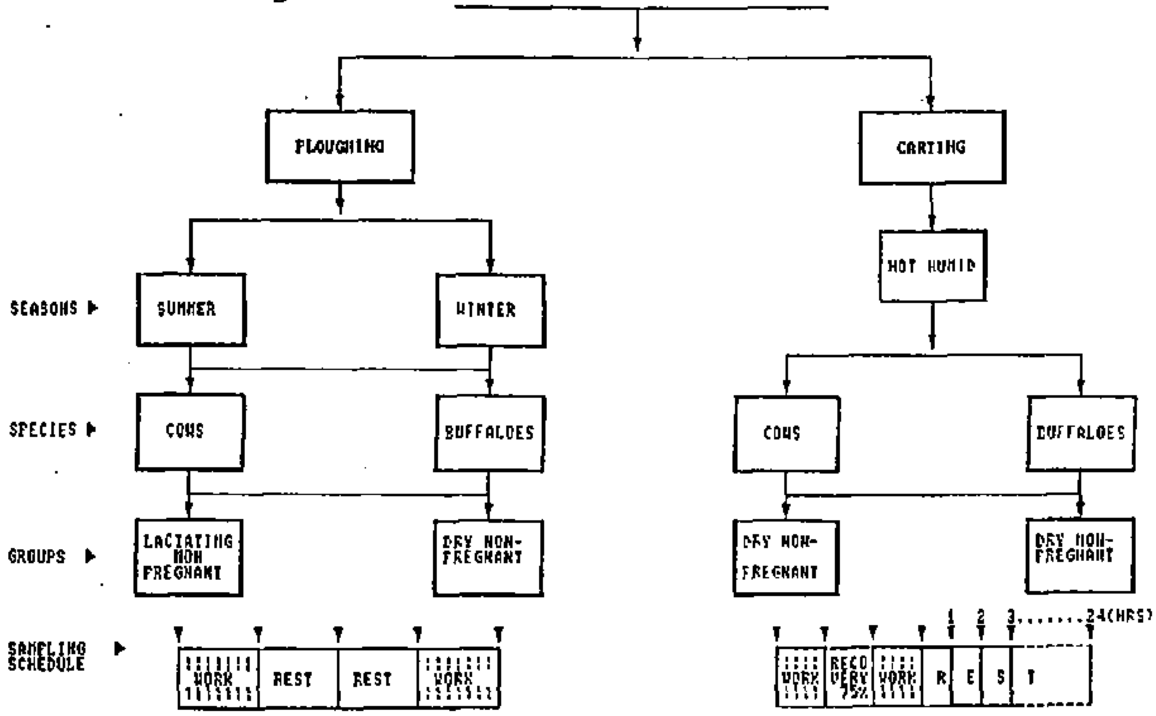


Fig. 3.0 : EXPERIMENTAL DESIGN



OBSERVATIONS :

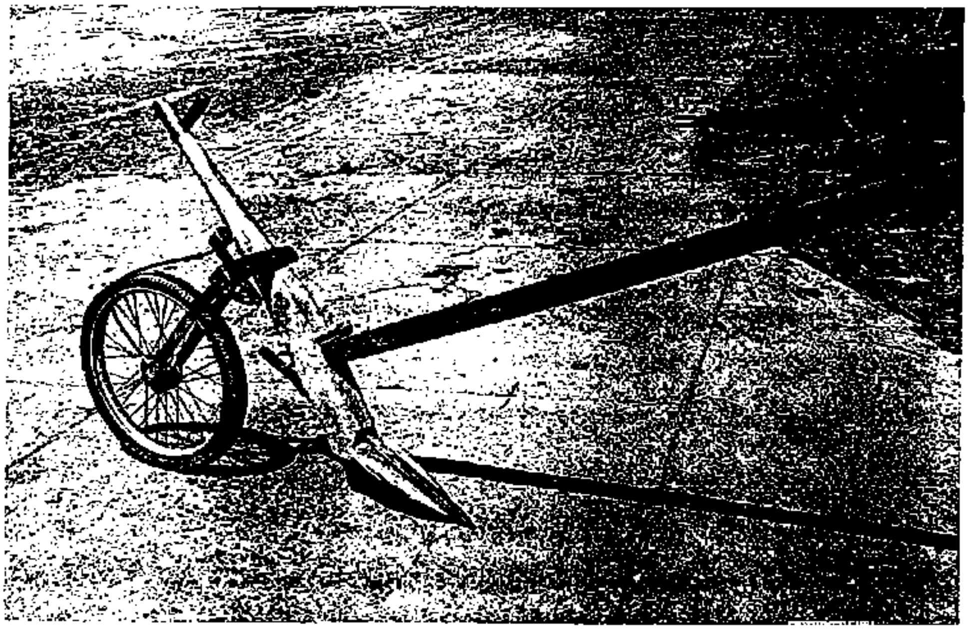
- PHYSIOLOGICAL REACTIONS
- HAEMATOLOGY
- ENERGY SUBSTRATE
- HEAT PRODUCTION
- VOLUNTARY FEED INTAKE
- HORMONES
- WORK OUTPUT
- ENERGETIC EFFICIENCY
- WORK-REST CYCLE

of utilization of females for work during winter and summer conditions.

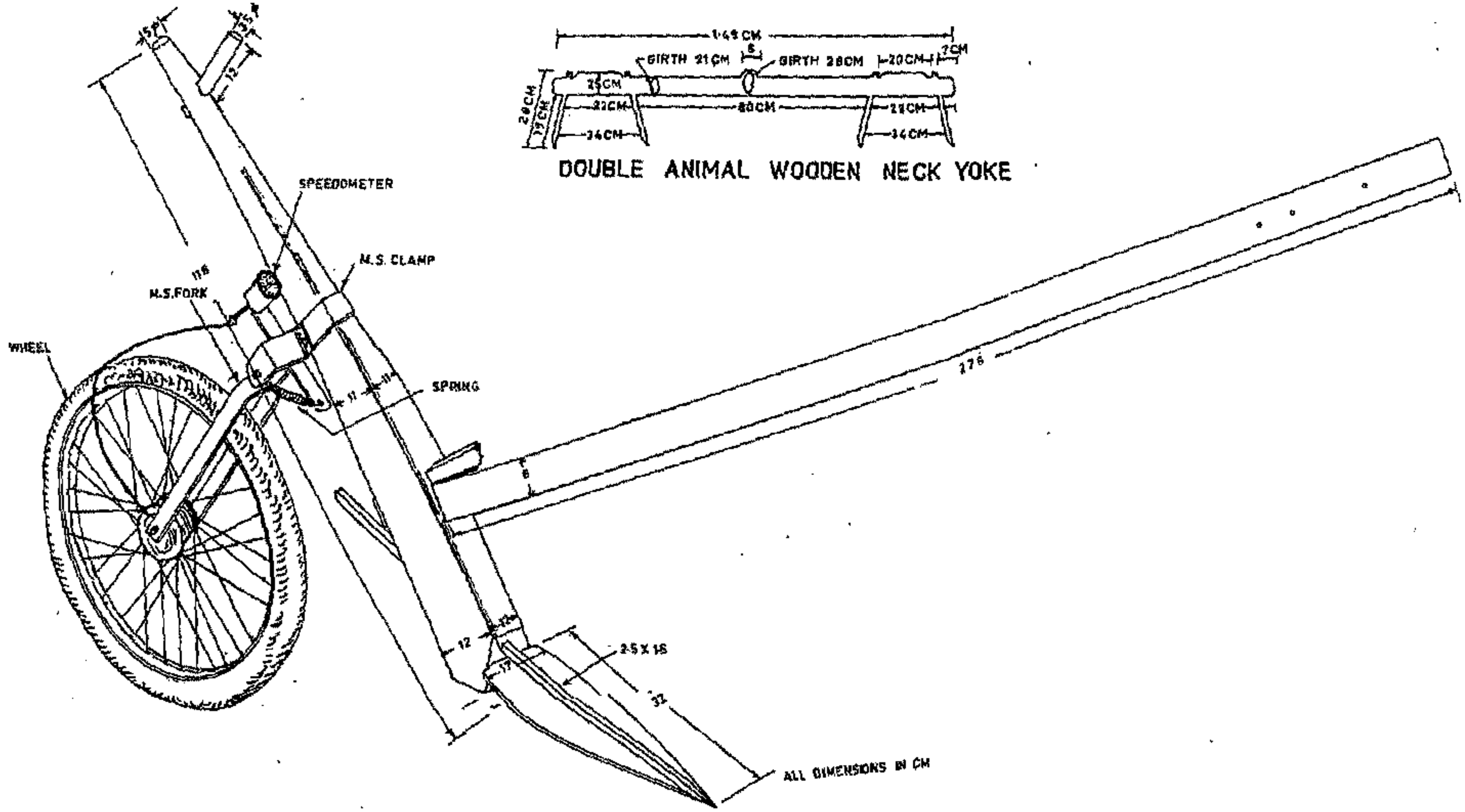
3.3.1 EXPERIMENT NO. 1 : PLOUGHING

In order to evaluate work performance and compare their work capacity, 5 lactating non-pregnant and 5 dry non-pregnant cows and buffaloes were subjected to ploughing. Animals were hitched in pair in a double neck yoke and to a desi plough. Ploughing experiments were performed during summer and winter in loamy soil with 20 to 30 per cent humidity. The details of plough and yoke used in the experiment have been given in Fig. 3.2. The ploughing experiments were carried out for a period of 2 to 3 h or till onset of fatigue whichever was earlier. Work was discontinued, if either of animals exhibited fatigue symptoms. The fatigue was assessed by the method of Upadhyay and Madan (1985b). A period of 2 h rest was given to animals and they were again used for ploughing.

The speed of animals was measured on a speedometer attached to plough (Photo. 3.1) at periodic intervals, the angle of plough was measured in relation to height at neck for work output calculations. The area ploughed during forenoon work session and afternoon session were independently measured. The depth and width of furrow was measured while ploughing. The ploughings were made in the loamy soil when moisture content of the soil ranged between 22 and 28 per cent. The soil was partly compact under present experimental conditions. All animals were monitored in field for their physiological responses. Standard methods were used to measure respiratory rate (nostril air/flank movement), pulse rate (coccygeal), rectal temperature (clinical thermometer) and oxygen consumption. Expired air was collected



3.1 (PHOTO) SPEEDOMETER ATTACHED TO PLOUGH



DESI WOODEN PLOUGH ALIGNED WITH SPEEDOMETER WHEEL

Fig. 3.2

in Douglas bag and volume and oxygen content were measured on wet test meter and Beckman oxygen analyser. Partitioning of heat load due to work and environment were calculated from the body temperature changes, assuming a linear rise, as per Bell *et al.* (1983). Blood samples were also collected from these animals at specified intervals and analysed for haemoglobin (Hb), haematocrit (Hct), plasma volume changes (Δ PV), glucose, lactic acid (LA) and plasma free fatty acid (FFA) and triiodothyronine (T_3), thyroxine (T_4), insulin, estrogen and progesterone were assayed. In order to quantify the effect of work from thermal and heat load experiments during work, other non-working animals were exposed to similar ambient conditions. Ploughing experiments were carried out during summer and winter seasons.

3.3.2 EXPERIMENT NO.2 : PHYSIOLOGICAL CIRCADIAN RHYTHM STUDIES

Before and after the completion of the trial, all the animals were monitored for the changes in physiological rhythms under natural conditions. Milk samples were collected from the lactating animals before, during and at the end of ploughing experiment to see the effect of work on the milk yield and its constituents, i.e. fat, protein and lactose.

3.3.3 EXPERIMENT NO. 3 : CARTING

Carting experiments were carried out on 4 dry non-pregnant buffaloes and cows each hitching them to a single animal pneumatic tyred bullock cart. In order to find out an optimum work-rest schedule, each animal was subjected to 5 and 10 quintal cart loads for a period of 3 h continuously or till fatigue onset whichever was earlier during hot humid periods. Thereafter, animals were given a rest pause sufficient to bring about 75 per cent recovery in their physiological reactions. After the recovery, animals were again subjected, in afternoon, to same work load till the onset of fatigue. After the end of second phase of work, animals were monitored for complete recovery in physiological reactions for a period of 24 h. All physiological, haematological, energy substrates and blood hormonal changes were measured in the pre- and post-work conditions.

3.3.4 WORK OUTPUT AND EFFICIENCY

Work output of animals were derived on the basis of average draught pull of 50 kg, Cos θ and speed of animal. The formula used for calculating work output was:

$$\text{Workout put (hp)} = \frac{\text{Corrected draught pull (kg)} \times \text{speed (m/min)}}{4{,}500}$$

The efficiency of work was derived from work output and energy expended based on RQ calculations (Brody, 1945). The formulae used for efficiency calculations were:

$$\text{(a) Gross energetic efficiency} = \frac{\text{Work output (Kcal)}}{\text{Energy expended (Kcal)}}$$

(b) Net energetic efficiency =

$$\frac{\text{Work output (Kcal)}}{\text{Energy expended} - \text{Energy expended for maintenance (Kcal)}}$$

3.3.5 BLOOD COLLECTION AND PROCESSING

Blood was collected by venupuncture of the right or left jugular vein. Heparin (20 to 30 IU/ml) was used as anti-coagulant. Two ml of blood was deproteinized immediately after collection for glucose and lactic acid determinations. Protein free filtrate was stored in deep freeze for analysis of glucose and lactic acid. Remaining blood was immediately stored in ice-water which was subsequently transferred to the laboratory for plasma separation by centrifugation at 3,000 rpm for 15 min in refrigerated centrifuge for hormone assays. The plasma obtained was stored in frozen state in deep freeze until estimation of triiodothyronine, thyroxine, insulin, estrogen and progesterone.

3.4 METHOD OF BLOOD ANALYSIS

3.4.1 HAEMATOLOGICAL AND ENERGY SUBSTRATES

Blood haemoglobin (Hb) was estimated by Sahli's acid hematin method as per Cohen and Smith method (1919) described by Hawk (1971). Haematocrit (Hct) was measured in duplicate using micro-capillary tubes and centrifuging them on Remi micro-haematocrit. Plasma volume changes during work were calculated on the basis of Hb and Hct using the methods of Van Beaumont *et al.* (1981).

Blood glucose was estimated by the method of Nelson-Somogyi (1944) in protein free filtrate which was obtained using 19 ml of 4.5 per cent Barium hydroxide [$Ba(OH)_2$] solution, and 19 ml of 5 per cent zinc sulphate. Lactic acid was determined in blood as per the method described by Barker and Summerson (1941).

Free fatty acid was determined by the extraction method (chloroform:heptane:methanol, 49:49:2) of Shipe *et al.* (1980) after modifying copper soap extraction method. The method used for determination of free fatty acids in milk was standardized for blood plasma.

3.4.2 METABOLIC HORMONES

The hormones thyroxine (T_4), triiodothyronine (T_3) and insulin were estimated by radioimmunoassay in the plasma samples using kits as per the standard procedure specified by Bhabha Atomic Research Centre (BARC), Bombay.

3.4.3 GONADAL AND PINEAL HORMONES

3.4.3.1 Progesterone

Blood plasma progesterone was analysed by sensitive, direct, rapid radioimmunoassay procedure of Kamboj and Prakash (1992). Briefly, the procedure was as follows.

Plasma samples before processing for hormone analysis were thawed at 37°C in a water bath and duplicate 20 ul of plasma samples and plasma standards(containing progesterone ranging from 4 pg to 250 pg per 20 ul of hormone free plasma), 300 ul of phosphate buffered saline (PBS: 2.68 g of KH_2PO_4, 8.3 g Na_2HPO_4, 8.5 g NaCl, 0.1 g thimersol and 1 g gelatin dissolved in 1,000 ml of distilled water, pH 7.2) was added. This was followed by the addition to 100 ul of progesterone specific antiserum (1:12,000) and 100 ul of ^3H progesterone (101 Ci/mmol, M/s. Radio Chemical Centre, Amersham, U.K.) to each tube at room temperature. All these were then incubated for immune reaction at room temperature (ranging from 20° to 25°C for 2 h. Free and antisera bound hormone was separated by the addition of 0.5 ml of freshly prepared cold charcoal dextran suspension (0.625% activated charcoal plus 0.0625% dextran in PBS). The tubes were then stirred, incubated at 0°C in ice water bath for 10 min and centrifuged at 2,000 g at 4°C for 15 min. The supernatant containing the bound progesterone was decanted into scintillation vials and counted in 5 ml of scintillation fluid containing 4 g of 2,5-diphenyl-oxazole and 0.1 g of 1,4[bis-2(5-phenyloxazolyl)] benzene in 100 ml toluene.

The sensitivity of the assay calculated on the basis of different standard curves for progesterone in plasma was 4 pg/tube which corresponded to 0.2 ng/ml plasma with 50 per cent binding sensitivity being 3.2 ng/ml plasma.

Intra-assay and inter-assay coefficients of variation for progesterone assay in buffalo plasma samples containing 0.74 and 2.03 ng/ml were 11 and 10 per cent and 13.5 and 11.5 per cent, respectively.

3.4.3.2 Estrogen

Estrogen in blood plasma was determined by RIA technique as described by Echternkamp *et al.* (1976) with some modifications. Briefly, the procedure was as follows.

Duplicate plasma samples (1.0 ml) were placed into 15x125 mm glass test tubes and extracted for one minute with 5 ml of diethyl ether. The lower aqueous layer was frozen in ice salt mixture and the upper organic layer was decanted in 12 x 100 mm glass tubes and was evaporated to dryness in a water bath. The walls of the tubes were washed with 2.0 ml diethyl ether and dried again. The residue was dissolved in 0.5 ml of 0.1 M sodium phosphate buffer, pH 7.0 (0.1 M $Na_2HPO_4.2H_2O$ and 0.1 M NaH_2HPO_4. $2H_2O$ mixed in a proportion to give pH 7.0) containing 0.1 per cent gelatin and and 0.1 per cent sodium azide and vortexed for 60 sec. *The tubes containing estrogen were warmed in water* bath at 40°C for 30 min to ensure complete solubilization of steroids.

After removing the tubes from the water bath, 0.1 ml tracer (10,000 cpm) was added and vortexed for 15 sec and incubated at *refrigerator temperature (4°C) overnight.*

This was followed by the addition of 0.1 ml antisera (1:36,000) to all tubes. The tubes were then vortexed for 30 sec and incubated at 40°C in water bath exactly for 30 min. The tubes were then transferred to ice water to incubate for 90 min. Five hundred ul of cold charcoal mixture of 0.625 per cent activated charcoal (625 mg in 100 ml) and 0.0625 per cent (62.5 mg in 100 ml) dextran suspension in 0.1 M sodium phosphate buffer pH 7.0) under constant stirring was added rapidly to each tube (keeping the tubes and charcoal mixture in ice water). All the tubes after gentle shaking were kept in ice water for 10 min. The tubes were then centrifuged in refrigerated centrifuge at 3,000 rpm for 10 min at 4°C. The supernatant containing the antisera bound estrogen was decanted into the glass scintillation vials. Ten ml of scintillation fluid (0.1 g POPOP and 4.0 g PPO in 1,000 ml toluene) was poured in all the vials and tightly capped. The mixture was left overnight at room temperature. The radioactivity and hormone concentration in each vial was determined by the liquid scintillation counter (LKB) programmed for microquantitation of hormone.

Along with unknown assay tubes, a set of tubes (each in triplicate) containing known quantity of standard ranging between 2.5 to 640 pg in 0.1 ml sodium phosphate buffer were taken to which 0.4 ml, of 0.1 M sodium phosphate buffer (pH 7.0) was added. All the tubes were then processed with unknown sample tubes. In addition, five sets of tubes were also taken and run along with assay as follows.

1. Three blank tubes containing 0.6 ml of 0.1 M Na_2PO_4 buffer (pH 7.0) and 0.1 ml tracer (10,000 cpm) to observe the non-specific binding of charcoal separation procedure.

2. Six maximum binding tubes containing 0.5 ml of 0.1 M Na_2PO_4 buffer (pH 7.0), 0.1 ml tracer and 0.1 ml antisera to obtain the percentage binding of tracer by the antibody.

3. Three tubes containing 0.1 ml, tracer diluted to 1.2 ml with 0.1 M Na_2PO_4 buffer (pH 7.0) to obtain total counts of tracer added. The contents of tubes were decanted into scintillation vials directly without any charcoal addition.

4. Recovery tubes containing known amounts of hormone (different levels, in triplicate). The volume was subjected to 1 ml with charcoal stripped plasma and extracted with diethyl ether in the same fashion as plasma samples.

5. Extraction efficiency tubes containing 0.1 ml tracer in 0.9 ml plasma and extracted with diethyl ether in the same fashion as unknown plasma sample. The extracted tracer was dissolved in 1.2 ml assay buffer like unknown samples, decanted directly into scintillation vial and counted by adding 10 ml scintillation fluid.

All the tubes considered for standard curve, non-specific binding, maximum binding, recovery and extraction efficiency were previously washed with 7 ml diethyl ether to dryness in water bath at $40^{o}C$.

3.4.3.3 Melatonin

For determination of plasma melatonin, method of Arendt (1975) was followed.

Melatonin tracer [N-acetyl-5-methoxy-tryptamine (^{3}H-melatonin)] of Dupoint, USA was used which did not bind with antiserum supplied by Arendt et al (Batch No. G/S/704-6483) and antiserum supplied by Niswender G.D.(R1055). The results for binding have been given here indicating that antigen and antisera did not bind. Therefore, RIA of melatonin could not be done in plasma samples.

(a) Experiment 1

Different dilutions of antibody (1:8000, 1:16,000; 1:32,000) were tried for binding with tracer using phosphate buffer saline of 7.1 pH, tricine buffered and EDTA-PBS buffer 0.5 ml with antibody. The procedure of Arendt was followed. One hundred ul of antibody was incubated at $4^{o}C$ for overnight, next day 0.1 ml of tracer was added to all the tubes.

Hormone was precipitated by 0.5 ml dextran coated charcoal and centrifuged for 10 to 12 min at $4^{o}C$ at 3,000 rpm. Supernatant was decanted in the scintillation vials and 5 ml scintillation fluid was added to the vials and then counts were taken by Beckman Instruments, Inc. LS Analyser ^{3}H. But hormone was not precipitated by using charcoal. The results found are given below:

Tube No.	Dilution	Counts per min (cpm)	Disintegration per minute (dpm)
1	Total count	7569.00	11896.00
2	(TC)	7099.00	11067.28
3		6382.00	10222.31
4	Non-specific	9680.00	15458.61
5	binding (NSB)	9737.00	15340.44
6	Dilution	9390.00	14979.21
7	1:8,000	9175.00	14636.17
8	Dilution	9642.00	15176.37
9	1:16,000	9694.00	15236.98
10	Dilution	9609.00	15305.03
11	1:32,000	10397.00	16328.43

(b) Experiment 2

Same buffer (phosphate buffer saline) was used and saturated ammonium sulphate solution was used as precipitant and other steps were similar to as described earlier. The results obtained were as follows.

Tube No.	Dilution	Counts per min (cpm)	Disintegration per minute (dpm)
1	Total count	1067	1672.36
2	(TC)	873	1389.09
3	Non-specific	1175	1831.76
4	binding (NSB)	1063	1663.35
5	Dilution	1296	2018.72
6	1:8,000	1404	2170.94
7	Dilution	1197	1911.30
8	1:16,000	1384	2174.77
9	Dilution	1608	2494.79
10	1:32,000	1212	1934.64

(c) Experiment 3

EDTA buffer was used in place of tricine, EDTA/PBS buffer keeping other steps similar.

Tube No.	Dilution	Counts per min (cpm)	Disintegration per minute (dpm)
1	Total count	1067	1672.36
2	(TC)	873	1389.09
3	Non-specific	1175	1831.76
4	binding (NSB)	1063	1663.35
5	Dilution	1345	2144.32
6	1:8,000	1395	2238.92
7	Dilution	1462	2306.46
8	1:16,000	1352	2130.64
9	Dilution	1482	2365.01
10	1:32,000	1448	2304.36

(d) Experiment 4

In this attempt, tricine buffer saline was used and precipitant was dextran coated charcoal.

Tube No.	Dilution	Counts per min (cpm)	Disintegration per minute (dpm)
1	Total count (TC)	6972.00	11065.69
2	Dilution	511.00	819.85
3	1:8,000	448.00	710.68
4	Dilution	256.00	412.48
5	1:16,000	395.00	627.80
6	Dilution	325.00	516.49
7	1:32,000	288.00	457.30

Tricine buffer precipitated all the hormones. All these attempts proved futile as antiserum and tracer did not show any binding. RIA of melatonin in blood plasma samples collected, therefore, was not possible under present circumstances.

3.5 STATISTICAL ANALYSIS

The results for physiological responses were analysed for mean, correlation coefficient and analysis of variance as per Snedecor and Cochran (1967).

CHAPTER 4

RESULTS

4.0 RESULTS

The present study aimed to explore the possibility and extent of use of bovine females in farming system was conducted on cows and buffaloes in summer, winter and hot humid seasons. The results for the experiments involving ploughing in summer and winter have been presented in Tables 4.1.1 to 4.1.9, Figs. 4.1.5.1 to 4.1.8.7 and statistical analysis in Tables 4.1.5.2, 4.1.5.6 and 4.1.7.4. The results of the carting experiments with 5 and 10 quintals loads have been presented in Tables 4.3.1 to 4.3.4.5, Figs. 4.3.1.1 to 4.3.4.5 and statistical analysis in Tables 4.3.1.2, 4.3.1.5 and 4.3.4.2.

4.1 PLOUGHING EXPERIMENTS

Ploughing in the loam soil was done using a wooden plough. Both dry non-pregnant (DNP) and lactating non-pregnant (LNP) cows and buffaloes were used for ploughing during summer and winter seasons. The results for work output, area ploughed, changes in physiological reactions, haematological, energy substrates and hormones, etc. with their statistical analysis have been presented in Tables 4.1.1 to 4.1.8.5.

4.1.1 WORK PERFORMANCE

The work performance of both dry non-pregnant buffaloes and cows during summer and winter seasons in terms of draft output, speed of work during ploughing and work performed in terms of area ploughed have been presented in Tables 4.1.1 and 4.1.2.

Table 4.1.1 Power output of DNP and LNP buffaloes during summer and winter seasons

Animals	Name of the tool	Working width (cm)	Average depth (kg)	Average draft (kg)	Cost 0	Corrected draft (kg)	Summer				Winter			
							Average working time (min)	Area covered (ha/ 6 h)	Average speed (km/h)	Average power output (hp)	Average working time (min)	Area covered (ha/ 6 h)	Average speed (km/h)	Average power output (hp)
DRY NON-PREGNANT														
I	Desi plough	18	21	25	0.904	22.60	53	0.252	3.26	0.59	50	0.205	3.06	0.48
II	-do-	18	21	25	0.892	22.29	45	0.199	2.60	0.41	50	0.222	3.06	0.49
III	-do-	18	21	25	0.882	22.05	50	0.272	3.51	0.55	49	0.195	2.52	0.40
IV	-do-	18	21	25	0.897	22.42	53	0.244	3.23	0.40	51	0.179	2.52	0.37
V	-do-	18	21	25	0.897	22.42	58	0.342	2.97	0.49	51	0.222	3.06	0.48
Overall average					0.894 $\pm$0.004	22.35 $\pm$0.09	52 $\pm$0.02	0.262 $\pm$0.030	3.11 $\pm$0.15	0.49 $\pm$0.04	50 $\pm$0.04	0.205 $\pm$0.008	2.84 $\pm$0.13	0.44 $\pm$0.22
LACTATING NON-PREGNANT														
I	Desi plough	18	21	25	0.888	22.19	53	0.218	3.06	0.39	58	0.267	3.18	0.52
II	-do-	18	21	25	0.904	22.60	43	0.213	3.00	0.45	61	0.232	2.84	0.48
III	-do-	18	21	25	0.888	22.01	45	0.201	2.87	0.40	58	0.262	3.18	0.51
IV	-do-	18	21	25	0.900	22.38	43	0.216	2.72	0.45	61	0.232	2.84	0.47
V	-do-	18	21	25	0.882	22.05	45	0.272	3.00	0.55	61	0.232	2.84	0.48
Overall average					0.892 $\pm$0.004	22.24 $\pm$0.11	46 $\pm$2.00	0.224 $\pm$0.012	2.93 $\pm$0.13	0.45 $\pm$0.03	60 $\pm$0.07	0.245 $\pm$0.008	2.98 $\pm$0.08	0.49 $\pm$0.01

Table 4.1.2 Power output of DNP and LNP cows during summer and winter seasons

Animals	Name of the tool	Working width (cm)	Average depth (cm)	Average draft (kg)	Cost θ	Corrected draft (kg)	Summer				Winter			
							Average working time (min)	Area covered (ha/ 6 h)	Average speed (km/h)	Average power output (hp)	Average working time (min)	Area covered (ha/ 6 h)	Average speed (km/h)	Average power output (hp)
							DRY NON-PREGNANT							
I	Desi plough	18	21	25	0.898	22.47	23	0.289	3.00	0.61	54	0.259	3.21	0.53
II	-do-	18	21	25	0.902	22.10	34	0.397	3.60	0.60	54	0.259	3.21	0.52
III	-do-	18	21	25	0.893	22.34	29	0.438	4.43	0.69	58	0.216	2.69	0.44
IV	-do-	18	21	25	0.904	22.60	30	0.326	2.55	0.49	58	0.216	2.69	0.44
V	-do-	18	21	25	0.893	22.34	29	0.300	3.51	0.44	58	0.259	3.21	0.53
Overall average					0.898 ±0.002	22.37 ±0.08	29 ±0.03	0.350 ±0.028	3.43 ±0.32	0.57 ±0.04	56 ±0.01	0.242 ±0.011	3.00 ±0.13	0.49 ±0.21
							LACTATING NON-PREGNANT							
I	Desi plough	18	21	25	0.895	22.42	26	0.342	3.49	0.70	48	0.265	3.06	0.55
II	-do-	18	21	25	0.902	22.55	34	0.195	2.53	0.40	45	0.303	3.98	0.62
III	-do-	18	21	25	0.911	22.77	38	0.295	3.16	0.53	53	0.242	3.00	0.50
IV	-do-	18	21	25	0.884	22.10	31	0.277	3.12	0.56	45	0.265	3.06	0.57
V	-do-	18	21	25	0.902	22.55	33	0.172	2.35	0.38	53	0.292	3.98	0.50
Overall average					0.899 ±0.004	22.47 ±0.11	32 ±0.02	0.256 ±0.032	2.93 ±0.21	0.51 ±0.06	49 ±0.02	0.263 ±0.011	3.42 ±0.23	0.55 ±0.02

4.1.1.1 Draft power, speed of work and area ploughed

The width of furrow cut by the plough was 18 cm and average depth of operation was 21 cm. The average draft exerted by a pair of working bullocks while pulling a traditional plough is about 50 kg, the corrected draft for individual working groups and work output in terms of horse power have been given in Table 4.1.1 and 4.1.2. While ploughing DNP cows travelled at an average speed of 3.22 ± 0.21 km/h and LNP cows at an average speed of 3.18 ± 0.26 km/h. The speeds were 2.98 ± 0.14 km/h for DNP buffaloes and 2.96 ± 0.03 km/h for LNP buffaloes.

Average area covered by DNP and LNP buffaloes were 0.262 ± 0.03 and 0.224 ± 0.12 ha/6 h. The speed and area ploughed by DNP buffaloes was more than the lactating non-pregnant buffaloes (Table 4.1.1). The average work output of a pair of DNP and LNP buffaloes respectively was 0.49 ± 0.04 hp and 0.45 ± 0.03 hp. The performance of DNP animals in terms of work output (hp) was more than LNP buffaloes implying that the DNP buffaloes performed at higher rates than LNP. The areas ploughed by DNP and LNP buffaloes during winter season was 0.205 ± 0.008 and 0.245 ± 0.008 h respectively. Average speed and horse power developed by the LNP buffaloes were 2.98 ± 0.08 km/h and 0.49 ± 0.01 hp during winter season; the respective values for DNP buffaloes were 2.84 ± 0.13 km/h and 0.44 ± 0.02 hp during summer. The average area ploughed by DNP cows was more during summer, being 0.35 ± 0.028 ha/6 h as compared to LNP cows, 0.256 ± 0.032 ha/6 h. Area ploughed by DNP cows was on an average more, indicating that DNP cows were able to travel at fast speeds and worked efficiently. The speed and horse power developed by DNP cows during summer season were 3.43 ± 0.32 km/h and 0.57 ± 0.04 hp and by LNP cows were 2.93 ± 0.21 km/h and 0.51 ± 0.06 hp respectively.

Area covered by DNP cows during winter season was relatively less than their performance during summer season. The average speed and work output during winter in DNP cows was 3.00 km/h and 0.49 ± 0.021 hp (Table 4.1.2). Results obtained during summer and winter seasons from the DNP and LNP buffaloes and cows show that cows may be able to work at a higher speed than the buffaloes. The cows also developed higher output than the buffaloes.

4.1.2 ENERGETIC EFFICIENCY

Results for the experiments of ploughing for buffaloes and cows have been presented in Tables 4.1.1 to 4.1.9.

DNP buffaloes while ploughing worked at an average rate of 0.49 ± 0.04 hp and produced energy at a rate of 165 ± 0.08 Kcal/h. These working animals were consuming TDN equivalent to 15128 ± 170.83 Kcal/day. Since these animals were DNP, therefore, were offered only maintenance ration and their TDN consumption was 3.78 ± 0.04 kg. These animals were on an average getting feed which was sufficient to maintain their body weights. The animals during winter worked at lower rates of 150 ± 7.3 Kcal and consumed energy in the form of TDN, 12576 ± 65.24 Kcal/day. The work output of lactating non-pregnant buffaloes during summer was 154.60 ± 3.25 Kcal and 160.8 ± 2.4 Kcal and during winter(table 4.1.4).

The DNP cows during summer worked at a rate of 182.0 ± 16.48 Kcal with a TDN intake of 3.99 kg. During winter these animals

Table 4.1.3 Energy expenditure and efficiency of work in cows and buffaloes

	Oxygen (%) in expended air		Corrected value of expended air (litres)		Value of true CO2 in expended air		Value of true O2 in expended air		Respiration quotient (RQ)		Energey expenditure (cal/min)		Gross energetic efficiency on RQ basis
	Before work	After work	Before work	After work	Before work	After work	Before work	After work	Before work	After work	Before work	After work	
							SUMMER						
DNP cows	18.27 ±0.07	18.63 ±0.17	50.65 ±5.29	83.16 ±5.45	1.18 ±0.15	1.59 ±0.06	1.41 ±0.17	1.93 ±0.05	0.84 ±0.33	0.81 ±0.02	6.82 ±0.81	9.41 ±0.29	28.68 ±3.38
LNP cows	17.98 ±0.16	18.51 ±0.08	53.67 ±4.04	72.62 ±4.00	1.41 ±0.14	1.68 ±0.11	1.65 ±0.16	2.04 ±0.12	0.85 ±0.01	0.82 ±4.75	8.02 ±0.79	9.83 ±0.60	27.63 ±2.16
DNP buffaloes	17.27 ±0.64	18.03 ±0.43	56.50 ±4.68	78.62 ±12.10	1.92 ±0.45	2.08 ±0.58	2.18 ±0.47	2.43 ±0.62	0.88 ±0.02	0.85 ±0.02	10.69 ±2.36	11.85 ±3.08	25.52 ±5.48
LNP buffaloes	17.66 ±0.30	18.08 ±0.22	53.39 ±5.95	72.56 ±4.97	1.62 ±0.32	1.87 ±0.31	1.80 ±0.38	2.19 ±0.33	0.86 ±0.01	0.85 ±0.01	9.08 ±01.87	10.66 ±1.67	25.85 ±2.72

Table 4.1.4 Intake of DM and TDN during summer and winter in cows and buffaloes

	Body wt (kg)	Body wt0.75 (kg)	TDN intake (kg)	DM intake (kg)	Energy expended (cal/d)	Work output (Kcal)	Gross efficiency (on TDN basis)
DNP buffalo (summer)	519.60±18.76	119.91±2.87	3.78±0.04	10.46±0.07	15128±170.83	165.00± 0.08	26.21±1.39
DNP buffalo (winter)	566.00±16.00	116.00±2.56	3.14±0.02	10.59±0.24	12576± 65.24	150.80± 7.28	28.80±0.00
LNP buffalo (summer)	602.40±31.46	121.44±4.73	4.56±0.04	11.51±0.10	18240±166.37	154.60± 3.25	20.34±0.39
LNP buffalo (winter)	605.40±37.63	121.86±5.73	4.37±0.06	11.64±0.16	17464±228.25	160.80± 2.42	22.10±0.22
DNP cow (summer)	418.20±24.43	102.64±3.93	3.39±0.05	7.89±0.16	13544±202.23	182.00±16.40	32.33±3.02
DNP cow (winter)	481.40±35.85	93.30±5.95	3.01±0.02	9.99±0.03	12032± 96.66	159.40± 6.15	31.77±1.10
LNP cow (summer)	473.60±25.42	101.41±4.09	4.22±0.04	9.57±0.09	16872±180.17	156.00±11.29	22.17±1.38
LNP cow (winter)	466.40±19.51	100.29±3.15	4.10±0.02	10.05±0.11	16400± 78.94	181.80±12.34	26.61±1.84

produced lower work, i.e. 159.40 ± 6.15 Kcal. Lactating non-pregnant cows during summer produced work equivalent to 156 Kcal but output during winter was higher (181.80 Kcal). The respective TDN consumptions were 4.20 and 4.10 kg. The energetic efficiency of work output calculated from energy expended during work as measured from the R.Q. calculations indicated that buffaloes and cows worked at an average efficiency of 20 to 28 per cent with a net energetic efficiency of about 38 ± 5.00 per cent depending on the speed and work output from individuals (Tables 4.1.3 and 4.1.4).

4.1.3 PHYSIOLOGICAL RESPONSES

The results for effects of ploughing on physiological reactions of cows and buffaloes and their statistical analysis have been presented in Tables 4.1.3.1 to 4.1.3.4 and Figs.4.1.3.1 to 4.1.3.3.

During present study, it was observed that the longer the animals worked, the higher were the body temperature, heart rate and respiration rate (Tables 4.1.3.1 to 4.1.3.4). The results for ploughing experiments during summer and winter have been presented.

4.1.3.1 Respiration rate (RR)

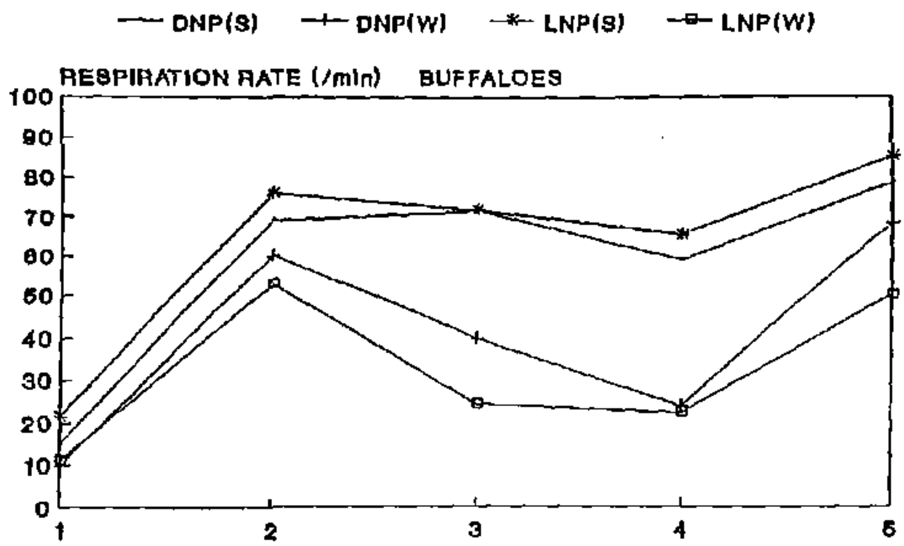
The results for the changes in the respiration rate of DNP and LNP cows and buffaloes as influenced by ploughing during summer and winter have been presented in Table 4.1.5.1 and Fig. 4.1.5.1 and statistical analysis in Tables 4.1.5.2 and 4.1.5.6.

Table 4.1.5.1 Respiration rate changes in working buffaloes and cows during summer and winter seasons

Periods	Dry non-pregnant		Lactating non-pregnant	
	Summer	Winter	Summer	Winter
		BUFFALOES		
BW	15.40 ± 1.12	9.40 ± 0.68	21.60 ± 3.90	11.20 ± 0.37
AW	69.20 ± 1.77	63.00 ± 3.67	76.60 ± 9.05	53.40 ± 8.86
Rest 1	70.80 ± 7.93	42.00 ± 7.90	72.40 ±12.23	24.80 ± 3.42
Rest 2	59.80 ± 7.99	24.40 ± 0.81	66.00 ±11.97	23.00 ± 3.08
EW	79.00 ± 6.61	72.00 ± 6.79	85.60 ± 8.49	50.80 ± 9.38
		COWS		
BW	30.00 ± 6.89	13.20 ± 0.58	29.80 ± 5.65	17.00 ± 1.09
AW	81.60 ± 8.45	86.80 ± 4.47	81.00 ± 7.51	61.80 ± 9.82
Rest 1	71.80 ± 7.21	16.80 ± 1.46	67.60 ± 5.48	30.20 ± 3.00
Rest 2	59.40 ± 3.91	15.00 ± 1.12	66.40 ± 5.90	20.60 ± 1.47
EW	79.00 ± 8.36	66.00 ±10.60	92.80 ± 2.81	42.20 ± 8.25

The values are mean ± SEM based on two replicates on 5 animals

Fig. 4.1.51: RESPIRATION RATE IN WORKING BUFFALOES & COWS DURING SUMMER & WINTER



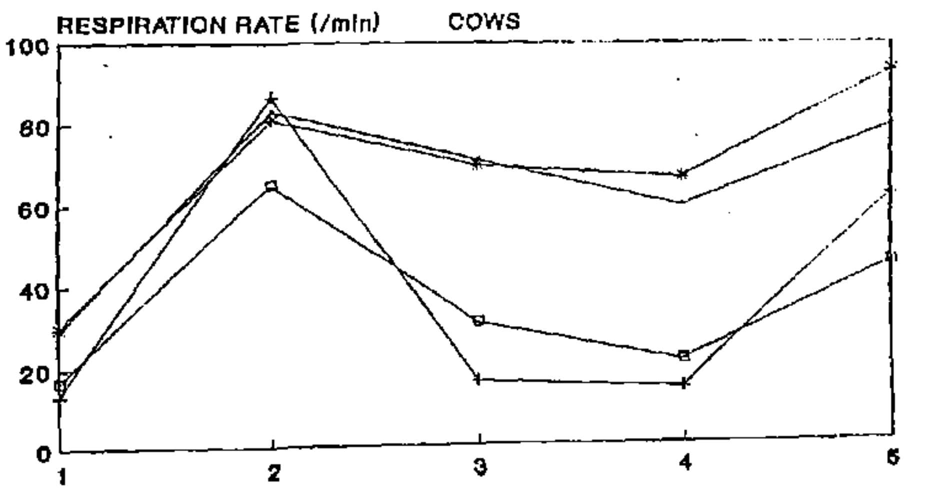


Table 4.1.5.2 Analysis of variance of physiological, haematological and biochemical parameters

Source of variation	d.f.	Physiological (m.s.s.)			Haematological (m.s.s.)		Biochemical (m.s.s.)	
		RR	PR	RT	Hb	PCV	Glucose	Lactic acid
Animals	4	526.89*	8.82	7.72**	1.02*	12.60**	17.62**	14.99**
Seasons	1	35324.82**	259.92*	187.21**	12.20**	182.41**	2.06	42.90**
Species	1	192.08	1067.22**	0.05	9.67**	117.05**	109.50**	7.08*
Groups	1	480.50*	2.42	10.35**	0.003	0.41	48.77**	111.79**
Periods	4	19719.91**	2523.24**	99.35**	6.53**	79.68**	102.96**	943.12**
Seasons x species	1	273.78	28.72	13.89**	9.25**	19.85**	7.42	60.55**
Seasons x groups	1	933.12*	0.32	0.78	1.25	53.05**	0.33	10.44*
Seasons x periods	4	2403.48**	40.71	1.08*	0.16	2.27	16.58**	4.13*
Species x groups	1	64.98	824.18**	17.94**	0.09	0.41	28.16**	37.15**
Species x periods	4	607.17*	31.16	2.83**	0.33	0.61	2.28	0.73
Groups x periods	4	450.96*	69.93	0.17	0.23	0.52	0.08	4.48*
Seasons x species x groups	1	524.88	169.28	0.99	0.08	6.13	5.73	65.43**
Seasons x species x periods	4	127.82	48.02	0.64	0.12	0.88	2.84	2.71
Seasons x groups x periods	4	299.08	17.81	0.63	0.25	0.63	0.95	0.65
Species x groups x periods	4	328.52	23.87	1.72**	0.08	0.39	0.52	2.26
All effects	4	122.82	90.54	0.19	0.08	0.44	1.50	1.68
Error	156	207.51	50.70	0.44	0.42	2.49	2.16	1.70

* P < 0.05; ** P < 0.01

Ploughing increased respiration rate (PR) of DNP and LNP buffaloes and cows in summer and winter. During summer, the pre-work mean RR of DNP and LNP buffaloes, respectively were 15.40 ± 1.12 and 21.60 ± 3.90/min which increased to 69.20 ± 1.77 and 76.60 ± 9.05 after work. The rest pause of 2 h after first phase of work decreased RR to 59.80 ± 7.99 and 66.00 ± 11.97. Second phase of work raised RR to 79.00 ± 6.61 and 86.60 ± 8.49 in DNP and LNP buffaloes respectively over the rest pause respiration values (Table 4.1.5.1). The increase in RR over pre-work value was 349.35 per cent in DNP buffaloes and 254.63 per cent in LNP buffaloes.

The pre-work average values for RR in DNP and LNP cows respectively were 30.00 ± 6.89 and 29.80 ± 5.65 during summer. Ploughing increased RR to 81.60 ± 8.45 and 81.00 ± 7.51 in DNP and LNP cows. The rest pause of 2 h decreased RR to 27.21 and 18.02 per cent in DNP and LNP cows, respectively. The decline in RR of DNP was faster than LNP cows. Further work after 2 h rest raised RR to 79.00 ± 8.36 and 92.80 ± 2.81/min in DNP and LNP cows. The magnitude of increase after second work was lower as compared to the first work phase but the absolute average values were higher (Table 4.1.5.1).

During winter, the average pre-work RR values were lower than the summer in both of the groups. Cows had higher values of RR not only at pre-work but also at post-work periods. The pre-work mean values of RR were 9.40 and 11.20 in DNP and LNP buffaloes during winter season. The rise after work was to a mean of 63.00 ± 3.67 and 53.40 ± 8.86/min in DNP and LNP buffaloes. During rest, RR decreased to 24.40 ± 0.81 and 23.00 ± 3.08 in DNP and LNP buffaloes respectively. The per cent increase after first work was 510.21 and 376.79 in DNP and LNP buffaloes. Second round of ploughing increased RR but the changes were almost similar to that observed during first phase.

The pre-work values of RR during winter were 13.20 $\pm$ 0.58 and 17.00 $\pm$ 1.09/min in DNP and LNP cows, respectively (Table 4.1.5.1). The respective per cent increase in RR due to work was 557.58 and 263.53 in DNP and LNP cows. The increase in RR of DNP cows was higher than LNP cows. Two hours rest decreased RR to almost pre-work levels in both the groups of cows. Second period of work increased RR to 66.60 $\pm$ 10.60 and 42.20 $\pm$ 8.25/min in DNP and LNP cows, respectively.

The correlation coefficient of RR with pulse rate (r = 0.56) and rectal temperature (r = 0.77) indicated a significant (P < 0.01) correlation implying that RR is influenced by pulse rate and rectal temperature during work. RR was negatively correlated (P < 0.01) to Hct (r=-.41) and glucose (r =-0.33).

Analysis of variance of RR indicates that season had significant (P < 0.01) effect on the RR. RR also varied significantly (P < 0.01) at different periods and interaction of season x groups, season x periods, and breed x period also had significant effect (P < 0.01) on the RR.

4.1.3.2 Pulse rate (PR)

During summer, the pre-work mean PR of DNP and LNP buffaloes were 69.60 $\pm$ 2.61 and 69.80 $\pm$ 3.49/min respectively which increased to 90.80 $\pm$ 2.98 and 90.20 $\pm$ 3.11 after work (Table 4.1.5.3). The per cent increase of PR over pre-work was 30.46 and 29.23 in DNP and LNP buffaloes (Fig. 4.1.5.2). The magnitude of increase due to work was similar in both the groups. The rest of 2 h decreased pulse to 82.00 ± 2.95/min in DNP buffaloes and 79.80 ± 1.59/min in LNP buffaloes. Further work after rest raised pulse to 91.20 ± 1.59 and 82.80 ± 3.44/min in DNP and LNP buffaloes, respectively. During 2 h rest period, PR decreased and exhibited almost similar changes in both the groups.

The pre-work mean values of PR during summer in DNP and LNP cows were 77.00 ± 3.90 and 73.80 ± 3.23/min respectively. The pre-work means were higher in DNP and LNP cows than the buffaloes during summer (Table 4.1.5.3). The PR increased to respective values of 92.00 ± 2.94 and 91.40 ± 3.87/min after work. The magnitude of increase in pulse due to work was slow in cows than buffaloes in both the groups. The rest of 2 h decreased pulse by 12.39 per cent in DNP and 14.87 per cent in LNP from their post-work PR. The decline in PR of LNP was faster than DNP cows. Second work period raised PR to 86.00 ± 3.11 and 97.20 ± 3.38/min in DNP and LNP cows respectively. The magnitude of increase in PR after second work was lower as compared to the first work phase but the absolute average values were higher (Table 4.1.5.3).

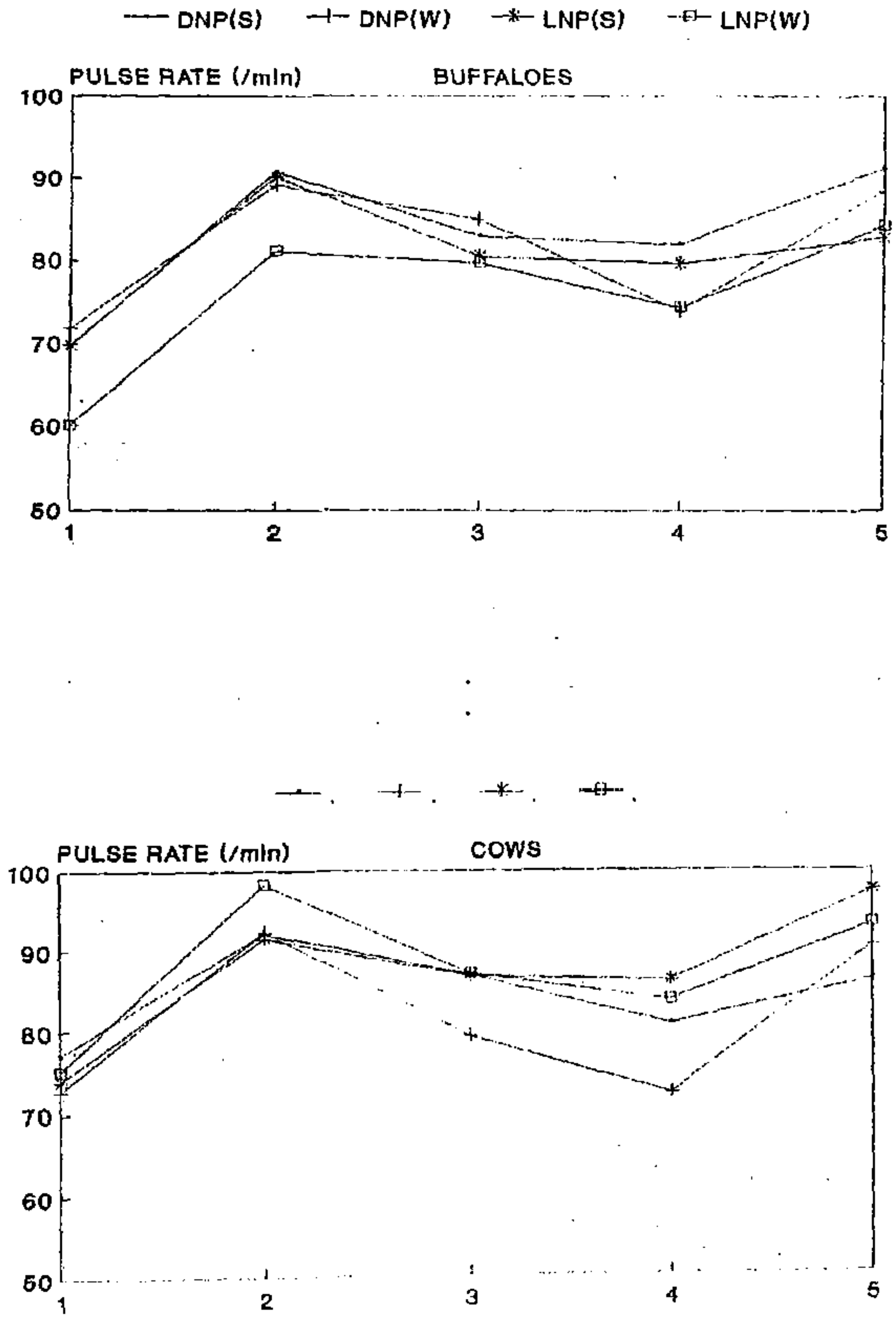
During winter the pre-work mean values of pulse were 71.80 ± 2.29 and 60.00 ± 0.95/min in DNP and LNP buffaloes. The increase in the PR due to work was to 89.20 ± 2.81 and 81.20 ± 5.20/min in DNP and LNP buffaloes. The increase in the PR due to work was limited to 35.33 per cent in LNP cows and 24.23 per cent in DNP cows. After rest, PR decreased to 74.20 ± 1.74/min in DNP buffaloes and 74.60 ± 3.36 in LNP buffaloes. Second round of ploughing increased PR to 88.40 ± 3.72/min in DNP and 84.20 ± 2.53 in LNP buffaloes.

Table 4.1.5.3 Pulse rate changes in buffaloes and cows during summer and winter seasons

Periods	Dry non-pregnant		Lactating non-pregnant	
	Summer	Winter	Summer	Winter
		BUFFALOES		
BW	69.60 ± 2.61	71.80 ± 2.29	69.80 ± 3.49	60.00 ± 0.95
AW	90.80 ± 2.98	89.20 ± 2.81	90.20 ± 3.11	81.20 ± 5.20
Rest 1	83.00 ± 2.19	85.00 ± 2.40	80.60 ± 1.69	79.80 ± 4.10
Rest 2	82.00 ± 2.95	74.20 ± 1.74	79.80 ± 1.59	74.60 ± 3.36
EW	91.20 ± 1.59	88.40 ± 3.72	82.80 ± 3.49	89.20 ± 2.53
		COWS		
BW	77.00 ± 3.90	72.60 ± 2.65	73.80 ± 3.23	75.00 ± 3.11
AW	92.00 ± 2.94	92.20 ± 5.06	91.40 ± 3.87	98.20 ± 1.02
Rest 1	86.80 ± 3.43	79.40 ± 3.78	86.60 ± 2.83	87.00 ± 2.86
Rest 2	80.60 ± 1.88	72.20 ± 2.50	86.00 ± 1.92	83.60 ± 4.12
EW	86.00 ± 3.11	90.20 ± 3.81	97.20 ± 3.38	93.00 ± 1.58

The values are the mean ± SEM based on two replicates on 5 animals

Fig. 4.1.5.2 : PULSE RATE IN WORKING BUFFALOES & COWS DURING SUMMER & WINTER



The pre-work mean values of PR during winter in DNP and LNP cows have been presented in Table 4.1.5.3. The pre-work mean values were 72.60 ± 2.65 and 75.00 ± 3.11/min in DNP and LNP cows, respectively. Work increased pulse to an average value of 92.20 ± 5.06 and 98.20 ± 1.20/min indicating respective increase of 27.0 and 31.0 per cent in DNP and LNP cows. Two hours rest decreased pulse to near normal pre-work values (Table 4.1.5.3).

The correlation coefficient analysis of PR indicated a significant ($P < 0.01$) positive correlation with PR ($r = 0.56$) and RT ($r = 0.77$). PR was negatively corrèlated ($P < 0.01$) with Hb, Hct and glucose ($r = -0.33$).

Analysis of variance of PR indicates that pulse rate was significantly affected by season ($P < 0.05$), and species and periods ($P < 0.01$). The interaction of species x groups had also significant ($P < 0.01$) effect on the PR.

4.1.3.3 Thermoregulatory changes

The results for changes in rectal temperature (RT) of DNP and LNP buffaloes and cows during summer and winter have been presented in Table 4.1.5.4 and Fig. 4.1.5.3. The statistical analysis in terms of correlation coefficient and analysis of variance have been presented in Tables 4.1.5.6 and 4.1.5.2.

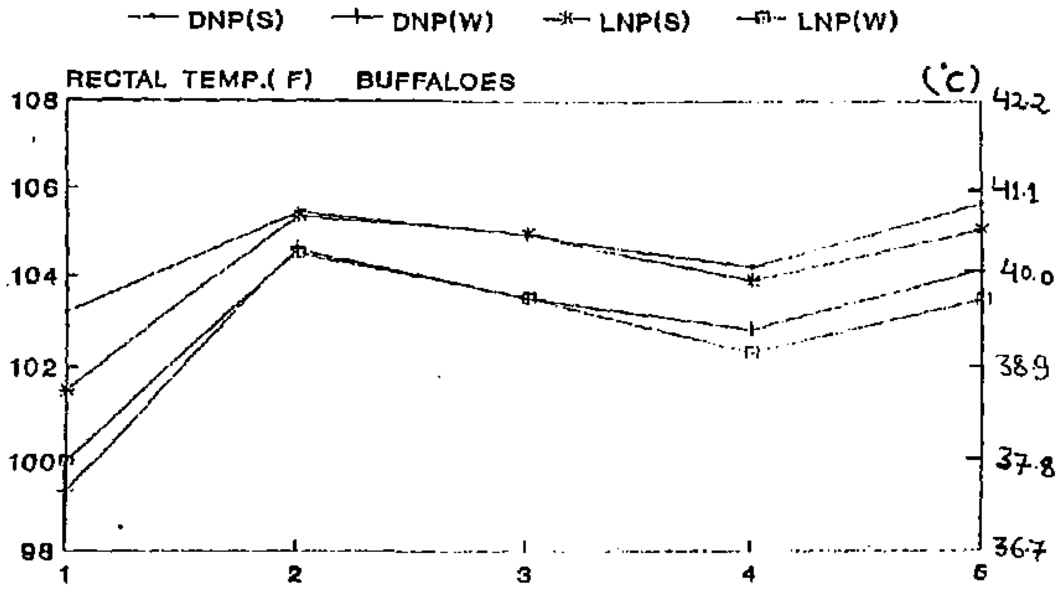
The rectal temperature (°C) of experimental animals ranged from 37.1 to 41.0°C during winter season in working cows and buffaloes.

The rectal temperature (°C) during summer ranged from 38.2 to 42.2°C, in buffaloes and 38.7 to 42.1°C in cows with a pre-

Table 4.1.5.4 Rectal temperature (^{o}C) changes in working buffaloes and cows during summer and winter seasons

Periods	Dry non-pregnant		Lactating non-pregnant	
	Summer	Winter	Summer	Winter
		BUFFALOES		
BW	38.50 $\pm$ 0.15	37.41 $\pm$ 0.13	38.16 $\pm$ 0.15	37.78 $\pm$ 0.10
AW	41.01 $\pm$ 0.25	40.36 $\pm$ 0.28	40.78 $\pm$ 0.14	40.32 $\pm$ 0.19
Rest 1	40.55 $\pm$ 0.38	39.76 $\pm$ 0.23	40.56 $\pm$ 0.17	39.90 $\pm$ 0.18
Rest 2	40.15 $\pm$ 0.47	39.39 $\pm$ 0.18	39.99 $\pm$ 0.19	39.10 $\pm$ 0.19
EW	40.56 $\pm$ 0.37	40.12 $\pm$ 0.19	40.64 $\pm$ 0.28	39.75 $\pm$ 0.20
		COWS		
BW	39.11 $\pm$ 0.06	37.92 $\pm$ 0.14	39.13 $\pm$ 0.21	38.20 $\pm$ 0.07
AW	40.83 $\pm$ 0.23	39.62 $\pm$ 0.07	41.29 $\pm$ 0.15	40.13 $\pm$ 0.19
Rest 1	40.21 $\pm$ 0.09	38.88 $\pm$ 0.06	41.09 $\pm$ 0.14	39.49 $\pm$ 0.14
Rest 2	39.79 $\pm$ 0.17	38.59 $\pm$ 0.14	40.94 $\pm$ 0.12	39.04 $\pm$ 0.09
AE	40.69 $\pm$ 0.27	39.40 $\pm$ 0.08	41.78 $\pm$ 0.11	39.74 $\pm$ 0.15

Fig. 4.153: RECTAL TEMPERATURE IN WORKING BUFFALOES & COWS DURING SUMMER & WINTER



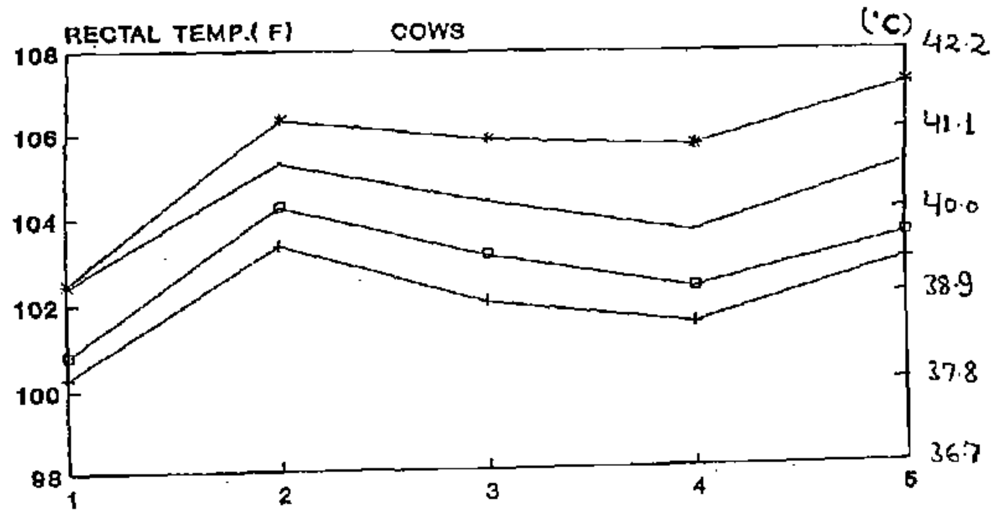


Table 4.1.5.6 Overall correlation coefficient between RR, PR, RT, Hb, PCV, glucose and lactic acid during ploughing experiment

Parameter	RR	PR	RT	Hb	Hct	Glucose	Lactic acid
Respiration rate/min	1.00						
Pulse/min	0.56**	1.00					
Rectal temp. (^{0}C)	0.77**	0.61**	1.00				
Haemoglobin (%)	-0.49*	-0.40**	-0.49*	1.00			
Haematocrit (%)	-0.55**	-0.50**	-0.58**	0.83**	1.00		
Glucose (mg/ml)	-0.32**	-0.39**	-0.29**	0.22**	0.26**	1.00	
Lactic acid (mg/ml)	0.48**	0.57**	0.57**	-0.28**	-0.33**	-0.32**	1.00

** $P < 0.01$; * $P < 0.05$

exercise mean of 39.11 ± 0.06°C and 39.13 ± 0.21°C. During summer, the respective pre-work mean RT of DNP and LNP buffaloes were 38.50 ± 0.15 and 38.16 ± 0.15°C, respectively. Work increased RT of DNP and LNP buffaloes and cows in summer and winter seasons. The RT after work increased to 41.01 ± 0.25°C and 40.78 ± 0.14°C in DNP and LNP buffaloes. The increase in RT due to work was 2.51°C and 2.62°C in LNP and DNP buffaloes, respectively. The average heat storage in DNP and LNP buffaloes during summer respectively was 73.15 ± 7.09 and 73.50 ± 5.36 kJ/min after first phase of work. Rest pause of 1 h had no effect on the RT and RT remained almost at same levels in most animals, but rest period of 2 h decreased RT to 40.15 ± 0.47 and 39.99 ± 0.19°C in DNP and LNP buffaloes. Two hours of rest was not sufficient to bring down the body temperature in summer. Further work after rest raised RT to 40.56 ± 0.37°C and 40.64 ± 0.28°C in DNP and LNP buffaloes, respectively. The heat storage in terms of kJ/min were 78.37 ± 10.59 and 67.44 ± 5.24 in DNP and LNP buffaloes after second phase of work.

The pre-work mean values of RT during summer in DNP and LNP cows were 39.11 ± 0.06 and 39.13 ± 0.21 respectively. The average initial RT was almost similar in both the groups (Table 4.1.5.4) as compared to RT of DNP and LNP. After work, the RT of DNP and LNP cows in summer increased to 40.83 ± 0.23°C and 41.29 ± 0.15°C respectively. The increase in RT over pre-work values was 1.72 and 2.16°C in DNP and LNP cows and the heat storage of these animals was 44.67 ± 2.43 and 56.77 ± 3.61 kJ/min during summer season. The rest period of 1 h resulted in lowering of RT of DNP and LNP cows to 40.21 ± 0.09 and 41.09 ± 0.14°C, respectively. After another hour of rest, the decline in RT of DNP cows was much greater than the LNP cows being 39.79 ± 0.17 and 40.94 ± 0.12°C. The RT of LNP cows remained markedly higher than the DNP cows being at the levels of 41.78 ± 0.11 and 40.69 ± 0.27 respectively. The heat storage after second phase of work was higher (69.92 ± 6.78 kJ/min) in LNP than in DNP cows (43.04 ± 8.23 kJ/min).

During winter, the mean RT of DNP and LNP buffaloes was less than the summer RT and remained at lower levels after work. After 1 h of rest, the mean RT of DNP and LNP buffaloes was 39.76 ± 0.23 and 39.90 ± 0.18^{o}C respectively. Another h of rest decreased RT in both the groups. At the end of the work, the mean RT values were 40.12 ± 0.19 and 39.75 ± 0.020 in DNP and LNP buffaloes, respectively. The increment in RT over pre-work levels was 2.71^{o}C in DNP and 1.97^{o}C in LNP buffaloes during winter after second phase of work. The heat storage in DNP was higher (88.32 ± 3.94 kJ/min) as compared to LNP (71.76 ± 9.00 kJ/min) buffaloes. When heat loads were partioned to eliminate effects of ambient conditions, heat storage due to work effects was 53.61 ± 0.36 kJ/min in DNP cows and 102.03 ± 46.72 kJ/min in DNP buffaloes. The respective figures for heat loads in LNP cattle and buffaloes due to work were 136.98 ± 77.78 kJ/m and 105.60 kJ/m during summer. The heat loads during winter were lower than observed during summer in cows and buffaloes.

In winter, the mean RT of DNP and LNP cows were 37.92 ± 0.14 and 38.20 ± 0.07^{o}C respectively. The increase in RT of the two groups was 1.70 and 1.93^{o}C after first phase of work in DNP and LNP cows respectively. The heat stored by the DNP cows was lower 46.19 ± 6.48 kJ/min than heat stored by LNP 52.19 ± 5.72 kJ/min during winter season. After 2 h of rest, the mean decline in RT of DNP and LNP cows was 1.20 and 1.03^{o}C which increased by 2.66^{o}C and 1.09^{o}C at the end of the work in DNP and LNP cows respectively.

Table 4.1.5.5 Heat storage (kJ/min) by working DNP and LNP buffaloes and cows during different seasons

Body weight (kg)	Summer I	Summer II	Body weight (kg)	Winter I	Winter II
		BUFFALOES			
DNP					
572.4 ±17.7	73.15 ±7.09	80.05 ±0.36	566.0 ±17.0	96.31 ±6.07	88.32 ±3.94
LNP					
587.2 ±34.9	73.50 ±5.36	67.47 ±5.24	619.4 ±36.7	92.10 ±10.07	71.76 ±9.00
		COWS			
DNP					
469.0 ±32.1	44.67 ±2.43	43.04 ±8.23	464.4 ±35.2	46.19 ±6.48	40.35 ±6.82
LNP					
457.6 ±19.9	56.77 ±3.61	69.92 ±6.78	462.0 ±21.2	52.19 ±5.72	40.54 ±2.59

The values are the mean ± SEM based on two replicates on 5 animals

Heat storage (kJ/min) by DNP cows and buffaloes at loads I and II

Body weight (kg)	Summer				Body weight (kg)	Winter			
	Load I		Load II			Load I		Load II	
	I	II	I	II		I	II	I	II
569.3 ±13.8	102.15 ±16.37	103.48 ± 9.79	87.37 ±11.56	72.17 ±16.07	449.5 ±32.9	62.06 ±8.63	66.81 ±7.20	47.34 ±11.32	55.17 ±10.76

The values are the means ± SEM based on two replicates on 4 animals

The fluctuations in RT were highly correlated to RR (r = 0.77) and PR (r = 0.61) in both cows and buffaloes ($P < 0.01$). Similarly, positive correlation (0.57) was recorded between RT and lactic acid correlation ($P < 0.01$). RT was negatively correlated to Hb in the blood ($r = -0.15$). Highly significant negative correlation was noted between RT and Hct ($r = -0.43$). Similar trend was noted for glucose also.

4.1.4 HAEMATOLOGY

The results for haematology in terms of haemoglobin and haematocrit for DNP and LNP buffaloes and cows during summer and winter, their analysis have been presented in Tables 4.1.61 and 4.1.6.2, Figs. 4.1.6.1 and 4.1.6.2 and their statistical analysis in Tables 4.1.5.2 and 4.1.5.6.

4.1.4.1 HAEMOGLOBIN

The results for haemoglobin (Hb) content of blood for different groups and seasons are presented in Fig. 4.1.6.1, Table 4.1.6.1 and statistical analysis in Tables 4.1.5.2 and 4.1.5.6.

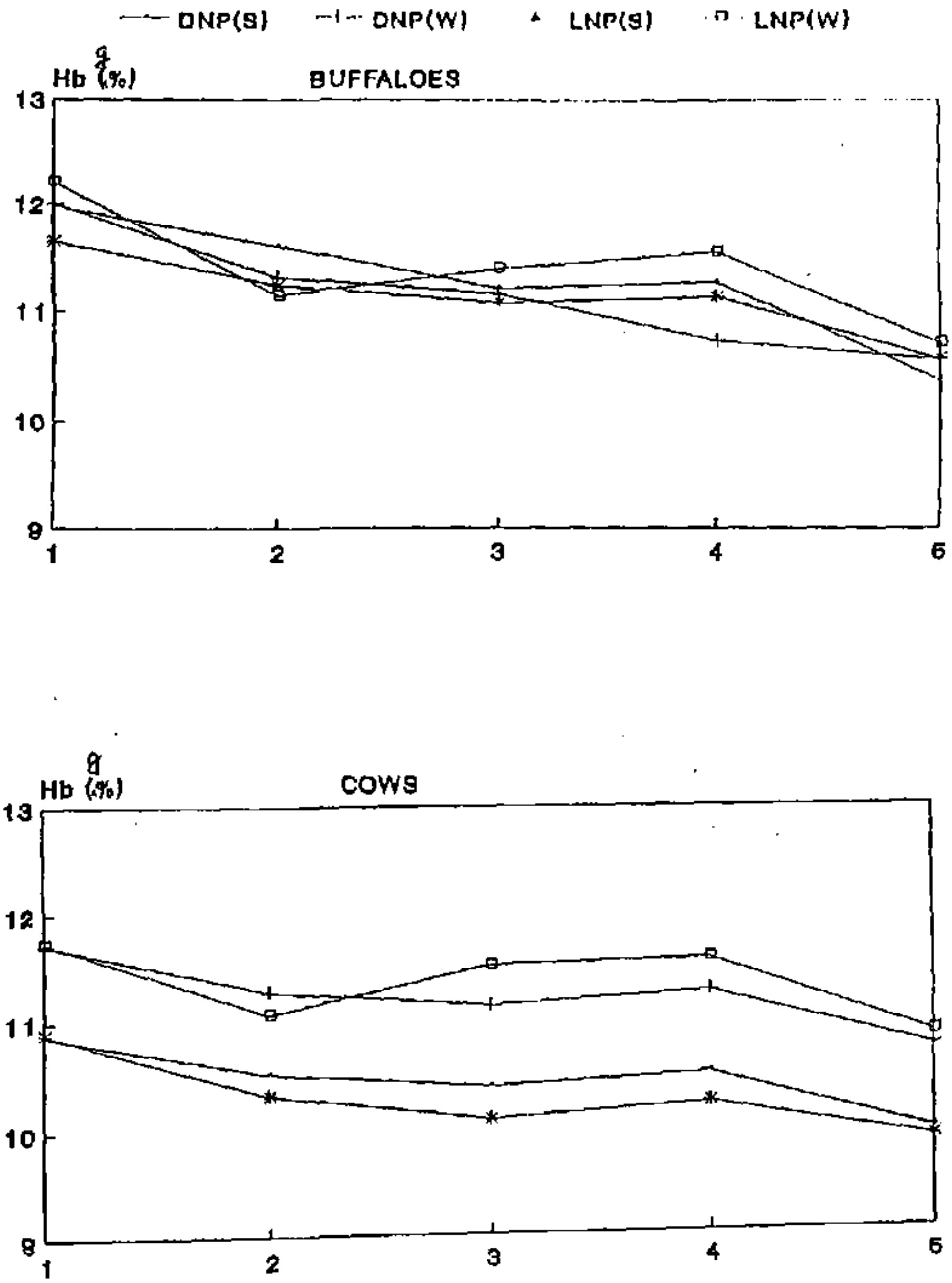
Ploughing slighty decreased haemoglobin (Hb) content in DNP and LNP buffaloes and cows. During summer, the pre-work mean Hb content of DNP and LNP buffaloes respectively were 11.98 ± 0.16 and 11.66 ± 0.19 per cent. The decrease in Hb content occurred due to work and the mean values were 11.62 ± 0.07 and 11.26 ± 0.19 per cent, respectively for DNP and LNP buffaloes. The rest pause of 2 h was not enough to bring back the Hb content to normal levels. Another period of work after rest further decreased Hb in LNP and DNP buffaloes during summer season (Table 4.1.6.1).

Table 4.1.6.1 Haemoglobin (g %) changes in working buffaloes and cows during summer and winter seasons

Periods	Dry non-pregnant		Lactating non-pregnant	
	Summer	Winter	Summer	Winter
		BUFFALOES		
BW	11.98 ± 0.16	12.00 ± 0.20	11.66 ± 0.19	12.20 ± 0.13
AW	11.62 ± 0.07	11.34 ± 0.29	11.26 ± 0.19	11.16 ± 0.27
Rest 1	11.24 ± 0.23	11.18 ± 0.35	11.10 ± 0.21	11.42 ± 0.26
Rest 2	11.30 ± 0.29	10.76 ± 0.45	11.16 ± 0.22	11.58 ± 0.23
EW	10.40 ± 0.14	10.60 ± 0.37	10.60 ± 0.17	10.74 ± 0.22
		COWS		
BW	10.88 ± 0.20	11.70 ± 0.32	10.94 ± 0.28	10.72 ± 0.19
AW	10.52 ± 0.21	11.26 ± 0.33	10.32 ± 0.35	11.06 ± 0.40
Rest 1	10.38 ± 0.21	11.12 ± 0.36	10.08 ± 0.43	11.48 ± 0.40
Rest 2	10.50 ± 0.91	11.24 ± 0.37	10.22 ± 0.50	11.54 ± 0.32
EW	9.96 ± 0.13	10.72 ± 0.45	9.88 ± 0.43	10.84 ± 0.34

The values are the mean ± SEM based on two replicates on 5 animals

Fig. 4.1.6.1: HAEMOGLOBIN IN WORKING BUFFALOES & COWS DURING SUMMER & WINTER



The pre-work mean values of Hb in DNP and LNP buffaloes during winter season were 12.00 ± 0.20 and 12.20 ± 0.13 g per cent. The mean Hb content during winter was higher than summer in both the groups of buffaloes (Table 4.1.6.1) which decreased to 11.34 ± 0.29 and 11.16 ± 0.27 per cent in DNP and LNP buffaloes after work. The rest pause of 2 h slightly increased the Hb content and mean values were 11.58 ± 0.23 in LNP buffaloes, but in case of DNP buffaloes the trend was reverse. The absolute mean values of Hb content after second pause of work was slightly higher during winter season than summer season in both the groups of buffaloes.

The pre-work mean values of Hb in cows in both of the groups, i.e., DNP and LNP during summer and winter were slightly lower than buffaloes. The pre-work mean values of Hb during summer were 10.88 ± 0.20 and 10.94 ± 0.28 g per cent in DNP and LNP cows, respectively. Ploughing decreased Hb to 10.52 ± 0.21 and 10.32 ± 0.35 g per cent in DNP and LNP cows. After 2 h rest pause, the Hb further decreased to the level of 10.50 ± 0.19 in DNP and 10.22 ± 0.50 g in LNP cows, respectively. Hb in working DNP and LNP cows further decreased, due to second pause of work, to 9.96 ± 0.13 and 9.88 ± 0.43 g in DNp and LNP cows.

The mean Hb content during winter was higher than summer season in both o the groups of cows. The pre-work mean values were 11.70 ± 0.32 and 11.72 ± 0.19 g in DNP and LNP cows, respectively, which decreased to 11.26 ± 0.33 and 11.06 ± 0.40 g after work in DNP and LNP cows. Rest pause of 2 h increased Hb levels to 11.54 g in LNP cows but in DNP cows the HB decreased slightly to 11.24 ± 0.37 g. Further work after 'rest' pause decreased Hb to 10.72 ± 0.45 and 10.84 ± 0.34 g per cent in DNP and LNP cows. Statistical analysis in terms of analysis of variance shows that Hb varied significantly ($P < 0.01$) among seasons, groups, species and periods and interaction of seasons x species also had significant effect on Hb. Hb exhibited a negative correlation ($P < 0.01$) with RR ($r = -0.49$), PR ($r = -0.50$) and RT ($r = -0.49$).

4.1.4.2 Haematocrit

The results for the effects of work on haematocrit (Hct) of cows and buffaloes during summer and winter have been presented in Table 4.1.6.2, Fig. 4.1.6.2 and statsitical analysis in terms of correlation coefficient and analysis of variance in Tables 4.1.5.6 and 4.1.5.2.

Ploughing decreased Hct of DNP and LNP buffaloes and cows during summer and winter. During summer, the pre-work mean Hct of DNP and LNP buffaloes respectively were 35.60 ± 0.75 and 35.20 ± 0.66 which decreased to 34.20 ± 0.37 and 33.40 ± 0.81 after work. The Hct decreased in DNP and LNP buffaloes after 2 h rest to 32.40. Further work decreased Hct to 31.60 ± 0.60 and 30.80 ± 0.58 in DNP and LNP buffaloes, respectively.

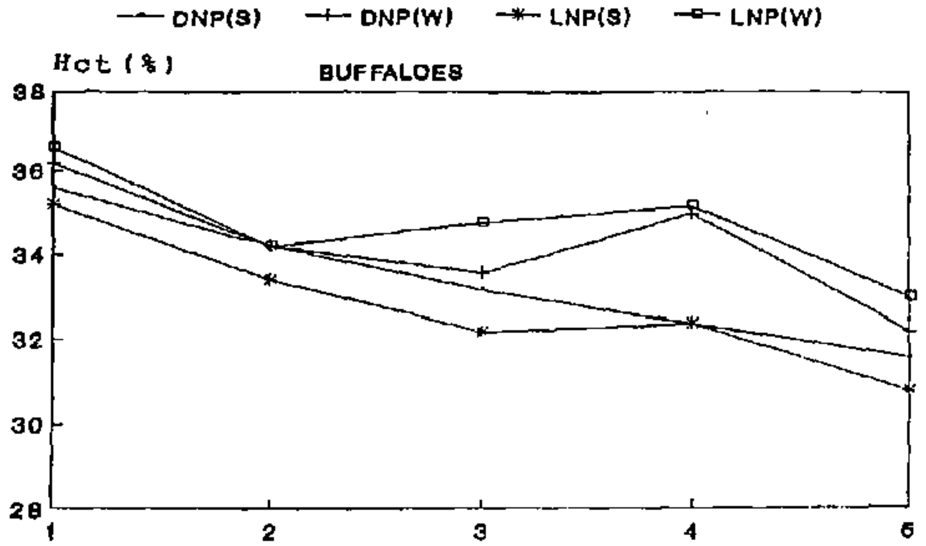
During summer, the pre-work mean values for Hct in DNP and LNP cows were lower than in buffaloes. The pre-work mean Hct for DNP and LNP cows during summer were 34.00 ± 0.55 and 32.20 ± 0.66 per cent, respectively. The rest pause of 2 h helped in regaining of Hct to the original levels of 32.00 ± 0.32 and 29.80 ± 1.11 in DNP and LNP cows. Work after rest further lowered Hct to 29.20 ± 0.66 and 28.80 ± 0.97, respectively in DNP and LNP cows during summer.

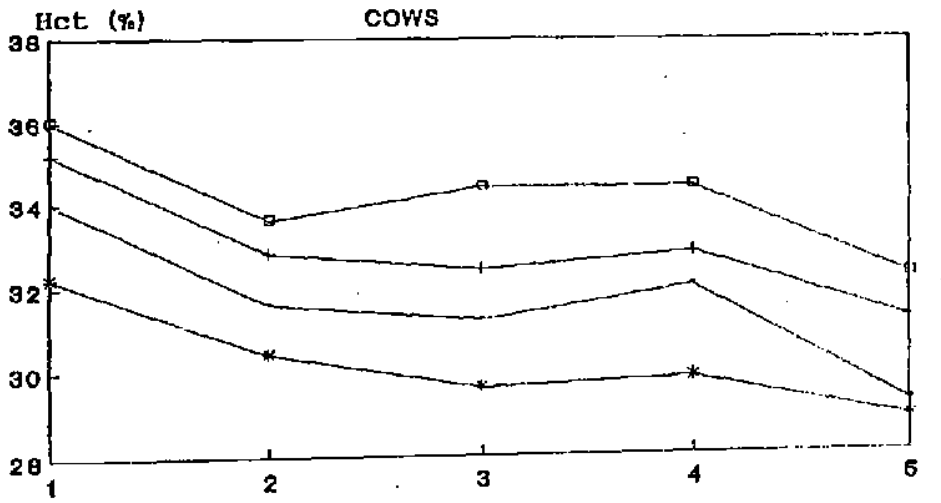
Table 4.1.6.2 Haematocrit (%) changes in working buffaloes and cows during summer and winter seasons

Periods	Dry non-pregnant		Lactating non-pregnant	
	Summer	Winter	Summer	Winter
		BUFFALOES		
BW	35.60 ± 0.75	36.20 ± 0.66	35.20 ± 0.66	36.60 ± 0.51
AW	34.20 ± 0.37	34.20 ± 1.07	33.40 ± 0.81	34.20 ± 0.58
Rest 1	33.20 ± 0.86	33.60 ± 0.81	32.20 ± 0.66	34.80 ± 0.80
Rest 2	32.40 ± 0.68	35.00 ± 1.67	32.40 ± 0.68	35.20 ± 0.58
EW	31.60 ± 0.60	32.20 ± 0.66	30.80 ± 0.58	33.00 ± 0.63
		COWS		
BW	34.00 ± 0.55	35.20 ± 0.66	32.20 ± 0.66	36.00 ± 0.45
AW	31.60 ± 0.81	32.80 ± 0.86	30.40 ± 0.81	33.60 ± 0.40
Rest 1	31.20 ± 0.73	32.40 ± 0.98	29.60 ± 0.67	34.40 ± 0.93
Rest 2	32.00 ± 0.32	32.80 ± 0.97	29.80 ± 1.11	34.40 ± 0.81
EW	29.20 ± 0.66	31.20 ± 0.80	28.80 ± 0.97	32.20 ± 0.66

The values are the mean ± SEM based on two replicates on 5 animals

Fig. 4.1.62: HAEMATOCRIT (%) IN WORKING BUFFALOES AND COWS DURING DIFFERENT SEASONS





The pre-work mean values of Hct were higher in buffaloes during winter than summer. The initial values of Hct were 36.20 ± 0.66 and 36.60 ± 0.51 in DNP and LNP buffaloes. Ploughing decreased Hct to 34.20 ± 1.07 and 34.20 ± 0.58 per cent in DNP and LNP buffaloes. The Hct remained at these low levels even after 2 h of rest period. Further work decreased the Hct to lower values of 32.20 ± 0.66 in DNP and 33.80 ± 0.68 in LNP buffaloes, respectively.

The pre-work mean values of Hct during winter were 35.20 ± 0.66 and 36.00 ± 0.45 in DNP and LNP cows. Ploughing decreased Hct to 32.80 ± 0.86 and 33.60 ± 0.40 in DNP and LNP cows, respectively. Hct remained at these levels even after a rest pause of 2 h. Hct decreased to 31.20 ± 0.80 and 32.20 ± 0.66 per cent in DNP and LNP cows after second pause of work. Analysis of variance showed that Hct differ significantly between animals, seasons, periods and interaction of seasons x species and seasons x groups also have significant effect. Hct showed a negative correlation with RR ($r = -0.55$), PR ($r = -0.50$) and RT ($r = -0.58$).

4.1.4.3 Plasma volume changes

The results for the plasma volume changes in DNP and LNP buffaloes and cows during summer and winter, after first and second period of work have been presented in Table 4.1.6.3.

The plasma volume changes in LNP buffaloes was pronounced than DNP buffaloes during summer. The plasma volume changed due to work to a mean value of 5.99 ± 1.10 per cent in DNP and 6.34 ± 0.96 per cent in LNP buffaloes. The mean values of plasma changes were 22.93 ± 1.90 and 20.39 ± 4.18 per cent in DNP and

Table 4.1.6.3 Plasma volume changes (%) in working animals during ploughing and carting experiments

Periods between	Dry non-pregnant		Lactating non-pregnant	
	Summer	Winter	Summer	Winter
		BUFFALOES		
BW-AW	5.99 ± 1.10	9.39 ± 2.97	6.34 ± 0.96	13.59 ± 3.62
BE-EW	22.93 ± 1.90	20.86 ± 4.04	17.57 ± 2.39	20.39 ± 4.18
		COWS		
BW-AW	7.23 ± 1.70	7.33 ± 0.88	8.79 ± 1.73	10.35 ± 3.11
BE-AW	16.00 ± 2.80	14.17 ± 2.56	16.72 ± 3.36	14.88 ± 3.28

Periods	Dry non-pregnant		Lactating non-pregnant	
	5 qtls	10 qtls	5 qtls	10 qtls
BE-AE	10.57 ± 1.34	8.57 ± 1.05	10.58 ± 1.28	8.90 ± 2.85
BE-EW	21.05 ± 5.08	10.44 ± 2.57	15.33 ± 2.81	13.30 ± 2.80
BE-last	7.62 ± 4.12	10.33 ± 0.10	11.27 ± 2.79	4.69 ± 0.63

LNP buffaloes during winter. Plasma volume changes in LNP buffaloes and cows during summer and winter were more as compared to DNP buffaloes and cows (Table 4.1.6.3).

The mean plasma volume change in DNP cows, during summer after first phase of work, was 7.23 ± 1.70 per cent and 8.79 ± 1.73 per cent. Changes in plasma volume after second period of work were 16.00 ± 2.80 and 16.72 per cent in DNP and LNP cows during summer season. Post3re st work effects were more prominent in plasma volume. The mean plasma volume changes in DNP and LNP buffaloes during winter were to the levels of 9.39 ± 2.97 and 13.59 ± 3.62 per cent, respectively. After a rest period of 2 h, plasma volume was still higher than the pre-work levels and further work, after rest, elevated the plasma volume to 20.86 ± 4.04 in DNP and 20.39 per cent in LNP buffaloes.

After first round of work, the plasma volume change was 7.33 ± 0.88 per cent and 10.35 ± 3.11 per cent in DNP and LNP cows during winter season.

4.1.5 ENERGY SUBSTRATES

The results for energy substrates and their statistical analysis have been presented in Tables 4.1.7.1 to 4.1.7.3 and Figs. 4.1.7.1 to 4.1.7.3.

4.1.5.1 Blood glucose

The glucose concentration before onset of work showed much variations in both buffaloes and cows. The results for the changes in the glucose concentrations of DNP and LNP buffaloes and cows during summer and winter have been presented in Table

4.1.7.1 and Fig. 4.1.7.1. The statistical analysis also presented in Tables 4.1.5.2 and 4.1.5.6.

Due to ploughing, a slight decrease in the glucose concentration was observed in all the working animals during both the seasons. The per cent change in blood glucose concentration due to work was less (-2.81%) in DNP buffaloes during summer than (-12.23%) in LNP cows during winter season. These changes indicate only a minor decline in glucose levels due to work in buffaloes.

The pre-work mean glucose concentrations of DNP and LNP buffaloes during summer were 42.42 ± 0.87 and 42.86 ± 0.33 mg respectively which decreased to 41.23 ± 0.89 and 41.80 ± 0.25 mg after work. After 1 h of rest, the glucose concentration remained almost similar to that observed after work, but further rest of 1 h increased the glucose to 42.26 ± 0.68 and 42.43 ± 0.29 mg per cent in DNP and LNP buffaloes. The increase in glucose was by 2.50 and 1.51 per cent during summer in DNP and LNP buffaloes due to rest pause of 2 h. Further work after rest decreased blood glucose to 39.16 ± 0.50 and 39.93 ± 0.32 mg per cent in DNP and LNP buffaloes.

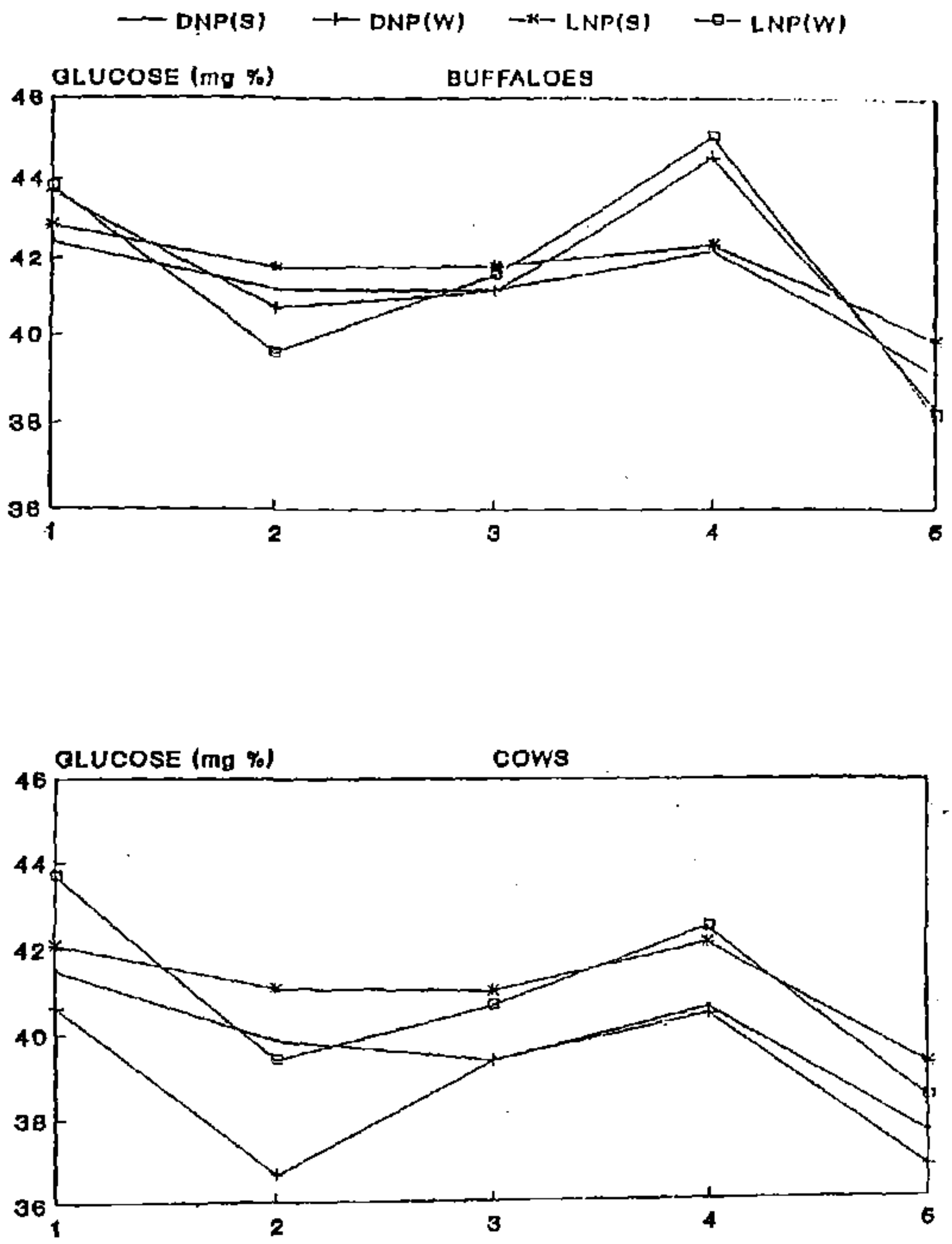
Ploughing decreased the glucose concentration of DNP and LNP cows during summer. During summer, the pre-work mean values of blood glucose in DNP and LNP cows were 41.49 ± 0.59 and 42.09 ± 0.25 mg/100 ml of blood, respectively. The decrease in glucose concentration was to levels of 39.84 ± 0.20 and 41.05 ± 0.25 due to ploughing work. Rest pause of 2 h increased glucose concentration to 40.57 ± 0.39 and 42.07 ± 0.12 mg per cent in DNP and LNP cows, respectively. Further work, after rest pause, decreased glucose levels to 37.56 ± 0.35 and 39.22 mg per cent in

Table 4.1.7.1 Glucose (mg/100 ml) changes in working buffaloes and cows during summer and winter seasons

Periods	Dry non-pregnant		Lactating non-pregnant	
	Summer	Winter	Summer	Winter
		BUFFALOES		
BW	42.42 ± 0.87	43.68 ± 0.21	42.86 ± 0.33	43.82 ± 0.37
AW	41.23 ± 0.89	40.75 ± 0.70	41.80 ± 0.25	39.63 ± 0.47
Rest 1	41.23 ± 0.82	41.19 ± 0.46	41.86 ± 0.15	41.63 ± 1.34
Rest 2	42.26 ± 0.68	44.57 ± 0.98	42.43 ± 0.29	45.07 ± 1.21
EW	39.16 ± 0.50	38.38 ± 0.66	39.93 ± 0.32	38.21 ± 1.23
		COWS		
BW	41.49 ± 0.59	40.63 ± 0.35	42.09 ± 0.25	43.69 ± 0.60
AW	39.84 ± 0.20	36.66 ± 0.29	41.05 ± 0.25	39.38 ± 1.50
Rest 1	39.33 ± 0.70	39.32 ± 0.19	40.98 ± 0.31	40.63 ± 1.07
Rest 2	40.57 ± 0.39	40.43 ± 0.31	42.07 ± 0.12	42.45 ± 0.90
EW	37.56 ± 0.35	36.76 ± 0.43	39.22 ± 0.37	38.38 ± 0.98

The values are the mean ± SEM based on two replicates on 5 animals

Fig. 4.17.1 : BLOOD GLUCOSE IN WORKING BUFFALOES COWS DURING SUMMER & WINTER



DNP and LNP cows, respectively. The decrease over pre-work accounted for 9.47 and 6.82 per cent in DNP and LNP cows.

During winter, the mean glucose concentration was higher, being 43.68 ± 0.21 and 43.82 ± 0.37 mg per cent in DNP and LNP buffaloes. The glucose levels dropped by 9.37 and 13.73 per cent in DNP and LNP buffaloes, these changes were higher than the changes observed during summer under identical conditions. During winter, 2 h rest pause returned the glucose levels to normal values. Further work, after rest pause, lowered glucose concentrations to 38.38 ± 0.66 and 38.21 ± 1.23 mg per cent, respectively in DNP and LNP buffaloes.

Correlation coefficient of glucose with other parameters revealed that glucose was significantly ($P < 0.01$) negatively correlated to RR ($r = -0.33$), PR ($r = -0.39$), RT ($r = -0.29$) and positively correlated ($P < 0.01$) to Hb (0.52) and Hct (0.39).

Analysis of variance show that glucose significantly differed ($P < 0.01$) between animals, species, groups and different intervals. Interactions of seasons x periods and species x groups had also significantly affected ($P < 0.01$) the glucose levels.

4.1.5.2 Lactic acid

The average blood lactic acid levels during different seasons and in DNP and LNP buffaloes and cows have been represented graphically (Fig.4.1.7.2) and also presented in Table 4.1.7.2. The statistical analysis is presented in Tables 4.1.5.2 and 4.1.5.6.

Fig. 4.1.7.2: LACTIC ACID IN WORKING BUFFALOES & COWS DURING SUMMER & WINTER

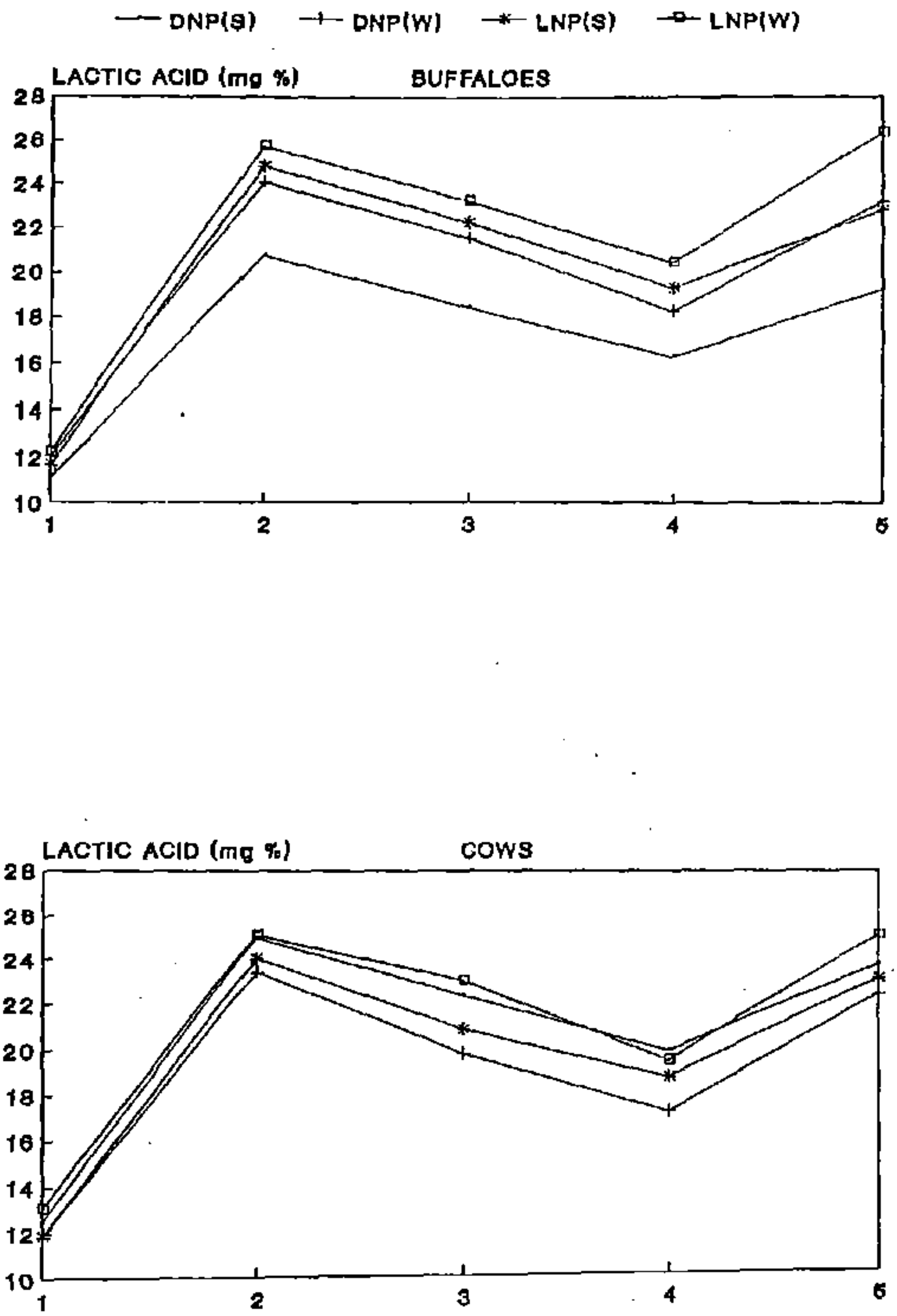


Table 4.1.7.2 Lactic acid (mg/100 ml) changes in buffaloes and cows during summer and winter seasons

Periods	Dry non-pregnant		Lactating non-pregnant	
	Summer	Winter	Summer	Winter
		BUFFALOES		
BW	11.07 ± 0.46	12.02 ± 0.32	11.67 ± 0.30	12.22 ± 0.58
AW	20.78 ± 0.60	24.12 ± 0.55	24.84 ± 0.33	25.73 ± 1.48
Rest 1	18.47 ± 0.77	21.59 ± 0.55	22.35 ± 0.58	23.28 ± 0.79
Rest 2	16.35 ± 0.61	18.53 ± 0.91	19.49 ± 0.49	20.50 ± 0.68
EW	19.30 ± 0.41	23.27 ± 0.72	22.85 ± 0.29	26.14 ± 1.03
		COWS		
BW	12.53 ± 0.48	11.78 ± 0.23	11.86 ± 0.32	13.11 ± 0.67
AW	24.95 ± 1.05	23.40 ± 0.28	24.03 ± 0.51	25.08 ± 0.73
Rest 1	22.35 ± 0.84	19.79 ± 0.22	20.85 ± 0.58	23.00 ± 0.28
Rest 2	19.86 ± 0.98	17.19 ± 0.14	18.73 ± 0.73	19.46 ± 0.55
EW	23.68 ± 0.82	22.35 ± 0.17	23.06 ± 0.36	25.01 ± 0.16

The values are the mean ± SEM based on two replicates on 5 animals

Lactic acid concentration increased due to ploughing during different seasons in buffaloes and cows, however, the changes in LA were not uniform at different periods of work.

The pre-work mean lactic acid content in DNP and LNP buffaloes during summer were 11.07 $\pm$ 0.46 and 11.67 $\pm$ 0.30 mg, respectively. The increase in mean lactic acid was observed after first period of work to 20.78 $\pm$ 0.60 and 24.84 $\pm$ 0.33 mg per cent (Table 4.1.7.2). This increase in the lactic acid was 87.71 and 112.85 per cent over pre-work values in DNP and LNP buffaloes, respectively. The rest pause of 2 h decreased lactic acid to 16.35 $\pm$ 0.61 mg in DNP and 19.49 $\pm$ 0.49 mg in LNP buffaloes. Two hours of rest was not sufficient to bring back the LA to normal pre-work levels. Further work, after rest, increased LA to 19.30 $\pm$ 0.41 and 22.85 $\pm$ 0.29 mg in DNP and LNP buffaloes. The pre-work mean lactic acid contents during summer in cows were 12.53 $\pm$ 0.48 and 11.86 $\pm$ 0.342 mg which increased due to work to 24.95 $\pm$ 1.05 and 24.03 $\pm$ 0.51 mg per cent in DNP and LNP cows. The rest pause decreased lactic acid levels by 25.63 and 28.30 per cent in DNP and LNP cows. Further work after 2 h rest increased the lactic acid content to 23.68 $\pm$ 0.82 and 23.06 $\pm$ 0.36 mg in DNP and LNP cows, respectively.

The pre-work mean values of LA in DNP and LNP buffaloes during winter were 12.02 $\pm$ 0.32 and 12.22 $\pm$ 0.58 mg, ploughing increased these levels to 24.12 $\pm$ 0.55 and 25.73 $\pm$ 1.48 mg per cent (Table 4.1.7.2). During rest, the lactic acid decreased to 21.59 $\pm$ 0.55 and 23.28 $\pm$ 0.79 mg after 1 h rest and 18.53 $\pm$ 0.91 and 20.50 $\pm$ 0.68 mg per cent after 2 h of rest in DNP and LNP respectively. Further work raised lactic acid content to 23.27 $\pm$ 0.72 and 26.14 $\pm$ 1.03 mg per cent in DNP and LNP cows.

The pre-work mean lactic acid contents during winter in DNP and LNP cows were 11.78 ± 0.23 and 13.11 ± 0.67 mg per cent. The ploughing for a mean duration of 1.23 h increased lactic acid levels to 23.40 ± 0.28 mg in DNP cows. LNP cows travelled to a mean duration of 1.17 h and exhibited a similar change in lactic acid. A rest pause of 2 h decreased lactic acid content by 36.13 and 28.90 per cent in DNP and LNP cows. Work after 2 h rest further increased the lactic acid content to 22.35 ± 0.17 and 25.01 ± 0.16 mg in DNP and LNP cows (Table 4.1.7.2).

Analysis of variance of data on lactic acid revealed that values for lactic acid significantly differed ($P < 0.01$) between animals, seasons, groups and due to periods of sampling. Interactions of seasons x species, species x groups and seasons x species x periods also had significant ($P < 0.01$) effect on lactic acid.

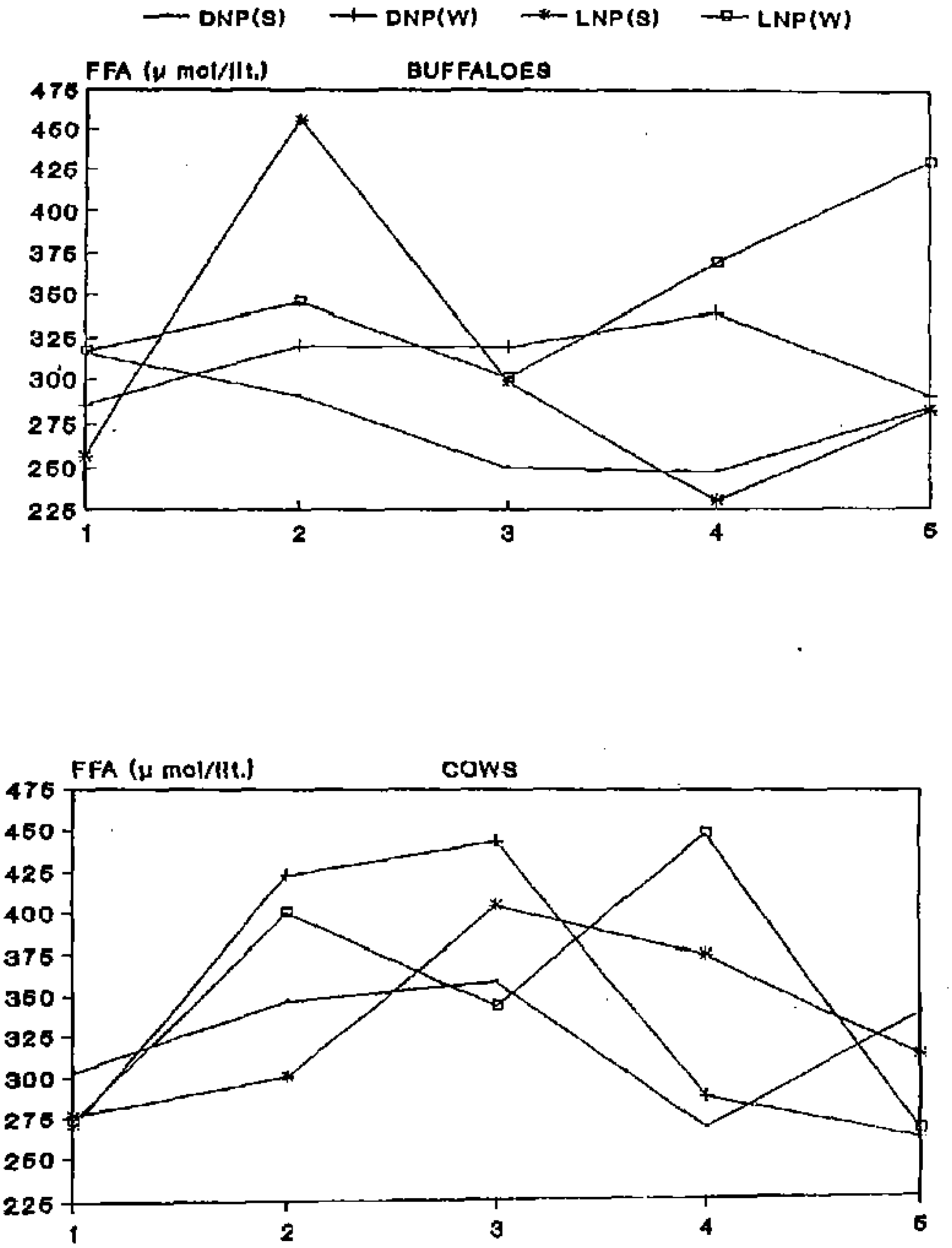
Correlation of lactic acid with other parameters indicated that lactic acid had a positive correlation ($P < 0.01$) with RR ($r = 0.48$), PR ($r = 0.57$), RT ($r = 0.57$) and was negatively correlated ($P < 0.01$) with Hb ($r = -0.40$), Hct ($r = -0.23$) and glucose ($r = -0.32$).

4.1.5.3 Free fatty acids

The results for the changes in the free fatty acid (FFA) of DNP and LNP cows and buffaloes during summer and winter have been presented in Table 4.1.7.3 and Fig. 4.1.7.3.

Ploughing generally increased blood FFA levels in buffaloes and cows during summer and winter. During summer, the pre-work

Fig. 4.1.73: FREE FATTY ACID IN WORKING BUFFALOES & COWS DURING SUMMER & WINTER



mean FFA and DNP and LNP buffaloes were 315.77 ± 73.26 and 256.83 ± 15.11 umol/l respectively which increased to 455.80 ± 122.30 umol/l in LNP buffaloes, but a decrease in FFA was observed in DNP buffaloes (Table 4.1.7.3). During rest, FFA decreased to 247.76 ± 10.66 and 230.53 ± 24.17 umol/l in DNP and LNP buffaloes during summer. Second phase of work raised FFA to 284.93 ± 29.70 and 282.77 ± 36.33 umol/l in DNP and LNP buffaloes. The per cent decrease in the concentration of FFA after 2 h of rest was 21.54 in DNP and 10.24 in LNP buffaloes (Fig. 4.1.7.3).

The pre-work average FFA values in DNP and LNP cows during summer were 302.23 ± 22.52 and 276.17 ± 24.01 umol/l, respectively. Ploughing increased these values to 346.67 ± 8.89 and 299.70 ± 21.76 umol/l in DNP and LNP cows. During rest pause, FFA respectively increased to 358.53 ± 79.56 and 403.80 ± 155.12 umol/l. Further 1 h rest did not exhibit any significant change in FFA level. Second work period raised FFA to 337.80 ± 42.01 umol/l in DNP cows (Table 4.1.7.3).

The pre-work FFA in DNP and LNP buffaloes were 285.73 ± 33.90 and 317.03 ± 41.80 umol/l in winter, respectively, which increased to 320.93 ± 18.60 in DNP buffaloes and 346.67 ± 23.52 umol/l in LNP buffaloes after work. FFA further increased during 2 h of rest pause. Second work period further raised FFA to 430.13 ± 82.67 umol/l. During winter season, in LNP and DNP buffaloes, the pre-work concentrations of free fatty acid were observed to be higher than in summer season. Due to work rise in the concentration of FFA was higher during winter season than summer season (Table 4.1.7.3).

DNP and LNP cows during winter season showed a reverse trend in the concentration of FFA as compared to DNP and LNP buffaloes during winter. Slightly lower values of FFA were observed in cows during winter (Table 4.1.7.3). The pre-work mean values of FFA were 268.57 ± 5.93 and 272.50 ± 22.38 umol/l in DNP and LNP cows, respectively. After work, FFA increased by 57.39 per cent and 46.78 per cent over pre-work levels in DNP and LNP cows, respectively. The mean values of FFA after first phase of ploughing were 422.70 ± 153.11 umol/L in DNP cows and 399.90 ± 131.94 umol/l in LNP cows. FFA exhibited a further increase after first and second hour of rest pause (Fig. 4.1.7.3).

4.1.6 HORMONAL CHANGES

4.1.6.1 Triiodothyronine

Blood hormonal changes in working cows and buffaloes were carried out by RIA and results for the analysis have been presented in Tables 4.1.8.1 to 4.1.8.5, Figs. 4.1.8.1 to 4.1.8.7 and statistical analysis in Table 4.1.7.4.

The results for the changes in levels of triiodothyronine (ng/ml) in DNP and LNP cows and buffaloes during summer and winter at different intervals of work and rest have been presented in Table 4.1.8.1 and Fig. 4.1.8.1.

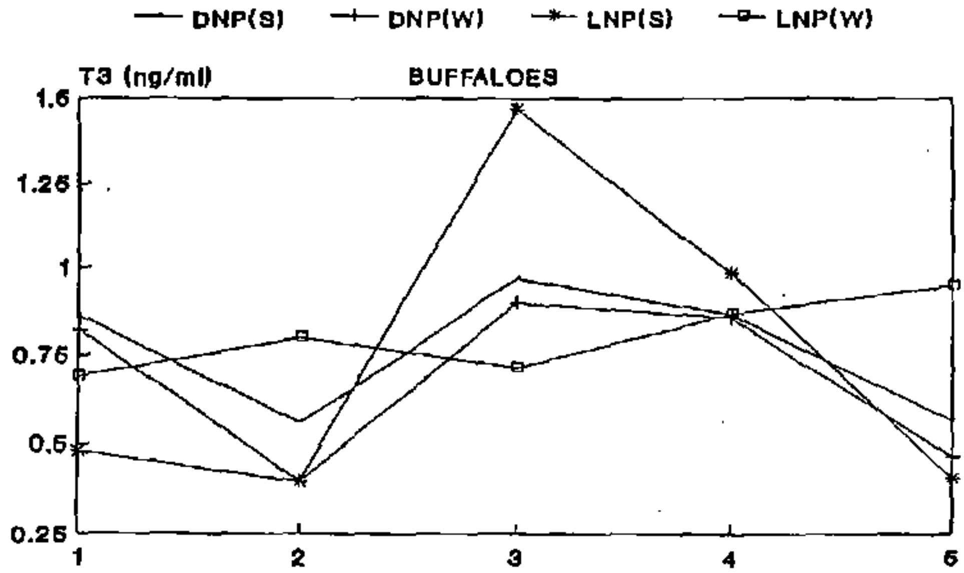
The pre-work mean values of triiodothyronine (T_3) ranged from 0.47 ± 0.17 to 1.41 ± 0.57 ng/ml in cows and buffaloes. The mean values of T_3 were 0.86 ± 0.50 and 0.48 ± 0.11 in DNP and LNP buffaloes, respectively. T_3 levels increased to 0.97 ± 0.44 and 1.47 ± 1.09 ng/ml in DNP and LNP buffaloes after 1 h of rest. Further rest for 1 h decreased the T_3 levels to 0.87 ± 0.09 and 0.99 ± 0.44 ng/ml respectively, in DNP and LNP buffaloes. Second

Table 4.1.8.1 Triiodothyronine (ng/ml) changes in buffaloes and cows during summer and winter seasons

Periods	Dry non-pregnant		Lactating non-pregnant	
	Summer	Winter	Summer	Winter
		BUFFALOES		
BW	0.86 $\pm$ 0.50	0.82 $\pm$ 0.34	0.48 $\pm$ 0.11	0.69 $\pm$ 0.12
AW	0.56 $\pm$ 0.19	0.40 $\pm$ 0.01	0.40 $\pm$ 0.05	0.80 $\pm$ 0.29
Rest 1	0.97 $\pm$ 0.44	0.90 $\pm$ 0.26	1.47 $\pm$ 1.09	0.72 $\pm$ 0.10
Rest 2	0.87 $\pm$ 0.09	0.86 $\pm$ 0.19	0.99 $\pm$ 0.44	0.87 $\pm$ 0.16
EW	0.57 $\pm$ 0.03	0.47 $\pm$ 0.01	0.41 $\pm$ 0.12	0.95 $\pm$ 0.15
		COWS		
BW	1.41 $\pm$ 0.57	0.47 $\pm$ 0.17	0.57 $\pm$ 0.26	0.60 $\pm$ 0.17
AW	0.79 $\pm$ 0.12	1.18 $\pm$ 0.11	0.81 $\pm$ 0.11	0.59 $\pm$ 0.02
Rest 1	0.49 $\pm$ 0.13	0.75 $\pm$ 0.24	0.51 $\pm$ 0.08	0.52 $\pm$ 0.03
Rest 2	0.22 $\pm$ 0.04	0.53 $\pm$ 0.08	0.67 $\pm$ 0.05	0.60 $\pm$ 0.04
EW	0.47 $\pm$ 0.01	0.48 $\pm$ 0.13	0.45 $\pm$ 0.08	0.52 $\pm$ 0.03

The values are the mean $\pm$ SEM based on two replicates on 3 animals

Fig. 4.1.81: TRIIODOTHYRONINE IN WORKING BUFFALOES & COWS DURING SUMMER & WINTER



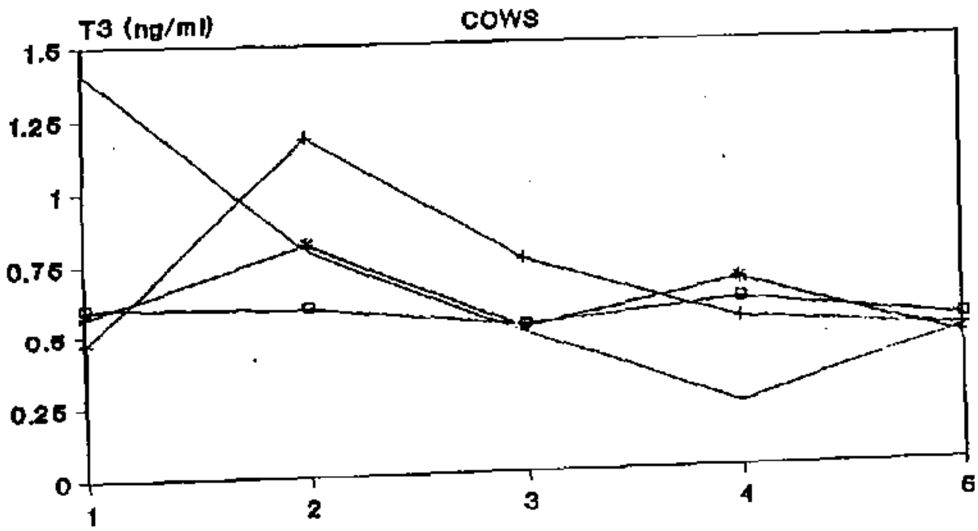


Table 4.1.7.4 Analysis of variance of FFA, T_3, T_4 and insulin during ploughing

Source of variation	d.f.	M.S.S.			d.f.	M.S.S.
		FFA	T4	T3		Insulin
Animals	2	343.06	187.09	0.308	1	0.66
Seasons	1	21000.35	1335.32**	0.004	1	0.05
Species	1	15473.99	768.70**	0.447	1	94.97**
Groups	1	15526.07	945.72**	0.015	1	375.15**
Periods	4	19197.20	87.67	0.211	4	30.80**
Seasons x Species	1	5317.61	727.11**	0.000	1	9.90
Seasons x Groups	1	445.65	1769.64**	0.014	1	3.23
Seasons x Periods	4	6392.74	29.38	0.121	4	8.25
Species x Groups	1	4824.86	786.85**	0.154	1	32.92
Species x Periods	4	15212.70	62.84	0.587	4	2.75
Groups x Periods	4	6368.49	29.98	0.196	4	12.22
Seasons x Species x Groups	1	581.49	1783.75**	0.055	1	15.15
Seasons x Species x Periods	4	14510.22	25.68	0.244	4	0.35
Seasons x Groups x Periods	4	10003.30	49.38	0.285	4	5.24
Species x Groups x Periods	4	14559.71	28.99	0.075	4	0.63
All effect	4	4562.18	121.74	0.220	4	2.84
Error	78	13482.92	26.239	0.187	39	5.81

work period decreased T_3 levels by 33.72 and 14.58 per cent in DNP and LNP buffaloes.

The pre-work mean values of triiodothyronine in DNP and LNP cows during summer were 1.41 ± 0.57 and 0.57 ± 0.26 ng/ml, respectively. These values are lower than the pre-work values of buffaloes during same season. The pre-work mean values during summer in cows were higher than the T_3 values during winter season. After first round of work, T_3 decreased in DNP cows but there was an increase in LNP cows. The absolute mean values after first round of ploughing were 0.79 ± 0.12 and 0.81 ± 0.11 ng/ml in DNP and LNP cows. During rest, T_3 levels further decreased to 0.49 ± 0.13 and 0.51 ± 0.08 ng/ml in DNP and LNP cows. Another hour of rest to DNP cows during summer decreased T_3 levels to 0.22 ± 0.04 ng/ml but in LNP cows the values lncreased to a mean of 0.67 ± 0.05 ng/ml. Second round of work increased T_3 levels to 0.47 ± 0.01 in DNP and 0.45 ± 0.08 ng/ml in LNP cows. These results do not indicate any specific pattern of change in T_3 levels due to work.

The pre-work mean values of T_3 were 0.82 ± 0.34 in DNP and 0.69 ± 0.12 ng/ml in LNP buffaloes. After first ploughing, the average values of T_3 were 0.40 ± 0.01 and 0.80 ± 0.29 ng/ml in DNP and LNP buffaloes. Two hours of rest period was provided to the working animals for recovery after first round of work during this period. The mean T_3 levels increased to 0.86 ± 0.19 and 0.87 ± 0.16 ng/ml in DNP and LNP buffaloes. Thereafter T_3 levels increased in LNP buffaloes and decreased to 0.47 ± 0.01 ng/ml in DNP buffaloes (Table 4.1.8.1).

The pre-work mean values of T_3 in DNP and LNP cows during winter were 0.47 ± 0.17 and 0.60 ± 0.17 ng/ml, respectively. Due to work period, an increase in T_3 content was observed in DNP cows, but the T_3 content remained almost at same levels in LNP cows. One hour of rest decreased the T_3 content to 0.75 $\pm$ 0.24 and 0.52 $\pm$ 0.03 ng/ml, respectively, in DNP and LNP cows. Further work period after 2 h of rest decreased T_3 (Table 4.1.8.1).

Statistical analysis in terms of correlation coefficient and analysis of variance did not show any signiicant effect.

4.1.6.2 Thyroxine

The results for thyroxine (T_4) in dry non-pregnant and lactating non-pregnant animals during summer and winter have been presented in Table 4.1.8.2 and Fig. 4.1.8.2.

The pre-work mean thyroxine levels were 21.47 $\pm$ 1.26 and 25.13 ng/ml in DNP and LNP buffaloes during summer, respectively. In DNP buffaloes, T_4 levels increased due to work but levels decreased in LNP buffaloes (Table 4.1.8.2). The rest period increased T_4 levels to 37.10 $\pm$ 10.18 and 23.30 $\pm$ 2.77 ng/ml in DNP and LNP buffaloes. Second phase of work further decreased T_4 levels to 21.96 $\pm$ 1.46 and 18.55 $\pm$ 7.20 ng/ml in DNP and LNP buffaloes, respectively (Table 4.1.8.2).

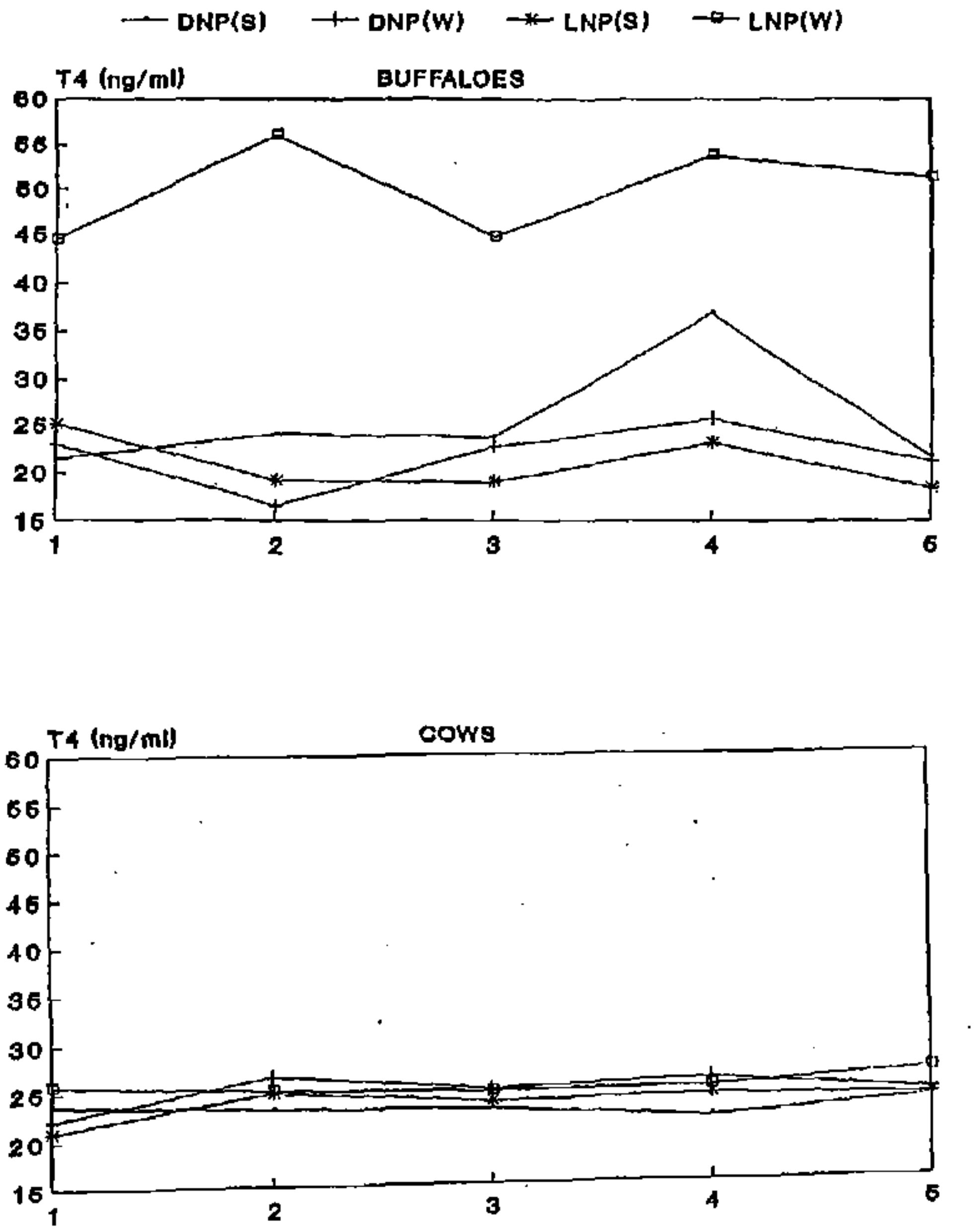
The pre-work mean values of T_4 were 23.70 $\pm$ 2.04 and 20.94 $\pm$ 1.60 ng/ml in DNP and LNP cows during summer season (Table 4.1.8.2). These pre-work mean values of T_4 in DNP and LNP cows were almost similar to those recorded in DNP and LNP buffaloes during summer season (Table 4.1.8.2). During summer, dry non-pregnant cows did not show any difference in T_4 level but an increase to 24.90 $\pm$ 1.81 ng/ml was observed in LNP cows after

Table 4.1.8.2 Thyroxine (ng/ml) changes in buffaloes and cows during summer and winter seasons

Periods	Dry non-pregnant		Lactating non-pregnant	
	Summer	Winter	Summer	Winter
		BUFFALOES		
BW	21.47 ± 1.26	22.93 ± 2.66	25.13 ± 2.88	44.33 ± 15.15
AW	24.22 ± 0.94	16.60 ± 2.10	19.29 ± 5.25	56.00 ± 21.60
Rest 1	23.90 ± 0.26	22.82 ± 4.65	19.11 ± 4.22	44.73 ± 14.23
Rest 2	37.10 ±10.18	25.93 ± 5.14	23.30 ± 2.77	53.83 ± 20.69
EW	21.96 ± 1.46	21.39 ± 2.66	18.55 ± 7.20	51.33 ± 7.71
		COWS		
BW	23.70 ± 2.04	22.19 ± 0.55	20.94 ± 1.60	25.78 ± 1.80
AW	23.12 ± 4.79	26.54 ± 2.17	24.90 ± 1.81	25.13 ± 1.95
Rest 1	22.89 ± 3.82	24.98 ± 2.67	23.75 ± 3.40	24.75 ± 1.30
Rest 2	21.77 ± 5.65	25.83 ± 1.56	24.24 ± 1.89	25.08 ± 2.57
EW	23.53 ± 4.79	24.36 ± 1.73	23.78 ± 4.66	26.48 ± 1.57

The values are the mean ± SEM based on two replicates on 3 animals

Fig. 4.1.82: THYROXINE LEVEL IN WORKING BUFFALOES & COWS DURING SUMMER & WINTER



first phase of work. After 2 h of rest period, the T_4 levels decreased to 21.77 ± 5.65 and 24.24 ± 1.89 ng/ml over the mean values recorded after first phase work period (Fig. 4.1.8.2).

Higher levels of T_4 content in LNP buffaloes were observed at different intervals of work and rest as compared to DNP buffaloes. The pre-work mean values of T_4 levels were 22.93 ± 2.66 and 44.33 ± 15.15 ng/ml in DNP and LNP buffaloes during winter season.

The pre-work mean values of T_4 content in DNP and LNP cows were 22.19 ± 0.55 and 25.78 ± 1.80 ng/ml during winter season. The T_4 contents during pre-work observed in DNP and LNP cows during winter were almost similar to the values observed during summer season (Table 4.1.8.2). Ploughing increased the T_4 content to 26.54 ± 2.17 ng/ml in DNP cows but the T_4 levels in LNP cows were not affected by work. Statistical analysis showed that T_4 differed significantly ($P < 0.01$) between seasons, species, groups and interaction of seasons x species, seasons x groups, species x groups and seasons x species x groups.

4.1.6.3 Insulin

The results for changes in insulin level due to work and rest in cattle and bu;ffaloes have been presented in Table 4.1.8.3 and Fig. 4.1.8.3.

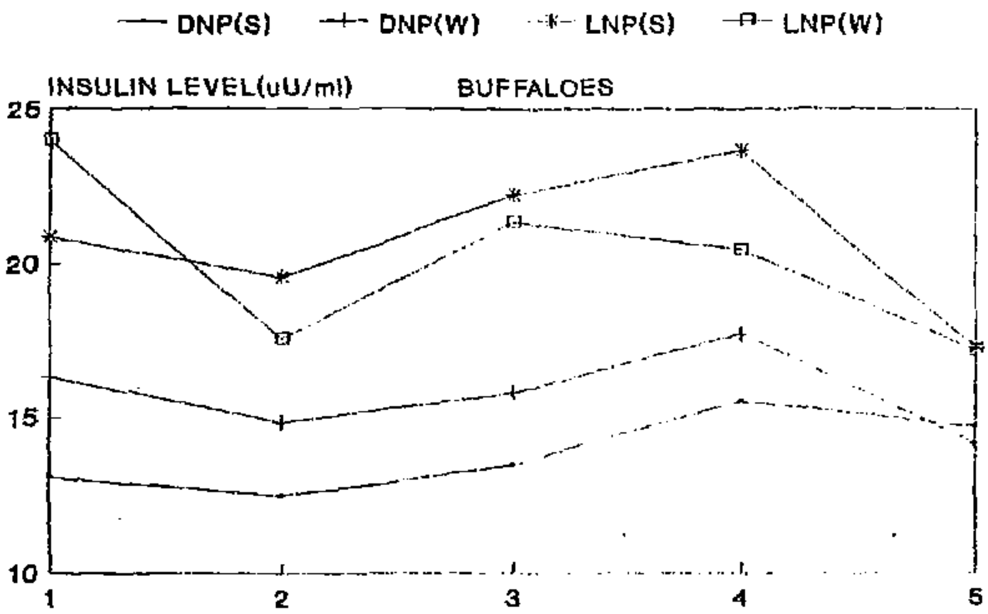
At the beginning of experiment, the insulin levels were 13.10 ± 1.10 and 20.89 uU/ml in DNP and LNP buffaloes. Ploughing decreased the levels of insulin in DNP and LNP buffaloes to 12.15 ± 0.26 and 19.56 ± 2.25 uU/ml, respectively. The work decreased insulin to a slight level (0.95 uU/ml) in buffalo over pre-work

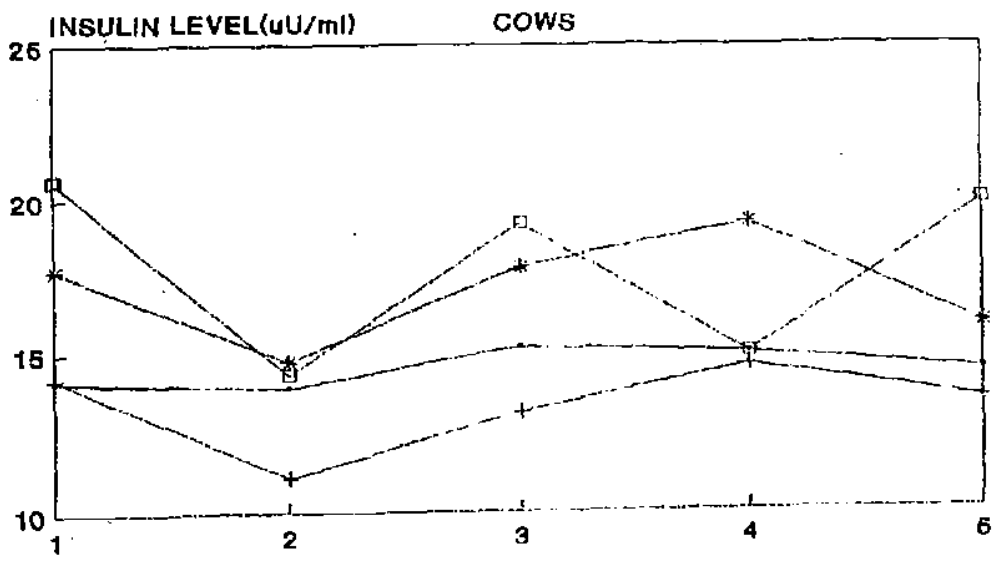
Table 4.1.8.3 Insulin (uU/ml) changes in buffaloes and cows during summer and winter seasons

Periods	Dry non-pregnant		Lactating non-pregnant	
	Summer	Winter	Summer	Winter
		BUFFALOES		
BW	13.10 ± 1.10	16.30 ± 1.91	20.89 ± 0.17	23.98 ± 1.19
AW	12.15 ± 0.26	14.85 ± 0.45	19.56 ± 2.25	17.49 ± 0.80
Rest 1	13.50 ± 1.71	15.80 ± 0.40	22.26 ± 2.46	21.39 ± 0.25
Rest 2	15.57 ± 0.91	17.70 ± 0.30	23.68 ± 3.87	20.53 ± 3.48
EW	14.74 ± 0.26	14.20 ± 0.60	17.26 ± 1.81	17.17 ± 0.30
		COWS		
BW	14.10 ± 0.30	14.20 ± 1.00	17.75 ± 0.25	20.61 ± 1.53
AW	13.90 ± 0.90	11.10 ± 0.30	14.75 ± 0.45	14.32 ± 4.06
Rest 1	15.20 ± 0.20	13.10 ± 0.30	17.83 ± 1.60	19.22 ± 3.20
Rest 2	15.00 ± 1.20	14.60 ± 0.40	19.25 ± 0.95	14.99 ± 0.14
EW	14.40 ± 1.60	13.50 ± 1.30	15.93 ± 2.77	19.95 ± 1.75

The values are the mean ± SEM based on two replicates on 3 animals

Fig. 4.1.8.3 : INSULIN LEVEL CHANGES IN WORKING BUFFALOES & COWS DURING SUMMER & WINTER





mean values but decrease was more in LNP buffaloes (1.33 uU/ml). During rest period, rise in the insulin was observed. At one hour rest, the mean values were 13.50±0.71 and 22.26±2.46 uU/ml in DNP and LNP buffaloes. Rest of one more hour increased the level of insulin by 3.42 uU/ml and 4.12 uU/ml in DNP and LNP buffaloes, respectively. Second work after 2 h of rest dropped insulin level to 14.74 ± 0.26 and 17.26 ± 1.81 uU/ml in DNP and LNP buffaloes.

During winter, pre-work insulin values were higher than summer in both of the groups. In DNP and LNP buffaloes, the pre-work mean insulin levels were 16.30 ± 1.91 and 23.98 ± 1.19 during winter which decreased to 14.85 ± 0.45 and 17.49 ± 0.80 uU/ml after work. During rest, insulin level increased to 15.80± 0.40 and 21.39 ± 0.25 uU/ml in DNP and LNP buffaloes, respectively. Second round of ploughing decreased insulin, but the changes were almost similar to that observed during first phase of work (Table 4.1.8.3 and Fig. 4.1.8.3).

Similar trend in DNP and LNP cows was found during summer and winter season. The pre-work mean values of insulin respectively were 14.10 ± 0.30 and 17.75 ± 0.25 uU/ml in DNP and LNP cows. The respective decrease in insulin due to work was 0.20 and 3.00 uU/ml in DNP and LNP cows during summer season. Rest period of 1 h raised the level of insulin to 19.25 ± 0.95 in LNP cows but levels were maintained in DNP cows (Table 4.1.8.3). Further work after 2 h of rest dropped level of insulin to 14.40± 1.60 and 15.93 ± 2.77 uU/ml in DNP and LNP cows (Fig. 4.1.8.3).

During winter, the resting mean values were 14.20 ± 1.00 and 20.61 ± 1.53 uU/ml in DNP and LNP cows. Ploughing decreased insulin by 27.93 and 20.34 per cent in DNP and LNP cows (Fig.

4.1.8.3). The rest pause of 2 h increased insulin to 14.60 ± 0.40 and 14.99 ± 0.14 uU/ml in DNP and LNP cows. Further work after 2 h of rest again declined the level of insulin to 13.50 ± 1.30 and 19.95 ± 1.75 uU/ml in DNP and LNP cows (Table 4.1.8.3). Statistical analysis showed significant ($P < 0.01$) difference between groups. species and periods and no significant correlation was observed with T_3, FFA and insulin.

4.1.6.4 Estrogen and progesterone

The results for the changes in circulating levels of progesterone and estrogen hormones in working cows and buffaloes have been presented in Tables 4.1.8.4 and 4.1.8.5, and Figs. 4.1.8.4 to 4.1.8.7.

The pre-work concentration of progesterone and estrogen varied in different animals which were dependant on the state of reproductive cycle. The concentrations of progesterone during summer in two buffaloes were 0.40 and < 0.05 ng/ml (Fig.4.1.8.4). The respective estradiol concentrations during summer were 12.80 and 13.87 pg/ml. Circulating levels of estradiol during winter in two working animals were 19.20 and 1.87 pg/ml (Table 4.1.8.4). The pre-work levels of estradiol and progesterone thus clearly indicate that these animals were at different stages of reproductive cycle since we did not inseminate them to avoid effects of pregnancy. The pattern of changes in progesterone and estrogen either due to work or rest were not uniform and varied to a great extent in different animals (Figs.4.1.8.4 to 4.1.8.7).

4.1.7 MILK YIELD AND COMPOSITION

The results for average weekly milk yield and composition of milk in terms of fat, protein and lactose (%) have been presented

Table 4.1.8.4 Plasma progesterone (ng/ml) and plasma estradiol-17β (pg/ml) in lactating buffaloes and cows during summer and winter seasons

Periods	SUMMER				WINTER			
	Progesterone		Estradiol-17β		Progesterone		Estradiol-17 β	
	Animals		Animals		Animals		Animals	
	1	2	1	2	1	2	1	2
				BUFFALOES				
BW	0.40	0.05	12.80	13.87	0.88	0.05	19.20	1.87
AW	0.05	0.05	13.87	13.84	2.69	0.05	1.27	4.80
Rest 1	0.05	0.05	13.87	17.07	1.52	0.06	5.07	1.00
Rest 2	0.05	0.06	13.87	14.93	2.22	0.05	4.80	1.73
EW	0.05	0.05	13.80	12.80	1.28	0.06	4.80	0.67
				COWS				
BW	1.12	0.05	11.20	4.00	0.05	0.06	1.00	1.20
AW	0.96	0.06	4.00	2.00	0.05	0.05	1.00	5.60
Rest 1	0.10	0.05	5.60	7.40	0.06	0.05	7.20	4.00
Rest 2	0.20	0.06	8.00	9.60	0.05	0.06	1.00	2.60
EW	1.20	0.05	1.00	1.00	0.06	0.05	1.00	10.00

Observation of 2 animals

Table 4.1.8.5 Plasma progesterone (ng/ml) and plasma estradiol-17β (pg/ml) in dry non-pregnant buffaloes and cows during summer and winter seasons

Periods	SUMMER				WINTER			
	Progesterone		Estradiol-17β		Progesterone		Estradiol-17β	
	Animals		Animals		Animals		Animals	
	1	2	1	2	1	2	1	2
				BUFFALOES				
BW	0.05	0.06	4.58	8.50	0.05	1.91	1.00	-
AW	0.06	0.05	5.53	6.80	0.05	2.22	1.20	-
Rest 1	0.05	0.04	1.73	9.60	0.05	2.07	1.00	-
Rest 2	0.06	0.05	5.73	9.60	0.05	2.22	1.00	-
EW	0.05	0.05	3.20	5.50	0.06	2.53	1.40	-
				COWS				
BW	0.08	0.48	10.40	6.80	0.50	1.20	10.73	18.13
AW	0.15	1.12	12.00	9.60	0.96	0.88	27.27	27.27
Rest 1	0.07	0.72	24.00	3.80	0.22	0.12	18.13	14.93
Rest 2	0.88	0.50	14.40	3.20	0.22	0.22	21.33	21.33
EW	0.10	0.52	17.10	1.00	0.48	0.56	18.83	18.83

Observation of 2 animals

FIG. 4.1.8.4 PLASMA PROGESTERONE & ESTRADIOL 17-β IN WORKING BUFF. DURING SUMMER & WINTER

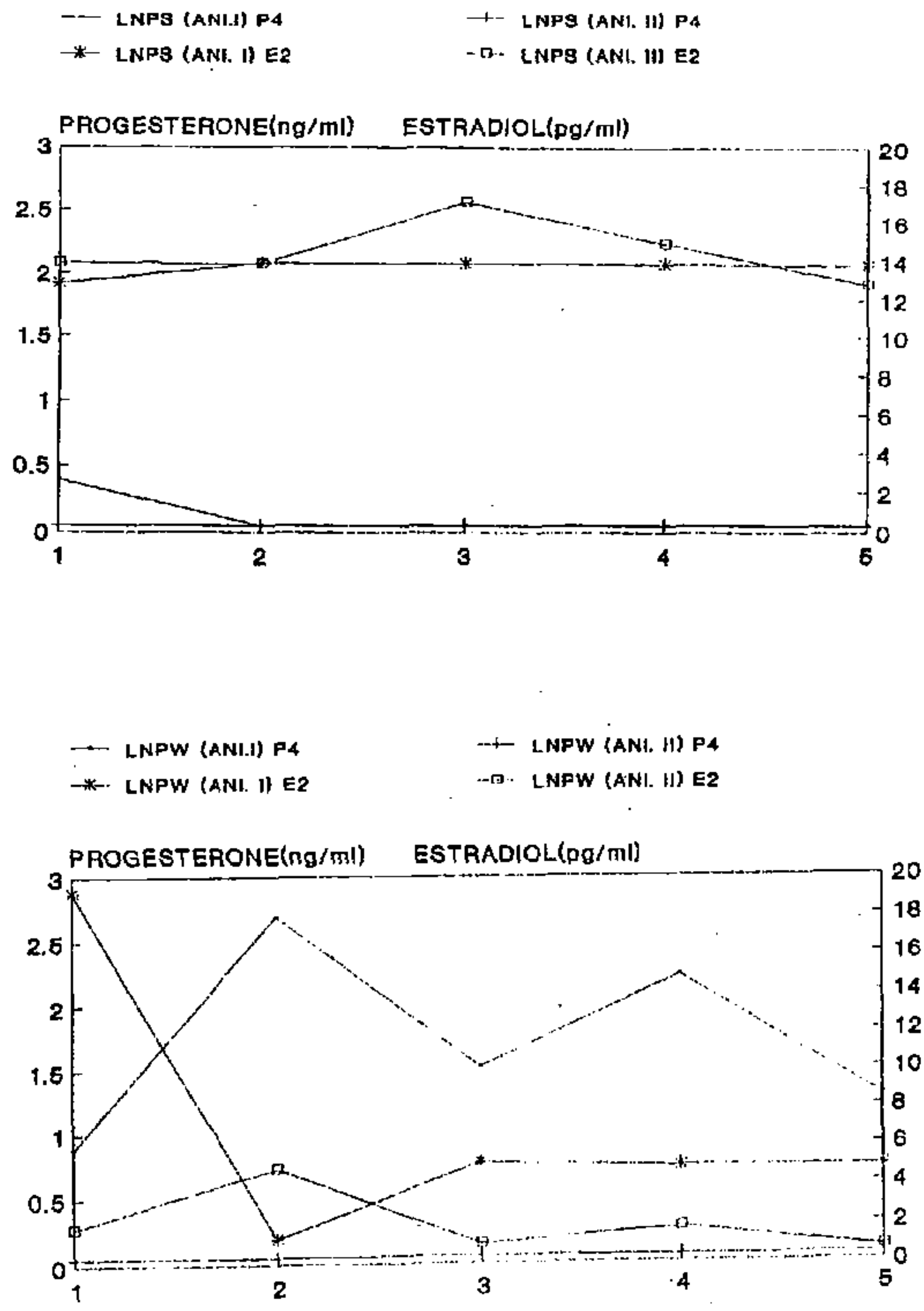
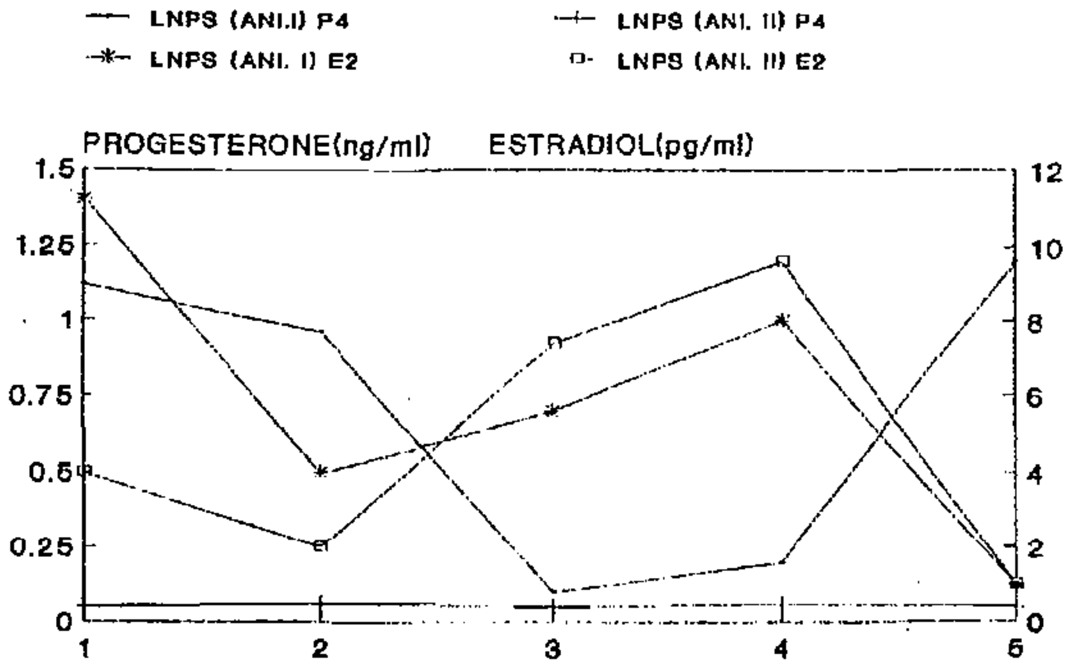


Fig. 4.1.8.5: PLASMA PROGESTERONE & ESTRADIOL 17-B IN WORKING COWS DURING SUMMER & WINTER



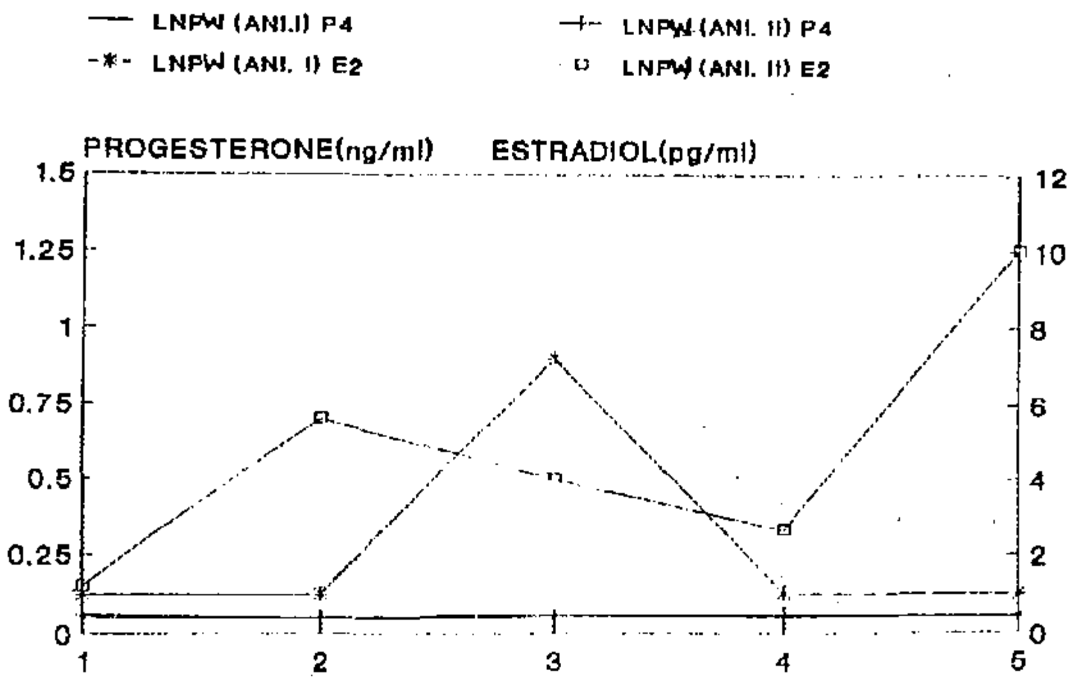


Fig. 4.1.8.6 : PLASMA PROGESTERONE & ESTRADIOL 17-β IN WORKING BUFF. DURING SUMMER

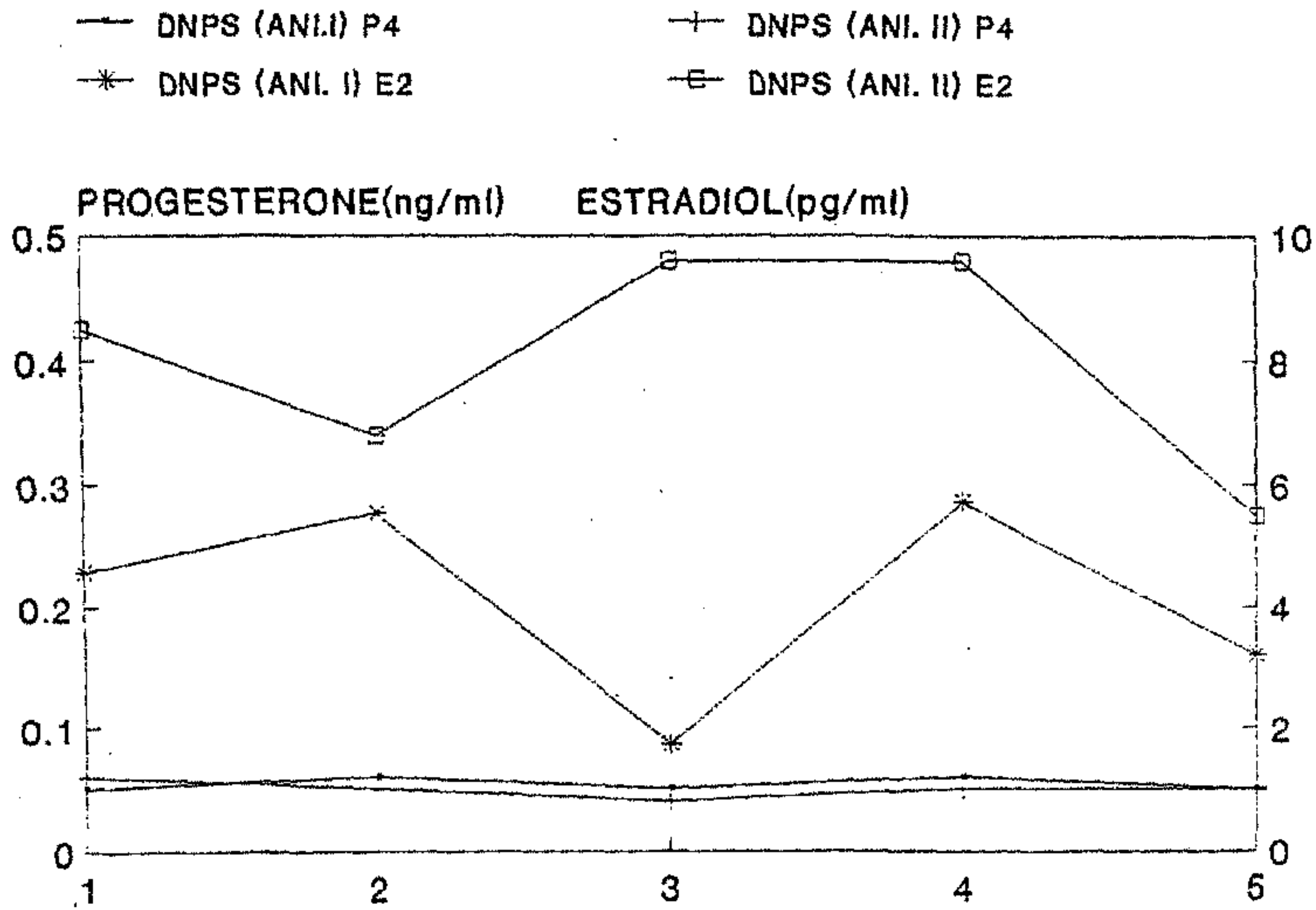
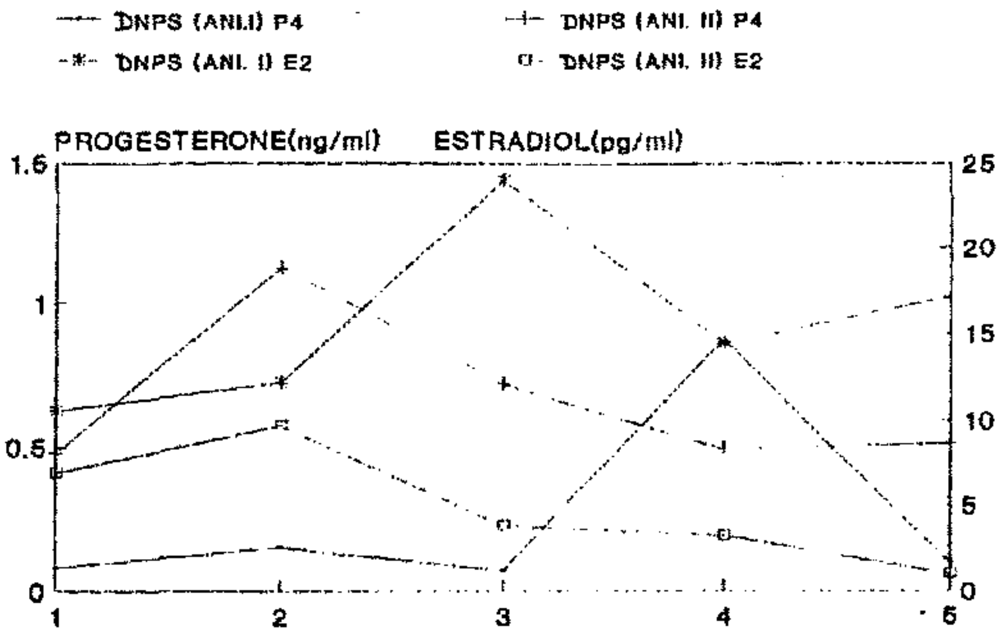
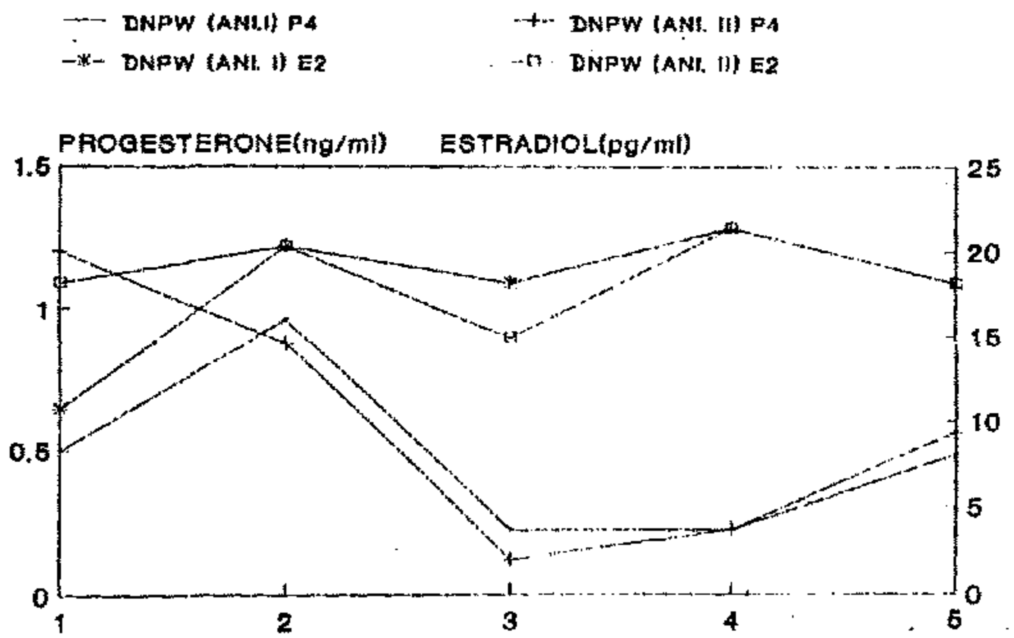


Fig. 4.1.8.7 : PLASMA PROGESTERONE & ESTRADIOL 17-β IN WORKING COWS DURING SUMMER & WINTER





in Table 4.1.9; Figs. 4.1.9 and 4.1.9.1, and their statistical analysis in Table 4.1.9.1.

The pre-work average milk yield for LNP buffaloes during summer was 4.43 ± 0.38 l/day. The mean fat, protein and lactose contents during pre-work phase were 7.91, 5.55 and 5.05 per cent, respectively. A drop in the milk yield was recorded due to effects of ploughing. Work decreased milk yield to 4.23 ± 0.26, 4.11± 0.24, 4.26±0.23 and 3.62±0.22 l/day and corresponding avera-ge fat, protein and lactose contents were 7.91 ± 0.51, 5.55 ± 0.41 and 4.70 ± 0.19 per cent during summer season in LNP buffaloes. The fat per cent in buffaloes remained similar during work period but lactose decreased and protein content increased during exercise (Table 4.1.9.1). The milk yield during post-work period were not similar to pre-work values. Post-work average values of milk yields were 4.07 ± 0.19, 3.98 ± 0.18, 4.11 ± 0.23 and 3.62 ± 0.22 l/day after 1st; 2nd, 3rd and 4th week of rest. After work, the average value of fat in milk was 7.82 ± 0.38 per cent which was slighltly lower than pre-work values. Content of protein in milk was 4.29 ± 0.26 per cent, which is almost similar to that observed during pre-work phase. Lactose content in milk was 4.54 ± 0.30 per cent indicating a decline after work phase. Overall average milk yield during summer in DNP cows was higher than LNP buffaloes. The decrease in the milk yield was 1.33 litres after four weeks. Corresponding average values of milk fat, protein and lactose during pre-work period were 4.59 ± 0.34, 3.95 ± 0.38 and 4.59 ± 0.10 per cent, respectively.

From the data presented in Table 4.1.9, it could be observed that milk yield decreased at faster rate in LNP cows than buffaloes during summer. The average milk composition in terms of fat, protein and lactose was 4.76 ± 0.22, 3.89 ± 0.15 and

Table 4.1.9 Changes in milk yield and its composition during work in cows and buffaloes

Periods between		Lactating non-pregnant buffaloes		Lactating non-pregnant cows	
		Summer	Winter	Summer	Winter
			MILK YIELD*		
BW	I	4.84 ± 0.33	4.20 ± 0.30	6.08 ± 0.53	4.24 ± 0.50
	II	4.43 ± 0.38	4.28 ± 0.31	5.38 ± 0.41	4.08 ± 0.56
DW	I	4.26 ± 0.23	3.75 ± 0.25	5.11 ± 0.34	3.66 ± 0.75
	II	3.62 ± 0.22	3.53 ± 0.30	5.06 ± 0.36	4.16 ± 0.79
EW	I	4.11 ± 0.23	3.43 ± 0.11	4.59 ± 0.31	3.85 ± 0.79
	II	3.91 ± 0.18	3.84 ± 0.19	4.61 ± 0.32	3.48 ± 0.81
			FAT PER CENT**		
BW		7.91 ± 0.60	6.95 ± 0.47	4.59 ± 0.34	4.49 ± 0.51
DW		7.91 ± 0.51	7.71 ± 0.39	4.76 ± 0.22	6.16 ± 0.69
EW		7.82 ± 0.33	7.63 ± 0.38	4.06 ± 0.23	5.47 ± 0.17
			PROTEIN PER CENT**		
BW		4.30 ± 0.40	4.01 ± 0.21	3.95 ± 0.38	3.20 ± 0.11
DW		5.55 ± 0.41	4.36 ± 0.25	3.89 ± 0.15	3.81 ± 0.14
EW		4.29 ± 0.26	4.08 ± 0.15	3.69 ± 0.17	3.43 ± 0.14
			LACTOSE PER CENT**		
BW		5.05 ± 0.17	4.89 ± 0.26	4.59 ± 0.10	4.65 ± 0.08
DW		4.70 ± 0.19	4.55 ± 0.22	4.63 ± 0.04	4.57 ± 0.13
EW		4.54 ± 0.30	4.90 ± 0.15	4.86 ± 0.05	4.94 ± 0.14

* The values are means of 2 weeks of milk yield
** The values are the means of two observations each

Fig. 4.19: AV.WEEKLY MILK YIELD OF BUFFALOES & COWS DURING SUMMER & WINTER

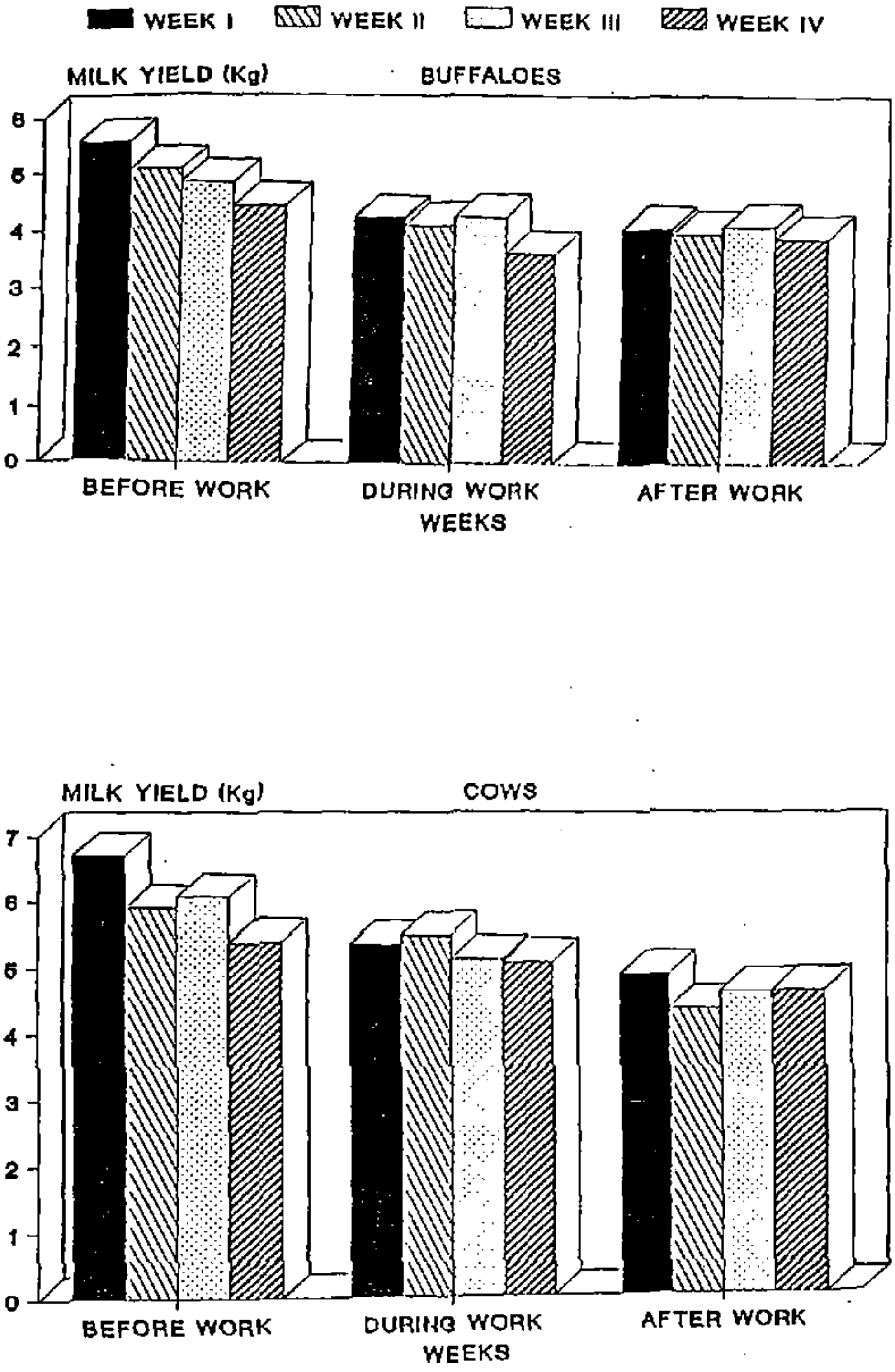


Fig. 4.1.9.1: FAT,PROTEIN & LACTOSE (%) IN WORKING BUFFALOES & COWS DURING SUMMER & WINTER

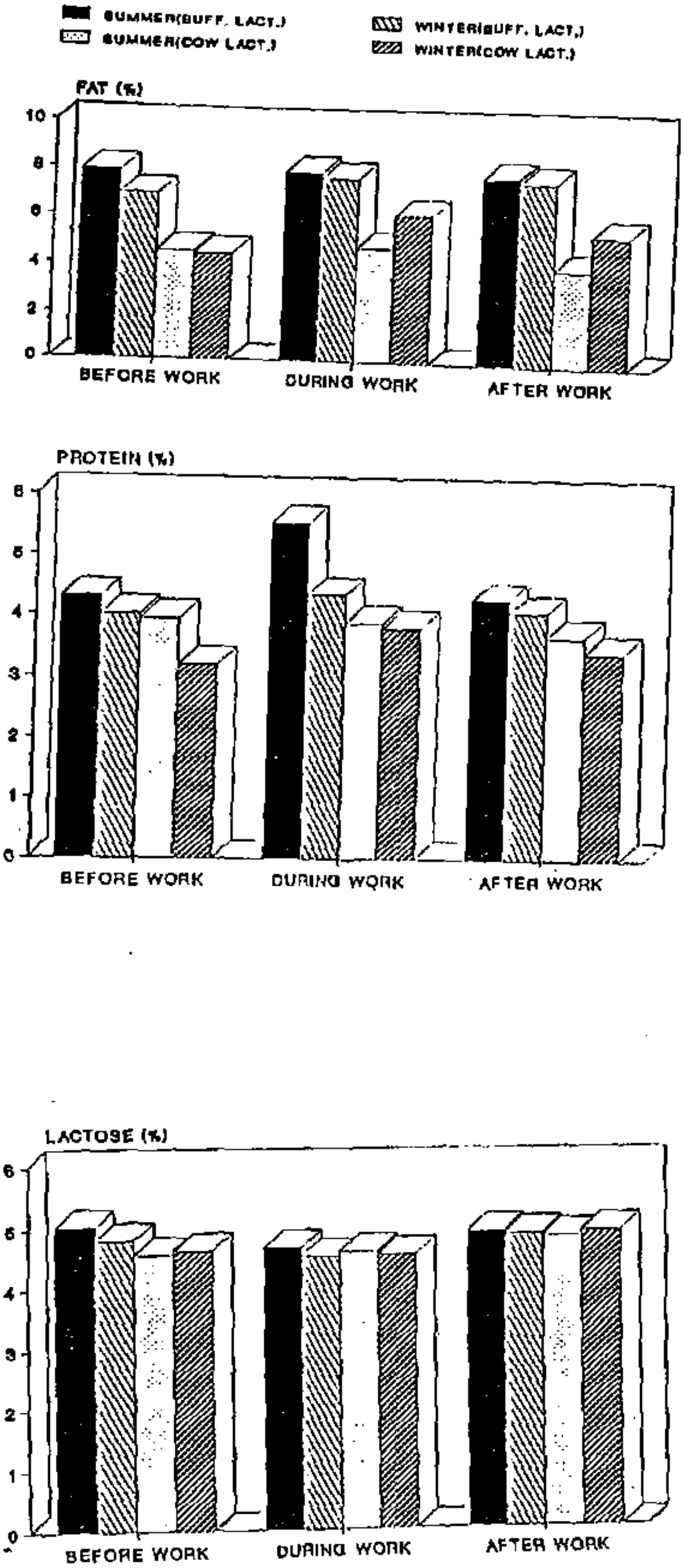


Table 4.1.9.1 Analysis of variance of fat, protein and lactose in working buffaloes and cows during summer and winter seasons

Source of variation	d.f.	M.S.S.		
		Fat	Protein	Lactose
Animals	4	2.74*	0.33	0.34*
Seasons	1	0.79	3.19**	0.01
Species	1	111.79**	8.93**	0.07
Periods	2	2.14	1.89**	0.24
Seasons x Species	1	6.93**	0.14	0.00
Seasons x Periods	2	2.17	0.21	0.15
Species x Periods	2	0.55	0.42	0.36
All effect interaction	2	0.23	0.83	0.08
Error	44	0.79	0.32	0.13

* $p < 0.05$; ** $P < 0.01$

4.63 ± 0.04 in LNP cows during work in summer season. Slight increase in fat and lactose was observed due to work effects (Table 4.1.1.9). Average milk yield during recovery period was found to be 4.86 ± 0.32, 4.34 ± 0.27, 4.59 ± 0.31 and 4.61 ± 0.32 l respectively after 1, 2, 3 and 4 weeks. The values of fat, protein and lactose were 4.06, 3.69 and 4.86 per cent at the start of work. A decrease in milk fat and protein and a slight increase in milk lactose was observed due to work (Table 4.1.9.1).

The weekly milk yield of LNP buffaloes during winter and their composition in terms of fat, protein and lactose have been presented in Table 4.1.9.1. The pre-work mean milk yield was 4.28 ± 0.31 litres. Corresponding fat, protein and lactose were 6.95 ± 0.47, 4.01 ± 0.21 and 4.89 ± 0.26 per cent, respectively. Ploughing decreased milk yield to 3.75 ± 0.25 and 3.53 ± 0.30 litres after 1 and 2 weeks of work. The corresponding average fat, protein and lactose levels in milk were 7.71 ± 0.39, 4.36 ± 0.25 and 4.55 ± 0.22 per cent, respectively.

After completion of ploughing animals were maintained for about 3 weeks for measurement of work effects and recovery. Post-work milk yields were lower than pre-work milk yield values (Table 4.1.9).

The milk yield and composition of milk during winter have been presented in Table 4.1.9. The pre-work mean values of milk yield after 1st and 2nd weeks, respectively were 4.24 ± 0.50 and 4.08 ± 0.56 l and their respective mean figures of fat, protein and lactose were 4.49 ± 0.51, 3.20 ± 0.11 and 4.65 ± 0.08 per cent.

Work decreased milk yield during first week to an average value of 3.66 ± 0.75 and 4.16 ± 0.79 l/day after 1st and 2nd week of work. Average milk fat was 6.16 ± 0.69 per cent, protein 3.81 ± 0.14 per cent and lactose was 4.57 per cent. After ploughing experiment, animals were maintained for recovery in milk yield and composition. The average milk yield was 3.85 ± 0.79 and 3.48 ± 0.81 l/day during winter season, a slight decrease in fat during rest period was observed to a level of 5.47 ± 0.17 per cent and the average protein and lactose were 3.43 ± 0.14 and 4.94 ± 0.14 per cent, respectively. Analysis of variance of fat, protein and lactose showed significant ($P < 0.01$) difference between animals, species and interaction of seasons x species in fat, protein differs between seasons, species and periods, and lactose showed a significant difference ($P < 0.05$) between animals.

4.2 CIRCADIAN RHYTHM VARIATIONS

In order to observe circadian rhythm in physiological, haematological, biochemical and circulating hormones, animals were kept under natural environmental conditions and were monitored at two hourly intervals for 24 h.

4.2.1 PHYSIOLOGICAL REACTIONS

The results for changes in RR, PR and RT in buffaloes and cows at 2 h intervals have been presented in Table 4.2.1.1.

Respiration rate, pulse rate and rectal temperature during 24 h did not show any marked variation. Respective means for RR, PR and RT for buffaloes at 8 A.M. were 19.25 ± 1.70, 74.00 ± 2.58/min and 38.46 ± 0.10°C, respectively, whereas the respective values for crossbred cows were 19.00 ± 3.70, 69.50 ± 5.12/min and 38.31 ± 0.06°C. Initial values in both of the species were

Table 4.2.1.1 Circadian variations in physiological reactions in buffaloes and cows

Species	Buffaloes			Cows		
Time interval (2h)	Respiration rate/min	Pulse rate/ min	Rectal temp (°C)	Respiration rate/min	Pulse rate/ min	Rectal temp (°C)
I	19.25 ± 1.70	74.00 ± 2.58	38.46 ± 0.10	19.00 ± 3.70	69.50 ± 5.12	38.31 ± 0.06
II	22.50 ± 2.22	73.00 ± 3.79	38.56 ± 0.13	24.50 ± 3.10	73.00 ± 4.93	38.66 ± 0.08
III	26.50 ± 3.95	80.50 ± 1.71	38.69 ± 0.08	34.75 ± 5.96	77.75 ± 5.36	38.86 ± 0.06
IV	23.00 ± 2.89	74.75 ± 1.89	38.99 ± 0.11	33.00 ± 1.73	83.50 ± 1.71	39.08 ± 0.10
V	21.25 ± 2.29	73.00 ± 1.73	39.17 ± 0.13	27.75 ± 1.44	78.75 ± 0.48	39.25 ± 0.08
VI	19.50 ± 0.96	74.50 ± 2.25	39.25 ± 0.03	26.00 ± 1.41	76.50 ± 0.96	39.25 ± 0.04
VII	16.25 ± 1.93	67.50 ± 2.06	39.28 ± 0.03	25.25 ± 2.43	72.00 ± 1.41	39.06 ± 0.03
VIII	14.00 ± 1.15	63.00 ± 2.48	39.33 ± 0.04	29.00 ± 3.87	72.00 ± 1.25	39.06 ± 0.03
IX	12.50 ± 1.19	60.75 ± 2.29	39.06 ± 0.03	24.00 ± 2.94	70.00 ± 0.82	38.81 ± 0.06
X	13.00 ± 0.41	60.25 ± 1.65	38.94 ± 0.06	22.50 ± 3.30	69.50 ± 1.71	38.74 ± 0.04
XI	13.75 ± 0.25	60.50 ± 1.71	38.78 ± 0.04	23.25 ± 2.50	73.25 ± 2.98	38.47 ± 0.03
XII	13.50 ± 0.96	63.50 ± 2.87	38.74 ± 0.06	23.75 ± 1.65	74.75 ± 3.45	38.66 ± 0.08

The values are mean ± SEM based on two replications on 5 animals almost similar. RR, PR and RT increased with the increase in environmental temperature. At 12.00 noon, RR, PR and RT of buffaloes increased to 26.50 ± 3.95, 80.50 ± 1.71/min and 38.69 ± 0.08°C, the increase was 7 breaths in RR, 7 beats in PR and 0.23°C in RT. The corresponding increase in cows was 15, 8 and 0.55°C. The changes in crossbred cows were more pronounced as the temperature increased. RR, PR and RT in buffaloes and cows remains at about these levels upto 6 P.M. but the values decrease to 16.25 ± 1.93, 67.50 ± 2.06/min and 39.28 ± 0.03°C at 8 P.M. in buffaloes and in cows the RR, PR and RT were 25.25 ± 2.43, 72.00 ± 1.41 and 39.06 ± 0.03°C respectively during summer season. These physiological parameters decreased to 12.50 ± 1.19/min,60.75 ± 2.29 bpm and 39.06 ± 0.03°C in buffaloes and 24.00 ± 2.94, 70.00 ± 0.82/min and 38.81 ± 0.06°C in crossbreds. Because last observations were taken from these animals in the morning at 6 A.M., the values remained near starting mean values (Table 4.2.1.1).

4.2.2 HAEMATOLOGICAL CHANGES

The results for Hb and Hct for rhythmic changes have been presented in Table 4.2.1.2.

The Hb and Hct values of buffaloes and crossbred cows remained almost at the basal levels throughout 24 h. The Hb and Hct in buffaloes and cows at the start of sampling were 11.45 ± 0.37 g per cent, 35.00 ± 0.70 per cent and 11.85 ± 0.17 g per cent and 33.00 ± 1.08 per cent, respectively. As the time progressed and environmental temperature rose up and radiant heat load increased, a slight variation in Hb and Hct was observed (Table 4.2.1.2). The values of Hb and Hct recorded at 4 P.M. were 10.78 ± 0.38 g per cent and 32.50 ± 1.04 per cent in buffaloes

Table 4.2.1.2 Circadian variations in Hb and Hct in cows and buffaloes

Periods	BUFFALOES		COWS	
	Hb (g %)	PCV (%)	Hb (g %)	PCV (%)
I	11.45 ± 0.37	35.00 ± 0.70	11.85 ± 0.17	33.00 ± 1.08
II	11.13 ± 0.28	33.75 ± 0.63	11.35 ± 0.36	33.75 ± 2.10
III	10.80 ± 0.28	33.50 ± 0.29	11.35 ± 0.26	34.50 ± 1.26
IV	10.85 ± 0.42	34.00 ± 0.91	11.25 ± 0.15	33.75 ± 1.44
V	10.78 ± 0.38	32.50 ± 1.04	11.00 ± 0.23	34.00 ± 1.35
VI	10.80 ± 0.41	34.00 ± 0.71	10.93 ± 0.39	33.50 ± 1.35
VII	11.05 ± 0.39	34.00 ± 0.00	11.10 ± 0.26	33.75 ± 0.85
VIII	11.03 ± 0.31	34.25 ± 0.75	11.23 ± 0.20	33.00 ± 1.00
IX	11.10 ± 0.34	34.00 ± 0.41	11.45 ± 0.26	33.75 ± 0.63
X	10.95 ± 0.21	33.00 ± 0.00	11.60 ± 0.32	33.75 ± 1.11
XI	10.85 ± 0.33	33.00 ± 0.58	11.28 ± 0.15	34.75 ± 0.85
XII	10.50 ± 0.31	32.25 ± 0.85	11.20 ± 0.09	34.50 ± 1.00

The values are mean ± SEM based on two replicates on 5 animals

and respective values in cows were 11.00 ± 0.23 g per cent and Hct 34.00 ± 1.34 per cent, these values remain almost similar at the end of 24 h observation.

4.2.3 ENERGY SUBSTRATES

The blood glucose and lactic acid in buffaloes varied from 44.20 ± 1.10 to 48.52 ± 1.55 mg per cent and 10.37 ± 0.49 to 11.99 mg per cent respectively. In cows, the blood glucose ranges from 42.71 ± 0.91 to 44.91 ± 0.62 mg per cent and lactic acid 9.50 ± 0.33 to 11.94 ± 0.51 mg per cent. These values remained at almost similar levels at different hours. The values of Hb and Hct at mid night were 44.20 ± 1.10 and 43.67 ± 1.27 mg per cent glucose in buffaloes and cows, respectively, the corresponding lactic acid contents were 10.85 ± 0.46 and 11.33 ± 0.36 mg per cent. The values of blood glucose at mid night were slightly higher and lactic acid were lower as compared to values found at 8 PM and during further sampling the values remained at similar levels.

The FFA levels ranged from 271.12 ± 4.45 to 400.56 umol/l in buffaloes and 301.11 ± 1.11 to 474.45 ± 226.23 umol/l in cows. The FFA did not show any specific trend of changes but fluctuated during experimental period (Table 4.2.1.3). The values of FFA during night hours at 4 AM were almost similar at a mean level of 400.56 ± 150.95 and 325.56 ± 41.24 umol/l in buffaloes and cows respectively.

4.2.4 HORMONAL CHANGES

The results for hormonal changes during different hours of sampling have been presented in Table 4.2.1.3. Insulin level

Table 4.2.1.3 Circadian changes in glucose, lactic acid, FFA, T_3, T_4 and insulin levels in buffaloes and cows

Periods (hours)	BUFFALOES						COWS					
	Glucose (mg %)	LA (mg %)	FFA (umol/l)	T3 (ng/ml)	T4 (ng/ml)	Insulin (uU/ml)	Glucose (mg %)	LA (mg %)	FFA (umol/l)	T3 (ng/ml)	T4 (ng/ml)	Insulin (uU/ml)
I	48.52 ±1.55	10.37 ±0.49	379.17 ±20.89	0.38 ±0.00	27.65 ±6.45	17.80 ±0.40	44.91 ±0.62	9.50 ±0.33	438.34 ±118.69	0.24 ±0.10	27.30 ±11.31	18.70 ±0.50
III	45.54 ±1.79	11.18 ±0.42	298.28 ±49.54	0.65 ±0.45	11.25 ±1.06	18.90 ±0.50	44.26 ±0.96	10.60 ±0.69	474.45 ±226.23	0.36 ±0.08	20.82 ±16.95	18.60 ±0.20
IV	45.71 ±2.11	11.99 ±0.38	336.67 ±96.95	0.92 ±0.38	13.10 ±3.25	18.50 ±0.30	42.71 ±0.91	11.94 ±0.51	301.11 ±111.11	0.19 ±0.03	17.40 ± 8.34	17.60 ±0.20
VII	45.27 ±0.27	11.21 ±0.20	271.12 ± 4.45	0.57 ±0.27	25.80 ±11.17	16.70 ±0.50	42.73 ±0.83	11.59 ±1.00	361.67 ±122.03	0.33 ±0.05	12.50 ± 5.66	18.90 ±0.60
IX	44.20 ±1.10	10.85 ±0.46	400.56 ±50.95	0.60 ±0.20	34.15 ±17.18	17.10 ±0.70	43.67 ±1.27	11.33 ±0.36	325.56 ± 41.24	0.35 ±0.15	22.90 ±17.54	19.20 ±1.40
XII	45.26 ±2.02	11.54 ±0.42	366.11 ±117.57	0.50 ±0.18	27.90 ±6.79	18.80 ±0.40	43.75 ±0.52	11.34 ±0.72	467.27 ±183.33	0.31 ±0.00	25.00 ± 0.01	19.15 ±0.75

The values are mean ± SEM based on two replicates on 5 animals

during 24 h of sampling ranged from 16.70 ± 0.50 to 18.90 ± 0.50 uU/ml in buffaloes and 17.60 ± 0.20 to 19.20 ± 1.40 uU/ml in cows. The levels of T_3 and T_4 did exhibit some changes during experimental period (Table 4.2.1.3).

At the beginning, the T_3 and T_4 levels in buffaloes were 0.34± 0.00 and 27.65 ± 6.45 ng/ml respectively and corresponding levels in cows were 0.24 ± 0.10 and 27.30 ± 11.31 ng/ml. The first values of T_4 for both species were almost similar. During next sampling at 12 noon, the values of T_4 decreased to 11.25 ± 1.06 and 20.82 ± 16.95 ng/ml in buffaloes and cows, respectively but T_3 level increased to 0.65 ± 0.45 and 0.36 ± 0.08 ng/ml. These values remained near basal levels during different periods and the values at the end of sampling were almost similar to that observed at the beginning of sampling schedule (Table 4.2.1.3).

4.3 CARTING EXPERIMENTS

While pulling 5 qtls cart load, DNP buffaloes travelled at an average speed of 3.08 km/h for about 2 hours at 10 qtl load the speed of buffalo remained almost similar to that of 5 qtl load but work time was reduced to 1.4 h. The cows while pulling 5 qtl load travelled faster at a speed of 3.38 km/h but were able to work for about 1.3 h only. When cows were subjected to pull 10 qtl load, the speed slightly decreased (3.19 km/h) and were able to work for about 1-1/2 h only.

4.3.1 PHYSIOLOGICAL REACTION

Dry non-pregnant (DNP) buffaloes and cows were subjected to cart load of 5 quintals (5 q) and 10 quintals (10 q) in a cart weighing 340 kg and 60 kg driver during hot humid seasons. The results of physiological responses during different intervals while pulling loads have been presented in Tables 4.3.1.1 to 4.3.1.4, statistical analysis in Tables 4.3.1.2 and 4.3.1.5 and Figs. 4.3.1.1 to 4.3.1.4.

4.3.1.1 Respiration rate

The results for the changes in respiration rate of DNP buffaloes and cows at 5 and 10 qtls cart loads have been presented in Table 4.3.1.1 and Fig. 4.3.1.1. Resting RR in the DNP buffaloes and cows ranged respectively between 11 and 24 and 18 and 39/min with a mean of 16.75 ± 2.69 and 28.75 ± 4.46/min. Both work conditions and continued hours of work increased the rate of respiration but per cent change was characteristically different among buffaloes and cows (Table 4.3.1.1). Five quintal load (load I) increased RR by 392.54 per cent in DNP buffaloes as compared to 232.17 per cent increase among DNP cows (Fig. 4.3.1.1). After work animals were given a rest pause, to return back to 75 per cent of normal in their RR, thereafter animals were again subjected to another period of work. Further work after rest pause increased RR by 552.22 per cent in the DNP buffaloes and by 325.22 per cent in LNP cows. Though the magnitude of change was similar but the absolute mean values were higher during first round of work. The final mean values after second work were 109.75 ± 2.78 and 122.25 ± 3.92 in buffaloes and cows. After the end of work, RR decreased at faster rates during first 2 h but thereafter decrease was slow. After second pause of work, animals took about 18 h to come back to pre-work values of RR. The mean values observed after 12 h of rest were 18.25 ± 1.49 in buffaloes and 35.00 ± 9.37 in cows. All the animals were monitored for recovery for 24 h after second round of work (Table 4.3.1.3).

Table 4.3 Time and distance covered by working DNP buffaloes and cows at 5 and 10 qtl loads

Animal number	Replicates	5 quintals			10 quintals		
		Time (h)	Distance (km)	Average speed (km/h)	Time (h)	Distance (km)	Average speed (km/h)
				BUFFALOES			
2238	I	2.38	6.50	2.47	1.45	4.48	2.56
	II	2.13	5.75	2.59	1.25	4.00	2.82
2918	I	1.55	7.03	2.72	1.30	3.50	2.33
	II	1.27	5.75	3.97	2.00	6.50	3.25
E-12	I	2.45	8.25	3.00	1.25	4.63	3.27
	II	1.45	7.05	4.00	1.22	4.63	3.39
3136	I	1.48	4.75	2.64	2.05	7.00	3.31
	II	1.37	5.25	3.25	2.15	5.00	2.22
Average		2.01 $\pm$0.10	6.29 $\pm$0.40	3.08 $\pm$0.22	1.43 $\pm$0.74	4.97 $\pm$0.04	2.89 $\pm$0.17
				COWS			
4482	I	1.30	5.63	3.75	1.30	4.50	3.00
	II	1.37	5.25	3.25	1.27	4.50	3.10
4591	I	1.28	5.50	3.75	1.30	5.50	3.67
	II	1.45	6.25	3.57	1.48	6.00	3.33
4770	I	1.30	5.25	3.50	1.35	4.25	2.68
	II	1.35	5.00	3.16	1.23	4.75	3.43
4924	I	1.37	5.00	3.09	1.10	3.50	3.00
	II	1.45	5.15	2.94	1.30	5.00	3.33
Average		1.36 $\pm$0.02	5.38 $\pm$0.15	3.38 $\pm$0.11	1.29 $\pm$0.03	4.75 $\pm$0.27	3.19 +0.27

Table 4.3.1.1 Respiration rate/min changes in working buffaloes and cows during different cart loads

Periods	Dry non-pregnant buffaloes		Dry non-pregnant cows	
	5 qtls	10 qtls	5 qtls	10 qtls
BW	16.75 ± 2.69	14.75 ± 0.75	28.75 ± 4.46	25.00 ± 4.34
AW-I	82.50 ±13.88	81.25 ±13.90	95.50 ±17.25	108.50 ±10.50
Recovery (75%)	40.50 ± 4.35	45.00 ±15.43	58.00 ±12.30	46.25 ± 4.19
AW-II	109.75 ± 2.78	80.25 ±11.05	122.25 ± 3.92	110.75 ± 9.38
Rest after hours				
1	65.50 ±10.21	50.00 ±10.16	94.00 ±19.11	60.75 ±13.12
2	48.00 ±10.21	38.25 ± 8.11	79.25 ±15.92	40.25 ± 7.47
3	33.75 ± 7.08	30.75 ± 9.24	63.75 ±11.35	33.50 ± 6.24
6	23.75 ± 4.19	24.75 ± 6.22	42.00 ± 8.76	31.00 ± 5.43
9	20.75 ± 2.29	21.00 ± 4.92	40.50 ± 7.05	29.25 ± 4.99
12	18.50 ± 1.19	16.25 ± 2.93	38.00 ± 5.99	24.25 ± 3.38
18	18.25 ± 1.49	16.00 ± 0.91	35.00 ± 9.37	26.50 ± 2.22
24	27.50 ± 3.30	16.75 ± 1.65	58.00 ± 8.07	55.50 ± 5.19

The values are mean ± SEM based on two replicates on 4 animals

Fig. 4.11: RESPIRATION RATE IN WORKING BUFFALOES & COWS DURING DIFFERENT LOADS

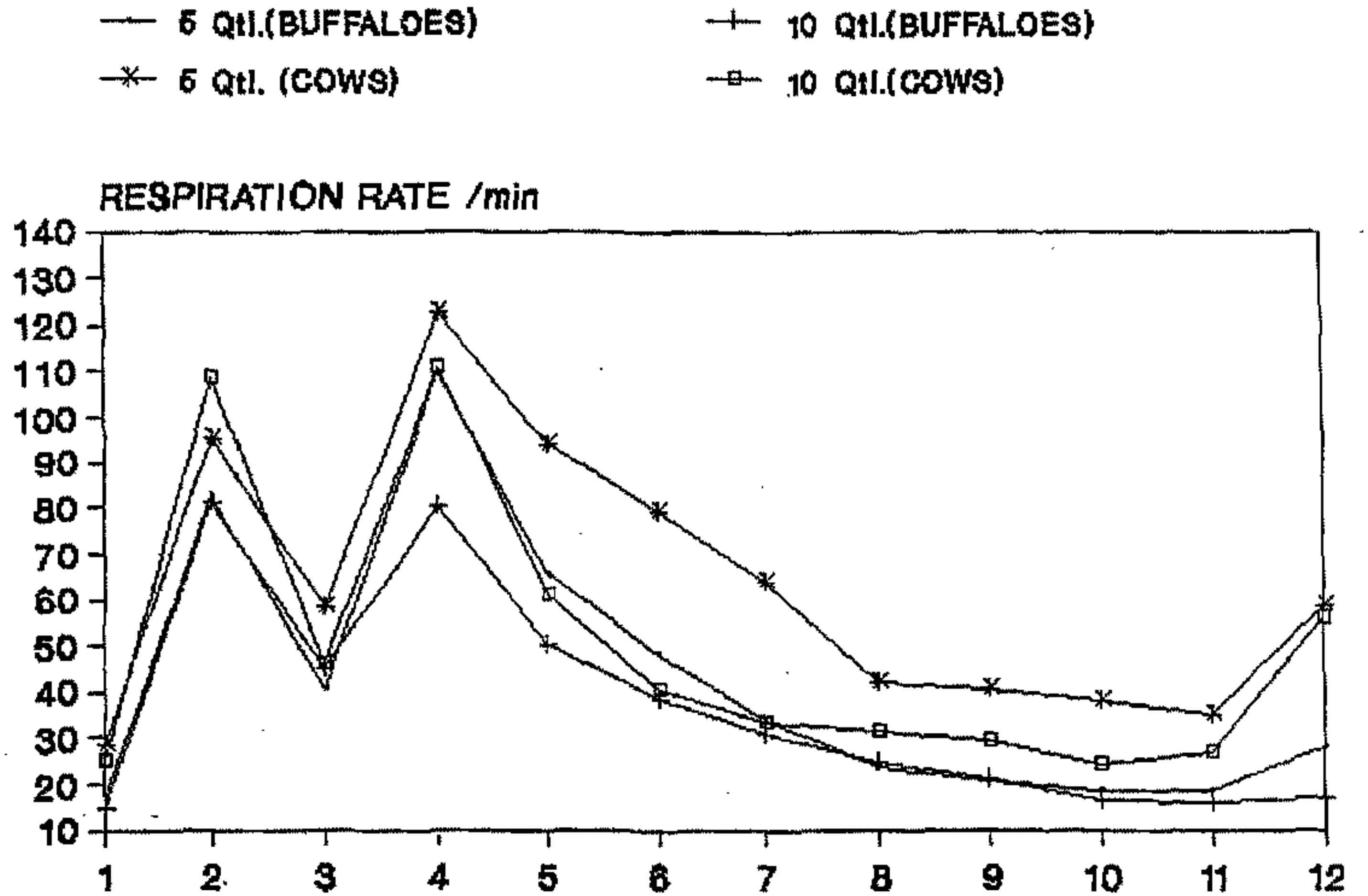


Table 4.3.1.2 Analysis of variance of physiological, haematological and biochemical parameters during carting experiment

Source of variation	d.f.	M.S.S.			M.S.S.		M.S.S.	
		RR	PR	RT	Hb	Hct	Glucose	Lactic acid
Animals	3	3074.51**	103.05*	5.17**	0.94*	27.69**	35.08**	0.28
Weights	1	4553.26**	634.38**	29.06**	9.68**	75.00**	56.41**	28.96**
Species	1	13753.26**	1819.17**	7.09**	10.41**	60.75**	14.11	48.63**
Periods	11	12161.99**	1212.47**	45.68**	2.44**	21.86**	16.89**	331.26**
Weight x Species	1	724.63**	51.05	0.41	3.55**	18.75**	209.40**	0.54
Weight x Periods	11	361.06**	21.68	1.16*	0.68**	1.23	3.44	5.12*
Species x Periods	11	181.31	44.72	0.95	0.75**	3.75*	7.34	2.85*
All effect interaction	11	226.75	18.55	0.18	0.72**	1.48	2.04	3.56
Error	141	236.73	19.30	0.52	0.26	1.76	4.08	2.29

** $p < 0.01$; * $p < 0.05$

Carting increased respiration of cows similar to buffaloes observed while pulling 5 qtl load. At the onset of 10 qtl work, pre-work mean values of RR for buffaloes and cows were 14.75 $\pm$ 0.75 and 25.00 $\pm$ 4.34/min, respectively. Subjecting of animals to 10 qtl load, increased RR to 81.25 $\pm$ 13.90/min in buffaloes and 108.50 $\pm$ 10.50/min in cows. Continued work of 2.18 h increased RR by 450.85 per cent in buffaloes and 334.00 per cent in cows. Rest of 1.25 and 1.24 h decreased the RR to about 75 per cent and values at the end of rest were 45.00 $\pm$ 15.43 and 46.25/min in buffaloes and cows, respectively. Work after rest increased RR to 80.25 $\pm$ 11.05 and 110.75 $\pm$ 9.38/min in buffaloes and cows. The respective per cent increases were 544.07 $\pm$ 343.00 per cent in DNP buffaloes and cows. After discontinuation of work, animals reached their normal values after about 12 h. The decrease in RR of the cows was quicker than the decrease in buffaloes. The mean values for the changes in RR during recovery have been presented in Table 4.3.1.1.

Statistical analysis in terms of analysis of variance and correlation with other parameters showed that RR was positively correlated ($P < 0.01$) with PR ($r = 0.81$), RT ($r = 0.84$) but negatively correlated ($P < 0.01$) with Hb ($r = -0.39$), Hct ($r = -0.29$) and glucose ($r = -0.36$). Analysis of variance indicated that RR differed significantly ($P < 0.01$) between animals, weights, species and sampling intervals.

4.3.1.2 Pulse rate

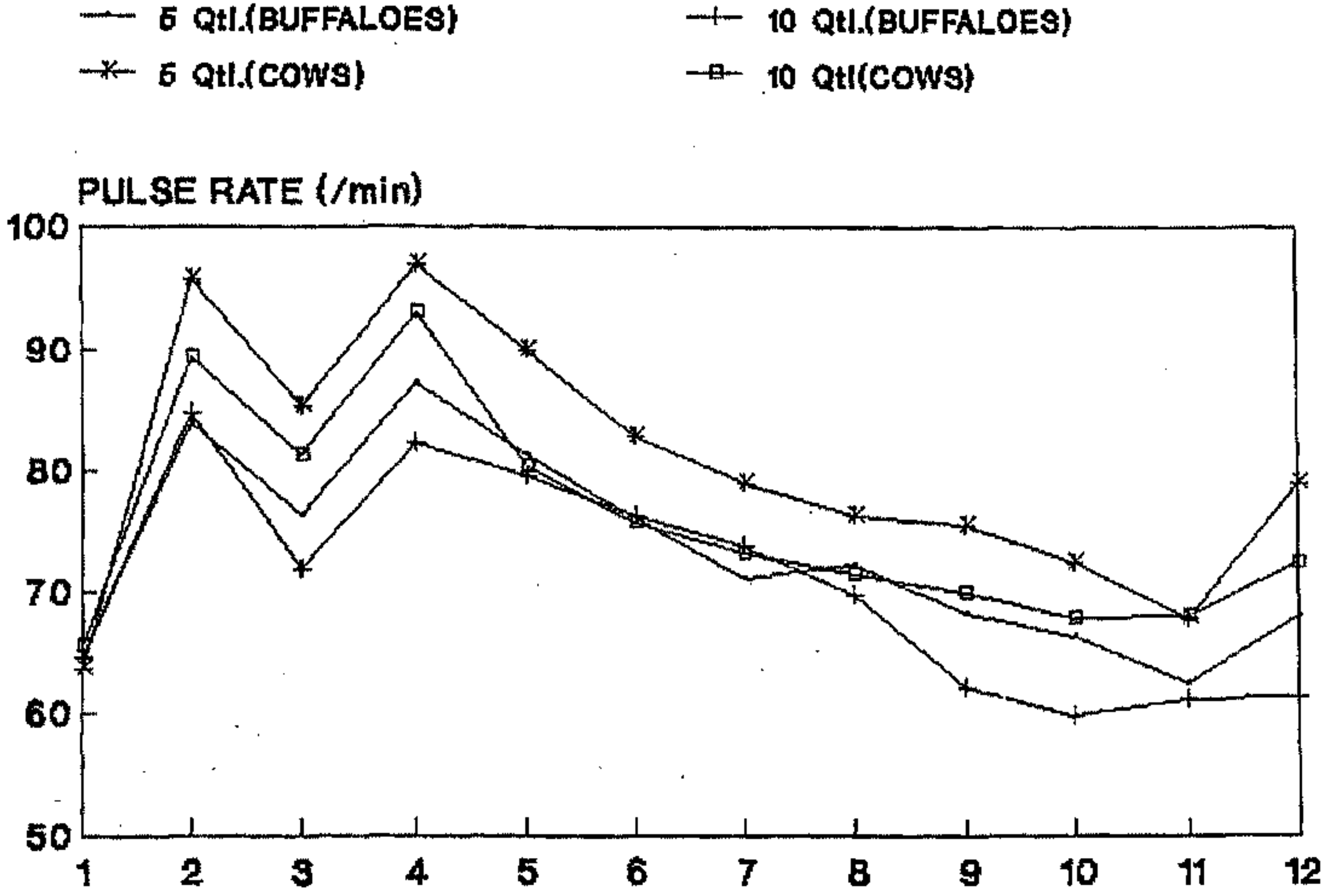
The results for the changes in pulse rate (PR) of buffaloes and cows at 5 and 10 qtl loads and subsequently during recovery have been presented in Table 4.3.1.3 and Fig. 4.3.1.2.

Table 4.3.1.3 Pulse rate/min changes in working buffaloes and cows during different cart loads

Periods	Dry non-pregnant buffaloes		Dry non-pregnant cows	
	5 qtls	10 qtls	5 qtls	10 qtls
BW	64.50 ± 6.14	64.50 ± 4.33	63.50 ± 3.12	65.50 ± 1.85
AW-I	84.00 ± 3.16	84.75 ± 1.84	95.75 ± 3.04	89.25 ± 1.89
Recovery (75%)	76.25 ± 1.65	71.75 ± 3.61	85.25 ± 0.85	81.25 ± 2.50
AW-II	87.25 ± 1.11	82.25 ± 0.48	96.75 ± 3.77	93.00 ± 1.22
Rest after hours				
1	81.50 ± 2.90	79.50 ± 1.50	90.00 ± 2.64	80.25 ± 2.46
2	76.00 ± 1.47	76.25 ± 0.75	82.75 ± 2.50	75.75 ± 1.60
3	71.00 ± 1.08	73.75 ± 1.80	79.00 ± 3.02	73.25 ± 1.11
6	72.25 ± 1.80	69.75 ± 2.09	76.25 ± 2.63	71.50 ± 0.87
9	68.25 ± 0.25	62.00 ± 1.08	75.50 ± 1.55	70.00 ± 0.41
12	66.25 ± 1.03	59.75 ± 1.55	72.50 ± 2.20	67.75 ± 0.63
18	62.50 ± 2.72	61.00 ± 0.71	67.75 ± 1.31	68.00 ± 1.47
24	68.00 ± 2.74	61.25 ± 1.55	79.00 ± 3.29	72.50 ± 1.71

The values are mean ± SEM based on two replicates on 4 animals

Fig.4.3.1.2: PULSE RATE IN WORKING BUFFALOES & COWS DURING DIFFERENT LOADS



In general, loading increased PR at different hours of work in cows and buffaloes but the increase was of higher magnitude in DNP cows than DNP buffaloes. The pre-work PR ranged from 50 to 80 in DNP buffaloes and 55 to 70/min in DNP cows, with a mean of 64.50 ± 6.14 and 63.50 ± 3.12/min. Pulse rate increased to 84.00 ±3.16 and 95.75±3.04/min in DNP buffaloes and cows, respectively indicating a greater change in PR of cows than buffaloes.

The rest pause was allowed to all the working animals for recovery to about 75 per cent in their physiological processes and the values of PR after 2.10 h and 2.13 were 76.25 ± 1.64 and 85.25 ± 0.85/min, respectively in buffaloes and cows. After a rest pause, animals again worked till fatigue onset and fatigue was observed after 1.26 h in DNP cows as compared to DNP buffaloes and they worked for 2.0 h before onset of fatigue. The average mean PR after second period of work was 87.25 ± 1.11 in DNP buffaloes and 96.75 ± 3.77/min in cows. The rise in PR in DNP cows due to second round of work was higher, about 1.5 times than in DNP buffaloes. Animals were assessed for recovery in PR for 24 h and pulse rate declined at slow rate during post-work period and normal resting values were reached after about 12 h in buffaloes but the crossbred cows took longer time to come back to pre-work normal values. Since the animals were monitored for the recovery upto next day, pulse rate exhibited an increase due to normal higher ambient temperatures at that time.

The mean pre-work values of pulse while pulling 10 qtl load were 64.50 ± 4.33 and 65.50 ± 1.85/min in DNP buffaloes and cows. Work of 10 qtl increased pulse in cattle and buffaloes (Table 4.3.1.3). Thereafter, animals were allowed to recover to about 75 per cent, and at the end of rest pause, the mean values were 71.75 ± 3.61 and 81.25 ± 2.50/min. Further work raised PR to

82.25 ± 0.48 and 93.00 ± 1.22/min in buffaloes and cows respectively. In these animals, PR took about 9 h to return to normal.

Statistical analysis indicated that PR significantly ($P < 0.01$) differed between weight, species and during intervals of sampling. PR also exhibited a positive correlation ($P < 0.01$) with RR ($r = 0.81$) and, RT ($r = 0.84$) but was negatively correlated ($P < 0.01$) with Hb, Hct and glucose (Table 4.3.1.3).

4.3.1.3 Rectal temperature

The results for the changes in rectal temperature (RT) of working buffaloes and cows at different cart loads have been presented in Table 4.3.1.4 and statistical analysis in Tables 4.3.1.2 and 4.3.1.5.

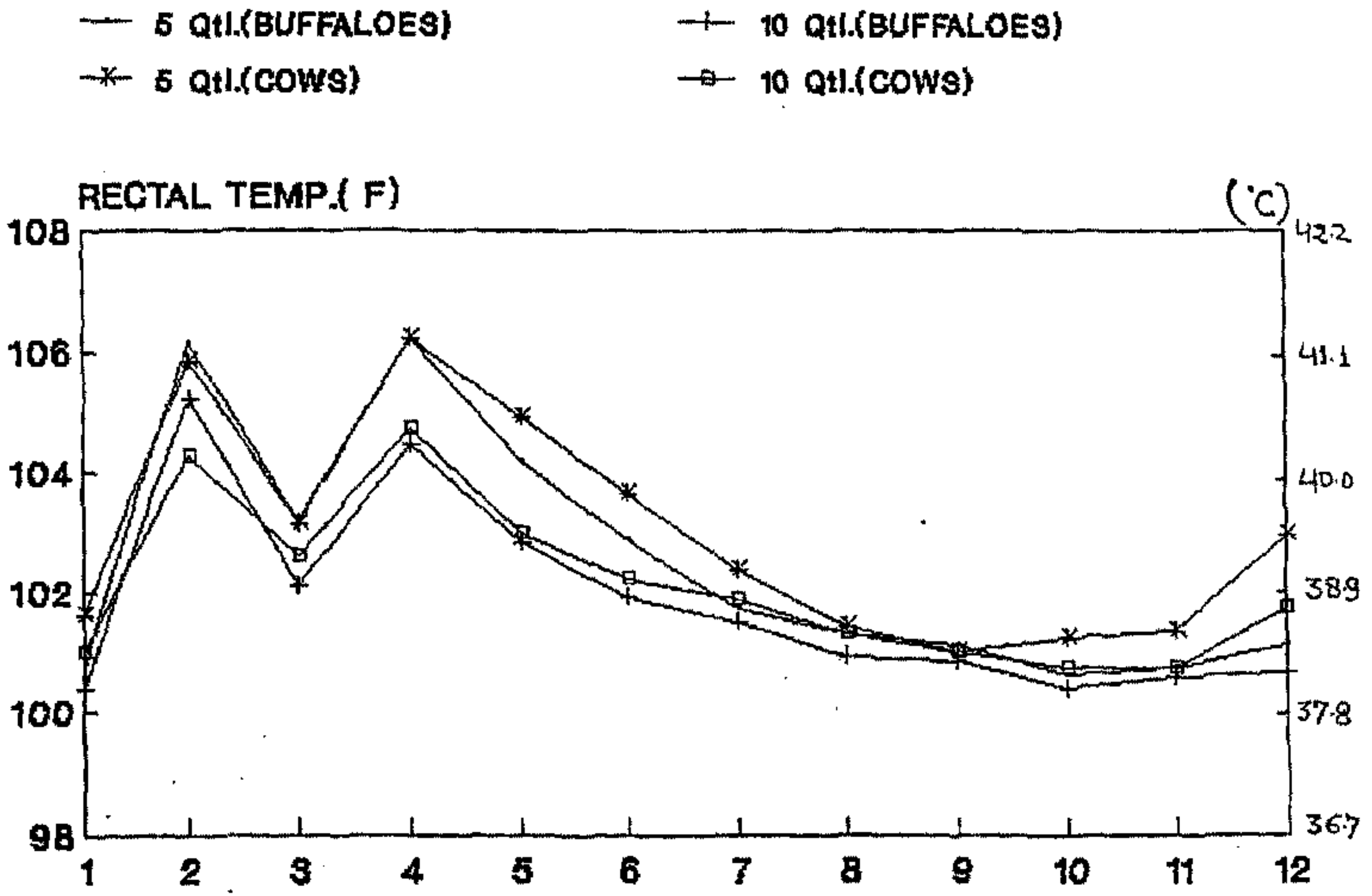
Pre-work RT ranged from 37.7 to 38.7°C in DNP buffaloes and 38.3 to 39.0°C in cows with a mean of 38.08 ± 0.31 and 38.65 ± 0.14°C respectively. When both buffaloes and cows were subjected to 5 qtl load (load I), their RT increased to 41.21 ± 0.44 and 41.02 ± 0.23°C, respectively. The increase in RT due to work over pre-work value was 3.13°C in buffaloes and 2.37°C in cows. The rest period decreased RT to 39.54 ± 0.13 in buffaloes, and to 39.53 ± 0.16°C in cows. The values of RT increased after second work to 41.22 ± 0.30°C in DNP buffaloes and 41.23 ± 0.19°C in DNP cows. After second round of carting, animals were assessed for recovery in rectal temperature (Fig. 4.3.1.3). DNP cows recovered earlier in their RT than buffaloes. DNP cows took about 6 h to return to pre-work RT (38.55 ± 0.14°C) but buffaloes took longer time of 9 h to return to 38.38 ± 0.10°C. The patterns of recovery for these animals have been presented in Fig. 4.3.1.3.

Table 4.3.1.4 Rectal temperature (^{o}C) changes in working buffaloes and cows during different cart loads

Periods	Dry non-pregnant buffaloes		Dry non-pregnant cows	
	5 qtls	10 qtls	5 qtls	10 qtls
BW	38.08 ± 0.31	37.99 ± 0.15	38.65 ± 0.11	38.32 ± 0.11
AW-I	41.21 ± 0.44	40.67 ± 0.53	41.02 ± 0.23	40.14 ± 0.37
Recovery (75%)	39.54 ± 0.13	38.95 ± 0.19	39.53 ± 0.16	39.21 ± 0.26
AW-II	41.22 ± 0.30	40.24 ± 0.59	41.23 ± 0.19	40.39 ± 0.17
Rest after hours				
1	40.10 ± 0.31	39.33 ± 0.22	40.50 ± 0.30	39.43 ± 0.10
2	39.37 ± 0.25	38.84 ± 0.19	39.79 ± 0.29	39.27 ± 0.20
3	38.72 ± 0.18	38.60 ± 0.14	39.09 ± 0.20	38.82 ± 0.08
6	38.50 ± 0.09	38.28 ± 0.09	38.55 ± 0.11	38.50 ± 0.13
9	38.38 ± 0.10	38.22 ± 0.09	38.32 ± 0.11	38.35 ± 0.15
12	38.09 ± 0.15	37.86 ± 0.24	38.44 ± 0.08	38.17 ± 0.11
18	38.18 ± 0.16	38.08 ± 0.15	38.53 ± 0.09	38.18 ± 0.01
24	38.61 ± 0.28	38.12 ± 0.20	39.42 ± 0.22	38.72 ± 0.15

The values are mean ± SEM based on two replicates on 4 animals

Fig 4.3.13: RECTAL TEMPERATURE IN WORKING BUFFALOES & COWS DURING DIFFERENT LOADS



The RT ranged from 37.6 to 38.2°C in DNP buffaloes and 38.1 to 38.6°C in DNP cows while pulling 10 qtl load with a mean of 37.99 ± 0.15 and 38.32 ± 0.14°C. The work of 2.18 h increased RT to 40.67 ± 0.53 in DNP buffaloes at load II, with an increase of 2.68°C over pre-work. When heat loads, both due to work and environment were partioned, cows stored heat of work at a rate 29.21 ± 0.70 kJ/min while pulling load I and at a rate of 25.10 ± 2.70 kJ/min while pulling load II. The respective values in buffaloes were 47.92 ± 5.98 kJ/min and 41.77 ± 2.89 kJ/min for load I and load II. DNP cows fatigued after a work of 2 h were given a rest pause of about 2 h 30 min to return to 75 per cent of their normal values. The mean values of RT after rest were 38.95 ± 0.19°C in DNP buffaloes and 39.2 ± 0.26°C in DNP cows. The rest period of about 2 h 30 min was not enough to bring back the RT in both cows and buffaloes. Further increase in the RT was noted after another period of work, the mean values of RT being 40.24 ± 0.59°C in buffaloes and 40.39 ± 0.17 in DNP cows after work (Table 4.3.1.4). Animals took about 12 h to come back to normal (Fig. 4.3.1.3).

Statistical analysis revealed that RT is positively correlated ($P < 0.01$) to RR ($r = 0.84$), PR ($r = 0.81$) and negatively correlated to Hb ($r = -0.39$), Hct ($r = -0.29$) and glucose ($r = -0.36$). ANOVA indicated that RT differed significantly between animals, weights, species and intervals of sampling ($P < 0.01$).

4.3.2 HAEMATOLOGICAL CHANGES

4.3.2.1 Haemoglobin (Hb)

The haemoglobin (Hb) changes in the working DNP cows and buffaloes during load I and load II, and at different hours of work have been presented in Table 4.3.2.1 and statistical analysis in Tables 4.3.1.2 and 4.3.1.5.

Table 4.3.2.1 Haemoglobin (g %) changes in working buffaloes and cows during different cart loads

Periods	Dry non-pregnant buffaloes		Dry non-pregnant cows	
	5 qtls	10 qtls	5 qtls	10 qtls
BW	12.28 ± 0.15	12.30 ± 0.24	11.25 ± 0.13	11.83 ± 0.09
AW-I	11.68 ± 0.13	11.65 ± 0.26	10.50 ± 0.10	11.18 ± 0.31
Recovery (75%)	11.75 ± 0.17	11.50 ± 0.19	10.43 ± 0.15	10.98 ± 0.23
AW-II	10.88 ± 0.51	11.20 ± 0.25	10.03 ± 0.13	10.70 ± 0.30
Rest after hours				
1	10.88 ± 0.43	11.50 ± 0.26	10.23 ± 0.14	11.00 ± 0.36
2	10.80 ± 0.36	11.35 ± 0.22	10.85 ± 0.10	11.23 ± 0.35
3	11.00 ± 0.37	11.73 ± 0.14	10.75 ± 0.09	11.25 ± 0.36
6	11.63 ± 0.14	11.70 ± 0.18	10.93 ± 0.09	11.28 ± 0.37
9	11.75 ± 0.10	11.70 ± 0.20	11.03 ± 0.09	11.35 ± 0.46
12	11.75 ± 0.06	11.95 ± 0.10	10.98 ± 0.06	11.53 ± 0.38
18	12.15 ± 0.17	12.05 ± 0.10	11.03 ± 0.17	11.65 ± 0.29
24	11.68 ± 0.39	11.70 ± 0.17	10.53 ± 0.17	11.48 ± 0.13

The values are mean ± SEM based on two replicates on 4 animals

Table 4.3.1.5 Overall correlation coefficient between RR, PR, RT, Hb, HCt, glucose and lactic acid during ploughing experiment

Parameter	RR	PR	RT	Hb	Hct	Glucose	Lactic acid
Respiration rate/min	1.00						
Pulse/min	0.56**	1.00					
Rectal temp. (°C)	0.77**	0.61**	1.00				
Haemoglobin (%)	-0.49*	-0.40**	-0.49*	1.00			
Haematocrit (%)	-0.55**	-0.50**	-0.58**	0.83**	1.00		
Glucose (mg/ml)	-0.32**	-0.39**	-0.29**	0.22**	0.26**	1.00	
Lactic acid (mg/ml)	0.48**	0.57**	0.57**	-0.28**	-0.33**	-0.32**	1.00

** $p < 0.01$; * $p < 0.05$

The pre-work mean Hb respectively were 12.28 ± 0.15 and 11.25 ± 0.13 g per cent in DNP buffaloes and cows. Pre-work Hb was higher in buffaloes than cows. The Hb in DNP buffaloes ranged from 11.9 to 12.2 g per cent and in DNP cows from 11.0 to 11.6 g per cent. Hb levels decreased due to work effects to 11.68 ± 0.13 g per cent in DNP buffaloes and 10.50 ± 0.10 g per cent in DNP cows, respectively (Table 4.3.2.1).

About 100 per cent recovery in Hb concentration was observed after 18 h of rest, the mean values were 12.05 ± 0.10 g per cent in DNP buffaloes and 11.65 ± 0.29 g per cent in DNP cows. A rise in Hb concentration has also been reported after second period of work. Statistical analysis of Hb in terms of analysis of variance showed that Hb differs significantly ($P < 0.01$) between animals, weights, species and periods. The interaction of weights x species and species x periods also had significant ($P < 0.01$) effect on Hb and correlation coefficient of Hb with RR ($r = 0.42$), PR ($r = -0.53$) and RT ($r = -0.44$) showed significant positive ($P < 0.01$) correlation, and a positive correlation ($P < 0.01$) with Hct was found.

4.3.2.2 Haematocrit (Hct)

The changes in the haematocrit (Hct) in DNP buffaloes and cows at load I and load II at different periods have been presented in Table 4.3.2.2, Fig. 4.3.2.1 and statistical analysis in Tables 4.3.1.2 and 4.3.1.5.

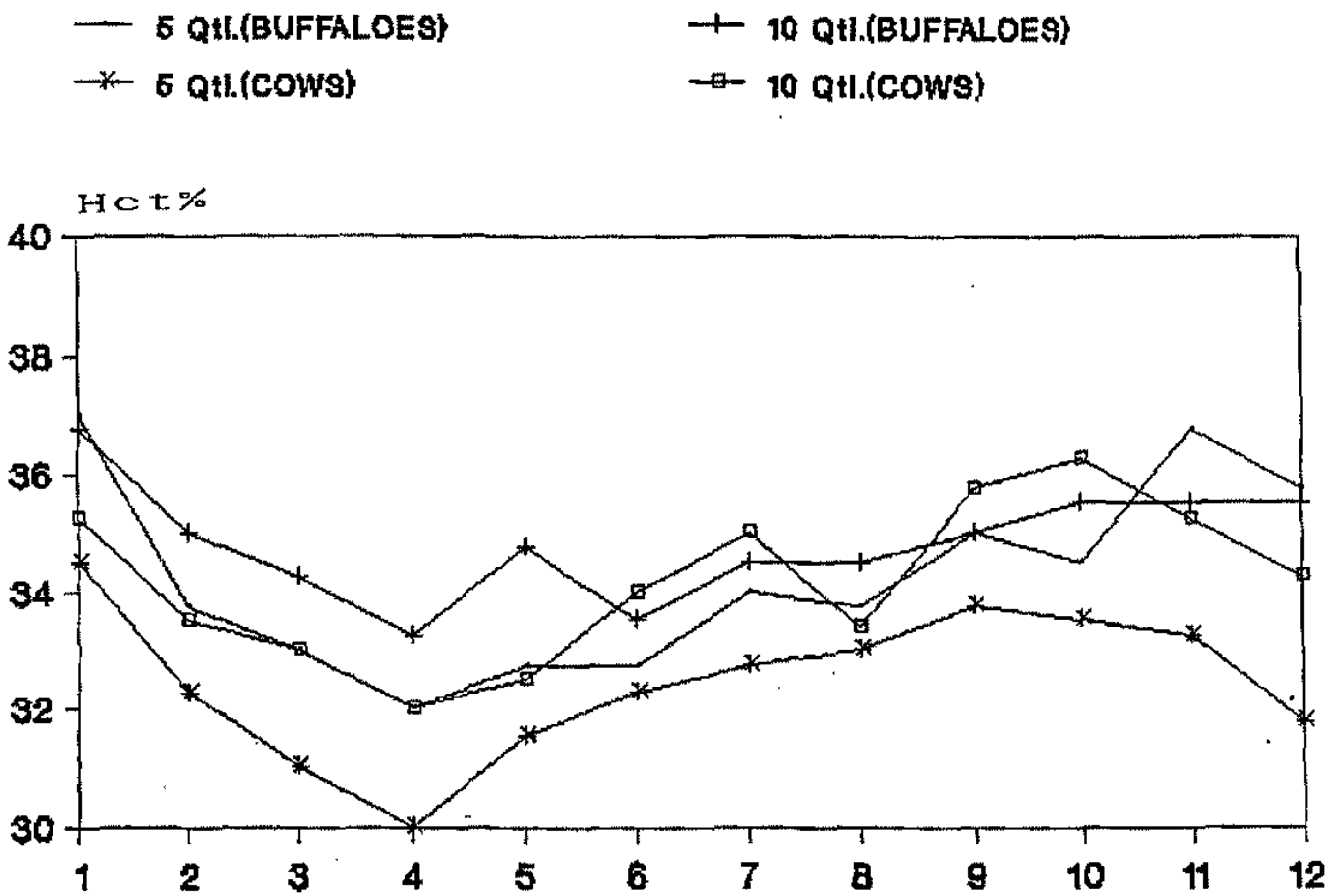
The pre-work mean value of Hct in cows was lower than buffaloes. The same trend was observed during different periods of intervals. The Hct ranged from 36 to 38 per cent in DNP

Table 4.3.2.2 Haematocrit (%) changes in working buffaloes and cows during different cart loads

Periods	Dry non-pregnant buffaloes		Dry non-pregnant cows	
	5 qtls	10 qtls	5 qtls	10 qtls
BW	37.00 ± 0.41	36.75 ± 1.11	34.50 ± 0.65	35.25 ± 0.48
AW-I	33.75 ± 0.63	35.00 ± 0.71	32.25 ± 0.85	33.50 ± 0.65
Recovery (75%)	33.00 ± 0.22	34.25 ± 0.95	31.00 ± 0.41	33.00 ± 0.41
AW-II	32.00 ± 0.91	33.25 ± 0.95	30.00 ± 0.41	32.00 ± 0.41
Rest after hours				
1	32.75 ± 0.75	34.75 ± 1.25	31.50 ± 0.96	32.50 ± 0.29
2	32.75 ± 0.75	33.50 ± 1.08	32.25 ± 0.83	34.00 ± 0.41
3	34.00 ± 1.35	34.50 ± 1.04	32.75 ± 0.63	35.00 ± 0.41
6	33.75 ± 1.03	34.50 ± 1.19	33.00 ± 0.41	33.38 ± 0.37
9	35.00 ± 0.71	35.00 ± 1.22	33.75 ± 0.63	35.75 ± 0.48
12	34.50 ± 0.50	35.50 ± 0.96	33.50 ± 0.50	36.25 ± 0.86
18	36.75 ± 0.25	35.50 ± 0.65	33.25 ± 1.26	35.25 ± 0.75
24	35.75 ± 0.48	35.50 ± 0.98	31.75 ± 0.48	34.25 ± 0.48

The values are mean ± SEM based on two replicates on 4 animals

Fig. 4.3.2.1: HAEMATOCRIT IN WORKING BUFFALOES & COWS DURING DIFFERENT LOADS



buffaloes with a mean value of 37.0 per cent and 34 to 36 per cent in DNP cows with the average values of 34.50 $\pm$ 0.65 per cent, respectively. During recovery, Hct did not reach to pre-work value, but values decreased further to 33.00 $\pm$ 0.22 per cent in DNP buffaloes and 31.00 $\pm$ 0.41 per cent in DNP cows with a range from 31 to 35 per cent and 30 to 32 per cent. Another work further decreased Hct; the difference between pre-work and after second work in Hct was 4 in DNP buffaloes but in DNP cows was 4.50.

The pre-work mean Hct during load II carting, respectively were 36.75 $\pm$ 1.11 per cent in DNP buffaloes and 35.25 $\pm$ 0.48 per cent in DNP cows which decreased to 35.00 $\pm$ 0.71 and 33.50 $\pm$ 0.65 after work. During rest, Hct further decreased to 33.25 $\pm$ 0.95 per cent in DNP buffaloes and 32.00 $\pm$ 0.41 per cent in DNP cows. DNP cows took about 9 h to recover fully in their Hct values but buffaloes took slightly longer period to return back to pre-work values. The values for recovery at different hours have been presented in Table 4.3.2.2 and Fig. 4.3.2.1.

Statistical analysis of Hct in terms of analysis of variance indicated that Hct differs significantly ($P < 0.01$) between animals, weights, species, periods and interaction of weights x species and species x periods. Correlation coefficient of Hct indicated that the Hct was negatively correlated ($P < 0.01$) with RR ($r = -0.40$), PR ($r = -0.54$), RT ($r = -0.47$) and lactic acid ($r = -0.34$) and positively correlated ($P < 0.01$) with the Hb ($r = +0.70$).

4.3.2.3 Plasma volume changes

The plasma volume changes in DNP cows were more than buffaloes (Table 4.1.6.3) during carting. After first phase of work, mean volume change in DNP buffaloes was 10.57 ± 1.34 per cent and in cows 10.58 ± 1.28 per cent.

The plasma volume changes were more during second round of carting than observed at first work. When animals were subjected to load II, the plasma volume changed by 8.57 ± 1.05 per cent and 8.9 ± 2.85 per cent in DNP buffaloes and cows after first phase of work. The change in plasma volume was higher in cows than buffaloes (Table 4.1.6.3).

4.3.3 ENERGY SUBSTRATES

The results for blood glucose and lactic acid in buffaloes and cows during different intervals of work and at different cart loads have been presented in Tables 4.3.3.1 and 4.3.3.2, Figs. 4.3.3.1 and 4.3.3.2 and statistical analysis in Tables 4.3.1.2 and 4.3.1.5.

4.3.3.1 Blood glucose

Blood glucose concentrations before onset of work showed variations in both buffaloes and cows. The pre-work levels of blood glucose in DNP buffaloes ranged between 44.30 to 51.27 mg per cent and ranged between 38.75 to 47.77 mg per cent in DNP cows. The glucose levels showed a variable trend and no characteristic or uniform change was observed during work in cows and buffaloes. Imposition of 5 qtl load (load I) during hot-humid season in DNP buffaloes and cows reduced glucose concentrations to 45.98 ± 0.77 and 42.98 ± 0.37 mg per cent from their respective pre-work values of 47.95 ± 0.69 and 45.06 ± 0.35 mg per cent. Slight increase in the mean sugar level was observed during rest pause in buffaloes and cows. Another work period further reduced the glucose concentrations to mean values of 44.30 ± 0.81 and 41.91 ± 0.18 mg per cent in DNP buffaloes and cows. Decline in the glucose concentration in buffaloes was much faster than cows. During the long rest pause, after end of work, glucose concentration increased and animals recovered their blood sugar levels after about 2-3 h of rest (Table 4.3.3.1).

The pre-work glucose concentrations in DNP buffaloes and cows were about similar, the mean values being 48.90 ± 1.08 and 48.84 ± 0.87 mg per cent in DNP buffaloes and cows. Imposition of heavy load dropped blood sugar levels by 6.20 per cent in DNP buffaloes and 5.76 per cent in DNP cows. Rest period after work slightly recovered glucose concentration (Table 4.3.3.1). After second work, animals were assessed for recovery and it was found that pre-work levels were attained in 3 to 4 h in cows but buffaloes took long time to come back to pre-exercise values (Table 4.3.3.1).

Analysis of variance of data indicated that differences in glucose were significant between animals ($P < 0.01$), loads ($P < 0.01$), periods ($P < 0.01$) and values were significantly affected by interaction of weight x species.

4.3.3.2 Blood lactic acid

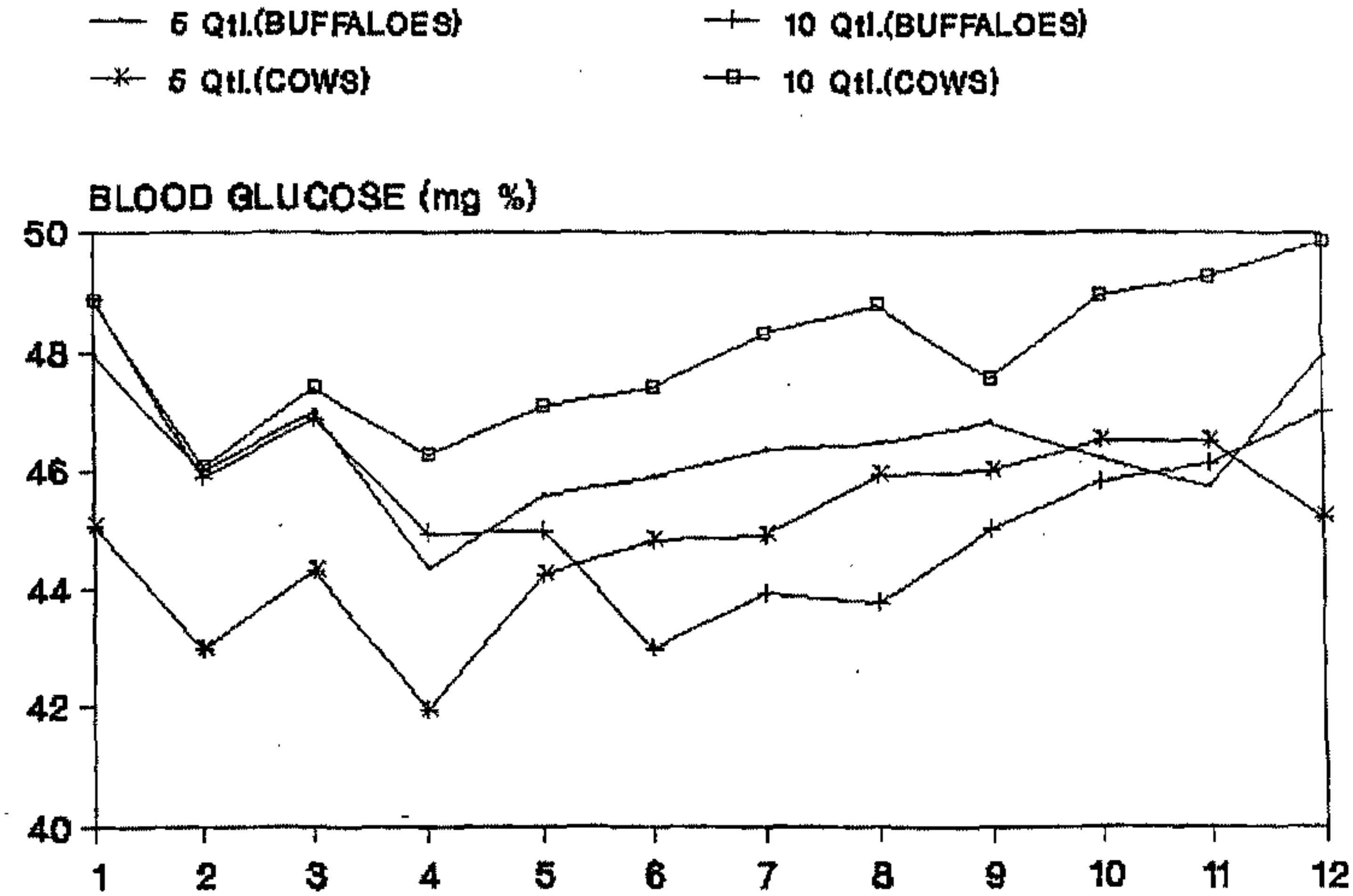
The lactic acid content of blood during rest varied from 10.77 to 15.44 mg per cent in DNP buffaloes and from 10.77 to 16.43 mg per cent in DNP cows. Lactic acid concentration increased due to load I in both buffaloes and cows. However, the changes were not uniform at different hours of work (Table 4.3.3.2). The overall pre-work mean lactic acid content was

Table 4.3.3.1 Blood glucose (mg %) changes in working buffaloes and cows during different cart loads

Periods	Dry non-pregnant buffaloes		Dry non-pregnant cows	
	5 qtls	10 qtls	5 qtls	10 qtls
BW	47.95 ± 0.69	48.90 ± 1.08	45.06 ± 0.35	48.83 ± 0.87
AW-I	45.98 ± 0.77	45.87 ± 0.63	42.98 ± 0.37	46.06 ± 0.84
Recovery (75%)	47.00 ± 0.54	46.90 ± 0.68	44.29 ± 0.48	47.38 ± 0.95
AW-II	44.33 ± 0.81	44.92 ± 0.57	41.91 ± 0.18	46.25 ± 2.32
Rest after hours				
1	45.54 ± 0.94	44.97 ± 1.40	44.24 ± 0.74	47.08 ± 1.12
2	45.86 ± 0.76	42.97 ± 1.77	44.82 ± 0.60	47.39 ± 1.47
3	46.34 ± 0.65	43.90 ± 1.50	44.88 ± 0.41	48.31 ± 1.37
6	46.45 ± 0.61	43.74 ± 1.60	45.91 ± 0.29	48.70 ± 1.30
9	46.82 ± 0.51	44.99 ± 1.51	46.00 ± 0.53	47.54 ± 2.10
12	46.18 ± 0.68	45.78 ± 1.26	46.48 ± 0.37	48.91 ± 1.62
18	45.70 ± 0.84	46.09 ± 1.52	46.48 ± 0.25	49.22 ± 1.41
24	47.93 ± 0.54	47.02 ± 1.41	45.21 ± 1.62	49.83 ± 1.42

The values are mean ± SEM based on two replicates on 4 animals

Fig. 4.33.1: BLOOD GLUCOSE IN WORKING BUFFALOES & COWS DURING DIFFERENT LOADS



12.99 ± 0.63 mg per cent in DNP buffaloes and 14.08 ± 0.60 mg per cent in DNP cows. Load I increased lactic acid content to 25.72± 0.96 mg per cent and 25.57 ± 0.74 mg per cent after first phase of work. A rest period in between decreased lactic acid to 23.88± 0.98 mg in buffaloes and 23.44 ± 0.79 mg per cent in cows and recovery in LA was incomplete.

Lactic acid in DNP buffaloes and cows increased to 27.18 ± 0.59 mg per cent and 25.57 ± 0.80 mg per cent, respectively. Due to second round of work, the increase in the lactic acid occurred by 109.24 per cent in DNP buffaloes and 81.61 per cent in DNP cows. This increase over pre-work was of higher magnitude than after first round of work. Longer rest was required to come back to normal level in lactic acid and complete recovery took about 18 h (Table 4.3.3.2).

The rise in the lactic acid content over pre-work was much more during load II as compared to load I. The pre-work average LA values of 12.88 ± 0.43 and 12.84 ± 0.53 increased to 25.54 ± 0.64 and 25.19 ± 0.71 mg per cent after work in DNP buffaloes and cows, respectively. During rest, LA decreased by 82.01 per cent in DNP cows. The lactic acid during rest period decreased to 23.07 ± 0.66 mg in DNP buffaloes and 23.37 ± 0.89 mg in DNP cows. The increase in the blood lactic acid due to second phase of work was to 25.83 ± 0.67 mg in DNP buffaloes and 25.47 ± 0.86 mg in DNP cows.

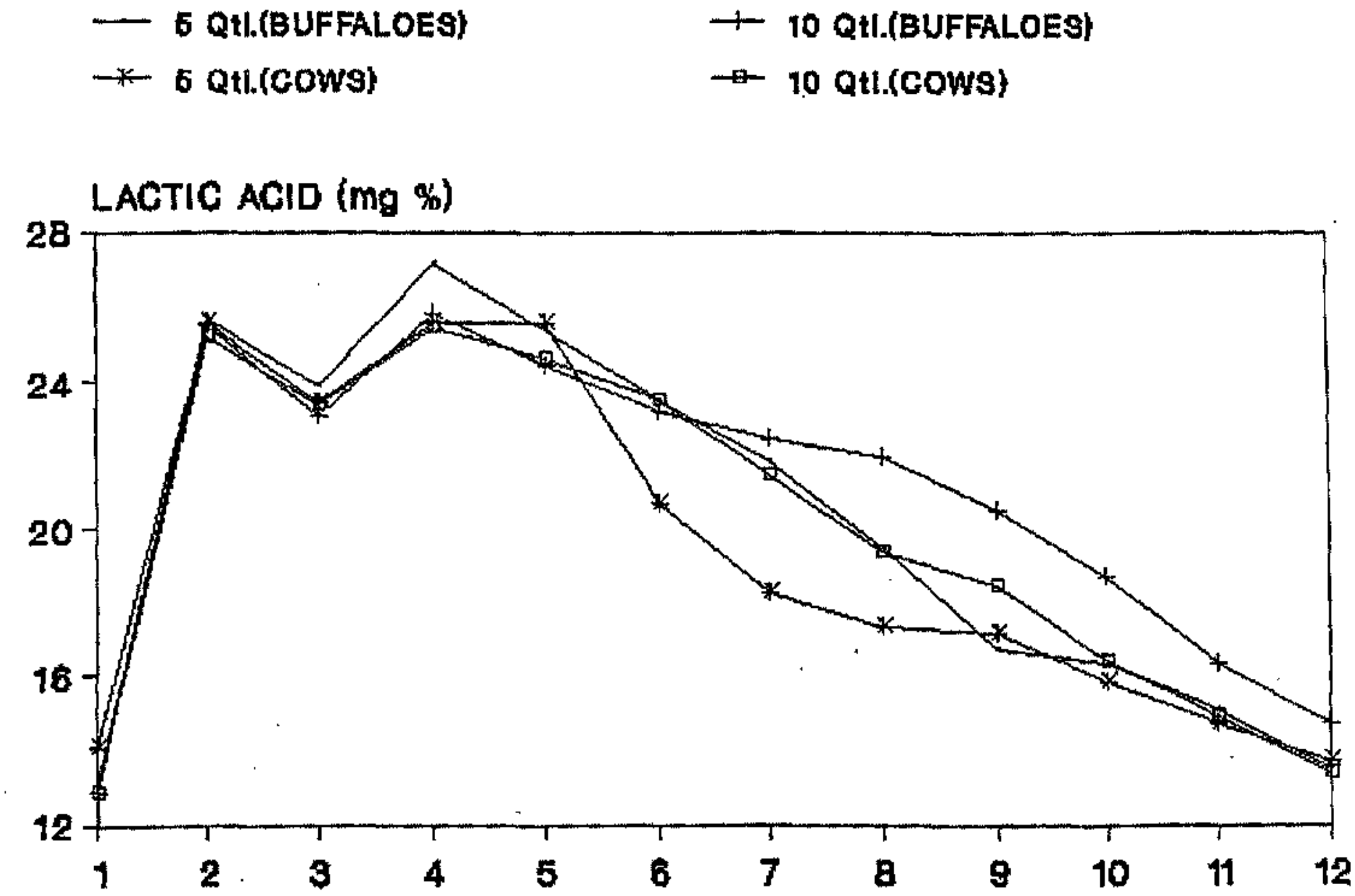
Statistical analysis of results revealed a significant variation ($P < 0.01$) between loads, species and intervals (Table 4.3.1.2).

Table 4.3.3.2 Lactic acid (mg %) changes in working buffaloes and cows during different cart loads

Periods	Dry non-pregnant buffaloes		Dry non-pregnant cows	
	5 qtls	10 qtls	5 qtls	10 qtls
BW	12.99 ± 0.63	12.88 ± 0.43	14.08 ± 0.60	12.84 ± 0.53
AW-I	25.72 ± 0.96	25.54 ± 0.64	25.57 ± 0.74	25.19 ± 0.71
Recovery (75%)	23.88 ± 0.98	23.07 ± 0.66	23.44 ± 0.79	23.37 ± 0.89
AW-II	27.18 ± 0.59	25.83 ± 0.67	25.57 ± 0.80	25.47 ± 0.86
Rest after hours				
1	25.38 ± 0.60	24.47 ± 0.54	25.56 ± 1.10	24.63 ± 1.10
2	23.51 ± 0.58	23.20 ± 0.62	20.69 ± 1.14	23.51 ± 0.58
3	21.82 ± 0.52	22.47 ± 0.62	18.25 ± 1.30	21.43 ± 0.87
6	19.53 ± 0.89	21.93 ± 0.80	17.30 ± 1.30	19.37 ± 0.78
9	16.71 ± 0.72	20.49 ± 0.59	17.11 ± 1.10	18.41 ± 0.79
12	16.33 ± 0.65	18.67 ± 0.67	15.79 ± 0.26	16.35 ± 0.56
18	15.03 ± 0.49	16.31 ± 0.84	14.66 ± 0.70	14.85 ± 0.56
24	13.51 ± 0.82	14.68 ± 0.27	13.66 ± 0.46	13.35 ± 0.17

The values are mean ± SEM based on two replicates on 4 animals

Fig. 4.3.3.2: LACTIC ACID IN WORKING BUFFALOES & COWS DURING DIFFERENT LOADS



The correlation coefficient of lactic acid with other parameters showed a significant positive correlation ($P < 0.01$) with RR ($r = 0.56$), PR ($r = 0.63$), RT ($r = 0.66$); RR was negatively correlated ($P < 0.01$) to Hb ($r = 0.23$) and Hct ($r = 0.34$). Lactic acid differed significantly ($P < 0.01$) between work loads, species and periods.

4.3.3.3 Free fatty acids

The results for plasma free fatty acids (FFA) in dry non-pregnant (DNP) buffaloes and cows at different cart loads have been presented in Table 4.3.3.3 and Fig. 4.3.3.3.

The pre-work average values of FFA were 331.33 ± 113.88 and 296.93 ± 41.81 umol/l in DNP buffaloes and cows, respectively. The FFA increased to 351.17 ± 88.44 umol/l in DNP buffaloes and 342.40 ± 78.92 umol/l, while pulling 5 qtl (load I) cart load. The increase in the FFA was more pronounced in DNP cows than buffaloes, rise in FFA over pre-work in absolute terms was 19.84 in DNP buffaloes whereas in cows was 45.47 umol/l. During rest period, FFA further increased to 419.66 ± 135.09 umol/l in buffaloes and 480.96 ± 123.30 umol/l in cows. Second period of work reduced level of FFA in blood (Table 4.3.3.3). FFA levels fluctuated during recovery period and no uniform pattern was observed. The mean values after 24 h of rest were 255.50 ± 1.98 in DNP buffaloes, but higher values were observed in DNP cows (Table 4.3.3.3).

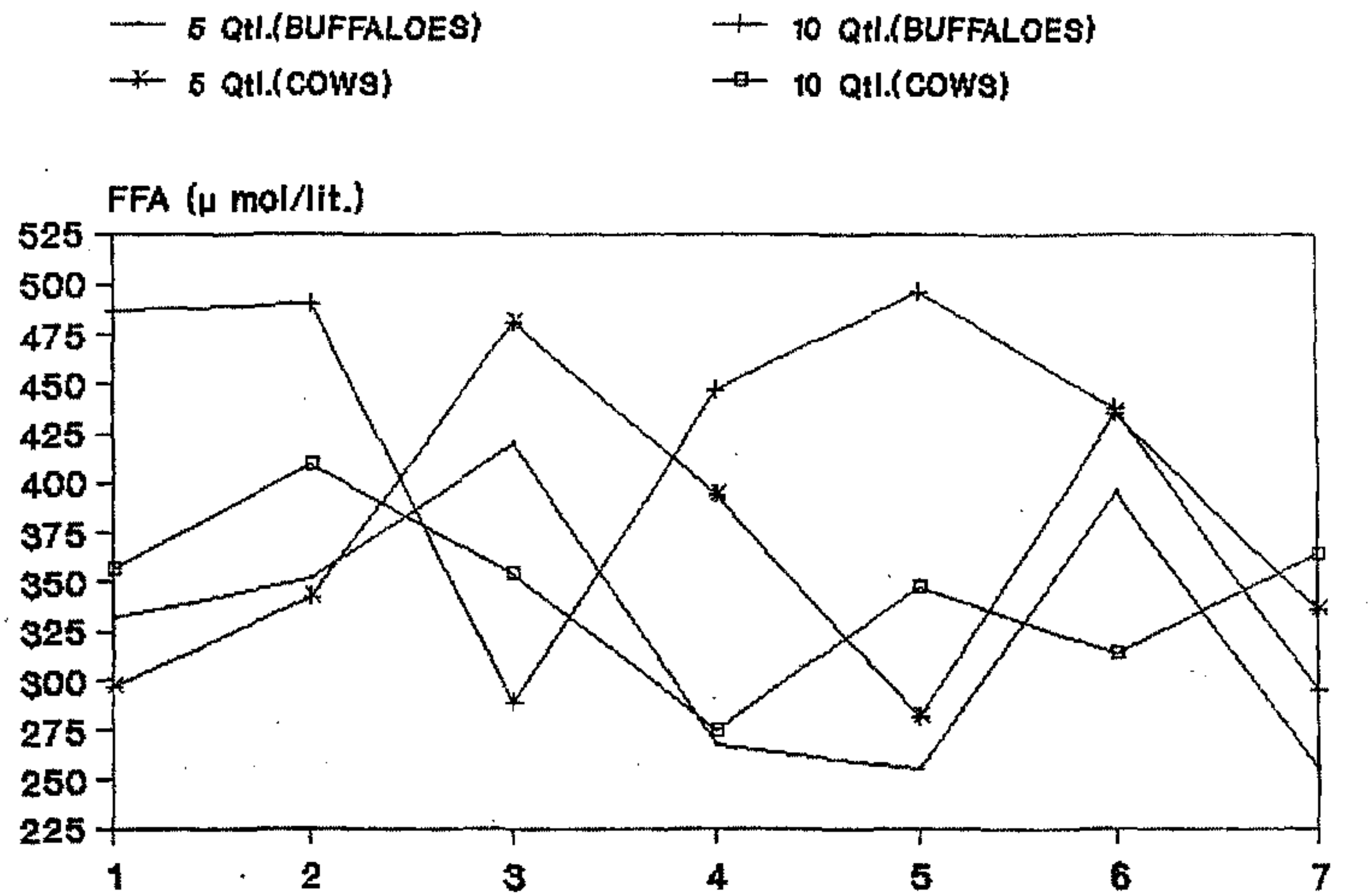
Similar pattern of rise in the plasma free fatty acid after work was observed during 10 qtl cart load (Table 4.3.3.3). Pre-work FFA values were lower in cows than buffaloes(Table 4.3.3.3). A rise in the FFA content was seen upto 489.92 ± 116.97 and

Table 4.3.3.3 Free fatty acid (umol/l) changes in working buffaloes and cows during different cart loads

Periods	Dry non-pregnant buffaloes		Dry non-pregnant cows	
	5 qtls	10 qtls	5 qtls	10 qtls
BW	331.33±113.88	486.80±110.48	296.93± 41.81	356.59± 48.79
AW-I	351.17± 88.44	489.92±116.97	342.40± 78.92	409.30± 70.52
Recovery (75%)	419.66±135.09	288.40± 27.98	480.96±123.30	354.27± 74.25
AW-II	267.40± 28.11	446.53±124.02	393.60± 67.79	274.00± 23.92
Rest after hours				
3	255.33± 13.54	496.10±161.79	280.62± 19.19	347.39± 43.79
12	395.10±138.03	437.90±161.79	434.90± 84.98	313.20± 29.61
24	255.50± 1.98	294.57± 34.57	334.67± 68.24	262.79± 29.94

The values are mean ± SEM based on two replicates on 3 animals

Fig. 4.33.3: FREE FATTY ACID IN WORKING BUFFALOES & COWS DURING DIFFERENT LOADS



409.30 $\pm$ 70.52 umol/l in buffaloes and cows after load II. Rest pause decreased FFA levels in both cows and buffaloes to respective mean values of 354.27 $\pm$ 74.25 and 288.40 $\pm$ 27.98 umol/l in buffaloes but no uniform pattern of change was observed in cows (Table 4.3.3.3). Three hours of rest increased FFA to 496.10 $\pm$ 161.79 and 347.39 $\pm$ 43.79 umol/l in dry buffaloes and cows. Rest periods of 7 h decreased the FFA in DNP buffaloes and cows to the respective values of 437.90 $\pm$ 161.79 and 313 $\pm$ 29.61 umol/l (Table 4.3.3.3). No significant correlation was found with T_4, FFA and insulin.

4.3.4. METABOLIC HORMONES

The results for metabolic hormones (T_3, T_4 and insulin) in DNP buffaloes and cows during work and rest have been presented in Tables 4.3.4.1 to 4.3.4.4 and Figs. 4.3.4.1 to 4.3.4.3.

4.3.4.1 Triiodothyronine

The results for plasma triiodothyronine (T_3) levels in DNP buffaloes and cows at different periods of work and rest have been presented in Table 4.3.4.1 and Fig. 4.3.4.1.

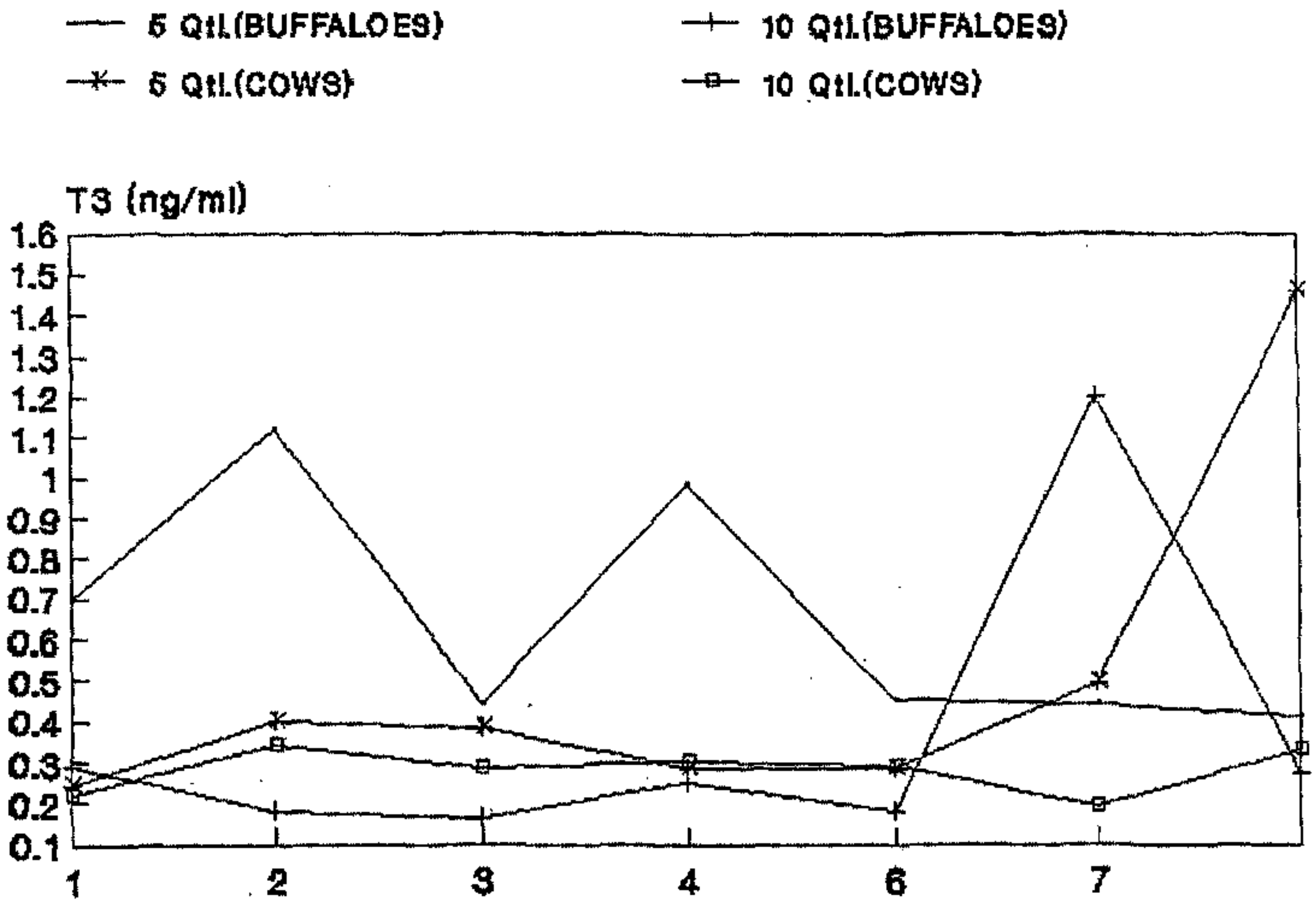
The resting pre-work T_3 levels in DNP buffaloes and cows were 0.70 $\pm$ 0.24 and 0.24 $\pm$ 0.03 ng/ml, respectively. Load I increased T_3 levels to 1.12 $\pm$ 0.89 and 0.40 $\pm$ 0.14 ng/ml in DNP buffaloes and cows. Rest pause decreased the plasma T_3 levels to 0.44 $\pm$ 0.19 and 0.38 $\pm$ 0.17 ng/ml in DNP buffaloes and cows. During rest period, T_3 levels did not show any uniform pattern (Table 4.3.4.1).

Table 4.3.4.1 Triiodothyronine (ng/ml) changes in working buffaloes and cows during different cart loads

Periods	Dry non-pregnant buffaloes		Dry non-pregnant cows	
	5 qtls	10 qtls	5 qtls	10 qtls
BW	0.70 ± 0.24	0.29 ± 0.05	0.24 ± 0.03	0.22 ± 0.04
AW-I	1.12 ± 0.89	0.18 ± 0.01	0.40 ± 0.14	0.34 ± 0.04
Recovery (75%)	0.44 ± 0.19	0.16 ± 0.00	0.38 ± 0.17	0.28 ± 0.08
AW-II	0.98 ± 0.45	0.25 ± 0.08	0.25 ± 0.03	0.30 ± 0.13
Rest after hours				
3	0.45 ± 0.16	0.18 ± 0.02	0.28 ± 0.13	0.29 ± 0.11
12	0.44 ± 0.16	1.20 ± 0.90	0.49 ± 0.24	0.19 ± 0.02
24	0.41 ± 0.05	0.27 ± 0.12	1.46 ± 0.88	0.33 ± 0.13

The values are mean ± SEM based on two replicates on 2 animals

Fig. 4.3.41: TRIIODOTHYRONINE IN WORKING BUFFALOES & COWS DURING DIFFERENT LOADS



At the beginning of 10 qtl cart load, the average values of T_3 were 0.29 ± 0.05 and 0.22 ± 0.04 ng/ml in buffaloes and cows, respectively. Heavy load did not induce pronounced changes and T_3 levels were observed to vary within normal physiological limits (Table 4.3.4.1). Statistical analysis in terms of analysis of variance showed that T_3 differed ($P < 0.05$) between animals and loads.

4.3.4.2 Thyroxine

The resting pre-work average values of T_4 in buffaloes and cows varied from 12.49 ± 1.60 to 44.77 ± 11.97 ng/ml, with pre-work levels being 12.73 ± 2.12 and 44.77 ± 11.97 ng/ml, respectively in DNP buffaloes and cows (Table 4.3.4.2). A drop in T_4 level was seen after work to 10.75 ± 3.65 and 25.95 ± 14.26 ng/ml. During recovery, respective levels increased to 26.93 ± 10.25 and 38.57 ± 11.54 ng/ml in DNP buffaloes and cows. Further work increased these levels to 43.03 12.25 ng/ml in DNP cows, but levels in buffaloes declined. After 24 h of rest period, the values of T_4 were 20.70 ± 2.78 in DNP buffaloes and 26.47 ± 5.22 ng/ml in DNP cows (Table 4.3.4.2).

4.3.4.3 Insulin

The results for insulin in DNP cows and buffaloes at 5 qtl and 10 qtl loads during hot humid season and at different hours of work and rest have been presented in Table 4.3.4.4 and Fig. 4.3.4.3.

The pre-work average values of insulin in DNP buffaloes and cows were 21.40 ± 0.51 and 17.07 ± 2.49 uU/ml. The insulin levels decreased after work to 17.21 ± 0.76 and 15.44 ± 2.03

Table 4.3.4.2 Analysis of variance for FFA, T3, T4 and insulin during carting experiment

Source of variation	d.f.	M.S.S.			d.f.	M.S.S.
		FFA	T4	T3		Insulin
Animals	2	9564.61	1172.07**	1.30*	1	2.77
Weight	1	29031.74	6189.26**	1.11*	1	0.43
Species	1	5997.26	262.17	0.41	1	51.01**
Periods	6	12223.76	92.27	0.15	6	29.16**
Weight x Species	1	70957.03	629.11	0.05	1	30.50*
Weight x Periods	6	28325.20	251.39	0.18	6	17.59
Species x Periods	6	11255.64	190.26	0.25	6	4.63
All effect interaction	6	8340.35	166.55	0.40	6	18.73
Error	54	23530.60	210.45	0.27	27	5.70

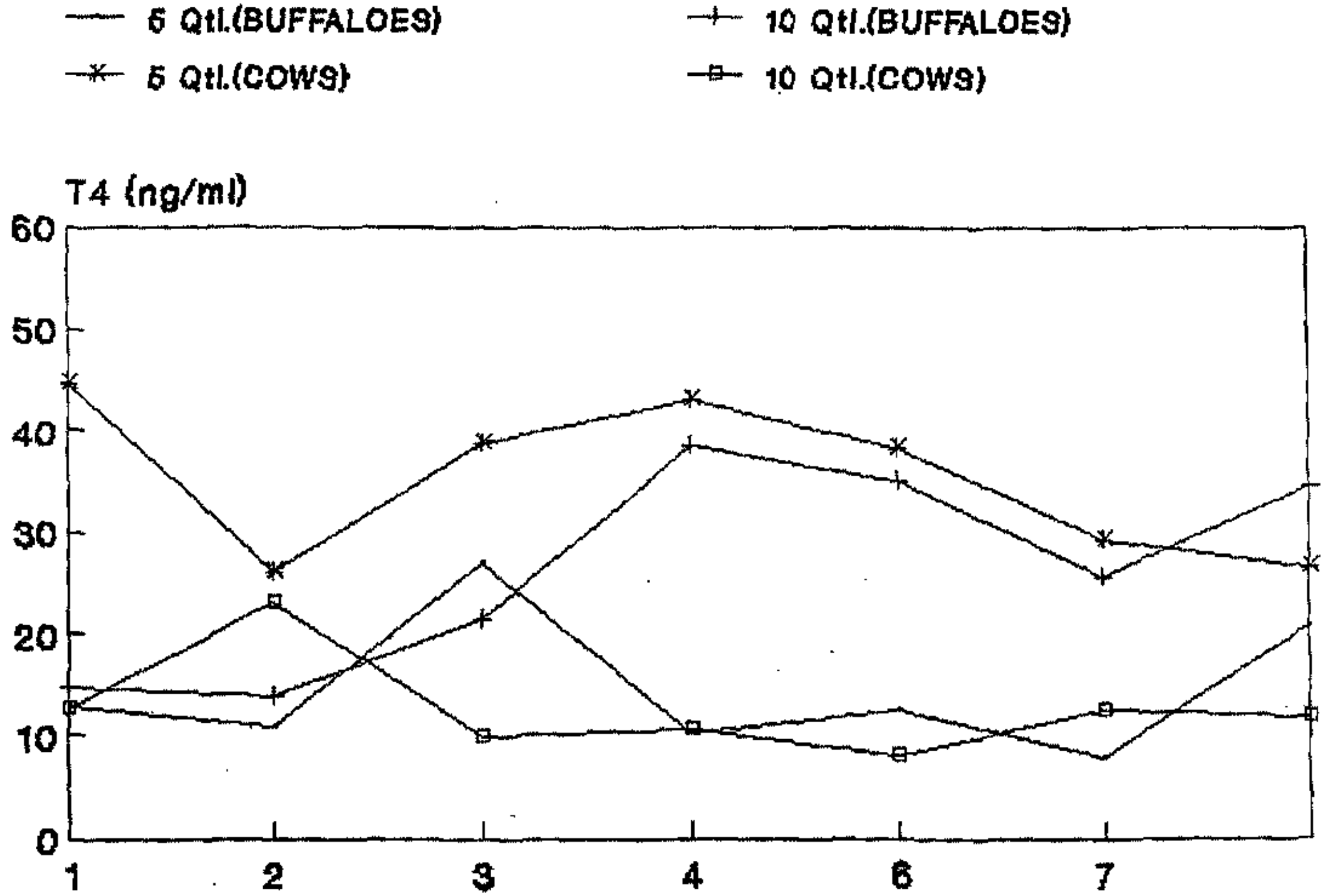
* $P < 0.05$; ** $P < 0.01$

Table 4.3.4.3 Thyroxine (ng/ml) changes in working buffaloes and cows during different cart loads

Periods	Dry non-pregnant buffaloes		Dry non-pregnant cows	
	5 qtls	10 qtls	5 qtls	10 qtls
BW	12.73 ± 2.12	14.66 ± 5.08	44.77 ±11.96	12.49 ± 1.60
AW-I	10.75 ± 3.65	13.77 ± 6.16	25.95 ±14.26	22.97 ± 4.56
Recovery (75%)	26.93 ±10.25	21.37 ±10.66	38.57 ±11.54	9.90 ± 2.46
AW-II	10.16 ± 3.04	38.43 ±25.33	43.03 ±12.25	10.42 ± 3.07
Rest after hours				
3	12.42 ± 6.72	35.03 ±11.00	38.27 ±11.80	8.01 ± 1.91
12	7.68 ± 2.44	25.43 ± 1.72	29.23 ± 2.92	12.27 ± 2.76
24	20.70 ± 2.78	34.53 ± 9.13	26.47 ± 5.22	11.74 ± 6.69

The values are mean ± SEM based on two replicates on 2 animals

Fig. 4.3.42: THYROXINE LEVEL IN WORKING BUFFALOES & COWS DURING DIFFERENT LOADS



uU/ml in DNP buffaloes and cows, respectively. Post-exercise insulin levels were 17.70 ± 0.76 and 16.92 ± 2.23 uU/ml in DNP buffaloes and cows. During recovery period, insulin levels increased (Table 4.3.4.4). The per cent increase in insulin was 14.88 in DNP buffaloes and 64.82 in cows after 24 h of rest. Recovery in the insulin levels took about 1-2 h. Almost similar results were observed in DNP buffaloes and cows during heavy work load (Table 4.3.4.4). Statistical analysis of results indicated that insulin levels differed significantly ($P < 0.01$) between species and periods. T_3 levels did not show any correlation with other parameters (Table 4.3.4.3).

4.3.4.4 Estrogen and progesterone

The results encountered for circulating estrogen and progesterone in DNP buffaloes and cows at loads I and II, and at different hours of work have been presented in Table 4.3.4.5. The progesterone concentration in DNP buffaloes varied from 0.88 to 6.25 ng/ml. No specific pattern of change was observed in most animals, but a few animals did exhibit a decrease in progesterone. The pre-work progesterone levels were 2.38 and 2.07 ng/ml in DNP buffaloes at load I and the respective values were 1.76 and 2.24 ng/ml at load II. During recovery period, the progesterone levels remained almost at the same level as observed at the beginning in all the DNP buffaloes and cows. DNP cows showed a much lower value of progesterone.

Estrogen levels varied from 2.00 to 19.20 pg/ml in DNP buffaloes, the respective values for DNP cows were 7.47 to 38.40 pg/ml. The estrogen concentration during different hours of work did not show any specific pattern of change in DNP cows and buffaloes.

Table 4.3.4.4 Insulin level (uU/ml) changes in working buffaloes and cows during different cart loads

Periods	Dry non-pregnant buffaloes		Dry non-pregnant cows	
	5 qtls	10 qtls	5 qtls	10 qtls
BW	21.40 ± 0.51	18.12 ± 0.76	17.07 ± 2.49	22.91 ± 2.75
AW-I	17.21 ± 0.76	15.90 ± 2.22	15.44 ± 2.03	21.59 ± 1.69
Recovery (75%)	17.70 ± 0.76	19.64 ± 1.02	16.92 ± 2.23	23.24 ± 0.42
AW-II	17.47 ± 0.48	15.19 ± 2.02	14.47 ± 1.65	18.33 ± 0.48
Rest after hours				
3	18.93 ± 0.35	19.61 ± 1.23	21.57 ± 2.14	18.35 ± 2.54
12	21.47 ± 1.47	14.39 ± 2.28	24.34 ± 1.05	19.50 ± 1.71
24	20.07 ± 0.88	15.56 ± 2.48	23.85 ± 1.83	21.50 ± 0.50

The values are mean ± SEM based on two replicates on 2 animals

Fig. 4.3.43: INSULIN LEVEL CHANGES IN WORKING BUFFALOES & COWS DURING DIFFERENT LOADS

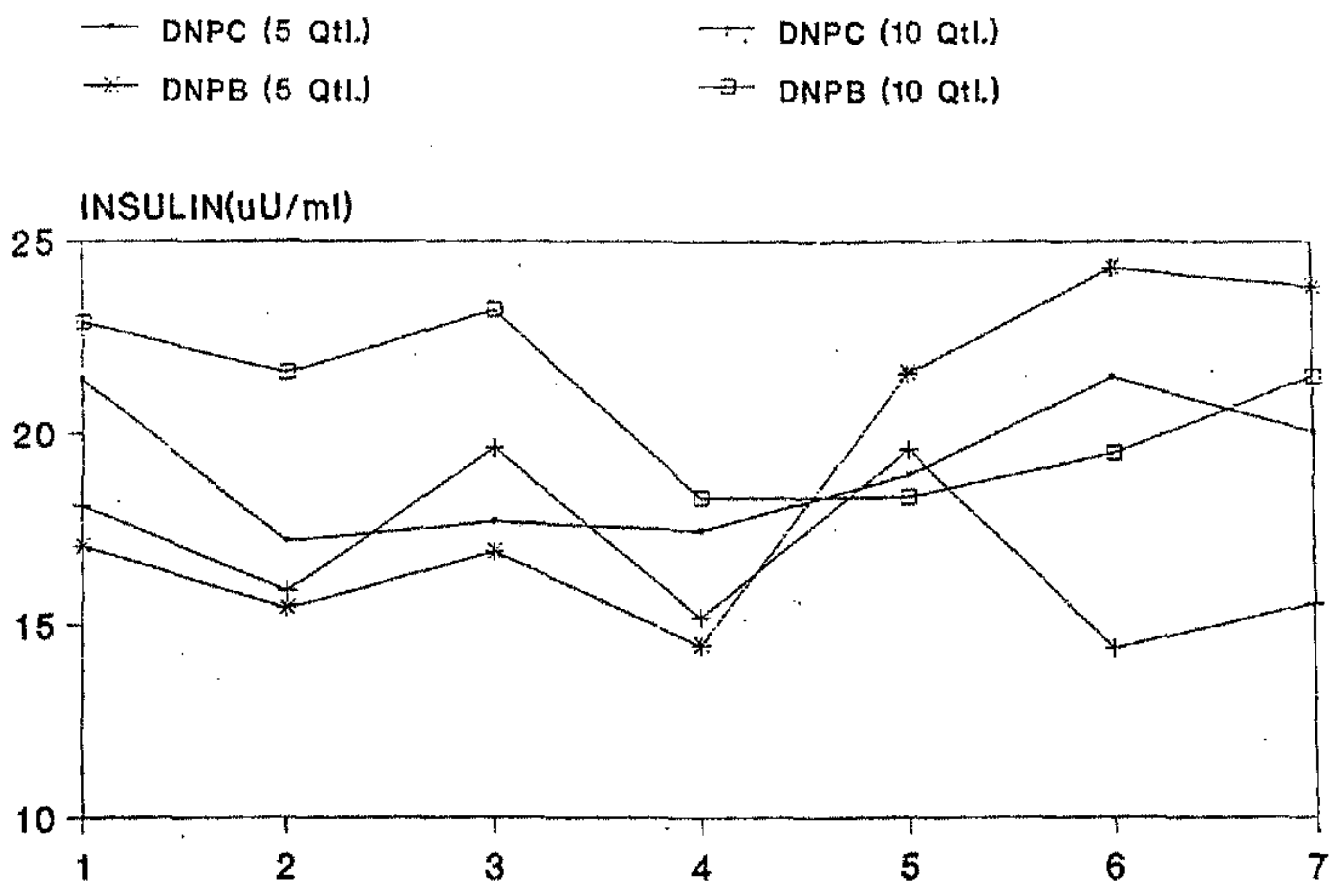
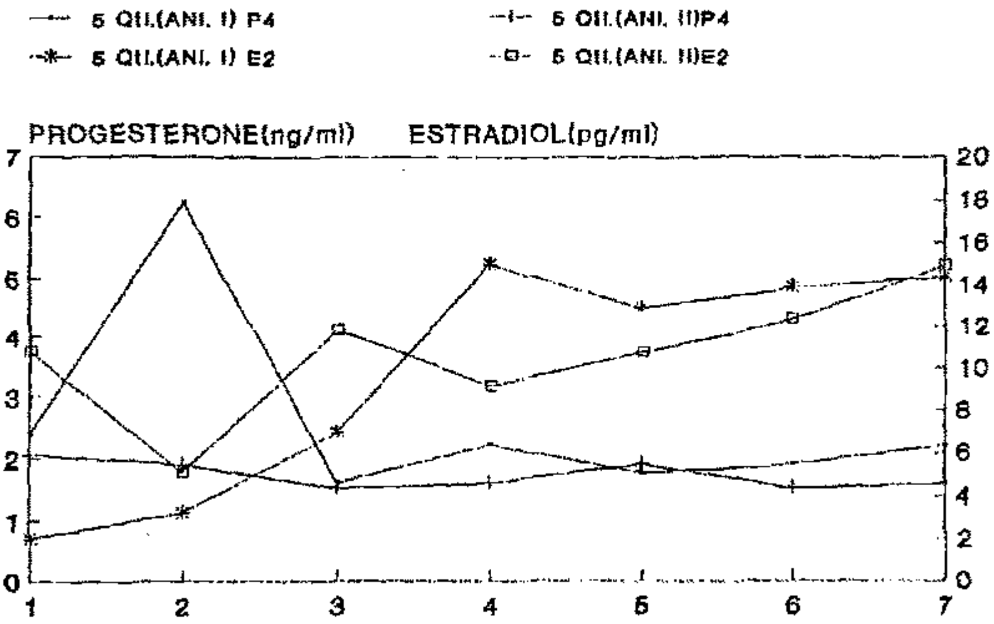


Table 4.3.4.5 Plasma progesterone (ng/ml) and plasma estradiol-17 β (pg/ml) changes in working buffaloes and cows during different cart loads

Periods	5 quintal load				10 quintal load			
	Progesterone		Estradiol		Progesterone		Estradiol	
	Animals		Animals		Animals		Animals	
	1	2	1	2	1	2	1	2
				BUFFALOES				
BW	2.38	2.07	2.00	10.67	1.76	2.24	15.47	14.40
AW-I	6.25	1.91	3.20	5.07	2.07	2.53	12.80	10.67
Recovery (75%)	1.60	1.52	6.93	11.73	2.06	1.91	13.60	12.80
AW-II	2.22	1.60	14.93	9.07	1.91	3.15	16.00	14.40
Rest after hours								
3	1.76	1.91	12.80	10.67	1.76	2.38	19.20	16.00
12	1.91	1.52	13.87	12.27	1.60	0.88	13.60	16.00
24	2.22	1.60	14.40	14.93	1.91	1.76	12.80	14.40
				COWS				
BW	0.50	0.06	13.87	27.73	0.05	0.05	17.60	20.27
AW-I	0.88	0.07	11.20	30.93	0.05	0.05	17.07	29.87
Recovery (75%)	0.88	0.05	10.13	34.13	0.06	0.05	17.60	16.53
AW-II	1.31	0.13	14.93	38.40	0.05	0.05	20.27	18.13
Rest after hours								
3	0.17	0.48	15.47	20.80	0.07	0.06	18.13	10.13
12	6.00	0.07	12.27	19.20	0.05	0.06	18.13	7.47
24	0.28	0.06	15.47	18.13	0.05	0.05	18.13	16.53

Fig. 4.3.4ii: PLASMA PROGESTERONE & ESTRADIOL 17-β IN WORKING BUFFALOES DURING DIFFERENT LOADS



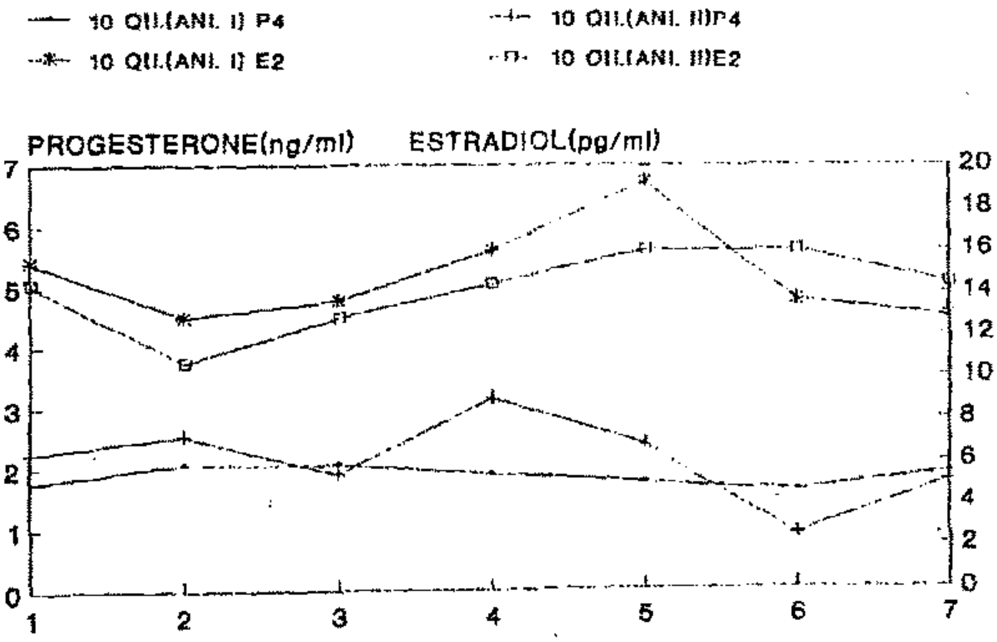
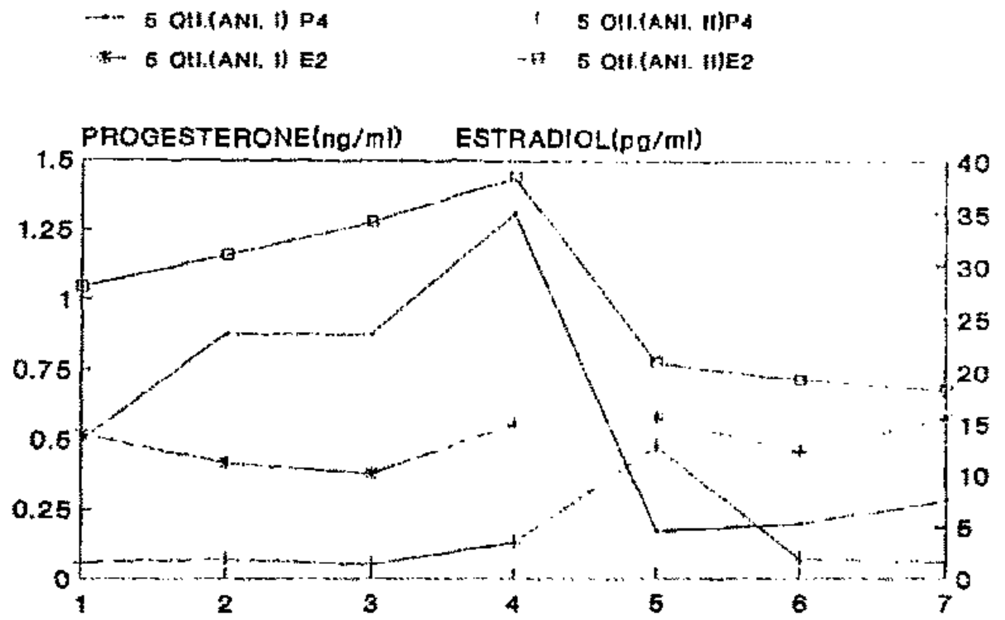
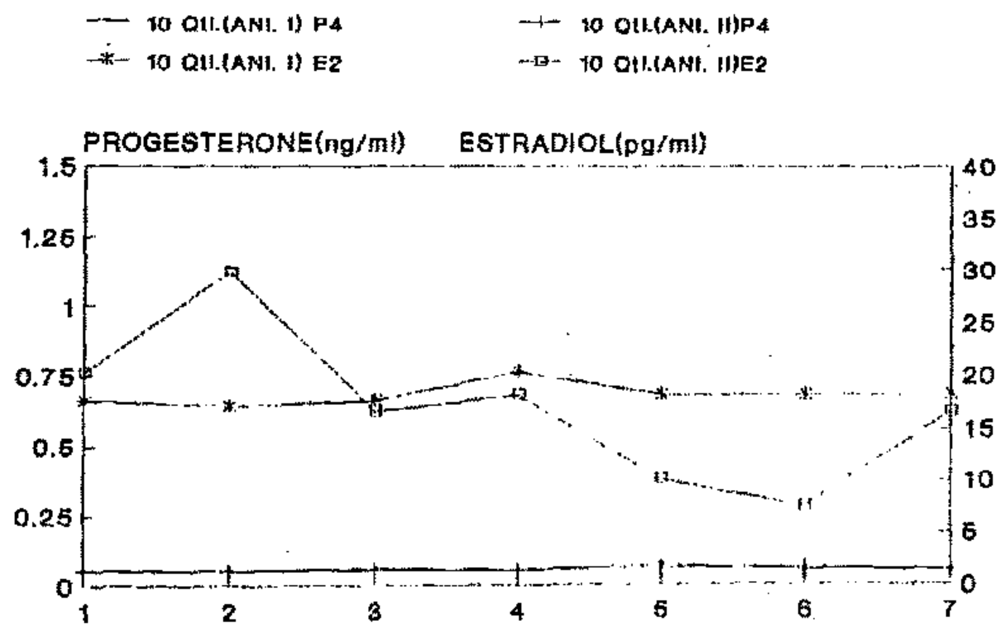


Fig. 4.3.45: PLASMA PROGESTERONE & ESTRADIOL 17-β IN WORKING COWS DURING DIFFERENT LOADS





CHAPTER 5

DISCUSSION

5.0 DISCUSSION

5.1 PLOUGHING

5.1.1 PHYSIOLOGICAL CHANGES

5.1.1.1 Respiration rate

Resting pre-work respiration rate (PR) of dry non-pregnant (DNP) and lactating non-pregnant (LNP) crossbred cows, during summer and winter, were observed to be higher than the pre-exercise values of buffaloes with the overall mean difference of about 11 breaths per minute during summer season (22.9 and 18.4 RR/min) and about 5 breaths/min (15.1 and 10.3 RR/min) during winter. These pre-work higher RR in crossbreds had greater magnitude of difference during summer than winter (Table 4.1.5.1). From these results we can conclude that the resting respiration rate of buffaloes are lower than crossbred cows. These differences in resting animals further indicate that buffalo at rest spent less oxygen to maintain their body weights under identical conditions and the pulmonary exchange processes at these rates were sufficient to maintain their metabolic needs and thermal equilibrium. In general, these average resting values for crossbred cows observed during present investigation are in agreement with the values observed in crossbred animals by Sastry (1969), Rao *et al.* (1974) and Acharya *et al.* (1979). The values observed in DNP and LNP buffaloes during summer are in agreement with the values observed by Nangia *et al.* (1980) and Martin and Teleni (1989) in buffaloes. Initial RR of buffaloes during winter are also in agreement of Kapoor (1985) and Dang (1990).

The differences in the RR in present investigation during summer and winter are significant and have been attributed to the variations in the ambient conditions,distinct climatic components specially temperature and humidity. RR in both the species, cows and buffaloes have been observed to be physiological compensated effects resulting in increase with increased ambient temperature and decrease with decreased ambient temperature. These changes observed were primarily due to compensating effect in body heat, due to changed environmental temperature (Thompson, 1973). Increase in the respiration was observed when animals were subjected to work during both the seasons. Similar trends in results have also been reported by Upadhyay (1982,1987), Upadhyay and Madan (1985a), Upadhyay and Rao (1985), Bhatnagar (1989) and Sadan Bag (1992).

The absolute values of RR in crossbreds were higher than values recorded in buffaloes. The changes interpreted in terms of per cent increase over pre-work RR revealed that per cent increase in crossbreds was lower than buffaloes. Reasons attributed were that crossbreds started with a higher pre-work rates than buffaloes, thus the capacity to increase in them was limited. The increase in the RR of crossbreds (DNP and LNP cows) during summer and winter were closely in agreement with the values reported by Acharya *et al*. (1979) during summer after 3 h of ploughing. In present study, almost similar values of RR were observed after 1-1/2-2 h work, most likely due to soil conditions and sex differences as in the present study females were the subject of experiment. But during winter almost similar values were found after 4 h of work. Similar per cent increase in the buffaloes has also been reported by Thakur *et al*. (1987).

The increase in the respiration rate during work is a chief compensatory mechanism to cope with the increased demand of oxygen of the actively working muscles. Increased RR help in increasing oxygenation of blood, to deliver oxygen at much faster rates to muscle cells (Naughton, 1979; Upadhyay and Madan, 1985a). A rest pause during work decreased RR in crossbred cows and buffaloes to variable magnitude (Table 4.1.5.1). The extent of changes in RR were often related to the duration of work and in general these animals did not recover to pre-work levels, during rest pause, after first month morning work phase. Two hours of rest was not enough to recover in RR to pre-work values. The decrease in RR was faster during post work period. Studies of Agarwal *et al.* (1982) on buffaloes have also indicated that about 8 h are needed to recover animals to pre-work levels.

Further work after rest respectively increased RR to 83.3 and 61.4 during summer and winter in buffaloes. The absolute values and per cent increase in the RR due to second round of ploughing were higher than the first round of ploughing. The per cent increase was 450.0, 496.0 in buffaloes during first working period during summer and winter, respectively. The corresponding increase in RR of cows were 185.5 and 54.4 per cent. The increase in the RR was more during second phase of ploughing during afternoon session as the rest period of 2 h was not enough to bring down the values, particularly under the open environmental conditions when solar radiation and ambient temperature was maximum. Increase in the respiratory rate with the increase of air temperature is one of the prominent and visible physiological response of working animals. Numerous reports have been published indicated increase in the respiratory frequency with increase in environmental temperature and have been reviewed by Bianca (1965) and Thompson (1973). RR increase with increase in relative humidity (Rhoad, 1936; Sheath and Miller, 1946) and decrease with drop in temperature (Kibler and Brody, 1949). Direct exposure to solar radiation also increases frequency and ventilation volume in buffaloes (Chaiyabutr *et al.*, 1983; Chikamune, 1987). Increase in RR upto 496 per cent in buffaloes and 392 per cent in cows have been encountered during the investigation. These were the attempts to maintain oxygen availability depending on level of work and to eliminate carbon dioxide from the body to maintain internal milieu. This attempt also helped in dissipation of heat of both work and enviornment. The experimental animals during summer exhibited panting with polyp nea and frothing.

5.1.1.2 Pulse rate

During present investigation, pre-work PR encountered in DNP crossbred and LNP cows were more than buffaloes during both the seasons. The lowest rate of 58 and 68 beats per min (bpm) were recorded in buffaloes and crossbreds respectively. The average pre-work PR were 69.7, 71.2 bpm in buffaloes and 75.4, 73.8 bpm in cows, during summer and winter season. These values were in close agreement with the values reported by Sastry (1969). Acharya *et al.* (1979) observed higher PR in crossbred and indigenous bullocks during summer and winter season. Rao *et al.* (1974) and Devadattam and Maurya (1978) have also found initial lower values of PR than observed during present study in cows. Present experimental working female buffaloes had higher pre-work mean PR than reported by Sornphasitti (1987).

The increase in PR is due to higher frequency of higher rate which occurs due to work under the influence of sympatho-adrenal activity. Increase in heart rate due to exercise/work have been reported in humans and animals (Engelhardt, 1977; Rowell, 1974; Bell *et al.*, 1983; Upadhyay and Madan, 1986; Upadhyay, 1989). The cardiac activity increases both due to intensity of work and speed of the animals at work (Parks and Manohar, 1983). The increase in the PR after first phase of work respectively was 90.50, 85.20 in buffaloes during summer and winter, whereas increase in PR of cows was of higher magnitude, i.e. 91.70 and 95.20/min during summer and winter repsectively. The values are closely comparable to the PR reported by about 90 bpm in Swamp buffaloes walking on a tread mill at 2.5 km/h for a minimum of 3 h pulling a draught load equivalent to 11 per cent of its body weight. In buffaloes, increase was about 29 per cent during both the seasons, but in cows the rise was 22 and 24 per cent during summer and winter, respectively. These results are in close agreement with the results reported by Thakur *et al.* (1987). After work in cows, the absolute values were of higher magnitude than buffaloes but per cent increase was lower than buffaloes. The reason for that may be that PR of the cows was higher during pre-work.

Increase in the PR from 52 to 97 bpm has been reported by Nangia *et al.* (1980) similar to the results found in the present study.

The increase in the heart rate represents a rise in cardiac activity to fulfil the increased demands for oxygen during exercise. The increased heart rate in response to exercise though chiefly occurs for supply of oxygen but also serves as a heat losing mechanism by increasing blood flow through the skin which is of great importance in thermolysis (Bazett *et al.*,1940). The increased cardiac activity improves blood flow through the skin by vasodilation of the subcutaneous blood vessels which also helps in heat dissipation.

Evidences from mammalian research have indicated that central nervous system initiates or sustains patterns of cardio-vascular response appropriate to particular sets of physiological conditions, particularly during stress of work or fear (Hilton and Spyer, 1980). Muscle vasodilation is a constant feature together with vasoconstriction in splanchnic and renal beds and in skin, while vasoconstriction and increased cardiac activity ensure an increased cardiac output. A decreased compliance of the pulmonary arteries contribute to the mobilization of blood reservoirs (Szidon and Fishman, 1971). These various responses are mainly brought about by the sympathetic outputs and vaso-constrictor nerve fibers to s keletal muscle are apparently inhibited when the vasodilator fibers are excited. This inhibition is independent of the baroreceptor reflex (Coote *et al.*, 1979).

Lower heart rate in buffaloes than crossbreds in present study may be an effect of conditioned chronotropic changes that usually involve the synergistic action of sympathetic and para-sympathetic cardiac innervations. Vagal influences may be more prominent in conditioned bradycardia,while changes in sympathetic outflow may prevail during conditioned tachycardia. However, regardless of the direction of heart rate change during work, the shortest latency change appears to be mediated by the vagal innervation (Cohen and Randall, 1984).

Pulse rate decreased during two hours of rest to 80 and 74 in buffaloes and 83.40, 77.90 in cows during summer and winter season and PR did not return to pre-work levels. Earlier studies on draught animals at the Institute have also reported that physiological reactions may not return to pre-exercise resting levels even upto 5-6 h (Upadhyay, 1989). Another work period after rest of 2 h increased the PR to the almost same level as observed after first phase of exercise. The per cent increase over pre-work values was about 24.82 and 30.00 per cent in buffaloes and 21.00 and 24.00 per cent in cows during summer and winter seasons.

The lower resting value of PR during summer in buffaloes and cows indicates a decrease in PR with the increase in temperature. Mullick and Kehar (1952) had reported an increase in pulse rate with the rise of environmental temperature, yet most of the workers have claimed that either pulse rate was unaffected by environmental temperature (Sheath and Miller, 1946; Riek and Lee, 1948; Williams *et al.*, 1960) or decreased with the rise in temperature. Studies on animals have often reported a rise in heart rate due to temperature effects, particularly in the tropics. This is most likely brought to correct the imbalances in heat production and storage and increased peripheral circulation help in elimination of heat. Since present study did not qantify the magnitude of change in heat loss due to increased circulatory responses, nothing could be authentically stated about the role of such a phenomenon particularly in the animals, crossbreds and buffaloes, which rely on skin cooling effects limitedly.

Since buffaloes and crossbreds were maintained under open conditions in winter, animals exhibited higher PR, particularly when the ambient temperature was low and animals had to exert more for maintaining thermal balance, therefore needed extra heat generation. At other point of time when animals were not exposed to very low temperature, values for PR were found to be lower in cows and lactating non-pregnant buffaloes during winter. These changes in PR may also be related to biologic adaptative processes resulting from exercise effects similar to reported by Upadhyay (1982) in bullock, and in human atheletes (Astrand and Rodhal, 1970; Astrand, 1981).

5.1.1.3 Rectal temperature

The mean rectal temperatures in crossbred cows 39.12°C and 38.06°C during summer and winter, which were higher than rectal temperature of 38.33° and 37.60°C observed in buffaloes during respective seasons. The difference in RT of cows and buffaloes during summer and winter was about 1°C in both of the seasons. The pre-work rectal temperature of buffaloes and cows are in close agreement with the values reported for crossbred (Acharya *et al.*, 1979; Devadattam and Maurya, 1978; Sreekumar and Thomas, 1989; Bhatnagar, 1989) and buffaloes (Nangia *et al.*, 1980; Thakur *et al.*, 1987; Dang, 1990; Sadan Bag, 1992).

The rise in the rectal temperature due to work over pre-work values was 2.57°, 2.74°C in buffaloes and 1.94°, 2.28°C in crossbred cows during summer and winter seasons. The increase of RT in buffaloes was more as compared to cows over pre-work values while working under natural environmental conditions with solar radiant heat load.

The rise in RT was more in buffaloes than crossbreds. Most likely, these changes were due to higher radiant heat load in case of buffaloes which they were unable to reflect due to less hair density. Buffaloes in general increase body temperature more than the Zebu or crossbreds. Increase in RT during work has been considered a limiting factor for continuous work output (Upadhyay, 1989). Earlier, Upadhyay (1987) had reported that increase of 2.5°C should be regarded as intolerable by the animals if other physiological reactions also increase linearly. The increase in the RT of crossbred cows during present study was in agreement with the values reported by Sreekumar and Thomas (1989) for crossbreds and Kangayam bullock, Maurya and Devadattam (1986) for Jersey and Red Sindhi crosses and Khillari bullock, and Upadhyay and Madan (1985a) for crossbred bullocks.

In case of buffaloes, similar results have also been reported by Taneja and Bhatnagar (1960), Rana *et al.* (1978) and Nangia *et al.* (1980).

Intensity, duration and speed of work determine the rate at which animal consumes energy and produce heat. Most of this energy is expended during work, except the portion which is utilized for work appears as heat which must be dissipated in order to maintain a constant body temperature. The strategies for dealing with this increased heat production will differ from animal to animal during different climatic conditions.

A drop in the rectal temperature after 2 h of rest was recorded in buffaloes during summer (0.83°C) and winter (1.09°C) and in case of cows decrease was 0.69°C during summer and 1.06°C during winter season. During winter, the drop in the rectal temperature was faster than summer as animals were able to lose heat to the environment being cooler than the body contrary to the summer when heat is transferred to the body from environment and animals are excessively distressed.

The rest pause of 2 h after ploughing under such conditions did not reduce the rectal temperature to pre-work levels. Therefore, to recover RT to normal, not only animals need to be protected from radiant heat but also added measures are essential if heat alleviation is to be aided to facilitate complete recovery of animals.

Further exercise increased the RT to 2.27° and 2.34°C in buffaloes and 2.12° and 1.51°C in cows, respectively during summer and winter. Increase in the RT was almost similar after first round of work. From our results we have concluded that the buffaloes increased rectal temperature faster than the cows because of less number of sweat glands and subcutaneous fat (Hafez, 1968). Heat load during summer increased rectal temperature of buffaloes linearly to 43°C. These levels indicated that buffaloes under stress store heat more than crossbreds. Since buffaloes have less number of sweat glands (1.83 to 4.32 per mm^2 of skin) as compared to indigenous bullocks (13 to 16 per mm^2 of skin), they get cool slower by sweating (Cockvill, 1974). Buffaloes at high temperature often exhibit distress symptoms like frothing and tongue protrusion. To prevent any damage to physiological systems and brain due to excessive heat load, behavioural manifestations, excessive frothing, tongue protrusion and drooling of saliva must be observed during working and a rest pause in between prolonged work period must be provided to working animals (Upadhyay and Madan, 1985a; Upadhyay and Rao, 1986; Upadhyay and Madan, 1987; Upadhyay, 1987).

The rate of evaporative heat loss in panting mammals during exercise can reach levels that are more than double than those occurring during rapid, shallow panting at rest in heat (Hales and Bligh, 1969). In dogs, sheep, cattle and buffaloes, respiratory minute volume increases rapidly during the work and continues to rise till a steady state is established in relation to work. This elevated respiratory evaporation, coupled closely to high rate of blood flow in the nasal and oral cavities, must account for the observation that panting mammals show the great brain cooling during exercise (Baker, 1982).

Blood flow to the tongue and the nasal mucosa in the dog is closely related to the body temperature and the rate of breathing (Pleschka *et al.*, 1979). Studies of blood flow demonstrate increased blood flow to the tongue, the nasal mucosa, and the maxillary turbinate in sheep (Hales *et al.*, 1979) in heat and exercise (Bell *et al.*, 1983).

5.1.2 HAEMATOLOGICAL CHANGES

The results obtained during the present investigation revealed that ploughing and carting for prolonged periods continuously is accompanied by limited but distinct haematological changes.

The overall pre-work mean Hct in buffaloes during summer and winter were 35.40 and 36.40 per cent respectively. The pre-work mean values in crossbred cows were 33.10 and 33.60 per cent during summer and winter. In both the species, lower mean values of Hct were observed during summer season than the winter season.

The pre-work mean Hb level was 11.82 and 12.10 g per cent in buffaloes during summer and winter respectively, but in case of cows the respective values were 10.91 and 11.71 g per cent. Hb contents were also higher during winter. Similar trends in the changes of Hb were also observed by Murti and Mullick (1960) and

Raghavan and Mullick (1962). The Hct and Hb contents in blood of cows and buffaloes have been reported to have negative correlation with ambient temperature. Decrease in Hb has also been *reported to be influenced by the direct solar radiation* in buffaloes and cattle (Shafie and Badreldin, 1962).

Pre-work Hb and Hct concentration was higher in buffaloes than in crossbred cows during both the seasons. These results are in general agreement to Shafie and Badreldin (1962) and indicate that at any particular environmental temperature, buffaloes have greater content of Hb. Low Hb contents in cattle have also been reported by Manresa *et al.* (1940), Bonsoma *et al.* (1940), Pal (1945) and Spealman *et al.* (1949).

The pre-work values of Hb obtained during this investigation are in general agreement to those reported by Singh *et al.* (1968a) and Rao *et al.* (1974). Haemoglobin concentration was *slightly lower* as compared to values of 12.13 $\pm$ 0.05 g per cent in crossbreds reported by Sreekumar and Thomas (1989). Variations in Hb have been related to the climatic changes and adaptability in cattle (Manresa et al., 1940).

Ploughing *reduced* Hct and Hb content in both cattle and buffaloes during summer and winter. The Hct reduced to 33.80 and 34.20 per cent in buffaloes and in cows 31.00 and 33.20 per cent during summer and winter respectively. The Hb content correspondingly decreased. The post-work Hb contents were 11.44 and 11.25 g per cent in buffaloes and 10.42 and 11.16 g per cent in crossbred cows, respectively during summer and winter seasons. Decline in haemoglobin and Hct levels due to effect of work have also been recorded by Singh *et al.* (1968a), Sastry *et al.* (1970) and Rao *et al.* (1974) in buffaloes. Upadhyay and Madan (1988) reported a decrease in the Hb and Hct contents during carting in Haryana and crossbred bullocks. Sreekumar and Thomas (1989) also reported similar trend in Hb and Hct after work in crossbred bullocks. The decline of the Hb and Hct in buffaloes during work were also in agreement with Rana *et al.* (1978), Singh *et al.* (1980), Nangia *et al.* (1980) and Upadhyay and Rao (1985).

Two hours rest further increased the concentration of Hb and Hct but the values did not reach the initial levels. Further work after rest pause of 2 h decreased the concentration of Hct to 31.20 and 32.60 per cent in buffaloes and in cows 29.00 and 31.70 per cent, at load I and load II respectively. The decline in Hb and Hct due to work effects is caused either due to hemodilution effects or due to intravascular hemolysis.

5.1.3 PLASMA VOLUME CHANGES

Plasma volume changes calculated on the basis of Hct and Hb indicate that plasma volume expand to 5.99 $\pm$ 1.10 and 6.34 $\pm$ 0.96 per cent in DNP and LNP buffaloes respectively during summer. The respective changes in DNP and LNP cows during same season were 7.23 $\pm$ 1.70 and 8.97 $\pm$ 1.73 per cent. The plasma volume changes in DNP and LNP cows during summer were higher as compared to both groups of buffaloes. The justification for the plasma volume changes may be that work in hot environment involves processes related to work wherein fluid loss needs to be compensated. In that attempt, both extracellular and intracellular volume changes and other physiological systems important for homeostasis of body fluid help (Senay, 1979). Studies on humans have revealed that exercise involves changes in fluid volume and both hemodilution and hemoconcentration occur during heavy exercise depending on state of hydration.

After recovery period, animals were again subjected to another period of work which further increased the per cent plasma volume, upto 22.93 $\pm$ 1.90 and 17.57 $\pm$ 2.39 in DNP and LNP buffaloes during summer season but in case of DNP and LNP cows changes were lower in magnitude than buffaloes, being 16.00 and 16.72 per cent respectively. During winter, the changes in plasma volume were lower than encountered during summer season. Upadhyay (1988) also found that continuous working of 3 h expanded plasma volume to an extent of 16 per cent, and reported that change could be even higher in some of the animals. In this investigation, it was interesting to note that female buffaloes often increased plasma volume greater than the crossbred cows under similar condition. The plasma volume expands to help animal system, in transport of nutrient, in maintenance of cardiac output and in transport of heat to tissues involved in heat dissipation. This conclusion finds support from our own results of RT increase, wherein increase in RT was less in crossbreds with higher expansion of plasma volume than the buffaloes, whose plasma volume expanded limitedly and temperature of body increased to higher levels.

5.1.4 ENERGY SUBSTRATE

5.1.4.1 Blood glucose

The true blood glucose levels encountered in the present investigation ranged from 34.50 mg per cent to 48.44 mg per cent in the working animals during both seasons. The average pre-work blood glucose level in buffaloes during summer and winter were 42.64 mg and 43.75 mg per cent and in cows 41.79 mg and 42.16 mg per cent respectively. From the results encountered, it is evident that blood glucose was higher during winter season in both of the species than the summer season.

The average glucose levels declined with the rise of air temperature but it did not have any specific trend as the higher values (52 to 60 mg %) were also recorded at lower temperatures. Pal *et al.* (1945), Riek and Lee (1948), Brody (1949) and Diven *et al.* (1958) observed that increasing air temperature had little or no effect on blood glucose level. Increase in glucose due to heat exposure has been reported by Singh and Bhattacharyya(1986).

Slight reduction in glucose concentration of cattle and buffaloes was observed due to work during summer and winter seasons after first work. These results are in agreement with the decreases in glucose levels reported by Bhatnagar (1989) and Anjuli (1988). Similar hypoglycemic responses due to work have also been reported in buffaloes (Singh *et al.*, 1979,1980) and Haryana and crossbred cattle (Upadhyay, 1982; Georgie *et al.*, 1970). Upadhyay and Madan (1988) also reported that changes in blood glucose due to work do not occur significantly. Hyperglycemic responses in animals have also been reported (Beninati *et al.*, 1956; Teleni and Hogan, 1989; Komarudin-Ma'sum and Teleni, 1991).

In present study during 2 h rest period after first work, mean blood glucose concentration reached to almost pre-work values indicating the magnitude of change in this study of minor consequences. This further revealed that blood glucose is either utilized to a limited extent during muscular exercise or that liver released glucose into blood stream from its store of glycogen or that the rate of release was so controlled that it kept with the rate of uptake by muscle. In human atheletes, who often work at their highest level of activity the glucose levels were not altered, and blood glucose levels remain almost constant (Newsholme, 1981). Ruminants, who limitedly use glucose for muscle contraction, thus are likely to have limited changes depending on integration of energy replenishing systems.

Further exercise after rest pause of 2 h decreased the blood glucose to 39.55 and 38.30 mg per cent in buffaloes during summer and winter respectively. The decrease in crossbred cows was 38.39 and 37.57 mg per cent during summer and winter seasons, respectively.

5.1.4.2 LACTIC ACID

The overall pre-exercise lactic acid (LA) levels observed during present investigation were 11.37 and 12.12 mg per cent in buffaloes and 12.20 and 12.45 mg per cent in crossbred cows during summer and winter seasons respectively. These results observed during present investigation were in agreement with the values recorded by Georgie *et al.* (1970) and Rao *et al.* (1974). Slightly higher values of LA (13.10 ± 0.96 mg %) were observed in young buffalo calves by Singh *et al.* (1980,198[illegible]) but lower values of LA in resting stage were reported by Singh and Bhattacharyya (1991).

Increase in the LA concentration during work was observed in the animals but the magnitude of rise varied in different climatic conditions. During summer, LA content due to exercise was doubled in buffaloes and crossbred cows. The increase in the LA content due to work are in agreement with the reports on cattle and buffaloes (Rao *et al.*, 1974; Singh *et al.*, 1979, 1980; Kapoor, 1985; Upadhyay and Madan, 1988; Martin and Teleni, 1989; Sreekumar and Thomas, 1989; Anjuli, 1988; Bhatnagar, 1989).

The rise in blood lactic acid encountered during present investigation is most likely due to anaerobic muscular activity at the commencement of work, particularly in fast twitch muscle fibre (Astrand, 1981) with low availability of oxygen, but after adaptation of the oxygen transport system and better capillarization of muscle, the energy demand of muscle is covered by aerobic process and the lactic acid gradually comes down and work is often continued for hours. Another mechanism by which LA levels could get lowered over continued work is the utilization of lactic acid produced by the muscle as a substrate in the Kreb's cycle in the same muscle or in the resting muscle (Poortmans, 1981). Additionally, the liver and heart muscle also possess capacity to utilize lactic acid (Astrand, 1981).

After first phase of work, animals were allowed to rest for 2 h during rest period LA decreased to 17.92 and 19.52 mg per cent in buffaloes and LA levels did not return to pre-work levels. Long rest pause of several hours will be required to return to pre-work level in the LA after work, because after 2 h of rest, LA did not return to pre-work levels.

Further increase in the LA content was encountered during present investigation after rest of 2 h. The increase was in physiological limits in both the species of animals during summer and winter seasons. The increase in LA content in buffaloes respectively was 21.08 and 24.71 mg per cent and in cows 23.37 and 23.68 mg per cent during summer and winter seasons, respectively. LA content did not increase excessively and values were rarely exceeded and often they remained near values observed after first work period.

5.1.4.3 Free fatty acids

The results obtained during the present study revealed that work of ploughing for a prolonged period exhibited distinct non-esterified fatty acid (NEFA) changes.

The overall pre-exercise mean NEFA levels were 286.3 and 301.3 umol/l in buffaloes and 289.2 and 270.5 umol/l in cows during summer and winter seasons respectively.

From the knowledge gained in non-ruminant species, it appears that plasma FFA could be of great importance in ruminant. Annison (1960), Patterson *et al.* (1964) and Reid and Hinks (1962) have noted that the plasma concentration of FFA in sheep is similar to that observed in non-ruminants, namely 100 to 900 ueq/l. Similar concentrations have been found in cattle by Adler and Wertheimer (1962), Adler *et al.* (1963), Williams *et al.* (1963) and Patterson (1963). In buffaloes during winter, the pre-exercise FFA level was higher than summer.

Similar increase in FFA was observed in sheep when exposed to cold temperature probably severe enough to induce summit metabolism (Slee, 1966), body fat reserves were rapidly mobilised and may provide a major source of energy. FFA will then be utilised for heat production in the liver and skeletal muscle.

The results encountered during present study revealed that FFA increased during work, the increase in buffaloes during summer and winter being 373.7 and 333.8 umol/l respectively. Similarly, increase in the FFA was observed due to work in cows, the values being 323.19 and 411.34 umol/l during summer and winter seasons, respectively. Kartiarso *et al.* (1989) found similar trend in the level of FFA and reported that the plasma concentrations of FFA increased during work, the increases being greater in the thin than in the fat animals and greater in cattle than buffaloes. Kartiarso *et al.* (1987a) found that FFA are important sources of energy in working cattle and buffaloes.

Teleni *et al.* (1991) also reported that FFA increased due to work.

Rest period of 2 h after work again increased the FFA to 239.91 and 355.65 umol/l in buffaloes, whereas in cows the values decreased to 320.22 and 367.17 umol/l during summer and winter seasons, respectively. Increases in FFA during rest period are in agreement with the results reported by Garg and Nangia (1979). After 2 h of rest, the plasma FFA levels further increased by 18.76 per cent over decreased values in buffaloes during summer.

From the results of present investigation, it can be concluded that FFA is the major energy source for the working animals. It is, therefore, important to make available both fat and carbohydrate rich diets both prior to work period and during work period to sustain work for longer duration or if output is to be improved (Wachirapakorn and Wanapat, 1989).

5.1.5 *METABOLIC HORMONES*

5.1.5.1 Triiodothyronine and thyroxine

The circulating levels of triiodothyronine (T_3) and thyroxine (T_4) among cows and buffaloes were quantified in the blood plasma drawn at different days and at different periods of work. The mean plasma T_4 levels ranged between 3.84 and 47.40 ng/ml in buffaloes during summer, and winter, the concentration ranged from 3.80 to 88.10 ng/ml, and in cows during winter season varied between 2.25 and 73.50 ng/ml. The mean pre-work values of T_4 in buffaloes were 23.30 and 22.32 ng/ml during summer and winter seasons. These pre-work mean values are in agreement with the values reported by Agarwal *et al.* (1983). The values found during present investigation before work were on lower side than the values reported by Dixit *et al.* (1984) and Bhatnagar (1989). However, upper values of T_4 are in agreement with Khurana (1983).

It is evident from the study that the higher values of T_3 and T_4 were found during winter season in both of the species.

Experimental evidences from different animal species chronically exposed to a cold environment have shown a significant rise in T_3 levels without much changes in either TSH or T_4 circulating values (Sterling and Lazarus, 1977; Collins, 1978; Morley, 1981). Studies of Aceves *et al.* (1987) have also shown that mild cold weather conditions (10 to 18^{o}C) caused a gradual and sustained T_3 increase in chronically exposed cows without significant change in T_4 circulating values.

Information on thyroid functions and hormonal changes during heat acclimation and work in buffaloes and cows is limitedly available except in climatic chamber studies (Yousef *et al.*, 1967; Magdub *et al.*, 1982). In general, these reports have led to the conclusion that heat exposure reduced thyroid gland activity (Thompson, 1973; Johnson and Vanjonack, 1976; Johnson, 1980). However, a detailed analysis of these studies suggested the occurence of a sequential adjustment in thyroid metabolism characterized by an initial decrease in T_4 concentration values which is followed by a return to control level.

In general, T_4 levels increased due to work over pre-work values in buffaloes from 28.46 to 29.03 ng/ml and in cows from 24.01 to 25.84 ng/ml during summer. In present study, after ploughing, T_3 levels decreased to 0.48 and 0.60 ng/ml during summer and winter season. The decreasing trend in plasma T_3 are in agreement with the trend observed by Khurana (1983), but Bhatnagar and Upadhyay (1990) reported a rise in plasma T_3 level after 5 min of exercise.

During rest period of 1 h, T_4 levels decreased in buffaloes and increased in T_3 levels. Increases in plasma T_3 levels have also been reported by Khurana (1983) in Haryana bullocks, while pulling heavy loads. T_4 concentration after rest decreased to 20.26 and 36.36 ng/ml in buffaloes and 23.65 and 25.42 ng/ml in cows during summer and winter seasons. The corresponding values of T_3 were 0.49 and 0.71 ng/ml and 0.46 and 0.50 ng/ml during summer and winter seasons, respectively. These values are in agreement with the reports of Khurana (1983) and Anjuli (1988).

5.1.5.2 Insulin

The pre-work levels of insulin in present investigation were found to be 14.70 uU/ml in DNP buffaloes and higher values of 22.44 uU/ml in LNP buffaloes. The respective values in DNP and LNP cows were 14.15 and 19.18 uU/ml. The higher levels of insulin in LNP animals have been attributed to higher metabolic rates of these animals, particularly to meet the necessities of glucose turn overs for higher lactose synthetic activity for milk production. These results observed during present investigation are in agreement with Basset and Macdell (1974) who found that the concentration of insulin in plasma are positively correlated with food or energy intake.

Decreasing trend in insulin was observed in all the working groups after first work phase. The mean values of plasma insulin in DNP and LNP buffaloes were 12.15 $\pm$ 0.26 and 19.56 $\pm$ 2.55 uU/ml during summer and 14.85 $\pm$ 0.45 and 17.49 $\pm$ 0.80 uU/ml during winter respectively. The decreasing trends in insulin were most likely to regulate the energy needs for muscle to mobilize FFA from fatty acid depots. Blum and Eichinger (1988) reported a decrease in T_3 and T_4 during walking in exercising calves. Similar trend was observed in DNP and LNP cows during both the seasons. During recovery phase, insulin levels increased rapidly (Table 4.1.8.3).

5.1.6 GONADAL HORMONES

5.1.6.1 Estrogen and progesterone

Gonadal hormones, estrogen and progesterone in DNP and LNP cows and buffaloes during summer and winter at different intervals of work have been presented in Tables 4.1.8.4 and 4.1.8.5, and Figs.4.1.8.4 to 4.1.8.7.

Plasma progesterone and estrogen levels did not show any marked changes at different intervals of work and rest. The progesterone concentration during summer in LNP buffaloes and cows varied from 0.05 to 0.40 ng/ml and from 0.05 to 1.20 ng/ml, respectively. These values are in agreement with Pandey (1979), who reported the values 0.06 to 0.09 ng/ml on day 1, 2 and 0.5 to 1.35 ng/ml on day 5 to 7 of the cycle. The values $<$ 0.05 ng/ml indicate that these animals were on the day of sample in oestrus because in the same samples the plasma estrogen level varied from 12.80 to 17.07 pg/ml. The estrogen concentration in LNP buffaloes and cows are in general agreement with the values reported by Prakash and Madan (1984). Kumar and Rattan (1990) reported similar values on day 2 of the cycle. Kumar *et al.* (1991) also found similar results in Murrah buffaloes and have reported a lower level of 0.18 $\pm$ 0.03 ng/ml for estrogen and 29.91 $\pm$ 1.51 pg/ml for progesterone on the day of estrus.

During winter, estrogen and progesterone content were also not affected by work at different hours of work. The results encountered during winter are also in agreement of Doneki and Nakahara, 1977; Pandey, 1979; Kumar *et al.*, 1991; Prakash and Madan, 1984. However, no studies are available on the variation in progesterone and estrogen due to effects of work or exercise. Since these values did not exhibit any specific pattern of change in either cattle and buffaloes, therefore, the exercise may not have any specific influence on gonadal circulating hormones.

5.1.7 MILK YIELD AND ITS COMPOSITION

The average milk yields recorded during present investigation were 4.64 kg/day in LNP buffaloes and 5.73 kg/day in cows during summer season and a decrease in the milk yield was observed during summer and winter in LNP buffaloes. The decrease in the milk yield was almost similar in LNP buffaloes during summer and winter seasons. Decrease in milk yield was more prominent only at later stages of lactation. Decrease in milk yield of working animals has also been reported by Rodriquez et al,(1989). The drop in the milk yield during summer is the effect of combination of environmental temperature and work. Milk yield decrease in working weeks of animals has also been reported (Kibria, 1982; Goe, 1983; Jabbar, 1983; Mathewman *et al.*, 1988). Increase in milk yield after work period provides further evidence of a work induced change on the milk yield. These animals after work did not reach pre-work yield, mainly due to the reasons that animals were in later stages of lactation.

The protein and lactose levels of milk in DNP buffaloes were 7.91 ± 0.60 and 6.95 ± 0.47 per cent and 6.95 ± 0.47 and 4.49 per cent in cows during summer and winter seasons, respectively. Fat per cent, in general, increased to 7.91 ± 0.51 and 7.71 ± 0.39 per cent in LNP buffaloes and 4.76 ± 0.22 and 6.16 ± 0.69 per cent in LNP cows during summer and winter, respectively. The increasing trend in the fat per cent due to work has also been observed by Mathewman *et al.* (1988). During post-work period, fat per cent were almost similar to pre-work phase. The increase in fat contents could be attributed to the greater availability of FFA in blood as a result of higher sympatho-adrenal activity during work.

The pre-work mean values of milk protein during present investigation were found to be 4.30 ± 0.40 and 4.01 ± 0.21 per cent in LNP buffaloes and 3.95 ± 0.38 and 3.20 ± 0.11 per cent in LNP cows, respectively during summer and winter seasons. The protein per cent in LNP cows was found to be lower as compared to buffaloes. These results are in agreement to the results reported by Mathewman *et al.* (1988).

The lactose concentration showed a decreasing trend due to work (Table 4.1.9). Mathewman *et al.* (1988) have also reported a declining trend in milk lactose due to work. The mean pre-work values of lactose were found to be 5.05 ± 0.40 and 4.01 ± 0.21 per cent in LNP buffaloes and 3.95 ± 0.38 and 3.20 ± 0.11 per cent in LNP cows during summer and winter seasons, respectively. These values are in general agreement with the Mathewman *et al.* (1988) and Mehta (1985). During work period, milk lactose levels slightly decreased in both buffaloes and cattle. The changes in lactose content of milk may be interpreted in terms of availability of glucose for synthesis of lactose. Since some of the animals did not exhibit a decrease in glucose due to work, most likely the effects on milk lactose and fat were glucose and FFA mediated (Larsen and Smith, 1974).

5.2 CIRCADIAN RHYTHM

The mean values for RR, PR and RT in buffaloes during present investigation were 19.25 ± 1.70 breaths/min, 74.00 ± 2.58 bpm and 38.46 ± 0.10°C and the respective values in cows were 19.00 ± 3.70/min, 69.50 ± 5.12/min and 38.31 ± 0.06°C. The values encountered during present investigation in the morning are in agreement with the values reported by Sastry (1969), Rao *et al.* (1974), Acharya *et al.* (1979), Devadattam and Maurya (1978) and Upadhyay (1987). The physiological parameters remained similar at different intervals. Slight increase in the RR, PR and RT has been observed due to increase of environmental temperature and radiant heat load. No such type of work has been reported on rhythm variations in physiological reactions in cattle and buffaloes. The values during present study remained almost at a steady level and were not affected due to variations in environmental conditions.

Only minor changes in haematological parameters Hb and Hct content were seen and they were of no physiological consequences in buffaloes and cows. The Hb and Hct varied from 10.50 ± 0.31 to 11.45 ± 0.37 g per cent and 32.25 ± 0.85 to 35.00 ± 0.70 per cent in buffaloes and 10.94 ± 0.39 to 11.85 ± 0.17 g per cent and 33.10 ± 1.08 to 34.75 ± 0.85 g per cent in cows. These values are normal values for cattle and buffaloes, the variation in the Hb and Hct shows that the experimental animals were well adapted to the particular environmental conditions. Similar to the changes observed in Hb and Hct, changes in glucose and LA were also not significant at different hours during experimental period.

This study on physiological rhythm variations during experiment indicate that our experimental animals were not distressed excessively due to environmental conditions and variations in physiological reactions, energy substrates etc. have only very limited compounding effects, particularly while work.

5.3 CARTING EXPERIMENT

5.3.1 PHYSIOLOGICAL CHANGES

Dry non-pregnant cows and buffaloes were subjected to 5 qtls and 10 qtls loads in a pneumatic tyred bullock cart for monitoring recovery in physiological process. The results for the carting trials have been presented in Tables 4.3.1.1 to 4.3.4.5.

The pre-work RR of buffaloes was lower than the RR of crossbred cows, the overall mean being 15.75 breaths/min for buffaloes and 28.88 breaths/min for crossbred cows. Loads I and II increased RR to an average of 81.88 breaths/min in buffaloes, which is about 413.52 per cent increase over pre-work values. The increase in the cows during work was 102.0 breaths/min indicating an increase of 279.46 per cent over pre-work values. This increase in respiration rate was brought about to meet energy demands mainly at different levels of work. Higher RR increase in buffaloes than crossbred cows indicated that RR was influenced due to higher changes in RT during work. Different levels of work induce changes in respiratory activity not only for supply of oxygen but to maintain steady state of oxygen and carbon dioxide tension in blood. The lactate levels which often regulate pulmonary activity are likely to influence both tidal volume and respiratory frequency (Wiggers, 1955).

In ruminants, cattle and buffaloes, particularly with limited faculty of thermolysis, these pulmonary responses are likely to compensate for the inadequate faculty of sweat loss mechanisms. The decrease in RR due to rest indicated that the pulmonary system is capable of returning to pre-work levels as early as possible but the work effects accumulated in the body often do not allow quick recovery in respiratory activity. Panting under the situation when environmental heat loads are great enough as during summer and hot humid periods, often complicates the recovery process. These animals, when subjected to another work period during afternoon after 75 per cent recovery, increased some of the physiological processes further and the effects were compounded effects of both environment and work. These environmental effects were more pronounced during hot humid period and in buffaloes particularly.

Increase in pulse rate to variable levels due to loads of 5 and 10 qtls was due to different levels of sympatho-adrenal activity in animals. The effects of work in crossbreds were more pronounced than in buffaloes. Buffaloes reached a lower level of HR at similar work loads and recovery in HR even after long overnight rest periods was not complete (Fig. 4.3.1.4). When the pulse rate increase was viewed, in terms of the changes in rectal temperature (Fig. 4.3.1.4), the buffaloes increased RT to higher levels indicating a greater heat storage of work particularly after second round. When the responses in RR, RT and PR are interpreted in relation to each other, these changes are due to a coordinated action in these processes. Increase in respiratory activity in buffaloes was more predominant and cardiac response was limitedly influenced thereby indicating that blood flow to skin was not an effective heat elimination process in buffaloes, mainly due to less number of sweat glands per unit of skin surface area. As is evidenced from the values of heat stored 102.15 ± 16.37 and 103.48 ± 9.79 kJ/min in buffaloes during 5 qtls load, and 87.37 ± 11.56 and 72.17 ± 16.07 kJ/min at 10 qtls load, buffaloes stored higher heat than crossbred cows under similar conditions (Table 4.1.5.5). In order to sustain work, these animals not only required rest periods in between but after the end of the day work or after stop due to fatigue, the prolonged hours were often needed for complete recovery as is evident from the recovery curves in physiological process (Figs. 4.3.1.1, 4.3.1.2 and 4.3.1.3).

5.3.2 *HAEMATOLOGICAL CHANGES*

Changes in Hb and Hct observed during work of carting at 5 and 10 qtls are physiological effects of work as has been indicated earlier in the discussion related to the effects of ploughing on Hb and Hct. Hct and Hb changes during present study are in normal physiological ranges which returned to normal levels during rest period. Most likely these changes were effects of plasma volume expansion in these animals. During the carting work, buffaloes expanded their plasma volume to 9.57 per cent and cows to 9.74 per cent after first round of work but the plasma volume expanded to about 15 per cent after second round of work (Table 4.1.4.3). These changes in plasma volume are brought into action through aldosterone-arginine-vasopressin mechanisms to maintain fluid and electrolyte balance. Whether the induced hyper-volemia is an osmotic expansion as a result of increased retention of crystalloid within the intravascular space or an oncotic expansion as a result of increased retention of colloids is still not clear. Upadhyay (1987) also observed that plasma volume increased due to work in heat as a result of hemodilution in buffaloes and cattle. These changes in Hct, Hb and plasma volume in cattle and buffaloes are transitional. Normally working animals do not deviate their Hct and Hb content and plasma volume do not expand beyond physiological limits.

5.3.3 ENERGY SUBSTRATES AND HORMONES

The changes in blood glucose, free fatty acids and metabolic hormones together indicate that both glucose and FFA are used for muscle energy. Since intensity of work during present study was moderate and animals were not excessively disturbed. The changes in glucose and FFA levels were limited to physiological levels, and indicated that FFA is primary fuel for muscle and glucose is limitedly used by muscle. Metabolic hormonal changes during work buffaloes also support the fact that animals depend on FFA to a greater extent for energy. Decreased level of insulin in plasma at different stages, as observed, also help mobilization of FFA from fat depots and it is supported by the thyroid activity, which is reduced due to high heat content of the body. The ruminants thus react to work in different manner than humans in whom energy is derived from glucose mainly and FFA only limitedly support the energy process for muscle work.

Working animals reached to their pre-work glucose levels after about 3 to 4 h or rest and after that remained almost at the similar level which indicated that blood glucose content is not affected due to work and return to almost pre-work levels is quick. Increased lactic acid content in blood due to work indicated that anaerobic metabolic pathways were in operation for supply of energy to limited extent as values of LA increased to about 25 to 26 mg per cent only from their initial values of 12 to 13 mg per cent (Table 4.3.3.2). In the beginning of work, muscle energy is derived by anaerobic process but as pulmonary activity, and cardiovascular system is stimulated, the aerobic process takes over and energy to working muscle is supplied by aerobic process mainly. Animals working at light to moderate levels often do not increase their blood LA levels excessively. Since our animals were performing work at moderate intensities, the LA content increase was of minor significance and of no patho-physiological consequence. This observation gets support from results of second phase when increase in LA was restricted to almost similar values observed after first round of work. Experimental animals used during present investigation were trained to work prior to actual experiment, thus these animals did not produce and store enough lactic acid in their blood. Report of Martin and Teleni (1989) that the lactic acid content increase to higher levels in untrained animal could not be supported from our observation as we used trained animals. The rise in LA observed during present study did not return to pre-work levels even after 5-6 h and often it took about 20 to 24 h. This indicated that LA during hot humid periods took longer periods to return to normal.

5.3.4 STEROID HORMONE

The average progesterone levels in DNP buffaloes at loads I and II were 2.62 $\pm$ 0.61 and 1.73 $\pm$ 0.08 ng/ml and the respective values for estrogen were 9.65 $\pm$ 2.07 and 10.63 $\pm$ 1.15 pg/ml. These pre-work values showed that the experimental animals were at different stages of estrus. These progesterone values are in general agreement with Jainuddin *et al.* (1983) and Prakash and Madan (1985). The estrogen levels observed in present study are similar to reported by Prakash and Madan (1984) in buffaloes.

Kumar and Rattan (1990) have also reported similar levels of estrogen in Murrah buffaloes.

The average concentrations of estrogen in DNP cows at loads I and II respectively were 13.3 $\pm$ 0.81 and 27.05 $\pm$ 2.98 pg/ml respectively. These values are in agreement with the values reported by Bachalaus *et al.* (1978) . These values indicate that at the time of work cows were around the estrus and buffaloes were in early luteal phase.

After second phase of work, estrogen and progesterone levels remained almost at similar levels without any significant change during rest pause.

5.3.5 WORK-REST CYCLE

During present study, buffaloes worked for 1.52 $\pm$ 0.09 h on an average and cows worked for 1.32 $\pm$ 0.03 h on an average. The recovery in most physiological responses took 1 to 2 h but LA and FFA levels took longer periods to return to pre-work levels. monitoring of physiological reactions after end of work indicated that most physiological processes are able to return to pre-work levels in about 10 to 12 h. Therefore, appropriate work-rest schedule during a day for females could be work;rest:work (2:1:2 or 2:2:2) hour during hot humid season in buffaloes and cows. At comfortable environments, these animals may be able to work for prolonged hours as climatic conditions do not stress the animal to the extent the summer or hot humid conditions do. This schedule of work-rest-work will bring back the animals to the original pre-work levels. If the animals are distressed excessively or environmental conditions are stressful, animals will have to be given frequent rest pauses. If prolonged work is required from animals, they may have to be discontinued after several days of work for 1 to 2 days for complete recovery in the physiological processes.

CHAPTER 6

SUMMARY AND CONCLUSION

6.0 SUMMARY AND CONCLUSION

Apparently healthy, ten crossbred cows and ten buffaloes were selected from the herd of NDRI, Karnal for experiments. Among these, five animals were dry non-pregnant (DNP) and other five animals were lactating non-pregnant (LNP). The ploughing experiments were carried out in loam soil with a wooden plough on both the groups of buffaloes and cows during summer (hot dry) and winter (cold humid). Only DNP cows and buffaloes were used for carting experiments with 5 and 10 qtls loads during rainy (hot-humid) season. Before subjecting the animals to actual work, all animals were trained for a period of 2-3 months for ploughing and carting. The present study was aimed at exploring the possibility of use of females for work,to compare their work performance and energetic efficiency during summer and winter, and develop work:rest cylce for proper use.

6.1 PLOUGHING EXPERIMENT

Draft power, speed of work and area ploughed by these animals were measured. The width of furrow cut by the plough was 18 cm and average depth of operation was 21 cm. The average draft exerted by a pair of working animal while pulling a traditional plough is about 50 kg. Ploughing by DNP cows was performed at an average speed of 3.22 ± 0.21 km/h and by LNP cows at 3.18 ± 0.26 km/h. The speed of work in DNP buffaloes was 2.98 ± 0.14 km/h and in LNP buffaloes 2.96 ± 0.03 km/h.

The average work output of a pair of DNP and LNP buffaloes respectively was 0.49 ± 0.04 hp and 0.45 ± 0.03 hp during summer season. The performance of DNP animals in terms of work output (hp) was more than LNP buffaloes implying that the DNP buffaloes performed at higher rates than LNP buffaloes. The average speed and hp developed by the LNP buffaloes were 2.98 ± 0.08 km/h and 0.49 ± 0.01 hp during winter, the respective values for DNP buffaloes were 2.84 ± 0.13 km/h and 0.44 ± 0.02 hp during winter. The area covered by DNP cows during winter season was relatively less than their performance during summer season.

The results, obtained during summer and winter season, on DNP and LNP buffaloes and cows, showed that cows may be able to work at a higher speed than the buffaloes. The cows also developed higher output than the buffaloes. DNP buffaloes while ploughing worked at an average rate of 0.49 ± 0.04 hp and produced work energy at a rate of 165 ± 0.08 Kcal/h. and consumed TDN 3.78 ± 0.4 kg equivalent to 15128 ± 170.83 Kcal/day. Since these animals were DNP, therefore, were offered only maintenance ration and their TDN consumption was 3.78 ± 0.04 kg. These animals during winter worked at lower rates of 150 ± 7.3 Kcal and consumed energy in the form of TDN equivalent to 12576 ± 62.24 Kcal/day. The work output of LNP buffaloes during summer was 154.60 ± 3.25 Kcal and during winter was 160.8 ± 2.4 Kcal. LNP cows during summer produced work equivalent to 156 Kcal but output was higher (181.80 Kcal) during winter.

The energetic efficiency of work output was calculated from work performed and energy expended during work, as measured from the respiratory quotient (RQ), indicated that buffaloes and cows worked at an average efficiency of 20 to 28 per cent with a net energetic efficiency of about 38 $\pm$ 5.00 per cent depending on the speed and work output from individuals.

Before starting experiment and after the work trial was completed, all animals were observed for the circadian changes in physiological, haematological, bio- chemical and circulating hormone. During observations, all animals were kept under natural environmental conditions and were monitored at 2 hourly intervals for complete 24 h. No marked changes except in physiological responses were observed.

During the experiments of ploughing, it was observed that the longer the animals worked, the higher were their body temperature, heart rate and respiration rate.

The pre-work mean RR of DNP and LNP buffaloes respectively during summer were 15.40 $\pm$ 1.12 and 21.60 $\pm$ 3.90/min, the values for DNP and LNP cows were 30.00 $\pm$ 6.89 and 29.80 $\pm$ 5.65/min. The pre-work values were lower in buffaloes and cows during winter. The per cent increase after first round of work was 510.21 and 376.79 in DNP and LNP buffaloes during winter. The pre-work level of pulse rate was higher in cows than buffaloes during both summer and winter seasons. The PR increased to about 80-90 beats per minute from their resting levels in cows and buffaloes.

The rectal temperature increased over pre-work values by 2 to 3^{o}C in buffaloes and 1 to 2^{o}C in cows during summer and winter seasons. The change in body heat storage as reflected through increased RT at different hours of work indicated that during work heat was generated for which animal had to bring about physiological regulation. Different climatic conditions brought an added factor for change in thermal load. When heat loads were partitioned to eliminate effects of ambient conditions, heat storage calculated due to work effects was 53.61 ± 0.36 kJ/min in DNP cows and 102.03 ± 46.72 kJ/min in DNP buffaloes. The heat stored in DNP buffaloes was more than in DNP cows. During summer season, the respective figures for heat storage in LNP cattle and buffaloes due to work were 136.98 ± 77.78 kJ/min and 105.60 ± 33.01 kJ/min. The heat storage during winter were lower than the observed during summer in cows and buffaloes. These results indicated not only higher heat gain during work, but also poor thermolysis as compared to cows. The tongue protrusion and frothing seen in them indicated an attempt to increase evaporative losses from respiratory tract in buffaloes.

Ploughing reduced both Hb and Hct levels in DNP and LNP buffaloes and cows during summer and winter season. The plasma volume changes calculated on the basis of Hct and Hb indicated that plasma volume expand to 5.99 ± 1.10 and 6.34 ± 0.96 per cent in DNP and LNP buffaloes, respectively, during summer. The respective changes in DNP and LNP cows were 7.23 ± 1.70 and 8.97 ± 1.73 per cent. The plasma changes in DNP and LNP cows during summer were higher as compared to both groups of buffaloes.

The true blood glucose ranged from 34.56 to 48.44 mg per cent in working animals. Slight reduction in glucose concentration of cattle and buffaloes was observed due to work during summer and winter seasons. Blood glucose returned to almost normal levels after about 2 hrs. This further revealed that blood glucose is either utilized to a limited extent during exercise or that liver released glucose to blood stream from its store of glycogen.

The pre-work lactic acid levels observed during present study were 10-12 mg per cent in buffaloes and crossbreds during summer and winter.Ploughing increased the LA levels by about 100 per cent over pre-work levels after 2 h of work. Complete recovery in blood lactic acid required about 9-18 h

Ploughing resulted into a decrease in plasma insulin, increase in FFA and with only minor changes in triiodothyronine and thyroxine in buffaloes during summer and winter.The changes in glucose were not pronounced during work but free fatty acids levels increased and insulin decreased. This indicated that the FFA was probably the chief energy source for working muscle, particularly in cows and buffaloes.

Studies on circulating levels of estrogen and progesterone did not exhibit any marked changes due to work or rest. This may be because they are gonadal hormones and gonadal functions are not changed due to work effects, rather there could be negative effect on work on gonadal functions.

In general, it could be concluded that buffaloes and cows may be able to work for a period of 1 to 2 h for ploughing. Buffaloes can sustain continuous work longer than cows. However, seasons play a prominent role in limiting animal performance.

6.2 CARTING EXPERIMENT

To develop work rest cycle for working females, 4 dry non-pregnant buffaloes and cows were subjected to 5 and 10 qtls of cart loads for 3 h continuously or till fatigue which was earlier. The carting experiments were conducted during hot humid season when average maximum relative humidity and temperature were 86.33 $\pm$ 3.67 per cent and 33.53^{o} 1.23^{o}C. The average working time while pulling load 5 qtl was more in DNP buffaloes and cows than carting load of 10 qtls. The average speed was 3.08 $\pm$ 0.22 and 3.38 $\pm$ 0.11 km/h at load I and the respective speeds at load II were 2.89 $\pm$ 0.17 and 3.19 $\pm$ 0.27 km/h for buffaloes and cows, respectively.

During carting experiment at both the loads, the respiration rate, pulse rate and rectal temperature increased. Various work hours increased RR of both buffaloes and cows. The net increase in RR was higher at load 10 qtls in both of the species. The RR, PR and RT normally took about 9 to 18 h after second round of work to come back to almost pre-work levels.Haemoglobin (Hb) and haematocrit (Hct) levels decreased due to work of carting. Blood glucose decreased due to carting work and lactic acid increased. Blood glucose came back to pre-work levels after 2 h of rest. Free fatty acids increased and insulin levels decreased.The thyroxine level decreased and triiodothyronine increased during work.Gonadal hormones, estrogen and progesterone, did not exhibit any specific pattern of change during carting.

Monitoring of physiological reactions after end of work indicated that most physiological processes are able to return to pre-work levels in about 10 to 18 h. Therefore, appropriate work:rest: work schedule during a day for females could be

2:1:2 or 2:2:2 hours during hot humid seasons in buffaloes and cows. This schedule of work: rest will bring back the animal to almost the pre-work levels. At comfortable environments, the animals may be able to work for prolonged hours.If the animals are distressed excessively or environmental conditions are impinging, animals will have to be given frequent rest pauses. During a work season, if animals are used for 5-6 days continuously, they may accumulate fatigue, therefore they may have to be discontinued,after several days of work, for 1-2 days for complete recovery in their physiological and biochemical processes.

This study on females thus concludes that dry non pregnant and lactating non pregnant cows and buffaloes may be used for light to moderate work for a period of 1-2 h continuously. However work of longer durations may also be taken with a work :rest cycle of 2:2:2 or 2:1:2 under comfortable environmental conditions. If the animals are distressed excessively or environmental conditions are imp inging, animals will have to be given frequent or longer rest pauses.

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