

STUDIES ON DRAFTABILITY IN KHILLAR CATTLE

by

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(Reg.No.04/34)

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in

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2007

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**I hereby declare that this thesis or a part there of
has not been submitted previously by me
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University or Institute
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diploma**

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Dated : / / 2007

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CERTIFICATE

This is to certify that the thesis entitled, “**STUDIES ON DRAFTABILITY IN KHILLAR CATTLE**”, submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri., Dist.-Ahmednagar (Maharashtra) in partial fulfilment of the requirements for the award of degree of **DOCTOR OF PHILOSOPHY (AGRICULTURE)** in **ANIMAL SCIENCE**, embodies the results of the piece of *bona fide* research work carried out by **Shri SANDEEP RANJIT PATIL**, under my guidance and supervision and no part of the thesis has been submitted for any other degree or diploma or publication in any other form.

The assistance and help received during the course of this investigation is duly acknowledged.

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Place : M.P.K.V., Rahuri

Dated : / / 2007

(A. S. Jadhav)

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“No work is done by a man alone.

The path is Visible when a path is shown”

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LIST OF ABBREVIATIONS

AN	:	Afternoon
DAP	:	Draft animal power
T x S x D	:	Type X Season X Duration
b.wt.	:	Body weight
BT/RT	:	Body temperature i.e. rectal temperature
BL	:	Body length (distance from point of shoulder to pin bone)
CD	:	Critical difference
Cm	:	Centimeter
⁰ C	:	Degree centigrade
df	:	Degree of freedom
⁰ F	:	Degree Fahrenheit
Fig	:	Figure
g.	:	Gram
gm%	:	Gram per cent
ha	:	Hectare
hp	:	Horse power
HR	:	Heart rate i.e. no. of heart beats/min
Hb	:	Haemoglobin
kg	:	Kilogram
km/hr	:	Kilometer per hour
K	:	Distance
m.	:	Meter
m ² /hr	:	Meter square per hour
mg%	:	Milligram per cent
min	:	Minute
MSS	:	Mean Sum of Squares
Nm	:	Nanometer
O ₂	:	Oxygen
PR	:	Pulse rate (nos. per min)
Qtl.	:	Quintal
RR	:	Respiration rate (nos./min)
SE	:	Standard error

ABSTRACT

“STUDIES ON DRAFTABILITY IN KHILLAR CATTLE.”

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Department : Animal Science and Dairy Science

The research work on draftability of Khillar bullocks was undertaken at Central Sugarcane Research Institute, Padegaon and farmers field at Ajande, Dhule districts.

Two healthy pairs, each of Pandharpuri Khillar, Kosa Khillar and Tapi Khillar were selected for the study. Four field operations viz., ploughing, sowing, harrowing, hoeing and carting performed by six pairs of bullocks were performed during three seasons separately viz ; summer, rainy and winter. The physiological observations were recorded according to the method given by Miller and Robertson (1959). Viz., respiration rate (per min), body temperature ($^{\circ}\text{F}$), pulse rate (per min). The haematological indices Viz. haemoglobin, glucose and lactic acid were recorded. The work performance were observed in terms of draft, speed, horse power and area covered.

The average RR, BT and PR in Khillar bullocks during ploughing were 41.19 beats/min, 101.63 $^{\circ}\text{F}$ and 75.98 beats/min, respectively. The significant ($P < 0.05$) variations in RR, BT and PR were observed in Pandharpuri, Kosa and Tapi Khillar. The decreasing trend in Hb and glucose were observed however, lactic acid level increased after ploughing. The overall mean for draft, speed, hp and area covered were 142.73 kg, 3.06 km/hr, 1.68 hp and 346.27 m^2/hr , respectively. The significant ($P < 0.01$) effect of type of Khillar were observed on their draft, speed, hp and area covered after ploughing.

The average RR, BT and PR in Khillar bullocks during sowing were 39.29 beats/min, 101.42 $^{\circ}\text{F}$ and 73.66 beats/min, respectively. The significant ($P < 0.05$) variations in RR, BT and PR were observed due to Pandharpuri, Kosa and Tapi type Khillar. The decreasing trend in Hb and glucose were observed but lactic acid were

increased after sowing. The overall mean for draft, speed, hp and area covered were 70.66 kg, 3.57 km/hr, 0.94 hp and 1099.77 m²/hr, respectively. The significant ($P < 0.01$) effect of type of Khillar were observed on draft, speed, hp and area covered after sowing operation.

The average RR, BT and PR in Khillar bullocks after harrowing operation were 38.15 beats/min, 101.49 °F and 72.70 beats/min, respectively. The significant ($P < 0.05$) variations in RR, BT and PR were observed due to Pandharpuri, Kosa and Tapi type Khillar. The decreasing trend in Hb and glucose were observed but lactic acid were increased after harrowing. The overall mean for draft, speed, hp and area covered were 59.57 kg, 3.58 km/hr, 0.79 hp and 1192.41 m²/hr, respectively. The significant ($P < 0.05$) effect of type of Khillar were observed on draft, speed, hp and area covered after harrowing operation.

The average RR, BT and PR in Khillar bullocks during hoeing were 37.66 beats/min, 101.25 °F and 69.89 beats/min, respectively. The significant ($P < 0.05$) variations in RR, BT and PR were observed due to Pandharpuri, Kosa and Tapi type Khillar. The decreasing trend in Hb and glucose were observed but lactic acid were increased after hoeing operation. The overall mean for draft, speed, hp and area covered were 42.34 kg, 3.77 km/hr, 0.59 hp and 1242.40 m²/hr, respectively. The significant ($P < 0.01$) effect of type of Khillar were observed on draft, speed, hp after hoeing.

The average RR, BT and PR in Khillar bullocks during carting were 37.22 beats/min, 101.18 °F and 67.84 beats/min, respectively. The significant ($P < 0.05$) variations in RR, BT and PR were observed in Pandharpuri, Kosa and Tapi Khillar. The decreasing trend in Hb and glucose were observed but lactic acid were increased after carting. The overall mean for speed were 4.19 km/hr. The significant ($P < 0.05$) effect were observed in speed in Pandharpuri, Kosa and Tapi Khillar during carting.

Amongst Pandharpuri, Kosa and Tapi type Khillar the time required to reach the fatigue stage was maximum in Kosa indicating its well adaptability in scarcity area.

1. INTRODUCTION

The importance of livestock is based on their production of milk and work in India. Bullocks are the major source of power for cultivating land and carting in rural area. In general, males are preferred for farm work i.e. ploughing, carting, tillage and other allied jobs and in rare cases females are used for such work. The utility of these animals vary to the great extent, depending on socio-economic status of farmer and farm size (Singh and Upadhyay, 1997^a).

The term draft refers to an act of moving load by drawing or force required to pull an implement. In India draft animal power (DAP) will continue to be the source of energy for many years to come, for agricultural operations and transportation of farm produce. Draught animal power is a classical example of large-scale application of appropriate technology concept to millions of small, marginal and medium farmers for cultivation of agricultural land and small-scale transportation. The draft power of animals has still remained a pivotal force in developing country like India. About 54.6% of farmers have below one hectare land, who can hardly offer a pair or even a single bullock. Further, even an average tractor owner maintains 1.66 draft animal as he can not totally dispense with them.

The agricultural land holding in most of states in India is smaller or marginal. The average size of holding is 1.6 ha. with 79% of holdings below 1.3 ha. Indian farmers have been dependent on draught animal power. In some areas due to unevenness of the soil, mechanization for agricultural operations is rather difficult. In such circumstances, use of bullocks is only alternative for draft work and agricultural operations. However, it has been observed that animals are used indiscriminately without giving consideration to the draft power capacity of these animals. It results into either over loading the animals beyond their capacity (Cruelty to animals) or under utilization of their draft power (wasting of energy). Numerically, India possesses the largest cattle population in the world. Though, the draft cattle are the largest contributors of farm power in our country, the

research carried out to make best use of them is very little. Vaugh (1947) reported that the bullocks developed drafts equivalent to 1/5 to 1/6 of their body weight. He showed that the maximum pull the bullocks could exert varied from 49.5 to 60.5% of their body weight.

Draft animal power (DAP) is the muscle power of animals used for harnessing of implements and rotary work. Modern agriculture is an energy intensive industry. Draught animal power is used for crop production and transportation. India possesses famous draught breeds of cattle such as Nagori, Khillar, Dangi, Helikar, Amrit Mahal, Kangayam and Malvi.

It is estimated that 67 per cent of energy input in the farming enterprise comes from animal sources. 23 per cent from human exertion and remaining 10 per cent from fossils. (Dayal, 1982). With regards to transportation, 68 per cent of good are handled by bullocks cart, 20 per cent as hand loads. 8 per cent by truck and tractor-trailer and 4 per cent by other means like cycle, boats, buses and jeep etc, (Ramaswamy *et al.*, 1982). These finding amply justify the importance of animal power in agriculture and transportation of goods in India.

India possesses 85 millions draft animals consisting of 72 million bullocks, 7.5 millions male buffaloes, 3.2 million horses and camel and remaining 2.3 million she buffaloes and 0.3 million cows. (Singh and Upadhyay, 1997^b). All these contribute to about 70% of the total energy in the farm and the rural transport. The energy contribution is estimated in the tune of 40,000 M.W. of electric power or 5 crore horse power (A bullock =0.6 H.P.) Five pairs of bullocks can put same power as putforth by tractor (Modi, 1997). The population of draught animals declined from 80.8 million in 1971-72 to about 67.55 million in 2001. The power availability too declined from 20.2 mkW to 19.4 mkW. The share of coverage of net cropped area is more by draught animal (54.3%) than tractors (19.2%) during 1996-97.

In spite of the above facts, in many areas of the world, full use is not yet made of animal power. It is estimated in Africa that high rate of increasing power

inputs up to a level of 0.4 KW per hectare, corresponding to a crop yield of 2.5 ton per ha. In this country one adult works about half hectare of land providing a power input of 0.1 KW per hectare (Inns, 1980) on this background, one pair of bullocks is being utilized for about 4 hectare of cropped area in our country (Raut 1982). Naturally, these inputs may hamper the crop yields of our country. It is therefore, necessary to harness our animal energy more effectively and popularize amongst Indian farmers. However, the application of increasing power inputs in Indian farming may not be feasible as the farms are becoming smaller in size with the progressive land litigations and division of family ownership. It is therefore essential to enhance the draft capacity of animals rather than increasing the number in order to elevate the power inputs. Because, nowadays the maintenance cost of working animal is very high. It is observed that the maintenance cost works out to rupees 52 to 61 per working day. (Reddy and Rastogi 1985). Providing gainful employment to the bullocks through improved dry land technology can reduce this cost.

Many species are used for draught purpose in India. The most common species are cattle, buffalo, horses, mules, donkeys, camels, elephants and yak. Average daily performance depends on species, rate and type of work and geographical location.

Maharashtra is the rich state in the biodiversity of draft animals. The region specific predominant draft breeds of Maharashtra are Khillar (Western region), Dangi (Konkan region), Gaolao (Vidarbha region), Red Kandhari and Deoni (Marathwada region), all these breeds are sturdy and can thrive well under low quality roughages and considerable draft power is generated through these draft breeds. The animal draft power is the prerequisite for Indian agriculture. Because the mechanization is not possible due to undulating land, small fragmented land, waterlogged land and small and marginal land holding (The average size of farm holding in India is 1.57 ha with 79 per cent farm holder having farm size of 1.34 ha). Prices of fuel and Kaccha road under these constraints animal draft power are

the only alternative for agricultural operations and transportation on the farm. However, very scanty information is available about the draft potential of Khillar breed and its contribution in agricultural operations and transportation in Maharashtra.

“Khillar” means a herd of cattle and the herdsman is known as “Khillari” or “Thillari”. Khillar bullocks are highly valued as fast paced, powerful, draught animals throughout the state of Maharashtra. Cows are poor milk yielders and mostly used for nursing their calves. Well fed animals attain maturity at the age of 14 to 15 months. The home tract of Khillar breed is the Sangli, Satara, Solapur and Satpura range of Khandesh (Dhule districts) of Maharashtra State. The breeding tract of Khillar bullocks at Junoni, Dist. Solapur in Maharashtra and Belgam, Bijapur, Dharwar, Gadag and Haveri in Karnataka.

Considering the major operations in the field including rural transport are performed by Khillar bullocks in this region a study of draft generation of these bullocks in relation to their physiological, haematological and draft capacity were undertaken in the breeding tract of Khillar breed at different locations with following objectives:

1. To study the draftability of Khillar cattle
2. To study the physiological indices and hematological traits
3. To study the comparative performance of Khillar cattle for draft performance at different locations.

2. REVIEW OF LITERATURE

Many developing countries in Asia and Africa still depend essentially on draught animal power for agricultural operations and rural transport. Draught animal power has been extensively used for crop production and rural transportation. India possessed the most famous draught breeds in the world. These breeds are Nagori, Khillar, Halikar, Amrit Mahal, Kangayam, Malvi, Haryana, Dangi, Gaolao, Deoni and Red Kandhari. Bullocks over 3 years old are the main source of draft animals for field operations. The population of draught animals has been declined from 80.75 million in 1971-72 to about 77.69 million in 1991-92 and is estimated as 77.13 million in 1996-97. In Maharashtra, all the cattle breeds have been developed for draft purpose. In spite of the importance of draught animal less is known about the draft capacity of Khillar bullocks, though some research findings are on record. Therefore, an attempt has been made to review the available literature on working capacity of different draught cattle breeds in foregoing pages.

2.1 Agriculture operation

Very scanty literature is available on the work capacity of Khillar bullocks. Some experiments were carried out at the Haryana Agricultural University, Hissar, with respect to physiological indices and changes in some blood attributes in response to pulling exercise. However, available literature on bullocks in response to exercise is reviewed as follows:

2.1.1 Physiological indices

(Respiration rate, body temperature and pulse rate)

Bhosrekar *et al.* (1966) worked on draft power of Tharparkar and Sahiwal bullocks and reported that respiration rate during humid season and autumn season as 101.9 ± 0.54 and 102.1 ± 0.39 , 101.8 ± 0.49 and 102.5 ± 0.80 , respectively. The respiration rate in both the breeds increased during ploughing in humid season

than autumn season. There seems to be no breed to breed differences in the respiration rate during different seasons.

Singh *et al.* (1968^a) used eight Haryana bullocks to study their physiological responses while working with three common agricultural implements viz, disc plough, harrow and cultivator. They reported that the pulse rate, respiration rate and body temperature of bullocks increased significantly during period of work. The increase in the respiration rate was mostly marked during disc ploughing followed by cultivating and harrowing. Whereas the increased pulse rate returned to normal within half an hour of completion of agricultural operations. The significant fall in pulse rate and temperature was observed after completion of the operations.

Rowell *et al.* (1969) reported that the blood flow increase through skin due to vasodilatation of sub cutaneous blood vessels during exercise was met by increasing cardiac output and achieved mainly by increase in heart rate.

Singh *et al.* (1970) reported the per cent rise in respiration rate, pulse rate and temperature during at 1st and 2nd hour as 66.42 and 81.02, 8.62 and 13.10 and 0.89 and 1.29, respectively. During the harrowing it was 51.02 and 59.18, 12.47 and 15.50 and 0.79 and 1.19, respectively. The decline in the pulse rate during disc ploughing and disc harrowing was significantly faster in Sahiwal bullocks than in Haryana. They recommended suitability of Sahiwal bullocks for interrupted farm operations where speed is not an important factor.

Sastry *et al.* (1970) studied the responses of pulse rate, respiration rate and rectal temperature in Brown Swiss x Sahiwal (F1) and Sahiwal bullocks during ploughing in winter and autumn seasons. All the three physiological reactions were found increasing progressively with increase of exercise and then fall gradually to the normal level of resting. The rise and fall in pulse and respiration rates after first half hour of exercise and rest period were generally very sharp. Body temperature on the other hand, tended to rise after about one hour of

ploughing. The pulse rate of bullocks reached peak value by 1 and 1 1/2 of exercise by which time the crossbreds had a steady increase in pulse rate.

Roy *et al.* (1972) conducted three different trials of ploughing with local country plough for 10 days period. They reported the higher magnitude of difference in body temperature, pulse rate and respiration rate in crossbreds than in Hariyana bullocks.

Rao *et al.* (1973) studied the draftability in Jersey x Sahiwal crossbred bullocks. They observed rise in pulse rate and respiration rate of crossbreds without distress symptoms even after continuous work during hot dry season (summer).

Bhutani and Nangia (1976) reported that increase in heart rate was the main contributing particular for the increase in cardiac output during exercise.

Acharya *et al.* (1979) compared the working capacity and behaviour of F₁ crossbred (Holstein × Hariyana) and non-descript indigenous bullocks during ploughing in rainy season. The respiration rate, during initial and at an interval of 1st, 2nd, 3rd and 4th hour in crossbred and indigenous cattle were 30.0 ± 0.82, 54.5 ± 3.30, 58.0 ± 2.25, 69.0 ± 2.33 and 73.5 ± 3.81 and 26.0 ± 1.00, 42.5 ± 3.39, 45.3 ± 4.26, 50.5 ± 3.89 and 60.5 ± 3.74, pulse rate were 62.5 ± 0.96, 90.5 ± 3.40, 99.0 ± 2.05, 103.5 ± 2.23, 106.0 ± 3.70 and 58.0 ± 1.41, 75.0 ± 3.66, 82.0 ± 5.34, 93.5 ± 3.59, 102.5 ± 3.46 and body temperature were 101.3 ± 0.26, 101.5 ± 0.26, 101.8 ± 0.28, 102.2 ± 0.36, 102.6 ± 0.48 and 101.2 ± 0.39, 101.8 ± 0.26, 101.8 ± 0.29, 102.1 ± 0.13 and 102.3 ± 1.92, respectively. The corresponding values for respiration rate during winter season were 23.5 ± 1.71, 35.0 ± 5.22, 40.0 ± 4.08, 44.0 ± 4.30 and 48.0 ± 3.36 and 20.5 ± 0.96, 29.5 ± 4.11, 33.0 ± 4.26, 36.5 ± 3.44 and 41.5 ± 3.35, pulse rate were 62.0 ± 1.47, 67.0 ± 1.73, 72.0 ± 3.12, 74.0 ± 3.42, 82.0 ± 3.63 and 60.0 ± 0.82, 65.5 ± 2.50, 69.0 ± 3.32, 74.0 ± 3.82, 79.0 ± 2.76 and body temperature were 100.10 ± 0.24, 101.0 ± 0.09, 101.4 ± 0.15, 101.9 ± 0.33 and 102.0 ± 0.44, 101.1 ± 0.06, 100.9 ± 0.09, 101.4 ± 0.26, 101.5 ± 0.26 and 101.9

± 0.13 , respectively. The respiration rate during summer season were 35.0 ± 2.38 , 56.5 ± 2.10 , 75.0 ± 3.54 , 82.5 ± 2.54 and 84.5 ± 4.68 and 32.8 ± 1.68 , 47.0 ± 2.21 , 56.5 ± 2.87 , 67.0 ± 3.24 and 68.0 ± 4.96 , pulse rate were 66.0 ± 2.45 , 92.5 ± 5.56 , 95.5 ± 3.25 , 106.0 ± 3.42 , 108.0 ± 3.08 and 60.5 ± 1.26 , 66.5 ± 1.50 , 78.0 ± 2.39 , 89.0 ± 2.14 , 95.5 ± 2.02 and body temperature were 100.8 ± 0.22 , 101.2 ± 1.50 , 101.5 ± 0.48 , 101.9 ± 1.50 and 102.2 ± 0.29 , 100.6 ± 0.22 , 101.2 ± 0.16 , 101.5 ± 0.22 , 101.9 ± 0.13 and 101.9 ± 0.05 , respectively.

Rautaray and Srivastava (1982) observed that during tillage operation in summer the respiration rate, pulse rate, and body temperature of bullocks increased with increase in working time. The respiration and pulse rate, however, increased sharply after two hours of work at higher draft level. At higher level of pulse rate and respiration rates, the bullocks developed various physical distress symptoms indicating the stage of onset of fatigue. During forenoon shift, when the ambient temperature increased the relative humidity decreased, the pulse and respiration rate of bullocks were found rapidly increasing at all the levels of draft. However during the 6th and 7th hour of working when an ambient temperature was decreasing and relative humidity was increasing, the pulse and respiration rates of bullocks were found to increase at a slower rate. The body temperature varied from 38.78 to 40.0°C . The recovery of pulse, respiration rate and body temperature of the bullocks were noticeable within one hour of the rest period. The study indicated that the ambient condition had a direct influence on the physiological parameters, which ultimately affected the work performance of bullocks in the field.

Nagpaul *et al.* (1984) compared the performance of crossbred and zebu cattle bullocks during carting and ploughing operations. The zebu and crossbred bullock pairs in summer and winter seasons were put to work continuously for four hours. They noticed a steady increase in pulse and respiration rates and body temperature in zebu as well as in crossbred bullocks. The increase was pronounced

in crossbred than zebu bullocks. The behaviour responses such as panting, dribbling of saliva and shelter seeking tendency during operation in summer and winter seasons were noted in crossbred bullocks and not in zebu cattle.

Belsare (1984) conducted the experiment on harrowing operation in Gir crossbred bullocks. He noted that in crossbred cattle the body temperature, respiration rate and pulse rate differed significantly between the start and end of harrowing operation. The pulse rate and respiration rate increased significantly ($p < 0.01$) in all the exercising bullocks. The respiration rate of bullocks at the end of two hours work increased to 29.042 beats/min from initial value of 28.458 beats/min, respectively. He indicated that the increase in the rectal temperature was 1.721°C in crossbred bullocks from initial to the end of 2 hours. The increase in heat production might be the result of muscle contraction during exercise. Whereas the increase in pulse and respiration rate might be attributed to fulfill the increased demand of oxygen required during exercise.

Abhayankar (1986) studied the impact of resting period on ploughing work of crossbred bullocks under dry hot climate condition of Vidharbha. He observed that all the physiological reactions i.e. body temperature, pulse rate and respiration rate increased during the ploughing operation. The absolute increase in respiration rate and pulse rate in T1 (A pair of crossbred bullocks was out to plough for 6 hours with an intermediate rest of 15 minutes after every hour of work), T2 (A pair of crossbred bullocks was made to plough for 6 hours with an intermediate rest of 15 minutes after every two hours of work), T3 (A pair of crossbred bullocks was out to plough for 6 hours with an intermediate rest of 15 minutes after three hour of work) and T4 (A pair of crossbred bullocks was made to plough continuously till exhaust without any intermediate rest to determine the maximum work performance) working period was 12.60 and 9.76, 16.43 and 11.04, 23.25 and 16.68, 48.50 and 26.5 beats/ min respectively.

Bhagat (1986) reported that the rectal temperature ($^{\circ}\text{C}$), respiration rate and pulse rate per minute were increased from 38.04 to 39.9, 20.91 to 53.66 and 46.91 to 64.62, respectively after 3 hrs of harrowing in crossbred bullocks.

Bhosrekar and Mangurakar (1989) studied the efficiency of ploughing operation in HF crossbred, Jersey crossbred and local bullocks. They reported rise in rectal temperature, pulse rate and respiration rates in all breeds under ploughing operation. The rise was found to be higher in HF crossbred bullocks than in Jersey crossbred and local bullocks.

Sreekumar and Thomas (1990) reported the respiration rate, pulse rate and body temperature in Kangayam bullocks in summer before and after ploughing as 22.51 ± 0.18 and 87.68 ± 0.56 , 51.68 ± 0.31 and 77.66 ± 0.77 , 38.42 ± 0.009 and 39.59 ± 0.02 , respectively. The corresponding values in crossbred bullocks (Jersey x Red Sindhi) were 24.70 ± 0.22 and 97.44 ± 0.29 , 54.81 ± 0.37 and 87.14 ± 0.55 and 38.68 ± 0.02 and 39.85 ± 0.012 , respectively. The respiration rate, pulse rate and body temperature in crossbred bullocks before work were significantly ($P < 0.05$) higher than that of indigenous bullocks. The physiological parameters significantly ($P < 0.05$) increased due to work in indigenous and crossbred bullocks.

Chhanwal (1990) studied the draft efficiency of crossbred bullocks. He observed that the body temperature of crossbred bullocks increased by 1.721°C after two hours of harrowing work in summer. Crossbred bullocks exhibited increase in respiration rate from 28.458 beats / min to 29.042 beats/ min. at the end of two hours work. These differences were significant. The rise in pulse rate was from 66.916 to 90.020 beats/ min in crossbred bullocks.

Patil *et al.* (1994) studied the draft performance of Deoni and HF x Deoni (F1) bullocks by subjecting them to ploughing and harrowing. The trials were conducted at 8.00 a.m. and continued without break for 3 hours. They observed non-significant differences between initial and final values of RT and PR of the

bullocks during both the field operations. The RT and PR during before and after ploughing and harrowing in Deoni were 98.3 and 106.6, 98.6 and 106.0 and 50 and 80, 44 and 76 and in HF x Deoni were 99.0 and 103.2, 98.0 and 102.8 ($^{\circ}\text{F}$) and 44 and 96, 52 and 96, respectively. However, significant differences in pulse rate were observed for temporary period, which regained to normal soon after the end of work. The workers inferred that the cross- bred (HF x Deoni) could efficiently be yoked for ploughing and harrowing at an ambient temperature of $< 35^{\circ}\text{C}$.

Anil and Thomas (1996) reported that before and after ploughing the respiration rate, pulse rate and rectal temperature in Kangayam bullocks were 16.15 ± 0.50 and 62.20 ± 3.91 beats/min, 62.65 ± 0.47 and 93.05 ± 0.20 beats/min and 100.46 ± 0.07 and 103.01 ± 0.29 $^{\circ}\text{F}$ and the corresponding values in buffalo were 14.55 ± 0.63 and 107.05 ± 2.12 beats/min, 61.05 ± 0.64 and 97.70 ± 2.00 beats/min and 100.32 ± 0.09 and 105.62 ± 0.19 $^{\circ}\text{F}$, respectively. They reported that in Kangayam bullocks the RR, PR and RT significantly increased due to work. The bullocks did not return to their normal physiological condition even after a rest of 1 hour of the work.

Soetanto *et al.* (1996) studied effect of exercise on physiological condition of Madura cattle. They carried out ploughing operation in dry land recorded the physiological conditions i.e. respiratory rate, heartbeat and rectal temperature at beginning, mid and last period of exercise. They reported that the load applied at 11 per cent of body weight for two hours exercise appeared to be too heavy for Madura cattle. The respiratory rate, heart beat and rectal temperature of Madura bullocks during ploughing increased significantly ($P < 0.05$).

Bijendrakumar *et al.* (1996) conducted an experiment on ploughing in 4 Haryana and 2 crossbred bullocks at Haryana Agricultural University, Hissar during winter and summer. They noticed the significant ($P < 0.01$) effect of season (SN), breed group, draft levels (D) and period (hrs of work, p) on RR, RT and PR. The average pre-exercise pulse rate of Haryana and crossbred bullocks was

55.79±0.78 beats/min and 70.25 ± 1.09 beats/ min which increased after 3 hours of exercise to 84.21 ± 2.51 beats/min and 110.04 ± 14.47 beats/min, respectively. The respiration rate during the pre- exercise period was higher in crossbred than in Hariana bullocks which increased from 30.78 ± 1.01 beats/ min to 81.87 ± 5.03 beats/ min and from 20.54 ± 0.54 beats/ min to 44.87 ± 2.7 beats/ min in crossbred and Hariana bullocks, respectively. Mean pre-exercise rectal temperature observed in crossbred and Hariana bullocks was 101.27 ± 0.06 °F and 100.80 ± 0.06 °F after 3 hours of exercise, which rose by 2.87 and 2.51°F in crossbred and Hariana bullocks, respectively. They indicated that the Hariana bullocks exhibited superiority in ploughing over the crossbreds. The crossbred bullocks required > 2 hrs rest after work (ploughing) to attain pre-work physiological status especially during summer

Dhangar (1999) reported that over all respiration rates per min. and body temp. of the bullocks during harrowing were 31.20 and 101.50 in Kankrej and 35.80 and 101.77 °F in crossbreds. The magnitude of increase was 66.13, 32.70 and 0.81 % in respiration rate and 0.61, 0.42 and 0.26% in body temperature during 1st, 2nd, and 3rd hour of work, respectively. Respiration rate during summer was higher by 13.24 and 12.99/min and body temperature by 0.9 and 1.20 °F during morning and afternoon session as compared to winter. The respiration rate of crossbreeds averaged 52.13/min of pre work and increased significantly by 26.98, 47.18 and 51.91 per min at 1,2,3 hour over pre-work (52.13/min) leading to a total rise of 99.58%.

Anonymous (2004) reported that the respiration rate in Gaolao and non-descript cattle during ploughing at initial and at an interval of 1st hr., 2nd hr., and after 3rd hr was 13.57 ± 0.23, 16.53 ± 0.26, 20.86 ± 0.33, 26.22 ± 0.35 and 13.86 ± 0.22, 17.95 ± 0.32, 24.32 ± 0.53, 30.86 ± 0.53, respectively. The corresponding values of body temperature were 100.9 ± 0.07, 101.47 ± 0.06, 101.91 ± 0.08, 102.34 ± 0.09 and 100.83 ± 0.09, 101.39 ± 0.07, 102.05 ± 0.08, 102.54 ± 0.05.

The pulse rate was 47.38 ± 0.81 , 51.72 ± 0.89 , 58.39 ± 0.74 , 63.89 ± 0.81 and 48.41 ± 0.83 , 54.04 ± 0.97 , 59.44 ± 1.05 , 64.30 ± 1.09 , respectively.

Anonymous (2004) observed that the respiration rate in Gaolao and non-descript cattle during sowing at interval initial and at an interval of 1st hr., 2nd hr., and 3rd hr were 13.57 ± 0.23 , 16.53 ± 0.26 , 20.86 ± 0.33 , 26.22 ± 0.35 and 13.86 ± 0.21 , 17.95 ± 0.32 , 24.32 ± 0.53 , 30.86 ± 0.53 beats/min, respectively. The corresponding values of body temperature were 100.9 ± 0.08 , 101.5 ± 0.10 , 101.61 ± 0.14 , 102.17 ± 0.09 and 100.83 ± 0.09 , 101.28 ± 0.08 , 101.65 ± 0.06 , 102.16 ± 0.06 °F. The pulse rate were 47.37 ± 0.81 , 51.06 ± 0.78 , 54.38 ± 0.71 , 58.78 ± 0.65 and 48.41 ± 0.83 , 52.69 ± 0.89 , 57.05 ± 0.95 , 61.83 ± 0.84 beats/min, respectively.

Anonymous (2004) reported that the respiration rate in Gaolao and non-descript cattle during harrowing at interval initial and at an interval of 1st hr., 2nd hr., and 3rd hr were 14.02 ± 0.15 , 16.69 ± 0.18 , 20.20 ± 0.18 , 23.88 ± 0.17 and 13.47 ± 0.11 , 17.37 ± 0.18 , 20.39 ± 0.25 , 23.86 ± 0.25 beats/min, respectively. The corresponding values of body temperature were 100.98 ± 0.09 , 101.37 ± 0.03 , 101.79 ± 0.04 , 102.27 ± 0.03 and 101.02 ± 0.05 , 101.52 ± 0.03 , 101.84 ± 0.02 , 102.30 ± 0.01 °F. The pulse rate were 46.44 ± 0.78 , 49.95 ± 0.72 , 52.69 ± 0.76 , $57.81 \pm 0.0.83$ and 48.06 ± 0.83 , 53.03 ± 0.79 , 57.61 ± 0.89 , 63.50 ± 0.86 beats/min, respectively.

2.1.2. Haematological parameters

The literature on the effect of muscular exercise on the blood picture of working ruminant is rather meager. Quite substantial amount of work has been carried out on race horses and human athletes. However, the work done so far on the hematological and biochemical parameters of working animals subjected to exercise has been reviewed hereunder:

2.1.2.a Haemoglobin

Mukherjee *et al.* (1961) studied draft capacity of Haryana bullocks and recorded that the per cent haemoglobin decreased in response to exercise in winter season, while it increased during rainy season.

Sastry (1969) studied the hematological responses of crossbred F1 (Brown Swiss x Sahiwal) and Sahiwal bullocks during ploughing test of two hours duration and subsequent rest of two hours in winter and autumn seasons. Haemoglobin concentration tended to fall after one hour of exercise and remained stable upto the end of second hour of exercise in case of Sahiwal bullocks. But in the case of crossbred, it tended to rise appreciably after one hour of exercise and then declined slightly by the end of second hour of exercise period in both seasons. The responses of haemoglobin levels in blood in two breeds were at par with each other. In crossbreds, the increased demand of O₂ enhanced the concentration of haemoglobin during work, while in Sahiwal, the concentration of haemoglobin gone down with exercise.

Rao *et al.* (1974) found a significant decrease in hemoglobin in crossbred bullocks (Jersey x Sahiwal) after the performance of exercise. Hence, they proved that during hot-dry months crossbred bullocks need rest after 2 hours of work, if they are to work during hotter part of the day.

Tripathi *et al.* (1978) found in healthy bulls, decreases in haemoglobin at high environmental temperature during exercise.

Singh *et al.* (1980) studied blood cellular constituents in relation to workload in buffalo during kharif season. The haemoglobin level before and after 3 hr. of work were 13.13 ± 0.55 and 11.35 ± 0.86 (g%). They observed significant decrease in the haemoglobin immediately after exercise.

Gattewar (1983) reported that the haemoglobin concentration in crossbred bullocks (HF x Haryana) increased from 10.60 to 10.93 (mg%) during harrowing.

Upadhyay and Madan (1988^b) reported that a little change in haemoglobin concentration of 0.42 to 0.56 mg% over a pre-work level in Haryana bullocks

during ploughing. The haemoglobin level at 0 hr, 1st, 2nd, and 3rd hr were 10.9, 10.5, 10.5 and 10.4 gm%, respectively.

Upadhyay and Madan (1988^a) reported decreased haemoglobin levels in crossbred and Haryana bullocks. The summer season was associated with a greater decline (from 11.4 to 10.5 gm%) than either hot humid (11.5 to 11.0 gm%) or winter (10.0 to 9.6 gm%).

Sreekumar and Thomas (1990^b) reported that the haemoglobin level in Kangayam and crossbred bullocks (Jersey x Red Sindhi) before and after work in dry land during hot humid climate. The Hb level during ploughing were 12.16 ± 0.14 and 11.00 ± 0.09 (gm%), 11.75 ± 0.13 and 10.28 ± 0.12 (gm%), respectively. In both the genetic groups the haemoglobin level decreased significantly ($P < 0.05$) after 4 hours of ploughing.

Chhikara and Singh (2000) studied the haematological parameters in crossbred bullocks at NDRI, Karnal and reported the overall mean of pre exercise haemoglobin (Hb) levels as 10.86 ± 0.22 gm per cent. The Hb level of bullocks declined to 9.91 ± 0.19 after one hour of work. This difference in Hb level before and after exercise was significant ($P < 0.01$).

Yawalikar (2000) reported the haemoglobin (gm%) level before and after ploughing operation during Kharif in Red Kandhari, Deoni, and Deoni X HF as 10.05 and 10.59, 9.07 and 10.12 and 10.44, 11.02, respectively. The corresponding values during summer were 10.10 and 10.76, 10.00 and 10.56 and 10.62 and 11.13, respectively. The haemoglobin (gm%) level before and after sowing operation during Kharif were 10.02 and 10.42, 10.05 and 10.43 and 10.42, 10.82, in Red Kandhari, Deoni and Deoni X HF respectively. The corresponding values during summer were 10.05 and 10.43, 10.10 and 10.52 and 10.55 and 11.01 (g%), respectively.

2.1.2.b. Blood Glucose

Georgie *et al.* (1970) reported that the exercise in steers caused a significant drop in blood glucose in 1st hour of exercise, but no further significant difference was observed during 2nd hour in crossbred and Sahiwal bullocks.

Upadhyay and Madan (1988^a) studied the blood acid base status and muscle metabolism in HF x Haryana bullocks and found that blood glucose (40.3 to 40.7 mg %) did not change significantly over continuous working.

Upadhyay and Madan (1988^b) reported that the glucose concentration before work was different in Haryana and crossbred bullocks during ploughing. The mean pre-work level of glucose was higher among Haryana (41.4 mg%) than crossbreds (39.2 mg%). Seasonal condition also had no significant effect on glucose level while working continuously.

Patil (1990) conducted study on draftability in HF x Deoni and Deoni bullocks. They carried ploughing and harrowing operation during February in black cotton soil for 3 hours from 8 am and reported that the alteration in blood glucose level could be associated with alteration of the substrate as a source of energy required for muscular activity and as a result of efficient homeostatic mechanism for glucose.

Singh and Upadhyay (1995) reported that the slight reduction in blood glucose concentration was observed due to work.

Dhangar (1999) reported that the level of glucose during ploughing in Kankrej bullocks at pre-work was 55.62 ± 1.83 mg% in summer and 54.97 ± 1.35 mg% in winter. They indicate that Kankrej bullocks the physiological work caused a significant decline (6.4 to 10.5 mg%) in blood glucose concentration during summer at all work.

Yawalikar (2000) worked on haematological studies in various indigenous and crossbred bullocks. They reported decreased glucose (mg%) level from before to after ploughing operation during Kharif in Red Kandhari, Deoni and Deoni X HF were 52.00 to 46.40, 54.10 to 48.12 and 56.12 to 48.94, respectively. Where as, in sowing operation the blood glucose (mg%) level decreased from before to

after sowing operation as 51.15 to 47.13, 53.00 to 48.57 and 55.12 to 49.52, respectively.

Chhikara and Singh (2000) carried out exercise in Haryana crossbred bullocks during summer (February to April) season at NDRI, Karnal. They concluded that in crossbred cattle the mean pre exercise blood glucose level decreased significantly ($P < 0.01$) from 56.94 ± 4.45 to 52.71 ± 1.99 mg per cent after one hour of work. Glucose served as a major source of fuel during exercise.

2.1.2.c. Lactic acid

Beninati (1957) who observed fatigue in the cattle caused due to constant haemoconcentration and rise in the blood lactic acid level because of muscular work. The level of lactic acid gradually decreased during the rest period.

Upadhyay and Madan (1988^b) found that continuous work caused increased lactic acid levels in blood during the first hour (13.0 to 17.0 mg %) of work in different seasons during ploughing in Haryana bullocks.

Sreekumar and Thomas (1990^b) conducted that the study on haematological changes due to work in Kangayam and crossbred bullocks. They observed that the lactic acid levels before and after work in indigenous and crossbred bullocks were 27.70 ± 0.12 and 39.37 ± 0.20 , 29.83 ± 0.31 and 40.72 ± 0.18 , respectively. They indicated that the lactic acid level in blood did not returned to pre exercise level even after 1 hr of rest and showed gradual decline, and also reported the lactic acid content of blood significantly ($P < 0.05$) higher in crossbred bullocks (Jersey x Red Sindhi) than indigenous bullocks during ploughing.

Singh and Upadhyay (1995) concluded that the blood lactic acid increased due to work almost double over pre work values during summer and winter and the increase was slightly significant ($P < 0.01$) in lactic acid due to anaerobic muscular activity at commencement of work with low availability of oxygen but after adaptation of oxygen transport system and better capillarization of muscle,

the energy demand of muscle was covered by anaerobic process and the lactic acid gradually comes down and work was often continued.

Singh and Upadhyay (1996) reported an average increase in lactic acid of 20.7 mg% and 23.05 mg% over pre-work in Haryana and HF X Haryana cross bred bullocks and of 18.3 mg% and 21.4 mg% over initial in crossbred draft cows.

Dhangar (1999) studied the comparative draftability power in Kankrej and crossbred bullocks and reported that the ploughing operation caused a significant decline in blood lactic acid to greater extent during summer. The magnitude of change increased with increase in intensity of work. The rise in lactic acid at L₃ (46.70 vs 32.78 mg%) and L₄ (75.69 vs 47.20 mg%) over pre work was almost 1.5 times during summer as compared to winter.

Chhikara and Singh (2000) studied haematological parameters during exercise in Haryana crossbred bullocks. They indicated that the lactic acid increased significantly ($P < 0.01$) from pre exercise level of 8.61 ± 1.21 to 8.71 ± 0.93 mg per cent in crossbred bullocks. They revealed that the increase in lactic acid content of blood indicate the energy requirement of actively working tissue during walking was met by both anaerobic and aerobic oxidation.

Yawalikar (2000) reported increased lactic acid (gm%) level from before to after ploughing operation during Kharif in Red Kandhari (5.73 to 8.62), Deoni (5.60 to 8.43) HF x Deoni (6.84 to 9.69) bullocks, respectively. The corresponding values of lactic acid during summer season were 5.87 to 8.83, 7.50 to 8.59 and 6.88 to 9.80, respectively.

2.1.3. Draftability

2.1.3.a. Draft

The draft performance of bullocks largely depends upon animal size, weight and conformation of the body, leg co- ordination, body structure qualities related to work. Strong and healthy bullocks have more potentiality to work i.e.

they can draw more draft and can work for a longer period of time without losing their efficiency.

Vaugh (1947) reported that the indigenous bullocks could develop the draft equivalent to $1/5$ to $1/6$ of their body weight, while the bullocks could exert the maximum pull which varied from 49.5 to 60.5 per cent of their body weight.

Swamy Rao (1954) reported that the Haryana crossbred bullocks developed draft varying from 14.5 to 24.5 per cent of their body weight with the best type harness.

Devadattam and Maurya (1978) studied draftability of Haryana bullocks at different loads varying from 52 to 175 kg under different atmospheric conditions. The draft pulled by the bullocks increased at a slower rate with in power output. They concluded that an average pair of Haryana bullocks could develop the optimum draft of 60 kg. A pair of bullocks of a total body weight 812.5 kg was subjected to pull 58.90, 63.50 and 82.50 kg draft in loading cart on hard soil for 3 kms. They concluded that an average pair of Haryana bullocks could develop the optimum draft of 60 kilogram. The draft pulled by the bullocks increased at a slower rate with increase in power output. They concluded that the power output of the bullocks decreased with increase in the duration of work. The decrement being faster in case of higher drafts due to a steep fall in the speed.

Maurya (1982) tested crossbred (Jersey x Red Sindhi) and local (Khillari) bullocks in response to carting exercise for a period of 6 hours with half hour rest after first 3 hours of testing during summer and winter seasons. The draft produced by Jersey x Red Sindhi and Khillar bullocks during summer and winter was of 66.50, 85.00, 123.50 and 152.00 kilogram, respectively. He further noted that the draft developed by crossbred bullocks varied from 11 to 18 per cent of their body weight.

Upadhyay and Madan (1982^a) evaluated the draft performance of Haryana and HF x Haryana crossbred bullocks by using hydraulic dynamometer attached to single bullocks pneumatic tyre cart, under hot-dry, hot-humid and cold-dry

climatic conditions for 5 q and 10 q pay-load in cart over a continued 3 hours of work. They recorded the mean pull value of 57 kg at 1000 kg payload.

Maurya and Devadattam (1982^a) evaluated work performance of two Jersey x Red Sindhi bullocks of 7 years of age having 460-494 kg; body weight. Each bullock was tested individually on pulling various drafts viz. 54.00, 58.25, 73.25 and 83.75 kg in wooden wheeled cart on hard ground in 2 phases each of 3 hours to a total of 6 hrs in a day. They reported that there was appreciable reduction in the work output on increased testing time. However, the fluctuations in draft capacity were more during hot weather as compared to cooler one.

Gattewar (1983) studied the working capacity and behaviour of crossbred vs zebu bullocks during harrowing. He found that the crossbred bullocks pulled a higher draft (64.45 kg) as compared to Harijana bullocks (66.61 kg) during harrowing. The draft pulled by the bullocks significantly ($P < 0.01$) affected by breed and season of work.

Rautaray and Srivastava (1983) studied the performance of Red Dane x Sahiwal crossbred bullocks during tillage in winter season under different draft conditions. They concluded that the bullocks had developed 184.4 kg draft (12.9% of body weight). They observed that Red Dane x Sahiwal crossbred bullocks during 7 hour continuous ploughing in summer season, could developed 134.4 kilogram draft. This value was corresponding to 12.9 per cent of the body weight of the bullocks. The maximum draft developed was 360.5 kilogram for a short period, which corresponded to 25.3 per cent of the body weight of the bullocks. The power and work output of bullocks decreased with an increase in working time in a prolonged operation.

Ranjan (1983) reported that the average weight of bullocks ranged from 500 to 900 kg developed draft of 60 to 80 kg at a speed of 0.6 to 0.8 meter per second.

Belsare (1991) found that the draft developed was 66.4 ± 0.64 , 107 ± 0.89 and 153.2 ± 1.14 kg in crossbred bullocks. The corresponding values in

indigenous bullocks were 60.1 ± 0.89 , 94.3 ± 0.69 and 129.4 ± 1.05 kg at an initial stage of transportation for empty cart i.e. 0 kg, 200 kg and 400 kg loads, respectively in the middle stage after transporting 200 and 400 kg loads over one kilometer distance, the draft developed was 65.4 ± 0.64 , 105.41 ± 0.85 and 151.8 ± 1.10 kg and 59.00 ± 0.77 , 92.8 ± 0.66 and 127.7 ± 0.84 kg in crossbred and indigenous bullocks, respectively. The values of draft developed while transporting over a distance of two kilometers in crossbred and indigenous bullocks were 64.4 ± 0.56 , 104.2 ± 0.79 and 150.7 ± 1.06 and 58.0 ± 0.71 , 91.2 ± 1.18 and 126.2 ± 1.98 kg for empty cart i.e. 0, 200 and 400 kg loads, respectively.

Abhayankar (1986) observed that the draft pulled by crossbred bullocks were 176.14, 199.55, 186.32 and 186.21 kg in one, two, three hours work and till exhaust with an average of 187.06, while studying impact of resting periods on ploughing work under dry hot climatic condition of Vidarbha region. The draft pulled by the crossbred bullocks corresponded to 20.99 per cent of body weight of bullocks. Moreover, the crossbred bullocks from two hours working interval pulled significantly more draft than rest of the period.

Bhagat (1986) reported the average draft pulled by bullocks (Sahiwal x Jersey) F₁ crossbred bullocks in summer season were 67.985, 68.63 and 68.17 kg draft in P₁ (15 minutes rest after every two hours), P₂ (15 minutes rest after every 3 hours) and P₃ (continuous work without rest), respectively during harrowing.

Gattewar *et al.* (1989) studied working capacity and behaviour of crossbred bullocks (F₁ x Zebu bullocks). They used two pairs of bullocks, one in each genetic group (HF x Haryana) for two hours harrowing operation with single action disc harrow with a constant speed during three different seasons. They reported that the Haryana and crossbred bullocks pulled a draft of 66.61 kg and 64.45 Kg., respectively. The draft pulled by bullocks in winter, hot humid and summer season, was 57.16, 67.64 and 62.80 Kg respectively.

Chhanwal (1990) studied the draft efficiency of crossbred (Jersey x Sahiwal) and buffalo bullocks during harrowing in dry hot season and reported the

draft pulled by crossbred bullocks (45.86 ± 1.79 kg) were significantly higher than the buffalo bullocks (41.41 ± 1.79 kg).

Bora *et al.* (1994) investigated draftability of Assam local and jersey x Assam local crossbred bullocks. The bullocks were put to cart with 600, 800 and 1000 kg payloads during winter as well as summer seasons. The pull exerted varied from 63.65 to 109.25 kg in Assam local and 70.80 to 114.94 kg in Jersey x local bullocks. Irrespective of load and season, pulling force and hp produced increased with increase in load imposed. Significant difference ($P < 0.05$) was observed in pull exerted and hp production due to breed group, load and working time.

Singh and Upadhyay (1997^b) reported the average draft (Kg) produced by dry non-pregnant and lactating non-pregnant buffalo were 22.0 ± 0.01 and 22.3 ± 0.1 Kg during ploughing operation in summer season.

Dhanger (1999) reported that Kankrej bullocks produced significantly higher (2.24 kg) draft while ploughing but during planking crossbred bullocks had 0.77 kg higher draft than Kankrej. The body weight showed positive association with draft generation and hp out put.

Dhangar *et al.* (2000) studied the draftability of pure Kankrej and Jersey x Kankrej bullocks during ploughing. They reported the overall draft generated per pair of bullocks as 59.94 ± 0.16 kg. The draft produced while ploughing averaged 79.96 ± 0.39 kg / pair.

Yawalikar (2000) reported the draft generated in summer for Red Kandhari 66.80, Deoni 76.20 and HF x Deoni 83.80 kg the corresponding values in kharif were 68.60, 78.00 and 84.60, respectively, during ploughing operation. The draft developed during sowing in summer were 55.80, 65.00 and 66.20 kg and in kharif were 58.00, 69.60 and 71.20 kg, respectively.

2.1.3.b. Speed

Singh *et al.* (1970) compared the performance of Sahiwal and Haryana bullocks during various agricultural operations in winter season and recommended suitability of Sahiwal bullocks for interrupted farm operations where speed is not an important factor after considering the rate of return of pulse rate normal and speed of the bullocks. The average speed of the Sahiwal bullocks was 2.21, 1.98 and 2.21 km per hour during disc ploughing, harrowing and tillage operations.

Roy *et al.* (1972) compared the performance of Haryana and Jersey x Haryana crossbred bullocks at Central Livestock Research cum Breeding Station, Haringhatta. Ploughing was conducted for 2 hours for 6 days in wet land (standing water of 1 to 2 feet with average temperature of 26.33° C and periodical rains with high humidity) vs two days on dry soil (with optimum moisture) the average efficiency of Haryana and crossbred bullocks was 0.053 and 0.068 ha/hr while ploughing on wet land and 0.036 and 0.044 ha/hr on dry land respectively. This was attributed to bigger size and higher speed in the case of crossbred bullocks under both the conditions.

Devadattam and Maurya (1978) studied the draftability of Haryana bullocks at Agricultural Engineering Institute, Raichur (Karnataka). A pair of bullocks of a total body weight of 812.5 kg was subjected to loading cart on hard soil and tar macadam surfaces for 3 km. They observed that the optimum value of speed for an average Haryana pair was 3.8 km / hr.

Acharya *et al.* (1979) studied comparative working capacity of crossbred (Holstein x Haryana) and non descript indigenous bullocks during ploughing operation in different seasons under Orissa conditions and revealed that the crossbred bullocks were found to be superior over indigenous bullocks. The crossbred bullocks exhibited more stamina, higher speed and greater capacity for work. They observed 51.50 ± 1.50 , 44.80 ± 0.48 , 42.50 ± 1.50 , 39.50 ± 2.10 meters/ min. speed in the case of crossbred bullocks as against 46.50 ± 1.9 , 42.50 ± 1.04 , 38.00 ± 1.22 , 34.80 ± 1.38 meters / min. speed in case of indigenous

bullocks during first, second, third and fourth hour of ploughing, respectively during summer season.

The workers from ICRISAT, Patancharu, India (Anonymous, 1979-80) studied the work performance of Hallikar bullocks of different body sizes in terms of speed on function of body size, draft, duration of work and climate for four pairs of bullocks having body weight of 370, 390, 431 and 550 kg, respectively were selected for pulling a fixed load on a wheeled tool carrier on a smooth road in cool, hot and hot humid season. They observed that the speed of the bullock declined linearly over passage of time. The larger animals walk slightly faster than smaller ones. The speed of the animals reduced from 3.42 to 2.6 km/hr during 6 hrs of exercise; it was also decreased with exercise when the draft decreased from 49 to 103 kg, i.e. an increase of 120 % rate of speed by about 12 %. There was a little difference in physiological responses of the cattle at two different speeds of exercise. This might have been due to the fact that during the test at the faster speed, air temperature was slightly lower and air movement was also greater. These workers suggested that superiority of Santa Gertrudis in walking ability over Herefords might be partly due to their higher heat tolerance and partly to a lower heat production during exercise. The latter one might be possible because of longer stride took while walking.

Premi (1979) reported that Hallikar bullocks could pull the maximum drafts of 13 to 16 per cent of their body weight during six hours of work when the animal yoked in Pairs. The Hallikar bullocks could work with an average speed of 3 km/hr during six hours continuous exercise. The speed increased with increase in body weight. The performance was better in cold season followed by hot humid and hot seasons. The speed of the bullocks decreased with the duration of work. During 6 hours of work the decrease in speed was one fourth of the initial speed.

Garg *et al.* (1981) used six healthy male calves of Murrah buffalo of one year old weighing 80 - 135 kg to study the physiological reactions in response to exercise. Each animal was made to pull a stone roller weighing 80 kg at a constant

speed of about 3 km per hour along an elliptical path of 100 meters outlined on even ground for 3 hours continuously at monthly intervals from August to April.

Rautaray and Srivastava (1982) carried out the field performance of crossbred (Red Dane x Sahiwal) bullocks in black soil during tillage operation in summer season. They found that the crossbred bullocks could negotiate 134.4 kg draft within the speed limit of 2.55 to 1.77 km/hr during seven hours continuous ploughing work in a day in summer season. This value was corresponding to 12.9 per cent of the body weight of the bullocks.

Upadhyay and Madan (1982^a) studied the work performance of Haryana and crossbred bullocks (Holstein x Haryana) of 5 to 7 years age during summer season. Single animal pneumatic tired bullock cart was used and the animals were driven at their normal speed of walking 3-4 miles per hour for 3 hours subjected to two loads of 5 to 10 quintals in addition to the weight of the cart i.e. 360 kg $\pm$ 60 kg of driver. The authors concluded that the crossbred bullocks could be comparable to Haryana bullocks under hot summer condition, provided crossbreds put to heavy loads for a short duration of work i.e. for one or two hours of work. Haryana bullocks travelled faster as compared to crossbred bullocks during first hour of exercise in different climatic conditions but during subsequent hours of walking and carting exercise, Haryana travelled less but crossbred travelled almost at the same speed observed in first hour of work. The reduction in the speed was marked in Haryana while pulling the load but crossbred travelled at almost similar speed.

Upadhyay and Madan (1982^b) compared draft performance of crossbred Haryana under different climatic condition in response to 3 hr working and carting exercise. Haryana bullocks travelled faster as compared to crossbred during first hour. But during subsequent hours of working and carting, Haryana travelled less but crossbred travelled almost at the same speed observed in first hour of work. The reduction the speed was marked in Haryana while pulling the load but crossbred travelled at almost similar speed.

Singh *et al.* (1982) studied draught capacity in twelve male buffalo calves of three years old from September to October. The animals pulled a stoneroller for 3 hours at the speed of 3 km/ hr along an elliptical path of 100 meters outlined on even kachha ground. Maurya (1982^b) reported very little drop in the speed of crossbred (Jersey x Red Sindhi) bullocks with increase in draft.

Gattewar (1983) observed that an average speed decreased from 3.14 to 2.53 km/hr and 2.90 to 2.33 km/hr in crossbred and Haryana bullocks respectively in response to two hours harrowing exercise.

Belsare (1984) reported that crossbred bullocks exhibited significantly higher (3.498 ± 0.237 km/hr) working speed than buffalo bullocks (3.258 ± 0.138 km/hr) during harrowing operation.

Rao and Upadhyay (1984) studied work performance of crossbred bullocks and observed that the bullocks carrying 4, 6 and 8 quintals load travelled at an average speed of 4.5, 4.3 and 3.9 km/hr. During pulling loads, heavier loads reduced speed of walking but the work done in terms of horse power was more. They concluded that during summer and hot-humid seasons, when temperature and humidity limits the performance of bullocks, the duration of ploughing and carting should not exceed over 2 hours, if continuous work output was desired and rest after every 2 hours was essential in order to perform optimum work and without harmful effect on animal.

Rautaray (1985) studied the output of a pair of bullocks during tillage operation in summer. It was observed that the average power output decreased with the increase in working time for all the draft conditions and similar was the trend in the case of crossbreds; Malvi and local bullocks also because of fall in working speed with time.

Abhayankar (1986) reported the working speed of crossbred bullocks during ploughing operation were 2.31 to 2.54, 2.39 to 2.51, 2.21 to 2.43, 2.31 to 2.35 kmph in T₁ (15 min rest after every hour of work), T₂ (15 min rest after every two hours of work), T₃ (15 min rest after every three hours of rest) and T₄

(without any intermediate rest to determine the maximum work performance) resting working period, respectively.

Bhagat (1986) reported that the average speed of the buffaloes was accelerated from 2.848 to 2.917 km/hr by feeding concentrate to adjust 20 percent more DCP in 3 hours harrowing.

Upadhyay and Madan (1987) studied four Haryana and four crossbred bullocks (Holstein x Haryana) for assessing the work performance, speed, draft and work output in horse power in carting operations. It was observed that none of the Haryana or crossbred bullocks could pull 2.0 tone of load. The 1.5 tone load was pulled by all Haryana and crossbred bullocks at different speeds. The 0.5 tone load was pulled easily. The average speed at which Haryana bullocks were able to walk freely varied from 4.5 to 6.0 km / hour compared to crossbreds, which were able to move at the speed of 4.5 to 4.8 km/ hour. Heavy loading of Haryana bullocks reduced their speed remarkably. However, the crossbreds carried load almost at the same speed as that of walking.

Gattewar *et al.* (1989) reported draft performance and working capacity of Haryana and crossbred bullocks (H.F x Haryana) by subjecting the animals to a harrowing operation for two hours in different seasons with bullock drawn single action harrow. It was observed that crossbred bullocks had higher speed during the operation as compared to Haryana bullocks. At the end of half hour operation, the average speed for crossbred was 3.14 km/hr at the end of 2 major operations, as against 2.90 km/hr in Haryana, while decreased to 2.3 km/hr. The rate of decrease in speed in both the breeds was almost similar. The bullocks exhibited greater speed during operation in winter followed by hot- humid and summer season. There was decrease in the speed of bullocks with increased duration of operation in all exercises.

Chhanwal (1990) studied the draft efficiency of Purnathadi buffaloes males and crossbred bullocks during the harrowing in summer season observed that the speed of the bullocks significantly decreased from 3.491 ± 0.247 km/hr in morning

shift to 3.265 ± 0.132 km/hr in afternoon shift. Crossbred bullocks exhibited significant (3.498 ± 0.237 km/hr) higher working speed than buffalo males (3.258 ± 0.138 km/hr). This might be due to species specific difference.

Belsare (1991) compared the work production of crossbred and indigenous bullocks by subjecting them to pull a cart with 0, 200 and 400 kg load for 2 km on farm road. The speed of carting was higher in indigenous bullocks in comparison to crossbred ones. Average speed for 0, 200 and 400 kg load was found as 6.54, 5.34 and 4.40 km/hr in indigenous and 6.20, 5.02 and 4.10 km / hr in crossbred bullocks, respectively. Thus, with increase in load, speed of the work reduced.

Udhan (1991) studied the comparative draftability of crossbred (HF x Deoni) and Deoni bullocks and reported that with the increase in load, the speed of the bullocks decreased gradually, it might be due to extra load added move muscular exertion the differences in speed at the three pair were non significant counteractive between load and pair was found non significant Deoni and cross breed speed of bullocks performed similar. When bullock yoked to different load showed increase in horse power and decrease in speed for lesser load, lesser will be the horse power. Crossbred and Deoni cattle pairs can sustain a load of 12.4 qts with a normal speed of 3.8 km per hour on a plain tar road.

Agarwal (1992) found that the speed of carting with pneumatic tyred cart was greater by 0.81 km/hr in Haryana and 0.71 km./ hr in crossbred bullocks as compared to wooden wheeled cart (5.58 and 5.26 km / hr)

Agarwal and Agarwal (1992) studied the draft power of 4 Haryana steers and 4 Haraina x Jersey and Haryana x Holstein steers. The animal pulled a cart with different payloads (0 - 2000kg) and the pulling power was measured with dynamometer. The speed declined from 9 km per hr for 0 kg payload to 4 km per hr for 2000 kg payload. The payload pulling power of Haryana bullocks ranged from 5.5 to 21 % of body wt. The corresponding values for crossbreds were 4.5-20%, They further indicated non-significant differences in crossbreds and Haryana bullocks.

Madan Lal (1996) reported that Nagori bullocks haul at the speed of 4.09 to 4.78 km/hr when subjected to cartload of 806-833 kg on evaluating the draft performance of Haryana and Exotic x Haryana crossbred bullocks under wooden wheeled and pneumatic tyred cart with a payload of 500 kg.

Singh and Upadhyay (1997^b) reported the average speed during ploughing in dry non-pregnant and lactating non-pregnant cow and buffalo in summer as 57 ± 5.0 , 49 ± 3.5 and 52 ± 3.6 , 49 ± 0.01 m/min, respectively. The corresponding values during winter season were 50 ± 2.2 , 51 ± 3.8 and 47 ± 2.0 , 49 ± 1.0 m/min., respectively.

Dhangar (1999) studied the comparative draftability power of Knakrej and crossbred bullocks and observed that the speed of crossbred bullocks tugged the cart speedily by 8.09% than Kankrej bullocks (4.14 VS 3.83 km/hr). The work during summer and afternoon resulted in a significant decline by 0.18 and 0.14 km/hr as compared to winter and morning, respectively. The reduction in carting speed during 1st, 2nd and 3rd hour was to the magnitude of 0.35, 0.26 and 0.24 km/hr, respectively. During summer also the crossbred could cart at a greater speed and had a lower in carting speed during summer than in Kankrej when compared with winter observation (0.23 VS 0.12 km/hr). During agricultural operation in Kankrej and crossbred bullocks, average speed was 3.41 and 3.74 km/hr, respectively. Over the period the speed of walking decline to the tune of 0.17, 0.16, and 0.19 km/hr over previous speed. During the third period the walking speed reduced double in magnitude in crossbreds than in Kankrej (0.25 vs 0.12 km/hr).

Yawalikar (2000) reported values of speed during ploughing in Kharif as 2.624 (Red Kandhari), 2.704 (Deoni) and 2.742 km/hr (HF x Deoni). The corresponding values during summer were 2.618, 2.676 and 2.640 km/hr, respectively. The speed during sowing in kharif and summer season were 2.716 and 2.688, 2.742 and 2.712 and 2.766 and 2.740 km/hr in Red Kandhari, Deoni and HF x Deoni, respectively.

Dhanagar *et al.*, (2000) reported the speed during ploughing in Kankrej and crossbreds as 3.41 and 3.74 km/hr, respectively.

Bhoite *et al.*, (2005) reported normal speed for different animal as 2.8 to 3.3, 2.0 to 3.0, 2.5 and 3.6 Km/hr, in bullocks, buffalo, cow and Horse, respectively.

2.1.3.c Horse power

Singh *et al.* (1968^a) studied the work performance and physiological responses of Hariana and Sahiwal bullocks performing common agricultural operations. The horse power developed by Hariana bullocks during tillage with cultivator, disc ploughing, and harrowing were 0.743, 0.803 and 0.974, respectively. The corresponding values for Sahiwal bullocks were 0.703, 0.837 and 0.627. The Hariana bullock developed significantly ($P < 0.01$) greater hp than Sahiwal bullocks. The breed difference was attributed to faster speed of Hariana bullocks as compared to Sahiwal.

Singh *et al.* (1970) compared the work performance of Sahiwal and Hariana bullocks during various agricultural operations. The average horse power generated by Sahiwal bullocks was 0.337, 0.627 and 0.703 during disc ploughing, harrowing and tilling operations, respectively. The horse power developed by Sahiwal during harrowing was significantly lower than those of Hariana bullocks.

Devadattam and Maurya (1978) studied draft ability of Hariana bullocks at different draft loads between 52 to 175 kg under various atmospheric conditions. They observed that the power output of the bullocks decreased with increase in the duration of testing period, the decrement being faster in the case of higher drafts due to a steep fall in speed. The optimum value of power for an average Hariana bullock pair was found to be 0.85hp.

Premi (1979) reported that the Hallikar bullocks could pull maximum draft of 13 to 16 per cent of the body weight during six hours of work. The Hallikar bullocks could generate an average horse power and work output of 0.91 and 5.53

hp/hr/pair, in six hours of continuous work, respectively. The power and work output of the bullocks depended upon the body weight, hours of work, draft and climate. When the draft increased, power and work output also increased with increase in body weight. The work output of the bullocks increased at the rate of 1.57 hp pair on every 100 kg increase in average body weight of the animal. The power generated was higher in cold followed by warm, humid and hot climate. The rate of power developed decreased with the duration of work. During six hours work, the power decreased to one fourth of the initial.

Maurya and Devadattam (1982^b) reported that the hp output of Haryana bullocks increased with increase in draft and reversed with ambient temperature. The average hp developed by the bullocks was the highest (1.046) and most uniform at 83.75 kg draft and 27.90°C ambient temperature. They opined that a draft of 80 kg/bullock was found optimum to get a fairly uniform and maximum output of 0.995 hp at maximum possible speed of 3.35 km / hr.

Rautaray and Srivastva (1982) carried out the field performance of crossbred (Red Dane x Sahiwal) bullocks in black soil during tillage operation in summer season. They noted that crossbred bullocks developed a power output equivalent to 1.7 to 1.9 hp during 7 hours continuous ploughing in a day in summer season. The power and work output of bullocks decreased with an increase in working time in a prolonged operation.

Upadhyay and Madan (1982^a) compared the work performance of Haryana and crossbred (Holstein x Haryana) bullocks for three hours continuous work in summer season. They observed that the horse power developed by crossbred bullocks during first hour of work was 0.52 while during second and third hour, it was 0.35 hp was developed. Haryana bullocks generated 0.60, 0.45 and 0.34 hp during first, second and third hour of work, respectively when draftload of 5 quintals was imposed. Under draft of 10 quintals, crossbred bullocks developed 0.95 and 0.71 hp during first and second hours of work. Haryana bullocks generated 0.93, 0.72 and 0.62 hp. During summer the Haryana bullocks could work

for three hours continuously but crossbred bullocks were fatigued by the end of two hours of exercise. The horsepower generated by crossbred bullocks was slightly higher than Hariana bullocks when the higher draft load was imposed.

Gattewar (1983) observed a significant decrease from 0.75 to 0.60 and 0.65 to 0.52 hp developed in crossbred and Hariana bullocks, respectively in two hours harrowing exercise. In hot- dry season, a significant decrease in horsepower developed were 0.68 to 0.54 and 0.54 and 0.57 to 0.47 in crossbred and Hariana bullocks, respectively.

Ranjan (1983) reported that an average weight of bullocks ranged from 500 to 900 kg generated 0.75 horse power during work.

Belsare (1984) observed that an average hp developed by crossbred bullocks was higher than the indigenous bullocks. An average horsepower developed at the initial stage of transportation for empty cart i.e. 0 kg, 200 kg and 400 kg loads were 1.49 ± 0.013 , 1.96 ± 0.017 , and 2.32 ± 0.015 in crossbred bullocks and in indigenous bullocks it were 1.42 ± 0.020 , 1.79 ± 0.015 and 2.04 ± 0.015 . An average horse power developed in middle stage after transportation over 1 km distance for 0,200 and 400 kg loads were 1.46 ± 0.013 , 1.92 ± 0.016 and 2.96 ± 0.015 in crossbred bullocks and in indigenous bullocks, the values were 1.46 ± 0.019 , 1.74 ± 0.014 and 2.0 ± 0.012 , respectively. An average horsepower developed in final stage after transportation over two kilometer distance for 0, 200 and 400 kg loads were 1.45 ± 0.148 , 1.9 ± 0.016 and 2.27 ± 0.015 in crossbred bullocks and in the case of indigenous bullocks, the values were 1.37 ± 0.018 , 1.73 ± 0.013 and 1.98 ± 0.012 , respectively.

Rautaray (1985) observed that an average power output decreased with the increase in working time for all the draft conditions and similar was the trend in the case for crossbred and local breed of bullocks. An average power output values were 1.42, 0.75 and 0.64 horse power for crossbred, Malvi and local breed of bullocks, respectively. Similarly with mould board plough, the average power output values were 1.48, 0.77 and 0.66 hp for crossbred, Malvi and local breed of

bullocks, respectively. At higher draft values although the power output was increased the bullocks could work only for shorter duration in a continuous operation and seven hours of work in a day was not possible.

Upadhyaya and Madan (1985^a) studied draft performance and efficiency of Haryana crossbred bullocks in hot-dry, hot-humid and cold-dry seasons with different draft loads and over continued hours of work and concluded that the heavy loads were pulled efficiently though at allowed speed than lighter loads at a higher speed. Under draft of 10 quintals, crossbred developed 0.95 and 0.71 horse power during first and second hours of work. Haryana bullocks generated 0.93, 0.72, and 0.62 horse power. During summer the Haryana bullocks could work for three hours continuously but crossbred bullocks were fatigued by the end of two hours of exercise. The horse power generated by crossbred bullocks was slightly higher than Haryana bullocks when the higher draft load was imposed. Therefore, the performance of crossbred bullocks could be comparable to those of Haryana bullocks when subjected to heavy load for a short duration of work i.e. for two hours of work.

Upadhyay and Madan (1985^b) reported that on an average Haryana bullocks developed greater horse power (0.515) than crossbred (0.43). More over the crossbreds got fatigued during hot and hot humid months after the second hour. The horse power developed by Haryana bullocks was equivalent to 0.32 during the first hour of work. During second hour of work, horse power reduced with maximum reduction of 19.31 per cent in hot humid conditions. The crossbred bullocks pulling cart developed 0.23 to 0.27 hp depending upon climatic conditions. The output remained same during second hour but decreased at third hour. The Haryana bullocks while pulling load (5 quintals) worked equivalent to 0.56 hp to 0.60 hp during first hour. The corresponding power output in crossbred bullocks varied from 0.47 to 0.53 hp.

Bhagat (1986) reported the horse power output from 0.735 to 0.789 during harrowing operation.

Abhayankar (1986) studied the impact of resting period on ploughing work of crossbred bullocks under dry hot climate conditions of Vidarbha. Power generation in 2 hr resting period was significantly higher (1.97hp) than 1 hours resting period (1.48 to 1.66 hp)

Bhoserkar and Mangurkar (1989) studied crossbred and local bullocks for carting on different road conditions with varying loads and found that the draft and horse power developed for farm, metal and tar road were 1.43, 1.25 and 1.36 hp for 1t load, by all pairs were almost equal except in local bullocks; the speed and power output marginally was higher as compared to crossbred bullocks.

Chhanwal (1990) reported that the crossbred bullocks generated significantly higher (0.549 ± 0.024 hp) horse power than that of buffalo bullocks (0.414 ± 0.021 hp) during harrowing operation.

Singh and Upadhyay (1997^b) compared the draftability of buffaloes and crossbred cows during summer and winter. The ploughing was carried out in loam soil with a wooden plough and traditional double neck yoke. The average horsepower (hp) developed by crossbred cows was 0.54 ± 0.05 in the summer and 0.52 ± 0.12 in the winter; corresponding values for buffaloes were 0.47 ± 0.04 and 0.47 ± 0.12 . They revealed that the average horsepower developed by crossbred cows during summer and winter were (57 ± 0.04 , 49 ± 0.21) comparatively higher than buffaloes (49 ± 0.04 and 44 ± 0.22 hp) developed in summer was higher than in winter in both crossbred cows and buffaloes.

Dhangar (1999) reported that the crossbred bullocks generated significantly higher horsepower than Kankraj during summer as compared to winter and in afternoon over morning. The increase in horsepower production with increase in payload was higher during winter as compared to summer. The crossbred bullocks had significantly higher horsepower production as compared to Kankrej (0.83 vs 0.77). As compared to Kankrej crossbred bullocks produced 6.49 and 10.53 per cent higher horsepower during morning and afternoon, respectively. The

horsepower produced during summer was 0.04 in Kankrej and 0.04 in crossbred bullocks when compared with the value recorded during winter.

Dhangar *et al.* (2000) reported that the hp produced by Kankrej bullocks during ploughing were 1.07 ± 0.02 hp.

Yawalikar (2000) reported the horsepower generated during ploughing in summer and kharif season in Red Kandhari, Deoni and HF x Deoni bullocks were 0.640, 0.738 and 0.712 and 0.662, 0.748 and 0.802, respectively. The corresponding value during sowing operation were 0.604, 0.726, 0.762 and 0.570, 0.674 and 0.700, respectively.

2.1.3.d. Area covered

Roy *et al.* (1972) compared the performance of Haryana and Jersey x Haryana crossbred bullocks at Central Livestock Research cum Breeding Station, Haringhatta. Ploughings were conducted for 2 hours for 6 days in wet land (standing water of 1 to 2 feet with average temperature of 26.33 °C and periodical rains with high humidity) vs. two days on dry soil (with optimum moisture). The average efficiency of Haryana and crossbred bullocks was 0.053 and 0.068 ha/ hr, for ploughing on wetland and 0.036 and 0.044 ha/hr on dry land, respectively. Thus, the area covered by crossbred bullocks was 25.56 % higher in comparison to Haryana. This was attributed to bigger size and higher speed in the case of crossbred bullocks under both the conditions.

Anand and Sundaresan (1974) compared ploughing capacity of crossbred and Haryana bullocks during 6 hours of working in different seasons and revealed that Haryana ploughed more area during the same period and seasons than the crossbred bullocks. The area ploughed in square meters was 2970, 2860 and 2440 by crossbred bullocks during winter, summer rainy season, respectively, whereas Haryana bullocks ploughed 3320, 3070 and 2903 square meter respectively.

Rao *et al.* (1974) also reported that Haryana bullock ploughed more area than crossbred bullocks in different seasons. The corresponding figures of area

ploughed in square meters were 3317, 3067 and 2933 for Haryana bullocks while the crossbred bullocks ploughed 2970, 2857 and 2483 square meter area during winter, summer and rainy seasons, respectively.

The workers of Parbhani (Anonymous, 1975-76) studied the draftability of Deoni and Friesian x Deoni crossbred bullocks. It was observed that a pair of Deoni and crossbred bullocks covered an area of 1403 and 1268.75m² / hour, respectively for harrowing.

Rana *et al.* (1978) studied physiological responses to exercise in castrated and uncastrated male buffalo calves by pulling a stoneroller for 3 hours at constant speed of about 3 kilometers per hour. The recta temperature, pulse and respiratory rates were significantly increased as crossbred bullocks ploughed 1750 ± 123.57, 2206 ± 78.49 and 1815 ± 78.98 square meters of area in rainy winter and summer seasons, respectively in four hours of continuous ploughing the corresponding figures for indigenous bullocks were 1518 ± 88.67 and 1558 ± 88.26 square meters, respectively.

Acharya *et al.* (1979) studied comparative working capacity of crossbred (Holstein x Haryana) and nondescript indigenous bullocks during ploughing operation in different seasons under Orissa conditions and revealed that the crossbred bullocks were found to be superior over indigenous bullocks. The crossbred bullocks exhibited more stamina, higher speed and greater capacity for work. The crossbred bullocks ploughed 1750 ± 123.57, 2206 ± 78.49 and 1815 ± 78.98 square meters in rainy, winter and summer seasons respectively in four hours of continuous ploughing operation. The corresponding figures for indigenous bullocks were 1518 ± 88.67, 1558 ± 88.26 and 1518 ± 88.26 square meters area.

The workers at Parbhani (Anonymous, 1980-81) tested Deoni, Red Kandhari and Holdeo (HF x Deoni) bullocks for various agricultural operations. viz. ploughing, harrowing and cultivation. The crossbred bullocks covered 577.3, 1616 and 1685.0 square meters area in one hour for ploughing, harrowing and cultivation operations, respectively. They concluded that Holdeo crossbred

bullocks were superior to Deoni and Red kandhari for various agricultural operation, except for ploughing.

Gattewar (1983) compared working capacity of crossbred and Haryana bullocks during harrowing operations in cold, hot- humid and hot- dry seasons. He noted that crossbred bullocks harrowed a hectare of land in 4.21, 5.09 and 5.71 hours while Haryana Bullocks harrowed hectare of land in 4.85, 5.78 and 6.20 hours during cool, hot-humid and dry- hot seasons, respectively.

Nagpaul *et al.* (1984) studied draft efficiency of Haryana and Jersey x Haryana crossbred bullocks for ploughing operations. The area ploughed by haryana and crossbred bullocks was 559 and 558 m² /hr in summer and 560 and 597 m² /hr in winter respectively.

Rao and Upadhyaya (1984) studied work performance of crossbred bullocks in ploughing operation. The young crossbred bullocks ploughed 2800, 2600 and 3100 square meter area during summer, hot – humid and winter seasons, respectively.

Rautaray (1985) reported that the work output of bullocks depends on the working width and depth of the tools and the walking speed of bullocks. The working width of the tools varied from 19 to 140 cm in case of sweeps and 15 to 46 cm decreased with the working time at all the working width of the tool during continuous operation. The hourly decrease in work output especially at greater working width and higher draft was due to fall in working speed of the bullocks with time. Many times, at higher drafts with continuous operation the bullocks had interrupted and staggered walking due to which the tools often moved over the previously opened furrow resulting into a lower work output. However, considering the working width of the tool volume of soil tilled and the physiological response of the bullocks, the maximum area covered with sweeps were 10140, 7060 and 4960 m² /7hr/day whereas with mould board plough the area covered were 4750, 2900 and 2245 m² /7hr/day for crossbred, Malvi and local breeds of bullocks, respectively.

Bhagat (1986) studied the performance of crossbred bullocks on additional concentrate level harrowing operation. He reported that the area covered by crossbred bullocks during harrowing during three hours of continuous work was 0.8211, 0.8182, 0.8458 ha in T₁, T₂, T₃ treatment, respectively.

Bhosrekar and Mangurakar (1989) compared the work ability of crossbreds with local bullocks during ploughing at three different locations having different soil texture. The area ploughed varied from 262.4 to 577.4 m² /hr in Holstein crossbreds, 237.9 to 588.9 m² /hr in Jersey crossbreds, and 257.9 to 433.6 m² /hr in local bullocks. The area ploughed at Ahmednagar (light soil, 433.6 to 588.9 m²/hr) was maximum followed by that at Urulikanchan (heavy clay soil 257.9 to 316.9 m² /hr). This was attributed to soil- texture differences at three locations.

Sreekumar and Thomas (1990^a) evaluated the draft performance of Kangayam and Jersey x Red Sindhi crossbred bullocks. Kangayam (462 m² /hr) bullocks ploughed 15 % more area as compared to their counterpart Jersey x Red Sindhi bullocks (364.2 m² /hr).

Chhanwal (1990) studied the draft efficiency of Purnathadi buffaloes and crossbred bullocks. He observed that the crossbred bullocks took significantly less time (4.468 ± 0.210 hrs.) than buffalo bullocks (4.843 ± 0.210 hrs.) to harrow one hectare of land. This work efficiency worked out to requirement of 8 percent less than in crossbred against buffalo bullocks. The crossbreed bullocks indicated more work efficiency over buffalo bullocks in both the shifts of working. This results in more time to harrow one hectare of land.

Madan Lal (1996) observed the milk yield and compositional changes as influenced by work and season in lactating buffaloes and crossbred cows. He reported that the area ploughed by buffaloes during summer and winter were 373 ± 20 m² /hr 408 ± 13 m² /hr., respectively. The corresponding values for cows were 427 ± 53 and 438 ± 18 m² /hr.

Dhangar (1999) observed overall area ploughed during 3 hour as 0.331 ± 0.04 ha / day (6 hours during winter) in all 4.13 % more area was ploughed in 3

hours period than that in summer (0.363 ha.) Kankarej bullock showed 2.51 % greater efficiency than crossbred. The efficiency of performing agricultural operation was lower by 2.91 % during afternoon than in morning.

Yawalikar (2000) reported the area covered during ploughing in kharif and summer season for Red Kandhari, Deoni and HF x Deoni were 596.00, 631.00, 633.00 m²/hr and 590.00, 620.40 and 624.40 m²/hr, respectively. The corresponding values during sowing operation were 1357.40, 1447.40, 1565.40 m²/hr and 1284.40, 1375.00 and 1499.00 m²/hr, respectively.

2.2 Carting

2.2.1. Physiological parameters

Mukherjee *et al.* (1961) studied twenty four Haryana bullocks for maximum loads that they were capable of drawing in carts in different seasons and found that pulse rate and respiration rate increased rapidly during the initial period of work and thereafter the increase was not rapid. The body temperature however increased steadily with the increased hours of work.

Rana *et al.* (1978) reported that the respiration rate, pulse rate and body temperature in uncastrated and castrated male buffaloes during 0 hr, 1st hr, 2nd hr and 3rd hr carting were 16 ± 1.40, 31 ± 6.40, 52 ± 9.31, 80 ± 11.81 and 16 ± 0.65, 29 ± 3.60, 48 ± 5.70 and 67 ± 6.60 beats/min, 56 ± 1.09, 71 ± 2.67, 82 ± 1.78, 98 ± 2.41 and 54 ± 2.30, 70 ± 2.19, 87 ± 2.76, 100 ± 2.75 beats/min and 37.5 ± 0.34, 38.2 ± 0.65, 40.2 ± 0.40, 41.1 ± 0.63 and 37.7 ± 0.28, 38.2 ± 0.37, 39.9 ± 0.16 and 40.8 ± 0.41 °C, respectively.

Acharya *et al.* (1979) observed the respiration rate, pulse rate and body temperature with maximum load before and after carting for crossbred bullocks (Holstein x Haryana) as 35.3 ± 0.48 and 50.0 ± 0.82/ min, 61.5 ± 0.96 and 122.5 ± 1.50/min, and 101.3 ± 0.05 and 102.5 ± 0.06 °F, respectively. The corresponding figures for the indigenous bullocks were 32.30 ± 1.11 and 38.80 ± 0.75/min, 58.80

± 1.11 and $110.50 \pm 1.50/\text{min}$, and 100.9 ± 0.10 and 102.40 ± 0.05 °F, respectively. The crossbreds showed a significant ($P < 0.01$) rise in their respiration and pulse rate over the indigenous bullocks during summer and winter seasons, while such increase in the respiration alone was observed to be significant ($P < 0.01$) in the winter season.

Premi (1979) studied the performance of Hallikar bullocks under varying conditions of load and climates. He observed an increase in respiration and pulse rate of bullocks during six-hour exercise with a wheeled tool carrier. The increase was rapid in the first hour of work and thereafter it was slow.

Singh *et al.* (1981) compared the physiological response under workload in entire, castrated and vasectomised adult male buffaloes. The animals were exercised by pulling the paired bullock cart loaded with sand bags weighing approximately double the weight of both buffalo calves for 3 hours from 10.00 am to 1.00 p.m. on hard metallic road. They observed the maximum post-exercise rise in temperature from 7.00 to 8.06 per cent in castrated and vasectomised group as against 7.75 per cent in the entire group. The recovery was slightly but not significantly faster in entire group. Respiration rate was strikingly increased from 110 to 136 per minute as against 10 to 15 as a basal rate after workload in all the groups of animals. The magnitude of change was higher in the first half of exercise than the later half. The recovery of the respiration rate was quickest of all the physiological parameters studied and reaching towards normal rate by about 8 hours of rest. The trend of increase in pulse rate was similar to that of respiration rate and body temperature. The animals had significantly higher pulse rates from 47 to 70 per cent during first half and 1 to 16 per cent in the later half of the exercise period. On an average maximum post-exercise rise in pulse rate was observed from 77 to 81 per cent in castrated and vasectomies group as against 79 per cent in the entire group.

Garg *et al.* (1981) used six healthy male calves of Murrah buffalo of one year old weighing 80-135 kg carting, to study the physiological reactions in

response to exercise. Each animal was made to pull a stone roller weighing 80 kg at a constant speed of about 3 km/hour along an elliptical path of 100 meters outlined on even ground for 3 hours continuously at monthly intervals from August to April. The rectal temperature (from before and after exercise 37.91 ± 0.10 and 41.02 ± 0.22 °C), pulse rate (from before and after exercise 55.04 ± 2.03 and 107.04 ± 1.61 beats/min) and respiration rate (from before and after exercise 16.37 ± 0.95 and 89.59 ± 5.10 beats/min) increased significantly ($p < 0.05$) in all the exercising male calves, inferring that the increase in rectal temperature in response to exercise might be attributed to heat production as result of muscle contraction during work, whereas increase in pulse and respiration rates might be attributed to fulfill the increased demand of oxygen required during exercise.

Maurya and Devadattam (1982^a) studied physiological responses of crossbred (Jersey $\times$ Red Sindhi) bullocks to different draft levels and ambient condition in response to carting exercise. The pulse rate, respiration rates and body temperature of the bullocks increased with testing time. The higher rate of increase in physiological responses was observed in the second working period i.e. during last 3 hours of exercise after giving half hour rest. Hence, it was suggested to give rest pause after every one and half.

Upadhyay and Madan (1982^b) observed that the physiological parameters increased at various loads at different hours of work in Hariyana and crossbred bullocks. The rate of increase was higher in crossbred than in Hariyana. The increase in rectal temperature, respiration and pulse rate, while pulling various loads was more marked during summer and hot humid than winter season.

Rao and Upadhyay (1984) studied the work performance of crossbred bullocks and found that in bullocks carrying 4,6, and 8 quintals of load, the pulse rate increased by 36, 42, and 44 per cent in respective load conditions. The corresponding respiration rate increase was 39, 67 and 74 per cent and rise in rectal temperature was 3.54, 4.52 and 5.27 per cent. They concluded that during

summer and hot humid season, when the temperature and humidity limit the performance of bullocks, the duration of carting should not exceed 2 hours so as to avoid harmful effect on animal. In young crossbreds, 38.60, 41.67 and 30.30 per cent in respiration rate was observed as against 33.33, 16.67 and 18.15 in elder crossbreds during hot-dry, hot humid conditions. Similarly, an increase of 63.89, 45.83 and 63.64 per cent in respiration rate was observed in younger crossbreds as against 128.57, 40.74 and 45.45 per cent increase in respiration rate in elder crossbreds during hot-dry, hot-humid and dry-cold conditions. The result of this investigation concluded that during hot-dry and humid season, when temperature and humidity limit the performance of bullocks, the duration of ploughing could not be exceeded over two hours of continuous work. Hence, a pause of 10 to 15 minutes after every two hours was suggested in order to perform optimum work and without any harmful effect to the animals.

Upadhyay and Madan (1985^b) reported respiration rate, rectal temperature and pulse rate during before and after carting in Haryana and crossbred bullocks as 24.9 and 85.3, 34.5 and 98.0 beats/min, 38.3 and 40.3, 38.4 and 40.6 °C and 55.4 and 95.0, 65.1 and 82.0, respectively.

Upadhyay and Madan (1986) reported significant ($P < 0.01$) increase in heart rate. Initial, 1st hr, 2nd hr and 3rd hr heart rate were 59, 76, 84, 87 and 70, 79, 82 and 85 in Haryana and crossbred bullocks during carting operation in summer, hot humid and winter seasons.

Upadhyay and Madan (1987) studied four Haryana and four Holstein x Haryana crossbred bullocks for carting various physiological processes involved in thermoregulation and associated behavioural manifestations exhibited by bullocks during carting operation under tropical climatic conditions. The body temperature as reflected through increased rectal temperature (RT) at different hours of work loads indicated that bullocks increased their RT. Haryana bullocks had uniformly lower RT than crossbred and rise in RT in both breeds was higher during first hour of work. Bullocks were unable to perform work under high loads when their RT

showed a higher increase (2.4°C). Haryana animals had comparatively better heat elimination mechanism. The magnitude of increase of RT during work in crossbred indicated poor thermolytic ability.

Udhan (1991) studied the comparison of draftability in crossbred (HF x Deoni) bullocks. He reported that with the increase in load, the respiration rate of the bullocks increased gradually. The difference in respiration rate was significantly higher in crossbred bullocks with higher body weight.

Belsare *et al* (1992) conducted 72 transportation trials using crossbred and indigenous bullocks by making pairs to haul a bullock cart with 0 kg (empty cart), 200 kg and 400 kg load for 2 kms on kaccha farm road during September – October. They observed that an average increase in RT in crossbred and indigenous bullocks were 0.22 to 0.56°C and 0.17 to 0.50°C , respectively. The increase in PR and RR was respectively 16.8 to 25.9 and 8.6 to 14.3 in crossbreds and 17.6 to 22.2 and 6.5 to 11.0 in indigenous bullocks, respectively. The variation in RT, RR and PR were highly significant ($P < 0.01$) for breed and load. The association with climatological parameters indicated that crossbreds were also quite goods for work.

Bijender Kumar *et al.* (1996) reported during carting operation the average pre-exercise pulse rate of Haryana and crossbred bullocks as 55.79 ± 0.78 and 70.25 ± 1.09 , which increased after three hour exercise to 84.21 ± 2.51 and 110.04 ± 14.47 , respectively. Respiration rate during the pre-exercise period was higher in crossbred than in Haryana and it increased from 30.78 ± 1.01 to 81.87 ± 5.03 and from 20.54 ± 0.54 to 44.87 ± 2.7 in crossbred and Haryana bullocks, respectively. Mean pre-exercise rectal temperature observed in crossbred and Haryana bullocks was $101.27 \pm 0.06^{\circ}\text{F}$ and $100.80 \pm 0.06^{\circ}\text{F}$, which rose to by 2.87 and 2.51 $^{\circ}\text{F}$ in crossbred and Haryana bullocks, respectively, after three hour exercise

Singh and Upadhyay (1997^b) studied the comparative performance of draftability of buffalo bullocks during carting. The physiological reactions i.e.

R.R., P.R, R.T. increased to 109.8 ± 0.2 beats/min, 87.5 ± 1.1 beats/min and 41.2 ± 0.3 °C, respectively.

Singh and Upadhyay (1997^d) studied the physico chemical responses of she buffaloes during cart loading under hot-humid season. The physiological reactions i.e. RR, HR and RT increased to 109.8 ± 2.8 beats/min., 87.3 ± 1.1 beats/min., and 41.2 ± 0.3 °C at load 5t and 80.3 ± 11.1 beats/min., 82.3 ± 0.5 beats/min and 40.2 ± 0.6 °C at 10t load, respectively.

Yawalikar (2000) reported the respiration rate, body temperature and pulse rate before and after carting in Red Kandhari, Deoni and HF x Deoni as 27.12 and 39.12, 29.15 and 43.75 and 30.10 and 41.70 beats/min., 100.87 and 102.48, 100.93 and 102.53 and 101.25 and 102.88 °F and 48.10 and 70.30, 49.12 and 69.92 and 58.30 and 83.30 beats/min., respectively.

2.2.2 Haematogilical parameters

2.2.2.a. Haemoglobin

Agarwal *et al.* (1982) recorded a decrease in haemoglobin per cent in exercised buffalo calves while pulling a strong roller weighing 100 kg for 3 hours continuously on “Kachha” ground.

Upadhyay and Madan (1985^b) reported decreased level of haemoglobin from before to after carting in Haryana and crossbred bullocks as 10.5 to 10.3 gm% and 10.6 to 10.1 gm%, respectively.

Upadhyay and Madan (1988^b) reported decreased haemoglobin levels in crossbred and Haryana bullocks. The summer season was associated with a greater decline (from 11.4 to 10.5 gm%) than either hot humid (11.5 to 11.0 gm%) or winter (from 10.0 to 9.6 gm%).

Singh and Upadhyay (1997^d) observed haemoglobin level as 12.2 ± 0.2 and 12.3 ± 0.2 gm% during carting with 5 qtls. and 10qtls. loads. The reduction of Hb level was observed in buffalo during carting.

Yawalikar (2000) reported the haemoglobin level as 10.27 and 10.93, 10.14 and 10.66, 10.75 and 11.05 gm% for before and after carting in Red Kandhari, Deoni and HF x Deoni during kharif season, respectively. The corresponding values during summer season were, 10.02 and 10.40, 10.07 and 10.57 10.87 and 11.35 gm%, respectively. He found that haemoglobin increased after work than before work and during summer over kharif season.

Chhikara and Singh (2000) observed the haemoglobin level as 10.86 ± 0.22 to 9.91 ± 0.19 gm% which decreased during carting. The decrease in Hb level was significant ($P < 0.01$) over their initial value in crossbred bullocks.

2.2.2.b. Glucose

Nangia *et al.* (1978) reported the glucose level in castrated and uncastrated male buffalo during before and after carting as 68.04 ± 2.75 and 67.64 ± 2.59 mg%, respectively.

Upadhyay and Madan (1988^b) observed the decreased concentration of blood glucose during initial, 1st hr, 2nd hr and 3rd hr in Hariana and crossbred bullocks as 41.4 to 41.1, 41.6 to 41.5 and 39.5 to 39.4, 39.4 to 39.8 mg% respectively, during carting.

Dhangar (1999) studied the comparative draftability power of Kankrej and crossbred bullocks. He reported that physical work caused a significant decline in blood glucose concentration the magnitude of change increased with increased intensity of work. The reduction in blood glucose level was maximum (11.0-16.9%) at L₃ and L₄ loads, followed by that at planking (6.4 to 10.5%) and cart load L₁ of L₂ (2.8-4.4%).

Yawalikar (2000) reported the glucose level before and after carting in Red Kandhari, Deoni and HF x Deoni during kharif as 50.42 and 43.57, 51.08 and 43.96, 53.10 and 45.89 mg%. The corresponding values during summer were 49.77 and 40.32, 49.82 and 40.81 and 52.12 and 42.27 mg%, respectively. He

found that glucose level decreased after work as compared to before work and during summer over kharif season.

Chhikara and Singh (2000) observed the decreased level of glucose as 56.96 ± 4.45 to 52.74 ± 1.99 gm%. The decrease in Hb level was significant ($P < 0.01$) over their initial value in crossbred bullocks during carting.

2.2.2.c. Lactic acid

Nangia *et al.* (1978) studied blood lactic acid in castrated and uncastrated male buffalo of 2 years old when subjected to work by pulling a stone roller weighing 80 kg at a constant speed of about 3 kilometers per hour on even 'kachha' ground for four hours continuously. They observed increased trend in blood lactic acid levels, whereas bicarbonate value decreased in response to exercise. Blood lactic acid and bicarbonate levels did not differ significantly between castrated and uncastrated male buffalo.

Singh *et al.* (1979) also worked on buffalo male calves of 3 years old in a pulling exercise of stoneroller of 100 kg for 3 hours at constant speed of 3 kilometers per hour. Blood lactic acid levels increased significantly while bicarbonate level decreased in response to exercise. The chloride levels in blood did not show any significant change in working buffalo.

Upadhyay and Madan (1985^b) subjected Haryana and Holstein x Haryana crossbred bullocks to 1 qt load in addition to a single bullock pneumatic tyred cart (340 kg + driver 60 kg) for continuous 3 hour work. Muscle biopsies indicated a lactic acid accumulation in crossbred bullocks than in indigenous bullocks after continuous work. The increase in level of lactic acid (mol/g) over pre work value was double in Holstein x Haryana bullocks (4.09 vs 1.86) than that in Haryana (1.90 vs 1.30), which indicated that glycolytic processes during work were more active in crossbreds.

Upadhyay and Madan (1988^b) observed the lactic acid level during initial, 1st hr, 2nd hr and 3rd hr in Haryana and crossbred bullocks as 11.7, 11.8, 18.4, 17.1 and 14.2, 16.3, 14.9 and 14.5 mg% respectively, during carting.

Sreekumar and Thomas (1990^b) reported lactic acid level before and after work in indigenous and crossbred bullocks as 27.70 ± 0.12 and 39.37 ± 0.21 , 29.83 ± 0.31 and 29.83 ± 3.11 and 40.72 ± 0.18 mg%, respectively.

Dhangar (1999) studied the comparative draftability power of Kankrej and crossbred bullocks. He observed the rise in lactic acid level at L₃ (46.70 VS 32.78%) and L₄ (75.69 VS 47.20%) over pre work, which was almost 1.5 times higher during carting in summer as compared to winter.

Yawalikar (2000) reported the lactic acid level before and after carting in Red Kandhari, Deoni and HF x Deoni during kharif and summer season as 5.70 and 11.26, 5.68 and 11.14, 7.0 and 12.70 gm%. and 5.81 and 11.50, 5.80 and 11.80, 7.30 and 13.33 gm%, respectively. He found that lactic acid level increased after work than before work and during summer over summer season.

Chhikara and Singh (2000) observed increased level of lactic acid from 8.61 ± 1.21 to 8.71 ± 0.93 mg%. The decrease in Hb level was significant ($P < 0.01$) over their initial value in crossbred bullocks.

2.2.3. Load

Mukherjee *et al.* (1961) studied twenty four Haryana bullocks for maximum loads that they were capable of drawing in carts in different seasons. The load pulled was expressed in terms of per cent body weight of the animals. They reported that the maximal load pulled by the Haryana bullocks varied from 310 to 340 per cent of their body weight. Maximal load pulled by the bullocks were more in winter season followed by rainy and summer seasons. Significant negative correlation (-0.35) was found between the pulse rate of bullocks at rest and maximal loads pulled by them.

Singh *et al.* (1979) also worked on he buffaloes of 3 years old in a pulling exercise of stoneroller of 100 kg for 3 hours at constant speed of 3 km/hour. Blood lactic acid levels increased significantly while bicarbonate level decreased in response to exercise.

Acharya *et al.* (1979) studied comparative working capacity of crossbred (Holstein x Haryana) and non- descript indigenous bullocks in carting exercise. The crossbred bullocks pulled significantly ($P<0.01$) maximal load of 1300 kg as against 1210 kg pulled by indigenous bullocks. They noted that the absence of hump in crossbred did not pose any problem during carting operation. The carting speed of crossbred and indigenous bullocks during 1st, 2nd, 3rd, 4th, 5th and 6th hr were 68, 58, 48, 43, 40.5, 39 and 67, 55, 44.5, 40.0, 37.0, 36.5 mt/min., respectively.

The workers from ICRISAT, Patanacheru, India (Anonymous, 1979-80) studied the performance of Hallikar bullocks of different body size in terms of speed/ hour, power developed and work output as function of body size, draft duration of work and climate. They found that the maximum loads (kilogram of pull) pulled by the smallest and largest pair of bullocks during six hours of work in cool season were 120 kg, respectively.

Garg *et al.* (1981) used six healthy male of Murrah buffalo of one year old weighing 80-135 kg to study the physiological reactions in response to exercise. Each animal was made to pull a stone roller weighing 80 kg at a constant speed of about 3 km/hour along an elliptical path of 100 meters outlined on even ground for 3 hours continuously at monthly intervals from August to April. The rectal temperature, pulse rate and respiration rate increased significantly (<9.05) in all the exercising male.

Agarwal *et al.* (1982) recorded a decrease in haemoglobin per cent and packed cell volume in exercised buffalo calves while pulling a stone roller weighting 100 kg for 3 hours continuously on ‘ kachha’ ground.

Upadhyaya and Madan (1985^b) studied the work performance of Haryana and crossbred bullocks (Holstein x Haryana) of 5 to 7 years old during summer

season. Single animal pneumatic tyred bullock cart was used and the animals were driven at their normal speed of walking 3 - 4 miles/hour for 3 hours subjected to two loads of 5 to 10 quintals. The speed during 1st, 2nd and 3rd hr in Haryana and crossbred bullocks were 6.00, 5.63 and 4.50 km/hr and 4.50, 4.50 and 3.00 km/hr, respectively.

Upadhyay and Madan (1987) studied four Haryana and four crossbred (Holstein x Haryana local) bullocks and reported none of the Haryana or crossbred bullocks could pull 2.0 tons of load. The 1.5 ton load was pulled by Haryana and crossbred bullocks at different speeds. The 0.5 ton load was pulled by animals with ease. Heavy loading reduced the speed of Haryana bullocks remarkably. The average speed at which Haryana bullocks were able to walk freely varied from 4.5-6.0 km/hr. compared to crossbred bullocks, which were able to move comparatively at slow pace 4.5-4.8 km/hr. However, the crossbreds carried load almost at the same speed as that of walking.

Udhan (1991) studied the draftability of crossbred (HF x Deoni) bullocks. He reported that with the increase in load the speed of bullock pairs decreased gradually. It might be due to the fact that extra load added more energy required and more muscular exertion. The differences in speed for three pairs were non-significant. Crossbred and Deoni bullocks pairs can sustain a load of 12.4 qts with a normal speed of 3.8 km/hour on a plain tar road. The output was to the extent of 0.78 horse power.

Belsare (1991) compared the work production of crossbred and indigenous bullocks by subjecting them to pull a cart with 0, 200 and 400 kg load for 2 km on farm road. The speed of carting was higher in indigenous bullocks in comparison to crossbred ones. Thus, with increase in load, speed of the work reduced.

Agarwal (1992) reported the performance of Haryana and crossbred bullocks under CWWC as well as IPTC, each with 500 kg payload. He observed the speed as 6.39 and 5.58 km/hr for Haryana and 5.97 and 5.26 km/hr for crossbred bullocks, respectively.

Agarwal and Agarwal (1992) reported optimum payload and draft power of crossbred versus Harijana bullocks. The draft power of 4 Harijana steers and 4 Harijana x Jersey and Harijana x Holstein steers was studied. The animal pulled cart with different payloads (0-2000kg) and the pulling power was measured with dynamometer. The speed declined from 9 km/hr for 0-kg payload to 4 km/hr for 2000 kg payload. In Harijana bullocks the payloads pulling power was 5.5 - 21 % of their body wt. Four Harijana (H) and four crossbred (HF x H, Jersey x H) bullocks (b.wt, 350 to 500 kg and age, 5-8 years) to haul 0, 500, 1000, 1500 and 2000 kg pay loads on the cart (325 kg +2 drivers, 120 kg) attached with a dial balance. A circular path on tar road covering a distance of 3.8 km was used and attempt was made to complete 3 rounds. The draft capacity of Harijana and crossbred (CB) bullocks under different payloads were measured. They concluded that 1000 kg was optimal payload for a single animal. They also indicated that crossbreds and Harijana bullocks did not differ in draft power.

Belsare *et al.* (1992) conducted 72 transportation trials using crossbred and indigenous bullocks by making pairs to haul a bullock cart with 0 kg, (empty cart) 200 and 400 kg load for 2 km on kaccha farm road during September – October.

Bora *et al.* (1994) investigated draftability of Assam local and Jersey x Assam local crossbred bullocks. The bullocks were put to cart with 600, 800 and 1000 kg payloads during winter as well as summer seasons. The pull exerted varied from 63.65 to 109.25 kg in Assam local and 70.80 to 114.94 kg in Jersey x local bullocks.

Madan Lal (1996) found the Nagori bullocks haul at the speed of 4.09 to 4.78 km/hr when subjected to cart a load of 806-833 kg on evaluating the draft performance of Harijana and exotic x Harijana crossbred bullocks under wooden wheeled and pneumatic tyred cart with a pay load of 500 kg.

Dhangar (1999) reported that the crossbred bullocks produced significantly greater draft particularly at higher load 900 kg (L3) and 1180 kg (L4) pay load. The increase in draft generated by Kankrej bullocks at 1180 (L4) pay load over 340 kg pay load (L1) was significantly lower during summer than in winter.

Draft performance under hot- dry, hot- humid and cold- dry climatic conditions for 5 q and 10q pay- load in a cart over a continued 3 hours of work was evaluated among Haryana (H) and Holstein x Haryana crossbred bullocks by Upadhyay and Madan (1982, 1985^a) using hydraulic dynamometer attached to a single bullocks pneumatic tyre cart. The workers recorded a mean pull value of 57 kg at 1000 kg payload.

Yawalikar (2000) reported the payload during carting as 150, 200 and 250 per cent of mean body weight of bullocks for Red Kandhari, Deoni and HF x Deoni and observed speed during carting as 3.834, 3.644 and 3.508 km/hr, 4.144, 3.940 and 3.850 km/hr and 4.486, 4.320 and 4.080 km/hr, respectively.

2.3. Fatigue Score

Maurya (1985) reported that the ambient temperature brings the animals (oxen) to a state of fatigue earlier than the amount of weight pulled by them. However, the heart rate increased significantly to about 39.13, 9.37 and 14.28 per cent from its preceding values after 1, 2 and 3 hours of work, respectively.

Upadhyay and Madan (1985^a) developed a fatigue score based on physiological reactions, distress symptoms and behavioural manifestations. Physiological reaction viz.; pulse rate, respiration rate and rectal temperature scored on a five point basis. Animal's excitability was given on a score of 5 point with no excitement to a state of highly furiousness. Leg inco-ordination and movement exhibitions were scored in the same manner. Appearance of froth was scored, froth first appearing to full mouth frothing considered in an ascending manner. Tongue appearance was taken open and tongue out continuously. The fatigue score totaled 40 point, out of which animals were evaluated; those attained value of 20 were declared fatigued. The assessment of fatigue on this basis was done in Haryana and crossbred bullocks. Mean fatigue score ranged from 20 to 26 in Haryana bullocks after 3 hours of work and about the same (22 to 27) in crossbred bullocks earlier even after 2 hours of work.

Upadhyay and Madan (1985^c) reported the fatigue score in bullocks for both physiological reactions and behavioural manifestations, which indicated that higher load produced greater changes than light load when pulled under different environments. Crossbred bullocks subjected to heavy load exhibited greater average score for RT (4°C HR 2.2). Both legs incoordination and frothing were also observed to be on higher scale, average value being 4.7 and 2.0. Haryana bullocks pulling heavy load secured higher score for physiological reactions. The total score of crossbred and Haryana bullocks during hot humid season ranged from 20 to 27 and 20 to 26, respectively.

Parmar and Gupta (1997) reported the average fatigue score in Haryana, HF x Haryana, HF x Sahiwal, Brown Swiss x Sahiwal and Jersey x Haryana, crossbred as 18.3, 20.2, 23.5, 21.0, 24.7 and 21.9, respectively.

Singh and Upadhyay (1997^a) studied the physico- chemical responses of she buffaloes during cartloads under hot-humid season. In all, 4 dry non- pregnant Murrah buffaloes, which had been individually trained for carting and loading, were subjected to a load of (i) 5 or (ii) 10 quintals for 2 periods of 2hr (or onset of fatigue, if earlier) separated by a rest period (2 –3 hr) to allow the physiological parameters, viz., respiration rate (RR), heart rate (HR) and rectal temperature (RT), to return to 75% of pre-work levels. The buffaloes worked for an average of 2.01 ± 0.1 and 1.43 ± 0.74 hr at an average speed of 3.08 ± 0.22 and 2.67 ± 0.17 km/hr with load (I) and (II), respectively. During each work period, RR, HR and RT increased.

Yadav *et al.* (2005) reported that the effect of season of work was statistically non- significant for all the fatigue score traits after 2 hr, as well as 3hr of continuous work, except for frothing after 2 hr of continuous work. The pair mean comparison across different seasons of work for frothing after 2 hr revealed that the highest score was in dry hot season (April-June) followed by dry humid (July- September) and it was lowest in winter.

3. MATERIAL AND METHODS

3.1. Location of the study

The research work on draft performance of Khillar bullocks was undertaken at Central Sugarcane Research Institute, Padegaon and farmers field at Dhule districts. Padegaon is situated at 18⁰ 12' N latitude 74⁰ 12' E longitude and Dhule is situated at 20⁰ 4' N Latitude 74⁰ E longitude. The rainfall of 800 mm in the Khillar breeding tract. The onset of monsoon from about 15 June to end of August of the year.

Pairing of experimental bullocks for different operations

Type	Pair No	Tattoo No. / Name of Bullock	Body weight (Kg)	Body Measurement		
				Body length (cm)	Chest girth (cm)	Height at wither (cm)
Pandharpuri Khillar	I	101	475.64	155	178	143
		102	467.28	154	177	142
		Mean	471.46	154.5	177.5	142.5
	II	103	468.02	156	176	146
		104	463.30	158	174	144
		Mean	465.66	157	175	145
Kosa Khillar	I	105	474.02	158	176	146
		106	478.71	156	178	148
		Mean	476.36	157	177	147
	II	107	466.24	159	174	147
		108	468.02	156	176	149
		Mean	467.13	157.5	175	148
Tapi Khillar	I	Ram	466.44	152	178	148
		Sham	450.01	150	176	146
		Mean	458.22	151	177	147
	II	Sarja	467.28	154	177	148
		Raja	453.81	153	175	147
		Mean	460.54	153.5	176	147.5

3.2. Selection of animals

Total six pairs healthy Khillar bullocks were randomly selected for the study, it comprised by two pairs of Pandharpuri Khillar (plate 1), two pairs of Kosa Khillar (Plate 2) and Tapi Khillar (Plate 3). All the animals were in the range of 3 to 4 ½ years of age. While selecting the animals, emphasis was given on the body weight rather than the age of the animals.

3.3. Experimental details

Four field operations and carting were performed by each pair of Khillar bullocks during three seasons viz.,

- a) Summer : February to May
- b) Rainy : June to September
- c) Winter : October to January

3.3.1 Ploughing

The operation was performed during three seasons on a normal black soil. Two pairs from each type were yoked to a plough on a piece of one acre land. The observations on physiological indices viz., respiration rate, body temperature and pulse rate were recorded for each bullock. Thereafter the ploughing was started which continued for three hours duration during forenoon (D_1) and afternoon (D_2) separately. Similar set of observations were repeated at an hourly interval during D_1 and D_2 . One pair of Khillar bullocks under each type were considered for collection of blood samples for hematological studies (haemoglobin, glucose and lactic acid) before start and after completion of ploughing.

3.3.2 Sowing

The sowing was undertaken during three seasons on a normal black soil. Two pairs of Khillar bullocks from each type were yoked to sow a piece of one acre land. The physiological indices viz., respiration rate, body temperature and

pulse rate were recorded for each bullock. Thereafter sowing was started and continued for three hours duration during forenoon (D_1) and afternoon (D_2) separately. Similar set of observations were repeated at one hour interval of the operation. Collection of blood samples for hematological studies (Hemoglobin, Blood Glucose and Lactic Acid) was undertaken before start and after completion of sowing for one pair of bullocks under each type of Khillar.

3.3.3 Harrowing

The harrowing operation was performed during three seasons on a normal black soil. Two pairs from each type of Khillar were yoked to harrow on a piece of one acre land. The physiological indices viz., respiration rate, body temperature and pulse rate were recorded for each bullock and then harrowing was started which continued for three hours duration during forenoon (D_1) and afternoon (D_2) separately. Similar set of observations were repeated at an hourly interval of the operation. Only one pair of bullocks under each type of Khillar were considered for collection of blood samples for hematological studies (glucose, hemoglobin and lactic Acid) before start and after completion of harrowing.

3.3.4. Hoeing

The hoeing was performed by six pairs of Khillar bullocks during three seasons on a normal black soil. Two pairs of bullocks from each type of Khillar were yoked to hoe a piece of one acre land. The physiological indices viz., respiration rate, body temperature and pulse rate were recorded for each bullock. Thereafter the hoeing was started which continued for three hours duration during forenoon (D_1) and afternoon (D_2) separately. Similar sets of observations were repeated at hourly interval of operation. Collection of blood samples for hematological studies (glucose, hemoglobin and lactic acid) were undertaken for only one pair of bullocks under each type of Khillar before start and after completion of hoeing.

3.3.5 Carting

Bajaj bullock cart was used for carting Khillar bullocks for a distance of 5, 10 and 15 km for pay load of 200 kg. The weight of the cart (270Kg), weight of driver (65 Kg) and pay load (200 kg) was considered for carting studies. The said carting was performed in three seasons. The physiological indices viz., respiration rate, body temperature and pulse rate were recorded for each of Khillar bullocks before start and after completion of carting. Only one pair of Khillar bullocks were considered for haematological studies viz., hemoglobin, glucose, and lactic acid. The collection of blood samples were done before start and after completion of carting. The mean weight of bullock was calculated as a total weight of 6 pairs of bullocks divided by 12 in the experiment i.e. 466.56 Kg.

Unit for loads during carting

Mean body weight of bullock (kg)	Weight of cart (kg) (A)	Weight of driver (kg) (B)	Total load (kg) (A + B)	Distance traveled (km)	Pay Load (C)	Total load (A + B + C)
466.56	270	65	335	K ₁ = 5 km K ₂ = 10 km K ₃ =15 km	200kg	535 kg

3.4. Agricultural operations

The physiological indices and haematological parameters for different agricultural operations for a pair of bullocks under each type of Khillar were recorded as per the methods given below:

3.4.1. Physiological indices

The physiological indices viz., respiration rate, body temperature and pulse rate were recorded according to the method given by Miller and Robertson (1959).

3.4.1.1. Respiration rate (per min)

Respiration rate was noted by counting the gushes of respired air at the back of the palm kept near the nostrils of the bullocks for one minute (Plate 4).

3.4.1.2. Body temperature (°F)

Body temperature was recorded with the standard clinical thermometer by inserting it into the rectum of animal for one minute. Care was taken to keep the bulb of thermometer in close contact with the rectal mucos (Plate 5).

3.4.1.3. Pulse rate (per min)

The pulse rate was recorded by feeling coccygeal artery for one minute (Plate 6).

3.4.2. Haematological parameters

Blood samples from each animal before and after the work (ploughing, harrowing, hoeing, sowing and carting) were collected from the jugular vein punctured with a sterile hypodermic needle and the sample was collected in a vial containing an anticoagulant (sodium citrate at the rate of 1mg / 5ml of blood sample and sodium fluoride at the rate of 1mg / 5ml of blood sample for preserving blood glucose) (Plate 7). The fresh blood samples thus collected were analyzed for hemoglobin and lactic acid. Each sample was then subjected to centrifuge for the separation of plasma. The plasma separated samples were analyzed for blood glucose.

The hematological analysis of blood samples were carried out for following constituents:

1. Haemoglobin
2. Blood glucose
3. Blood lactic acid

3.4.2.1. Haemoglobin estimation

The “Sahlis” acid heamatin method (Oser, 1965) as described below was used for estimation of haemoglobin (Plate 8):

Method

1. The oxalate blood in the specimen tube was mixed by rotation.
2. Standard (N/10) HCL was placed in diluting tube up to mark 10 on the percentage side
3. The oxalated blood was drawn up to the mark in the pipette to indicate the level of 20 cm.
4. The tip was wiped. The overshoot of the blood was tapped on the finger.
5. The pipette was introduced into the tube in which N/10 HCL was taken. The blood was allowed to flow out. When all the blood has flown the pipette was rinsed slightly sucked the acid and then blown it out gently without causing any air bubbles to disturb the acid and blood. This was repeated twice. The distilled water was drawn in to the pipette and then add this was to the fluid in the tube.
6. The tube was gently shaken to mix the blood and acid, and kept in a dark place for 30 minutes.
7. The tube was then kept in the comparator. Distilled water was added drop by drop, stirred with glass stirrer after each addition. This procedure was repeated till the colour in the tube matches with the colour of the standard in the comparator. During matching the stirrer was rinsed from the solution.

8. When the colour was matched the tube was removed from comparator and the level of the fluid was read in the grams per 100 ml of blood.

3.4.2.2. Estimation of blood glucose

The serum separated plasma sample (0.04ml) was taken in test tube to which 3.00 ml of solution-I (prepared by adding 50 ml of distilled water to glucose enzyme reagent) was added. To this 3.00 ml distilled water was added (Plate 9). The sample was mixed well and kept for incubation at the room temperature (37°C) for 15 minutes after which the sample was taken out, stirred and put in Spectronic-20 at 510 mm wavelength. The sample test tube was compared with standard and blank. The sample for standard was prepared by adding 0.04 ml of glucose standard solution (100 mg per cent), 3.00 ml solution-I and 3.00 ml distilled water to the test tube. Similarly, a blank sample was prepared by adding 3.00 ml of solution-I and 3.00 ml distilled water in separate test tube (Keilin and Hartree, 1948).

$$\text{Glucose (mg/ 100ml of blood)} = \frac{\text{O.D. test} - \text{O.D. Blank}}{\text{O.D. std- O.D. Blank}} \times 100$$

3.4.2.3. Estimation of lactic acid

The blood lactic acid in was estimated by method described by Barker and Summerson (1941).

Method

The glucose and other interfering material of the protein free blood filtrate were removed by the Van Slyke-Salkowski method of treatment with copper sulphate and calcium hydroxide. An aliquot of the resulting solution was heated with concentrated sulphuric acid to convert the lactic acid in to acetaldehyde,

which was then determined colorimetrically by reaction with p-hydroxy diphynyl in the presence of copper ions. The procedure was described as follow:

Reagents

1. Copper sulphate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) 20 % solution
2. Copper sulphate ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) 4% solution
3. Powdered calcium hydroxide
4. Concentrated sulphuric acid
5. P-hydroxy diphynyl 1.5 % in 0.5 % sodium hydroxide.
6. Standard solution: Prepared by dissolving 0.213gm of lithium lactate in sulphuric acid and making the volume up to 1000 ml with distilled water. It was diluted as 1: 20 to obtain a standard containing 10 mg / ml lactic acid.

Technique

1. The blood collected in a vial containing sodium fluoride was deproteinised with tungstic acid at a 1:10 dilution. Tungstic acid proposed by Follin and Well (1919) was most common agent used for deproteinisation of blood.
2. Transfer 2ml of protein free filtrate representing 0.2 ml of blood was transferred to graduated centrifugal tube marked at 10 ml.
3. In a second similar tube 5 ml of standard lactic acid solution containing 0.01 mg of lactic acid / ml was placed and in third tube distilled water was added to act as a blank.
4. Add 1 ml of copper sulphate solution (20%) was added to each tube and diluted to 10 ml mark with distilled water.

5. Powdered calcium hydroid (1mg) was added to each tube, shaken vigorously until the contents are uniformly dispersed allowed to stand for ½ hr.
6. The precipitate in the tube was removed by centrifugation (3000RPM) for 10 minute and 1 ml of clean fluid (supernatant) from each tube was transferred to thoroughly clean and dry test tube having an inverted diameter of 18 to 23 mm.
7. To each tube add 0.05 ml of copper sulphate solution (4%) was added to each tube followed by 6 ml of conc. Sulphuric acid from a burette drop by drop and content were mixed well during the addition.
8. Tubes were placed upright in boiling water for 5 min and transferred to cold water (running tap water) for cooling down to 20°C or below.
9. After cooling down the content 0.1 ml of P-hydroxy biphenyl reagent (coloring reagent) was added drop by drop each tube. The reagent precipitated out.
10. The tube was placed in a beaker containing water of having temperature 30° C for 30 min.
11. Finally the tubes were placed in boiling water for 1 ½ min removed and cooled to room temperature.
12. Optical density was measured at 560 mm. Using water for setting the photometer at density o.

Calculation

Optical density of blank was determined and it was subtracted from the value of density of a standard and unknown. The value so obtained as substituted in the following formula to obtain amount of lactic acid per 100 ml of blood.

$$\frac{\text{Optical density of Unknown sample}}{\text{Optical density of Standard}} \times 0.005 \times 50 \times 100$$

Optical density of standard

3.4.3. Body measurement traits and body weights

The body measurement traits were recorded as per FAO (1986)

3.4.3.1 Chest girth

Circumference just behind the point of elbow.

3.4.3.2 Height at wither

Vertical distance from the ground to the point behind the hump.

3.4.3.3 Body length

Body length was measured from the point of shoulder to the point of pin bone.

3.4.3.4 Body weight

Body weight was calculated by using following formula :

$$\text{Weight in pound} = \frac{G^2 \times L}{300}$$

Where,

G= Chest girth (inches)

L= Body length in (inches)

3.5. Draftability

3.5.1. Draft

Maximum pull (kg) exerted by the each pair of bullocks was recorded by Digital Dynamometer of 200 and 500 kg capacity joined to the beam of the implement.

The pull observations recorded during three hour exercise. Values of the draft corrected for angle of pull (CosA) were computed according to the method described by Premi (1979) from equation 1 and 2

$$\text{Cos A} = \frac{X}{Y} \text{-----1}$$

Where, X = Base line of the implement
Y = Hypotenuse line of the implement

$$D = P \times \text{Cos A} \text{-----2}$$

Where,
D = Draft (kg)
P = Pull exerted (kg)

3.5.2. Speed

Speed was recorded in seconds with the help of a stopwatch to cover the distance marked in the field at every 100 meter. The values of the speed in km/hr were computed with the help of following equation :

$$S = \frac{L \times 3.6}{T}$$

Where,
S = Speed (km / hr)
L = Distance moved or traveled (mt)
T = Time required by the bullocks to travel 100 meter (sec)
3.6 = Conversion factor for km/ hr

3.5.3. Horse power

Values of the horsepower computed as per Broody (1945):

$$Hp = \frac{D \times S}{75}$$

Where,

Hp = Horse power

D = Draft developed (kg)

S = Speed (mt / sec)

3.6 Statistical analysis

Factorial Randomised Block Design was utilized for analysis of data for different agricultural operations viz., ploughing, sowing, hoeing, harrowing and carting as described by Panse and Sukhatme (1976).

3.7. Fatigue score card

The experimental animals were subjected to 1.0 ton load in addition to a bullock cart (270kg) and driver (65kg). The work was carried out for 3 hrs or until animal reached the fatigue stage. The bullocks were subjected to continuous work. The observations viz. respiration rate, body temperature and pulse rate, were recorded before starting the work and after 3 hrs or till fatigue was developed. The same observations were repeated twice for each bullocks pair.

The symptoms exhibited by bullocks were recorded and plotted in fatigue score card developed by Upadhyay and Madan (1985^b) as below :

3.5 Fatigue score card

Sr. No	Parameter	Score Scale					Total
1	Respiration rate	Ro + 15	Ro + 30	Ro + 45	Ro + 60	R ₀ + 75	5
2	Pulse rate	Po + 10	Po + 20	Po + 30	Po + 40	Po + 50	5
3	Temp (° F)	To + 0.5	To + 1.0	To + 1.5	To + 2.0	To + 2.5	5
4	Frothing	First appearance	Dribbling of saliva starting	Continuous dribbling	Appearance of froth on upper lip	Full mouth frothing	5
5	Leg Incoordination	Stride uneven	Occasional dragging of feet	Frequent dragging of feet	No co-ordination in fore hind legs	Unable to move	5
6	Excitement	Composed	Disturbed	Nostrils dilated and bad temperament	Movement of eye ball with excitement	Furious and trying to stop	5
7	Inhibition to progressive movement	Brisk	Free movement	Slow walking	Very slow	Stop walking	5
8	Tongue protrusion	Mouth close	Occasional opening	Frequent appearance	Continuous protrusion	Tongue fully out	5

Ro, Po and to represent respiration rate pulse rate and rectal temperature respectively, at total score 20 the animal is fatigue.

4. RESULTS AND DISCUSSION

4.0 General :

The results obtained on different parameters, when the bullocks were yoked for ploughing, sowing, harrowing, hoeing and carting operations during summer, rainy and winter seasons have been presented in this chapter.

4.1 Ploughing (Plate 10)

4.1.1 Physiological indices

The physiological indices viz., respiration rate, body temperature and pulse rate before work, after 1st hr, 2nd hr and after completion of work during each trial have been discussed.

4.1.1.1 Respiration rate

Average mean RR in Khillar bullocks was 41.19 beats/min (Table 1). The mean for respiration rate were observed to be 41.52, 37.13 and 44.60 in the case of Pandharpuri (T₁), Kosa (T₂) and Tapi (T₃) Khillar, respectively (Fig. 1). These finding confirmed with the results of Sreekumar and Thomas (1990) in Kangayam bullocks during ploughing. The analysis of variance revealed that the significant ($P < 0.05$) variations in RR were observed in Pandharpuri, Kosa and Tapi Khillar (Table 2). The mean for RR during summer, rainy and winter season were 44.73, 42.21 and 36.23 beats/min (Fig. 1). Almost similar results were reported by Acharya *et al.* (1979) in crossbred and indigenous bullocks. The analysis of variance revealed that season had significant ($P < 0.05$) effect on RR. During summer, it was higher followed by rainy and winter season (Table 1). The means for RR during forenoon and afternoon were 39.77 and 42.40, respectively (Fig. 1). The RR was significantly ($P < 0.05$) higher during afternoon than forenoon period (Table 1). The means for RR during before work, after 1st, 2nd hour and after 3rd hour of ploughing were 22.23, 40.73, 47.91 and 53.45, respectively. Similar

results were reported by Anonymous (2004) in Gaolao (13.57, 16.53, 20.86 and 26.22 at an interval of initial, 1st, 2nd, and 3rd hr of work) during ploughing.

Table 1. Means for respiration rate in Khillar bullocks during ploughing

Particular		Respiration rate (beats/ min)
μ		41.19
Type (T)	Pandharpuri Khillar (T ₁)	41.52 ^b
	Kosa Khillar (T ₂)	37.14 ^a
	Tapi Khillar (T ₃)	44.60 ^c
	S.E.±	0.32
	C.D. at 5%	0.88
Season (S)	Summer (S ₁)	44.73 ^c
	Rainy (S ₂)	42.21 ^b
	Winter (S ₃)	36.32 ^a
	S.E.±	0.32
	C.D. at 5%	0.88
Time (D)	Forenoon (D ₁)	39.77 ^a
	Afternoon (D ₂)	42.40 ^b
	S.E.±	0.26
	C.D. at 5%	0.72
Intervals (I)	Before work (I ₁)	22.24 ^a
	1 st hour (I ₂)	40.74 ^b
	2 nd hour (I ₃)	47.92 ^c
	After 3 rd hour (I ₄)	53.46 ^d
	S.E. ±	0.37
	C.D. at 5 %	1.02

* Different superscripts indicates significant difference

The significant ($P < 0.05$) variation in respiration rate were observed in different interval of working (Table 2), it indicated that as the working hours increased the RR also increased. The increase in respiration rate helped the animals to dissipate excess heat generated in the body during exercise. The higher

level of respiration rate was observed on Tapi Khillar, during summer, at afternoon and after completion of work.

As the duration of work progressed the respiration rate also increased which might be due to increased demand for oxygen by the tissue during work and compensatory effort to effect thermolysis. These results closely resembled with Bhosrekar *et al.* (1966) in Thaparkar and Sahiwal bullocks, Singh *et al.* (1968^a) in Haryana bullocks and Nagpaul *et al.* (1984) in crossbred and zebu bullocks.

Table 2. Analysis of variance for respiration rate during ploughing in Khillar bullocks

Source of variation	Df	MSS	F value at 5%
Replication	3	226.2257	
Type (T)	2	1352.337*	1.024017
Season (S)	2	1786.524*	0.886825
Time (D)	1	498.7535*	0.886825
Interval (I)	3	13324.16*	0.724089
TS	4	103.6441*	1.024017
TD	2	24.64931*	1.536026
TI	6	246.8553	NS
SD	2	10.00347*	1.77365
SI	6	139.5428	NS
DI	3	30.04051*	1.77365
TSI	12	14.06539	NS
TDI	6	9.547454	NS
SDI	6	9.707176	NS
TSDI	12	5.208912	NS
Error	213	9.826633	
Total	283		

During ploughing, the analysis of variance (Table 2) revealed that the interaction effects for respiration rate between T x S, T x D, S x D, D x I were significant ($P < 0.05$) during ploughing and T x I, S x I, T x S x I, T x D x I, S x D x I and T x S x D x I were non- significant.

4.1.1.2. Body temperature

The average BT in Khillar bullocks was 101.63 °F (Table 3). The body temperature was observed as 101.76, 101.29 and 101.89 °F in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar, respectively (Fig. 2). Almost similar results were reported by Acharya *et al.* (1979) in crossbred (HF x Haryana) and non-discript indigenous bullocks. The analysis of variance revealed that the significant ($P < 0.05$) variations in respiration rate were observed due to type of Khillar (Table 4). The average for BT during different seasons were 102.41, 101.85 and 100.70 °F in summer, rainy and winter season, respectively (Fig. 2). The season had significant ($P < 0.05$) effect on BT in Khillar. During summer, it was higher followed by rainy and winter season (Table 3). The means for body temperature during forenoon and afternoon were 101.43 and 101.88 °F, respectively (Fig. 2). Similar results were reported by Yawalikar (2000) in Red Kandhari, Deoni and HF x Deoni during ploughing. The BT was significantly ($P < 0.05$) higher during afternoon than forenoon period (Table 3). The means for BT in Khillar bullocks before work, after 1st, 2nd hour and after 3rd hour ploughing were 100.14, 101.61, 102.28 and 102.56 °F, respectively (Fig. 2). The variations in BT were significant ($P < 0.05$) attributed to the different intervals of working (Table 4). It indicated that as the working hours increased the BT also increased.

Table 3. Means for body temperature in Khillar bullocks during ploughing

Particular		Body temperature (°F)
μ		101.63
Type (T)	Pandharpuri Khillar (T ₁)	101.77 ^b
	Kosa Khillar (T ₂)	101.29 ^a
	Tapi Khillar (T ₃)	101.89 ^b
	S.E. ±	0.05
	C.D. at 5%	0.15
Season (S)	Summer (S ₁)	102.41 ^c
	Rainy (S ₂)	101.85 ^b
	Winter (S ₃)	100.70 ^a
	S.E. ±	0.05
	C.D. at 5%	0.15
Time (D)	Forenoon (D ₁)	101.43 ^a
	Afternoon (D ₂)	101.88 ^b
	S.E. ±	0.04
	C.D. at 5%	0.12
Interval (I)	Before work (I ₁)	100.14 ^a
	1 st hour (I ₂)	101.61 ^b
	2 nd hour (I ₃)	102.28 ^c
	After 3 rd hour (I ₄)	102.57 ^d
	S.E. ±	0.06
	C.D. at 5 %	0.17

* Different superscripts indicates significant difference

These results confirmed with those reported by Singh *et al.* (1970) in Sahiwal bullocks, Acharya *et al.* (1979) in crossbred and non-descript indigenous bullocks, Sreekumar and Thomas (1990^a) in Kangayam bullocks and Anonymous

(2004) in Gaolao and non-descript cattle during ploughing. The increase in BT was due to the heat set free on account of the increased lactic acid production by muscle and its removal through oxidation process (Sastry *et al.* 1970). The higher level of body temperature was observed in Tapi Khillar during summer, at afternoon and after completion of work. The rise in body temperature with progression of work was more during summer, therefore, affected the work capacity of the animals. This could be due to higher environmental heat load.

The greater rise of temperature at the end of work over periods has been recorded in crosbreds as compared to Hariana by some researchers (Acharya *et al.*, 1979; Upadhyay and Madan, 1985^a). The effects of season / climate and ambient temperature was found to be significant on physiological responses of working bullocks in the previous studies of Maurya and Devadattam (1982^a).

The probable reason for increased body temperature in Tapi Khillar might be due to limited sweating gland capacity and less number of sweat glands per unit area of the skin. Under such situation, the animals were unable to loose heat of work, which affected the work performance. The present findings confirmed with the results of Shastry *et al.*, (1970), in Brown Swiss and Sahiwal bullocks. Patil (1990) concluded that numerical increase in body temperature might be attributed to heat production as a result of muscle concentration during work similar to that occurring due to exercise. Dhangar (1999) reported that during summer body temperature values were significantly higher in comparison to winter and higher values during afternoon over forenoon session.

**Table 4. Analysis of variance for body temperature during ploughing in
Khillar bullocks**

Source of variation	Df	MSS	F value at 5%
Type (T)	3	1.861019	
Season (S)	2	9.53691*	0.151645
Time (D)	2	73.11264*	0.151645
Interval (I)	1	14.67014*	0.123818
TS	3	84.23019*	0.175105
TD	4	1.250712*	0.262657
TI	2	0.156701	NS
SD	6	0.749873*	0.30329
SI	2	0.327639	NS
DI	6	0.968657*	0.30329
TSD	3	0.504213	NS
TSI	4	0.19592	NS
TDI	12	0.114022	NS
SDI	6	0.099109	NS
TSDI	6	0.118102	NS
Error	12	0.098675	NS
Total	213	0.287333	

The analysis of variance revealed that the interaction effect between T x S, T x D, S x D and D x I for body temperature were significant ($P < 0.05$). The interaction effect between viz., T x I, S x I, D x I, T x S x D, T x S x I, T x D x I, S x D x I and T x S x D x I did not affect body temperature during ploughing.

4.1.1.3. Pulse rate

The overall mean for PR in Khillar bullocks was 75.98 beats/min (Table 5). The pulse rates were observed to be 77.83, 72.33 and 77.80 beats/min in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar, respectively (Fig. 3). These results were supported by the finding of Singh *et al.* (1968^a) in Haryana bullocks, Sastry *et al.* (1970) in Brown Swiss x Sahiwal bullocks, during ploughing operation. The analysis of variance revealed that the significant ($P < 0.05$) variations in PR were attributed to the types of Khillar viz., Pandharpuri, Kosa and Tapi Khillar (Table 6). The mean for PR during different seasons were 79.86, 75.63 and 72.48 beats/min in summer, rainy and winter season, respectively (Fig. 3). Almost similar results were reported by Acharya *et al.* (1979) in crossbred and non-descript indigenous bullocks. The season had significant ($P < 0.05$) effect on pulse rate. During summer, it was higher followed by rainy and winter season (Table 5). The mean for PR during forenoon and afternoon were 74.59 and 77.39, respectively (Fig. 3). The PR was significantly ($P < 0.05$) higher during afternoon than forenoon period (Table 5). The means for PR in Khillar bullocks before work, after 1st, 2nd hour and after ploughing were 60.81, 77.15, 81.08 and 84.92 (Fig. 3). The significant ($P < 0.05$) variations in PR were observed at different intervals of working (Table 6), it indicated that as the working hours increased the PR increased.

Table 5. Means for pulse rate in Khillar bullocks during ploughing

Particular		Pulse rate (beats / min)
μ		75.98
Type (T)	Pandharpuri Khillar (T ₁)	77.83 ^b
	Kosa Khillar (T ₂)	72.33 ^a
	Tapi Khillar (T ₃)	77.80 ^b
	S.E. ±	0.18
	C.D. at 5%	0.49
Season (S)	Summer (S ₁)	79.86 ^c
	Rainy (S ₂)	75.63 ^b
	Winter (S ₃)	72.48 ^a
	S.E. ±	0.18
	C.D. at 5%	0.49
Time (D)	Forenoon (D ₁)	74.59 ^a
	Afternoon (D ₂)	77.39 ^b
	S.E. ±	0.15
	C.D. at 5%	0.40
Interval (I)	Before work (I ₁)	60.81 ^a
	1 st hour (I ₂)	77.15 ^b
	2 nd hour (I ₃)	81.08 ^c
	After 3 rd hour (I ₄)	84.92 ^d
	S.E. ±	0.21
	C.D. at 5 %	0.57

* Different superscripts indicates significant difference

The higher values for pulse rate were observed in Tapi Khillar, during summer, at afternoon and after completion of work. The increase in pulse rate represented a rise in cardiac activity to fulfill the increased demand for oxygen

during exercise. The These results were in close agreement with Patil *et al.*, (1994), Sreekumar and Thomas (1990^a), Bijendrakumar *et al.*, (1996) and Dhanger (1999) who observed similar trend of rise and fall in pulse rate in response to exercise and rest in crossbred and indigenous bullocks.

Table 6. Analysis of variance for pulse rate during ploughing in Khillar bullocks

Source of variation	Df	MSS	F value at 5%
Replication	3	16.27199	
Type (T)	2	962.5313*	0.493414
Season (S)	2	1318.635*	0.493414
Time (D)	1	563.9201*	0.40287
Interval (I)	3	8101.124*	0.569745
TS	4	7.994792*	0.854617
TD	2	8.128472	NS
TI	6	55.90162*	0.986827
SD	2	1.649306	NS
SI	6	36.3669*	0.986827
DI	3	32.93866*	0.805741
TSD	4	0.717014	NS
TSI	12	1.358218	NS
TDI	6	1.869213	NS
SDI	6	4.056713	NS
TSDI	12	1.159144	NS
Error	213	3.041944	
Total	287		

The present findings confirmed with the results of Mukherjee *et al.*, (1961) who reported increase in pulse rate during ploughing operation in local animals. Rowell *et al.*, (1969) reported that the blood flow increase through skin due to vasodilatation of sub cutaneous blood vessels during exercise was met by increasing cardiac output and achieved mainly by increase in heart rate. Bhutani and Nangia (1978) also concluded that increase in heart rate was the main contributing factor for increase in cardiac output during exercise. Similar increase in pulse rate in response to exercise in indigenous bullocks were observed by Sastry *et al.*, (1970) and Acharya *et al.*, (1979) who reported higher rates of respiration accompanied by early manifestation of panting and frothing during rainy and summer seasons. Similar increase in pulse rate in response to exercise in indigenous and crossbred bullocks was observed by Patil (1990). Patil *et al.*, (1994) studied the draftability of humpless HF x Deoni bullocks and compared with Deoni bullocks for ploughing. They reported a significant increase in pulse rate at ploughing.

The variations in pulse rate were significantly ($P < 0.05$) attributed to the different interaction effect viz., T x S, T x I, S x I and D x I during ploughing operation in Khillar bullocks. However, in interaction between T x D, S x D, T x S x D, T x S x I, T x D x I, S x D x I and T x S x D x I did not influence the pulse rate.

4.1.2 Haematological parameters

A large and rapid metabolic and haematological changes, take place in proportion work stress and greater demand for O₂ during work to the intensity of work. By determining certain biological constituents like glucose and lactic acid and haematological parameters before, during and after the work gives a good indication about ability of the animal to sustain with the adverse effects of work stress and adjustment of animals physiological system. The haematological study

in terms of Haemoglobin, Blood glucose and Lactic acid before and after ploughing was conducted.

4.1.2.1. Haemoglobin

The means for haemoglobin content in the blood of Pandharpuri, Kosa and Tapi Khillar during before and after ploughing were 10.56 and 9.84, 10.56 and 9.90 and 11.12 and 10.48 gm% respectively (Table 7, Fig. 4). The present investigation revealed the decreasing trend in haemoglobin content during before work to after work in Khillar cattle, which might be due to haemodilution and destruction of red blood cells.

Table 7. Means for Hb in Khillar bullocks during ploughing

Type	Haemoglobin (gm%) (Before work)	Haemoglobin (gm%) (After work)
Pandharpuri Khillar (T ₁)	10.56	9.84
Kosa Khillar (T ₂)	10.56	9.90
Tapi Khillar (T ₃)	11.12	10.48

Almost similar results were reported by Mukherjee *et al.*, (1961) in Haryana, Sastry (1969) in Sahiwal, Yawalikar (2000) in Red Kandhari, Deoni and HF x Deoni. Tripathi *et al.*, (1978) found decrease in packed cell volume and haemoglobin at high environmental temperature in healthy bulls. Garg *et al.*, (1981) observed a significant ($P < 0.01$) decrease in hematocrit values in exercised bullocks. The gas carrying capacity of blood particularly in terms of PO_2 was affected, inspite of the fact that blood haemoglobin levels remained unaltered. The said increase in carrying capacity was attributed to the saturation of haemoglobin (Astrand and Rodhal, 1970).

4.1.2.2. Blood glucose

The means of glucose content in the blood of Pandharpuri, Kosa and Tapi Khillar before and after ploughing were 56.95 and 48.24, 54.90 and 50.27 and 55.00 and 47.78 mg%, respectively (Table 8, Fig. 5). The present investigation revealed decreasing trend in glucose content during before work to after work in Khillar cattle. Glucose normally serves as a major source of fuel during exercise.

Table 8. Means for glucose in Khillar bullocks during ploughing

Type	Glucose (mg%) (Before work)	Glucose (mg%) (After work)
Pandharpuri Khillar (T ₁)	56.95	48.24
Kosa Khillar (T ₂)	54.90	50.27
Tapi Khillar (T ₃)	55.00	47.78

Similar results were reported by Georgie *et al.*, (1970) in crossbred and Sahiwal bullocks, Singh and Upadhyay (1995) in crossbred and Dhangar (1999) in Kankrej bullocks. They found that varying intensity of load caused a decline in blood glucose level.

Patil (1990) reported that the alteration in blood glucose level could be associated with alteration of the substrate as a source of energy required for muscular activity as a result of efficient homeostatic mechanism for glucose.

In protracted muscular work the hyperglycemia that is often seen as apart of the general adaptation syndrome is masked by the specific blood sugar reducing effect of muscular work and this is apparently superimposed over the usual hyperglycemic curve, Selye (1950).

These findings confirmed with the results of Gupta *et al.*, (1992). They further reported the level of glucose at pre- work as 55.62 ± 1.83 mg% in summer. The physical work caused a significant decline in blood glucose concentration to a greater extent during summer for ploughing. Singh and Upadhyay (1995) studied

physico-chemical responses of she buffaloes during cart loads under hot humid season. They reported that haemoglobin, haematocrit and blood glucose level decreased and lactic acid level increased.

4.1.2.3. Blood lactic acid

The means of lactic acid content in the blood of Pandharpuri, Kosa and Tapi Khillar before and after ploughing were 7.73 and 8.80, 7.00 and 8.00 and 5.75 and 8.72 gm%, respectively (Table 9, Fig. 6).

Table 9. Means for lactic acid in Khillar bullocks during ploughing

Breed	Lactic acid (gm%) (Before work)	Lactic acid (gm%) (After work)
Pandharpuri Khillar (T ₁)	7.73	8.80
Kosa Khillar (T ₂)	7.00	8.00
Tapi Khillar (T ₃)	5.75	8.72

The increasing trend in formation of lactic acid during ploughing in Khillar bullocks due to very intense muscular activity, revealed that the circulatory system could not bring oxygen and glucose to the skeletal muscles fast enough. Hence muscle glycogen was used as a reserve fuel and broken to form lactate, which further generated ATP as energy source. As insufficient oxygen was available, the lactate could not be metabolized further in the muscle and diffused in blood, where its concentration increased. Almost similar results were also reported by Gattewar (1983), Yawalikar (2000) in Red Kandhari, Deoni and HF x Deoni, and Dhangar (1999) in crossbred and indigenous bullocks. These results also confirmed with the reports of Beninati (1957) who observed fatigue in the cattle caused due to constant haemoconcentration and rise in the blood lactic acid level because of muscular work. The level of lactic acid gradually decreased during the rest period.

Georgie *et al.*, (1970) also reported similar rapid increase in blood lactic acid level due to exercise in Sahiwal and crossbred bullocks. Nangia *et al.*, (1978) observed increased trend in blood lactic acid level in male buffalo calves of 2 years when subjected to work by pulling a stone roller. Chaudhary *et al.*, (1985) reported that blood lactic acid increased in response to level declined copper phosphate. Upadhyay and Madan (1985^b) reported an increase in muscle lactic acid to the tune of 0.6 to 2.23 u mol/gm. These results were also in a agreement with Dhangar (1999) that the changes in blood lactic acid levels during both the seasons at ploughing were greater. The rise in blood lactic acid concentration could be due to increased anaerobic muscular activity, greater activity being at higher intensity of loads.

4.1.3 Work performance during ploughing

The work performed by Khillar bullocks during ploughing was studied with regard to draft generated, speed of the work, area covered and horse power (hp) generated after each trial.

4.1.3.1. Draft generated during ploughing

The overall mean for draft generated by Khillar bullocks during ploughing was 142.73 kg (Table 10). Almost similar results were reported by Maurya and Devadattam (1996) in Jersey x Red Sindhi and Khillar bullocks (123.50 and 152.0 kg). The draft generated during ploughing operation were 143.90, 162.91 and 133.37 kg by Pandharpuri (T₁), Kosa (T₂) and Tapi (T₃) Khillar, respectively (fig. 7). The analysis of variance revealed that the significant ($P < 0.01$) variations in draft were attributed to the type of Khillar (Table 11). The mean for draft generated during ploughing by Khillar bullocks during summer, rainy and winter were 145.72, 151.76 and 142.70 kg (Fig. 7). These results confirmed with Maurya (1982) in crossbred and Khillar bullocks during summer and winter seasons. Season had significant ($P < 0.01$) effect on draft (Table 11). The draft increased

during rainy was higher as compared to summer and winter season. The means for draft generated during forenoon and afternoon were 149.11 and 144.34 kg, respectively (Fig. 7). Draft generated was significantly ($P < 0.01$) higher during forenoon than afternoon period (Table 10).

Table 10. Means for draft generated by Khillar bullocks during ploughing

Particular		Draft (kg)
μ		142.73
Type (T)	Pandharpuri Khillar (T_1)	143.90 ^b
	Kosa Khillar (T_2)	162.91 ^c
	Tapi Khillar (T_3)	133.37 ^a
	S.E. $\pm$	0.63
	C.D. at 1%	2.39
Season (S)	Summer (S_1)	145.72 ^b
	Rainy (S_2)	151.76 ^c
	Winter (S_3)	142.70 ^a
	S.E. $\pm$	0.63
	C.D. at 1%	2.39
Time (D)	Forenoon (D_1)	149.11 ^b
	Afternoon (D_2)	144.34 ^a
	S.E. $\pm$	0.52
	C.D. at 1%	1.96

* Different superscripts indicates significant difference

Similar results were also repoted by Vaugh (1947) in indigenous bullocks, Swamy Rao (1954) in Haryana crossbred bullocks and Dhangar (1999) who observed similar trend in increase in draft at ploughing in crossbred and indigenous bullocks.

Table 11. Analysis of variance for draft during ploughing in Khillar bullocks

Source of variation	Df	MSS	F value	
			at 5%	at 1%
Replication	3	1.667		
Type (T)	2	5380.063**	1.797	2.396
Season (S)	2	509.938**	1.797	2.396
Time (D)	1	408.00**	1.467	1.957
TS	4	13.688	NS	----
TD	2	10.938	NS	----
SD	2	12.188	NS	----
TSD	4	10.188	NS	----
Error	51	9.610	----	----
Total	71	-----	----	----

All the interaction effects on draft generated were non- significant during ploughing.

Premi (1979) reported that the Hallikar bullocks could pull maximum draft of 13 to 16 per cent of the body weight during six hours of work. The power and work output of the bullocks depends upon the body weight, hours of work, draft and climate. When the draft increased, power and work output also increased, which ultimately increased with increase in body weight. The magnitude of draft negotiated by animal would depend upon species, breed, type and nature of work, load imposed on them, season, climate and harness used.

4.1.3.2 Speed observed during ploughing

Average speed of Khillar bullocks during ploughing was 3.06 km/hr (Table 12). The speed observed during ploughing were 3.06, 3.12 and 3.00 km/hr in the

case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar, respectively (Fig. 8). The variance analysis revealed that the significant ($P < 0.01$) variations in speed were observed in Pandharpuri, Kosa and Tapi Khillar (Table 13). The means for speed during ploughing by Khillar bullocks during summer, rainy and winter were 2.99, 3.07 and 3.12 km/hr (Fig. 8). The significant ($P < 0.01$) variations in speed were observed during different seasons (Table 13). The speed during ploughing was higher in winter followed by rainy and summer season. The means for speed during forenoon and afternoon were 3.09 and 3.03 km/hr, respectively (Fig. 8). These results were in agreement with those reported by Anonymous (1979-80) in Hallikar bullocks, Premi (1979) in Hallikar bullocks, Upadhyay and Madan (1982^a) in Haryana and Gattewar (1983) in crossbred and Haryana bullocks. The speed was significantly ($P < 0.01$) higher during forenoon than afternoon (Table 12).

Table 12. Means for speed of Khillar bullocks during ploughing

Particular		Speed (km/hr)
μ		3.06
Type (T)	Pandharpuri Khillar (T_1)	3.06 ^b
	Kosa Khillar (T_2)	3.12 ^a
	Tapi Khillar (T_3)	3.00 ^a
	S.E. $\pm$	0.005
	C.D. at 1%	0.017
Season (S)	Summer (S_1)	2.99 ^a
	Rainy (S_2)	3.07 ^b
	Winter (S_3)	3.12 ^c
	S.E. $\pm$	0.005
	C.D. at 1%	0.017
Time (D)	Forenoon (D_1)	3.09 ^b
	Afternoon (D_2)	3.03 ^a
	S.E. $\pm$	0.004
	C.D. at 1%	0.014

* Different superscripts indicates significant difference

The non- significant interaction effects for speed between T x S, T x D, S x D and T x S x D were observed during ploughing.

Sigh *et al.*, (1970) reported the average speed of Sahiwal bullocks as 2.21, 1.98. and 2.21 km/hr. during disc ploughing, harrowing and tillage operation, respectively.

Premi (1979) observed that the Hallikar bullocks could work with an average speed of 3 km/hr during six hours continuous exercise. Maurya (1982) studied the draftability of crossbred bullocks under hot conditions. He noted that crossbred bullocks work at a speed of 3.35 km/hr.

Table 13. Analysis of variance for speed during ploughing in Khillar bullocks

Source of variation	Df	MSS	F value	
			at 5%	at 1%
Replication	3	0.003		
Type (T)	2	0.084**	0.013	0.017
Season (S)	2	0.097**	0.013	0.017
Time (D)	1	0.065**	0.011	0.014
TS	4	0.00	NS	----
TD	2	0.00	NS	----
SD	2	0.001	NS	----
TSD	4	0.001	NS	----
Error	51	0.001	----	----
Total	71	-----	----	----

The decrease in speed with increased duration of operation was observed in Khillar bullocks. Gattewar *et al.*, (1989) Chanwal (1991) and Dhangar (1999) also observed similar results.

4.1.3.3 Horse power (hp) developed during ploughing

The average for hp developed by Khillar bullocks during ploughing was 1.68 hp (Table 14). The means for horse power in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar were 1.67, 1.88 and 1.48 during ploughing, respectively (Fig. 9), which matches very well with the value reported by Rautary and Srivastava (1982) in Sahiwal crossbred bullocks (1.7 to 1.9 hp during ploughing). The Kosa Khillar generated highest hp during ploughing indicating power generating capacity under prevailing climatic condition. The variance analysis revealed that the significant ($P < 0.01$) variations in hp were attributed to the type of Khillar (Table 15). The mean for horse power during ploughing by Khillar bullocks during summer, rainy and winter were 1.62, 1.73 and 1.69 (Fig. 9). Season had significant ($P < 0.01$) effect on hp. Higher hp was produced during rainy followed by winter and summer season (Table 14). The means for horse power during forenoon and afternoon were 1.72 and 1.64, respectively (Fig. 9). The hp generated was significantly ($P < 0.01$) higher during forenoon than afternoon period (Table 14). These results were in agreement with those reported by Premi (1979) in Hallikar, Gattewar (1983) in crossbred and Haryana, Upadhyay and Madan (1985^a) in Haryana crossbred bullocks, Maurya and Devedattam (1986) in crossbred bullocks and Dhangar (1999) in crossbred and indigenous bullocks.

Table 14. Means for horse power generated by Khillar bullocks during ploughing

Particular		Horse power (hp)
μ		1.68
Type (T)	Pandharpuri Khillar (T ₁)	1.67 ^b
	Kosa Khillar (T ₂)	1.88 ^c
	Tapi Khillar (T ₃)	1.48 ^a
	S.E. $\pm$	0.010
	C.D. at 1%	0.038
Season (S)	Summer (S ₁)	1.62 ^a
	Rainy (S ₂)	1.73 ^c
	Winter (S ₃)	1.69 ^b
	S.E. $\pm$	0.010
	C.D. at 1%	0.038
Time (D)	Forenoon (D ₁)	1.72 ^b
	Afternoon (D ₂)	1.64 ^a
	S.E. $\pm$	0.008
	C.D. at 1%	0.031

* Different superscripts indicates significant difference

Results of present work are confirmed with the result of Sing *et al.*, (1970) who studied the work performance and physiological responses of Haryana and Sahiwal bullocks performing common agriculture operations. The horse power developed by Haryana bullocks during disc ploughing was 0.803 by Sahiwal and 0.627 by Haryana bullocks. Premi (1979) recorded that the power and work output of Hallikar bullocks increased at the rate of 1.57 horse power hour per pair on every hundred kilogram increase in average body weight of the animals.

Rautaray (1985) reported that the relationship exists between average horse power output with working time at different draft conditions in a pair of Malvi bullocks. The average horse power output decreased with the increase in working time for all the draft conditions in crossbred and local breed.

Table 15. Analysis of variance for horse power during ploughing in Khillar bullocks

Source of variation	Df	MSS	F value	
			at 5%	at 1%
Replication	3	0.001		
Type (T)	2	0.971**	0.029	0.038
Season (S)	2	0.075**	0.029	0.038
Time (D)	1	0.136**	0.023	0.031
TS	4	0.014**	0.050	0.066
TD	2	0.001	NS	----
SD	2	0.002	NS	----
TSD	4	0.001	NS	----
Error	51	0.002	----	----
Total	71	-----	----	----

The significant ($P < 0.01$) interaction effect were observed between T x S for hp produced during sowing. However, non- significant interaction effects for hp between T x D, S x D and T x S x D were observed during ploughing.

4.1.3.4 Area covered by the bullocks at ploughing

Average for area covered by Khillar bullocks during ploughing was 346.27 m²/hr (Table 16). The area covered by Pandharpuri (T₁), Kosa (T₂) and Tapi (T₃) Khillar during ploughing were 347.31, 354.71 and 336.80 m²/hr, respectively (Fig.

10). The present findings are confirmed with the results of Roy *et al.*, (1972) in Haryana bullocks, Anand and Sundresan (1974) in Haryana bullocks. The variance analysis revealed that the significant ($P < 0.01$) variations in area covered were observed in Pandharpuri, Kosa and Tapi Khillar (Table 17). The means for area covered during ploughing by Khillar bullocks during summer, rainy and winter were 336.60, 343.24 and 358.98 (Fig. 10). Season had significant ($P < 0.01$) effect on area covered. The higher area was covered during winter followed by rainy and summer season (Table 16). The means for area covered during forenoon and afternoon were 347.90 and 344.64, respectively (Fig. 10). The area covered was significantly ($P < 0.01$) higher during forenoon than afternoon period (Table 16). Almost similar results were reported by Rao *et al.*, (1974) in crossbred bullocks.

Table 16. Means for area covered by Khillar bullocks during ploughing

Particular		Area covered (m ² /hr)
μ		346.27
Type (T)	Pandharpuri Khillar (T ₁)	347.31 ^b
	Kosa Khillar (T ₂)	354.71 ^c
	Tapi Khillar (T ₃)	336.80 ^a
	S.E. ±	0.49
	C.D. at 1%	1.85
Season (S)	Summer (S ₁)	336.60 ^a
	Rainy (S ₂)	343.24 ^b
	Winter (S ₃)	358.98 ^c
	S.E. ±	0.49
	C.D. at 1%	1.85
Time (D)	Forenoon (D ₁)	347.90 ^b
	Afternoon (D ₂)	344.64 ^a
	S.E. ±	0.39
	C.D. at 1%	1.51

* Different superscripts indicates significant difference

Table 17. Analysis of variance for area covered during ploughing in Khillar bullocks

Source of variation	Df	MSS	F value	
			at 5 %	at 1 %
Replication	3	9.333		
Type (T)	2	1944.000**	1.389	1.853
Season (S)	2	3171.000**	1.389	1.853
Time (D)	1	192.000**	1.134	1.513
TS	4	199.500**	2.406	3.209
TD	2	2.000	NS	----
SD	2	0.500	NS	----
TSD	4	5.750	NS	----
Error	51	5.745	----	----
Total	71	-----	----	----

The present findings confirmed the reports Acharya *et al.* (1979) in crossbred bullocks, Nagpaul (1984) in Hariana, Rao and Upadhyay (1984) in crossbred bullocks, Abhyankar (1986) in crossbred bullocks, Sreekumar and Thomas (1990^a) in Kangayam and crossbred bullocks, Dhangar (1999) in Kankarej bullocks and Jadhav and Jagtap (2000) in crossbreed and indigenous bullocks during ploughing.

The variations in area covered were significant ($P < 0.01$) attributed to the different interaction effect viz., T x S during ploughing operation in Khillar bullocks. However, in interaction between T x D, S x D, T x S x D did not influence the area covered.

4.2. Sowing (Palte 11)

The operation of sowing was performed during three season summer, rainy and winter.

4.2.1 Physiological indices

The physiological indices viz., respiration rate, body temperature, pulse rate before work, after 1st hr, 2nd hr and after 3rd hour completion of work during each trial in Khillar bullocks have been discussed.

4.2.1.1. Respiration rate

The average of RR in Khillar bullocks was 39.29 beats/min (Table 18). The mean for respiration rate was observed to be 39.88, 35.42 and 42.35 beats/min in the case of Pandharpuri (T₁), Kosa (T₂) and Tapi (T₃) Khillar, respectively (Fig. 11). These finding confirmed with the results of Sreekumar and Thomas (1990^a) in Kangayam bullocks. The analysis of variance revealed that the significant ($P < 0.05$) variations in RR were observed due to type of Khillar (Table 19). The mean for respiration rate during summer, rainy and winter season were 41.74, 41.03 and 34.88 beats/min (Fig. 11). Almost similar results were reported by Acharya *et al.* (1979) in crossbred and indigenous bullocks. Season had significant ($P < 0.05$) effect on RR in Khillar bullocks. During summer, it was higher followed by rainy and winter season (Table 18). The means for RR during forenoon and afternoon were 37.94 and 40.49, respectively (Fig. 11). The RR were significantly ($P < 0.05$) higher during afternoon than forenoon period (Table 18). The respiration rate during before work, after 1st, 2nd hour and after 3rd hour of sowing were 22.08, 37.90, 44.93 and 51.96 beats/min (Fig. 11). These results were in close agreement with those reported by Anonymous (2004) in Gaolao (13.57, 16.53, 20.86 and 26.22 at initial, 1st, 2nd, and 3rd hr interval). The variations in RR significant ($P < 0.05$) were attributed to the different intervals of working (Table 19). It indicated that as the working hours increased the RR also increased. The increase in

respiration rate helped the animals to dissipate excess heat generated in the body during exercise. As the duration of work progressed the respiration rate also increased which might be due to the increased demand for oxygen by the tissue during work and compensatory effort to effect thermolysis.

Table 18. Means for respiration rate in Khillar bullocks during sowing

Particular		Respiration rate (beats/min.)
μ		39.29
Type (T)	Pandharpuri Khillar (T ₁)	39.88 ^b
	Kosa Khillar (T ₂)	35.42 ^a
	Tapi Khillar (T ₃)	42.35 ^c
	S.E.±	0.25
	C.D. at 5%	0.69
Season (S)	Summer (S ₁)	41.74 ^c
	Rainy (S ₂)	41.03 ^b
	Winter (S ₃)	34.88 ^a
	S.E.±	0.25
	C.D. at 5%	0.69
Time (D)	Forenoon (D ₁)	37.94 ^a
	Afternoon (D ₂)	40.49 ^b
	S.E.±	0.20
	C.D. at 5%	0.57
Intervals (I)	Before work (I ₁)	22.08 ^a
	1 st hour (I ₂)	37.90 ^b
	2 nd hour (I ₃)	44.93 ^c
	After 3 rd hour (I ₄)	51.96 ^d
	S.E. ±	0.29
	C.D. at 5 %	0.80

* Different superscripts indicates significant difference

These results closely resembled with Bhosrekar *et al.* (1966) in Thaparkar and Sahiwal bullocks, Singh *et al.* (1968^a) in Haryana bullocks and Nagpaul *et al.* (1984) in crossbred and zebu bullocks and Dhangar (1999) who observed similar trend of rise and fall in respiration rate in response to exercise and rest in crossbred and indigenous bullocks.

These findings confirmed with the results of Graf and Petersen (1953) who reported a highly significant increase in respiration rate (54.2%) heart rate (67.9%) and rise in rectal temperature in response to vigorous exercise for 10 minutes in the dairy cattle. Thompson *et al.* (1964) reported that changes in the physiological responses be induced by direct solar radiation. Increase in the respiration rate was in tune with the greater demand for oxygen by the tissue during exercise.

Bhosrekar *et al.*, (1966) reported that respiration rates showed most variations due to change in atmospheric conditions. There seems to be no breed to breed difference in their adaption to different climatic conditions. Singh *et al.* (1970) compared the performance of Sahiwal and Haryana bullocks during different agricultural operations and reported that the fall in the respiration rate while resting after the agricultural operations with disc plough, disc harrow and cultivator was significantly faster in Sahiwal bullocks than in Haryana. They recommended suitability of Sahiwal bullocks for interrupted farm operation where speed is not an important, particularly after considering the rate of return of respiration rate to normal and speed of the bullocks.

Dhangar (1999) reported that during summer respiration rates were significantly higher in comparison to winter. The respiration rates were also higher during afternoon over forenoon session.

**Table 19. Analysis of variance for respiration rate during sowing in
Khillar bullocks**

Source of variation	Df	MSS	F value at 5%
Replication	3	93.1331	
Type (T)	2	1187.094*	0.802777
Season (S)	2	1364.042*	0.695225
Time (D)	1	467.67*	0.695225
Interval (I)	3	11766.62*	0.567649
TS	4	45.90104*	0.802777
TD	2	0.107639*	1.204165
TI	6	150.2141	NS
SD	2	13.38889*	1.39045
SI	6	118.7037	NS
DI	3	32.84606*	1.39045
TSD	4	7.779514*	1.135298
TSI	6	2.644676	NS
TDI	6	5.606481	NS
SDI	12	3.566551	NS
TSDI	213	6.039205	
Error	287	----	

Acharya *et al.*, (1979) compared the working capacity and behaviour of F₁ crossbred (Holstein x Hariana) and non- descript indigenous bullocks in a ploughing and carting trials in rainy, winter and summer seasons. The crossbred showed higher rates of respiration and pulse accompanied by an early manifestation of panting and salivary frothing during rainy and summer seasons. The crossbred bullocks also exhibited more stamina, higher speed and greater

capacity for work than the non- descripts indigenous bullocks. Bhosrekar and Mangurkar (1989) reported rise in rectal temperature, pulse rate and respiration rate under ploughing operation, these physiological indices were found higher in HF crossbred bullocks than in Jersey crossbred and local bullock.

Bijenderkumar *et al.*, (1996) also reported that Haryana bullocks exhibited superiority in ploughing and carting over cross – breed.

Dave and Mukherjee (2001) reported that increase in respiration rate with increase in operating time and draftload with the bullocks.

The interaction effect between T x S, T x D, S x D and D x I and T x S x D for respiration rate were significant ($P < 0.05$) in Khillar bullocks. However, the interaction effects for respiration rate between T x I, S x I, T x S x I, T x D x I, S x D x I, T x S x D x I were non- significant during sowing.

4.2.1.2 Body temperature

The overall means for body temperature in Khillar bullocks was 101.42 °F (Table 20). The body temperature during sowing operation were observed to be 101.44, 101.12 and 101.71 in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar, respectively (Fig. 12). The variance analysis revealed that the significant ($P < 0.05$) variations in BT were observed due to type of Khillar (Table 21). These findings confirmed with the results of Acharya *et al.*, (1979) in crossbred (Holestein x Haryana) bullocks and Bhosrekar and Mangurkar (1989) in HF crossbred bullocks. The body temperature were observed as 102.10, 101.53 and 100.62 °F during summer, rainy and winter season (Fig. 12). Season had significant ($P < 0.05$) effect on BT in Khillar bullocks. The means for body temperature during forenoon and afternoon were 101.24 and 101.60 °F, respectively (Fig. 12). The BT was significantly ($P < 0.05$) higher during afternoon as compared forenoon period (Table 20). The means for body temperature in Khillar bullocks before work, after 1st, 2nd hour and after sowing were 100.12, 101.30, 102.97 and 102.29 °F (Fig. 12). The significant ($P < 0.05$)

variations in BT were attributed to the different intervals of working (Table 21), it indicated that as the working hours increased the BT also increased in Khillar bullocks. Almost similar results were reported by Yawalikar (2000) in Red Kandhari, Deoni and HF x Deoni bullocks. Patil *et al.*, (1994) in Deoni and HF x Deoni and Dhangar (1999) who observed trend of rise and fall in body temperature in response to exercise and rest in crossbred and indigenous bullocks.

Table 20. Means for body temperature in Khillar bullocks during sowing

Particular		Body temperature (°F)
μ		101.42
Breed (B)	Pandharpuri Khillar (T ₁)	101.44 ^b
	Kosa Khillar (T ₂)	101.12 ^a
	Tapi Khillar (T ₃)	101.71 ^c
	S.E.±	0.05
	C.D. at 5%	0.13
Season (S)	Summer (S ₁)	102.10 ^c
	Rainy (S ₂)	101.53 ^b
	Winter (S ₃)	100.62 ^a
	S.E.±	0.05
	C.D. at 5%	0.13
Time (D)	Forenoon (D ₁)	101.24 ^a
	Afternoon (D ₂)	101.60 ^b
	S.E.±	0.04
	C.D. at 5%	0.11
Intervals (I)	Before work (I ₁)	100.12 ^a
	1 st hour (I ₂)	101.30 ^b
	2 nd hour (I ₃)	101.97 ^c
	After 3 rd hour (I ₄)	102.29 ^d
	S.E. ±	0.05
	C.D. at 5 %	0.15

* Different superscripts indicates significant difference

Dhangar (1999) reported that during summer body temperature was significantly higher in comparison to winter, it was also higher during afternoon over morning period. These results were comparable with the present findings.

Dave and Mukherjee (2001) reported that rectal temperature increased with advancing of working time and increase in draught load. The maximum variation in rectal temperature was observed always at highest draught load and at the end of the longest duration of work in the working bullocks.

Table 21. Analysis of variance for body temperature during sowing in Khillar bullocks

Source of variation	Df	MSS	F value at 5%
Type (T)	3	1.520557	
Season (S)	2	8.362604*	0.1311527
Time (D)	2	53.69038*	0.1311527
Interval (I)	1	9.512068*	0.107391
TS	3	66.29582*	0.151874
TD	4	1.22189*	0.227812
TI	2	0.038276	NS
SD	6	0.95008*	0.263054
SI	2	0.037335	NS
DI	6	0.80035*	0.263054
TSD	3	0.284916	NS
TSI	4	0.059699	NS
TDI	12	0.027332	NS
SDI	6	0.003763	NS
TSDI	6	0.008438	NS
Error	12	0.007525	NS
Total	213	0.216152	

The interaction effect between T x S, T x D, S x D and D x I for body temperature were significant ($P < 0.05$) (Table 21). However, interaction effects viz., T x I, S x I, T x S x D, T x S x I, T x D x I, S x D x I and T x S x D x I for body temperature during sowing were non significant.

4.2.1.3 Pulse rate

The overall mean for pulse rate in Khillar bullocks was 73.66 beats/min (Table 22). The pulse rates were observed to be 75.01, 69.85 and 75.72 in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar, respectively during sowing operation (Fig. 13). These results were supported by the findings of Singh et al. (1968^a) in Harijana bullocks. The analysis of variance revealed that the significant ($P < 0.05$) variations in PR were attributed to the types of Khillar viz., Pandharpuri, Kosa and Tapi Khillar (Table 23). The means for PR were observed as 76.75, 72.96 and 70.87 during summer, rainy and winter season (Fig. 13). These results were in close agreement with Acharya et al. (1979) in crossbred and non-descript indigenous bullocks. Variance analysis indicated that season had significantly ($P < 0.05$) influenced the PR. The PR was higher in summer followed by rainy and winter season (Table 22). The means for pulse rate during forenoon and afternoon were 71.74 and 75.31, respectively. The PR was significantly ($P < 0.05$) higher during afternoon than forenoon period in khillar bullocks (Table 22). The means for pulse rate in Khillar bullocks before work, after 1st, 2nd hour and after sowing were 59.94, 73.47, 78.53 and 82.17, respectively. The significant ($P < 0.05$) variations in PR were observed at different intervals of working (Table 23), which indicated that as the working hours increased the PR also increased. The increase in pulse rate represented a rise in cardiac activity to fulfill the increased demand for oxygen during exercise and also served as a heat losing mechanism by increasing blood flow through the skin. These finding confirmed with the results of Sreekumar and Thomas (1990^a) in Kangayam bullocks, Bijendrakumar *et al.* (1996) in Harijana bullocks and Dhangar (1999) who observed similar trend of rise

and fall in pulse rate in response to exercise and rest in crossbred and indigenous bullocks.

Table 22. Means for pulse rate in Khillar bullocks during sowing

Particular		Pulse rate (beats/min)
μ		73.66
Type (T)	Pandharpuri (T ₁) Khillar	75.01 ^b
	Kosa Khillar (T ₂)	69.85 ^a
	Tapi Khillar (T ₃)	75.72 ^b
	S.E.±	0.49
	C.D. at 5%	1.36
Season (S)	Summer (S ₁)	76.75 ^c
	Rainy (S ₂)	72.96 ^b
	Winter (S ₃)	70.87 ^a
	S.E.±	0.49
	C.D. at 5%	1.36
Time (D)	Forenoon (D ₁)	71.74 ^a
	Afternoon (D ₂)	75.31 ^b
	S.E.±	0.40
	C.D. at 5%	1.11
Intervals (I)	Before work (I ₁)	59.94 ^a
	1 st hour (I ₂)	73.47 ^b
	2 nd hour (I ₃)	78.53 ^c
	After 3 rd hour (I ₄)	82.17 ^d
	S.E. ±	0.57
	C.D. at 5 %	1.57

* Different superscripts indicates significant difference

Singh *et al.*, (1970) also noted that the fall in the pulse rate while resting after the agricultural operations with disc plough, disc harrow and cultivator was significantly faster in Sahiwal bullocks than in Haryana. They recommended suitability of Sahiwal bullocks for interrupted farm operation where speed was not important particularly after considering the rate of return of pulse rate to normal. Bhosrekar and Mangurkar (1989) also reported rise in rectal temperature, pulse rate and respiration rates under ploughing operation. The rise was found higher in HF crossbred bullocks than in Jersey crossbred and local bullocks.

Table 23. Analysis of variance for pulse rate during sowing in Khillar bullocks

Source of variation	Df	MSS	F value at 5%
Type (T)	3	38.36111	
Season (S)	2	983.7118*	1.364538
Time (D)	2	851.7222*	1.364538
Interval (I)	1	917.3472*	1.114141
TS	3	6819.37*	1.575633
TD	4	36.35243	NS
TI	2	23.25347	NS
SD	6	47.56829	NS
SI	2	33.18056	NS
DI	6	59.67593*	2.729077
TSD	3	61.93981*	2.228282
TSI	4	28.10243	NS
TDI	12	26.51447	NS
SDI	6	17.72106	NS
TSDI	6	19.60648	NS
Error	12	19.40336	NS
Total	213	23.26487	
Type (T)	287		

Dave and Mukherjee (2001) reported that the rate of increase in pulse rate was approximately proportional to the increase in draught load up to 14kg draught force/100 kg live weight but beyond this the increase was high.

The variations in pulse rate were significantly ($P < 0.05$) attributed to the different interaction effects viz., T x S, D x T and I x S x D during sowing operation in Khillar bullocks. However, interaction between T x D, T x I, S x D, S x I, T x S x D, T x S x I, T x D x I, S x D x I and T x S x D x I did not influence the pulse rate.

4.2.2 Haematological parameters

The haematological study in terms of levels of haemoglobin, blood glucose and lactic acid recorded before and after sowing was conducted. The results have been given below:

4.2.2.1. Haemoglobin

The overall mean for haemoglobin content in the blood of Pandharpuri, Kosa and Tapi Khillar before and after sowing were 10.60 and 9.91, 10.62 and 9.99 and 11.09 and 10.62 gm%, respectively (Table 24, Fig. 14). The decrease in the level of haemoglobin during after work might be due to the phenomenon of destruction of some erythrocytes, which caused stress of exercise in Khillar bullocks Singh *et al.* (1968^a) reported that reduction in number of erythrocytes might have brought down the haemoglobin level. The Kosa Khillar were thus in possession of better adaptive mechanism against stress of work when compared with Pandharpuri and Tapi Khillar.

The results revealed that the decreasing trend in haemoglobin content during before work to after work in Khillar cattle, which might be due to haemodilution and destruction of red blood cells. Almost similar results were reported by Chhikara and Singh (2000) in crossbred bullocks. contradictory results were reported by Yawalikar (2000) in Red Kandhari, Deoni and HF x Deoni

Tripathi *et al.*, (1978) found in healthy bulls decrease in packed cell volume and haemoglobin at high environmental temperature.

Garg *et al.*, (1981) noted a significant decrease ($P < 0.01$) in hematocrit values in exercised.

Table 24. Means for Hb in Khillar bullocks during sowing

Type	Haemoglobin(gm%) (Before work)	Haemoglobin (gm%) (After work)
Pandharpuri Khillar (T ₁)	10.60	9.91
Kosa Khillar (T ₂)	10.62	9.99
Tapi Khillar (T ₃)	11.09	10.62

4.2.2.2. Blood glucose

The mean of glucose content in the blood of Pandharpuri, Kosa and Tapi Khillar before and after sowing were 56.88 and 51.30, 54.90 and 51.27 and 52.20 and 48.00 mg%, respectively (Table 25, Fig 15).

The present investigation revealed decreasing trend in glucose content during before work to after work in Khillar cattle. Glucose normally serves as a major source of fuel during exercise. These results were also in close agreement with Singh and Upadhyay (1996) who observed a decline of blood glucose post-work Singh *et al.*, (1980) and Gupta (1992) reported decline in blood glucose in bullocks during sowing.

Table 25. Means for blood glucose in Khillar bullocks during sowing

Type	Glucose (mg%) (Before work)	Glucose (mg%) After work
Pandharpuri Khillar (T ₁)	56.88	51.30
Kosa Khillar (T ₂)	54.90	51.27
Tapi Khillar (T ₃)	52.20	48.00

These finding confirmed with the results of Georgie *et al.*, (1970) in crossbred and Sahiwal bullocks. Gupta *et al.*, (1992) observed significant decline in blood glucose concentration during summer season at all work. Patil (1990) reported that the alteration in glucose level could be associated with utilization of the substrate as a source of energy required for muscular activity and a result of efficient homestatic mechanisim for glucose.

4.2.2.3. Blood lactic acid (gm%)

The means for lactic acid content in the blood of Pandharpuri, Kosa and Tapi Khillar before and after sowing were 7.63 and 8.20, 6.98 and 7.75 and 5.67 and 7.40 gm%, respectively (Table 26, Fig. 16).

Table 26. Means for lactic acid in Khillar bullocks during sowing

Type	Lactic acid (gm%) (Before work)	Lactic acid (gm%) (After work)
Pandharpuri Khillar (T ₁)	7.63	8.20
Kosa Khillar (T ₂)	6.98	7.75
Tapi Khillar (T ₃)	5.67	7.40

The results revealed that the increasing trend in lactic acid content during before work to after work in Khillar cattle. These results were inline with Georgia *et al.*, (1970) in crossbred and Sahiwal bullocks and Dhangar (1999) who observed similar trend to rise and fall in lactic acid level in response to exercise and rest in crossbred and indigenous bullocks.

Beninati (1957) observed fatigue in the cattle caused due to constant haemoconcentration and rise in the blood lactic acid level because of muscular work. The level of lactic acid gradually decreased during the rest period.

Dhanger (1999) reported that the rise in blood lactic acid concentration could be due to increased anaerobic muscular activity, greater activity being at higher intensity of loads.

The increasing trend in formation lactic acid during sowing in Khillar bullocks due to very intense muscular activity revealed that the circulatory system couldn't bring oxygen and glucose to the skeletal muscles fast enough. Hence muscle glycogen was used as a reserve fuel and broken to form lactate, which further generated ATP as energy source. As insufficient oxygen was available the lactate could not be metabolized further in the muscle and diffused in blood, where its concentration increased.

4.2.3 Work performance

The draftability of Khillar bullocks during sowing was studied in terms of draft generated, speed of the work, horse power (hp) developed and area covered.

4.2.3.1 Draft developed during sowing

The overall mean for draft generated by Khillar bullocks during sowing was 70.66 kg (Table 27). The draft generated in Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar were 73.52, 79.07 and 59.40 kg, respectively during sowing operation (Fig. 17). The analysis of variance revealed that the significant ($P < 0.01$) variations in draft generated were observed in Pandharpuri, Kosa and Tapi Khillar (Table 28). The means for draft generated during sowing by Khillar bullocks during summer, rainy and winter were 69.93, 73.85 and 68.21 kg (Fig. 17). Season had significant ($P < 0.01$) effect on draft produced. The highest draft was generated during rainy season followed by summer and winter season (Table 27). The means for draft produced during forenoon and afternoon were 72.00 and 69.33 kg, respectively in Khillar bullocks (Fig. 17). Yawalikar (2000) in Red Kandhari, Deoni and HF x Deoni confirmed present investigation during sowing.

The draft was significantly ($P < 0.01$) higher during forenoon than afternoon period (Table 27). Maurya and Devadattam (1986), Gattewar (1983) and Abhyankar (1986) also observed similar trend of increase in draft at sowing in crossbred and indigenous bullocks.

Table 27. Means for draft generated in Khillar bullocks during sowing

Particular		Draft (kg)
μ		70.66
Type (T)	Pandharpuri Khillar (T_1)	73.52 ^b
	Kosa Khillar (T_2)	79.07 ^c
	Tapi Khillar (T_3)	59.40 ^a
	S.E.±	0.27
	C.D. at 1%	1.04
Season (S)	Summer (S_1)	69.93 ^b
	Rainy (S_2)	73.85 ^c
	Winter (S_3)	68.21 ^a
	S.E.±	0.27
	C.D. at 1%	1.04
Time (D)	Forenoon (D_1)	72.00 ^b
	Afternoon (D_2)	69.33 ^a
	S.E.±	0.22
	C.D. at 1%	0.85

* Different superscripts indicates significant difference

Devadattam and Maurya (1978) reported the draft developed by Haryana bullocks as only 7.5% of the body weight.

Table 28. Analysis of variance for draft during sowing in Khillar bullocks

Source of variation	Df	MSS	F value	
			at 5%	at 1%
Replication	3	0.688		
Type (T)	2	2467.297**	0.781	1.041
Season (S)	2	200.469**	0.781	1.041
Time (D)	1	129.063**	0.637	0.850
TS	4	7.070**	1.352	1.804
TD	2	0.813	NS	----
SD	2	1.531	NS	----
TSD	4	0.891	NS	----
Error	51	1.815	----	----
Total	71	-----	----	----

The interaction effect between T x S for draft generated were significant ($P < 0.01$). However, non-significant interaction effects for draft between T x D, S x D, and T x S x D were observed during sowing. Literature on interaction effect on draft generated was scanty.

4.2.3.2 Speed during sowing

Average speed of Khillar bullocks during sowing was 3.57 km/hr (Table 29). The means for speed during sowing were observed as 3.57, 3.69 and 3.43 km/hr in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar, respectively (Fig. 18). The variance analysis revealed that the significant ($P < 0.01$) variations in speed during sowing were observed in Pandharpuri, Kosa and Tapi Khillar (Table 30). The means of speed during sowing by Khillar bullocks during summer, rainy and winter were 3.46, 3.57 and 3.66 km/hr (Fig. 18). Season

had significant ($P < 0.01$) effect on speed. The higher speed was observed during winter followed by rainy and summer season (Table 29). The means for speed during forenoon and afternoon were 3.60 and 3.54, respectively (Fig. 18). The speed of Khillar bullocks was significantly ($P < 0.01$) higher during forenoon as compared to afternoon (Table 29). Present results were almost similar to that of Belsare (1984) in crossbred bullocks, Upadhyay and Madan (1987) in Haryana and crossbred bullocks and Yawalikar (2000) in Red Kandhari, Deoni and HF x Deoni bullocks.

Table 29. Means of speed in Khillar bullocks during sowing

Particular		Speed (km/hr)
μ		3.57
Type (T)	Pandharpuri Khillar (T ₁)	3.57 ^b
	Kosa Khillar (T ₂)	3.69 ^c
	Tapi Khillar (T ₃)	3.43 ^a
	S.E.±	0.007
	C.D. at 1%	0.027
Season (S)	Summer (S ₁)	3.46 ^a
	Rainy (S ₂)	3.57 ^b
	Winter (S ₃)	3.66 ^c
	S.E.±	0.007
	C.D. at 1%	0.027
Time (D)	Forenoon (D ₁)	3.60 ^b
	Afternoon (D ₂)	3.54 ^a
	S.E.±	0.006
	C.D. at 1%	0.022

*Different superscripts indicates significant difference

Table 30. Analysis of variance for speed during sowing in Khillar bullocks

Source of variation	Df	MSS	F value	
			at 5%	at 1%
Replication	3	0.000		
Type (T)	2	0.437**	0.020	0.027
Season (S)	2	0.229**	0.020	0.027
Duration (D)	1	0.070**	0.017	0.022
TS	4	0.015**	0.035	0.047
TD	2	0.001	NS	----
SD	2	0.000	NS	----
TSD	4	0.000	NS	----
Error	51	0.001	----	----
Total	71	-----	----	----

The interaction effect between T x S for speed were significant ($P < 0.01$). However, non-significant interaction effects for speed between T x D, S x D, and T x S x D were observed.

4.2.3.3. Horse power during sowing

The overall mean hp developed by Khillar bullocks was 0.94 hp during sowing (Table 31). The means for horse power in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar were 0.97, 1.08 and 0.75 during sowing, respectively (Fig. 19). The analysis of variance revealed that the significant ($P < 0.01$) variations in hp were observed in Pandharpuri, Kosa and Tapi Khillar (Table 32). The Kosa Khillar generated highest hp during sowing indicating power generating capacity under prevailing climatic condition. The means for horse

power during sowing by Khillar bullocks during summer, rainy and winter were 0.89, 0.98 and 0.93 (Fig. 19). Season had significant ($P < 0.01$) effect on hp. Higher hp was produced during rainy followed by winter and summer season (Table 31). The means for horse power during forenoon and afternoon were 0.96 and 0.91, respectively (Fig. 19). The hp generated was significantly ($P < 0.01$) higher during forenoon than afternoon period (Table 31).

Table 31. Means for horse power generated in Khillar bullocks during sowing

Particular		Horse power (hp)
μ		0.94
Type (T)	Pandharpuri Khillar (T_1)	0.97 ^b
	Kosa Khillar (T_2)	1.08 ^c
	Tapi Khillar (T_3)	0.75 ^a
	S.E.±	0.004
	C.D. at 1%	0.014
Season (S)	Summer (S_1)	0.89 ^a
	Rainy (S_2)	0.98 ^c
	Winter (S_3)	0.93 ^b
	S.E.±	0.004
	C.D. at 1%	0.014
Time (D)	Forenoon (D_1)	0.96 ^b
	Afternoon (D_2)	0.91 ^a
	S.E.±	0.003
	C.D. at 1%	0.011

*Different superscripts indicates significant difference

Similar increase in horse power with decrease in atmospheric temperature was recorded by Premi (1979) in Hallikar, Maurya and Dhangar (1999) in Kankrej and crossbred bullocks.

**Table 32. Analysis of variance for horse power during sowing in
Khillar bullocks**

Source of variation	Df	MSS	F value	
			at 5%	at 1%
Replication	3	0.000		
Type (T)	2	0.675**	0.010	0.014
Season (S)	2	0.044**	0.010	0.014
Time (D)	1	0.047**	0.009	0.011
TS	4	0.003**	0.018	0.024
TD	2	0.001	NS	----
SD	2	0.000	NS	----
TSD	4	0.000	NS	----
Error	51	0.000	----	----
Total	71	-----	----	----

The significant ($P < 0.01$) interaction effect were observed between T x S for horse power produced during sowing. However, non- significant interaction effects for horse power between T x D, S x D and T x S x D were observed during sowing.

4.2.3.4 Unit area covered during sowing

The overall mean for area covered by Khillar bullocks during sowing was 1099.77 m²/hr (Table 33). The area covered by Pandharpuri (T₁), Kosa (T₂) and Tapi (T₃) Khillar during sowing were 1105.77, 1144.87 and 1048.66 m²/hr, respectively (Fig. 20). Almost similar results were reported by Dhangar (1999) in Kankrej and Yawalikar (2000) in Red Kandhari, Deoni and HF x Deoni bullocks. The variance analysis revealed that the significant ($P < 0.01$) variations in area covered were observed in Pandharpuri, Kosa and Tapi Khillar (Table 34). The

means for area covered during sowing by Khillar bullocks during summer, rainy and winter were 1079.47, 1099.15 and 1120.68 m²/hr (Fig. 20). Season had significant ($P < 0.01$) effect on area covered. The higher area was covered during winter followed by rainy and summer season by Khillar bullocks (Table 33). The means for area covered during forenoon and afternoon were 1102.15 and 1097.38 m²/hr, respectively (Fig. 20). The area covered by Khillar bullocks was significantly ($P < 0.01$) higher during forenoon than afternoon period (Table 33).

Table 33. Means for area covered by Khillar bullocks during sowing

Particular		Area covered (m²/hr)
μ		1099.77
Type (T)	Pandharpuri Khillar (T ₁)	1105.77 ^b
	Kosa Khillar (T ₂)	1144.87 ^c
	Tapi Khillar (T ₃)	1048.66 ^a
	S.E.±	0.50
	C.D. at 1%	1.91
Season (S)	Summer (S ₁)	1079.47 ^a
	Rainy (S ₂)	1099.15 ^b
	Winter (S ₃)	1120.68 ^c
	S.E.±	0.50
	C.D. at 1%	1.91
Duration (D)	Forenoon (D ₁)	1102.15 ^b
	Afternoon (D ₂)	1097.38 ^a
	S.E.±	0.41
	C.D. at 1%	1.56

* Different superscripts indicate significant difference

The present findings confirmed the results of Roy *et al.*, (1972) for Jersey x Haryana and Haryana bullocks, Dhanger (1999) in Kankrej and Yawalikar (2000) in Red Kandhari, Deoni and HF x Deoni bullocks.

Table 34. Analysis of variance for area covered during sowing in Khillar bullocks

Source of variation	Df	MSS	F value	
			at 5%	at 1%
Replication	3	2.667		
Type (T)	2	56184.000**	1.433	1.912
Season (S)	2	10196.000**	1.433	1.912
Duration (D)	1	408.000**	1.170	1.561
TS	4	322.000**	2.483	3.311
TD	2	12.000	NS	----
SD	2	16.000	NS	----
TSD	4	10.000	NS	----
Error	51	6.118	----	----
Total	71	-----	----	----

The significant ($P < 0.01$) interaction effect between T x S for area covered were observed in Khillar. However, non- significant interaction effects for area covered between T x D, S x D and T x S x D were observed during sowing.

4.3 Harrowing operation (Plate 12)

4.3.1 Physiological indices

The physiological indices viz., respiration rate, body temperature and pulse rate, before work, after 1st hr, 2nd hr and after 3rd hour completion of work during each trial have been discussed.

4.3.1.1 Respiration rate

Average RR in Khillar bullocks was 38.15 beats/min (Table 35). The means for respiration rates were observed as 38.39, 34.78 and 41.13 in the case of Pandharpuri (T₁), Kosa (T₂) and Tapi (T₃) Khillar, respectively (Fig. 21). These finding confirmed the results of Acharya et al. (1979) in crossbred, Anonymous (2004) in Gaolao and non-descript cattle. The analysis of variance revealed that the significant ($P < 0.05$) variations in RR were observed due to type of Khillar viz., Pandharpuri, Kosa and Tapi Khillar (Table 36). The means for respiration rate during summer, rainy and winter season were 41.04, 40.06 and 33.19 beats/min (Fig. 21). These results were in close agreement with Acharya *et al.* (1979) in crossbred and indigenous bullocks. Season had significant ($P < 0.05$) effect on RR in Khillar bullocks. The higher RR was observed during summer followed by rainy and winter season (Table 35). The means for RR during forenoon and afternoon were 36.77 and 39.43, respectively (Fig. 21). The RR were significantly ($P < 0.05$) higher during afternoon than forenoon period (Table 35). The respiration rate during before work, after 1st, 2nd hour and after 3rd hour of ploughing were 22.18, 36.54, 43.74 and 49.94 (Fig. 21). Almost similar results were reported by Anonymous (2004) in Gaolao (13.57, 16.53, 20.86 and 26.22 at an interval initial, 1st, 2nd, and 3rd hr). The variations in RR were significant ($P < 0.05$) attributed to the different intervals of working (Table 36). It indicated that as the working hours increased the RR also increased in Khillar bullocks.

The increase in RR helped the animals to dissipate excess heat generated in the body during exercise.

Table 35. Means for respiration rate in Khillar bullocks during harrowing

Particular		Respiration rate (beats/min)
μ		38.15
Type (T)	Pandharpuri Khillar (T ₁)	38.39 ^b
	Kosa Khillar (T ₂)	34.78 ^a
	Tapi Khillar (T ₃)	41.13 ^c
	S. E. ±	0.21
	CD at 5 %	0.58
Season (S)	Summer (S ₁)	41.04 ^c
	Rainy (S ₂)	40.06 ^b
	Winter (S ₃)	33.19 ^a
	S. E. ±	0.21
	CD at 5 %	0.58
Time (D)	Forenoon (D ₁)	36.77 ^a
	Afternoon (D ₂)	39.43 ^b
	S. E. ±	0.17
	CD at 5 %	0.47
Interval (I)	Before work (I ₁)	22.18 ^a
	1 st hour (I ₂)	36.54 ^b
	2 nd hour (I ₃)	43.74 ^c
	After 3 rd hour (I ₄)	49.94 ^d
	S. E. ±	0.24
	CD at 5 %	0.66

* Different superscripts indicates significant difference

As the duration of work progressed the respiration rate also increased which might be due to increased demand for oxygen by the tissue during work and compensatory effort to effect thermolysis. These results closely resembled with

Bhosrekar *et al.* (1966) in Thaparkar and Sahiwal bullocks, Singh *et al.* (1968^a) in Haryana bullocks and Nagpaul *et al.* (1984) in crossbred and zebu bullocks.

These findings confirmed with the results of Dhangar (1999) who observed similar trend of rise and fall in respiration rate in response to exercise and rest in crossbred and indigenous bullocks.

Dhangar (1999) reported that during summer respiration rate were significantly higher in comparison to winter and that respiration rates were higher during afternoon over forenoon session.

Table 36. Analysis of variance for respiration rate during harrowing in Khillar bullocks

Source of variation	Df	MSS	F value at 5%
Replication	3	94.84606	
Type (T)	2	972.1076*	0.575748
Season (S)	2	1753.691*	0.575748
Time (D)	1	509.3368*	0.470096
Interval (I)	3	10269.93*	0.664816
TS	4	52.23785*	0.997224
TD	2	6.878472	NS
TI	6	124.3391*	1.151495
SD	2	5.107639	NS
SI	6	134.103*	1.151495
DI	3	25.32755*	0.940192
TSD	4	1.508681	NS
TSI	12	6.851273	NS
TDI	6	0.702546	NS
SDI	6	0.112269	NS
TSDI	12	0.32581	NS
Error	213	4.141839	
Total	287		

The interaction effect between T x S, T x I, S x I and D x I for respiration rate were significant ($P < 0.05$) in Khillar bullocks. However, the interaction effects viz., T x D, S x D, T x S x D, T x S x I, T x D x I, S x D x I and T x S x D x I did not affect respiration rate during harrowing.

4.3.1.2 Body temperature

Average for BT in Khillar bullocks was 101.49 °F (Table 37). The BT were observed as 101.58, 101.05 and 101.75 °F in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar, respectively during harrowing operation (Fig. 22). Almost similar results were reported by Acharya *et al.* (1979) in crossbred (HF x Haryana) and non-descript indigenous bullocks. Similar results were also reported by Yawalikar (2000) in Red Kandhari, Deoni and HF x Deoni. The variance analysis revealed that the significant ($P < 0.05$) variations in BT were observed due to type of Khillar (Table 38). The body temperature were observed as 102.25, 101.22 and 100.91 °F during summer, rainy and winter season (Fig. 22). Season had significant ($P < 0.05$) effect on BT in Khillar (Table 38). During summer, it was higher followed by rainy and winter season (Table 37). The means for body temperature during forenoon and afternoon were 101.28 and 101.63 °F, respectively. The BT were significantly ($P < 0.05$) higher during afternoon than forenoon period (Table 37). The means for body temperature in Khillar bullocks before work, after 1st, 2nd hour and after 3rd hour harrowing were 100.32, 101.33, 101.89 and 102.30 °F (Fig. 22). These results confirmed with Singh *et al.* (1970) in Sahiwal bullocks, Acharya *et al.* (1979) in crossbred and non-descript indigenous bullocks, Sreekumar and Thomas (1990) in Kangayam bullocks and Anonymous (2004) in Gaolao and non-descript cattle during ploughing. The variations in BT were significantly ($P < 0.05$) attributed to the different intervals of working (Table 38), it indicated that as the working hours increased the BT also increased. The increase in body temperature might be due to the heat set free on

account of the increased lactic acid production by muscle and its removal through oxidation process (Sastry *et al.* 1970).

Table 37. Means for body temperature in Khillar bullocks during harrowing

Particular		Body temperature (°F)
μ		101.49
Type (T)	Pandharpuri Khillar (T ₁)	101.58 ^b
	Kosa Khillar (T ₂)	101.05 ^a
	Tapi Khillar (T ₃)	101.75 ^c
	S. E. ±	0.052
	CD at 5 %	0.14
Season (S)	Summer (S ₁)	102.25 ^c
	Rainy (S ₂)	101.22 ^b
	Winter (S ₃)	100.91 ^a
	S. E. ±	0.052
	CD at 5 %	0.14
Time (D)	Forenoon (D ₁)	101.28 ^a
	Afternoon (D ₂)	101.63 ^b
	S. E. ±	0.042
	CD at 5 %	0.11
Interval (I)	Before work (I ₁)	100.32 ^a
	1 st hour (I ₂)	101.33 ^b
	2 nd hour (I ₃)	101.89 ^c
	After 3 rd hour (I ₄)	102.30 ^d
	S. E. ±	0.06
	CD at 5 %	0.16

* Different superscripts indicates significant difference

Graf and Peterson (1953) reported the increase in body temperature due to exercise. Dhangar (1999) also reported that during summer body temperature was significantly higher in comparison to winter, it was also higher during afternoon over forenoon period.

Dave and Mukherjee (2001) reported that rectal temperature increased with advancing of working time.

Table 38. Analysis of variance for body temperature during harrowing in Khillar bullocks

Source of variation	Df	MSS	F value at 5%
Replication	3	0.697482	
Type (T)	2	12.77629*	0.145299
Season (S)	2	47.31568*	0.145299
Time (D)	1	8.939401*	0.118636
Interval (I)	3	52.93343*	0.167777
TS	4	2.163257*	0.251665
TD	2	0.018872	NS
TI	6	0.296996	NS
SD	2	0.014263	NS
SI	6	0.797415*	0.290598
DI	3	0.245783	NS
TSD	4	0.024152	NS
TSI	12	0.105507	NS
TDI	6	0.006209	NS
SDI	6	0.006739	NS
TSDI	12	0.008588	NS
Error	213	0.263788	
Total	287		

The significant ($P < 0.05$) interaction effect between T x S and S x I for body temperature were observed in Khillar bullocks. The interaction effects viz., T x D, T x I, S x D, D x I, T x S x D, T x S x I, T x D x I, S x D x I and T x S x D x I did not affect BT during harrowing.

4.3.1.3. Pulse rate

The overall mean for PR in Khillar bullocks was 72.70 beats/min (Table 39). The PR were observed as 73.24, 67.97 and 75.18 in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar, respectively during harrowing operation (Fig. 23). These results were supported by the finding of Singh *et al.* (1968^a) in Haryana bullocks, Sastry *et al.* (1970) in Brown Swiss x Sahiwal bullocks. The analysis of variance revealed that the significant ($P < 0.05$) variations in PR were attributed to the types of Khillar viz., Pandharpuri, Kosa and Tapi Khillar (Table 40). The PR were observed as 74.32, 71.04 and 71.03 during summer, rainy and winter season (Fig. 23). Season had significant ($P < 0.05$) effect on PR in Khillar bullocks. The higher PR was observed in summer followed by rainy and winter season (Table 39). The means for PR during forenoon and afternoon were 70.37 and 73.89, respectively (Fig. 23). Almost similar results were reported by Acharya *et al.* (1979) in crossbred and non-descript indigenous bullocks. The PR was significantly ($P < 0.05$) higher during afternoon than forenoon period (Table 39). The means of PR in Khillar bullocks before work, after 1st, 2nd hour and after 3rd hour harrowing were 59.09, 72.39, 76.44 and 80.59 (Fig. 23). The significant ($P < 0.05$) variations in PR were observed at different intervals of working (Table 40), it indicated that as the working hours increased the PR also increased. The increase in pulse rate represented a rise in cardiac activity to fulfill the increased demand for oxygen during exercise. These finding confirmed with the results of Dhangar (1999) who observed similar trend of rise and fall in pulse rate in response to exercise and rest in crossbred and indigenous bullocks.

Singh *et al.*, (1970) also noted that the fall in the pulse rate while resting after the agricultural operations with disc harrow was significantly faster in Sahiwal bullocks than in Hariana. They recommended suitability of Sahiwal bullocks for interrupted farm operations. The speed was not an important especially after considering the rate of return of pulse rate to normal level. Bhosrekar and Mangurkar (1989) also reported rise in pulse rate. The rise was found higher in HF crossbred bullocks than in Jersey crossbred and local bullocks.

Table 39. Means for pulse rate in Khillar bullocks during harrowing

Particular		Pulse rate (beats/min)
μ		72.70
Breed (B)	Pandharpuri Khillar (T ₁)	73.24 ^b
	Kosa Khillar (T ₂)	67.96 ^a
	Tapi Khillar (T ₃)	75.18 ^c
	S. E. ±	0.27
	CD at 5 %	0.75
Season (S)	Summer (S ₁)	74.32 ^b
	Rainy (S ₂)	71.04 ^a
	Winter (S ₃)	71.03 ^a
	S. E. ±	0.27
	CD at 5 %	0.75
Time (D)	Forenoon (D ₁)	70.37 ^a
	Afternoon (D ₂)	73.89 ^b
	S. E. ±	0.22
	CD at 5 %	0.61
Interval (I)	Before work (I ₁)	59.09 ^a
	1 st hour (I ₂)	72.39 ^b
	2 nd hour (I ₃)	76.44 ^c
	After 3 rd hour (I ₄)	80.59 ^d
	S. E. ±	0.31
	CD at 5 %	0.86

* Different superscripts indicates significant difference

Dave and Mukherjee (2001) reported that the rate of increase in pulse rate was approximately proportional to the increase in draught load upto 14 kg draught force/100 kg live weight but beyond this the increase was high. Anonymous (2004) reported that there was significant rise in pulse rate in Gaolao, non-descript and buffalo breed at different speed.

Table 40. Analysis of variance for pulse rate during harrowing in Khillar bullocks

Source of variation	Df	MSS	F value at 5%
Replication	3	30.34722	
Type (T)	2	1338.983*	0.753231
Season (S)	2	345.6285*	0.753231
Time (D)	1	889.0139*	0.61501
Interval (I)	3	6245.486*	0.869756
TS	4	48.30035*	1.304634
TD	2	10.06597	NS
TI	6	50.85764*	1.506462
SD	2	12.73264	NS
SI	6	12.26736	NS
DI	3	37.04167*	1.230021
TSD	4	3.206597	NS
TDI	6	1.246528	NS
SDI	6	2.010417	NS
TSDI	12	1.282986	NS
Error	213	7.089006	
Total	287		

The variations in pulse rate were significantly ($P < 0.05$) attributed to the different interaction effect viz., T x S, T x I and D x I during harrowing operation in Khillar bullocks. However, interaction between T x D, S x D, S x I, T x S x D, T x D x I, S x D x I, T x S x D x I did not influence the pulse rate.

4.3.2. Haematological parameters

The haematological study in terms of levels of haemoglobin, blood glucose and lactic acid recorded before and after harrowing were conducted. The results have been given below:

4.3.2.1. Haemoglobin

The means for haemoglobin (gm%) content in the blood of Pandharpuri, Kosa and Tapi Khillar before and after harrowing were 10.56 and 9.03, 10.55 and 9.83 and 11.03 and 10.52 gm%, respectively (Table 41, Fig 24).

The present investigation revealed decreasing trend in haemoglobin content during before work to after work in Khillar cattle, which might be due to haemodilution and destruction of red blood cells. Almost similar results were reported by Mukherjee *et al.*, (1961) in Haryana, Sastry (1969) in Sahiwal, Yawalikar (2000) in Red Kandhari, Deoni and HF x Deoni and Tripathi *et al.*, (1978) found decrease in packed cell volume and haemoglobin at high environmental temperature in healthy bulls. Garg *et al.*, (1981) observed a significant ($P < 0.01$) decrease in hematocrit values in exercised bullocks.

Table 41. Means for Hb in Khillar bullocks during harrowing

Type	Haemoglobin (gm%) (Before work)	Haemoglobin (gm%) (After work)
Pandharpuri Khillar (T ₁)	10.56	9.03
Kosa Khillar (T ₂)	10.55	9.83
Tapi Khillar (T ₃)	11.03	10.52

The probable reason for decrease in Hb level in Khillar bullocks might be due to the fact that the gas carrying capacity of blood particularly in terms of Po₂ was affected, inspite of the situation that blood haemoglobin levels remained unaltered. The said increase in carrying capacity was attributed to the saturation of haemoglobin (Astrand and Rodhal, 1970).

4.3.2.2. Blood glucose

The means of glucose (mg%) content in the blood of Pandharpuri, Kosa and Tapi Khillar before and after harrowing were 56.95 and 49.71, 54.90 and 51.16 and 54.08 and 46.69 mg% respectively (Table 42, Fig. 25).

The present investigation revealed the decreasing trend in glucose content during before work to after work in Khillar cattle. Similar results were also reported by Singh and Upadhyay (1996) who observed a decline of blood glucose post work. Gupta *et al.* (1992) reported decline in blood glucose in bullocks.

Table 42. Means for blood glucose in Khillar bullocks during harrowing

Type	Glucose (mg%) (Before work)	Glucose (mg%) (After work)
Pandharpuri Khillar (T ₁)	56.95	49.71
Kosa Khillar (T ₂)	54.90	51.16
Tapi Khillar (T ₃)	54.08	46.69

The results of present study were in agreement with those reported by Georgie *et al.*, (1970) in crossbred and Sahiwal bullocks, Singh and Upadhyay (1995) in crossbred and Dhangar (1999) in Kankrej bullocks. They found that the varying intensity of load caused a decline in blood glucose level.

Patil (1990) reported that the alteration in blood glucose level could be associated with alteration of the substrate as a source of energy required for muscular activity and a result of efficient homeostatic mechanism for glucose.

Anonymous (2004) observed significant decline in blood glucose concentration during summer season at all work. In protracted muscular work the hyperglycemia that was often seen as apart of the general adaptation syndrome was masked by the specific blood sugar reducing effect of muscular work and that was apparently superimposed over the usual hyperglycemic curve, Selye (1950).

These findings confirmed the results of Gupta *et al.*, (1992) who reported the almost similar results. He reported that the level of glucose at pre- work was 55.62 ± 1.83 mg% in summer. The physical work caused a significant decline in blood glucose concentration to a greater extent during summer at all works. Singh and Upadhyay (1995) studied physico-chemical responses of she buffaloes during cart loads under hot humid season. They reported that haemoglobin haematocrit and blood glucose level decreased and lactic acid level increased.

4.3.2.3. Blood lactic acid

The means of lactic acid content in the blood of Pandharpuri, Kosa and Tapi Khillar before and after harrowing were 7.74 and 8.66, 7.0 and 7.8, and 5.87 and 8.33 gm%, respectively (Table 43, Fig, 26).

Table 43. Means for lactic acid in Khillar bullocks during harrowing

Type	Lactic acid (gm %)	
	Before work	After work
Pandharpuri Khillar (T ₁)	7.74	8.66
Kosa Khillar (T ₂)	7.00	7.80
Tapi Khillar (T ₃)	5.87	8.33

The present study revealed increasing trend in lactic acid content from before work to after work during summer season in Khillar cattle. Almost similar results were also reported by Gattewar (1983), Yawalikar (2000) in Red Kandhari, Deoni and HF x Deoni, and Dhangar (1999) who observed similar trend of rise

and fall in lactic acid level in response to exercise and rest in crossbred and indigenous bullocks.

These results confirmed with the results of Beninati (1957) who observed fatigue in the cattle due to constant haemoconcentration and rise in the blood lactic acid level due to muscular work. The level of lactic acid gradually decreased during the rest period.

Georgie *et al.*, (1970) also reported rapid increase in blood lactic acid level due to exercise in Sahiwal and crossbred bullocks. Nangia *et al.*, (1978) observed increasing trend in blood lactic acid level in male buffalo calves of 2 years.

Chaudhary *et al.*, (1985) reported that blood lactic acid increased and copper phosphate level declined. Upadhyay and Madan (1985) reported on increase in muscle lactic acid to the tune of 0.6 to 2.23 μ mol/gm.

4.3.3 Work performance

The draftability of Khillar bullocks during harrowing was studied in terms of draft generated, speed of the work, horse power (hp) developed and area covered.

4.3.3.1. Draft developed during harrowing

The average draft generated by Khillar bullocks during harrowing was 59.57 kg (Table 44). The draft generated in Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar were 61.04, 69.30 and 48.37, respectively during harrowing (Fig. 27). Almost similar results were reported by Chhanwal (1990) in crossbred bullocks (Jersey x Sahiwal 45.86 kg). The variance analysis revealed that the significant ($P < 0.01$) variations in draft developed were attributed to the types of Khillar (Table 45). The means for draft generated during harrowing by Khillar bullocks during summer, rainy and winter were 59.35, 62.97 and 56.38 kg (Fig. 27), these results confirmed with Bhagat (1996) in crossbred bullocks, Gattewar *et al.* (1989) in HF x Haryana. Season had significant ($P < 0.01$) effect on draft developed. During

rainy season it was higher followed by summer and winter season (Table 44). The means for draft during forenoon and afternoon were 61.37 and 57.77 kg, respectively (Fig. 27). The draft was significantly ($P < 0.01$) higher during forenoon than afternoon period (Table 44).

Table 44. Means for draft generated in Khillar bullocks during harrowing

Particular		Draft (Kg)
μ		59.57
Type (T)	Pandharpuri Khillar (T ₁)	61.04 ^b
	Kosa Khillar (T ₂)	69.30 ^c
	Tapi Khillar (T ₃)	48.37 ^a
	S. E. $\pm$	0.32
	CD at 1 %	1.22
Season (S)	Summer (S ₁)	59.35 ^b
	Rainy (S ₂)	62.97 ^c
	Winter (S ₃)	56.38 ^a
	S. E. $\pm$	0.32
	CD at 1 %	1.22
Time (D)	Forenoon (D ₁)	61.36 ^b
	Afternoon (D ₂)	57.77 ^a
	S. E. $\pm$	0.26
	CD at 1 %	1.00

* Different superscripts indicates significant difference

Our results confirm the observations of Upadhyay and Madan (1982^a) in Haryana, Maurya and Devadattam (1982^b) in Jersey x Red Sindhi, Gattewar (1983) in crossbred and Abhyankar (1986) in crossbred who observed similar trend of in

draft produced. Devadattam and Maurya (1978) reported the draft developed by Haryana bullocks as only 7.5% of the body weight.

Table 45. Analysis of variance for draft during harrowing in Khillar bullocks

Source of variation	Df	MSS	F value	
			at 5%	at 1%
Replication	3	15.620		
Type (T)	2	2667.961**	0.918	1.225
Season (S)	2	261.406**	0.918	1.225
Time (D)	1	232.594**	0.750	1.000
TS	4	1.270	NS	----
TD	2	2.289	NS	----
SD	2	3.094	NS	----
TSD	4	0.285	NS	----
Error	51	2.510	----	----
Total	71	-----	----	----

During harrowing interaction effects between T x S, T x D, S x D and T x S x D for draft were non- significant in Khillar bullocks.

4.3.3.2. Speed during harrowing

Average speed of Khillar bullocks during harrowing was 3.58 km/hr (Table 46). The speed observed during harrowing were 3.56, 3.69 and 3.49 in Pandharpuri (T₁), Kosa (T₂) and Tapi (T₃) Khillar, respectively (Fig. 28). The analysis of variance revealed that the significant ($P < 0.01$) variations in speed were observed in Pandharpuri, Kosa and Tapi Khillar (Table 47). The means of speed during harrowing by Khillar bullocks during summer, rainy and winter were

3.46, 3.58 and 3.70 (Fig. 28). Season had significant ($P < 0.01$) effect on speed in Khillar. The higher speed was observed during winter followed by rainy and summer season (Table 46). The means for speed during forenoon and afternoon were 3.62 and 3.55, respectively (Fig. 28). These results were in agreement with those reported by Anonymous (1979-80) in Hallikar bullocks, Premi (1979) in Hallikar bullocks, Upadhyay and Madan (1982^a) in Haryana and Gattewar (1983) in crossbred and Haryana bullocks. The speed of Khillar bullocks significantly ($P < 0.01$) higher during forenoon as compared to afternoon period (Table 46). These findings confirmed with the results of Abhyankar (1986) in crossbred and Yawalikar *et al.*, (2003) in Red Kandhari, Deoni and HF x Deoni.

Table 46. Means for speed in Khillar Bullocks during harrowing

Particular		Speed (km/hr)
μ		3.58
Type (T)	Pandharpuri Khillar (T ₁)	3.56 ^b
	Kosa Khillar (T ₂)	3.69 ^c
	Tapi Khillar (T ₃)	3.49 ^a
	S.E. ±	0.007
	C.D. at 1%	0.025
Seasons (S)	Summer (S ₁)	3.46 ^a
	Rainy (S ₂)	3.58 ^b
	Winter (S ₃)	3.70 ^c
	S.E. ±	0.07
	C.D. at 1%	0.025
Time (D)	Forenoon (D ₁)	3.62 ^b
	Afternoon (D ₂)	3.55 ^a
	S.E. ±	0.005
	C.D. at 1%	0.020

* Different superscripts indicates significant difference.

Table 47. Analysis of variance for speed during harrowing in Khillar bullocks

Source of variation	Df	MSS	F value	
			at 5%	at 1%
Replication	3	0.001		
Type (T)	2	0.266**	0.019	0.025
Season (S)	2	0.361**	0.019	0.025
Time (D)	1	0.076**	0.015	0.020
TS	4	0.023**	0.032	0.043
TD	2	0.001	NS	----
SD	2	0.000	NS	----
TSD	4	0.000	NS	----
Error	51	0.001	----	----
Total	71	-----	----	----

Gattewar (1983) observed that an average speed decreased from 3.14 to 2.53 km/hr and 2.90 to 2.33 km/hr in crossbred and Hariana bullocks, respectively in response to two hours harrowing exercise.

The variations in speed were significantly ($P < 0.01$) attributed to the interaction effect T x S during harrowing in Khillar bullocks. However, interaction between T x D, S x D, and T x S x D did not influence the speed.

4.3.3.3. Horse power during harrowing

The overall mean for hp developed by Khillar bullocks was 0.79 hp during harrowing (Table 48). The means for horse power were 0.80, 0.95 and 0.62 in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar, respectively during harrowing (Fig. 29), which matches very well with the value reported by Rautary and Srivastava (1982) in Sahiwal crossbred bullocks. The analysis of variance

revealed that the significant ($P < 0.01$) variations in hp were observed in Pandharpuri, Kosa and Tapi Khillar (Table 49). The means for horse power generated during harrowing by Khillar bullocks in summer, rainy and winter were 0.76, 0.84 and 0.78 respectively (Fig. 29). Season had significant ($P < 0.01$) effect on hp. The higher hp was produced during rainy followed by winter and summer season (Table 48). The means for horse power during forenoon and afternoon were 0.82 and 0.76, respectively (Fig. 29). The hp generated was significantly ($P < 0.01$) higher during forenoon than afternoon period (Table 48). These results confirmed the earlier findings reported by Premi (1979) in Hallikar, Gattewar (1983) in crossbred and Haryana, Upadhyay and Madan (1985^a) in Haryana crossbred bullocks, Maurya and Devedattam (1986) in crossbred bullocks and Dhangar (1999) in crossbred and Kankrej bullocks.

Table 48. Means for horse power generated by Khillar bullocks during Harrowing

Particular		Horse power (hp)
μ		0.79
Type (T)	Pandharpuri Khillar (T ₁)	0.80 ^b
	Kosa Khillar (T ₂)	0.95 ^c
	Tapi Khillar (T ₃)	0.62 ^a
	S.E. $\pm$	0.005
	C.D. at 1%	0.02
Season (S)	Summer (S ₁)	0.76 ^a
	Rainy (S ₂)	0.84 ^c
	Winter (S ₃)	0.78 ^b
	S.E. $\pm$	0.005
	C.D. at 1%	0.02
Time (D)	Forenoon (D ₁)	0.82 ^b
	Afternoon (D ₂)	0.76 ^a
	S.E. $\pm$	0.004
	C.D. at 1%	0.016

* Different superscripts indicates significant difference

Table 49. Analysis of variance for horse power during harrowing in Khillar bullocks

Source of variation	Df	MSS	F value	
			at 5%	at 1%
Replication	3	0.001		
Type (T)	2	0.637**	0.015	0.020
Season (S)	2	0.039**	0.015	0.020
Time (D)	1	0.069**	0.012	0.016
TS	4	0.002	0.026	NS
TD	2	0.001	NS	----
SD	2	0.001	NS	----
TSD	4	0.000	NS	----
Error	51	0.001	----	----
Total	71	-----	----	----

The significant ($P < 0.05$) interaction effect were observed between T x S for horse power produced during harrowing. However non-significant interaction effects for horse power between T x D, S x D and T x S x D observed during harrowing.

4.3.3.4. Unit area covered during harrowing (m²/hr)

The average area covered by Khillar bullocks during ploughing was 1192.41 m²/hr (Table 50). The area covered by Pandharpuri (T₁), Kosa (T₂) and Tapi (T₃) Khillar during harrowing were 1198.69, 1237.37 and 1141.16, respectively (Fig. 30). Almost similar results were reported by Acharya *et al.* (1979) in HF x Haryana, Gattewar (1983) in Haryana and Bhagat (1986) in crossbred bullocks. The variance analysis revealed that the significant ($P < 0.05$) variations in area covered were observed in Pandharpuri, Kosa and Tapi Khillar

(Table 51). The means for area covered during harrowing by Khillar bullocks during summer, rainy and winter were 1172.38, 1191.65 and 1213.18 (Fig. 30). Season had significant ($P < 0.05$) effect on area covered. The higher area was covered during winter followed by rainy and summer season by Khillar bullocks (Table 50). The means for area covered during forenoon and afternoon were 1197.15 and 1187.66, respectively (Fig. 30). The area covered by Khillar bullocks was significantly ($P < 0.05$) higher during forenoon than afternoon period (Table 50).

Table 50. Means for area covered by Khillar bullocks during harrowing

Particular		Area covered (m ² /hr)
μ		1192.41
Type (T)	Pandharpuri Khillar (T ₁)	1198.69 ^b
	Kosa Khillar (T ₂)	1237.37 ^c
	Tapi Khillar (T ₃)	1141.16 ^a
	S.E. ±	0.53
	C.D. at 5%	1.48
Season (s)	Summer (S ₁)	1172.38 ^a
	Rainy (S ₂)	1191.65 ^b
	Winter (S ₃)	1213.18 ^c
	S.E. ±	0.534
	C.D. at 5%	1.480
Time (D)	Forenoon (D ₁)	1197.15 ^b
	Afternoon (D ₂)	1187.66 ^a
	S.E. ±	0.43
	C.D. at 5%	1.20

* Different superscripts indicates significant difference

The present finding confirmed the results of Roy *et al.*, (1972) in Haryana bullocks, Anand and Sundaresan (1974) in Haryana bullocks. Rao *et al.*, (1974) in crossbred bullocks, Acharya *et al.* (1979) in crossbred bullocks, Nagpaul (1984) in Haryana, Rao and Upadhyay (1984) in crossbred bullocks, Abhyankar (1986) in crossbred bullocks, Sreekumar and Thomas (1990^a) in Kangayam and crossbred bullocks, Dhangar (1999) in Kankarej bullocks and Jadhav and Jagtap (2000) in crossbreed and indigenous bullocks.

In general agreement with the findings of Roy *et al.*, (1972^b) for Jersey x Haryana and Haryana bullocks at ploughing, Gattewar (1983) for HF X Haryana and Haryana bullock at harrowing. The area covered for harrowing was more in winter than rainy and summer. Thus, atmospheric temperature influenced the work. Similar finding were recorded by Yawalikar *et al.*, (2003) in Red Kandhari, Deoni and HF x Deoni.

Table 51. Analysis of variance for area covered during harrowing in Khillar bullocks

Source of variation	Df	MSS	F value
			at 5%
Replication	3	1.286296	
Type (T)	2	56247.53*	1.480247
Season (S)	2	9998.116*	1.480247
Time (D)	1	1622.601*	1.208617
TS	4	340.061*	2.563863
TD	2	6.668889	NS
SD	2	15.42389	NS
TSD	4	14.41597	NS
Error	51	6.844434	----
Total	71	-----	----

The significant ($P < 0.01$) interaction effect between T x S for area covered were observed in Khillar bullocks. However, non- significant interaction effects for area covered between T x D, S x D and Tx S x D were observed during harrowing.

4.4 Hoeing (Plate 13)

4.4.1 Physiological indices

The physiological indices in terms of respiration rate, body temperature and pulse rate before work, 1st hour, 2nd hour and after 3rd hour during hoeing were recorded. The results have been given below:

4.4.1.1 Respiration rate

The average for RR in Khillar bullocks was 37.66 beats/min (Table 52). The means for RR were observed as 37.44, 34.77 and 40.76 in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar, respectively during hoeing (Fig. 31). These finding confirmed with the results of Acharya et al. (1979) in crossbred, Anonymous (2004) in Gaolao and non-descript cattle. The analysis of variance revealed that the significant ($P < 0.05$) variations in RR were due to type of Khillar viz., Pandharpuri, Kosa and Tapi Khillar (Table 53). The means for respiration rate during summer, rainy and winter were 40.13, 39.81 and 33.02 (Fig. 31). These results were in close agreement with those reported by Acharya *et al.* (1979) in crossbred and indigenous bullocks. Season had significant ($P < 0.05$) effect on RR in Khillar bullocks. The higher RR was observed during summer followed by rainy and winter season (Table 52). The means for RR during forenoon and afternoon were 36.29 and 39.02, respectively (Fig. 31). The RR were significantly ($P < 0.05$) higher during afternoon than forenoon period (Table 52). The means for RR in Khillar bullocks before work, after 1st, 2nd hour and after 3rd hour hoeing were 22.29, 36.25, 43.08 and 49.00 (Fig. 31). Almost similar results were reported by Anonymous (2004) in Gaolao (13.57, 16.53, 20.86 and 26.22

during at an interval of initial, 1st, 2nd, and 3rd hr). The significant ($P < 0.05$) variations in RR were attributed to the different intervals of working (Table 53). It indicated that as the working hours increased the RR also increased in Khillar bullocks.

The increase in respiration rate helped the animals to dissipate excess heat generated in the body during exercise. These finding confirmed with results of Acharya *et al.*, (1979) in HF x Haryana, Bhosrekar *et al.* (1966) in Tharparkar and Sahiwal, Udhan (1991) Patil *et al.*, (1994) in Deoni and HF x Deoni and Dhangar (1999) who observed similar trend of rise and fall in respiration rate in response to exercise and rest in crossbred and indigenous bullocks.

Table 52. Means for respiration rate in Khillar bullocks during hoeing

Particular		Respiration rate (beats/min)
μ		37.66
Type (T)	Pandharpuri Khillar (T ₁)	37.44 ^b
	Kosa Khillar (T ₂)	34.77 ^a
	Tapi Khillar (T ₃)	40.76 ^c
	S.E.±	0.19
	C.D. at 5%	0.54
Season (S)	Summer (S ₁)	40.13 ^c
	Rainy (S ₂)	39.81 ^b
	Winter (S ₃)	33.02 ^a
	S.E.±	0.19
	C.D. at 5%	0.54
Time (D)	Forenoon (D ₁)	36.29 ^a
	Afternoon (D ₂)	39.02 ^b
	S.E.±	0.16
	C.D. at 5%	0.44
Intervals (I)	Before work (I ₁)	22.29 ^a
	1 st hour (I ₂)	36.25 ^b
	2 nd hour (I ₃)	43.08 ^c
	After 3 rd hour (I ₄)	49.00 ^d
	S.E. ±	0.22
	C.D. at 5 %	0.62

*Different superscripts indicates significant difference

Table 53. Analysis of variance for respiration rate during hoeing in Khillar bullocks

Source of variation	Df	MSS	F value at 5%
Replication	3	72.66088	
Type (T)	2	864.4479*	0.542155
Season (S)	2	1549.573*	0.542155
Time (D)	1	536.2813*	0.442667
Interval (I)	3	9508.365*	0.626026
TS	4	97.30208*	0.93904
TD	2	1.885417	NS
TI	6	109.6146*	1.084309
SD	2	3.135417	NS
SI	6	129.7257*	1.084309
DI	3	31.59606*	0.885335
TSD	4	1.395833	NS
TDI	6	1.08912	NS
SDI	6	0.741898	NS
TSDI	12	0.891204	NS
Error	213	3.672617	
Total	287		

The interaction effect between T x S, T x I, S x I and D x I for respiration rate were significant ($P < 0.05$). The interaction effects viz., T x D, S x D, T x S x D, T x S x I, T x D x I, S x D x I and T x S x D x I did not affect respiration rate during hoeing.

4.4.1.2 Body temperature

Average for BT in Khillar bullocks was 101.25 °F (Table 54). The BT were observed as 101.47, 100.59 and 101.81 °F in the case of Pandharpuri (T₁), Kosa (T₂) and Tapi (T₃) Khillar, respectively during hoeing (Fig. 32). Almost similar results were reported by Acharya *et al.* (1979) in crossbred (HF x Haryana) and non-descript indigenous bullocks, Yawalikar (2000) in Red Kandhari, Deoni and HF x Deoni. The variance analysis revealed that the significant ($P < 0.05$) variations in BT were observed due to types of Khillar viz., Pandharpuri, Kosa and Tapi Khillar (Table 55). The body temperature were observed as 101.85, 101.34 and 100.68 °F during summer, rainy and winter season, respectively (Fig. 32). Season had significant ($P < 0.05$) effect on BT in Khillar bullocks. During summer, the BT was higher followed by rainy and winter season (Table 54). The means for body temperature during forenoon and afternoon were 101.12 and 101.47 °F, respectively (Fig. 32). The BT were significantly ($P < 0.05$) higher during afternoon than forenoon period (Table 54). The means for body temperature in Khillar bullocks before work, after 1st, 2nd hour and after 3rd hour hoeing were 100.11, 101.19, 101.72 and 102.15 °F, respectively (Fig. 32). These results confirmed with Singh *et al.* (1970) in Sahiwal bullocks, Acharya *et al.* (1979) in crossbred and non-descript indigenous bullocks, Sreekumar and Thomas (1990) in Kangayam bullocks and Anonymous (2004) in Gaolao and non-descript cattle. The variations in BT were significant ($P < 0.05$) different at intervals of working (Table 55), which indicated that as the working hours increased the BT also increased.

Table 54. Means for body temperature in Khillar bullocks during hoeing

Particular		Body temperature (°F)
μ		101.25
Type (T)	Pandharpuri Khillar (T ₁)	101.47 ^b
	Kosa Khillar (T ₂)	100.59 ^a
	Tapi Khillar (T ₃)	101.81 ^c
	S.E.±	0.06
	C.D. at 5%	0.17
Season (S)	Summer (S ₁)	101.86 ^c
	Rainy (S ₂)	101.34 ^b
	Winter (S ₃)	100.68 ^a
	S.E.±	0.06
	C.D. at 5%	0.17
Time (D)	Forenoon (D ₁)	101.12 ^a
	Afternoon (D ₂)	101.47 ^b
	S.E.±	0.05
	C.D. at 5%	0.14
Intervals (I)	Before work (I ₁)	100.11 ^a
	1 st hour (I ₂)	101.19 ^b
	2 nd hour (I ₃)	101.72 ^c
	After 3 rd hour (I ₄)	102.15 ^d
	S.E. ±	0.071
	C.D. at 5 %	0.19

* Different superscripts indicates significant difference

The increase in body temperature might bbe due to the heat set free on account of the increased lactic acid production by muscle and its removal through oxidation process Dhangar (1999) reported that during summer body temperature

was significantly higher in comparison to winter, it was higher during afternoon over forenoon period. The results of present findings were comparable with Dave and Mukherjee (2001) who reported that rectal temperature increased with advancing of working time and increase in draught.

Table 55. Analysis of variance for body temperature during hoeing in Khillar bullocks

Source of variation	Df	MSS	F value at 5%
Replication	3	2.487685	
Type (T)	2	37.91014*	0.169986
Season (S)	2	33.29087*	0.169986
Time (D)	1	9.102222*	0.138793
Interval (I)	3	55.56917*	0.196283
TS	4	1.868681*	0.294425
TD	2	0.035972	NS
TI	6	0.51167	NS
SD	2	0.01191	NS
SI	6	0.430729	NS
DI	3	0.303981	NS
TSD	4	0.012535	NS
TSI	12	0.060625	NS
TDI	6	0.023426	NS
SDI	6	0.037975	NS
TSDI	12	0.033877	NS
Error	213	0.361042	
Total	287		

The significant ($P < 0.05$) variation in body temperature were attributed to the interaction effects viz., T x S during hoeing in Khillar bullocks. However, interaction between T x D, T x I, S x D, S x I, D x I, T x S x D, T x S x I, T x D x I, S x D x I, T x S x D x I did not influence the BT.

4.4.1.3. Pulse rate

The overall mean for pulse rate in Khillar bullocks was 69.89 beats/min (Table 56). The means for pulse rate were observed to be 71.77, 64.89 and 73.09 in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar, respectively during hoeing operation (Fig. 33). These results were supported by the findings of Singh *et al.* (1968^a) in Haryana bullocks. The analysis of variance revealed that the significant ($P < 0.05$) variations in PR attributed to the type of Khillar viz., Pandharpuri, Kosa and Tapi Khillar (Table 57). The means for pulse rate during summer, rainy and winter were 72.96, 70.76 and 66.04, respectively (Fig. 33). These results were in close agreement with Acharya *et al.* (1979) in crossbred and non-descript indigenous bullocks. Season had significant ($P < 0.05$) effect on PR. PR was higher during summer followed by rainy and winter season (Table 56). The means for respiration rate during forenoon and afternoon were 68.37 and 71.46, respectively. The PR was significantly ($P < 0.05$) higher during afternoon than forenoon period in Khillar bullocks (Table 56). The means for pulse rate in Khillar bullocks before work, after 1st, 2nd hour and after 3rd hour hoeing were 58.35, 69.86, 73.71 and 77.76, respectively (Fig. 33). The significant ($P < 0.05$) variations in PR were observed at different intervals of working (Table 57), which indicated that as the working hours increased the PR also increased. The increase in pulse rate represented a rise in cardiac activity to fulfill the increased demand for oxygen during exercise and also served as a heat losing mechanism by increasing blood flow through the skin. Chhikara and Singh (2000) reported that the heart rate increased significantly ($P < 0.001$) over before work values after one hour of exercise.

Table 56. Means for pulse rate in Khillar bullocks during hoeing

Particular		Pulse rate (beats / min.)
μ		69.89
Type (B)	Pandharpuri Khillar (T ₁)	71.77 ^b
	Kosa Khillar (T ₂)	64.89 ^a
	Tapi Khillar (T ₃)	73.09 ^c
	S.E.±	0.25
	C.D. at 5%	0.71
Season (S)	Summer (S ₁)	72.96 ^c
	Rainy (S ₂)	70.76 ^b
	Winter (S ₃)	66.04 ^a
	S.E.±	0.25
	C.D. at 5%	0.71
Time (D)	Forenoon (D ₁)	68.37 ^a
	Afternoon (D ₂)	71.46 ^b
	S.E.±	0.20
	C.D. at 5%	0.58
Intervals (I)	Before work (I ₁)	58.35 ^a
	1 st hour (I ₂)	69.86 ^b
	2 nd hour (I ₃)	73.71 ^c
	After 3 rd hour (I ₄)	77.76 ^d
	S.E. ±	0.29
	C.D. at 5 %	0.82

* Different superscripts indicates significant difference

These finding confirmed with the results of Bhosrekar *et al.* (1966) in Tarparkar and Sahiwal, Roy *et al.* (1972) in Haryana, Acharya *et al.* (1979) in HF

x Haryana, Bhagat (1986) in crossbred and Dhangar (1999) in crossbred who observed similar trend of rise and fall in pulse rate in response to exercise and rest in crossbred and indigenous bullocks.

Table 57. Analysis of variance for pulse rate during hoeing in Khillar bullocks

Source of variation	Df	MSS	F value at 5%
Replication	3	15.62384	
Type (T)	2	1859.545*	0.70941
Season (S)	2	1199.003*	0.70941
Time (D)	1	687.5868*	0.579231
Interval (I)	3	5032.457*	0.819156
TS	4	42.60243*	1.228734
TD	2	7.399306	NS
TI	6	74.12384*	1.41882
SD	2	33.33681*	1.003257
SI	6	19.72106*	1.41882
DI	3	42.15162*	1.158462
TSD	4	5.196181	NS
TSI	12	8.195023	NS
TDI	6	1.005787	NS
SDI	6	0.804398	NS
TSDI	12	0.872106	NS
Error	213	6.288162	
Total	287		

The variations in pulse rate were significantly ($P<0.05$) attributed to different interaction effect viz., T x S, T x I, S x D, S x I and D x I during hoeing in Khillar bullocks. However, interaction between Tx D, T x S x D, T x S x I, T x D x I, S x D x I, T x S x D x I did not influence the pulse rate in Khillar bullocks.

4.4.2 Haematological parameters

The haematological study in terms of levels of haemoglobin, blood glucose and lactic acid recorded before and after hoeing in Khillar bullocks. The results have been given below:

4.4.2.1. Haemoglobin

The overall means for haemoglobin content in the blood of Pandharpuri, Kosa and Tapi Khillar before and after hoeing were 10.58 and 9.92, 10.71 and 10.05 and 11.05 and 10.58gm%, respectively (Table 58, Fig. 34). The results revealed that the decreasing trend in haemoglobin content before work to after work in Khillar bullocks. This might be due to haemodilution and destruction of red blood cells. Almost similar results were also reported by Mukherjee *et al.* (1995) in Haryana bullocks, Gattewar (1983) in HF x Haryana, Chhikara and Singh (2000) in crossbred bullocks. The contradictory results were reported by Yawalikar (2000) in Red Kandhari, Deoni and HF x Deoni.

Garg *et al.*, (1981) noted a significant decrease ($P< 0.01$) in hematocrit values in exercised.

Table 58. Means for Hb in Khillar bullocks during hoeing

Breed	Haemoglobin (gm%) (Before work)	Haemoglobin (gm%) (After work)
Pandharpuri Khillar (T ₁)	10.58	9.92
Kosa Khillar (T ₂)	10.71	10.05
Tapi Khillar (T ₃)	11.05	10.58

The decrease in the level of Hb during after work might be due to the phenomenon of destruction of some erythrocytes, which caused stress of exercise in Khillar bullocks.

4.4.2.2 Blood glucose

The means for glucose (mg%) content in the blood of Pandharpuri, Kosa and Tapi Khillar before and after hoeing were 56.88 and 52.17, 54.90 and 52.18 and 52.70 and 48.06 mg%, respectively (Table 59, Fig. 35).

The present investigation revealed decreasing trend in glucose content during before work to after work in Khillar cattle. Glucose normally serves as a major source of fuel during exercise. These results were also in close agreement with Singh and Upadhyay (1996) who observed a decline of blood glucose post-work, Singh *et al.*, (1980) and Gupta *et al.* (1992) reported decline in blood glucose in bullocks.

Table 59. Mean for blood glucose in Khillar bullocks during hoeing

Breed	Glucose (mg%) (Before work)	Glucose (mg%) (After work)
Pandharpuri Khillar (T ₁)	56.88	52.17
Kosa Khillar (T ₂)	54.90	52.18
Tapi Khillar (T ₃)	52.70	48.06

These finding confirmed the results of Anonymous (2004) who observed significant decline in blood glucose concentration during all seasons. In protracted muscular work the hyperglycemia which was often seen as apart of the general adaptation syndrome masked by the specific blood sugar reducing effect of muscular work and which apparently superimposed over the usual hyperglycemic curve. (Selye, 1950). The reduction in level of blood glucose might be due to the alteration in glucose level could be substrate with alteration of the substrate as a

source of energy required for muscular activity as a results of efficient homeostatic mechanism for glucose.

4.4.2.3. Blood lactic acid

The means for lactic acid content in the blood of Pandharpuri, Kosa and Tapi Khillar before and after hoeing were 7.63 and 8.07, 6.97 and 7.62 and 5.69 and 7.52 gm%, respectively (Table 60, Fig. 36).

Present results were almost similar to that of Gattewar (1983) in crossbred, Georgia *et al.*, (1970) in crossbred, Dhangar (1999) in Kankrej and Anonymous (2004) who observed similar trend of rise in lactic acid level in response to exercise in crossbred and indigenous bullocks.

Table 60. Means for lactic acid in Khillar bullocks during hoeing

Breed	Lactic acid (gm%) (Before work)	Lactic acid (gm%) (After work)
Pandharpuri Khillar (T ₁)	7.63	8.07
Kosa Khillar (T ₂)	6.97	7.62
Tapi Khillar (T ₃)	5.69	7.52

Dhangar (1999) reported that the rise in blood lactic acid concentration could be due to increased anaerobic muscular activity, greater activity being at higher intensity of loads.

4.4.3 Work performance

The draftability of Khillar bullocks during hoeing was studied in terms of draft generated, speed of the work, horse power (hp) developed and area covered.

4.3.3.1 Draft developed during hoeing

The average draft developed during hoeing was 42.34 kg (Table 61). The draft generated in Pandharpuri (T₁), Kosa (T₂) and Tapi (T₃) Khillar were 41.38,

48.00 and 37.25, respectively during hoeing (Fig. 37). Almost similar results were reported by Chhanwal (1990) in crossbred bullocks (Jersey x Sahiwal 45.86 kg). The analysis of variance revealed the significant ($P < 0.01$) variations in draft generated in Pandharpuri, Kosa and Tapi Khillar (Table 62). The means for draft generated during hoeing by Khillar bullocks during summer, rainy and winter were 41.60, 46.17 and 39.25, respectively (Fig. 37). Season had significant ($P < 0.01$) effect on draft produced. The highest draft was generated during rainy followed by summer and winter season (Table 61). The means for draft produced during forenoon and afternoon were 43.34 and 41.35, respectively in Khillar bullocks (Fig. 37). These results confirmed with Bhagat (1996) in crossbred bullocks, Gattewar et al. (1989) in HF x Haryana. The draft was significantly ($P < 0.01$) higher during forenoon than afternoon period (Table 61). These results were in close agreement with Upadhyay and Madan (1982^a) in Haryana, Maurya and Devadattam (1982) in Jersey x Red Sindhi, Gattewar (1983) in crossbred and Abhyankar (1986) in crossbred who observed similar trend of in draft.

Table 61. Means for draft generated in Khillar bullocks during hoeing

Particular		Draft (kg)
μ		42.34
Type (T)	Pandharpuri Khillar (T ₁)	41.38 ^b
	Kosa Khillar (T ₂)	48.00 ^c
	Tapi Khillar (T ₃)	37.25 ^a
	S.E.±	0.25
	C.D. at 1%	0.97
Season (S)	Summer (S ₁)	41.60 ^b
	Rainy (S ₂)	46.17 ^c
	Winter (S ₃)	39.25 ^a
	S.E.±	0.25
	C.D. at 1%	0.97
Time (D)	Forenoon (D ₁)	43.35 ^b
	Afternoon (D ₂)	41.34 ^a
	S.E.±	0.20
	C.D. at 1%	0.79

* Different superscripts indicate significant difference

Table 62. Analysis of variance for draft during hoeing in Khillar bullocks

Source of variation	Df	MSS	F value	
			at 5%	at 1%
Replication	3	0.674		
Type (T)	2	762.902**	0.727	0.970
Season (S)	2	297.887**	0.727	0.970
Duration (D)	1	71.219**	0.594	0.792
TS	4	1.965	NS	----
TD	2	0.133	NS	----
SD	2	0.789	NS	----
TSD	4	1.020	NS	----
Error	51	1.574	----	----
Total	71	-----	----	----

All the interaction effects on draft generated were non- significant.

4.4.3.2 Speed during hoeing

Average speed of Khillar bullocks during hoeing was 3.77 km/hr (Table 63). The speed observed during hoeing were 3.79, 3.91 and 3.63 in case of Pandharpuri (T₁), Kosa (T₂) and Tapi (T₃) Khillar, respectively (Fig. 38). The variance analysis revealed that the significant ($P < 0.01$) variations in speed were observed in Pandharpuri, Kosa and Tapi Khillar (Table 64). The means of speed during hoeing by Khillar bullocks during summer, rainy and winter were 3.67, 3.79 and 3.86 (Fig. 38). Season had significant ($P < 0.01$) effect on speed. The speed during hoeing was higher in winter followed by rainy and summer season (Table 63). The means for speed during forenoon and afternoon were 3.82 and 3.74, respectively (Fig. 38). These results were in agreement with those reported

by Anonymous (1979-80) in Hallikar bullocks, Premi (1979) in Hallikar bullocks, Upadhyay and Madan (1982^a) in Haryana and Gattewar (1983) in crossbred and Haryana bullocks. The speed was significantly ($P < 0.01$) higher during forenoon than afternoon period (Table 63).

Table 63. Means for speed in Khillar bullocks during hoeing

Particular		Speed (km/hr)
μ		3.77
Type (T)	Pandharpuri Khillar (T ₁)	3.79 ^b
	Kosa Khillar (T ₂)	3.91 ^c
	Tapi Khillar (T ₃)	3.63 ^a
	S.E.±	0.006
	C.D. at 1%	0.024
Season (S)	Summer (S ₁)	3.67 ^a
	Rainy (S ₂)	3.79 ^b
	Winter (S ₃)	3.86 ^c
	S.E.±	0.006
	C.D. at 1%	0.024
Time (D)	Forenoon (D ₁)	3.82 ^a
	Afternoon (D ₂)	3.74 ^b
	S.E.±	0.005
	C.D. at 1%	0.020

* Different superscripts indicates significant difference

Table 64. Analysis of variance for speed during hoeing in Khillar bullocks

Source of variation	Df	MSS	F value	
			at 5%	at 1%
Replication	3	0.001		
Type (T)	2	0.485**	0.018	0.024
Season (S)	2	0.228**	0.018	0.024
Duration (D)	1	0.111**	0.015	0.020
TS	4	0.012**	0.032	0.042
TD	2	0.001	NS	----
SD	2	0.000	NS	----
TSD	4	0.001	NS	----
Error	51	0.001	----	----
Total	71	-----	----	----

The interaction effect between T x S for speed were significant ($P < 0.01$). However, interaction effects viz., T x D, S x D, and T x S x D for speed during hoeing were non- significant.

4.4.3.3 Horse power during hoeing

The average hp developed by Khillar bullocks during hoeing was 0.60 hp (Table 65). The horse power observed during hoeing were 0.58, 0.71 and 0.50 in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar, respectively (Fig. 39), which matches very well with the value reported by Rautary and Srivastava (1982) in Sahiwal crossbred bullocks. The variance analysis revealed that the significant ($P < 0.01$) variations in hp were attributed to the type of Khillar (Table 66). The means for horse power during hoeing by Khillar bullocks during summer,

rainy and winter were 0.56, 0.65 and 0.57 (Fig. 39). Season had significant ($P < 0.01$) effect on hp. During rainy, it was higher as compared to winter and summer season (Table 65). The means for horse power developed during forenoon and afternoon were 0.62 and 0.57, respectively (Fig. 39). The hp developed was significantly ($P < 0.01$) higher during forenoon than afternoon period (Table 65).

Table 65. Means for horse power generated by Khillar bullocks during hoeing

Particular		Horse power (hp)
μ		0.60
Type (T)	Pandharpuri Khillar (T_1)	0.58 ^b
	Kosa Khillar (T_2)	0.71 ^c
	Tapi Khillar (T_3)	0.50 ^a
	S.E. $\pm$	0.008
	C.D. at 1%	0.022
Season (S)	Summer (S_1)	0.56 ^a
	Rainy (S_2)	0.65 ^b
	Winter (S_3)	0.57 ^c
	S.E. $\pm$	0.008
	C.D. at 1%	0.022
Time (D)	Forenoon (D_1)	0.62 ^b
	Afternoon (D_2)	0.57 ^a
	S.E. $\pm$	0.006
	C.D. at 1%	0.018

* Different superscripts indicates significant difference

These results were in agreement with those reported by Premi (1979) in Hallikar, Gattewar (1983) in crossbred and Haryana, Upadhyay and Madan (1985^a) in Haryana crossbred bullocks, Maurya and Devedattam (1986) in crossbred bullocks and Dhangar (1999) in crossbred and indigenous bullocks.

Table 66. Analysis of variance for horse power during hoeing in Khillar bullocks

Source of variation	Df	MSS	F value	
			at 5%	at 1%
Replication	3	0.002		
Type (T)	2	0.279**	0.022	0.029
Season (S)	2	0.052**	0.022	0.029
Time (D)	1	0.044**	0.018	0.024
TS	4	0.001	NS	----
TD	2	0.002	NS	----
SD	2	0.000	NS	----
TSD	4	0.002	NS	----
Error	51	0.001	----	----
Total	71	-----	----	----

All the interaction effects for horse power developed were non- significant during hoeing.

4.4.3.4 Unit area covered during hoeing

The overall mean for area covered by Khillar bullocks during ploughing was 1242.40 m²/hr (Table 67). The area covered by Pandharpuri (T₁), Kosa (T₂) and Tapi (T₃) Khillar during hoeing were 1248.69, 1287.37 and 1191.16, respectively (Fig. 40). Almost similar results were reported by Acharya *et al.* (1979) in HF x Haryana, Gattewar (1983) in Haryana and Bhagat (1986) in crossbred bullocks. The variance analysis revealed that the significant ($P < 0.05$) variations in area covered were observed in Pandharpuri, Kosa and Tapi Khillar (Table 68). The means for area covered during hoeing by Khillar bullocks during summer, rainy and winter were 1222.38, 1241.65 and 1263.18 (Fig. 40). Season had significant ($P < 0.05$) effect on area covered. The higher area was covered

during winter followed by rainy and summer season by Khillar bullocks (Table 67). The means for area covered during forenoon and afternoon were 1247.15 and 1237.66, respectively (Fig. 40). The area covered by Khillar bullocks was significantly ($P < 0.05$) higher during forenoon compared to afternoon period (Table 67). The present finding confirmed the results of Roy *et al.*, (1972) in Haryana bullocks, Anand and Sundresan (1974) in Haryana bullocks, Rao *et al.*, (1974) in crossbred bullocks, Acharya *et al.* (1979) in crossbred bullocks, Nagpaul (1984) in Haryana, Rao and Upadhyay (1984) in crossbred bullocks, Abhyankar (1986) in crossbred bullocks, Sreekumar and Thomas (1990^a) in Kangayam and crossbred bullocks, Dhangar (1999) in Kankarej bullocks and Jadhav and Jagtap (2000) in crossbreed and indigenous bullocks.

Table 67. Means for area covered by Khillar bullocks during hoeing

Particular		Area covered (m²/hr)
μ		1242.40
Type (T)	Pandharpuri Khillar (T ₁)	1248.69 ^b
	Kosa Khillar (T ₂)	1287.37 ^c
	Tapi Khillar (T ₃)	1191.16 ^a
	S.E.±	0.53
	C.D. at 5%	1.48
Season (S)	Summer (S ₁)	1222.38 ^a
	Rainy (S ₂)	1241.65 ^b
	Winter (S ₃)	1263.18 ^c
	S.E.±	0.53
	C.D. at 5%	1.48
Time (D)	Forenoon (D ₁)	1247.15 ^b
	Afternoon (D ₂)	1237.66 ^a
	S.E.±	0.43
	C.D. at 5%	1.20

* Different superscripts indicates significant difference

Table 68. Analysis of variance for area covered during hoeing in Khillar bullocks

Source of variation	Df	MSS	F value
			at 5%
Replication	3	1.286296	
Type (T)	2	56247.53*	1.480247
Season (S)	2	9998.116*	1.480247
Duration (D)	1	1622.601*	1.208617
TS	4	340.061	NS
TD	2	6.668889	NS
SD	2	15.42389	NS
TSD	4	14.41597	NS
Error	51	6.844434	----
Total	71	-----	----

The interaction effects for area covered viz., T x S, T x D, S x D, T x S x D were non- significant during hoeing.

4.5. Carting (Plate 14)

The results of carting operation performed by Khillar bullocks during summer, rainy and winter season have been presented and discussed in following paragraphs.

4.5.1. Physiological indices

The results on respiration rate, body temperature and pulse rate of Khillar bullocks before and after each trial on carting have been given below:

4.5.1.1. Respiration rate

The mean for respiration rate in Khillar bullocks was 37.22 during carting (Table 69). The respiration rates were observed as 39.28, 33.37 and 39.48 in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar, respectively during carting operation (Fig. 41). These results were in agreement with Rana et al. (1978) in bullocks and Acharya et al. (1979) in crossbred bullocks. The variance analysis revealed that the significant ($P < 0.05$) variations in RR were observed due to type of Khillar viz., Pandharpuri, Kosa and Tapi Khillar (Table 70). The means for respiration rate during summer, rainy and winter were 39.90, 38.80 and 33.43 (Fig. 41). Season had significant ($P < 0.05$) effect on RR in Khillar bullocks. The higher RR was observed during summer followed by rainy and winter season (Table 69). The means for respiration rate in Khillar bullocks before and after carting were 22.29 and 52.47 beats/min (Fig. 41). After the carting operation RR was significantly ($P < 0.05$) higher in comparison to before carting (Table 69). The means for respiration rate after carting for a distance of 5 km (K_1), 10 km (K_2) and 15 km (K_3) were 34.37, 37.42 and 40.35, respectively (Fig. 41). The significant ($P < 0.05$) variations in RR were observed at different distances of carting (Table 70). It indicated that as the carting distance increased the RR also increased in Khillar bullocks. These results confirmed the normal values for this parameter (Melvin and Willian, 1993).

Dhangar (1999) who observed corresponding trend of increase in respiration rate after carting in response to exercise. The increase in respiration rate in the present work due to exposure of animal to carting exercise could be due to the consumption of O_2 during the peak level of muscular activity. Evidences showed that O_2 consumption increased as much as 190 to 300 times than that of resting state of animal. In response to the demand for more O_2 the rate of breathing promptly increased.

Table 69. Means for respiration rate in Khillar bullocks after carting operation

Particular		Respiration rate (beats/min)
μ		37.22
Type (T)	Pandharpuri Khillar (T ₁)	39.28 ^b
	Kosa Khillar (T ₂)	33.37 ^a
	Tapi Khillar (T ₃)	39.48 ^b
	S.E.±	0.36
	C.D. at 5%	1.02
Season (S)	Summer (S ₁)	39.90 ^c
	Rainy (S ₂)	38.80 ^b
	Winter (S ₃)	33.43 ^a
	S.E.±	0.368
	C.D. at 5%	1.02
Intervals (I)	Before carting (I ₁)	22.29 ^a
	After carting (I ₂)	52.47 ^b
	S.E. ±	0.30
	C.D. at 5 %	0.83
Distance (k)	5 km (K ₁)	34.37 ^a
	10 km (K ₂)	37.41 ^b
	15 km (K ₃)	40.34 ^c
	S.E. ±	0.36
	C.D. at 5 %	1.02

* Different superscripts indicates significant difference

The respiration rate in the present study was more during summer than rainy and winter. In all domestic animals increased frequency of breathing continuously as environmental temperature rises (Melvin and Willian, 1993).

Dhangar (1999) also reported the significant increased in respiration rates during summer as compared to winter in Kankrej bullocks.

Table 70. Analysis of variance for respiration rate after carting operation in Khillar bullocks

Source of variation	Df	MSS	F value at 5%
Replication	3	42.99383	
Type (T)	2	866.7824*	1.020927
Season (S)	2	863.8102*	1.020927
Distance (K)	2	642.088*	1.020927
Interval (I)	1	49201.85*	0.833583
TS	4	48.96296*	1.768297
TK	4	13.63657	NS
TI	2	260.7824*	1.443808
SK	4	31.14352*	1.768297
SI	2	489.4769*	1.443808
KI	2	520.9769*	1.443808
TSK	8	3.41088	NS
TKI	4	12.92824	NS
TSKI	8	3.438657	NS
Error	159	9.767412	
Total	215		

The interaction effect between T x S, T x I, S x K and S x I for respiration rate were significant ($P < 0.05$) in Khillar bullocks. However, interaction effects viz., T x K, T x S x K, T x K x I and T x S x K x I did not influence the RR during carting in Khillar bullocks.

4.5.1.2. Body temperature

The overall means for body temperature in Khillar bullocks was 101.18 °F after carting operation (Table 71). The average body temperatures were observed to be 101.34, 100.77 and 101.48 °F in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar, respectively after carting operation (Fig. 42). The analysis of variance revealed that the significant ($P < 0.05$) variations in BT were observed in Pandharpuri, Kosa and Tapi Khillar (Table 72). The means for body temperature during summer, rainy and winter season were 101.60, 101.16 and 100.83 °F (Fig. 42). Season had significant ($P < 0.05$) effect on BT in Khillar bullocks after carting. During summer, it was higher followed by rainy and winter season (Table 71). The means for body temperature in Khillar bullocks before and after carting were 100.34 and 102.06 °F (Fig. 42). After carting the BT was significantly ($P < 0.05$) higher (Table 71). The means for body temperature during 5 km (K_1), 10 km (K_2) and 15 km (K_3) were 100.83, 101.26 and 101.51, respectively (Fig. 42). The significant ($P < 0.05$) variations in BT were observed at different distance of working (Table 72). It indicated that as the working distance increased the BT also increased. The body temperature increased similarly from pre to post-work level, during summer followed by rainy and winter season. These results were in close agreement with Belsare *et al.*, (1992) in crossbred and indigenous bullocks, Bijendrakumar *et al.*, (1996) in Haryana and crossbred bullocks, Yawalikar *et al.*, (2003) in Red Kandhari, Deoni and HF x Deoni bullocks, who observed such trend of increase in body temperature.

Table 71. Means for body temperature in Khillar bullocks after carting operation

Particular		Body temperature (°F)
μ		101.18
Type (T)	Pandharpuri Khillar (T ₁)	101.34 ^b
	Kosa Khillar (T ₂)	100.77 ^a
	Tapi Khillar (T ₃)	101.48 ^c
	S.E. ±	0.048
	C.D. at 5%	0.13
Season (S)	Summer (S ₁)	101.60 ^c
	Rainy (S ₂)	101.16 ^b
	Winter (S ₃)	100.83 ^a
	S.E. ±	0.048
	C.D. at 5%	0.13
Interval	Before carting (I ₁)	100.34
	After carting (I ₂)	102.06 ^b
	S.E. ±	0.039
	C.D. at 5%	0.10
Distance (K)	5 km (K ₁)	100.83 ^a
	10 km (K ₂)	101.26 ^b
	15 km (K ₃)	101.51 ^c
	S.E. ±	0.48
	C.D. at 5%	0.13

* Difference superscripts indicates significant difference

Table 72. Analysis of variance for body temperature after carting in Khillar bullocks

Source of variation	Df	MSS	F value at 5%
Replication	3	3.144273	
Type (T)	2	10.19356*	0.134709
Season (S)	2	10.66502*	0.134709
Duration (D)	2	8.622234*	0.134709
Interval (I)	1	159.1522*	0.10999
TS	4	0.864673*	0.233323
TK	4	0.159013	NS
TI	2	0.806639*	0.190508
SK	4	0.207303	NS
SI	2	1.803612*	0.190508
KI	2	6.073417*	0.190508
TSK	8	0.079249	NS
TSI	4	0.070334	NS
TKI	4	0.056869	NS
SKI	4	0.16857	NS
TSKI	8	0.055021	NS
Error	159	0.170053	
Total	215		

The interaction effect between T x S, T x I, K x I and S x I for body temperature were significant ($P < 0.05$). The interaction effects viz., T x K, T x S x K, T x K x I and T x S x K x I did not affect body temperature after carting operation in Khillar bullocks.

4.5.1.3 Pulse rate

The overall mean for pulse rate in Khillar bullocks was 67.84 beats/min (Table 73). The pulse rates were observed to be 67.72, 62.28 and 70.72 in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar, respectively during carting operation (Fig. 43). The analysis of variance revealed that the significant ($P < 0.05$) variations in PR were attributed due to the types of Khillar viz., Pandharpuri, Kosa and Tapi Khillar (Table 74). The means for pulse rate during summer, rainy and winter were 70.51, 66.79 and 66.42 (Fig. 43). Variance analysis indicated that season had significantly ($P < 0.05$) influenced the PR. The PR was higher in summer followed by rainy and winter season (Table 73). The means for pulse rate in Khillar bullocks before and after carting were 57.00 and 78.81 (Fig. 43). After carting the PR was significantly ($P < 0.05$) higher than before carting in Khillar bullocks (Table 73). The means for pulse rate after carting for a distance of 5 km (K_1), 10 km (K_2) and 15 km (K_3) were 65.72, 68.12 and 69.87, respectively (Fig. 43). The significant ($P < 0.05$) variations in PR were observed at different distance of working (Table 74), which indicated that as the working distance increased the PR also increased. These findings confirmed with those reported by Belsare *et al.*, (1992) in crossbred and indigenous bullocks, Bijenderkumar *et al.*, (1996) in Haryana and crossbred bullocks, Yawalikar *et al.*, (2003) in Red Kandhari, Deoni and HF x Deoni bullocks, who observed such a trend of increase in pulse rate.

Dhangar (1999) reported that during summer pulse rate was significantly higher in comparison to winter season in Kankrej bullocks.

Table 73. Means for pulse rate in Khillar bullock after carting operation

Particular		Pulse rate (beats / min)
μ		67.84
Type (T)	Pandharpuri Khillar (T ₁)	67.72 ^b
	Kosa Khillar (T ₂)	62.28 ^a
	Tapi Khillar (T ₃)	70.72 ^c
	S.E.±	0.30
	C.D. at 5%	0.84
Season (S)	Summer (S ₁)	70.51 ^b
	Rainy (S ₂)	66.79 ^a
	Winter (S ₃)	66.42 ^a
	S.E.±	0.30
	C.D. at 5%	0.84
Intervals (I)	Before carting (I ₁)	57.00 ^a
	After carting (I ₂)	78.81 ^b
	S.E. ±	0.25
	C.D. at 5 %	0.69
Distance (k)	5 km (K ₁)	65.72 ^a
	10 km (K ₂)	68.12 ^b
	15 km (K ₃)	69.87 ^c
	S.E. ±	0.30
	C.D. at 5 %	0.84

* Different superscripts indicates significant difference

Sreekumar and Thomos (1990) and Bijenderkumar *et al.*, (1996) reported that the heart beat rate was significantly higher during summer than winter.

Dhangar (1999) reported that the heart beat increased with increase in load as it caused more exertion.

Table 74. Analysis of variance for pulse rate after carting operation in Khillar bullocks

Source of variation	Df	MSS	F value at 5%
Replication	3	31.2716	
Type (T)	2	535.4074*	0.84947
Season (S)	2	369.3935*	0.84947
Distance (K)	2	312.9769*	0.84947
Interval (I)	1	25697.85*	0.693589
TS	4	94.78241*	1.471325
TK	4	11.51157	NS
TI	2	75.46296*	1.201332
SK	4	5.935185	NS
SI	2	53.39352*	1.201332
KI	2	296.8102*	1.201332
TSK	8	1.584491	NS
TKI	4	3.19213	NS
SKI	4	12.31019	NS
TSKI	8	1.97338	NS
Error	159	6.762171	
Total	215		

The interaction effect between T x S, T x I, S x I and K x I for pulse rate were significant ($P < 0.05$). The interaction effects among T x K, S x K, S x K, T x

K x I, S x K x I and T x S x K x I did not affect PR after carting operation in Khillar bullocks.

4.5.2. Haematological parameters

The studies on haemoglobin, blood glucose and lactic acid before and after carting was conducted during summer season. The results are given below:

4.5.2.1. Haemoglobin concentration after carting operation

The overall means of haemoglobin (gm %) content drawn from the bullocks before and after carting during summer season were 10.74 and 9.79, respectively (Table 75, Fig. 44).

Table 75. Means for haemoglobin in Khillar bullocks before and after carting

Type	Haemoglobin (gm%) (Before carting)	Haemoglobin (gm%) (After carting)
Pandharpuri Khillar (T ₁)	10.57	9.72
Kosa Khillar (T ₂)	10.58	9.55
Tapi Khillar (T ₃)	11.07	10.12
Overall mean	10.74	9.79

The decrease in the level of haemoglobin before and after carting might be due to the phenomenon of destruction of some erythrocytes, which caused stress of exercise in Khillar bullocks. Singh *et al.* (1968^b) reported that reduction in number of erythrocytes might have brought down the haemoglobin level. The Kosa Khillar were thus in possession of better adaptive mechanism against stress of work when compared with Pandharpuri and Tapi Khillar.

The present investigation revealed decreasing trend in haemoglobin content before carting to after carting in Khillar bullocks. These results were also in close agreement with Upadhyay and Madan (1985^b) in Haryana, Upadhyay and Madan

(1988) in crossbred and Haryana, Chhikara and Singh (2000) in crossbreds who observed similar trend in decrease in haemoglobin level in response to exercise.

4.5.2.2. Blood glucose concentration

The overall means of blood glucose content drawn from the bullocks before and after carting during summer season were 55.20 and 49.82 mg%, respectively in Khillar bullocks (Table 76, Fig. 45):

Table 76. Means for blood glucose in Khillar bullocks before and after carting

Type	Blood glucose (mg%) Before carting	Blood glucose (mg%) Aftercarting
Pandharpuri Khillar (T ₁)	56.95	49.82
Kosa Khillar (T ₂)	54.90	51.02
Tapi Khillar (T ₃)	53.77	48.64
Overall mean	55.20	49.82

The present investigation revealed decreasing trend in glucose content before carting to after carting in Khillar bullocks, due to the haemodilution and destruction of red blood cells. These findings confirm with those reported by Georgie *et al.*, (1970), Upadhyay and Madan (1988) in Haryana bullocks, Yawalikar (2000) in Red Kandhari, Deoni and HF x Deoni and Chhikara and Singh (2000) in crossbred bullocks.

Upadhyay and Madan (1988) found that continuous work caused a decline in Hb level in blood. The decline in Hb was marked among Haryana bullocks. However, blood glucose (40.3 to 40.7 mg%) did not change significantly over continuous hours of working.

Singh and Upadhyay (1997^c) reported that during each work period, blood glucose level decreased. Dhangar (1999) found that the physical work caused a

significant decline in blood glucose concentration with an elevation in blood lactic acid to a greater extent during summer while doing all type of work. The magnitude of change increased with increase in intensity of work.

4.5.2.3. Lactic acid concentration

The means for lactic acid (gm%) before and after carting were 6.83 and 8.37 gm%, respectively in Khillar bullocks (Table 77, Fig. 46):

Table 77. Mean for lactic acid in Khillar bullocks before and after carting

Type	Lactic acid (gm%) (Before carting)	Lactic acid (gm%) (After carting)
Pandharpuri Khillar (T ₁)	7.73	8.60
Kosa Khillar (T ₂)	7.00	8.90
Tapi Khillar (T ₃)	5.76	7.62
Overall mean	6.83	8.37

The present investigation revealed increasing trend in lactic acid content during before work to after work in Khillar cattle. These findings confirmed with those reported by Upadhyay and Madan (1985^b, 1988) in Haryana and HF x Haryana bullocks, Sreekumar and Thomas (1990) in indigenous and crossbred bullocks, Dhangar (1999) in Kankrej and crossbred bullocks and Chhikara and Singh (2000) who observed similar trend in increasing lactic acid. The increasing trend in formation of lactic acid during carting in Khillar bullocks due to a very intense muscular activity revealed that the circulatory system couldn't bring oxygen and glucose to the skeletal muscle fast enough. Hence muscle glycogen was used as a reserve fuel and broken to form lactate which further generated ATP as energy source. As insufficient oxygen was available the lactate could not be

metabolized further in the muscle and diffused in blood, where as concentration of lactic acid increased in blood.

4.5.3. Speed at carting

Average speed of Khillar bullocks during carting was 4.19 km/hr (Table 78). The means for speed during carting were observed as 4.07, 4.67 and 3.85 km/hr in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar, respectively (Fig. 47). Almost similar results were reported by Upadhyay and Madan (1987) in Haryana and crossbred bullocks. The variance analysis revealed that the significant ($P < 0.05$) variations in speed during carting were observed in Pandharpuri, Kosa and Tapi Khillar (Table 79). The means for speed during carting by Khillar bullocks during summer, rainy and winter were 4.047, 4.14 and 4.40 km/hr (Fig. 47). Season had significant ($P < 0.05$) effect on speed. The higher speed was observed during winter followed by rainy and summer season (Table 78). The means for speed during 5 km, 10 km and 15 km were 4.36, 4.19 and 4.04 km/hr, respectively (Fig. 47). The significant ($P < 0.01$) variations in speed of Khillar bullocks were observed at different distances (Table 79). It indicated that as the distance increased the speed of Khillar bullocks decreased. These results were in close agreement with Gattewar (1983), Acharya *et al.* (1979) in HF x Haryana, Belsare (1984) in crossbred bullocks and Dhangar (1999) in Kankrej bullocks.

The present findings confirmed with the results reported by Nagpaul *et al.*, (1979), Roy *et al.*, (1984), Acharya *et al.*, (1979), Maurya (1982), Gattewar (1983), Upadhyay and Madan (1982). Dhangar (1999) also found similar results in Jersey x Kankrej and Kankrej bullocks during carting.

Table 78. Means for speed in Khillar bullocks during carting

Particular		Speed (km/hr)
μ		4.19
Type (T)	Pandharpuri Khillar (T ₁)	4.07 ^b
	Kosa Khillar (T ₂)	4.67 ^c
	Tapi Khillar (T ₃)	3.84 ^a
	S.E.±	0.02
	C.D. at 5%	0.08
Season (S)	Summer (S ₁)	4.04 ^a
	Rainy (S ₂)	4.13 ^b
	Winter (S ₃)	4.40 ^c
	S.E.±	0.02
	C.D. at 5%	0.08
Distance (k)	5Km (K ₁)	4.35 ^c
	10Km (K ₂)	4.19 ^b
	15Km (K ₃)	4.03 ^a
	S.E. ±	0.02
	C.D. at 5 %	0.08

* Different superscripts indicates significant difference.

Table 79. Analysis of variance for speed during carting operation in Khillar bullocks

Source of variation	Df	MSS	F value	
			at 5%	at 1%
Replication	3	0.151		
Type (T)	2	6.435**	0.061	0.081
Season (S)	2	1.231**	0.061	0.081
Distance(K)	2	0.927**	0.061	0.081
TS	4	0.054*	0.106	NS
TK	4	0.017	NS	----
SK	4	0.022	NS	----
TSK	8	0.021	NS	----
Error	78	0.017	----	----
Total	107	-----	----	----

4.6 : Fatigue score attained by Pandharpuri, Kosa and Tapi Khillar during carting

The Khillar bullocks were subjected to a 1 ton load in addition to bullock cart (270kg) and driver (65kg). The work was carried continuously until the animal reached fatigue stage (Plate 15). The means for fatigue score were as follows:

Table 80. Means for fatigue score attained by Khillar bullocks during carting

Particular	Pandharpuri Khillar (After 3.05hr)	Kosa Khillar (After 3.25hr)	Tapi Khillar (After 2.40 hr)
Respiration rate	3.50	3.20	4.2
Pulse rate	3.60	3.35	3.60
Temp (° F)	3.90	3.60	3.95
Frothing	3.80	3.50	4.15
Leg incoordination	2.90	3.50	3.30
Excitement	2.90	2.20	3.75
Inhibition to progressive movement	3.00	3.30	3.55
Tongue protrusion	3.50	2.50	3.4
Range:	22 to 27	20 to 26	24 to 29

Kosa Khillar bullocks carrying a load of 1t covered a mean distance of 4.25 km/hr during the first and second hours but in the third hour the speed of work fell to 3.15 km/hr. In the first and second hour the Pandharpuri Khillar performed the work at the same speed (mean 4.25 km/hr). However, during the third hour the speed of work gone down to 2.95 km/hr. In the first hour the Tapi Khillar performed the work at the speed 3.90 km/hr but during the second hour the speed decreased to 3.40 km/hr and during the third hour the bullocks were declared

fatigued on the basis of excessive distress symptoms and physiological reactions. During continued work, Kosa, Pandharpuri and Tapi animals exhibited signs of distress, e.g. profuse salivation, excitement, leg incoordination, movement inhibition and tongue protrusion. Pandharpuri, Kosa, and Tapi Khillar bullocks which were fatigued while pulling a 1t load were given scores of 22 to 27, 20 to 26 and 24 to 29, respectively (Table 80.)

The increase in rectal temperature after work was near about similar in Pandharpuri and Tapi Khillar, whereas the increase in heart rate was less in Kosa than Pandharpuri and Tapi. The absolute increase in respiration rate was greater in Tapi Khillar than Pandharpuri and Kosa Khillar.

The present findings confirmed the results of Upadhyay and Madan (1985^a) who observed that the Haryana and crossbred bullocks, which were fatigued while pulling a 1t load were given scores of 20 to 26 and 22 to 27, respectively. Yadav *et al.*, (2005) reported that the effect of season of work non- significant for all the fatigue score traits after 2 hr, as well as 3hr of continuous work, except for frothing after 2 hr of continuous work. The pair mean comparison across different seasons of work for frothing after 2 hr revealed that the highest score was in dry hot season (April-June) followed by dry humid (July- September) and it was lowest in winter.

Depth of operation

Table 81. Mean value for depth (cm) in different agricultural operations

Khillar bullock pair	Ploughing			Harrowing			Hoeing			Sowing		
	Summer	Rainy	Winter	Summer	Rainy	Winter	Summer	Rainy	Winter	Summer	Rainy	Winter
1	2	3	4	5	6	7	8	9	10	11	12	13
T1	19	19.20	18.5	4.5	5	4.3	8.2	8.5	8.0	13.60	14	13.0
T2	19.20	20.00	19	5	5.3	4.9	9	9.3	8.7	14.10	15	13.70
T3	18.50	19.10	18	4	4.5	4.2	7.5	8.0	7.0	12.15	12.50	12

T₁ : Pandharpuri Khillar T₂ : Kosa Khillar T₃ : Tapi Khillar

**Table 82. Normal values for physiological indices and haematological
Parameters in bullocks**

1. Physiological indices	
	Normal Values
Respiration rate	15 to 20 (per min)
Body temperature	99.5 to 101.5 (⁰ F)
Pulse rate	42 to 60 (per min)
2. Haematological parameters	
	Normal Values
Haemoglobin (Hb)	8 to 11 (gm%)
Blood glucose	45 to 55 (mg%)
Blood lactic acid	5 to 20 (gm%)

5. SUMMARY AND CONCLUSIONS

A. SUMMARY

5.1. Khillar breed is the pride of Maharashtra. Though cows were low yielders, the males were preferred for their sole use in agriculture, where they played pivotal role in major field operations viz., ploughing, sowing, harrowing, hoeing in medium to deep black cotton soil in western Maharashtra, Transport of farm produce from village to market place on 'Kachha' as well as 'Pakka' road was also performed by Khillar bullocks.

Scientific information on the comparative working capacity of Kosa, Pandharpuri and Tapi type Khillar bullocks during ploughing, sowing, harrowing, hoeing and carting has been generated with these objectives, the present research entitled "Studies on draftability in Khillar cattle" was carried out.

5.2. All the trials were conducted at Central Sugarcane Research Institute, Padegaon and farmers field at Ajande, in Dhule districts. The agricultural operations were carried out for three hours during forenoon and afternoon and were conducted during different seasons viz; summer, rainy and winter.

5.3. The physiological and haematological responses as well as the draftability traits were recorded for different agricultural operations in the case of Pandharpuri, Kosa and Tapi Khillar during summer, rainy and winter seasons.

5.3.1. Ploughing

Average mean for RR in Khillar bullocks was 41.19 beats/min. The mean respiration rate were 41.52, 37.13 and 44.60 in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar. The corresponding values for RR during summer, rainy and winter season were 44.73, 42.21 and 36.23 beats/min. The means for RR

during forenoon and afternoon were 39.77 and 42.40. The RR during before work, after 1st, 2nd hour and after 3rd hour of ploughing were 22.23, 40.73, 47.91 and 53.45, respectively. The significant ($P < 0.05$) variation in respiration rate was observed in type, season, time and interval during ploughing.

The average BT in Khillar bullocks was 101.63 °F. The body temperature were 101.76, 101.295 and 101.893 in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar. The average BT during different seasons were 102.41, 101.85 and 100.70 °F in summer, rainy and winter season, respectively. The corresponding values for BT during forenoon and afternoon were 101.43 and 101.88 °F. The means for BT in Khillar bullocks before work, after 1st, 2nd hour and after 3rd hour ploughing were 100.14, 101.61, 102.28 and 102.56 °F, respectively. The variations in BT were significant ($P < 0.05$) attributed to the different types, season, time and interval during ploughing.

The overall mean for PR in Khillar bullocks was 75.98 beats/min. The means for pulse rates were 77.83, 72.33 and 77.80 beats/min in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar, respectively. The mean PR during different seasons were 79.86, 75.63 and 72.48 beats/min in summer, rainy and winter season, respectively. The corresponding values for PR during forenoon and afternoon were 74.59 and 77.39. The means for PR in Khillar bullocks before work, after 1st, 2nd hour and after ploughing were 60.81, 77.15, 81.08 and 84.92. The significant ($P < 0.05$) variations in PR were observed at different type, season, time and intervals of working.

The mean for haemoglobin content in the blood of Pandharpuri, Kosa and Tapi Khillar before and after ploughing were 10.56 and 9.84, 10.56 and 9.90 and 11.12 and 10.48 gm%, respectively. The corresponding values for glucose content were 56.95 and 48.24, 54.90 and 50.27 and 55.00 and 47.78 mg%, and for lactic acid 7.73 and 8.80, 7.00 and 8.00 and 5.75 and 8.725 gm%, respectively.

The overall mean for draft generated by Khillar bullocks during ploughing was 142.73 kg. The draft generated during ploughing were 143.90, 162.91 and

133.37 kg by Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar, respectively. The means draft generated during ploughing by Khillar bullocks during summer, rainy and winter were 145.72, 151.76 and 142.70 kg. The corresponding values for draft during forenoon and afternoon were 149.11 and 144.34 kg, respectively. Significant ($P < 0.01$) effect on draft generated were observed in type, season and time during ploughing.

Average speed of Khillar bullocks during ploughing was 3.06 km/hr. The speed observed during ploughing were 3.06, 3.122 and 3.00 km/hr in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar. The corresponding values for speed during ploughing by Khillar bullocks during summer, rainy and winter seasons were 2.99, 3.07 and 3.12 km/hr, and during forenoon and afternoon were 3.09 and 3.03 km/hr. The significant ($P < 0.01$) variations in speed were observed at different type, seasons and time.

The overall mean for hp developed by Khillar bullocks was 1.68 hp. The horse power observed during ploughing were 1.67, 1.88 and 1.48 in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar. The means for horse power during Ploughing by Khillar bullocks during summer, rainy and winter were 1.62, 1.73 and 1.69. The corresponding values for horse power during forenoon and afternoon were 1.72 and 1.64, respectively. The hp was significant ($P < 0.01$) effect on type, season and time were observed during ploughing.

The average area covered by Khillar bullocks during ploughing was 346.27 m²/hr. The area covered were 347.31, 354.71 and 336.80 in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar, respectively. The means for area covered during ploughing by Khillar bullocks during summer, rainy and winter were 336.60, 343.24 and 358.98. The corresponding values for area covered during forenoon and afternoon were 347.90 and 344.64, respectively. The area covered was significant ($P < 0.01$) effect to type, season and time during ploughing.

5.3.2. Sowing

The average for RR in Khillar bullocks was 39.29 beats/min. The means for respiration rate was observed to be 39.88, 35.42 and 42.35 in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar. The corresponding values for RR during summer, rainy and winter season were 41.74, 41.03 and 34.88 beats/min. The means for RR during forenoon and afternoon were 37.94 and 40.49. The RR during before work, after 1st, 2nd hour and after 3rd hour during sowing were 20.08, 37.90, 44.93 and 51.96, respectively. The significant ($P < 0.05$) variation in respiration rate was observed in type, season, time and interval during sowing.

The overall mean for BT in Khillar bullocks was 101.42 °F. The body temperature during sowing were observed as 101.43, 101.12 and 101.70 °F in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar. The BT were observed as 102.10, 101.53 and 100.62 °F during summer, rainy and winter season, respectively. The corresponding values for BT during forenoon and afternoon were 101.24 and 101.60 °F. The means for BT in Khillar bullocks before work, after 1st, 2nd hour and after 3rd hour sowing were 100.12, 101.29, 102.97 and 102.29 °F, respectively. The variations in BT were significant ($P < 0.05$) attributed to the different type, season, time and interval during sowing.

The overall mean for PR in Khillar bullocks was 73.66 beats/min. The mean pulse rate during sowing were observed to be 75.01, 69.85 and 75.72 beats/min in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar, respectively. The mean PR during different seasons were 76.75, 72.96 and 70.87 beats/min in summer, rainy and winter season, respectively. The corresponding values for PR during forenoon and afternoon were 71.74 and 75.31 beats/min. The means for PR in Khillar bullocks before work, after 1st, 2nd hour and after sowing were 59.94, 73.47, 78.53 and 82.17 beats/min, respectively. The significant ($P < 0.05$) variations in PR were observed at different type, season, time and intervals of working.

The mean for haemoglobin (gm%) content in the blood of Pandharpuri, Kosa and Tapi Khillar before and after sowing were 10.60 and 9.91, 10.62 and 9.99 and 11.09 and 10.62 gm%, respectively. The corresponding values for glucose (mg%) content were 56.88 and 51.30, 54.90 and 51.27 and 52.20 and 48.00 mg%, and for lactic acid (gm%) 7.63 and 8.20, 6.98 and 7.75 and 5.67 and 7.40 gm%, respectively.

The overall mean for draft generated by Khillar bullocks during sowing was 70.66 kg. The draft generated in Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar were 73.52, 79.07 and 59.40 kg, respectively. The means for draft generated during sowing by Khillar bullocks during summer, rainy and winter were 69.93, 73.85 and 68.21 kg. The corresponding values for draft generated during forenoon and afternoon were 72.00 and 69.33 kg, respectively. Significant ($P < 0.01$) effect on draft were observed in type, season and time during sowing.

Average speed of Khillar bullocks during sowing was 3.57 km/hr. The means for speed during sowing were observed as 3.57, 3.69 and 3.43 km/hr in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar. The corresponding values for speed during sowing by Khillar bullocks during summer, rainy and winter were 3.46, 3.57 and 3.66 km/hr and during forenoon and afternoon were 3.60 and 3.54 km/hr. The significant ($P < 0.01$) variations in speed were observed at different type, seasons and time.

The average hp developed by Khillar bullocks was 0.94 hp. The mean for horse power during sowing were 0.97, 1.08 and 0.75 in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar. The means for horse power during sowing by Khillar bullocks during summer, rainy and winter were 0.89, 0.98 and 0.93. The corresponding values for horse power during forenoon and afternoon were 0.96 and 0.91, respectively. The hp generated was significant ($P < 0.01$) effect on type, season and time were observed during sowing.

The overall mean for area covered by Khillar bullocks during sowing was 1099.77 m²/hr. The area covered by Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3)

Khillar during sowing were 1105.77, 1144.87 and 1048.66 m²/hr, respectively. The means for area covered during sowing by Khillar bullocks during summer, rainy and winter were 1079.47, 1099.15 and 1120.68 m²/hr. The corresponding values for area covered during forenoon and afternoon were 1102.15 and 1097.38 m²/hr, respectively. The area covered was significantly ($P < 0.01$) effect to type, season and time during sowing.

5.3. 3. Harrowing

Average for RR in Khillar bullocks was 38.15 beats/min. The means for respiration rates were observed as 38.39, 34.78 and 41.13 beats/min in the case of Pandharpuri (T₁), Kosa (T₂) and Tapi (T₃) Khillar. The corresponding values for RR during summer, rainy and winter season were 41.04, 40.06 and 33.19 beats/min. The means for RR during forenoon and afternoon were 36.77 and 39.43 beats/min. The RR during before work, after 1st, 2nd hour and after 3rd hour during harrowing were 22.18, 36.54, 43.74 and 49.94 beats/min, respectively. The significant ($P < 0.05$) variation in respiration rate was observed in type, season, time and interval during harrowing.

The average BT in Khillar bullocks was 101.49 °F. The body temperature were observed as 101.58, 101.05 and 101.75 °F in the case of Pandharpuri (T₁), Kosa (T₂) and Tapi (T₃) Khillar. The average BT during different seasons were 102.25, 101.22 and 100.91 °F in summer, rainy and winter season, respectively. The corresponding values for BT during forenoon and afternoon were 101.28 and 101.63 °F. The means for BT in Khillar bullocks before work, after 1st, 2nd hour and after 3rd hour harrowing were 100.32, 101.33, 101.89 and 102.30 °F, respectively. The variations in BT were significant ($P < 0.05$) attributed to the different types, season, time and interval during harrowing.

The overall mean for PR in Khillar bullocks was 72.70 beats/min. The pulse rates were observed as 73.24, 67.97 and 75.18 beats/min in the case of Pandharpuri (T₁), Kosa (T₂) and Tapi (T₃) Khillar, respectively. The means for PR during different seasons were 74.32, 71.04 and 71.03 beats/min in summer, rainy

and winter season, respectively. The corresponding values for PR during forenoon and afternoon were 70.37 and 73.89. The means for PR in Khillar bullocks before work, after 1st, 2nd hour and after harrowing were 59.09, 72.39, 76.44 and 80.59. The significant ($P < 0.05$) variations in PR were observed at different type, season, time and intervals of working.

The mean for haemoglobin content in the blood of Pandharpuri, Kosa and Tapi Khillar before and after harrowing were 10.56 and 9.03, 10.55 and 9.83 and 11.03 and 10.52 gm%, respectively. The corresponding values for glucose content were 56.95 and 49.71, 54.90 and 51.16 and 54.08 and 46.69 mg%, and for lactic acid 7.74 and 8.66, 7.00 and 7.80 and 5.87 and 8.33 gm%, respectively.

The means draft generated by Khillar bullocks during harrowing was 59.57 kg. The draft generated in Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar were 61.04, 69.30 and 48.37 kg, respectively. The means for draft generated during harrowing by Khillar bullocks during summer, rainy and winter were 59.35, 62.97 and 56.38 kg. The corresponding values for draft during forenoon and afternoon were 61.37 and 57.77 kg, respectively. Significant ($P < 0.01$) effect on draft were observed in type, season and time during harrowing.

Average speed of Khillar bullocks during harrowing was 3.58 km/hr. The speed observed during harrowing were 3.56, 3.69 and 3.49 km/hr in Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar. The corresponding values for speed during harrowing by Khillar bullocks during summer, rainy and winter were 3.46, 3.58 and 3.70 km/hr, and during forenoon and afternoon were 3.62 and 3.55 km/hr, respectively. The significant ($P < 0.01$) variations in speed were observed in different type, seasons and time.

The overall mean for hp developed by Khillar bullocks were 0.79 hp. The means for horse power were 0.80, 0.95 and 0.62 in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar. The means for horse power generated during harrowing by Khillar bullocks in summer, rainy and winter were 0.76, 0.84 and 0.78, respectively. The corresponding values for horse power generated during

forenoon and afternoon were 0.82 and 0.76, respectively. The significant ($P < 0.01$) variations in hp were observed in type, season and time during harrowing.

The average area covered by Khillar bullocks during harrowing was 1192.41 m²/hr. The area covered by Pandharpuri (T₁), Kosa (T₂) and Tapi (T₃) Khillar were 1198.69, 1237.37 and 1141.16 m²/hr, respectively. The means for area covered during harrowing by Khillar bullocks during summer, rainy and winter were 1172.38, 1191.65 and 1213.18. The corresponding values for area covered during forenoon and afternoon were 1197.15 and 1187.66, respectively. The area covered was significantly ($P < 0.01$) attributed to type, season and time during harrowing.

5.3.4. Hoeing

Average means for RR in Khillar bullocks was 37.66 beats/min. The means for respiration rate were observed as 37.44, 34.77 and 40.76 in the case of Pandharpuri (T₁), Kosa (T₂) and Tapi (T₃) Khillar. The corresponding values for RR during summer, rainy and winter season were 40.13, 39.81 and 33.02 beats/min. The means for RR during forenoon and afternoon were 36.29 and 39.02. The means for RR during before work, after 1st, 2nd hour and after 3rd hour during hoeing were 22.29, 36.25, 43.08 and 49.00, respectively. The significant ($P < 0.05$) variation in respiration rate was observed in type, season, time and interval during hoeing.

The average for BT in Khillar bullocks was 101.25 °F. The body temperature were observed as 101.47, 100.59 and 101.81 °F in the case of Pandharpuri (T₁), Kosa (T₂) and Tapi (T₃) Khillar. The means for BT during different seasons were 101.86, 101.34 and 100.68 °F in summer, rainy and winter season, respectively. The corresponding values for BT during forenoon and afternoon were 101.12 and 101.47 °F. The means for BT in Khillar bullocks before work, after 1st, 2nd hour and after 3rd hour hoeing were 100.11, 101.18, 101.72 and

102.15 °F, respectively. The variations in BT were significant ($P < 0.05$) attributed to the different types, season, time and interval during hoeing.

The overall mean for PR in Khillar bullocks was 69.89 beats/min. The means for pulse rates were observed to be 71.77, 64.89 and 73.09 beats/min in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar, respectively. The means for PR during different seasons were 72.96, 70.76 and 66.04 beats/min in summer, rainy and winter season, respectively. The corresponding values for PR during forenoon and afternoon were 68.37 and 71.46 beats/min. The means for PR in Khillar bullocks before work, after 1st, 2nd hour and after hoeing were 58.35, 69.86, 73.71 and 77.76 beats/min, respectively. The significant ($P < 0.05$) variations in PR were observed at different type, season, time and intervals of working.

The means for haemoglobin content in the blood of Pandharpuri, Kosa and Tapi Khillar before and after hoeing were 10.58 and 9.92, 10.71 and 10.05 and 11.05 and 10.58 gm%, respectively. The corresponding values for glucose content were 56.88 and 52.17, 54.90 and 52.18 and 52.70 and 48.06 mg% and for lactic acid 7.63 and 8.07, 6.97 and 7.62 and 5.69 and 7.52 gm%, respectively.

The average draft generated by Khillar bullocks during hoeing was 42.34 kg. The draft generated in Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar were 41.38, 48.00 and 37.25 kg, respectively. The means for draft generated during hoeing by Khillar bullocks during summer, rainy and winter were 41.60, 46.17 and 39.25 kg. The corresponding values for draft generated during forenoon and afternoon were 43.34 and 41.35 kg, respectively. Significant ($P < 0.01$) effect on draft were observed in type, season and time during hoeing.

Average speed of Khillar bullocks during hoeing was 3.77 km/hr. The speed observed during hoeing were 3.79, 3.91 and 3.63 km/hr in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar, respectively. The corresponding values for speed during hoeing by Khillar bullocks in summer, rainy and winter were 3.67, 3.79 and 3.86 km/hr, and during forenoon and afternoon were 3.82 and

3.74 km/hr, respectively. The significant ($P < 0.01$) variations in speed were observed at different type, seasons and time.

The average hp developed by Khillar bullocks was 0.60 hp. The horse power observed during hoeing were 0.58, 0.71 and 0.50 in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar. The means for horse power during hoeing by Khillar bullocks during summer, rainy and winter were 0.56, 0.65 and 0.57. The corresponding values for horse power during forenoon and afternoon were 0.62 and 0.57, respectively. The hp was significantly ($P < 0.01$) attributed to the type, season and time were observed during hoeing.

The overall mean for area covered by Khillar bullocks during hoeing was 1242.40 m²/hr. The area covered by Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar during hoeing were 1248.69, 1287.37 and 1191.16 m²/hr, respectively. The means for area covered during hoeing by Khillar bullocks during summer, rainy and winter were 1222.38, 1241.65 and 1263.18. The corresponding values for area covered during forenoon and afternoon were 1247.15 and 1237.66, respectively. The area covered was significantly ($P < 0.05$) attributed to the type, season and time during hoeing.

5.3.5. Carting

The overall mean for respiration rate in Khillar bullocks was 37.22 beats/min after carting. The respiration rates were observed as 39.28, 33.37 and 39.48 beats/min in the case of Pandharpuri (T_1), Kosa (T_2) and Tapi (T_3) Khillar, respectively. The means for respiration rate during summer, rainy and winter were 39.90, 38.80 and 33.43 beats/min. The corresponding values for respiration rate in Khillar bullocks before and after carting were 22.29 and 52.47 beats/min. The means for 5 km (K_1), 10 km (K_2) and 15 km (K_3) were 34.37, 37.42 and 40.35 beats/min, respectively. The significant ($P < 0.05$) variations in RR were observed at different type, season and distance after carting.

The overall mean for body temperature in Khillar bullocks was 101.18 °F after carting. The average body temperatures were observed to be 101.34, 100.77 and 101.48 °F in the case of Pandharpuri (T₁), Kosa (T₂) and Tapi (T₃) Khillar, respectively. The means for body temperature during summer, rainy and winter season were 101.60, 101.16 and 100.83 °F. The corresponding values for body temperature in Khillar bullocks before work, and after carting were 100.34 and 102.06 °F. The means BT for a distance 5 km (K₁), 10 km (K₂) and 15 km (K₃) were 100.83, 101.26 and 101.51, respectively. The significant (P < 0.05) variations in BT were observed at different type, season and distance.

The overall mean for pulse rate in Khillar bullocks was 67.84 beats/min. The pulse rates were observed to be 67.72, 62.28 and 70.72 beats/min in the case of Pandharpuri (T₁), Kosa (T₂) and Tapi (T₃) Khillar. The means for pulse rate during summer, rainy and winter were 70.51, 66.79 and 66.42 beats/min. The corresponding values for pulse rate in Khillar bullocks before and after carting were 57.00 and 78.81. The means for pulse rate during 5 km (K₁), 10 km (K₂) and 15 km (K₃) were 65.72, 68.12 and 69.87 beats/min, respectively. The significant (P < 0.05) variations in PR were observed at different type, season and distance of carting.

The mean for haemoglobin content in the blood of Pandharpuri, Kosa and Tapi Khillar before and after carting were 10.57 and 9.72, 10.58 and 9.55 and 11.07 and 10.12 gm%, respectively. The corresponding values for glucose content were 56.95 and 49.82, 54.90 and 51.02 and 53.77 and 48.64 mg%, and for lactic acid (gm%) 7.73 and 8.60, 7.00 and 8.90 and 5.76 and 7.62 gm%, respectively.

Average speed of Khillar bullocks during carting was 4.19 km/hr. The means for speed were observed as 4.07, 4.67 and 3.85 km/hr in the case of Pandharpuri (T₁), Kosa (T₂) and Tapi (T₃) Khillar. The means for speed during carting by Khillar bullocks during summer, rainy and winter were 4.04, 4.14 and 4.40 km/hr. The corresponding values for speed during 5 km, 10 km and 15 km were 4.36, 4.19 and 4.04 km/hr. The significant (P < 0.05) variations in speed were observed at different type, season and distance.

B. CONCLUSIONS

- The variations in respiration rate, body temperature and pulse rate during different agricultural operations viz., ploughing, sowing, harrowing and hoeing in Khillar bullocks were significantly influenced due to type, season, time and interval. However, Kosa Khillar showed proportionately less variation in all physiological indices as compared to Pandharpuri and Tapi Khillar. Similarly respiration rate, body temperature and pulse rate were higher during summer, in the afternoon and after 3 hrs of work in Khillar bullocks. Among the different agricultural operations the physiological responses were highest during ploughing and lowest during hoeing.
- The significant decreasing trend in haemoglobin and blood glucose level during different agricultural operations viz., ploughing, sowing, harrowing and hoeing were observed in Khillar bullocks after work as compared to before work. Among the different agricultural operations the decline in haemoglobin and blood glucose was higher during ploughing and lowest during hoeing. Whereas, the production of lactic acid was contrary to above haematological parameters.
- Among the different agricultural operations the highest draft and hp was produced during ploughing. Whereas, lowest draft and hp was produced during hoeing. However, the speed and area covered by Khillar bullocks were lowest in ploughing and highest in hoeing.
- During carting operation the season significantly influenced the physiological indices, haematological parameters and speed of Khillar bullocks. The higher RR, BT and PR were observed during summer and lower level during winter in Khillar bullocks. However, the haemoglobin, blood glucose level and speed of Khillar bullocks significantly decreased during summer. The highest speed during carting operation was observed

during winter season. The level of lactic acid in blood after carting operation was highest in Khillar bullocks.

- The time required to reach the fatigue stage in Kosa Khillar was significantly higher. Whereas, it was significantly lower in Tapi Khillar indicating the adaptability of Kosa Khillar in scarcity zones of Maharashtra.

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8.VITA

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