Chapter 3:
General Materials and Methods

3.1 General

Procedures followed and materials used in the work reported in this thesis were common to several of the individual experiments, and in order to avoid repetition these will be described in detail here. Some of the methods used also required experimental development and verification, and these details will also be reported in this part. Most sections in this chapter apply to both the field and laboratory work undertaken. In the field, dry (DB) and wet (WB) bulb temperatures, and maximum and minimum temperatures were recorded from mercury in glass thermometers at animal height and in the sun at the times shown in Tables 1, 5, 8 and 11.

3.2 Rectal Temperature (RT)

Field work: RT was used as a measure of "core" or "deep body" temperature, and was routinely measured using a clinical thermometer inserted 10 cm for 1 minute. At regular intervals the accuracy of the various thermometers was checked by callibration against a standard mercury-in-glass thermometer in stirred water.

Laboratory work: RTs were continously monitored at 10-sec intervals by thermocouples and a multi-channel potentiometric recorder. Each copper-constantan (38 S.W.G.) thermocouple was mounted on a 12 cm long plastic probe and inserted 10 cm into the rectum (Fig. 4).

3.3 Respiration Rate (RR)

Field work: RR was measured by counting flank movements for 1 minute using a stop watch (TM-104 model).

Laboratory work: RRs were measured by pneumograph-belt, tambour and chart recorder (Plate 1). A typical chart recording is shown in Plate 2.

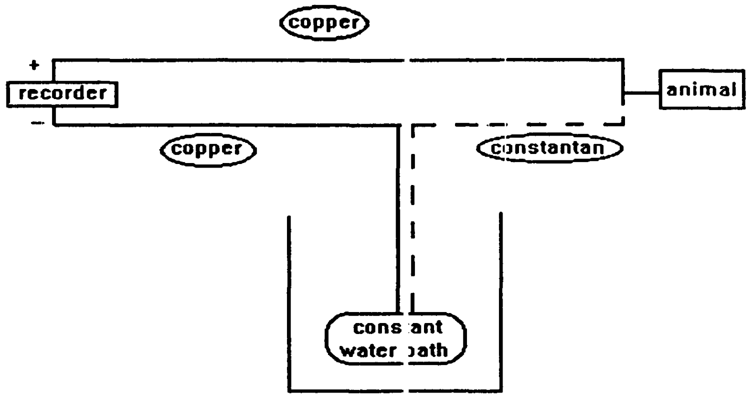


Fig. 4 Typical thermocouple circuit for measuring RT and ST in goats in the climate laboratory (—— copper; ------ constantan wire)

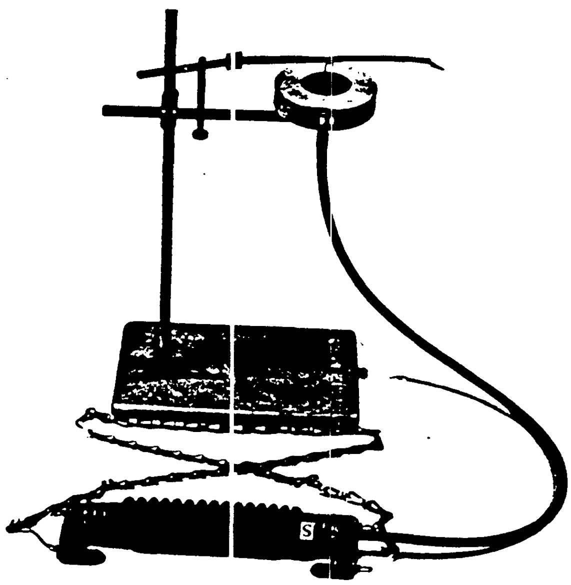


Plate 1: Apparatus for measuring RR in goats in the climate laboratory: A pneumograph-belt (S) and recording tambour (T)

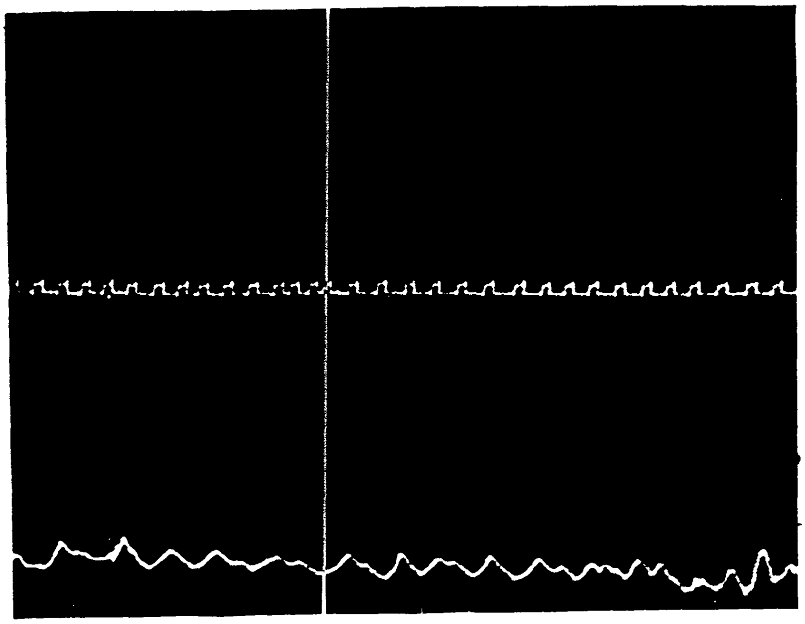


Plate 2: Papergraph record of the RR of a goat in the climate laboratory

3.4 Skin Temperature (ST)

Field work: During field work STs were routinely measured using a thermistor thermometer with digital read-out ("Digi-Thermo") and a 20 cm-long probe of 0.3 cm external diameter. The end of the probe (the location of the thermistor) was pressed lightly against the skin until a steady reading was achieved (approx. 1 minute).

Laboratory work: STs while walking in the climate room were continously measured in three different positions (rump, loin and ear), using 38 S.W.G. copper-constantan thermocouples and a multi-channel potentiometric recorder (see section 3.1). At regular intervals the accuracy of the thermocouples were checked by callibration against a standard mercury-in-glass thermometer in a thermostatically controlled and constantly stirred water bath (TE-7 TEMPETTE). Test junctions were attached by using polyethylene plastic tape and positioned transversally to the skin.

3.5 Packed Cell Volume (PCV) and Haemoglobin (Hb)

Blood was obtained from the jugular vein and collected into tubes containing lithium heparin. The PCV and Hb concentrations were measured by standard laboratory procedures (JAIN, 1986) as follows:

3.5.1 *PCV:*

1. Two capillary tubes (duplicates) were filled with anticoagulant-treated blood to within 2 cm of one end. The tube was wiped clean with a tissue and sealed with 'Cristaseal'.

2. The tubes were placed in a Micro Haematocrit Centrifuge ("HAWKSLEY, ENGLAND"), with the sealed ends toward the periphery. Tubes were centrifuged for 6 minutes at 5000 rpm.

3. PCV was read in a Microhaematocrit Reader.

3.5.2 *Hb:*

1. 5 mL of Drabkin's reagent was placed in each of the required tubes (two per sample plus one blank).

2. 0.02 mL of blood was placed in each of the duplicate test tubes, using an automatic disposable pipette.

3. The contents of the tubes were throughly mixed and allowed to stand for 10 minutes.

4. The absorbance was read on a spectrophotometer at 540 nm against the blank.

3.6 Sweating Rate (SR)

SR was measured in three different locations (rump, loin and ear) using the dessicating capsule method (BROOK and SHORT, 1960). The capsules used were 7 cm in diameter and 5 cm in depth and contained 80 g of silica gel which was regenerated for 12 h at 80°C after every second SR estimate. The capsule was attached to the skin for 3 minutes on a 10x10 cm clipped patch and all figures were extrapolated to $g/m^2/h$. The capsules were weighed before and after use to 3 decimal points on a digital electronic balance, and when not in use were stored in a desiccator.

3.7 Respiratory Moisture Loss (RML)

RML from sampled air (2% of the total air flow) was measured in the laboratory only by using an open circuit nose mask with sampling tubes connected to acid catches and gas meters (Fig. 5). Sufficient 98% sulfuric acid (15 ml) was placed in each acid catch, and weighing was done before and after each test period to 3 decimal points on a digital electronic balance. All results were then corrected for temperature and time irregularities (if any) and extrapolated to mg/min. The air flow through the system are 90 litre/minute.

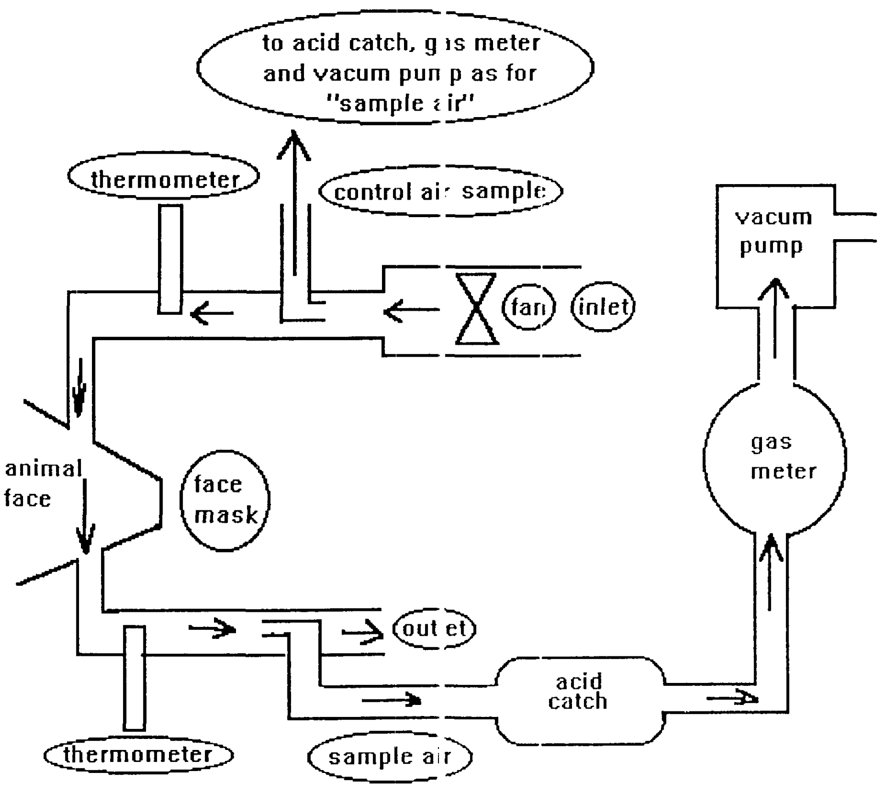


Fig. 5 Diagram of the circuit used to measure the RML of goats in the climate laboratory

3.8 Live Weight (LW)

a. *Field:* All cattle and buffalo were weighed by using "Salter" clockface mechanical scales with a capacity of 0 to 2000 kg by 1 kg accuracy.

b. *Laboratory:* Goats were weighed by using "Salter" clockface mechanical scales with a capacity of 0 to 150 kg by 500 g. accuracy.

3.9 Condition Score (CS)

CS of the goats, cattle and buffalo (JEFFERIES, 1966) and (ANON, 1983) were estimated as follows:

CS.1: Very lean:

Body angular, narrow and slab sided.

Backbone raised and sharp.

Ends of short ribs sharp and easily felt.

CS.2: Lean:

Backbone raised and barely covered.

Pin and hip bones obvious and barely covered.

Ends of short ribs smooth but easily felt.

CS.3: Medium:

Backbone slightly raised, smooth and rounded over top.

Pin and hip bones lightly covered.

Ends of short ribs smooth but can still be felt.

Moderately rounded appearance.

CS.4: Fat:

Smooth rounded appearance.

Backbone can only just be felt.

Pin and hip bones smooth and rounded.

Ends of short ribs cannot be felt.

3.10 Animal work

A treadmill (200 cm long x 75 cm wide x 150 cm high) with a strong metal cage mounted above it was located in a hot room and its speed varied in different experiments from 3 to 3.8 km/h. The treadmill had a similar basic principle of operation to that described by ANDERSON *et al.* (19'7). During the field experiments farmers used single-furrow mouldboard-type ploughs ("tenggala") pulled by Bali-cattle and buffalo.

3.11 Climate Conditions Experienced

Field work: When not being used for experimentation the pairs of animals were housed in small, traditional huts (5 m long x 5 m wide x 2.5 m high), each of which was made of bamboo, had a thatched roof of coconut leaves, and was surrrounded by a hedge. Temperatures inside the huts varied from 15-20°C and RH from 70 to 80%.

Laboratory work:

a. *Control room:* When not being used for observations, all goats were individually housed in pens (185 cm x 125 cm x 100 cm) in an adjacent control room which was air-conditioned at 20 ± 1°C; 45 ± 2% RH and 0.20 m/sec air movement.

b. *Hot room:* The hot room was thermostatically controlled and air conditioned at the temperature relevant to each experiment. One full day was allowed for the hot room to equilibrate after each change of temperature.

3.12 Feed and Feeding

a. *Field work:* The buffalo and cattle were fed *ad - libitum.* In Bali botanical composition of forage fed to cattle consists of 62% grass, 26% tree leaves, 7% straw and 5% other broad leaf species; for the buffalo it containts 16% more grass, but 85% less tree leaves and 75% less straw (NITIS, 1985). Chemical compositions of the local native grass were shown in Table 1 (NITIS *et al.*, 1985).

b. *Laboratory work:* All goats were fed a pelleted ration (75% lucerne chaff; 24.5% cracked grain; 0.5% mineral premix) and water was available *ad-libitum.*

3.13 Animals/Exercise

Field work: All buffalo and cattle used were experienced working animals, and thus training was undertaken for only 2 days before each experiment. For 2 hours/d each pair was accustomed to walking and stopping for measurements of RR, RT and ST to be taken at 30 minute intervals. The animals were also accustomed to the blood sampling after some trainings (jugular venepuncture) which was to be done before and after exercise.

Table 1: Names and chemical compositions (% DM) of the species of roughages fed to the buffalo and cattle used in the field trials on Bali

Biological name	Ca	P	K	Na	Mg	Cl
Axonopus compressus	0.41	0.42	1.85	0.010	0.43	0.05
Bothriochloa	0.29	0.48	2.05	0.015	0.35	0.65
Cynodon	0.30	0.35	2.33	0.016	0.10	0.69
Cyperus	0.30	0.47	3.22	0.061	0.32	0.95
Digitaria ciliaris	0.24	0.95	3.31	0.017	0.22	0.38
Digitaria	0.22	0.56	3.05	0.014	0.31	0.36
Eleusine	0.70	0.37	2.71	0.010	0.22	0.50
Imperata	0.10	0.29	2.60	0.012	0.17	0.38
Isachne	0.26	0.50	2.59	0.025	0.30	0.84
Leersia	0.25	0.28	2.56	0.026	0.20	0.65
Oplismenus	0.47	0.36	3.14	0.033	0.41	1.31
Panicum	0.27	0.43	2.37	0.045	0.20	0.63
Polytrias	0.40	0.47	2.06	0.021	0.18	0.38
Themeda	0.22	0.32	1.96	0.005	0.11	0.20

After NITIS *et al.* (1985)

Laboratory work: Initially, the goats were habituated to handling or walking on the treadmill. Firstly, they were trained to handling, the use of a halter, and the experimental area (about 2 weeks). Then, for about 3 weeks they were introduced to walking on the treadmill for a total of about 2 hours/day/animal (1 hour in the morning and another 1 hour in the afternoon). Any animal showing signs of distress was rested untill the next day. In a separate training schedule, tl e goats were habituated to wear a face mask while walking on the treadmill. This t ok about 1 week and a similar time of 2 hours/day/animal with an allocation o 1 hour in the morning and 1 hour in the afternoon was followed. For each experiment the animals were retrained by walking on the treadmill for 1 hour/animal (30 minutes in the morning and another 30 minutes in the afternoon) for just 1 day.

3.14 Statistical Analysis

The major statistical procedur used was analysis of variance. Analyses were generally carried out according to the statistical procedures of STEEL and TORRIE (1980) for analysis of data incorporati ig repeated measures, using the "BMDP" (DIXON *et al.*, 1983) statistical package availa le to t e author on the METZ computer system at the University of New England. Th details of the analyses will be described in the experimental chapters. The error bars on each graphs are standard error of means (SEMs).

3.15 Experimental Animals

Field work: During field work cattle and buffalo were originated from Bali and hired from local farmers. While working period such animals were controlled by the owner for operation.

Laboratory work: Goats in thr e different breed of Saanen, Toggenburg and Saanen were available at the Animal House complex, University of New England, Armidale.

Chapter 4:

The Effects of Season (hot/dry and cool/humid) on Physiological Responses of Cattle and Buffalo Working in the Field in Bali

4.1 Experiment 1: Male and Female Bali Cattle

4.1.1 Introduction

Male and female Bali cattle are used for ploughing in Bali in both irrigation paddy fields and dryland areas during both major climatic seasons, the hot/dry (March - September) and the cool/humid (or "rainy"; October untill February). Temperatures (DB) during the hot/dry are the highest, by 5-10°C, but relative humidity in that season is 20-25% less (at about 70%) than during the cool/humid one.

In European cattle, MURRAY and YEATES (1967) reported that heifers were more heat tolerant than bulls when walked at either 2.7 or 4.3 km/h under hot, sunny, subhumid conditions in Australia. As yet no experiments have been reported in the literature, on the comparative heat tolerance of male and female Bali cattle working in the field.

This experiment was thus undertaken on mature *Bos javanicus* or "Bali-cattle" in the superhumid zone of Bali (Indonesia). Performance was monitored outdoors under uncontrolled temperature conditions, using animals of the same age and body condition score, but differing in body weight, during normal ploughing operations on farms.

4.1.2 Materials and Methods

Three pairs each of entire male (bull) and female (cow) Bali cattle, with body weights of 333.3 ± 62.4 and 270.0 ± 14.1 kg respectively and similar body condition scores of 3.0 (JEFFERIES, 1966) were employed.

The experiment was done at Sangsit village about 80 km from Denpasar (the capital city), on the northern part of Bali island, and 5 - 10 m above sea level. Three tenant farmers were actively involved and the animals were fed *ad libitum* with native grass

(NITIS, 1985). Experiments were carried-out in January and August during the cool/humid and hot/dry seasons respectively, with 2 replicates in each season, 3 days work for each replicate and 3 days off between the 2 replicates. Observations were made at 30 minute intervals during 2.5 h of work and during a subsequent 1 h recovery period. The "normal" experimental day started at 07.00 in the morning and finished by 11.00 h, and corresponded to the usual time when ploughing is undertaken locally.

A 2x2x6x8 factorial design (2 seasons, 2 sexes, 6 days of exercise with 1 day resting in between and 8 consecutive times of measurement every 30 minutes) was used.

4.1.3 Results

DB temperatures during the cool/humid and hot/dry seasons varied from 24.5 to 34.5°C and 20 to 43°C respectively, RH from 60 to 98% and 70 to 85% respectively. Details of the climate situation can be seen in Table 2.

Respiration rate (RR):

Mean RR differed significantly between seasons ($P < 0.01$), sexes ($P < 0.05$), days ($P < 0.01$) and times ($P < 0.001$) during exercise and recovery (Table 3). There were no significant interactions. Responses were lower during the cool/humid season (52 vs 75/min), and in females (61 vs 66/min). On day 1, RR was lower (by 14/min) than on day 2, and then remained steady before showing progressive declines on days 5 and 6. With increasing time during work, gradual increases in RR were recorded (the overall increase was 84/min; $P <0.001$). After work, during the first and second 30 minute intervals of the recovery period, significant and progressive reductions in RR occured, and 1 h after work values remained significantly elevated above pre-work levels (Table 3).

Rectal temperature (RT):

RT differed significantly between seasons ($P < 0.01$), sexes ($P < 0.01$), days ($P < 0.01$) and times ($P < 0.001$) during exercise and recovery, and no significant interactions were recorded. During the cool/humid season RT was lower than in the hot/dry (39.1 vs 39.5°C), and females had a lower mean RT (39.2°C) than males (39.4°C). On day 1, RT

Table 2: Environmental temperatures during field trials with Bali-cattle at Sangsit village, Bali, Indonesia in the cool/humid and hot/dry seasons

		A. Cool/humid season :				B. Hot/dry season :			
		D.B. (°C)	W.B. (°C)	max. (°C)	min. (°C)	D.B. (°C)	W.B. (°C)	max. (°C)	min. (°C)
day 1:	7.00	28.5	26.5			21.0	20.0		
	9.00	29.5	27.0			32.0	24.0		
	11.00	33.5	29.5	35.0	25.5	39.5	30.0	37.0	22.0
day 2:	7.00	26.5	25.5			20.0	19.0		
	9.00	32.5	29.0			29.0	25.0		
	11.00	34.5	30.5	39.5	24.0	37.0	29.0	37.0	22.0
day 3:	7.00	25.0	24.0			21.0	19.0		
	9.00	30.5	28.5			32.0	27.0		
	11.00	32.5	29.0	35.0	25.0	36.0	28.0	32.0	22.0
day 4:	7.00	25.0	24.0			22.0	20.0		
	9.00	27.0	26.5			32.0	26.0		
	11.00	27.5	27.0	29.0	24.5	42.0	32.0	42.0	19.0
day 5:	7.00	24.5	24.0			21.0	19.0		
	9.00	26.5	26.0			31.0	27.0		
	11.00	31.5	29.5	32.5	24.0	43.0	33.0	43.0	20.0
day 6:	7.00	27.0	26.0			22.0	21.0		
	9.00	28.5	27.0			37.0	30.0		
	11.00	31.0	28.5	34.0	27.0	43.0	32.0	41.0	21.0
mean:	7.00	26.1	25.0			21.2	19.7		
	9.00	29.1	27.3			32.2	26.5		
	11.00	31.8	29.0	39.5	24.0	40.1	30.4	43.0	19.0

was lower by 0.1°C than on day 2, and then followed a gradual decline (Table 3). With time during work, gradual increases in RT were recorded (the overall increase was 1.9°C; P <0.001). After the first and second 30-minute intervals of the recovery period, significant reductions occured in RT, but the final value recorded (39.2°C) remained significantly above the pre-work level (38.3°C).

Table 3: Mean respiration rates (RR/min) and rectal temperatures (RT °C) of male and female Bali-cattle working in the field during the cool/humid and hot/dry seasons

Season:	Cool/humid	Hot/dry	SEM	Level of significance
RR:	52a	75b	0.040	**
RT:	39.1a	39.5b	0.002	**

Sex:	male	female	SEM	Level of significance
RR:	66a	61b	0.040	*
RT:	39.4a	39.2b	0.002	**

Day :	D1	D2	D3	D4	D5	D6	SEM	Level of significance
RR:	54a	68b	68b	69b	62c	60c	0.100	**
RT:	39.4a	39.5b	39.4a	39.[illegible]c	39.1d	39.1d	0.005	**

Time: (hours)	0	0.5	1	1.5	2	2.5	recovery: 0.5	recovery: 1	SEM	Level of significance
RR:	18a	38b	58c	77d	90e	102f	77d	48g	0.200	***
RT:	38.3a	38.7b	39.0c	39.[illegible]d	39.9e	40.2f	39.6[illegible]	39.2[illegible]	0.006	***

Values within lines with dissimilar superscripts differ significantly (***P < 0.001, **P < 0.01 and *P < 0.05)

Skin temperature (ST):

For ST there were significant effects associated with both the day x sex (P <0.01) and sex x time (P < 0.05) interactions, but the trends in the two sexes were very similar (Fig. 6). Over days, males had significantly higher ST than females except for days 2 and 5. With increasing time during the working period, gradual increases in ST were recorded, males had significantly higher values than females, at all intervals after 0.5 h exercise. After work, during the first and second 30-minute intervals of the recovery period, significant and progressive reductions occured, but 1 h after work ST remained significantly elevated above pre-work levels. ST differed significantly between seasons (P < 0.01); values in the cool/humid season were lower than in the hot/dry (37.1 vs 37.6°C).

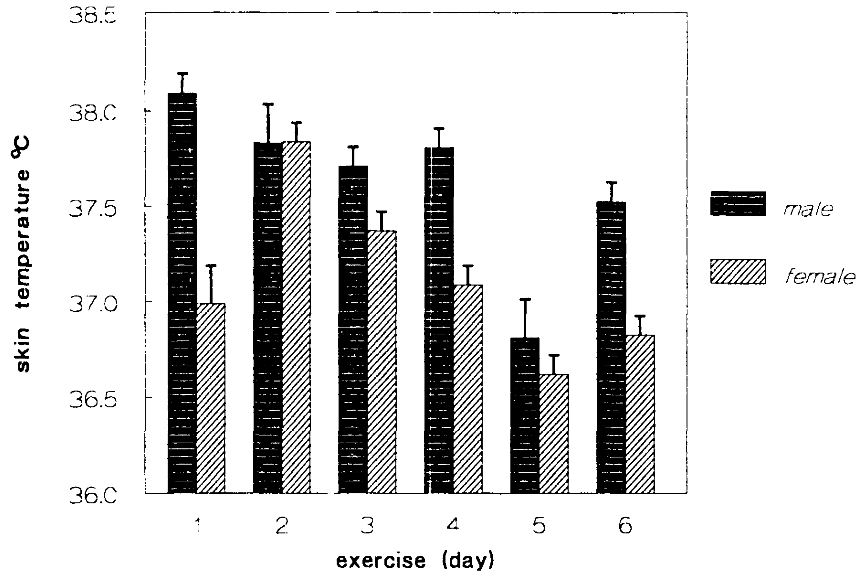
Packed Cell Volume (PCV):

PCV data are presented in Table 4, which indicates significant differences between sexes, times and seasons (P < 0.05). For example, during the 2.5-hour working period the PCV decreased from 27.4 to 25.6 %.

Table 4: Mean PCV (%) of male and female Bali-cattle working in the field during the cool/humid and hot/dry seasons

	PCV (%)		SEM	Level of significance
sex (male and female)	28.2a	24.7b	0.6	*
time (0 and 2.5 h)	27.4a	25.6b	0.6	*
season (cool/humid and hot/dry)	21.6a	31.3b	0.6	*

Values within lines with dissimilar superscripts differ significantly (*P < 0.05)



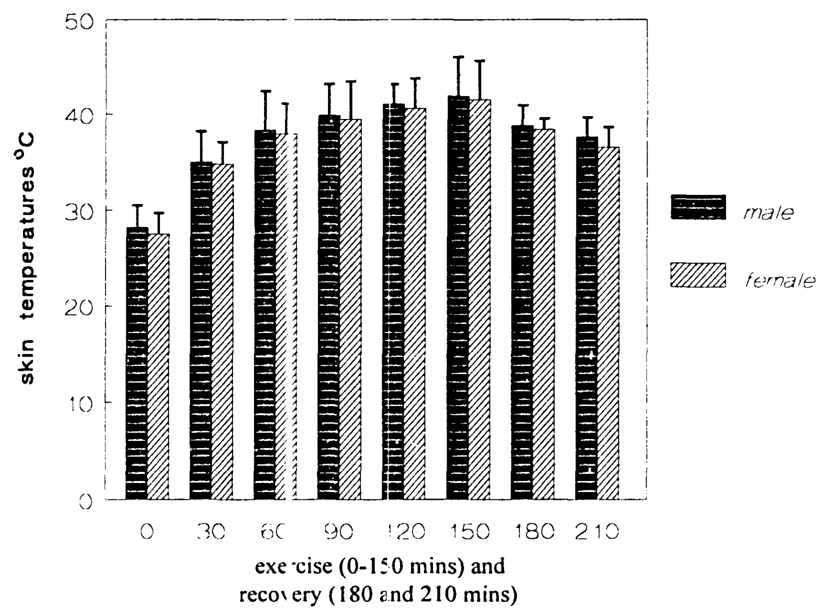


Fig. 6 Mean ST of male and female Bali-cattle working for 150 minutes in the field on Bali during the cool/humid and hot/dry seasons, and during a subsequent 60 minute recovery period

4.2 Experiment 2: Male and Female Black Swamp Buffalo

4.2.1 Introduction

Swamp buffalo are used for DAP in Bali by about 25% of farmers as an alternative to Bali-cattle. Several experiments have been carried-out on swamp buffalo in Indonesia but none relating to the thermoregulation of male and female animals. Other experiments have examined the effects of body weight on responses during exercise. For example, PEARSON (1989) reported that when buffaloes carted loads for 6 h/d (and for distances of 16 to 17 km) at environmental temperatures of 24 to 37°C, RT in both small (237 to 320 kg) and large (401 to 464 kg) individuals increased by about 3.5°C to 41.5 and 42°C respectively. The only relevant literature on sex differences relates to cattle (MURRAY and YEATES, 1967): when the hair coats were clipped and the animals walked at 4.3 km/h, bulls displayed the greatest increase in RT of 1.9°C (from 38.7 to 40.6°C), followed by heifers and steers with increases of 1.4 and 1.2°C respectively after 4 hours.

The current experiment was undertaken with mature male (bull) and female swamp buffalo, working in the rice fields in Bali in both the rainy and hot seasons.

4.2.2 Materials and Methods

Three pairs each of male and female swamp buffalo were used, their mean body weights being 375.0 ± 20.4 and 346.7 ± 16.5 kg respectively. All were in condition score 3.5. Mean daily environmental temperatures during the cool/humid and hot/dry seasons at 07.00, 09.00 and 11.00 were 26.1, 29.[illegible] and 31.8; and 22.4, 32.3 and 33.6°C respectively. Full details of daily temperature variations are presented in Table 5.

A 2x2x6x8 factorial design was employed, the factors being 2 seasons (cool/humid and hot/dry), 2 sexes, 6 consecutive days with 1 day resting in between and 8 measurements per day at 30 minute intervals.

4.2.3 Results

DB temperature during the cool/humid and hot/dry seasons varied from 24.5 to 34.5°C and from 21 to 35°C respectively; RH from 60 to 95% and 65 to 85% respectively (Table 5).

Table 5: Environmental temperatures during field trials with Swamp Buffalo at Sinabun village, Bali, Indonesia in the cool/humid and hot/dry seasons

		A. Cool/humid season:				B. Hot/dry season:			
		D.B. (°C)	W.B. (°C)	max. (°C)	min. (°C)	D.B. (°C)	W.B. (°C)	max (°C)	min (°C)
Day 1:	7.00	28.5	26.5			25.0	22.0		
	9.00	29.5	27.0			34.0	26.0		
	11.00	33.5	29.5	35.0	[illegible]	35.0	27.0	37.0	21.0
Day 2:	7.00	26.5	25.5			22.0	19.0		
	9.00	32.5	29.0			32.0	25.0		
	11.00	34.5	30.5	34.5	24.0	34.0	27.0	34.0	20.0
Day 3:	7.00	25.0	24.0			23.0	21.0		
	9.00	30.5	28.5			31.0	26.0		
	11.00	32.5	29.0	35.0	[illegible]	32.0	27.0	34.0	21.0
Day 4:	7.00	25.0	24.0			21.0	20.0		
	9.00	27.0	26.5			31.0	25.0		
	11.00	27.5	27.0	29.0	24.5	32.5	25.5	37.0	19.0
Day 5:	7.00	24.5	24.0			22.0	18.0		
	9.00	26.5	26.0			32.0	25.0		
	11.00	31.5	29.5	32.5	24.0	34.0	25.0	37.5	19.0
Day 6:	7.00	27.0	26.0			21.5	19.0		
	9.00	28.5	27.0			33.0	25.0		
	11.00	31.0	28.5	34.0	27.0	34.0	25.0	39.0	19.0
mean:	7.00	26.1	25.0			22.4	19.8		
	9.00	29.1	27.3			32.3	25.3		
	11.00	31.8	29.0	35.0	24.0	33.6	26.1	39.0	19.0

Respiration rate (RR):

The season x sex interaction for RR was significant ($P < 0.05$), with males being relatively more stressed than females in the hot/dry season (77.7 vs 67.4 breaths/minute compared to 30.1 vs 24.9 breaths/minute respectively; Fig. 7). The trends were similar in both seasons, however, and thus did not interfere with interpretation of the main effects. RR varied significantly between days (P < 0.01). The highest RR occurred on day 3 (53.7 breaths/minute); values then declined progressively to 47.9/min on day 6. With times within each day, there were significant differences (P < 0.001) in RR, which increased gradually within the 2.5 h work period to a mean of 81/min. Values then declined (by 43/min; P < 0.05) progressively when the animals were placed in the shade and rested for 1 h.

Rectal temperature (RT):

Between the two seasons, RT was found to differ significantly (P < 0.01) and no significant interactions were found. RT was higher during the hot/dry season, with mean values of 39.5°C in comparison to 38.6°C in the cool/humid season (Table 6). RT in males was significantly higher than in females (P < 0.01) by a mean magnitude of 0.3°C. RT also declined progressively from days 1 to 6 (Table 6). With times within each day, there were significant differences (P < 0.001) in RT which increased gradually within the 2.5 h work period. Values then declined (P < 0.05) progressively when the animals were placed in the shade and rested for 1 h (Table 6).

Skin temperature (ST):

Within the two seasons, ST was found to differ significantly (P < 0.01) and none of the interactions were significant. ST was greater during the hot/dry season, with mean values of 37.3°C in comparison to 36.2°C in the cool/humid season (Table 6). In males ST were significantly higher than in females (P < 0.05) by a mean magnitude of 0.5°C. ST also varied significantly between days (P < 0.05). Between times, there were significant differences (P < 0.01) for ST, which increased gradually within the 2.5 h work period. Values then declined (P < 0.05) progressively when the animals were rested in the shade for 1 h (Table 6).

Table 6: Mean rectal and skin temperatures (RT and ST °C) of male and female swamp buffalo working in the field during the cool/humid and hot/dry seasons

Season:	Cool/humid	Hot/dry	SEM	level of significance
RT:	38.6a	39.5b	0.002	**
ST:	36.2a	37.3b	0.005	**

Sex:	male	female	SEM	Level of significance
RT:	39.2a	38.9b	0.002	**
ST:	37.0a	36.5b	0.005	*

Day :	D1	D2	D3	D4	D5	D6	SEM	Level of significance
RT:	39.4a	39.2b	39.2b	38.9c	38.9c	38.6d	0.005	**
ST:	37.8a	37.3b	37.4b	35.6c	36.3d	36.1d	0.020	*

Time: (hours)	0	0.5	1	1.5	2	2.5	recovery rate: 0.5	1	SEM	Level of significance
RT:	37.9a	38.4b	38.7c	39.2d	39.6e	40.0f	39.5e	39.1g	0.006	***
ST:	30.1a	33.1b	35.7c	38.2d	39.8e	41.3f	38.4d	37.2g	0.020	**

Values within lines with dissimilar superscripts differ significantly (***$P < 0.001$, **$P < 0.01$ and *$P < 0.05$)

Packed Cell Volume (PCV):

In the different sexes, times and seasons, PCV was significantly different ($P < 0.05$; Table 7). Values were lower in males than females, and in the cool/humid than the hot/dry season (23.7 vs 25.6 and 20.8 vs 28.5 % respectively), and decreased during work (ie. time; 25.6 vs 23.7 %; Table 7) .

Table 7: Mean PCV (%) of male and female swamp buffalo working in the field during the cool/humid and hot/dry seasons

	PCV (%)		SEM	Level of significance
sex (male and female)	23.7a	25.6b	0.5	*
time (0 and 2.5 h)	25.6a	23.7b	0.5	*
season (cool/humid and hot/dry)	20.8a	28.5b	0.5	**

Values within lines with dissimilar superscripts differ significantly (**P < 0.01; *P < 0.05)

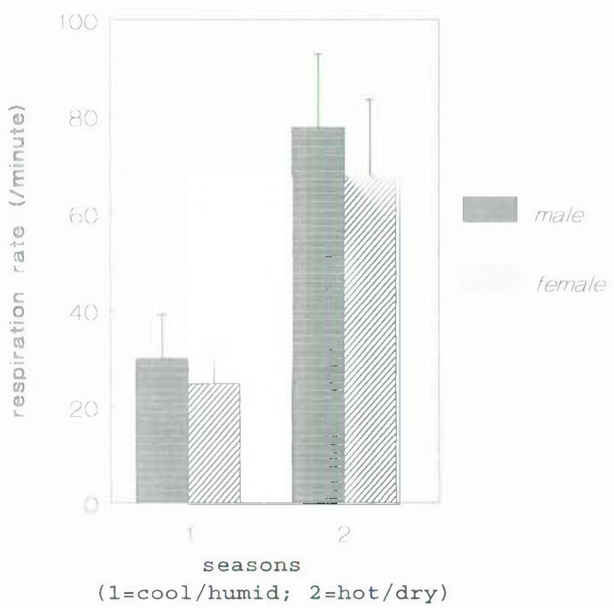


Fig. 7 Mean RR of male and female swamp buffalo yoked together in the field in Bali, Indonesia, during ploughing in the cool/humid and hot/dry seasons

4.3 Experiment 3: Female Bali Cattle and Black Swamp Buffalo Yoked Together in the Field

4.3.1 Introduction

The yoking together of Bali-cattle and swamp buffalo is a common approach to DAP beyond the "subak" areas, e.g. for ground levelling in the villages, and for building and social activities. The fact that both species are yoked together allows a direct comparison to be made of their responses to work. Early work by BADRELDIN *et al.* (1951) in Africa showed that cattle always had higher levels of RR and RT than buffaloes (31.2 and 24.4/minute; 38.3 and 38.0°C respectively). However buffaloes seemed to suffer much more from hot weather than cattle, and the relative increases in RT and RR with air temperature were more pronounced in buffaloes than cattle during both summer and winter. An experiment on the yoking together of cattle and buffalo was conducted in Australia, but no information on the comparative responses was presented (BAKRIE *et al.*, 1989c). To extend the work of BADRELDIN *et al.* (1951) to practical work under tropical conditions, the current experiment was conducted in Bali (Indonesia) with female Bali-cattle and swamp buffalo compared during both the cool/humid and hot/dry seasons.

4.3.2 Materials and Methods

Three pairs each of female Bali-cattle and swamp buffalo were employed, with mean body weights of 316.7 ± 23.6 and 366.7 ± 23.6 kg respectively. All were of condition score 3.5. The animals were fed *ad-lib* on local native grass by their owners. The experiment was conducted during March (cool/humid) and August (hot/dry), 1994.

A 2x2x6x8 factorial design was employed, the factors being 2 seasons (cool/humid and hot/dry), 2 species, 6 consecutive days with 1 day resting in between and 8 measurements per day at 30 minute intervals.

4.3.3 Results

DB temperature during the cool/humid and hot/dry seasons varied from 25 to 32°C and from 19 to 35°C respectively; RH from 50 to 97% and 60 to 80% respectively. Details of the temperature situation are shown in Table 8.

Respiration rate (RR):

The species x day interaction for RR was significant ($P < 0.01$); for the first three day values were highest in swamp buffalo, but not significantly so (means of 60, 52 and 49 vs 58, 50 and 47/minute). Thereafter (days 4-6), the reverse was significantly true, and while RR in buffalo continued to decline, that in Bali-cattle was maintained at a plateau level of about 45/minute (Fig. 8). Within the cool/humid and hot/dry seasons RR differed significantly ($P < 0.05$), with mean values of 42 and 52/minute (Table 8). At different observation times during work, RR increased markedly ($P < 0.01$) to reach overall means of 83 breaths/minute. Values declined gradually during recovery to mean rates after 30 and 60 minutes of 63 and 48 breaths/minute.

Table 8: Environmental temperatures during field trials with Bali cattle and buffalo at Sinabun village, Bali, Indonesia, in the cool/humid and hot/dry seasons

		A. Cool/humid season :				B. Hot/dry season :			
		D.B. (°C)	W.B. (°C)	max (°C)	min (°C)	D.B. (°C)	W.B. (°C)	max (°C)	min (°C)
day1:	7.00	26.0	25.0			23.0	20.0		
	9.00	29.0	27.0			34.0	27.0		
	11.00	31.0	29.0	32.0	25.0	34.5	27.5	39.0	22.0
day2:	7.00	25.0	24.0			19.0	17.0		
	9.00	29.5	27.0			34.0	25.0		
	11.00	31.0	28.0	32.5	24.0	35.0	25.5	35.5	19.0
day3:	7.00	25.0	23.5			21.5	19.5		
	9.00	30.0	26.0			33.0	26.0		
	11.00	31.0	27.0	33.0	24.0	35.0	26.5	35.0	19.0
day4:	7.00	25.0	24.0			23.0	20.0		
	9.00	31.0	26.5			32.0	25.0		
	11.00	32.0	27.0	32.5	24.0	33.0	25.0	32.0	21.5
day5:	7.00	26.0	25.0			24.0	21.0		
	9.00	28.0	26.0			32.0	26.5		
	11.00	29.0	27.0	32.0	25.0	33.0	26.5	33.0	20.0
day6:	7.00	25.0	24.0			23.0	20.5		
	9.00	29.0	26.0			33.0	26.5		
	11.00	31.0	27.0	31.0	24.0	34.0	26.5	34.0	22.0
mean:	7.00	25.3	24.3			22.3	19.7		
	9.00	29.4	26.4			33.0	26.0		
	11.00	30.8	27.5	33.0	24.0	34.1	26.3	39.0	19.0

Rectal temperature (RT):

For RT, the interactions between species x season, species x day and species x time were different at $P < 0.01$, $P < 0.05$ and $P < 0.01$ respectively. The species x seasons interaction (Fig. 9) indicated that while Bali-cattle had slightly lower RT than swamp buffalo during the cool/humid season (NS), the reverse was true during the hot/dry season, when the difference averaged 0.6°C ($P < 0.05$). Such an interaction invalidates overall comparison of the two main effects involved, and suggests comparisons need to be made on the basis of species x season combinations. In the case of the species x day interaction, there were quite marked differences between days, but RT in Bali-cattle was consistently greater than in swamp buffalo (by from 0.1°C. NS to 0.4°C, $P < 0.05$) and on this basis a direct comparison of the main effects was considered valid. For the species x time interaction, there was a consistent trend for the RT of Bali-cattle to exceed that of the buffalo between 0 and 120 minutes of work with a mean magnitude from 0.3 to 0.7°C ($P < 0.05$), thereafter (150 minutes and recovery periods) RT of the buffalo exceeded that of cattle from 0.1 (NS) to 0.3°C ($P < 0.05$; Fig. 8).

Skin temperature (ST):

Since there were no significant interactions; within the main effects of cool/humid and hot/dry seasons ST differed significantly ($P < 0.05$), with mean values of 35.3 and 36.7°C (Table 9). Bali cattle had lower ST (35 4 and 36.7°C) than buffalo (Table 9). There were also significant differences in ST between days ($P < 0.05$): values declined progressively until day 5 and then increased slightly on day 6. At different observation times during work, ST increased markedly ($P < 0.01$) to reach overall means of 40.4°C. ST declined gradually during recovery to values after 30 and 60 minutes of 37.0 and 36.2°C respectively.

Table 9: Mean skin temperatures (ST °C) of female Bali-cattle and swamp buffalo working in the field during the cool/humid and hot/dry seasons

Season:	Cool/humid	Hot/dry	SEM	level of significance
ST:	35.3a	36.7b	0.010	*

animals:	Bali-cattle	buffalo	SEM	level of significance
ST:	35.4a	36.7b	0.010	**

Day :	D1	D2	D3	D4	D5	D6	SEM	level of significance
ST:	37.1	36.3	36.2	35.4	3[illegible].4	35.7	0.030	*

Time: (hours)	0	0.5	1	1.5	2	2.5	recovery rate: 0.5	1	SEM	level of significance
ST:	29.2	31.6	35.7	38.5	39.5	40.4	37.0	36.2	0.040	**

Values within lines with dissimilar superscripts differ significantly (**P < 0.01 and *P < 0.05)

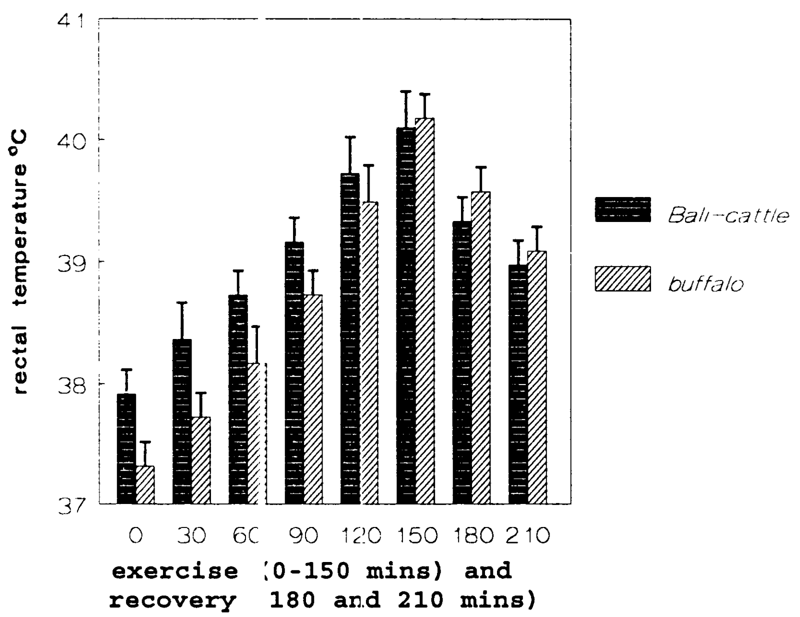
Packed Cell Volume (PCV):

The only significant difference observed for PCV was for values in the hot/dry season (29.3%) to exceed those in cool/humid season (25.1%; Table 10).

Table 10: Mean PCV (%) of Bali-cattle and buffalo working in the field during the cool/humid and hot/dry seasons on Bali

	PCV (%)		SEM	Level of significance
species (Bali cattle and buffalo)	27.7	26.6	0.7	ns
time (0 and 2.5 h)	28.0	26.3	0.7	-
season (cool/humid and hot/dry)	25.1	29.3	0.7	**

Values within lines with dissimilar superscripts differ significantly (**P < 0.01; -P < 0.1 and ns= non-significant)



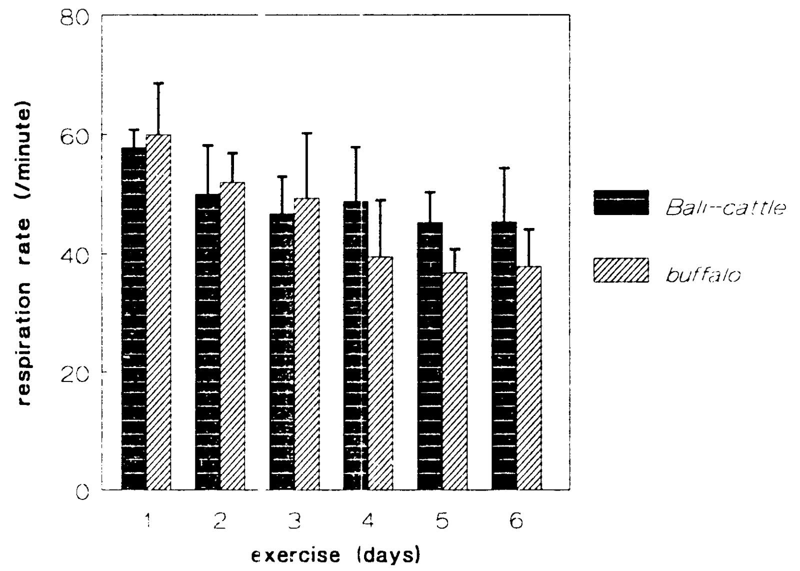


Fig. 8 Mean RT and RR of female Bali-cattle and swamp buffalo working in the field of Bali, Indonesia (mean of cool/humid and hot/dry season values)

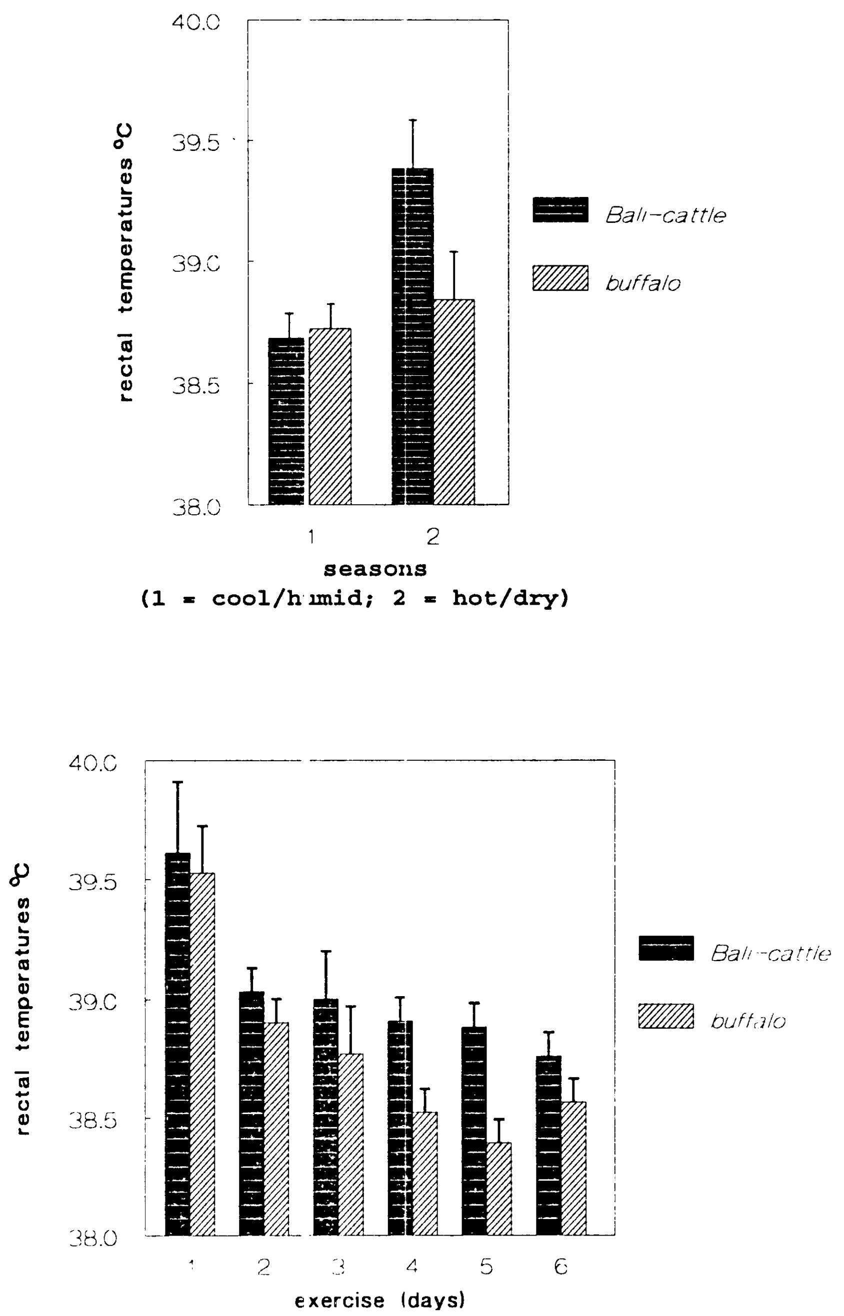


Fig. 9 Mean RT of female Bali-cattle and swamp buffalo working in the field of Bali, Indonesia during the cool/humid and hot/dry season and during the course (days 1-6) of the experiment (means for both seasons)

4.4 Experiment 4: Black and White coat Female Swamp Buffalo

4.4.1 Introduction

Both black and white coat swamp buffalo are used for DAP in Bali-Indonesia. To date no experiments have been sighted in which buffalo of these 2 colours have been compared. In cattle RIEMERSCHMID and ELDER (1945) found the mean absorptivity of white Zebus to be 49%, compared to 78% for red Afrikaners and 89% for black Aberdeen Angus. Additionally, clipping the curly winter hair coat of a Sussex beast resulted in only a 2% reduction in the total absorptivity, presumably due to only a slight change in colour caused by clipping. In New Zealand White rabbits, KASA (1991) reported that heat-tolerant individuals reflected 9% more sunlight than did intolerant ones, even though their coat colours (white) were visually similar.

In view of seasonal differences in light and radiation intensity (associated with cloud cover during the rainy season), and thus likely differences in the responses of different coloured animals, the current experiment was undertaken on black and white coat swamp buffalo working in the rice fields during both the rainy and hot seasons (e.g. to test for a season x hair colour interaction).

4.4.2 Materials and Methods

Three pairs each of black and white coat swamp buffalo, with mean body weights of 366.7 ± 23.6 and 350 ± 20.5 kg respectively and 3.5 body condition score were used. A 2x2x6x8 factorial design was employed, the factors being 2 seasons, 2 colours, 6 days of exercise with 1 day resting in between and 8 consecutive measurements at 30 minute intervals. The experiment was done in March (cool/humid) and September (hot/dry), 1994.

4.4.3 Results

Mean daily temperature (DB) during the cool/humid and hot/dry seasons varied from 24 to 31°C and from 22 to 35°C respectively; RH from 60 to 98% and from 65 to 85% respectively. Details of the climate conditions are presented in Table 11.

Table 11: Environmental temperatures during field trials with white coat and black buffalo at Sinabun village, Bali, Indonesia, in the cool/humid and hot/dry seasons

		A. Cool/humid season :				B. Hot/dry season :			
		D.B. (°C)	W.B. (°C)	max. (°C)	min. (°C)	D.B. (°C)	W.B. (°C)	max. (°C)	min. (°C)
day1:	7.00	26.5	26.0			23.0	19.0		
	9.00	28.5	26.5			34.0	26.0		
	11.00	29.5	27.5	31.0	26.0	35.0	26.5	38.5	21.0
day2:	7.00	26.5	26.0			22.0	19.0		
	9.00	28.5	26.5			33.0	26.0		
	11.00	30.0	28.0	32.5	25.0	32.5	25.5	38.8	20.0
day3:	7.00	26.5	26.0			22.0	20.0		
	9.00	28.5	27.0			33.0	26.0		
	11.00	29.5	27.5	30.0	25.5	33.5	26.5	35.5	20.0
day4:	7.00	26.0	25.0			23.0	21.5		
	9.00	29.5	27.0			35.0	26.0		
	11.00	30.0	27.5	31.0	25.0	35.5	26.5	38.0	21.0
day5:	7.00	26.0	25.0			23.0	22.0		
	9.00	29.0	26.5			32.0	26.0		
	11.00	31.0	28.5	31.0	24.0	34.5	26.5	36.0	20.0
day6:	7.00	24.0	23.0			23.0	20.0		
	9.00	29.5	26.5			32.0	26.0		
	11.00	31.0	27.5	31.0	24.0	35.0	27.0	36.0	22.0
mean:	7.00	25.9	25.2			22.7	20.3		
	9.00	28.9	26.7			33.2	26.0		
	11.0	30.2	27.8	32.5	24.0	34.3	26.4	38.8	20.0

Respiration rate (RR):

The day x colour and time x colour interactions for RR were significant ($P < 0.01$ and $P < 0.05$ respectively; Figs. 10). With day x colour, the trends were for RR to be consistently lower in white coat than in black animals except for day 1. On a day-by-day basis, RR differed significantly between white coat and black buffalo on days 3 and 4, but not on days 2, 5 and 6. With regards the day effect, RR increased gradually until day 4, but on days 5 and 6 it declined slightly. Significant time x colour interactions were also observed in RR ($P < 0.05$), the white coat animals had consistently lower RR in all cases except for the final observation (210 min, Fig. 10). Significant effects at individual times occured only after 120 and 150 min. Between seasons values in the cool/humid season were lower than in the hot/dry (21 and [illegible]9/minute; P < 0.01).

Rectal temperature (RT):

The day x colour and time x colour interactions for RT were significant (P < 0.01 and P < 0.05 respectively), the white coat animals had consistently higher RT than the black ones (Fig. 11). Significant differences between white coat and black animals were found on all individual days except in days 3 and 6, with magnitudes of 0.5, 0.3, 0.1, 0.2, 0.2 and 0.1°C. With time during exercise, white coat animals recorded higher RT than black ones. Differences at all individual times except 0 and 30 min were significant (P < 0.05). RT differed with seasons (P < 0.01); values in the cool/humid season being lower than in the hot/dry (38.6 and 39.1°C).

Skin temperature (ST):

In the absence of interactions, ST differed with seasons (P < 0.01; Table 12);

Table 12: Mean skin temperatures (ST °C) of white coat and black buffalo working in the field during the cool/humid and hot/dry seasons on Bali

Season:	Cool/humid	Hot/dry	SEM	level of significance
ST:	37.1a	37.7b	0.006	**

Colour:	white coat	black	SEM	level of significance
ST:	37.2a	37.7b	0.006	**

Day :	D1	D2	D3	D4	D5	D6	SEM	level of significance
ST:	37.4a	36.7b	37.3a	38.0c	37.6a	37.5a	0.020	*

Time: (hours)	0	0.5	1	1.5	2	2.5	recovery rate: 0.5	1	SEM	level of significance
ST:	31.0a	33.5b	37.2c	40.1d	4[illegible].2e	42.1f	37.9g	36.4h	0.020	**

Values within lines with dissimilar superscripts differ significantly (**P < 0.01 and *P < 0.05) values in the cool/humid season being lower than in the hot/dry (37.1 and 37.7°C). With time during work ST increased ($P < 0.01$) to reach overall means of 42.1°C after 2.5 hr of work. ST declined during 60 minutes of recovery, but still remained significantly elevated above initial levels. Of the main effects, it was found that black animals had higher ST (37.7 and 37.2°C; $P < 0.01$) than white coat ones.

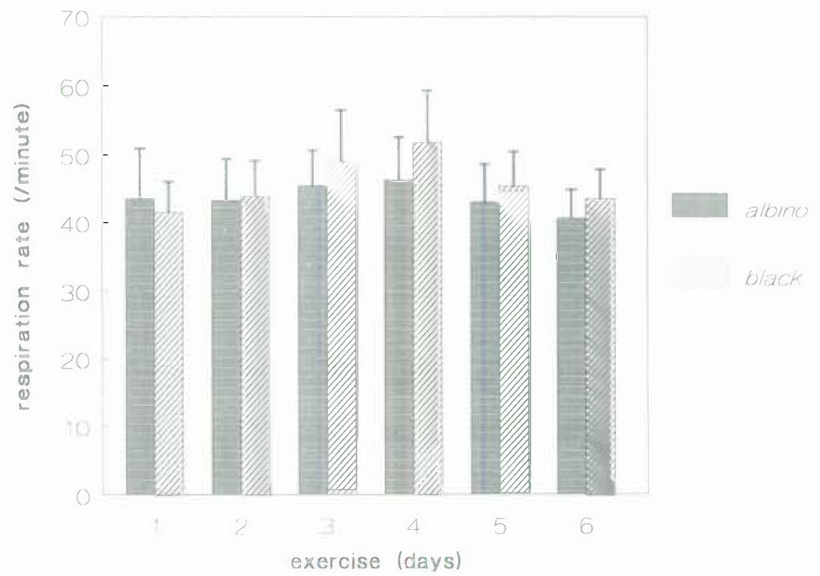
Packed Cell Volume (PCV):

Differences in PCV with both time and season were also significant ($P < 0.05$; Table 13). PCV decreased after 2.5 h exercise by 1.3 percentage points ($P < 0.05$), and was higher (27.2%) during the hot/dry than during the cool/wet season (23.9%: $P < 0.05$).

Table 13: Mean PCV (%) of white coat and black buffalo working in the field during the cool/humid and hot/dry seasons on Bali

	PCV (%)		SEM	Level of significance
breed (white coat and black buffalo)	25.7a	25.4a	0.3	ns
time (0 and 2.5 h)	26.2a	24.9b	0.3	*
season (cool/humid and hot/dry)	23.9a	27.2b	0.3	*

Values within lines with dissimilar superscripts differ significantly (*$P < 0.05$ and ns= non-significant)



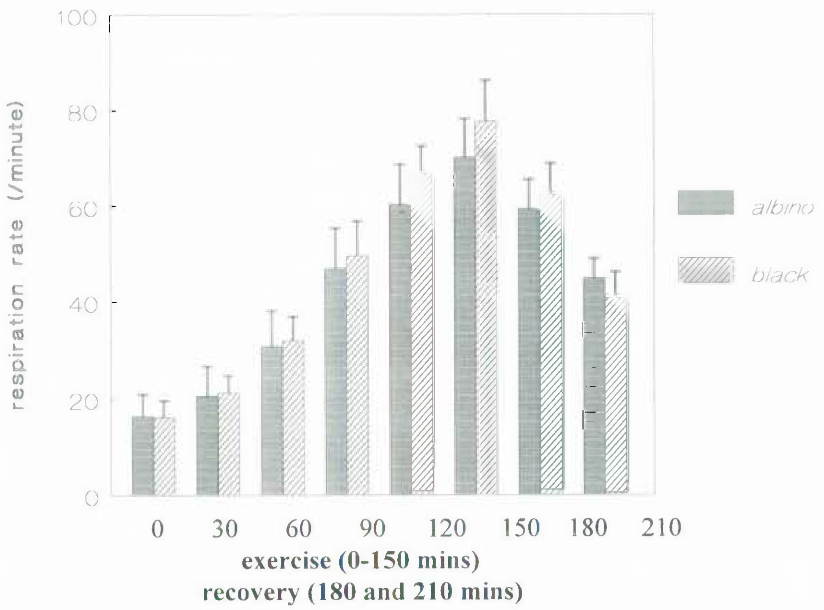
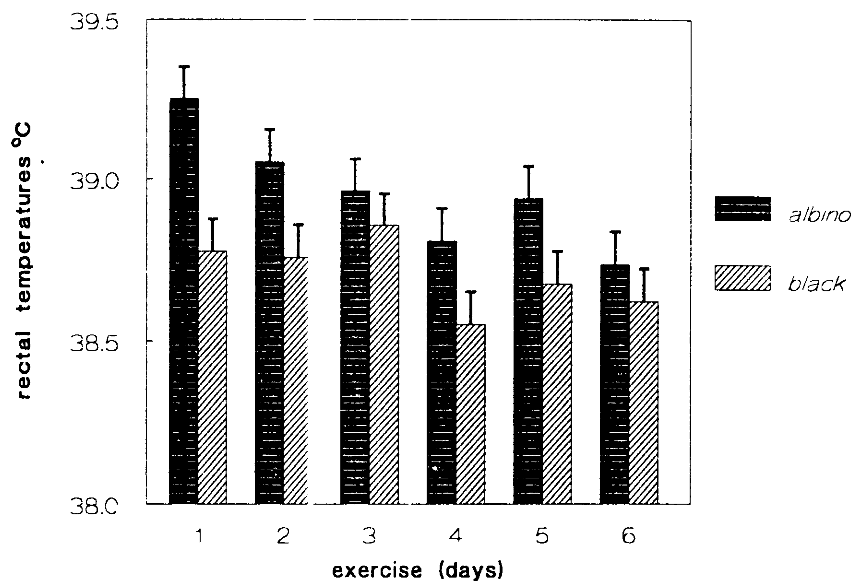


Fig. 10 Mean RR of female white coat and black swamp buffalo working in the field on Bali (mean of the cool/humid and hot/dry seasons)



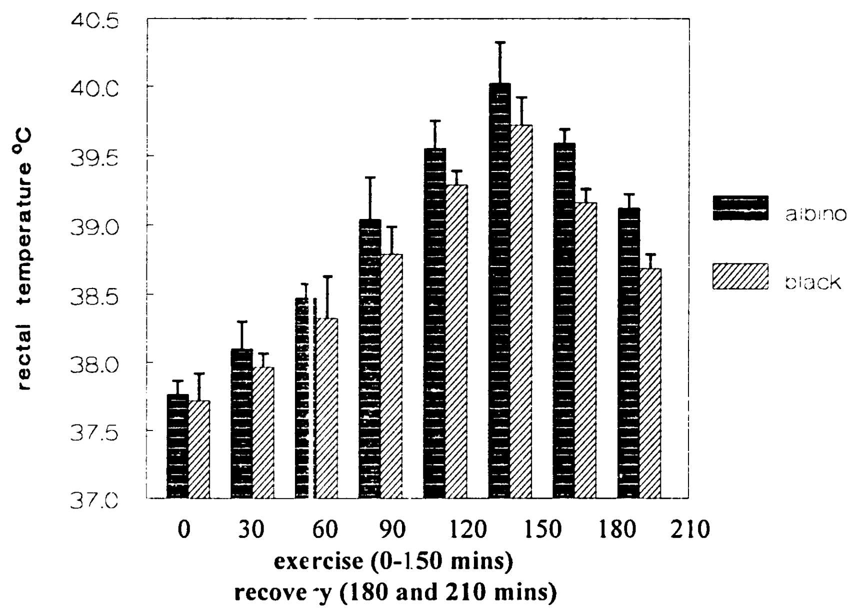


Fig. 11 Mean RT of female white coat and black swamp buffalo working in the field on Bali (mean of the cool/humid and hot/dry seasons)

4.5 Discussion

From the overall results, it can be seen that increases in environmental temperature, and/or increasing duration of work (the two effects were confounded in these field trials) were associated with increases in RR and RT. These findings support those of MURRAY and YEATES (1967) who observed gradual increases in RR and RT in bulls, steers and cows when walking at temperatures of 24 - 31°C. According to MURRAY and YEATES, ST decreased with time of walking, apparently as a response to increased sweating. Such a response was not observed in the current trials, but on the whole the ST in the Herefords of MURRAY and YEATES (1967) was higher than in Bali-cattle, and on that basis it can be concluded that the Herefords observed by MURRAY and YEATES (1967) were more stressed than the current Bali-cattle.

From the current results it can be concluded that the higher the ET during work, the more stressed the animal was. This finding is in general agreement with QUINLAN and RIEMERSCHMID (1941), who found that the mean ST of Sussex cattle was 37.0 ± 0.4°C in the sun (from 09.00 to 15.00h) but 36.0 ± 0.4°C in the shade. BEAKLEY and FINDLAY (1955a) supported this finding: in their study when Ayrshire calves were exposed to ET from 30 to 40°C, ST increased from approximately 37 to 39°C. A similar pattern occurs in sheep. BROWN, (1971), for example, found that ST of sheep standing in the sun increased from 36.5 to 37.5°C at about 07.30 h to a maximum of approximately 44 °C by about 10.00 h. Additionally, on theoretical grounds, differences in coat colour and depth, fibre diameter and medullation, skin depth and sweat gland activity could also have contributed to the observed differences in ST between Herefords and Bali-cattle.

With respect to sex differences, males were less tolerant than females in both Bali-cattle and buffalo. This result is in general agreement with MURRAY and YEATES (1967) who reported that during walking trials with unclipped cattle under the sun at 24 to 31°C at 4.3 km/h, bulls displayed a higher mean RT of 40.7°C compared to only 40.1°C in heifers. Even at the slower speed of 2.7 km/h, bulls still showed higher RT than heifers (40.3° vs 39.6°C). The inferior thermoregulatory performance of males could have been due to their longer stride, as well as a possibly greater heat production associated with walking. The mass of muscle involved in locomotion is greater in males than in females. In the current experiments mean stride lengths of male and female Bali-cattle and buffalo were 77 ± 9 vs 73 ± 9 and 75 ± 2 vs 65 ± 3 cm respectively. In the same animals mean body lengths were 193 ± 2 vs 193 ± 1 and 192 ± 7 vs 183 ± 2 cm and mean leg lengths were 116 ± 2 vs 110 ± 1 and 115 ± 4 vs 107 ± 6 cm respectively. As a result of their longer stride, males tended to walk faster during work and thus to pull along the female to which they were yoked together for comparative purposes. The exact extent of this effect is unknown, but it would undoubtedly have added somewhat to the work performed by males. The current investigations revealed the same pattern of response as reported by YEATES and MURRAY (1966) who found that Herefords, which walked with smaller steps than Santa Gertrudis, displayed greater increases in RT and RR. Overall, it can be concluded that anatomically, *Bos indicus* cattle are better adapted for walking than the British breeds; they have longer legs in proportion to body size, and therefore a longer stride.

It is has long been known (e.g. BRODY, 1945) that males produce more heat than females of the same body weight. BRODY expressed such differences through the equations $Y=4.41W^{0.35}$ and $Y=16.4W^{0.068}$ for basal heat production (Y) in males and females respectively. In part, the higher heat production of males could be associated with their larger mass of muscle. It is widely recognized that male farm animals are heavier than females throughout life. For example, SAHOO and MISHRA (1990) reported that in Binjharpuri cattle the birth weights of male and female calves were 18 ± 0.4 and 15 ± 0.3 kg, respectively. Similarly, TAYLOR *et al.* (1989) reported that mature carcass weights of male sheep were higher than those of females (16.3±4.2 and 13.1±3.2 kg respectiely). Similar results have been reported by many others, including SAHOO and MISHRA (1989) and PANDA and MISHRA (1990). Such differences in weight are reflected in the experiment of PEARSON (1989), who reported that when buffaloes carted loads for 16 to 17 km at temperatures of 24 to 37°C RT at the end of work averaged 41.5 and 42.0°C respectively in small (237 to 320 kg) and large animals (401 to 464 kg). Under the same conditions, cattle showed less than 1°C fluctuation in body temperature during the working day and the difference in body temperature between small (360 to 424 kg) and large (551 to 557 kg) animals was only 0.1°C. Therefore, it can be concluded that heavier animals, whether expressed as a result of either sex or growth/maturity differences, react more to heat load in comparison to lighter-younger ones. To confirm this phenomenon under controlled conditions, laboratory (climate chamber) experiments were undertaken on goats of both sexes and different breeds during treadmill exercise (Experiments 5 and 9).

From the results of the two seasons in the current work, it can be seen that RR, RT and ST were all lower during the rainy compared to the hot season. These findings are in general agreement with BADRELDIN *et al.* (1951) who reported that during winter (5 to 26°C) animals had a lower RR and RT, and that both parameters reached higher levels during the summer months. The different reactions of Bali-cattle and buffalo (higher RR and RT in Bali-cattle) reported here, support the finding of BADRELDIN *et al.* (1951) that cattle had higher RR and RT than buffaloes (31.2 and 24.4/minute; 38.3 and 38.0°C respectively). However, the buffaloes in both the current experiment and that of BADRELDIN *et al.* showed a relatively greater increase in RT and RR than cattle, and appeared to suffer more from the effects of hot weather and work.

From the current species x time interactions, RT increases with time of work can be described by the linear equations $Y=0.4X + 37$ and $Y=0.2X + 38$ for buffalo and Bali-cattle respectively, which clearly demonstrate that the rate of increase of RT (slope) in buffalo was higher than in Bali-cattle and clearly meant that the buffalo were affected more than Bali-cattle. Even though small in magnitude, these differences were highly significant statistically, and may be considered as species characteristics due to genetic influences operating through such factors as heat production, hair coat type (insulative and reflective value) and efficiency of evaporative cooling (sweating and panting). A complex trait such as heat tolerance is likely to be controlled by many genes and will thus be governed by the normal rules of quantitative (population) genetics (FALCONER, 1960). With regards ST, Bali-cattle (red colour) were less affected (1.3°C lower ST) than buffalo (black colour). This may be due to the fact that the black buffaloes had darker skins and thus absorbed more radiant heat than Bali-cattle. Similar results were also found in experiment 4, namely a lower ST in white coat compared to black buffalo (37.2 and 37.7°C respectively). This is the same pattern of response as reported by PHILLIPS (1948), who found that buffaloes absorbed more heat when exposed to solar radiation than did cattle.

The above results are also in agreement with those of RIEMERSCHMID and ELDER (1945) who reported the mean absorptivity of white Zebu to be 49%, compared to 78% for red Afrikaners and 89% for the black Aberdeen Angus. In addition, since the number of hairs per unit area of skin surface indicates the number of sweat glands present (FINDLAY, 1950; FINDLAY and YANGE, 1950), buffalo may be considered to have fewer sweat glands than cattle. Furthermore, the buffaloes used here were heavier than the cattle, and thus had a relatively lower skin area : weight ratio than the cattle, the heat lost from their skin would be relatively less than in the smaller cattle.

The above characters could collectively have contributed to the greater discomfort showed by buffaloes during work, and could also explain the fact that RR and RT increased with time more in buffalo than in Bali-cattle. Such a result is in close agreement with BAKRIE *et al.* (1989b, 1989c), who found that RT and RR reached higher levels following one hour of work by buffalo than after 2 hours' work by cattle, and with PEARSON (1989), who found while cattle worked uniformly throughout the day, buffaloes slowed noticeably in the last hour.

The fact that white coat buffalo were apparently less tolerant than black ones (RT 0.3°C higher) could be associated with lack of pigment in the white coat's skin, but no relevant information was found in the literature on this point and further experimentation is thus required on this point.

The overall results for PCV showed a significant decrease during working, and during hot/dry as compared to the cool/humid season. These findings extend those of ARAVE *et al.* (1978), who found that mean PCV decreased, but only from 37.8 to 37.7% after exercise in Holstein cows at a treadmill speeds between 3.5 and 5.5 km/h. Similar results have also been reported by HAYS *et al.* (1978) and IGBOKWE *et al.* (1992). Various explaination could apply to this phenomenon, including destruction of red blood cell during exercise (SING *et al.*, 1968b), and changes in splenic function (IGBOKWE *et* *al.*, 1992; UPADHYAY and MADAN 1985a; and PEARSON and ARCHIBALD, 1989). In addition, CHEN *et al.* (1993) pointed out that both the number of red blood cells and haemoglobin level decreased after exercise in rats, by 4 and 1% respectively, and suggested an increase in plasma volume such as has been observed (CONVERTINO *et al.*, 1980).

The rule of splenic function proposed by DOOLEY (1973) is another possible explanation. According to this theory, the spleen, a blood reservoir, is able to release blood cells when the animal becomes stressed and take them back as the animal acclimatises. This has clearly been shown to follow an insulin injection in sheep: the hematocrit increases by about 40% within 2 hours. It is concluded for the cattle and buffalo used in the current field trials that, when PCV reached a steady state, or decreased, it was an indication that acclimatisation had occurred in those animals. Conversely, when PCV increased, the animals were considered to have been stressed.

Overall, it can be concluded that there were differences in physiological responses between the sexes (male and female; both Bali-cattle and buffalo), breeds (black and white coat swamp buffalo) and species (Bali-cattle and buffalo). The male in each case was more stressed than the female, white coat buffalo were more stressed than black ones, and buffalo were more stressed than Bali-cattle. Since the experiments were conducted in the field, environmental temperature could not be controlled and management (particularly feeding strategy) is likely to have varied between farmers. These factors confirmed the need for the series of detailed, controlled experiments which were subsequently conducted in the climate chambers at Armidale, and which are reported in the following Chapters.