EFFECT OF WORK CRUSHING SUGARCANE ON PREGNANCY AND LACTATION IN CATTLE AND BUFFALOES

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Summary

The suitability of female cattle (Brahman × Holstein) and buffaloes (Murrah × Jafarabadi) for work on a sugarcane crusher was tested. The animals were fed chopped sugarcane tops and elephant grass supplemented with rice bran and urea-molasses blocks. In experiment 1, six cattle and six buffaloes, (with three animals seven to eight months pregnant at the start of the experiment in each group), worked individually, alternate weeks for 90 minutes a day for 6 d/week. Within the 90 min, cattle did more work than buffaloes ($p < 0.05$), and non-pregnant animals did more than pregnant ones ($p < 0.01$). There were no significant differences in sugarcane crushed between the pregnant and non-pregnant animals, but cattle crushed significantly ($p < 0.05$) more cane per day than buffaloes. During work animals lost weight, but gained the weight back during resting weeks, when fodder intakes were higher. There were no significant differences in live weight change and fodder intakes between pregnant and non-pregnant animals during the six weeks. In experiment 2, four pairs of lactating cows and buffaloes crushed sugarcane for 3 h/d, 6 d/week for three weeks. Work done was higher in cattle than buffaloes, but cane crushed was marginally lower. All animals lost weight during work, particularly in the first week, but gained weight during the week after work. Daily milk yield was lower during the working weeks (-0.55 ± 0.15 kg) than in the week before work. Butter fat yield showed no significant change. One buffalo showed ovarian activity and oestrus behaviour during the work. Two cows showed ovarian activity within one month after the work.

It was concluded that pregnant and lactating cows and buffaloes can effectively operate a cane crusher, however a temporary reduction in milk yield can be expected in the working period, and ovarian activity may be suppressed.
(**Key Words** : Sugarcane Crusher, Work, Cattle, Buffalo, Pregnancy, Lactation)

Introduction

In tropical countries, sugarcane is a multi-purpose crop supplying human food, feed for monogastric and herbivore animals and fuel for cooking (Preston and Murgueitio 1992). In villages in Bangladesh, Colombia and Vietnam, smallholder farmers use animal-powered crushers to extract sugarcane juice. The crushers are low cost and have a reliable crushing capacity (Miah and Sarker, 1990; Witt, 1991). Smallholder farmers choose animal-powered sugar cane crushers rather than motorised crushers because of the high costs which have to be paid for motors and fossil fuels. In addition, farmers could profitably use their local resources such as animals, feeds and family labour to produce the sugar and sugar by-products without relying on importation.

Cattle and buffaloes are the most common species used for draught. Traditionally males are preferred because of their larger body size and hence greater working capacity, but in some countries females are increasingly being used for work (e.g. Jainudeen, 1985; Matthewman, 1987). The use of working cows has shown potential for increasing farm productivity and income, because they are multipurpose and can be used to produce calves and milk in addition to work (Zerbini and Gemeda, 1993). However, evidence available from Asia and Africa showed

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that work may seriously affect the fertility and productivity of the cows, particularly when nutrition is poor (Jabbar, 1983; Momongan, 1985; Zerbini, et al., 1993).

It has been suggested by Miah and Sarker (1990) that sugarcane crushing demands a much higher energy expenditure from animals than ploughing and threshing. Hence work on a sugarcane crusher may have negative effects on pregnancy and lactation when cows are used. An understanding of the effects of this work on cow productivity is of benefit to smallholder farmers, to help them to manage their own animals, with minimal risk to animal health and productivity.

Materials and Methods

Two experiments were carried out at the Instituto Major Campesino, Buga, Colombia in 1992.

Sugarcane crusher

A cane crusher (Chattanooga Plow Company type 23, USA) was set up under a grass-covered roof. It had three vertical iron rollers, 18.0 cm long. The two outer rollers had a circumference of 55.0 cm and the larger central roller had a circumference of 110.0 cm. The outer rollers rotated in the opposite direction to the central roller to enable cane to be fed in from both sides. The sugar cane stalks were fed between the outer and inner rollers to crush it. Grooves in the rollers assisted crushing and channelled the juice into the collection vessel. Number of canes fed through the rollers at any one time and type of cane also had an effect on the draught force required to operate the crushing rollers, but where possible these were standardised during each experiment, so that comparisons between animals could be made. The diameter of the circle around which the animals walked to operate the crusher was 8 m.

Animals, work and nutrition

Experiment one

Six female cattle 6-8 years of age (Brahman × Holstein) and six female buffaloes 4-6 years of age (Murrah × Jafarabadi) were used. Three cattle and three buffalo were seven to eight months pregnant at the start of the experiment. Average live weights at the beginning of the experiment were 429.7 ± 55.1 kg in pregnant cattle, 543.5 ± 10.7 kg in non-pregnant cattle, 464.2 ± 7.4 kg in pregnant buffaloes and 488.2 ± 41.7 kg, in non-pregnant buffaloes.

Before the experiment started, animals were trained to work the cane crusher for one and a half months (buffaloes) or three months (cattle). During the experiment the animals worked for a week and rested for a week alternately over a six week period. Work consisted of the animals working individually for 90 minutes each day except Sunday. After the six weeks work individually, the animals worked in pairs, within species, for two continuous weeks, six days per week.

The animals were fed a mixture of chopped sugarcane tops and elephant grass (50:50 by fresh weight) and had access to a urea-molasses block *ad libitum*. Rice bran was fed at 0.5 kg/d to non-pregnant animals and 1.0 kg/d to pregnant animals. Resting animals had access to feed and water while the others were working.

Experiment two

Four lactating cattle (Brahman × Holstein) in the third month of lactation at the start of work and four lactating buffaloes (Murrah × Jafarabadi), three animals in the third month of lactation and one in the seventh month of lactation at the start, were worked in pairs in the experiment. Average live weights of the teams at the start of the experiment were 811 ± 14.8 kg for cattle and 1,004 ± 51 kg for buffaloes.

Animals worked in pairs for 180 minutes each day (90 minutes in the morning, 90 minutes in the afternoon). After 45 minuts of work the animals had a 15 minute break. Each pair worked consecutively for six days per week (excluding Sunday), for three weeks. After each break, the position of the animals was changed around on the cane crusher (from the outside to the inside or vice versa). The diet was the same as that given in the first experiment, but the rice bran was fed at 2 kg/d. When not working the animals had free access to water.

Measurements

In both experiments, animals were weighed on two days at the end of every week. Feed and water intakes were recorded daily, and urea-molasses blocks were weighed each week. Feed given and feed refusals were sampled daily and each was pooled over the week. The samples were dried at 60℃ for three days, ground through a 2 mm screen and then pooled for analysis. Except for crude protein, proximate analysis was carried out in a laboratory in Colombia. Gross energy of feeds, *in vitro* organic matter digestibility (Mbwile and Uden, 1991) and crude protein were analysed at the laboratory of the Department of Animal Nutrition and Management at the Swedish University of Agricultural Sciences, according to the Association of Official Analytical Chemists (1990).

In the first experiment, degradability of feed samples was studied in three rumen-fistulated cattle using the nylon bag technique (Ørskov et al., 1980; Ørskov and Ryle, 1990). Extent of degradability of feed samples in the rumen was checked after 12, 24, 36 and 48 hours *in sacco*.

The force P was measured in the pull line during each working period using a load cell (Type F241-Z0447 of 3 kN capacity with TR-200 digital readout, Novatech Measurements Ltd, Sussex, TN38 9NT, UK) mounted between the animal(s) and the beam. The draught force was calculated according to Miah and Sarker (1990) as follows:

$$E = (X^2 - (Y - K)^2)^{1/2}$$

$$Cosq = E/X$$

$$\text{Draught force} = P \times Cosq$$

Where P = Force (load cell reading) in Newton

E = Horizontal length of rope in m.

X = Length of hitching rope from yoke to beam free end in m.

Y = Height of animal neck from the ground in m.

K = Height of free end of beam from the ground where the rope is hitched in m.

Speed of working was recorded by counting the number of circuits made within the time, recorded using a stopwatch. Work done was calculated from average draught force and distance travelled. Recovery time was expressed as the time taken for heart rate to return to resting level after work. Estimated energy expended for work was calculated according to Lawrence and Stibbards (1990) and expressed as a multiple of maintenance.

The weight of cane crushed, cane juice and brix produced were recorded at the end of every working period with each animal or team, to assess the crusher capacity and efficiency. Crusher efficiency was expressed as kg juice produced/100 kg cane crushed. The animal efficiency was expressed as kJ work done/100 kg cane crushed.

In the second experiment heart rate, respiration rate, body temperature, ambient temperature and relative humidity were recorded before, after 45 minutes work and after 90 minutes of work. Heart rate (the pulse taken in the tail vein) and respiration rate were taken within 2 minutes of each animal stopping work.

In the first experiment the ease of parturition, health of the cows, and birth weight of the calves were recorded. In the second experiment daily milk yield was measured. Milk samples were taken every second day in the week before, during and after the working weeks. These were analysed for butter fat content by the Gerber method (Richardson, 1985) and progesterone concentration, determined using a commercially available ELISA kit (Ovuchek, Cambridge Veterinary Sciences Ltd., Cambridgeshire, CB6 1SE, UK). Data obtained from this semi-quantitative assay provided indications of ovarian activity in the animals.

Statistical analysis

In the first experiment data were analysed by least-squars analysis of variance using the General Linear Model procedure for the performances recorded when animals worked on the cane crusher. Differences in live weights, and feed and water intakes between working and resting weeks were analysed using paired t-tests.

In the second experiment differences in live weights, feed and water intakes, milk yield and milk fat content in the weeks before, during and after working were analysed using paired t-tests. Means were expressed ± standard errors.

Most of the analyses were performed using Minitab release 8.2 (MINITAB Inc., Texas 78130-1558, USA).

Results

Experiment one

Single animal performance crushing sugarcane

The draught force produced by cattle working individually was significantly ($p < 0.05$) higher than that produced by the buffaloes. Non-pregnant animals generated a significantly ($p < 0.001$) higher draught force than that produced by pregnant animals (table 1). Cattle tended to walk faster around the crusher circle than buffaloes, but the difference was not statistically significant. As a result of their greater speed and draught force generated, the total work done and average power output of the single cattle were significantly ($p < 0.05$) higher over the 90 minutes working period than those of the single buffalo. Differences between pregnant and non-pregnant animals were also significant ($p < 0.01$; table 1). Expressed as a percentage, over the seventh to tenth month of pregnancy, the pregnant animals produced 82.5 % of the draught force, 83.4% of the work done, and showed 84.5% of the crushing efficiency of the non-pregnant ones. Similar calculations for the buffaloes showed that the pregnant animals produced 74.2% of the draught force, 56.9% of the work done, and 76.3% of the crushing capacity of the non-pregnant animals.

The quantity of cane crushed by the cattle was higher than that by the buffaloes ($p < 0.05$). Differences between pregnant and non-pregnant animals were also significant ($p < 0.01$; table 1). There was no significant difference in the amount of cane crushed by pregnant and non-pregnant animals. In the experiment there was a significantly ($p < 0.001$) better crusher efficiency, i.e. juice produced/kg

TABLE 1. AVERAGE PERFORMANCE OF PREGNANT AND NON-PREGNANT CATTLE AND BUFFALOES WORKING SINGLY 90 MIN PER DAY 3 WEEKS OVER A 6 WEEK PERIOD CRUSHING SUGARCANE.

Criteria	Cattle		Buffalo		Sig. level		
	Preg.	Non-preg	Preg.	Non-preg	Sp	St	Sp × St
Live weight (kg)	430	544	464	488	ns	*	ns
Speed (m/s)	0.73	0.72	0.53	0.69	ns	ns	ns
Draught force (N)	387	469	328	442	*	***	ns
Work done (kJ)	1,515	1,817	939	1,649	*	***	ns
Work done (kJ/kg $M^{0.75}$)	14.8	17.2	9.0	15.9	*	**	ns
Power (W)	256	364	170	306	*	**	ns
Cane crushed (kg)	180	213	132	173	*	ns	ns
Brix (number)	15.0	14.9	16.7	16.3	***	ns	ns
Crusher efficiency (%)[1]	51.7	53.0	46.3	48.2	***	**	ns
Animal efficiency[2]	836	850	708	949	ns	*	*
Recovery time (min)[3]	27.4	24.2	25.0	23.4	ns	ns	ns
E.E.W.[4]	0.25	0.28	0.17	0.26	ns	ns	ns

[1] Crusher Efficiency = Juice (kg)/crushed cane (kg) × 100.
[2] Animal Efficiency = work done (kJ)/100 kg cane crushed.
[3] Recovery time = time taken for heart rate to return to resting level after work.
[4] E.E.W. = Energy expended for work as multiple maintenance.
Sp: Species; St: State; ns: not significant; $*p < 0.05$; $**p < 0.01$; $***p < 0.001$.

cane crushed using cattle than using buffaloes for the work, but significantly ($p < 0.001$) more brix of sugar produced by the buffaloes. The animal efficiency, recovery time, and estimated energy expended for work were not significantly different between species, although non-pregnant animals were significantly ($p < 0.05$) more efficient than pregnant ones (table 1).

Live weight change and fodder and water intakes

Pregnant and non-pregnant animals had significantly higher live weights during the resting weeks than in the working weeks (table 2). In pregnant animals, fodder intake was significantly higher during the resting weeks than in the working weeks, but in the non-pregnant group these differences were not significant (table 2). Work did not significantly affect daily consumption of urea-molasses block or water (table 2).

TABLE 2. LIVE WEIGHT, FODDER, BLOCK AND WATER INTAKES OF PREGNANT AND NON-PREGNANT ANIMALS DURING THE WORKING WEEKS COMPARED TO THE RESTING WEEKS

	Pregnant			Non-pregnant			Sig. (P-NP)
	Working	Resting	Sig.	Working	Resting	Sig.	
Live weight (kg)	453	461	***	542	551	**	ns
Fodder intake							
(kg DM/d)	4.36	4.73	*	5.81	6.07	ns	ns
(g DM/$M^{0.75}$)	43.9	47.7	*	52.5	54.8	ns	ns
Block intake							
(kg DM/d)	0.68	0.77	ns	2.03	1.90	ns	*
(g DM/$M^{0.75}$)	7.13	7.98	ns	9.10	8.00	ns	ns
Water intake							
(1/d)	17.7	16.8	ns	18.1	18.1	ns	ns
(1/kg DM)	3.55	3.14	ns	2.83	2.78	ns	ns

ns: not significant; $*p < 0.05$; $**p < 0.01$; $***p < 0.001$; (P-NP) Pregnant − Non-pregnant.

Chemical composition and degradation of feed

The chemical compositions of the fodder mixture fed (sugarcane tops and elephant grass, 50:50 by fresh weight) and feed refusals are given in table 3. The protein content was higher and the cellulose content was lower in the fodder fed than in the refusal. The degradation, *in sacco* in rumen fistulated cattle, of sugarcane tops was significantly ($p < 0.05$) greater after 72 h than that of elephant grass. The degradation of the fodder mixture *in sacco* was intermediate between the values for sugarcane tops and elephant grass and was not significantly different from either (table 4).

TABLE 3. MEAN CHEMICAL COMPOSITION OF FEEDS {DRY-MATTER (DM) BASIS} IN EXPERIMENT ONE

	Fodder[1]	Refusal	Rice bran[2]	UMB[2]
Dry matter (g/kg)	137	140	890	870
Protein (g/kg DM)	83.0	71.8	120	290
Fibre (g/kg DM)	353	375	240	70
Fat (g/kg DM)	17.2	14.7	120	40
NFE (g/kg DM)	433	417	430	450
Ash (g/kg DM)	114	122	80	150
NDF (g/kg DM)	564	663	–	–
ADF (g/kg DM)	444	524	–	–
Gross energy (MJ/kg DM)	14.97	15.01	18.13	11.88

[1] Mixture of sugarcane tops and elephant grass 50:50 by fresh weight.

[2] Results of the producing company.

UMB urea-molasses block; NFE: nitrogen free extracts; NDF: netural detergent fibre; ADF: acid detergent fibre.

TABLE 4. RELATIVE DEGRADATION (%) OF SUGAR CANE TOP (SCT), ELEPHANT GRASS (EG), SOYBEAN HULL, RICE BRAN AND FODDER (SCT : E 50 : 50) GIVEN TO ANIMALS IN RUMEN OF CATTLE (N = 3).

Hours	SCT	EG	Fodder	Rice bran	Soybean hull
Blank	35.6	24.4	29.7	76.2	20.5
12	41.4	29.8	35.3	82.5	33.5
24	46.8	39.8	44.9	90.9	56.0
48	56.7	50.4	55.2	93.3	79.7
72	63.5[a]	59.0[b]	61.1[ab]	94.7[c]	94.4[c]

[abcd] Values with different superscripts are significantly different ($p < 0.05$).

Animal performance working in pairs on the cane crusher

The results for work performance are given in table 5. Values from pregnant cattle were not available. The draught forces produced by non-pregnant cattle were higher than those generated by non-pregnant and pregnant buffaloes, Speed of working was greater in the non-pregnant than in the pregnant animals. The amount of cane crushed by paired animals was highest for the non-pregnant cattle, followed by the non-pregnant buffaloes, with the pregnant buffales crushing the least cane in the 90 minute period (table 5). In terms of animal efficiency it appeared that it was more efficient to work animals individually (table 1) than working them in pairs (table 5).

TABLE 5. MEAN (±S.E.) WORK PERFORMANCE OF PAIRS OF NON-PREGNANT CATTLE AND PREGNANT AND NON-PREGNANT BUFFALOES CRUSHING SUGARCANE 90 MIN PER DAY FOR 2 WEEKS.

Criteria	Non-preg. cattle	Preg. buff.	Non-preg. buff.
Liveweight (kg)	1,074 ± 45	1,002 ± 5	1,007 ± 26
Speed (m/s)	0.65 ± 0.06	0.50 ± 0.03	0.63 ± 0.03
Draught force (N)	1,102 ± 30	595 ± 17	739 ± 25
Work done (kJ)	3,912 ± 382	1,595 ± 105	2,517 ± 245
Work done (kJ/kg $M^{0.75}$)	20.8 ± 1.69	8.8 ± 0.6	14.1 ± 1.13
Power (W)	720 ± 70	300 ± 17	470 ± 80
Crushed cane (kg)	335 ± 17	179 ± 12	262 ± 18
Brix (number)	16.4 ± 0.16	14.9 ± 0.08	15.3 ± 0.10
Crusher efficiency[1]	54.6 ± 1.01	50.1 ± 0.02	52.2 ± 0.97
Animal efficiency[2]	1,161 ± 60	889 ± 4	960 ± 30
E.E.W.[3]	0.33 ± 0.03	0.18 ± 0.01	0.26 ± 0.02

[1,2,3] - see table 1.

Experiment two

Animal performance working in pairs on the cane crusher

The results for work performance are given in table 6. The live weights of lactating cattle were less than those of the lactating buffaloes and they generated a lower draught force, however, like the cattle in the first experiment, they had a faster speed of walking than the buffaloes. Consequently total work done by the lactating cattle and average power output in the three hour working day were higher in the cattle than in the buffalo. Despite these differences there was little difference in output. The amount of cane crushed, sugar brix produced, and crusher efficiency were similar in both species (table 6). Animal efficiency was lower in cattle than buffaloes.

TABLE 6. MEAN (±S.E.) WORK PERFORMANCE OF LACTATING CATTLE AND BUFFALOES WORKING IN PAIRS ON THE SUGARCANE CRUSHER FOR THREE HOURS PER DAY

Criteria	Cattle Mean ± s.e.	Buffalo Mean ± s.e.
Live weight (kg)	811 ± 14	1,004 ± 51
Speed (m/s)	0.62 ± 0.04	0.42 ± 0.04
Draught force (N)	498 ± 2	589 ± 5
Work done (kJ)	3,329 ± 222	2,680 ± 254
Wd (kJ/M$^{0.75}$)	37.4 ± 2.7	26.0 ± 1.5
Power (W)	308 ± 21	248 ± 23
Crushed cane (kg)	372 ± 13	389 ± 26
Brix (number)	17.3 ± 0.3	16.3 ± 0.3
Crusher efficiency[1]	45.5 ± 3.1	48.0 ± 2.3
Animal efficiency[2]	898 ± 41	687 ± 20
E.E.W.[3]	0.37 ± 0.02	0.26 ± 0.02

[1,2,3] - see table 1.

There were significant increases in pulse and respiration rates and body temperature after working 45 minutes and 90 minutes in both cattle and buffaloes. Average pulse rates at 0, 45 and 90 minutes of work were 74, 97 and 97 beats/min in cattle and 56, 72 and 74 beats/min in buffaloes. Average respiration rates at 0, 45 and 90 minutes of work were 31, 45 and 46 breaths/min in cattle and 20, 25 and 26 breaths/min in buffaloes. Before work the average body temperature was 39℃ in cattle and 38.6 ℃ in buffalo. After work average body temperature showed a non-significant increase of 0.41℃ in both species. Daily ambient temperature and relative humidity during work varied between 24.4-25.5℃ and 0.66-0.72, respectively.

Live weight change and fodder and water intakes

There were significant ($p < 0.05$) decreases in live weight of cattle and buffaloes during work (table 7). The greatest change was seen in the first week. in the week after work animals gained weight.

There was no significant difference in daily feed and water intakes during the experiment, although animals tended to eat less forage and block during the first week of work (table 7).

Chemical composition of feed

In this experiment the fodder mixture (sugarcane tops and elephant grass 50:50 by fresh weight) had an average dry matter (DM) content of 137 g/kg. The crude protein content was 72 g/kg DM, gross energy was 15.0 MJ/kg and *in vitro* organic matter digestibility (VOS) was 62.3. The rice bran and urea molasses block had DM contents of 892 g/kg and 892 g/kg respectively, crude protein contents of 160 g/kg DM and 290 g/kg DM, calculated gross energies of 18.1 MJ/kg DM and 12 MJ/kg DM and the rice bran had a VOS of 89.0.

Milk yield, milk fat and milk progesterone

Average milk yields were significantly ($p < 0.05$) lower during the three week working period (average milk yield of buffaloes was 3.8 kg/d and cattle was 6.1 kg/d) than in the week before work (buffaloes 4.2 kg/d, cattle 6.8 kg/d) or the week after work (buffaloes 4.3 kg/d, cattle 6.6 kg/d). Average butter fat yields across species in the week before work (363 g/d) and in the working period (356 g/d) were not significantly different.

During the working period, with the exception of one animal, which was mated three weeks before working, the progesterone profiles of the seven animals indicated that only one buffalo showed ovarian activity postpartum. This animal then showed oestrus behaviour. Results of the progesterone analyses also indicated that two cows resumed ovarian activity during the resting period in the weeks after work (figure 1 and 2).

Discussion

Animal performance

The experiments showed that cattle and buffaloes with a live weight of over 400 kg could operate a sugarcane crusher satisfactorily either working alone or as a pair. The draught force generated by the animals was influenced by their size. The larger animals in both experiments generated a higher draught force than the smaller ones, with the combined live weight of the pairs generating the highest draught force during operation of the crusher. Work done in a given period is dependent on distance travelled as well as draught force. The cattle in both experiments consistently walked faster than the buffaloes. As a result they did more work than the buffaloes. However, this was not necessarily translated

TABLE 7. THE LIVE WEIGHT, FODDER, BLOCK AND WATER INTAKES OF LACTATING BUFFALOES AND CATTLE DURING THE FIRST (1ST) AND THE THIRD WORKING WEEK (3RD) AND THE WEEK AFTER WORKING (A) COMPARED TO THE WEEK BEFORE WORK (B)

	Week				Significance		
	B	1st	3rd	A	(B-1st)	(B-3rd)	(B-A)
Buffalo :							
Liveweight (kg)	502	485	483	491	*	**	**
Fodder intake							
(kg DM/day)	6.48	6.34	6.54	6.45	ns	ns	ns
(g DM/M$^{0.75}$)	63.1	61.7	63.5	62.5	ns	ns	ns
Block intake							
(kg DM/day)	0.35	0.42	0.43	0.37	ns	ns	ns
(g DM/M$^{0.75}$)	4.19	5.89	6.01	5.39	ns	ns	ns
Water intake							
(1/day)	27.2	26.8	24.0	25.1	ns	ns	ns
(1/kg DM/day)	3.97	3.98	3.49	3.70	ns	ns	ns
Cattle :							
Liveweight (kg)	406	392	398	405	*	ns	ns
Fodder intake							
(kg DM/day)	6.42	6.27	6.40	6.60	ns	ns	ns
(g DM/M$^{0.75}$)	71.6	69.7	71.3	73.4	ns	ns	ns
Block intake							
(kg DM/day)	1.62	1.31	1.65	1.50	ns	ns	ns
(g DM/M$^{0.75}$)	17.8	14.6	18.7	16.8	ns	ns	ns
Water intake							
(1/day)	22.9	28.3	25.9	23.3	ns	ns	ns
(1/kg DM/day)	2.92	3.87	3.25	2.93	*	ns	ns

ns: not significant difference; $^*p < 0.05$; $^{**}p < 0.01$.

into greater amounts of cane being crushed or brix produced. Different cane varieties were used during the experiments. This probably accounted for the different amounts of sugar brix produced per unit of cane crushed, rather than the differences being due to any animal species effects.

The results suggested that walking speed is important in selecting animals to work on a sugar-cane crusher, provided that the animal(s) selected are strong enough to be able to provide a high enough sustainable draught force to operate the machine. An animal with a long, active walk would seem to be preferable to a short striding animal or a lazy one, requiring constant encouragement. In this respect the cattle were better than the buffaloes, and appeared temperamentally more suited to the work.

It has been reported that oxen used singly are able to cultivate approximately 70% of the land that paired oxen can normally prepare (Jabbar, 1993). In the present study the crusher capacities of single working animals were 64-74% that of pairs. These observations suggest that whatever the task, output from an animal can be expected to be about 70% of a team i.e. the more animals that are in a team, the less work is done per animal, although the total work done can increase.

Farmers in Colombia also used single horses to operate cane-crushers. In preliminary observations in the villages (Thu, unpublished) of single horses working a similar, but slightly smaller model of cane-crusher to that used in the present experiment (roller length 14.5 cm), average draught force measured was 210 ± 12.7 N. The horses worked at a speed of 1.43 ± 0.096 m/s. This was considerably faster than the cattle and buffalo in the present study. The rate of cane crushed was 127.0 ± 9.3 kg/h, which was within the range of rates of cane crushed by the cattle working individually in this experiment (120-142 kg/h; table 1).

The draught forces used to operate the crusher in the present experiments with pairs of animals (500-1,100 N)

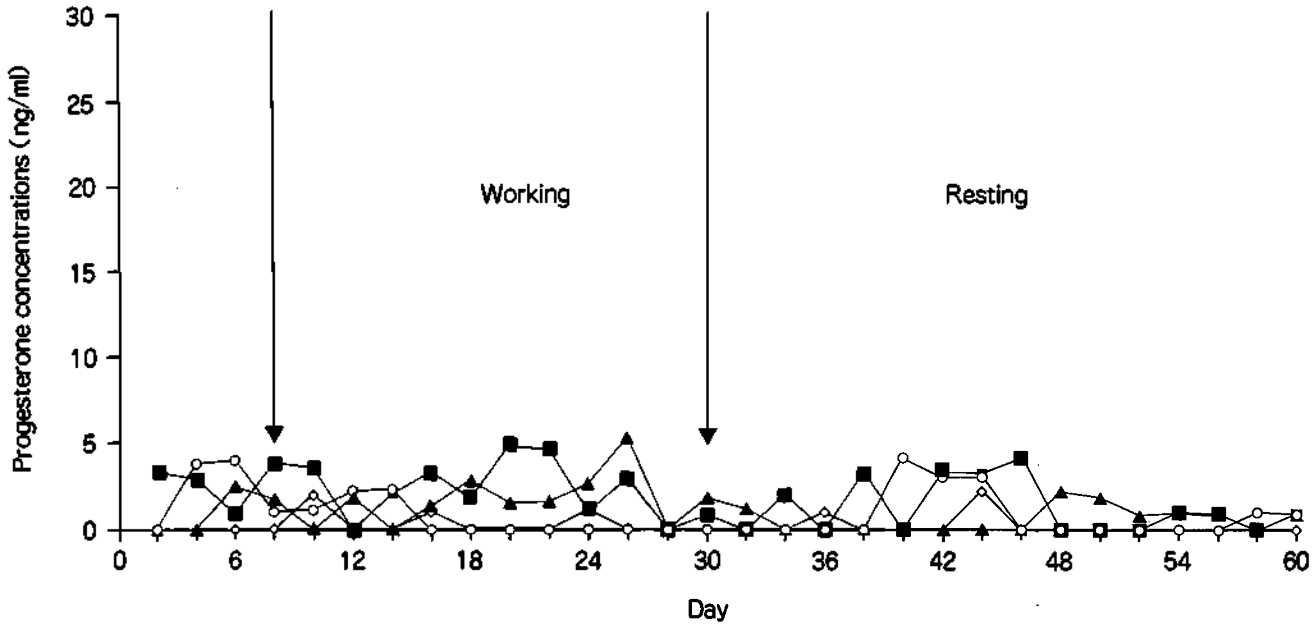

Figure 1. Milk progesterone profiles of two cattle (▲, ■) and two buffalo (◇, ○) showing no ovarian activity when operating a sugarcane crusher for three consecutive weeks.

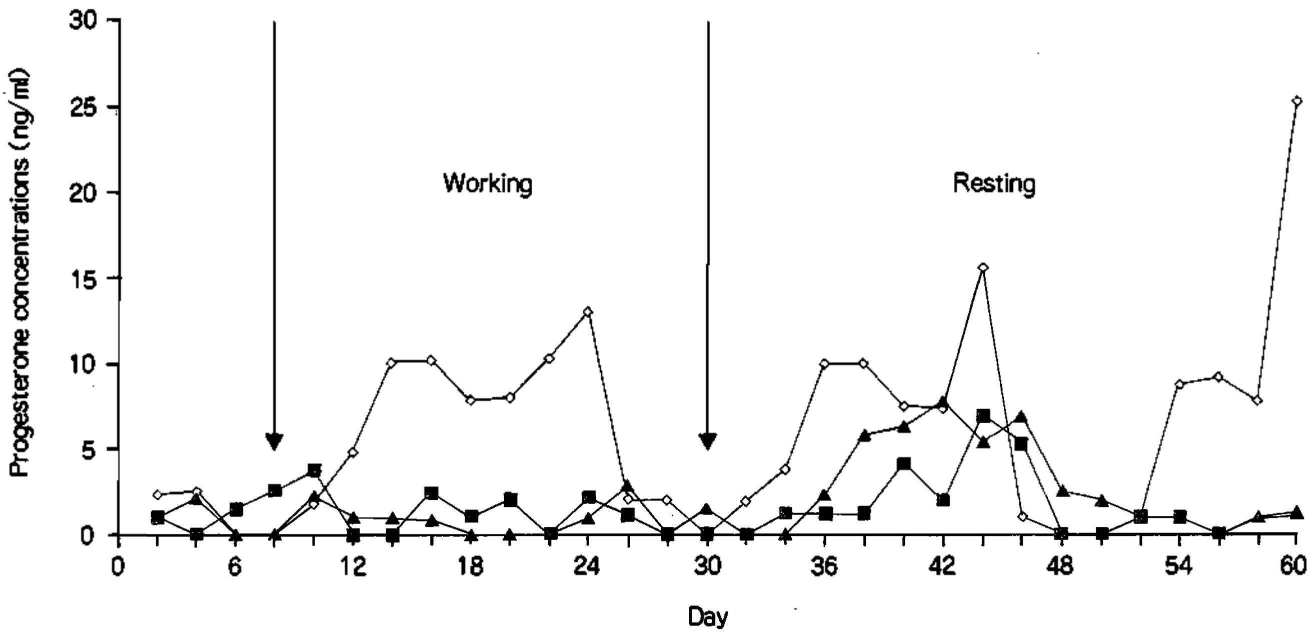

Figure 2. Milk progesterone profiles of two cattle (▲, ■) and one buffalo (◇) showing ovarian activity when operating a sugarcane crusher for three consecutive weeks.

were generally lower than those reported by Miah and Sarker (1990), who studied animal-powered sugarcane crushers in India (865-1,665 N). They reported rates of work of pairs of buffalo and cattle of 700-1,400 W, which were at least double the power output generated by single and paired animals in the present study (250-720 W). The rate of cane crushed was 144-242 kg/h (Miah and Sarker, 1990), compared with the crusher capacity in the present experiment using paired animals of 119-223 kg/hr. Clearly the amount of animal power required to operate a cane crusher is dependent on the type of machine available and the variety and age of cane crushed. These two parameters will also determine the effort required by the working animals. Miah and Sarker (1990) only considered it possible to use pairs of animals for up to three hours, before the animals tired. In the present experiment the time taken for heart rate to return to resting levels after work (table 1) and the relatively small changes in respiration rate and body temperature of the lactating cattle and buffaloes during work suggested that the work in this study was not unduly stressful. Buffaloes and cattle have shown much greater changes in respiration rates and body temperatures while working before becoming fatigued (Upadhyay and Rao, 1985; Pearson, 1989).

Estimated energy expenditures expressed as a multiple of maintenance in the present study were similar to those recorded in other farm operations. For example the estimated energy expenditures over three hours of work (0.37 ± 0.02 for cattle and 0.26 ± 0.02 for buffaloes, experiment 2) were similar to those values recorded for animals ploughing three hours in wet land (0.37 in cattle and 0.24 in buffaloes; Bakrie and Ma'sum, 1993), or carting loads for three hours over dirt tracks (0.37 in buffaloes and cattle; Pearson, 1989).

Fodder intake and live weight

According to Lawrence (1985) a roughage diet containing more than 9 MJ of ME/kg DM should be sufficiently good quality for the draught ruminant to eat enough to meet its daily requirements for work. The fodder given in the present experiment fulfilled these requirements, containing more than 9.0 MJ ME/kg DM. ($q = 0.60$). The diet was additionally supplemented with rice bran and urea-molasses block. During working weeks animals showed some weight loss (tables 2 and 7). This may have been partly associated with the reduced fodder intake seen in the working weeks.

Winugroho (1990) reported higher daily intakes and DM digestibility of rice straw/field grasses in buffaloes working for six days than in resting buffaloes that were not allowed access to food and water while the other buffaloes were working. In other studies of feed intakes by working and resting cattle consuming rice straw with and without tree fodder, and buffaloes consuming rice straw with and without field grasses, the animals consumed significantly less food, and lost weight, in the working weeks than when they were not working (Wanapat and Wachirapakorn, 1987; Bamualim and Ffoulkes, 1988; Pearson, 1990; Pearson and Lawrence, 1992). Feeding time in these studies was not restricted on resting days. Work reduced the time available for feeding, which could have at least partly accounted for the similarly reduced food intake seen in working weeks in experiment 1 of the present study. Young (1982) and Weston (1985) suggested that the increased heat load in working animals could decrease gut motility and rate of passage. This would also reduce appetite and food intake on working days. Pregnant animals in particular had higher fodder intakes and live weights in resting than in working weeks. This suggested that the effects were more marked when animals were pregnant.

In the longer term animals may adapt their intakes to meet additional requirements for work. In experiment 1, there was a gradual increase in fodder intake and live weight throughout the experiment. This upward trend has been reported in other experiments in which animals were worked over several weeks and consumed a high forage diet (Ffoulkes et al., 1987; Pearson and Lawrence, 1992). Similarly, Zerbini, et al. (1993) reported a 10% increase in the weekly intake of hay by lactating cows that were working regularly over several weeks (4 d/week), compared to intakes by lactating cows that were not being used for work. The lactating animals in experiment 2 showed little change in fodder intakes as a result of work, although values in the first week of work tended to be lower than in subsequent weeks (table 7). Animal live weight losses during working weeks did not exceed 4% live weight. Theoretical calculation of the energy requirements for maintenance, milk production (AFRC, 1993) and work (Lawrence, 1985) and calculation of energy consumption, based on DM intake and feed composition, suggested a surplus of energy consumption of 18.5 MJ/day in the lactating cattle, and a deficit of 9.08 MJ/day in lactating buffaloes in experiment two. This matched the live weight changes observed (table 7).

Work and pregnancy

Pregnant animals were able to work on the cane-crusher, but did so at a lower rate than their non-pregnant counterparts (table 1). In the cattle this difference in work performance may have been at least partly due to differences in live weight between the pregnant and non-pregnant animals, since the average live weight of the non-pregnant cattle was over 100 kg heavier than that of the pregnant group. In the buffalo, where the difference in live weight between the pregnant and non-pregnant was small (about 10 kg), pregnancy may have had a greater effect. That there is a detremental effect of pregnancy on work output is supported by current farming practices in Asia. Farmers working with pregnant cattle or buffaloes often stop working them two to four weeks before parturition when pregnancy tends to reduce work output considerably and/or their girth makes them difficult to pair up (e.g. Teleni et al., 1993). Work during pregnancy did not appear to have any deleterious effects on parturition, or survival of the calves after birth.

Effect of work on milk production and reproduction

In the present study milk yield was reduced during the working weeks in all the lactating animals regardless of the stage of lactation, but the effect was temporary, and milk yield recovered to pre-work levels in the week after work. Matthewman et al., (1993) observed similar effects of exercise on lactation in Hereford cattle. In experiment two the observation that yield of milk fat was unaffected by work, again agreed with the findings of Matthewman et al. (1993). They also observed that exercise reduced yields of milk protein and lactose and suggested that a major response to exercise was a metabolic adjustment in the use of substrates that were required for milk protein and lactose synthesis, which was transitory (Matthewman et al., 1993). This would substantiate the suggestion by Lindsay, (1959) and Leng (1980) that glucose availability may be a constraint to the maintenance of milk production during work. Interestingly, Matthewman et al. (1993) found that exercise reduced outputs of milk, milk protein and milk lactose to similar extents, whether diets were designed to have either a high or low glucogenic potential. They suggested that as the diets themselves influenced lactational performace in line with expectation, either the increased energy demands of exercise could be met non-specifically regarding the source of metabolic fuel or that for their diets, supplies of critical nutrients (e.g. glucose) were always above a minimum threshold. Clearly the interaction between work, diet and milk production warrants further investigation.

When studying the effect of work on ovarian activity of swamp buffalo cows, Bamualim, et al. (1987) concluded that there was a tendency for ovarian activity to decrease in buffalo subjected to work. Zerbini et al. (1993) reported work was associated with a delay in conception, which seemed to be independent of any dietary effects, since it was observed even when cows were supplemented. It has been suggested that reduced blood sugar levels resulting from work could affect implantation (Zerbini and Gemeda, 1993). In the present experiment, although the number of animals studied was small, the results appeared to also show a depression in ovarian activity associated with work. Clearly, further studies of the interaction of feeding, work and body condition post-partum on the return to oestrus and subsequent pregnancy in working female cattle and buffaloes is warranted. It would also be useful to analyse milk progesterone, if effects of work on reproduction are to be studied in detail.

Conclusions

The cane-crusher used in the present experiment had a lower draught requirement than other crushers (e.g. Miah and Sarker, 1990) and could be operated satisfactorily by individuals as well as pairs of buffaloes or cattle of live weights of more than 400 kg. The study showed that cattle and buffalo could be used to crush sugar cane when they were pregnant or lactating. Farmers should expect a lower work output from pregnant animals at least after the seventh month of pregnancy, and in lactating animals a transitory decrease in milk yield in working weeks.

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