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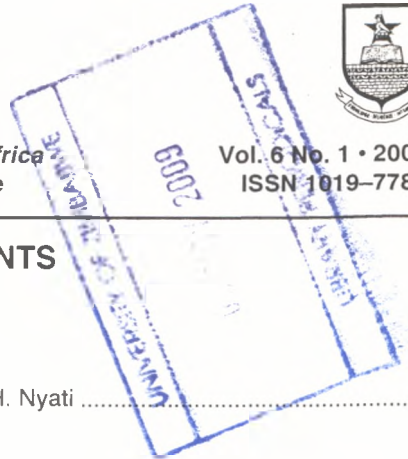
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# The potential of single-hitched donkeys (*Equus asinus*) in cultivation tasks in Zimbabwe

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This study was conducted at Matopos Research Station (Zimbabwe) during the 1995/96 summer cropping season to investigate the effect of soil type, animal sex and live weight of single-hitched donkeys in cultivation tasks. Twenty-four donkeys comprising males and females, equally represented in heavy (>130kg) and light (<130kg) weight groups were used in the study. Linear body measurements, work output and physiological parameters were measured from single-hitched donkeys. Soil type significantly affected working distance ( $P<0.01$ ) and working speed ( $P<0.001$ ), but had no significant effect ( $P>0.05$ ) on total work done. Sex had no significant effect ( $P>0.05$ ) on work output. Live weight significantly ( $P<0.001$ ) influenced working distance, draught force, elapsed working time and total work done. The single-hitched donkeys worked for a maximum period of twenty minutes per session. Linear body measurements were good predictors ( $R^2=0.41$ ,  $P<0.001$ ) of work output. Rectal body temperatures changed from pre-work resting values of  $37.6 \pm 0.01^\circ\text{C}$  to  $39.3 \pm 0.07^\circ\text{C}$  at work stoppage. Heart rates also changed from pre-work resting levels of  $54.2 \pm 2.53$  to  $118.7 \pm 3.45$  beats per minute at work stoppage. These changes were associated with the refusal by the animals to continue working. There was no significant ( $P>0.05$ ) effect of sex and live weight on heart rate and rectal temperature changes during the post-work recovery period. Only resting time significantly ( $P<0.001$ ) affected changes in the studied physiological parameters during the recovery period. The results highlighted the importance of live weight in influencing work performance of single-hitched donkeys in cultivation tasks. Heavy donkeys of either sex are more useful than light donkeys for cultivation purposes on heavy and light soils. Live weight is more useful than other linear body measurements as a predictor of work output in cultivation tasks by single-hitched donkeys. Work-related physiological changes limit the work capacity of single working donkeys in cultivation, hence adequate rest pauses are necessary.

**Keywords:** donkeys, draught animals, cultivation, work.

## Introduction

Most smallholder farmers in Zimbabwe are found in agro-ecological regions IV and V. Agricultural productivity in these areas is generally low, largely due to inadequate and untimely availability of draught power (Tembo, 1989). Cattle are the traditional source of draught power in Zimbabwe. The only alternative source of draught power in this sector is the donkey. However, a full utilization of the draught potential of the donkey is limited by inadequate information on its draught capabilities and management.

The recurrent droughts over the last two decades have resulted in severe depletion of the cattle population by up to 75 percent, leaving the majority smallholder farmers with limited access to draught power (Ellis-Jones *et al.*, 1994). Draught power shortage in Zimbabwe is evident, particularly during peak tillage operations such as land preparation, cultivation and weeding. The current land reform program in Zimbabwe is characterized by an increase in the number of smallholder and resettlement farms as well as increased demand for draught power. This program, coupled with the ailing cattle restocking exercise in communal areas have posed a great challenge on the need to exploit and efficiently utilize other available draught power resources, particularly donkeys. Donkeys are not widely used for tillage purposes in Zimbabwe, possibly because they are considered to be weak when compared to cattle and their geographical distribution is limited. Zimbabwe has an estimated donkey population of 492 000 (Central Statistical Office, 1997). They dominate in the semi-arid areas where they are well adapted due to their hardiness (Prasad, *et al.*, 1989).

Donkeys are normally hitched in teams for tillage purposes in Zimbabwe (Nengomasha, 1997). However, such harnessing practices are usually associated with energetic efficiency losses of up to 10 percent per animal, for every extra animal in the team (Barwell and Ayre, 1982; Viebig, 1982). Therefore hitching them as singles for use in light tillage tasks is one possible means of improving their utilization, thereby alleviating draught power shortage in the smallholder-farming sector. The use of donkeys as singles is not a widely practised, but potentially beneficial innovation in Zimbabwe. However, the full utilization of single-hitched donkeys in light tasks is partly hindered by limited information on their working abilities and management as singles. Available literature on donkeys reveal that, although they are light and produce less work output than draught cattle, they are able to generate work 20 percent more efficiently per kilogram of live weight (Prasad *et al.*, 1989). Thus, the exploitation of their high relative efficiency based on live weight by harnessing them as singles in light task such as cultivation could improve their utilization and reduce crop damage due to manoeuvrage problems between plant rows (Betkar and Kutzbach, 1991). The need for adjustable yokes to suit variable inter-row spacing for different crops may also be reduced.

When evaluating work performance of draught animals, there is need to consider critical factors influencing work output. These include animal species, breed, nutrition, health status, age, sex, animal size and live weight as determined

by linear body measurements (Pearson and Ouassat, 1996), animal handler, terrain, season and environmental conditions (Srivastava, 1989). The objective of the study was to investigate the effects of animal sex and live weight on the draught performance of single-hitched donkeys in cultivation tasks on different soil types. The relationship between linear body measurements and work output parameters was studied and physiological responses to work activity were characterized.

## **Materials and Methods**

### *Study site, animals and harnessing*

This study was conducted at Matopos Research Station, Zimbabwe, during the wet season of 1995 to 1996. The station lies at an altitude of 1 350 metres and receives an annual rainfall range of 500 to 700 mm and an average daily temperature of  $22 \pm 3^\circ\text{C}$ .

Twenty-four trained donkeys from Matopos Research Station and Matobo district, west of Zimbabwe were selected for the study. These were subjectively grouped into light (<130 kg) and heavy (>130 kg) weight categories, equally represented in male and female classes. During the experimental period, the donkeys grazed on natural pastures for between four and six hours a day and were allowed free access to drinking water.

A tool bar developed by The Deutsche Gesselleschaft fur Technische Zusammenarbeit (GTZ) and fitted with a single cultivator tine was used in the study. A breast band collar harness (Barwell and Ayre, 1982) with adjustable collar straps was used to link the donkey to the tool bar. The harnessed donkey was attached to the toolbar via traces from each side of the breast band harness to a swindle tree. The swindle tree was linked to the tool bar via a trek chain, 1.5m long. The study was conducted on clay and red loam soils as described by Thompson (1960) and the moisture content was subjectively considered as suitable for cultivation.

### *Experimental design, work programme and measurements*

Eight animals were used between 0600 hours and 1200 hours per working day. Each animal was hitched to perform cultivation operations for one day per soil type. The order of work by a donkey in each sex and live weight category on each soil type was randomised in a balanced design. Each cultivation session was targeted to run until the single-hitched animals showed signs of fatigue as described by Upadhyay and Madan (1985).

Mechanical work output variables, namely draught force, working distance and elapsed working time, were measured using an ergometer as described by Lawrence and Pearson (1985). A rectal thermometer probe and stethoscope were used to monitor rectal body temperature and heart rate changes respectively, from each donkey. These physiological variables were measured at rest pre-work, at work stoppage and at 5-minute intervals for up to one hour after work stoppage and were used, instead of blood metabolite analysis as indirect physiological

indicators of fatigue (Faulkner, 1981) because they are cheaper and faster to measure. Single-hitched donkeys were allowed to move at their own speed and minimum coercive force was used. Ambient temperature records (maximum, minimum, and mean) were monitored during each cultivation session. Linear body measurements were recorded from the donkeys before the trials to determine their frame size and to classify them into heavy and light weight categories using relationships described by Ely and French (1993). These include: body condition score, heart girth (cm), umbilical girth (cm), height at withers (cm), body length (cm), and foreleg cannon bone circumference (cm). Live weight was measured using a portable electronic system, Ruddweigh KM-2 (Ruddweigh Australasia, Pty. Ltd, NSW, Australia).

### *Statistical analyses*

The data was initially tested for normality using the Anderson-Darlington Normality test (Minitab Inc., 1994). Analyses of variance were performed on the data using Generalised Linear Model and Least Squares means procedures of the Statistical Analysis System (SAS, 1990) to test for the effects of soil type, animal sex and live weight on work output. Pearson's correlation analysis between the linear body measurements and work output parameters was also performed. Analysis of variance was used to test for the effects of time, sex and live weight and their interactions on, within and between animal variation in rectal temperature and heart rates post-work. Multiple regression of linear body measurements on work output parameters was performed using the forward selection procedure.

## **Results**

### *Effect of soil type, sex and live weight on work output*

There was no significant difference ( $P > 0.05$ ) in the amount of draught force exerted and total work output between red loam and clay soils (Table 1). However, working speed of donkeys varied significantly ( $P < 0.05$ ) between the two soil types. They worked faster on clay than on red loam soil. Animal sex had no significant effect ( $P > 0.05$ ) on the measured work parameters. Live weight significantly ( $P < 0.001$ ) influenced work output, with heavy donkeys across both sex categories performing better than their light counterparts, but at similar speed.

### *Relationship between linear body measurements and work output parameters*

Linear body measurements, particularly live weight were positively correlated with work output parameters (Table 2). Linear body measurements, excluding heart girth and body condition score significantly ( $P < 0.01$ ) influenced total work output. There were poor relationships ( $P > 0.05$ ) between draught force, working speed and linear body measurements. Results in Table 3 show that linear body measurements significantly affected work output ( $R^2 = 0.41$ ,  $P < 0.001$ ).

**Table 1: Work output data of single-hitched donkeys cultivating on clay and sandy loam soils at Matopos Research Station**

Work parameter	Clay soil				Red loam soil				+s.e.m	Level of significance		
	Heavy Male	Light male	Heavy female	Light female	Heavy male	Light male	Heavy female	Light female		Sex	Live weight	Soil type
Distance (km)	1.16	0.62	0.81	0.61	0.79	0.52	0.73	0.64	0.085		***	
Draught force (N)	343.8	420.9	400.7	347.4	467.1	326.1	464.7	315.1	30.853	*	***	
Working time (s)	912.2	714	1 216.4	644.4	888.7	771.2	947	678.5	104.29		***	
Speed (m/s)	0.89	0.86	0.97	0.98	0.83	0.84	0.84	0.78	0.064			*
Work done (kJ)	398.5	252.5	319	212.5	329.2	205.2	367.5	173.5	36.37		***	

\*s.e.m=standard error of mean, \*= $P < 0.05$ , \*\*\*= $P < 0.001$

**Table 2: Correlation coefficients between linear body measurements and work output parameters in cultivation.**

Trait	Work parameter				
	Distance Moved(km)	Draught force (N)	Working Time (s)	Speed (m/s)	Work Output
Lwt	0.36*	0.24	0.32*	0.15	0.46***
Hg	0.39**	0.25	0.42	0.06	0.48
Ug	0.26	0.40**	0.31	-0.07	0.46**
Htw	0.32*	0.22	0.31	-0.05	0.41**
Bl	0.19	0.41**	0.23	-0.08	0.39**
Ffcc	0.43**	0.18	0.40	-0.33	0.44**
Cs	0.27	-0.04	0.31	0.02	0.25

NB. Lwt=Live weight; Hg=Heart girth; Ug=Umbilical girth; Htw=Height at withers; Bl=Body length; Ffcc=Foreleg cannon bone circumference; Cs=Condition score; \*= $P < 0.05$ ; \*\*= $P < 0.01$ ; \*\*\*= $P < 0.001$

**Table 3: Regression equations for predicting work output parameters in cultivation with standard errors in brackets.**

Dependent Variable	a	Independent variable (b)						R <sup>2</sup>
		Lwt (kg)	Hg (cm)	Bl (cm)	Ug (cm)	Ffcc (cm)	Cs	
Distance (km)	1.01 (0.0739)	0.03 (0.001)	0.01 (0.009)	-0.01 (0.007)	—	0.06 (0.0031)	0.06 (0.043)	0.30**
Working Time (s)	1 221.81 (76.154)	2.4 (0.821)	5.62 (0.952)	—	—	52.08 (21.526)	71.91 (24.510)	0.29**
Work Output(kJ)	699.45 (83.253)	1.29 (0.545)	0.61 (0.385)	—	2.46 (0.203)	23.84 (8.725)	16.28 (6.429)	0.41***

a=intercept; b=regression coefficient; Lwt=Live weight; Hg=Heart girth; Ug=Umbilical girth; Htw=Height at withers; Bl=Body length; Ffcc=Foreleg cannon bone circumference; Cs=Condition score; R<sup>2</sup>=coefficient of variation; \*\*= $p < 0.01$ ; \*\*\*= $P < 0.001$

#### *Physiological changes associated with work activity*

Work activity resulted in an increase in rectal temperature of single-hitched donkeys from pre-work resting values of  $37.6 \pm 0.01^\circ\text{C}$  to  $39.3 \pm 0.07^\circ\text{C}$  at work stoppage. Similarly, heart rates rose from pre-work resting levels of  $54.2 \pm 2.53$  to  $118.7 \pm 3.45$  beats per minute at work stoppage. These changes were associated with the appearance of signs of fatigue and refusal of animals to continue working even under coercion. Full recovery had still not been achieved after one hour of the



recovery period. There were no significant ( $P>0.05$ ) effects of sex, live weight and their interactions on post-work variations of heart rate and rectal body temperature. Only resting time significantly influenced ( $P<0.001$ ) post-work variations of the measured physiological parameters.

## Discussion

Ideally, clay soils are expected to require more draught force and therefore difficult to work on than red loam soils due to their physical structure and high susceptibility to compaction (Ward *et al.*, 1979). However, the results of this study showed no significant differences in work performance of donkeys between the two soil types. Therefore the use of single-hitched donkeys in cultivation tasks would be beneficial to smallholder farmers in the semi-arid parts of Zimbabwe where sandy soil is the predominant type (Nengomasha, 1997).

In general, male draught animals are known to do more sustained work than their female counterparts (Howard, 1980). However, in the present study, sex of donkey did not have a significant effect on work performance, suggesting a similar draught potential between males and females in cultivation tasks as singles. In practice some farmers in the smallholder-farming sector in Zimbabwe tend to use pregnant and lactating donkeys for tillage purposes due to a shortage of draught animals and ignorance of their physiological status. Work-related stress is known to have negative effects on pregnancy, particularly in the last trimester (Nengomasha, 1997). Its effect on pregnant donkeys is currently not well documented and thus warrants further investigation.

The strong influence of live weight on work output parameters across all sex categories observed in the present study highlights its importance in determining draught capabilities of working animals. These results concur with those obtained by Barton (1987) and Bunyavjehewin (1990) in which heavy draught animals generated more work output than light animals. Smallholder farmers in Zimbabwe would benefit more from using heavy donkeys for cultivation purposes as singles. They may also secure large-framed donkeys for use as singles in cultivation, given a positive relationship between frame size and live weight (Nengomasha *et al.*, 1995; Pearson and Ouassat, 1996). The findings of this study have important implications on the feeding management of individually harnessed donkeys (Dube, 1996). In Zimbabwe, feed quality and availability fluctuate seasonally, causing live weights and work capacities of draught animals to fluctuate too (Bartholomew *et al.*, 1993). Therefore, appropriate supplementary feeding strategies of single working donkeys on crop residues should be adopted, particularly during the long dry season when veld quality is poor, to prevent weight loss and improve draught performance during the next cropping season.

According to Goe (1983), donkeys are capable of generating a draught force of up to 190 Newtons per animal. In the present study the draught forces exerted by single-hitched donkeys to pull the tool bar during cultivation were almost twice this value and were associated with continuous work for a maximum period of 15

minutes. These draught forces appear to be too high for cultivation which is generally classified as a light task (Munzinger, 1982). Practically, sustained work performance of donkeys could be achieved through ensuring appropriate calibration of the cultivator working depth and performing this operation when soil moisture content is not too low. Carrying out this operation at juvenile stages of weed growth could also help to reduce draught force exerted and prolong work performance.

Nengomasha *et al.*, (1999) suggested that speed has an effect on total work output of draught animals. However, in the present study, speed did not exhibit any quantifiable effects on total work output. The poor relationship between linear body measurements and working speed (Table 2), suggests that working speed in light tillage tasks is not a function of animal size as suggested by Upadhyay (1989), but possibly depends on animal handling, nature of terrain and variations in cultivation depth. Live weight featured as a prominent contributor in the prediction of work output using the regression equation (Table 3), possibly due to its significant relationship ( $r=0.46$ ;  $P<0.001$ , Table 2) with work output parameters. This supports the general conclusion from previous studies that work output of draught animals is largely a function of live weight (Barton, 1987).

Pre-work resting heart rates obtained in the present study fall within the range of 39 to 69 beats per minute reported for draught oxen (O'Neill, 1989). Similarly, work stoppage heart rates obtained from working donkeys also fall within the range of 105 to 140 beats per minute observed by O'Neill and Kemp (1989), and Richards and Lawrence (1984). However, the donkeys used in this study exhibited a slow rate of recovery post-work in comparison with full recovery within five minutes of work stoppage recorded in working oxen (Pearson and Archibald, 1989). The increased heart rate and rectal body temperature of working donkeys observed in the study were possibly due to the combined effect of high summer ambient temperature and increased metabolic heat generation by skeletal muscles due to work. This was a possible cause of the early onset of fatigue and work stoppage (Nielson, 1992). The post-work physiological changes in the present study highlighted the need for adequate rest periods in single-working donkeys to minimize the cumulative negative effects of lack of full recovery.

## Conclusion

The study has shown that single-hitched donkeys, regardless of sex can potentially be used for cultivation purposes on heavy and light soils. Heavy donkeys would be more useful for such tasks than light donkeys. Live weight is a more useful indicator of work performance of single-hitched donkeys in cultivation tasks than other linear body measurements. Single-working donkeys should receive adequate rest periods if work output is to be sustained. Physiological changes associated with extreme environments have not been widely studied on the working Zimbabwean donkey. Hence environment-specific work management schedules incorporating the information on physiological changes obtained in this study could help to reduce work-related heat stress and increase their work performance.

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## REFERENCES

- BARTHOLOMEW, P. W., Khibe, T., Little, D. A. and Ba, S. 1993 Effect of change in body weight and condition during the dry season on capacity for work of draught oxen. *Tropical Animal Health and Production* **26**:50-58.
- BARTON, D. 1987 Draught Power in Bangladesh. Thesis. Faculty of the school of Development Studies, University of East Anglia, UK.
- BARWELL, I. and Ayre, M. 1982 The harnessing of draught animals. Intermediate Technology Publications, Ardington, Oxfordshire, UK.
- BETKER, J. and KUTZBACH, H. D. 1991 The role of donkeys in agricultural mechanisation in Niger: Potential and limitations. In: Donkeys, mules and horses in tropical agricultural development. Fielding D. and Pearson R. A. (eds). Centre for Tropical Veterinary Medicine, University of Edinburgh, Scotland, UK., 223-230.
- BUNYAVEJCHEWIN, P. 1990 Buffalo Power in Thailand. Advances in Draught Animal Research and Development. Draught Animal Efficiency Limiting Factors. Upadhyay R. C. (ed) Sunil Publications, India.
- CENTRAL STATISTICS OFFICE (CSO) 1997 Agriculture and Livestock survey in Communal Lands 1994/95. Central Statistics Office, Harare, Zimbabwe.
- DUBE, Z. 1996 The use of single working donkeys (*Equus asinus*) in light tillage operations in Zimbabwe. M.Sc Thesis, University of Zimbabwe.
- ELLIS-JONES, J., MUVIRIMI, F., NENGOMASHA, E. M., and MSARA, P. 1994 A rapid rural appraisal of Semukwe, Chikwanda and Sebungwe communal farming areas with emphasis on the use of draught animals. Project working document No. 1. OD/94/20. Natural Resources International. Chatham, Kent, UK.
- ELY, J. L. and FRITZ, J. M. 1993 Estimating the body weight of donkeys. *Veterinary Record*, **132**:250.
- FAULKNER, J. A. 1981 Heat and contractile properties of skeletal muscle. In: Environmental Physiology: Aging, Heat and Altitude. New Hovath S. M. and Yousef M. K. (eds) New York, Elsevier, North Holland.
- GOE, M. R. 1983 Current status of research on animal traction. *World Animal Review* **45**:2-17.
- HOWARD, C. R. 1980 The draught ox: Management and uses. *Zimbabwe Rhodesia Agricultural Journal* **77**(1): 19-33.
- LAWRENCE, P. R. and PEARSON, R. A. 1985 Factors affecting the measurement of draught force, work output and power of oxen. *Journal of Agricultural Science Cambridge* **105**:703-714.
- LAWRENCE, P. R. and STIBBARDS, R. J. 1990 The energy cost of walking, carrying and pulling loads on flat surfaces by Brahman cattle and Swamp Buffalo. *Animal Production* **50**: 20-29.
- MINITAB INC. 1994 MINITAB for Windows Version 10.2. State College, Pennsylvania, USA.
- MUNZINGER, P. 1982 Animal traction in Africa. Germany Agency for Technical Cooperation (GTZ). Eschborn, West Germany.

- NENGOMASHA, E. M., PEARSON, R. A. AND SMITH, T. 1999 The donkey as a draught power resource in smallholder farming in semi-arid western Zimbabwe. 1. Live weight and food and water requirements. *Animal Science* **69**:297–304.
- NENGOMASHA, E. M. 1997 The donkey (*Equus asinus*) as a draught animal in smallholder farming areas of the semi-arid regions of Zimbabwe. PhD. Thesis, University of Edinburgh Scotland, UK.
- NENGOMASHA, E. M., PEARSON, R. A. AND JELE, N. 1995 *Phenotypic characteristics of working donkeys in Africa*. Paper given at the ATNESA Workshop 'Meeting the challenges of animal traction'. 4-8 December 1995. Ngong Hills, Kenya.
- NIELSON, B. 1992 Stress causes fatigue! Exercise performance during acute and repeated exposure to hot and dry environments. *Medical Sport Science* **34**:207-217.
- O'NEILL, D. H. 1989 Research to improve the effectiveness of ox powered cultivation (Project R3906). AFRC Institute of Engineering Research, Overseas Division report.
- O'NEILL, D. H. AND KEMP, D. C. 1989 A comparison of work outputs of draught oxen. *Journal of Agricultural Engineering Research* **43**:33-44.
- PEARSON, R. A. AND ARCHIBALD, R. F. 1989 Biochemical and haematological changes associated with periods of work in draught oxen. *Animal Production* **48**:375–384.
- PEARSON, R. A. AND OUASSAT, M. 1996 Estimation of live weight and body condition-scoring system for working donkeys in Morocco. *Veterinary Record* **138**:229–233.
- PRASAD, V. L., MAROVANIDZE, K., KHOMBE, C. T. AND NYATHI, P. 1989 The use of draught power in communal areas: Insights and interventions. Paper presented at the annual symposium. Department of Research and Specialist Services. Harare.
- RICHARDS, J. I. AND LAWRENCE, P. R. 1984 The estimation of energy expenditure from heart rate measurements in working oxen and buffalo. *Journal of Agricultural Science Cambridge* **102**:711–717.
- STATISTICAL ANALYSIS SYSTEMS, SAS. 1990 SAS/STAT Guide for personal SAS computers, North Carolina, USA.
- SRIVASTAVA, N. S. L. 1989 Research on Draught animal Power in Rural Development. In: Draught Animals in Rural Development. Hoffmann D., Nari J. and Petheram R. J. (eds). Proceedings of an International Research Symposium Cipanas, Indonesia, 3–7 July 1989 *ACIAR Proceedings* No.27. 53–60.
- TEMBO, S. 1989 Draught animal power research in Zimbabwe: current constraints and research opportunities. Hoffmann D., Nari J. and Petheram R. J. (eds). Proceedings of an International Research Symposium Cipanas, Indonesia, 3-7 July 1989. *ACIAR Proceedings* No.27, 61–68.
- THOMPSON, J. G. 1960 Matopos Research Station: soil survey report. Chemistry branch. Federal Ministry of Agriculture, Southern Rhodesia.
- UPADHYAY, R. C. 1989 Draught bullock Selection:-some consideration. *Draught Animal News* **10** 19–20.
- UPADHYAY, R. C. AND MADAN, M. L. 1985 Studies on blood acid-base status and muscle metabolism in working bullocks. *Animal Production* **40**:11–16.
- VIEBIG, E. G. 1982 Alternative energy technologies Centre for Appropriate Technology College of Engineering. Guindy, Madras, India.
- WARD, H. K., RICHARDSON, F. D., DENNY, R. P. AND DYE, P. J. 1979 Matopos Research Station: a perspective. *Rhodesia/Zimbabwe Agricultural Journal* **76**: 5–18.



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