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The donkey as a draught power resource in smallholder farming in semi-arid western Zimbabwe
2. Performance compared with that of cattle when ploughing on different soil types using two plough types

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Abstract

The work performance of two teams of four donkeys (heavy, 680 kg and light, 460 kg) and one pair of Jersey crossbred oxen (646 kg) was compared when they ploughed 4 h/day on four types of soil (clay, redsoil, sandy soil and sandy clay) using two types of plough, a conventional ox plough (40 kg) and a lighter prototype, the 'Walco' plough (32 kg) on an experimental farm. Work parameters were also measured with farmers' cattle and donkey teams ploughing on farms in Matobo and Nkayi districts. Working speed, power and effective field capacity (EFC) were higher for the ox-team (1·03 m/s, 920 W and 14·5 h/ha for the conventional plough and 0·99 m/s, 745 W and 13·9 h/ha for the Walco plough) and the heavier donkey team (0·87 m/s, 689 W and 14·2 h/ha for the conventional plough and 0·87 m/s, 787 W and 17·3 h/ha for the Walco plough) than for the lighter donkey team (0·59 m/s, 461 W and 22·1 h/ha for the conventional plough and 0·64 m/s, 445 W and 23·4 h/ha for the Walco plough). Expressed as a proportion of live weight or metabolic live weight there were no significant differences in draught forces exerted between teams but power output per unit live weight was greater in the ox-team than in the light donkey team but similar to that in the heavy donkey team. The Walco plough required a lower force (742 N) to operate than the conventional plough (816 N) but apart from this did not have any marked advantages over the conventional plough. On-farm, team sizes of donkeys varied from three to seven animals (team weight 340 kg to 1007 kg) and cattle team sizes from two to four animals (team weights 558 to 1709 kg). Regardless of team number, the heavier teams tended to out-perform the lighter teams (speed range 0·63 to 1·08 m/s, power 395 to 1136 W, EFC 9·1 to 25 h/ha)) with one exception, a well trained team of two oxen (team weight 879 kg, speed 1·02 m/s, power 775 W, EFC 9·1 h/ha). Donkeys tended to plough at a slower pace than oxen, with a lower power output, although when weight differences between teams were equalized (four heavy donkeys compared with two oxen), then there was little to chose between the species. Results suggested that teams of three or more donkeys can effectively be used for ploughing on the soils tested. The results highlighted the importance that team live weight and training/experience have in determining work performance.

Keywords: *cattle, donkeys, draught animals, ploughing, work.*

Introduction

The shortage of cattle for draught animal power (DAP), following a succession of droughts has increased the use of donkeys in crop production activities, including ploughing. For most smallholder farmers, particularly those in semi-arid areas, the donkey is the only alternative to cattle for DAP. Ellis-Jones *et al.* (1994) found that despite the increase in use, there was a lack of research and extension information available to farmers which resulted in poor management of this species. In Zimbabwe, Prasad *et al.* (1991) and Hagmann and Prasad (1995) observed that donkeys were capable of ploughing although not with the same efficiency as cattle. The lighter body weight of donkeys, when compared

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with cattle, is a disadvantage, which potentially makes them less suitable for heavy tasks such as ploughing.

Traditionally, the main plough type available to smallholder farmers in Zimbabwe is the conventional single mouldboard plough (hereafter referred to as the conventional plough). This plough was designed for use with cattle, particularly large-framed oxen, which are the preferred type of draught animal in the smallholder farming sector (Ellis-Jones *et al.*, 1994). However, because of its weight, farmers considered it to be unsuitable for use with donkeys (Ellis-Jones *et al.*, 1994), and lighter ploughs might be more appropriate. Implement manufacturers in Zimbabwe have started designing single mouldboard plough types of lower gravitational weight adapted for use with donkeys (Walco Manufacturing Pvt Ltd, Zimbabwe; Mbanje, 1997) but have not looked at them in operation. Apart from the difference in weight, there are few structural differences between the conventional and lighter ploughs designed for donkeys.

A study was carried out at Matopos Research Station to evaluate the draught performance of donkey and cattle teams ploughing on different soil types using the conventional plough and a prototype of the lighter single mouldboard plough (hereafter referred to as the Walco plough). The performance of donkeys and cattle, belonging to smallholder farmers, was also evaluated on-farm at two sites, Nkayi and Matobo Districts, in western Zimbabwe.

Material and methods

On-station study

Animals. Four male donkeys (mean age 9 years), four female donkeys (mean age 5 years) and two Jersey crossbred oxen (mean age 3 years) were used. The Jersey crossbred oxen were progeny from the Matopos smallscale Dairy Project where indigenous dams (Tuli and Nkone breeds) were mated to a Jersey bull. Three teams comprising the four male donkeys (team 1), four female donkeys (team 2) and two oxen (team 3), were formed. The total live weights of the teams at the start of the study were 680 kg, 460 kg and 646 kg for teams 1, 2 and 3, respectively. The mean body condition scores for the teams of donkeys were 7 and 5, on a scale of 1 to 9 as described by Pearson and Ouassat (1996), for teams 1 and 2, respectively. The mean body condition score for the team of oxen was 6 on a scale of 1 to 9 (Nicholson and Butterworth, 1986). The team of male donkeys was subjectively considered as 'heavy' and the team of female donkeys as 'light'. All animals had been trained to pull in the past but received a minimum of 3 weeks of practice/training in ploughing prior to the start of the study to ensure they were accustomed to work.

Ploughs. A conventional plough (Master Farmer, Bulawayo Steel Products, Zimbabwe) weighing 40 kg and the Walco plough, weighing 32 kg, were used. Apart from the weight, the main structural difference between the two ploughs was a 30% longer beam on the lighter plough designed for donkeys compared with the conventional plough beam length.

Harnessing. Animals were spanned abreast in pairs in each team. Breastband harnesses (Barwell and Ayre, 1982), were used to attach the donkey teams (teams 1 and 2) to the ploughs. The backstraps on the harnesses were adjustable, to ensure a good fit on any donkeys regardless of frame-size. Individual donkeys were attached to the plough via traces from each side of the breast band harness to individual swingle trees. The individual swingle trees of each pair of donkeys were linked via eveners to a short chain attached to the plough. For the oxen a conventional Zimbabwean double neck-yoke (Howard,1980) was used. Pairs of oxen were attached to the plough via a trek chain attached from the mid point of the double-neck yoke to the plough.

Soil types. The teams ploughed on four soil types: clay, redsoil, sandy and sandy-clay soil. A brief description of the soil types is given below (after Thompson, 1960; Ward *et al.*, 1979). (1) Clay (vertisols): black colluvial soils found mainly in valley bottoms with a high clay content (36% clay, 26% silt and 38% sand) and a high nutrient content. They are susceptible to waterlogging. (2) Redsoil: reddish-brown clay soils (36% clay, 29% silt and 35% sand) of moderate nutrient status on the low slopes. (3) Sandy: low silt and clay content (6% clay, 7% silt and 87% sand) with physical conditions ideal for plant growth. (4) Sandy clay: more clay content than sandy but retains mainly sandy soil characteristics.

Experimental design and work programme. Each team worked 1 day on each soil type. The order of work of the teams on each soil type was randomized. On a working day the team being monitored worked for 4 h/day in the morning, starting at 06:00 h and ploughed for 2 h with each plough type. Each plough was used 'first' or 'second' on an equal number of occasions with each team in a balanced design.

Measurements. An ergometer (Lawrence and Pearson, 1985) was used to measure the average draught force exerted by the animals to pull the plough and the distance covered while working. The force was measured using a load cell (type F241T of capacity 0 to 3000 N, Novatech Measurements Ltd, St Leonards-on-Sea, East Sussex, UK). This and the odometer

were linked to an electronic unit which continuously integrated force and distance to record work done. The load cell was attached between the implement and the animals so that all the force exerted by the animals passed through it in a straight line. Power, speed of working, ploughing depth (depth of cut of ploughshare), ploughing width (width of cut from landside to furrow edge), total area ploughed, effective field capacity (EFC; h/ha) and soil moisture content (samples oven dried at 60°C for 48 h) were also recorded. EFC (h/ha) was calculated from the total area worked in ha and the total work time taken from the start of the first furrow to the end of the last furrow.

Readings of the accumulated work output, distance worked and elapsed working time were taken every 15 min from the ergometer during the 2 h of working with each plough type. Teams worked at their own speed and minimal coercion was used. Ambient temperatures (maximum, minimum and mean) were monitored during ploughing sessions.

Statistical analysis. The data were initially subjected to normality and variance tests using the Anderson Darling Normality Test (MINITAB Inc., 1994) to test for requirements of analysis of variance (ANOVA). Most of the parameters did not fulfil the requirements for ANOVA. Therefore, the data were subjected to statistical analysis using non-parametric tests, namely the Mann-Whitney and Kruskal-Wallis procedures (MINITAB Inc., 1994).

On-farm studies

Animals. In Nkayi District 28 cattle (oxen, bulls and cows) and six donkeys (males and females) were used (see Table 5 for details of composition of teams). The animals belonged to smallholder farmers who were members of an irrigation scheme. In Matobo District, a total of 37 male and female donkeys belonging to smallholder farmers were studied but only those working for more than 1 h (22) were included in the analysis (see Table 5 for details of composition of teams). These farmers did not own cattle.

Procedures and measurements. In Nkayi District all teams ploughed on redsoil, the predominant soil type in the irrigation scheme. Each team ploughed an area of 0·1 ha, within their allotted area in the scheme, which took approximately 2 h. Breastband harnesses were used for the donkeys and double neck yokes for the cattle teams. Two conventional ploughs (Master Farmer, Bulawayo Steel Products, Zimbabwe) and two ergometers were used simultaneously.

In Matobo District, donkey teams ploughed on clay, redsoil, sandy and sandy-clay soils. Unlike Nkayi District, the area ploughed and the time spent working by the teams depended on the farmers' ploughing programme on the day of recording. Breastband harnesses were used. In both districts, the farmers handled the animals at all times and were encouraged to follow their normal ploughing and handling procedures. The level of coercion was monitored and subjectively rated as: *minimal* (score 1) when the coercion was considered unlikely and *excessive* (score 2) when it was considered likely to cause injury or be detrimental to the animals and their performance. The temperament of the animals was also monitored and subjectively scored as *docile or submissive* (score 1) when animals were obedient and easy to handle and *temperamental or unstable* (score 2) when animals were disobedient, stubborn, restless and difficult to handle.

Measurements of work parameters were the same as in the on-station study but two teams were recorded simultaneously each day using two ergometers. Only 1 day of measurements was possible with each team, therefore, in comparing observations with those on-station only subjective comparisons were made, based on the quantitative data obtained.

Results

On-station study

Animals. Every effort was made to ensure that all teams worked in similar weather and soil moisture conditions. The median ambient temperature during the study was 24°C and median soil moisture content was 3·1%. The donkeys were more docile and easier to work with (score 1) than the team of oxen (score 2). After opening the first furrow, both donkey teams did not require leading. However, with the team of oxen leading the animals was necessary at all times.

There were no significant differences ($P > 0.05$) between the teams in the draught forces exerted to pull either plough, although the lighter team tended to generate the lowest force (Table 1). The working speed was higher ($P < 0.05$) for the ox team (team 3) and the 'heavy' team of donkeys (team 1) compared with the 'light' team of donkeys (team 2). Similarly, the power output generated was greater ($P < 0.05$) for the oxen and the heavier donkey team than for the lighter donkey team. There were no significant differences ($P > 0.05$) between the three teams in the area ploughed, the ploughing depth and width, when using the conventional plough, although area ploughed and EFC were most favourable for the heavier teams (Table 1). When ploughing with the Walco plough, differences in EFC were significant ($P < 0.05$) between teams. The team of oxen required significantly less time to plough 1 ha than the lighter donkey team but took a similar time to that of the

Table 1 *Pooled data (medians) of two teams of donkeys and one of oxen ploughing with a conventional single mouldboard plough and a lighter plough designed for donkeys (Walco) on clay, redsoil, sandy and sandy-clay soils at Matopos Research Station*

	Conventional single mouldboard plough				Lighter single mouldboard plough (Walco)			
	Team				Team			
	1 'heavy' male donkeys	2 'light' female donkeys	3 oxen	Significance	1 'heavy' male donkeys	2 'light' female donkeys	3 oxen	Significance
Draught force (N)	867	778	900		747	685	749	
Speed (m/s)	0·87[a]	0·59[b]	1·03[a]		0·87[a]	0·64[b]	0·99[a]	
Power output (W)	689[a]	461[b]	920[a]		649[a]	445[b]	745[a]	
Area ploughed (m^2)	770	452	597		787	455	517	
Ploughing depth (cm)	13·5	13·0	15·0		12·5	12·0	13·0	
Ploughing width (cm)	26·5	24·5	28·0		26·0	24·5	26·0	
Effective field capacity (h/ha)	14·2[a]	22·1[b]	14·5[a]		17·3[ab]	23·4[b]	13·9[a]	

[a,b] Medians in the same rows with different superscripts differ significantly at $P < 0·05$.

heavy donkey team ($P < 0·05$). Differences between the EFCs of the two donkey teams using the Walco plough were not significant (Table 1).

Comparisons were also made of the performance of the donkey and ox teams based on the total team live weight (LW) and metabolic live weights ($LW^{0·75}$) when ploughing with the conventional plough on all soil types (Table 2). The total team LW and $LW^{0·75}$ weights of the heavier donkey and the ox teams were significantly higher ($P < 0·05$) than for the lighter team of donkeys. When the draught forces exerted were calculated per animal, they were higher ($P < 0·05$) for oxen than for donkeys but were not significantly different between donkey teams. Power output per animal was significantly higher ($P < 0·05$) for oxen than donkeys, while donkeys in the heavier team generated more power ($P < 0·05$) than those in the lighter team. However, when the same draught parameters were calculated per kg LW and kg $LW^{0·75}$, there were no significant differences ($P > 0·05$) in the draught forces exerted between the donkeys and the oxen (1·4, 1·7 and 1·3 N per kg LW for heavy and light donkey and the ox-teams, respectively). The power output per kg LW and kg $LW^{0·75}$ was higher ($P < 0·05$) for the oxen compared with the light donkey team but similar ($P > 0·05$) to that of the heavy donkey team. Differences between the donkey teams were not significant. Similar trends were shown when the animals were using the Walco plough.

Plough types. Apart from the draught force required to pull the ploughs which was higher ($P < 0·05$) for the conventional plough than for the Walco plough, there were no significant differences ($P > 0·05$) in the

Table 2 *Comparisons (medians) of draught forces (N) and power output (W) based on total team live weight (kg) and total team metabolic weight (kg) of teams of donkeys and oxen ploughing with a conventional single mouldboard plough on clay, redsoil, sandy and sandy-clay soils at Matopos Research Station*

Team	Total team live weight	Total team metabolic live weight†	Draught force per head	Power output per head	Draught force per kg live weight	Power output per kg live weight	Draught force per kg metabolic live weight	Power output per kg metabolic live weight
(1) 'heavy' male donkeys (no. = 4)	611[a]	174[a]	217[a]	173[a]	1·4	1·1[ab]	5·0	4·0[ab]
(2) 'light' female donkeys (no. = 4)	470[b]	143[b]	195[a]	116[b]	1·7	1·0[a]	5·5	3·2[a]
(3) Jersey crossbred oxen (no. = 2)	661[a]	155[a]	450[b]	461[c]	1·3	1·3[b]	5·5	5·6[b]
Significance	*	*	*	**		*		*

[a,b] Medians in the same column with different superscripts differ significantly at $P < 0·05$.
† Total team metabolic live weight ($LW^{0·75}$) was calculated as the $LW^{0·75}$ of each animal multiplied by the number of animals in a team.

Table 3 *Pooled data (medians) of the performance of two teams of donkeys and one of oxen ploughing with the conventional single mouldboard plough and the lighter single mouldboard plough designed for donkeys at Matopos Research Station*

	Conventional single mouldboard plough (no. = 12)†	Lighter single mouldboard plough (no. = 11)	Significance
Ploughing depth (cm)	13	12	
Ploughing width (cm)	26	26	
Draught force (N)	816[a]	742[b]	*
Speed (m/s)	0·85	0·83	
Power output (W)	677	640	
Effective field capacity (h/ha)	15·6	18·5	

† Total number of measurements from the three teams; medians in the same rows with different superscripts differ significantly at $P < 0.05$.

parameters measured between the two plough types (Table 3).

Soil types. The results presented in Table 4 were pooled for the three teams ploughing with the two plough types. Differences between the four soil types in draught force, speed of working, power output generated and EFC of the teams were not significant ($P > 0.05$). However, ploughing depth was greatest ($P < 0.01$) on sandy soils compared with the other soil types, while the ploughing width was narrowest ($P < 0.05$) on redsoils compared with the other soil types. The soil moisture content of the different soil types during the ploughing periods was similar ($P > 0.05$).

On-farm studies

Draught performance of teams on-farm in Nkayi and Matobo districts are shown in Table 5. In Matobo District, because the time spent working was largely determined by the farmers, there were wide variations between the various teams in the time spent working. Therefore, to enable more equitable subjective comparisons between these teams and those on-station, only the results of teams that worked for more than 1 h are presented. Generally, the draught performance of the animals depended on the total team LW, with the heavier teams performing better than the lighter teams. However, one lighter team in Nkayi District (team 8, Table 5) generated a greater power output, worked faster and had a better EFC than the heavier teams.

The donkey teams were generally slower, generated less power output and had a poorer EFC than the cattle teams. The draught performance of the cattle:donkey mixed team in Nkayi District (team 6, Table 5) tended to be intermediate between the cattle-only and donkey-only teams. Generally, the temperament of the animals was scored as *docile* and *submissive*, although three of the teams were considered *temperamental* and *unstable*. There was only one case where the use of coercion was considered *excessive* (not presented in Table 5).

Subjective comparisons of the on-station and the on-farm results showed little differences in the performances of the draught animal teams in the two environments.

Discussion

The results of this study showed that the draught performance of a team of four donkeys (average weight 170 kg each) can be similar to that of a team

Table 4 *Pooled data (medians) of the performance of two donkey and one ox team ploughing on four soil types using the conventional single mouldboard plough or the lighter plough designed for donkeys at Matopos Research Station*

	Soil type				
	Sandy	Clay	Redsoil	Sandy clay	Significance
Draught force (N)			731		
Speed (m/s)			0·91		
Power output (W)			698		
Effective field capacity (h/ha)			18·4		
Ploughing depth (cm)			12[b]		**
Ploughing width (cm)			24[b]		**
Soil moisture content (%)			2·9		

[a,b] Medians in the same rows with different superscripts differ significantly at $P < 0.05$.

Table 5 *Total team live weight (TLW), draught force (DF), speed, power output and effective field capacity (EFC) of cattle and donkey teams ploughing on redsoils in Nkayi and on sandy, clay, redsoils and sandy-clay soils in Matobo District*

Teams†	TLW (kg)	DF (N)	Speed (m/s)	Power (W)	EFC (h/ha)	Power output (W/kg LW)	Temperament	Coercion
Nkayi District								
(1) 4 oxen	1709	1451	0·78	1136	11·1	0·66	1	1
(2) 4 oxen	1609	908	0·76	692	14·3	0·43	2	1
(3) 3 cows, 1 bull	1387	1009	1·08	1087	10·0	0·78	1	1
(4) 3 cows, 1 bull	1102	1149	0·81	929	11·1	0·84	1	1
(5) 2 bulls, 2 oxen	974	1233	0·82	1007	12·5	1·03	1	1
(6) 2 cows + 2 donkeys	898	1119	0·75	842	14·3	0·93		1
(7) 2 bulls	893	1143	0·77	898	12·5	1·00	1	1
(8) 2 oxen	879	756	1·02	775	9·1	0·85	1	1
(9) 4 donkeys	658	823	0·62	510	14·3	0·77	1	1
(10) 2 cows	558	832	0·63	527	11·1	0·94	2	1
Matobo								
(11) 7 donkeys	1007	812	0·74	601	9·1	0·60	1	1
(12) 6 donkeys	854	794	0·60	475	12·5	0·56	1	1
(13) 6 donkeys	733	605	0·78	469	16·7	0·61	2	1
(14) 3 donkeys	340	609	0·65	395	25·0	1·16	1	1

† Teams of cattle consisted of oxen, cows or bulls; teams of donkeys consisted of males (geldings, stallions) and females in various combinations.

of two oxen of comparable team weight when ploughing. Working speed and power output was lower and EFC poorer when donkeys of average live weight of 115 kg were used for ploughing. Prasad *et al.* (1991) reported that on a weight to weight basis, the output of donkeys in southern Zimbabwe was 1·2 times higher than that of cattle. This difference was not seen in the present study. However any superiority in performance of donkeys may have been counteracted by the greater number in a team (4), compared with that in the ox team (2). Goe (1983) suggested the more animals that work in a team the less work is achieved per unit animal such that a team of four animals has a reduced performance of proportionately about 0·22 over a single animal of equivalent weight, with a team of two animals intermediate.

The draught force exerted during ploughing was similar with the ox team and the heavier donkey team when expressed as a unit of live weight (LW or $LW^{0.75}$) even though there were four animals in the team of donkeys and only two oxen.

According to the Food and Agriculture Organization (1984), donkeys are capable of producing a continuous effort of proportionately between 0·17 and 0·20 of their weight for 3 to 3·5 h/day. In the present study the draught force required to pull the ploughs averaged about 217 N per animal for the heavier donkey team (Table 2), equivalent proportionately to 0·12 of live weight. This team of donkeys was able to work continuously for 4 h without exhibiting fatigue. Draught force required to pull the plough (about 195 N per animal) was equivalent to proportionately about 0·16 of live weight for the lighter team. The significantly lower power output from this team per animal and per unit live weight and the higher EFC recorded compared with the ox-team and the other donkey team suggest that while the animals could work, performance was becoming unsatisfactory. The poorer EFC suggested stoppages were more frequent in this team, in addition to the slower speed of working.

Goe (1983) suggested that donkeys were capable of exerting draught forces equivalent to 250 N per animal. Under the conditions of the present study, the value of 250 N per donkey appears to be high for ploughing in Zimbabwe, where the duration of work can often exceed 4 h. Prasad *et al.* (1991) working with teams of four donkeys (mean live weight 120 kg) pulling sledges with a draught force requirement of 950 N (about 238 N per donkey), reported that the donkeys could only work for 2 h before signs of fatigue were observed and animals

refused to work. Betker and Kutzbach (1991) proposed that draught forces of 190 N per donkey were probably optimal for this species in Niger. Donkeys in south-western Zimbabwe weigh on average 142 kg (Nengomasha *et al.*, 1999) and, from the present study, can sustain work when ploughing at draught forces proportional to about 0·12 to 0·16 of their live weight. Hence four donkeys would be able to exert draught forces of between 180 and 222 N per animal, around the figure of 190 N per donkey proposed by Betker and Kutzbach (1991). It must be noted that even at 'optimal' exertion of draught force, the speed at which the donkeys work is an important factor affecting performance of the donkeys. Hagmann and Prasad (1995) noted that four donkeys (mean live weight 144 kg) ploughing at speeds of almost 1·1 m/s in the first 1·5 h of work and exerting draught forces of 183 N per animal, could not work more than 2·5 h/day.

The lighter Walco plough required significantly less draught force to operate it. Whether the differences in draught forces between the two plough types can be attributed to differences in the weights alone, is not known. Implement manufacturers do not always regard the weight of the plough as the most important factor in draught requirement (Inns, 1991). However in the present experiment lightening the weight seems to have been an effective means of reducing the draught force of the implement bringing it within the range of smaller animals.

The predominant soil type in the smallholder farming areas in semi-arid parts of Zimbabwe, is sandy soil. Theoretically, the physical structure of sandy soils should allow deeper penetration of the plough than on heavier clay soils which are prone to waterlogging (Ward *et al.*, 1979). This was the case in the present study where ploughing depth was significantly ($P < 0·01$) deeper on sandy soils compared with the clay soils although no significant differences ($P > 0·05$) were observed in the draught force requirements between the soil types in this instance. The soil moisture content, which can also have a significant effect on draught forces, was similar ($P > 0·05$) between the soil types during the time of ploughing, which will have helped reduce variation in the draught forces needed to plough. However it is useful to note that the common soil types within the area did not require very different draught forces to plough with a mouldboard plough and a reasonable performance can be achieved by a team of four donkeys or two oxen on any of the soils.

Performances of draught animals on–farm, as might be expected, were more variable than those on-station, although within the same range as recorded for donkeys and cattle teams on-station. Variation in experience of operators and animals, team sizes and composition as well as implements will have accounted for most of the variation. In all studies draught performance tended to improve with an increase in the total team weight (Table 5). However the variable EFCs between teams, which were not always explained by speed or power, suggest that some of the farmers were relatively inefficient in working and spent considerable amounts of work-time not moving, presumably either adjusting ploughs, resting animals or in other activities. In Nkayi, the performance of the donkey team and the cattle:donkey mixed team (teams 9 and 6, respectively, Table 5) was generally poorer when compared with the cattle only teams, reflecting the observations on-station and by others (Prasad *et al.*, 1991; Hagmann and Prasad, 1995).

Training and experience had a marked effect on a team's performance. For example in Nkayi District, a lighter team of two oxen (team 8, Table 5) which was more experienced and better trained, following voice commands, out performed a heavier team (team 2, Table 5) which showed poor temperament and lacked work experience and training. The latter team was less efficient (EFC of 14·3 h/ha compared with 9·1 h/ha for the lighter team). Large variations in the power output expressed per unit of live weight on-farm also illustrate the greater variation in performance and further emphasize the importance of training and work experience of the animals used for DAP.

The number of donkeys per team on farms in Matobo District ranged from three to seven depending on the number of animals available to the farmers. Most farmers preferred to use more animals per team citing that this enabled them to finish ploughing in time for the planting season. Sex of donkey appeared to have no measurable effects on performance and farmers would use either.

The study has shown that potentially donkeys can be used for heavy draught tasks such as ploughing provided the total team weight is sufficient to pull the plough for the period necessary to finish land preparation in time for wet season planting. When ploughing in teams of four, donkeys perform best if teamed such that the draught force required to do the work is equivalent to no more than proportionately 0·13 of the animals live weight. In this situation performance can be similar to that of an ox-team of similar combined weight over a 4-h period. Donkeys can plough at forces equivalent to 0·16 of their live weight but output is lower and is unlikely to be sustained for longer than 4 h. A lighter plough required a lower draught force to pull it in the common soil types in the area and therefore

seems to be more suitable for use with donkeys than with the heavier conventional ox-plough. The study also highlighted the effect that level of training and experience of draught animals can have on output and ease of working.

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