J. of Agril. Mach. & Mech.2(1), 1995 : 71-77

PERFORMANCE OF DRAUGHT ANIMAL AND HARNESSING SYSTEM

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ABSTRACT

Bullock. buffalo, cow and ox are commonly used as draught animals in developing south and south east Asian and some African countries. In most situations, draught animals are a more appropriate power source for the farmers. Traditionally a yoke is used to take off power from the animal' neck. Compared to tractor power very little work has been done on animal draught power and harnessing systems, their design and testing, and the economics of using draught animals. Some of the recent work on animal draught power and harnessing systems are mentioned and potential of research areas are identified.

INTRODUCTION

The importance of farm mechanization to increase production and to improve the quality of farm produce is well recognized in the agriculture of developed countries. The role of mechanization in developing countries, on the other hand, is still questioned. It is a wide-spread opinion that, due to the scarcity of capital and technical know-how and the abundance of low-cost labour and animal power, mechanization can only rarely be justified in the developing countries. The use of animal draught can be classified as the intermediate stage of mechanization. The population of working animals in several countries has been estimated by RAMASWAMY (1985) and shown Table 1. The table gives a rough guide to the global distribution of working animals. The country with the largest working animal population is India and the most prevalent species is the ox. Studies in India in 1986 found that animal power was 64% of the total available farm power in the region and that draught animals were mostly under utilized, contributing only 11% of the total required.

Selecting and adapting agricultural machinery to local conditions is not always easy. The type of machinery to be used depends on the economic standards of the local population and the ease of adoption of such machinery to the field conditions. Thus, before implementing full-scale mechanization in some developing countries, where low-cost human and animal power is abundant, importance should be given to the creation of an economic base through the efficient use of animal power. A thorough study on animal is necessary to understand how they behave and produce power under different conditions of draught, length of operating time and climate. This knowledge will also be useful for the improvement of animal-operated equipment. The design and fabrication of animal-powered equipment should be made from the experimental knowledge of draught animals.

Table 1. Estimated working animal populations by country

(million)

Country	Cattle	Bufalloes	Horse	Mule	Donkeys	Camels	Total
India	110.0	16.0	1.0	0.1	1.0	1.7	129.8
China	53.0	17.0	11.0	4.0	7.4	1.1	93.5
Bangladesh	10.0	1.0	-	-	-	-	11.0
Thailand	3.0	5.0	-	-	-	-	8.0
Pakistan	7.0	0.5	0.5	0.1	2.3	0.8	11.2
Ethopia	6.0	-	1.5	1.4	3.9	1.0	13.8
Indonesia	3.5	2.0	-	-	-	-	5.5
Burma	4.0	1.2	-	-	-	-	5.2
Nepal	2.8	2.0	-	-	-	-	4.8
Philippines	0.6	3.0	0.3	-	-	-	3.9
Mexico	2.8	-	6.5	3.2	3.2	-	15.7
Brazil	2.6	n.a.	2.0	1.7	1.7	-	8.0
Turkey	2.5	-	0.6	0.3	1.4	-	4.8
Columbia	1.3	-	1.0	0.6	0.6	-	3.5
Tanzania	1.0	-	-	-	0.2	-	1.2
Egypt	1.0	n.a.	-	-	-	-	1.0
Chile	0.3	-	0.5	-	-	-	0.8
Peru	0.1	-	0.4	0.2	0.5	1.2	2.4
Total	211.5	47.7	25.3	16.6	2.2	5.8	324.1

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Many types of agricultural equipment suitable for animals have been developed and tested in developing countries. The research results reveal that animal drawn eqtuipment could be used highly efficiently for crop production up to a certain level of farm ownership and development. From a year long survey in India, SINGH and CHANCELLOR (1974) found that the mere substitution of mechanical power for animal power in farm operation did not cause a significant increase in crop yield. Energy-wise draught animal use is also economic compared to mechanical power sources. SISWOSUMARTO (1983) found that in the case of West Java, power tiller farms used the highest energy input, followed by animal and human farms, but the yields were almost equal for both wet and dry season on those three levels of farms. SINGH and YADAO (1979) conducted a field study in the Philippines and concluded that the human cost in using power tillers was almost twice than that of using animals on rice farMw. On maize farms, the cost of using animals was one-third of that using traMwors. However, the net farm income per hectare on both farms using mechanical power was higher than that using animal power. These results and studies do not support the idea that developing countries should stop the use of animals and animal-farm implements in agriculture.

Efforts to improve the utilization of animal power and the development of efficient animal-drawn implements are still continuing. Recent research works on animal draught ability and harnessing systems are briefly reviewed and discussed in the following sections.

REVIEW AND DISCUSSION

a. Performance of bullocks

Bullocks constitute a major portion of the energy used in agriculture in developing countries. The output capacity of bullocks is generally measured in terms of their draught-ability, which is related to body weight and size. Sarker (1981) reported that the average body weight of draught bullocks in Bangladesh varies from 175 to 250 kg, whereas many reported that for various Indian and Pakistani breeds of bullock (Bos indicas), the average body weight varies from 320 to 640 kg, height (up to withers) varies from 1.6 to 1.9 m and length (shoulder point to pin bone) varies from 1.7 to 2.2m. YUSUF (1963) reported that the bullock's draft capacity was 1/10 of the body weight in a 6-hour working day. ICAR (1969) stated that the bullock's draft capacity varied from 8 to 20% of their body weight. It also stated that while ploughing, a pair of bullocks developed 0.2 to 1.4 kW of power at a travel speed of 2.3 to 27 km/h. SINGH *et.al.*(1989) conducted a study in India to investigate the performance of Hollikes bullocks in terms of speed and power developed as a function of the body size, duration of work, draught load and climate. A wheeled tool carrier with a sledge chained to it was used for the measurement of the draft. Four pairs of bullocks with an average body weight, height and length of 436 kg, 1.42 m and 1.46 m respectively were used in the experiments. The effect of duration of work on average power developed and speed of work was evaluated. The effects are shown in Fig. 1 & 2 respectively. The initial average power, 0.79 kW, developed by a pair of bullocks decreased to 0.55 kW, a 30% reduction, after 6 working hours. The average working speed after 6 hours was 26% lower than the speed at the beginning of the work. The reduction in power developed and working speed showed proportionate decrease as the working duration increased. The average speed and power output in a 6 hour working day were 3 km/h and 0.68 kw per pair. The effect of draft on the power development and working speed were also noted. It was found that an increase in the draft caused an increase in the power developed and a decrease in the working speed (Fig. 3 & 4). Approximately 90% more power was developed and the working speed was reduced when the draft was increased by 30% from 0.48 kN to 1.05 kN.

b. Performance of Oxen

It is believed that performance of Oxen varies mainly with body weight. A base line survey was conducted by GEO (1987) amongst farmers of the Ethiopian Highlands to determine the practice and extent of use of draught oxen. It was found that oxen were used approximately 50 days/year for tillage activities and 15 days/year for threshing. Daily ploughing periods averaged 5.5 hours, though generally not for more than 4 consecutive days. Oxen weighing an average of 280 kg developed an average force output equivalent to 18 - 23% of body weight, depending on the length of the fallow period and tillage frequency. Animals travelled at speeds of 0.38-0.55 m/sec. Tillage depth was 9 - 16 cm. Power output of teams averaged 0.5 kW. No significant relationship was found between team weight and force output. Land class and percentage of stone did not significantly affect force. Subsequent ploughing in preparing plots accounted for significant variation in force output. However, neither single nor multiple tillage variables adequately predicted force or power output of teams.

KEBEDE *Et.al.*(1990) conducted studies with 3 types of crossbred (Simmental X local, Jersey X local and Friesian X local) and 1 local breed of oxen. Three pairs of oxen were and used from each group. A loading cart fitted with hydraulic brakes was used to apply 3 levels of pull equal to 10%, 15% and 20% of the combined body weight of the oxen. It was found that all cross-breeds use in the study had a higher working speed compared to the local oxen (Fig. 5a). As the level of pull increased the working speed decreased for all breeds. The highest working speeds of 0.69, 0.80, 0.79 and 0.76 m/s for local, Simmental X local, Jersey X local and Friesian X local oxen, respectively were attained at the pull levels of 10% body weight. Frisian X local had a higher working speed at the heavier load compared to the other breads of oxen. The average power output of the local oxen was found to be significantly lower than the cross-bred oxen (Fig. 5b). The power output of Jersey X local oxen was significantly lower than that of the other cross-bred oxen. O'NEILL and KEMP (1989) conducted experiments on 11 pairs of oxen in India over a two year period to obtain a better understanding of the factors that influence work output. They studied seven variables, namely draught force, the angle between the line of action of the draught force and the horizontal, forward progression, heart rate, respiration rate, body temperature and steping rate. More than 50 field trials were carried out with the oxen pulling either a bakhar (a horizontally mounted blade operating at a depth of about 70 mm) or a loaded car. The performance results for each ox are summarized in Table 2.

The values illustrated the wide ranges of effort and power associated with draught animal cultivation. For the bakher, for example, the mean draught force ranged from 330 N to 1230 N and the power from 220 to 560 W. Heart rate, generally regarded as a reliable indication of work-load, correlates reasonably well with power. The linear regressions, which include resting values, are as follows:.

Ox 2: Heart rate = 0.06 * power + 72 ($r^2 = 0.89$) .....(1)
Ox 10: Heart rate = 0.58* power + 51 ($r^2 = 0.95$) .....(2)

c. Performance of buffaloes

Sarker .and Hanif (1990) reported draft out put buffaloes in sugarcane crushing in the range of Use of buffaloes as draught animals for land preparation in Bangladesh is declining over the years. Recently their utilizations are found in the transport, crushing of sugarcane.

CAUZ-FRANCISCO (1990) conducted studies at the Philippine Carabao Research and Development Canter (PCRDC), in Nueva Ecija to obtain information on draught-ability of buffaloes. Four Philippine Swamp buffaloes and four Philippine Swamp-Marrah F1 crossbred castrated male buffaloes weighing about 520 kg and 5-7 years old were compared while ploughing 2500 sq.m of paddy field and upland area. It was found that the Philippine Swamp buffaloes had a speed of 0.6 m/s in dry land ploughing and 0.51 m/s wet land ploughing. On the other hand, the Philippine-Murrah cross-breeds worked at a speed of 0.50 m/s in dry land ploughing and 0.54 m/s in wet land ploughing. There was no significance in the time taken to plough the 2500 sq.m of land. The native buffalo took about 8.89 hr and 7.14 hr to plough 2500 sq.m of dry land and were land, respectively, while the crossbred took 8.29 hr and 8.72 hr, respectively. The draw bar power of Swamp buffalo was 272 W and that of Phil-Murrah crossbreeds was 264W for were ploughing. The corresponding figures for dry ploughing were 298 W and 252 W respectively. No significance was noted between the two types. Likewise, no significant differences between types were seen in the increase in pulse, respiration, emperature and blood eosinophil concentration during work. This uggested that the crossbreeds and native buffaloes of the same bod weights had similar physiological responses to work.

Table 2. Summary of performance results (O'NE LL and KEMP,1989)

Ox Nos.	Implement	Mean horzon draft force (N)	Mean vert. force on harness (N)	Mean speed (m/s)	Mean power (W)	Mean heart rate (min^{-1})	Mean breathing rate min^{-1}	Mean stepping rate min^{-1}
2	bakhar	1277	768	0.49	59	121	23	-
2	bakhar	671	271	0.72	529	171	46	27
2	seed drill	845	325	0.91	855	126	93	40
2	took carrier	984	301	1.06	1006	125	41	43
2	load car	1212	247	0.93	1112	129	27	-
2	ditto	610	246	1.00	609	113	45	44
2	ditto	682	276	0.82	559	103	95	40
10	bakhar	328	213	0.68	218	72	49	31
10	tropicultor	557	129	0.75	485	84	54	-
10	loading car	424	138	1.01	433	77	21	-
10	ditto	1221	305	0.95	1154	-	50	-
10	ditto	782	308	0.97	731	96	88	42
10	ditto	1222	494	0.98	1191	113	82	44
15	local	257	94	0.74	212	120	38	-
15	plough	379	153	0.84	326	119	-	44
18	bakhar	485	130	0.67	365	99	38	-
18	loaded car	469	152	1.04	468	108	37	-

d. Performance of Camels

Use of camels as draught animal is found in India, Sudan, Somalia and some Arab countries. India has over 6.3% of the world camel population, the highest in the world after Somalia and Sudan. The camels are multipurpose animals primarily used for draught, transport and agricultural operations. Draught force developed by the Indian camels (camelsus dromedaries) had been measured by RAI and KHANNA (1990). It was found that the adult camels pulled loads (1200, 1500 and 1800 kg) for 4 hours at an average speed of 5 km/hr. The draught force general varied from 90 to 120 kg amounting to 17-22% of the body weight.

e. Modeling the pull developed by animals

The neck method of harnessing is most commonly used with bullocks in India. In this method, the point of hitching (i.e. the point where force acts) is located in front of the center of gravity of the body of the bullock and the line of action passes slightly above the center of the gravity. Because the line of pull is away from the center of gravity (CG) of the bullock, there is a relative torque acting round the CG in the clockwise direction. Considering those points, DEVNANI (1982) developed the following draught equation by apply the condition of equilibrium of forces for a single animal (Fig. 6).

$$P = \mu W \frac{L^{1}}{(L - \mu h_2)\, Cos\theta - \mu L_2 Sin\theta} \quad ....(4)$$

where, P = pull develop
W = weight of animal
μ = coefficient of friction between ground and feet of animal
L = distance between from and hind feet
L_1= distance of CG from the front foot of animal
L_2= distance of point of action at the yoke from the front foot of animal
θ = angle of pull with the ground.

The analysis above was given for a single animal. It would be about 90% of the value when used in pairs. The value of W in the equation would be the weight of the pair of bullocks. The change of location of the yoke will result in a change in the values of L_1, h_2 and O. Therefore, under different methods of harnessing, the value of the pull would be changed.

Taking Q as very small so that CosQ = 1 and SinQ were negligible, m = 0.3, h_2 = 0.65 L and with the center of gravity halfway between the front and hind feet, the author calculated P = 0.18 W. Thus, the theoretical maximum pull the animal can develop when moving over a level surface with a uniform velocity was 18 percent of its weight.

The author also developed equations for the trunk method of harnessing, shoulder plus trunk method of harnessing and neck plus forehead method of harnessing. The author concluded that those equations might be useful in designing an efficient harness for better draught output.

f. Performance of single animal harness

Single animals are very limitedly used in primary tillage. The possibility of using a single animal for low draught tasks, such as transport or secondary tillage and weeding, requires the selection of a good single animal yoke and a good method of harnessing to make best use of the animal's power. KEBEDE and KELEMU (1990) conducted studies to evaluate a rigid neck yoke (Fig. 71) and an improved version of the V-yoke (Fig. 7b).

In the test, an ox weighing 300 kg was used. Three draught loads of 30 kg, 45 kg and 60 kg were applied using a loading device. The results showed that the speed and power obtained by using the improved V-shaped yoke were slightly higher than those obtained using the right neck type for all loads (Table 3). The highest power output was obtained with the 45 kg load for both harnesses. With the 60 kg load, continuous encouragement was required to move the ox while working with a rigid neck yoke and sings of stress were observed.

Work on improvement of harness for a pair of animals was reported by Hussain, *et al.*(1979).Improvement of work performance was upto 25%.

An improved single ox collar and harness system (Fig. 8) has been developed and tested by WRIGHT (1990) in Lesotho, Africa. Tests had showed that oxen seemed to have more than twice as much pulling power using the new collars compared to pole yokes. A local ox of approximately 600 kg live weight pulled a harrow with 40 kg of ballast much more easily wearing the collar, than he and his team mate combined did with a pole yoke. The collar and harness costs approximately twice as much as a pole yoke system. The author concluded that only half the number of animals are required to provide if the cost of the collar was much more competitive, since the cost of the animals was usually many times greater than the cost of the harness system.

Table 3. Speed and power output of a single ox using the rigid neck yoke and modified version of V-yoke (KEVEDE and KELEME, 1990)

Load (kg)	Type of Harness			
	Improved V-yoke		Rigid neck yoke	
	Speed (m/s)	Power (W)	Speed (m/s)	Power (W)
30	0.525	150.13	0.514	146.56
45	0.442	188.18	0.426	182.98
60	0.322	182.51	0.303	174.30

SUGGESTION

Research on draught animal power utilization in the developing countries has been very limited. On the otherhand use of draught animal compared to mechanical sources is still abundant in Asian and African countries. Efforts to improve the design, fabrication and adoption of animal-drawn implements need further R&D works and studies on draught animals.The following have been identified as research areas where more attention needs to be given.

1. Development of low cost measuring device for draft output.
2. Development of relationship between weight and draft force.
3. Effect of animal type, age, speed of work, duration of work, climatic condition on power output capacities.
4. The effect of work-rest cycle on the performance of draught animals.
5. Performance of draught animal with different animal- implement combinations.
6. Development of harness or yoke based on animal and implement variables to improve draft capacity.
7. Recommend suitable management practices and safety of animals during work through ergonomic study.

The linkages and communication among the scientists of various disciplines working on draught animal should be established and strengthened in order to improve quality of tillage preparation and crop yield for the benefits of millions of farmers still using animals as power source for different farm operations.

REFERENCE

Cruz-francisco, M.L. (1990). Research on local and crossbred draught buffaloes at the PCRDC. Draught Animal News, 12: 7-8 DEVVANI, R.S. (1982). Mechanics of animal traction. Journal of Agricultural Engineering, 19(3): 71-79.

FAO (1972). The employment of draught animals in Africa. Food and Agriculture Organization of United Nations, Rome.

Goe, M.R. (1987). Animal traction on smallholder farms in the Ethiopian highlands. University Microfilms international, 300N, Zeeb Road, Ann Arbor, Michigan, USA.

ICAR (1969). Handbook of agriculture. Indian council of agricultural research, New Delhi.

Hussain,A.A.M. and Hussain, M.D. (1979). Design and dvelopment of neck harness for cattles in Bangladesh. Deparmental Report No. 1, Farm Power & Machinery Dept., Bangladesh Agric. University, Mymensingh, Bangladesh.

Kebede, A. and F. Kelemu (1990). Performance evaluation of single animal harness. Draught Animal News, 13: 16-18.

Kebede, A., Gemeda, T. and Tilahun, M. (1990). Comparative study on work performance of crossbred and local oxen. Draught Animal News 12: 14-17.

O'neill, D.H. and D.C. Kekp (1989). A comparison of work output of draught oxen. J. Agric. Eng. Res. 43, 33-44.

Rai, A.K. and N.D. Khanna (1990). Studies on draughtability in Indian Camels at the National Research Center on Camel. Draught Animal News 12: 1-4.

Ramaswamy, N.S. (1985). Draught animal power in the third world. In "An introduction to workirfg animals" ed. J.L. Falvey, MPW, Australia, 1-7.

Sarker, R.I.(1981). Research and development needs for improved utilization of animal draught power in Bangladesh. AMA, Vol. XII, No. 4,pp 24-26.

Sarker, R.I. and M. Hanif Miah (1990). Draught power requirement and performance study of animal driven sugarcane crusher. Draught Animal News No. 13.

Singh, G. and G.S. Yadao (1979). Field study of agricultural mechanization in central Mindanao, Philippines, AMA, Winter 1979.

Singh, G. and W.J. Chancellor (1974). Studies of relation between farm mechanization and crop yield, AMA, Summer 1974.

Singh, G., Premi, S.C.L. and V.M. Salokhe (1989). Performance of bullocks under different load and climatic conditions. AMA 20(4): 23-26, 30.

Siswosumarto, H. (1983). Farm mechanization planning in Jatiluhur area, M. Engg. Thesis, Asian Institute of Technology. (unpublished).

Wright, R.D. (1990). The Wright ox collar. Draught Animal News. 13: 34-36.

Yusuf, M. (1963). Increased power from domestic animals. The agricultural Engineering. Vol. 8: 9-13.

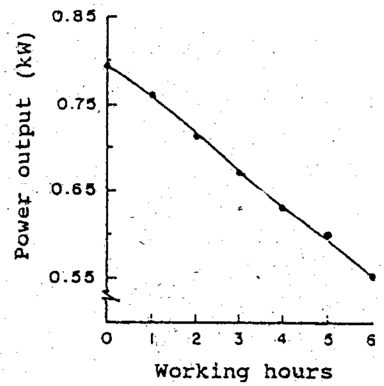

Fig. 1 : Effect of working hours on the average power output of a pair of bullocks (after Singh et al., 1989)

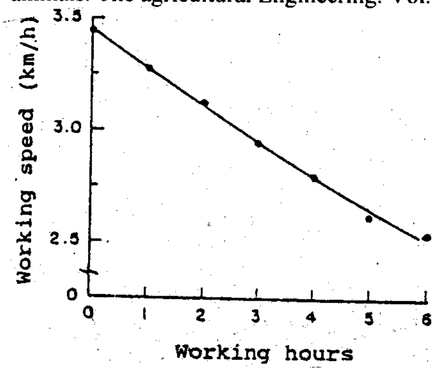

Fig. 2 : Effect of duration of work on the speed of the bullocks (after Singh et al., 1989)

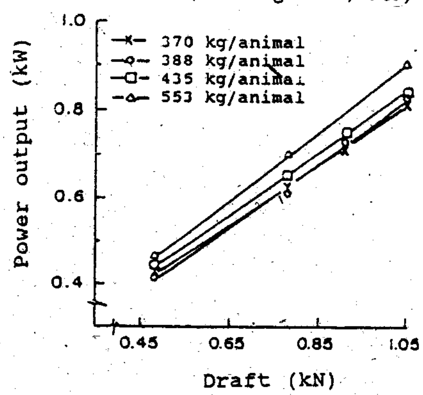

Fig. 3 : Effect of draft on the power developed by various pairs of bullocks (after Singh et al., 1989)

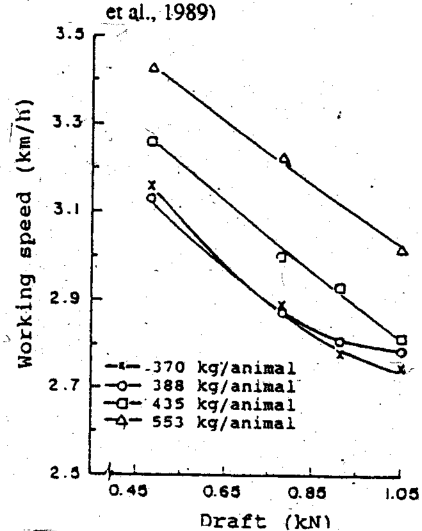

Fig. 4 : Effect of draft on the working speed of the bullocks (after Singh et al., 1989)

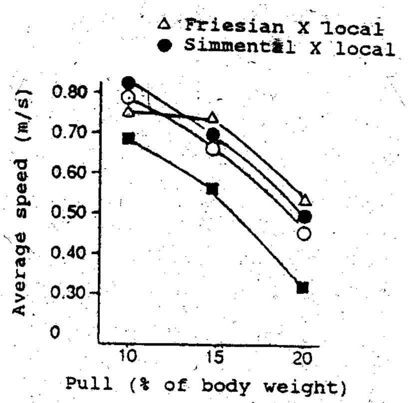

Fig. 5(a) : Average speed of cross breed and Local oxen at different levels of pull (after Kebede et al., 1990)

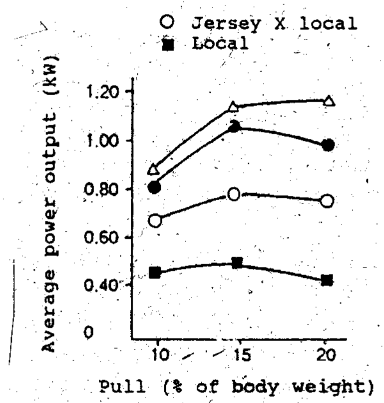

Fig. 5(b) : Average power output per pair of cross breed and local oxen at different levels of pull (after Kebede et al., 1990)

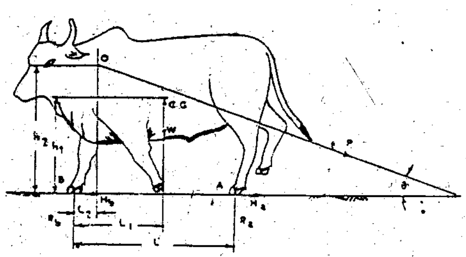

Fig. 6 : Free body diagram of forces acting on a bullock pulling an implement using neck type yoke (Devanani, 1982)

H_a = horizontal reaction at rear foot
H_b = horizontal reaction at front foot
R_c = vertical reaction at the rear foot
R_d = vertical reaction at the front foot

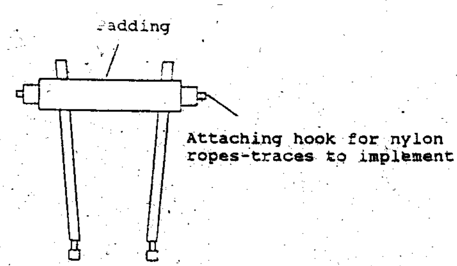

Fig. 7(a) : Wooden Ethiopian yoke modified for single animal (after Kebede and Kelemu, 1990)

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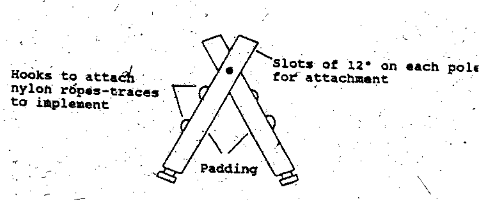

Fig. 7(b) : Improved version of the Ethiopian inverted V-yoke (after Kebede and Kelemu, 1990)

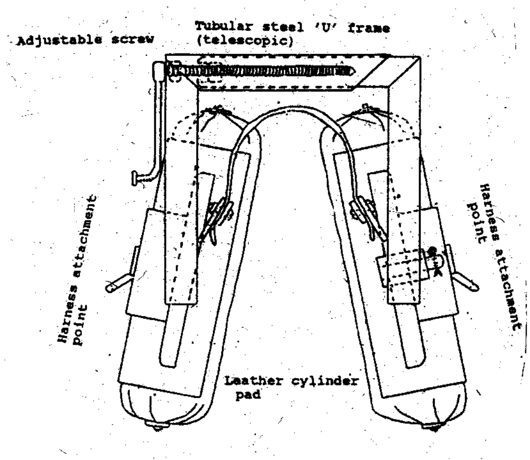

Fig. 8 : Front view of the Wright ox collar (Wright, 1990)