PERFORMANCE OF DRAFT ANIMALS AT WORK IN MOROCCO

DRAFTABILITY AND POWER OUTPUT

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SUMMARY

Key words : *Horse, mule, donkey, camel, molboard, plow, draftability, power*

A horse, 2 mules, 2 donkeys and a camel were tested as single animals and in teams with 2 types of moldboard plows and a wooden country plow. The horse and the mule, working as single animals, produced average draft force of 795 N and 923 N (30 % and 20 % of their body weights), respectively, and their power output was 973 W. A single, female camel produced 568 N average draft force (13,8 % of its body weight) and 591 W power output. In contrast, the teams of horse and donkey, and horse and mule, produced almost the same power output as that of single animals. Single animals were tired and needed rest after working for 1 h, but teams could work longer. Small and large animals experienced additional stress when teamed together because of differences in their natural walking speeds and stepping rates.

I- INTRODUCTION

In Morroco draft animals play a very important role in agriculture. They are used extensively for tillage, sowing, inter-row weedint, and transportation. An interesting feature of draft-animal use in Morocco is that different types of animals are paired in teams. Almost all possible combinations of horse, donkey, mule, and camel are used to make teams of two animals. The common implements used with draft animals are single botton molboard plow (charrue marocaine), wooden country plow (araire), pea tooth harrow, and tine harrow. The potential of multi-row seed drills and animal-drawn multipurpose wheeled tool carriers (WTC) for dryland farming is being investigated by the Centre Régional de la Recherche Agronomique (CRRA), Settat (Bansal and El Gharras, 1987). The working methods, draft, and power requirements of these equipments are different from those of conventional types. However, published information on draftability, power output, and physiological response of animals working in different teams is not available yet.

A project was carried out at CRRA in 1987, in collaboration with AFRC Institute of Engineering Research (AFRC Engineering), UK, and Institut Agronomique et Veterinaire Hassan II (IAV Hassan II). Morocco, to study the performance of draft animals. The specific objectives of the project were to study (1) the draftability, power output, and endurances of different combinations of draft animals. (2) the draft and power requirement of selected implements, and (3) the effect of different levels of load on the physiological response. This caper contains results related to objectives 1 and 2.

II- MATERIALS AND METHODS

Experiments were conducted on well leveled Vertisol fields with a horse, 2 mules, 2 donkeys, and one female camel. All animals had training and had worked before. The animals were given additional practice for one month with the test implements, prior to the experiments. During this period, problems related to harnesses, attaching implements, and fitting of sensors were resolved. Harnesses were chosen from the conventional ones used by farmers, so that harness type was not a variable in the study.

During the practice period, general health and body weight of all the animals was monitored. For those losing or gaining weight, the ration of barley was adjusted accordingly. Finally, the camel received 5 kg, horse and mules got 4 kg each, and donkeys got 2 kg each of barley every day.
Physical measures of the animals are given in Table I.

For recording data in the field, a computerized instrumentation developed by AFRC Engineering, UK, was used. This system works with a series of sensors fitted to animals and to the implement (O'Neill et al. 1987). The animal parameters recordent were heart, breathing and stepping rates, and body temperatures of one animal and the stepping rate of the second animal. The variables recorded on the implement were draft (horizontal component of pull force, N), angle of pull (deg.) and distance traveled (m).

In addition to data secured on the computerized system, certain physiological parameters on animals were recorded by clinical methods before and soon after work. These parameters were rectal temperature, heart rate, breathing rate, blood concentration of glucose, protein, potassium, sodium, and haematocrite (Benlamlih et al. 1987).

Table 2 contains details on the environmental factors during the test period and soil moisture content. In the first few passes before data logging, the working of the plow was set to avoid excessive load on animals and the radar (used for sensing distance pulses) was calibrated. Data was then logged for 2 min. The computer was then disconnected from the sensors, and the animals continued to work normally. After 20 min, it was connected again and data was logged for approximately 2 min. In this way, in about 1 h wourk data was logged at four intervals, i. e., for 2 min at the begining of the work, and at 20, 40, and 60 min from the begining.

III- TREATMENTS

Tests were conducted with 4 combinations (teams) of animals and 3 single animals for plowing, using 3 types of plows, as follows :

1. **Animal teams**
   a - Horse and donkey
   b - Horse and mule
   c - Camel and donkey
   d - Pair of donkeys
   e - Single horse
   f - Single mule
   g - Single camel

2. **Implements**
   - Moldboard plow (Charue métallique)
   - Wheeled tool carrier (WTC) with a 22 cm moldboard plow
   - Country plow (araire)

The single-bottom moldboard plow made in Morocco is about 20 cm wide, and is drawn by a chain. The WTC and the country plow have draw poles for pulling, and they cannot be attached to single animals. Thus, the pair of donkeys and single animals were tested with a moldboard plow (Charrue métallique) only.

IV- RESULTS AND DISCUSSION

1. Single animals

Data for single animals showed that the horse developed an average draft of 795 N (81 kg) during continuous work for 1 h (Table 3), which was 30 % of ils body weight. The mule weighing 460 kg gave an average draft force equivalent to 20 % of its body weight. The female camel produced 568 N (58 kg) draft force, which works out to 13.8 % of its body weight. The draftability of animals is often taken as 10-15 % of their body weights (Hopfen 1969). Tolaine and Roston (1958) reported average tractive effort of horses in Brazil to be 10-12 % of their body weight. The draft potential of mules weighing 350-500 kg was earlier reported as 50 to 60 kg (Hopfen 1969).

Figures in Table 4 show that power output of a single horse and a single mule was equal at 978 W (1.31 hp), but for the camel it was 591 W (0,79 hp). The output from the horse and the mule was higher because they worked only for 1 h. Continuous working for longer time might have lowered their walking speed and consequently the power output.

2. Teams of animals

It was generally observed that single animals were tired after 1 h of work with the moldboard plow. The horse and the mule, in particular, were observed to be sweating and breathing hard and had to be rested after 1 h. In contrast, when working in a team, both animals were comfortable and maitained uniform speed and high power ouput with the moldboard plow.

The combination of a camel and a donkey pulling a moldboard plow showed that the donkey contributed significantly to the total power output of 827 W. For some reason, the power output from this team was low for both, the WTC and the country plow. One possible explanation is that the moldboard plow drawn by a chain was easy to attach to the double-tree. But the beams of the WTC and the country plow posed harnessing problems. It appeared that the teaming of a camel with a donkey is inappropriate for working with an implement drawn through a beam, because of the differences in their heights and stepping distances.

Draft and power output of teamed animals were observed to be lower than those of individual animals working independently. In the horse and mule team, the mule used was lighter (315 kg) and older (12 years). This team produced a draft of 857 N for the moldboard plow, 803 N for the WTC, and 565 N for the country plow. The power output was 977 W for the moldboard plow, and 627 W for the country plow

(Table 4). Thus, the horse and mule together produced only about 7 % higher draft than the draft produced by the horse alone (795 N). Moreover, the power output of this team was the same as that of a single horse or the younger mule for pulling the same implement. Thus, the horse in a team with a mule was working at about 50 % of its potentail capacity.

A similar trend can be seen for other teams involving the donkey. The pulling capacity of a dondey can be estimated from the working of a team. A team of 2 donkeys gave 634 N average draft and 602 W power output (Tables 3 and 4). Assuming that both donkeys made equal efforts, then the draft and power output of one are 317 N and 301 W, respectively. On an individual animal basis, the draft and power output of the horse and donkey team work out to be 1112 N and 1279 W, and that of the camel and donkey team are 885 N and 892 W, for a moldboard plow. The horse and donkey team recorded 790 N average draft and 711 W average power output for pulling the same implement. Similarly, the camel and donkey team showed 795 N average draft and 827 W average power output. These results indicate that, on the basis of power output, the horse and donkey team worked at 56 % and the camel and donkey team at 93 % of their potential capacities.

The effect of different levels of power output of the 3 teams can be seen as an important factor determining endurance of these animals for continuous work and the need for rest. For example, the horse and mule team, working at about 50 % of its potential capacity, would have experienced less fatigue than the horse and donkey team operating at 56 % capacity, and still less than the camel and donkey team working to 96 % capacity. Thus, for pulling a moldboard plow, a camel and donkey team would have needed more frequent rests than the other teams.

3. Draft and power requirement of implements

When animals are teamed, particularly large ones such as a horse and a mule, the draft produced appears to be very much dependent on the draft requirement of the implement. For example, the moldboard plow seems to have an average draft requirement in the range of 790 n to 623 N for normal working, which also determined the pull force applied by the animals. For single camel and the pair of donkeys, this plow was set to work shallower or take lesser width of cut so that these animals could pull it. The wheeled tool carrier with attached plow recorded the highest average draft of 803 N. The country plow's draft requirement was the least averaging betwen 550 N et 636 N. Thus it can be concluded that the moldboard plow had the highest draft requirement followed by the WTC and the country plow, which needed the lowest draft. In other words, the country plow is good only for small animals or combinations of one small and one large animal (such as a donkey with a horse). On the other hand, the moldboard plow and the WTC fitted with a moldboard plow are better suited to a team of large animals such as 2 mules, 2 horses, or a combination of a horse and a mule, because of relatively higher draft and power requirements.

4. Walking speeds

Result on walking speeds (Tabel 4) show that animals walked faster or slower in a team, depending upon the walking speed of their companion. For example, the horse working alone with a moldboard plow registered an average speed of 1.23 m s -1 (leaving out the starting figure of 1.44 m = s -1). The horse slowed down to 0.90 m s-1 when it worked with a donkey, and to 1.14 m s-1 with a mule for pulling the same implement. On the contrary, the donkey and the mule, which registered individual speeds at 0.83 m s-1 and 1;06 m s-1, had to walk faster to keep pace with the horse. A camel had to slow down from 1.04 m s-1 to 0.92 m s-1 in team with a donkey for pulling a WTC or the country plow, and the dondey had to walk donkey for pulling a WTC or the country plow, and the donkey had to walk faster. This represents an additional stress on the smaller animal (donkey) and the slower animal (mule) when they are teamed with a faster (horse) or a larger (camel) animal.

5. Stepping rate vs. walking speed

The stress factor on animals in team with a larger or a smaller animal can also be seen from the relationship between their stepping rate and speed. Figure 1 shows the effect of walking speed on the stepping rate of a camel pulling the moldboard plow alone, and in a team with a donkey. For a single working animal, this relationship is almost linear (r = 0.94). But in a team with a donkey, the stepping rate of the camel was not proportionate to its speed (r = 0,70), which shows that the latter lost walking rhythm. Similar results were obtained for a donkey which had smooth stepping when harnessed with another donkey. But in team with a horse its stepping was in complete disorder with respect to walking speed. It shows that teaming of a large and a small animal together is not a good practice as it adversely affects their stepping and may be posing difficulties to both animals.

IV- CONCLUSIONS

The main conclusions of the study are as follows :

1- A team of a horse and a mule produced nearly the same or slightly less draft force and power output as was produced by a single horse pulling a moldboard plow. These animals appeared nearly exhausted after 1 h when working singly. The main effect of teaming was on capability of animals to sustain loads, which determines work duration and the need for rest.

2- In general, at the begining of work, all animals showed a high speed but slowed down within 20 min. It was found that small (donkey) and slow (mule) animals had to walk faster than their own natural rhythm when harnessed with faster (horse) and large (camel) animals. This factor could have put additional stress on them.

3- The stepping rate of animals pulling a moldboard plow independently was found to have a linear relationship with speed. However, this linear relationship was not found for an animal working in a team with a larger or a smaller animal, indicating that both animals in a team may be experiencing difficulty.

4- The country plow appeared to be suitable for small animals (a pair of donkeys) or a combination of a small animal with a large animal such as a donkey with a horse, because of its low draft and power requirements. On the other hand, the moldboard plow and the wheeled tool carrier fitted with a moldboared plow are better suited to a team of large animals because of relatively high draft and power requirements.

5- Harnessing the camel and donkey team to an implement drawn by a bean remains to be resolved satisfactorily. This team worked well with moldboard plow drawn by a chain attached to the double-tree and produced a high power output of 827 W. But because of harness problems and poor comptability of the two animals, the draft and speed of this team were reduced for the WTC and the country plow.

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Table 1 :

Physical measures of the animals tested

Animal					Height of		
Identification	type	Age (years)	Body weight (kg)	wither (m)	Rear leg hinge (buttocks) (m)	Front knee (m)	Rear knee (m)
2	Mule	4	460	1..43	1.40	0.80	0.85
3	Mule	12	315	1.48	1.50	0.87	0.95
4	Horse	4	270	1.37	1.33	0.81	0.90
5	Donkey	4	180	1.15	1.18	0.69	0.73
6	Donkey	4	170	1.14	1.22	0.71	0.78
7	Camel	4	419	1.76	1.68	1.14	1.03

Table 2 :

Details of the environmental factors from 8 to 15 November 1987, Sidi El Aydi, Morocco

	Range	Mean	CV (%)
Minimum temperature, (°C)	7-13	9.3	23.9
Maximum temperature, (°C)	18-23	21.6	8.0
Relative humidity, (%)			
at 0700 hr.	41-89	75.3	17.8
at 1400 hr.	52-82	70.9	15.1
at 1800 hr.	35-82	70.1	23.0
Soil moisture (% g g -1)	25.7-26.8	26.2	2.9

Table 3 :

Average draft force (N) applied by different teams of animals to pull 3 types of implements

	Minutes from beginning of work				Mean	SE (+)
	0	20	40	60		
Moldboard plow						
Horse and donkey	ND 1	830	776	762	790	20.7
Horse and mule	ND	856	851	864	857	3.8
Camel and donkey	673	851	861	ND	795	61.1
Pair of donkeys	542	726	ND	ND	634	51.2
Single horse	741	814	831	ND	795	27.6
Single mule	ND	938	908	ND	923	15.0
Single camel	462	674	ND	ND	568	76.5
Wheeled tool carrier with a moldboard plow						
Horse and donkey	494	856	837	ND	729	117.8
Horse and mule	833	773	ND	ND	803	30.1
Camel and donkey	ND	630	683	ND	657	26.6
Country plow						
Horse and donkey	590	703	463	787	636	70.3
Horse and mule	554	481	457	770	565	71.2
Camel and donkey	ND	639	461	ND	550	89.3

1. ND = Not determined.

Table 4 :

Average walking speed (m = s^{-1}) and power output (W) of animals for three types of implements

	Minutes from the begining of work				Average working Speed *	SE (+)	Average Power output (W)
	0	20	40	60			
Moldboard plow							
Horse and donkey	ND	1.00	0.81	0.91	0.90	0.05	711
Horse and mule	ND	1.18	1.12	1.13	1.14	0.02	977
Camel and donkey	1.32	1.05	1.03	ND	1.04	0.01	827
Pair of donkeys	1.38	0.83	ND	ND	0.83		602
Single horse	1.44	1.23	1.23	ND	1.23		978
Single mule	ND	0.97	1.15	ND	1.06	0.09	978
Single camel	1.27	1.04	ND	ND	1.04		591
Wheeled tool carrier with moldboard plow							
Horse and donkey	1.15	ND	1.13	ND	1.13		824
Horse and mule	1.33	ND	ND	ND			1068
Camel and donkey	ND	0.88	0.95	ND	0.92	0.03	604
Country plow							
Horse and donkey	1.12	1.07	1.22	1.19	1.16	0.04	738
Horse and mule	1.27	0.99	1.19	1.16	1.11	0.06	627
Camel and donkey	1.03	0.92	0.93	ND	0.92		506

* Average walking speed is the average of observations from 20 minutes onwards.
ND = Not determined

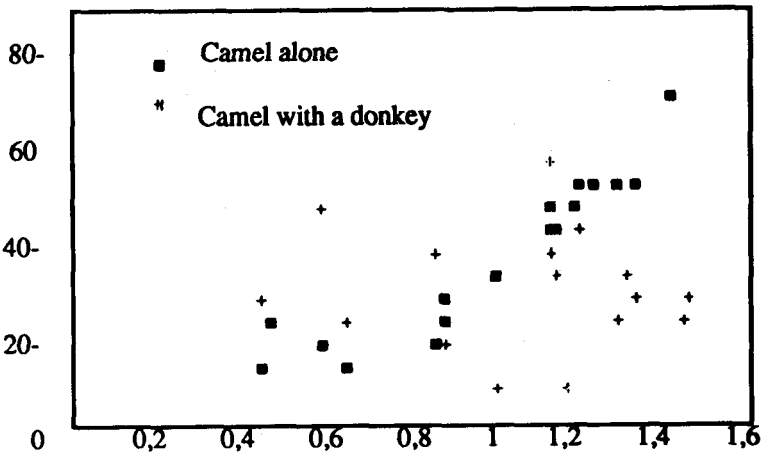

FIg. 1 Stepping rate vs. Walking speed of a camel working alone and with a donkey.

Mots clés
Abda, Chaouia, Aléa, Orge, Elevage, Aride, Sécheresse, Système de culture,

RESUME

Les auteurs exposent les résultats de recherches récentes menées sur les régions des Abdas et de la Chaouia où se côtoient plusieurs types d'agricultures et où l'élevage et l'agriculture sont des activités comparables. La place qu'occupe la première activité est illustrée par la place de choix reservée à l'orge dans les assolements organisés par les exploitations de la région qui constitue de loin la première source d'aliments pour le bétail.

En s'appuyant sur des résultats d'enquêtes les auteurs, montrent que la culture de l'orge apparait comme un facteur qui structure la sole céréalière même quand les contraintes climatiques deviennent plus sévères comme au cours des sécheresses récentes qui ont frappé la région d'étude. La culture de l'orge serait-elle l'illustration d'un parmi la panoplie des moyens que mettent en oeuvre les agriculteurs pour prendre en compte le risque climatique ?