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RESEARCH ARTICLE

Performance evaluation of an animal drawn manure spreader cum cart

■ **S. T. PATIL AND** P. A. MUNDE

ABSTRACT

Indian soils are poor in nitrogen. Nearly 1/3 rd of Indian soils are acidic. Food shortage in 1960s necessitated green revolution, ushering in the use of high dose of chemical fertilizers and poisonous plant protection chemicals adversely affecting the health of the soil. But long term use of these fertilizers causes degradation of soil, compaction and reduces soil fertility. Organic manures when incorporated into the soil it add nutrients it. Application of FYM improves soil fertility. Therefore, there is wide scope to its application. FYM contains almost all the essential nutrient required for soil. The addition of farm yard manure to the field is carried out traditionally. So there is scope of work to distribute the farm yard manure uniformly on the soil surface. By considering these aspects, an animal drawn manure spreader cum cart with electricity generation unit was design and fabricated.The research work and testing was undertaken at the site of the AICRP on UAE CAET, V.N.M.K.V., Parbhani.The developed Manure spreader consist a chassis having two iron wheels, axel assembly, bearing, flat type agitator, peg tooth agitator, body frame for mounting the trapezoidal shaped manure box, hitching system and tool box.The application rate of manure varies from 2.46 to 10.06 t/ha for varies in opining area of cover 0.04 m^2 to 0.16m^2. The co-efficient of variation of uniformity for manure distribution varied from 18 -20 per cent. The designed manure spreader cum cart gave desired manure application rate (9 – 10t/ha) at an opining area of cover 0.16m^2 at the operational speed of 2.63km/hr and draft required was 637 N. The draft and power requirement of manure spreader were 637 N and 0.46 kW, respectively within the draft ability limit of pair of bullock.The field capacity and field efficiency of machine were 0.21 ha/hrand 84 per cent at operational speed 2.51 km/hr.The manure spreader cum cart was used for carting with 500 kg load on Tar road and Kaccha road by Red Kandhari bullocks. The draft observed for Tar road with no load and 500 kg load conditions by Red Kandhari bullocks was 37 and 41 kg. respectively. The draft observed on Kaccha road for no load and 500 kg load conditions was 40 and 48 kg, respectively by Red Kandhari bullocks. Speed observed on Tar road for no load and 500 kg load conditions by RK bullock was 4.29 and 3.88 km/hr, respectively. The speed on Kaccha road was 4.04 and 3.48 km/hr, respectively. Power observed for no load and 500 kg load conditions was 0.40 and 0.43, respectively for RK bullock on tar road. And 0.43 and 0.48 Kw for no load and 500 kg load conditions, respectively on Kaccha road for RK bullock. The increased respiration rate and pulse rate was observed after 2 hrs continuous work on tar and Kaccha road is within the safe limit of fatigue score.

KEY WORDS : FYM, Agitator, Manure box, Cart, Spreader, Field efficiency, Application rate, Draft, Speed

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INTRODUCTION

Animal power is a renewable energy source that is particularly suited to family-level farming and to local transport. Animal power is generally affordable and accessible to the small holder farmers, who are responsible for

much of the world's food production. Draught animals have been used in India for field operations, transport and agro-processing. There are about 79 per cent small and marginal farmers who have limited land holdings and resources. These farmers rely on draught animals and human power for farm operations. Even today, taking 2.5 ha as command area per animal pair, over 57 per cent of the farming area is being commanded by draught animals.

The importance of livestock in India is based on their production both in terms of milk and work. The bullocks are the main source of work in all the field operation and carting on the road. Bullocks are the major source of power of Indian villages for performing various field operations. The primary use of animal husbandry in Maharashtra has been the draft utility of bullocks for different kind of agricultural operation. As per Singh (2000) with the modernization of agricultural, the use of mechanical power in agricultural has increased but draught animal power (DAP) continuous to be used on Maharashtra farms due to small holdings and mix cropping agriculture. More than 55 per cent of total cultivated area is still being managed by using draught animals against about 20 per cent by tractors and remaining one is managed by man power, power tiller and agricultural related machinery. Due to introduction of mechanical power sources the population of draught animal is declining but still more than 50 per cent net sown area is cultivated by animal power source. Draught cattle population in Maharashtra is 64 million from which gives draught cattle power of 24,47,302.22 kW. Organic manures such as farm yard manure, green manure etc., when incorporated into the soil not only add nutrients such as nitrogen etc, but the soil is enriched by the fixation of atmospheric nitrogen. The experiments with farm yard manure have shown that the physical properties of soil are improved when compared to the soil treated with artificial fertilizers.The farmyard manure application is a basic input operation in crop production. The application system includes equipment for loading of manure at storage facilities, transporting to the application sites, and applying the proper quantity of manure uniformly to soil-crop systems.

As our agriculture is facing the problems of soil degradation, loss offertility and soil health, the use of farm yard manure and organic materials is the way out. A larger portion of nitrogen is made available as and when the FYM decomposes. Availability of potassium and phosphorus from FYM is similar to that from inorganic sources. Application of FYM improves soil fertility (Reddy, 2005). Therefore, there is wide scope to its application. Constituents of FYM are dung, urine and litter. The estimated dung production for cattle is 4.5 kg/head/day (Ravindranath *et al.*, 2005).

The research study was conducted for developing the manure spreaderwas carried out at AICRP on UAE, CAET, V. N. M. K. V. Parbhani. Manure spreader was designed for the capacity of 500 kg. Opening of the manure spreader was developed for better adjustment of manure application rate in the field. For better power transmission from ground wheel to the agitator and pulverizer shaft a gear train was designed. For 90 degree motion transmission bevel gears were used.

Manure spreader was developed in such a way that it can also be used as cart in the field when manure application was not necessary.

EXPERIMENTAL PROCEDURE

Procedure :

Spreader was filled with the FYM. Manure collection plastic sheet (1×1m) were place on the ground at equal interval longitudinal to the line of travel. After engaging spreader was operated at selected speed. After the pass sheet were collected and weighed with and without manure. Manure in known area of plastic sheet was collected and weighed. Density of manure was determined and mass was calculated. Moisture content of the FYM was measured on dry basis.

Draft requirement :

Draft was calculated from the multiplication of pull into angle made by animal with the direction of travel. The draft was calculated as below.

$$D = P \cos^{-} \quad \text{.....(1)}$$

where,

D = Draft in kg

Table A : Specifications of developed Manure spreader cum cart	
Over all dimensions (l × w × h)	4100 × 1300 ×1450 mm
Weight of manure spreader	340 kg
Type of manure box	Trapezoidal shaped
Total volume	1.14 m^3
Type of spreading unit	Agitator with 32 blades of 25 mm flat, total length 1000 mm and pulverizer having 10 mm bars, 18 Nos. total length 1000 mm.
Bevel gear	Lower pair 18 and 10, Upper pair 16 and 10 teeth
Iron wheel diameter	1000 mm
Ground clearance	500 mm
Capacity	500 kg
Width of spreading	1000 mm
Power source	A pair of bullock
Suitable for	Manure spreading, transport of material.

P= Pull in kg and

θ = Angle of pull w.r.t. horizontal.

Angle of repose measurement :

When bulk granular materials are poured onto a horizontal surface, a conical pile will form. The internal angle between the surface of the pile and the horizontal surface is known as the angle of repose and is related to the density, surface area of hopper, size and shapes of the particles. Material with a low angle of repose forms flatter piles than material with a high angle of repose.

It can be calculated by formula:

$$^{-} = \tan^{-1}(h/r) \quad \text{.....(2)}$$

where,

h = Height of pile

r = Radius of pile.

Field capacity :

The field capacity of the spreader can be calculated with the help of following formulae (Sahay, 2006).

– Theoretical field capacity,

$$\text{Theoretical field capacity}\left(\frac{ha}{h}\right) = \frac{\text{Width of covrage (m) x speed}\left(\frac{km}{h}\right)}{10} \quad \text{.....(3)}$$

– Effective field capacity,

$$\text{Effective field capacity}\left(\frac{ha}{h}\right) = \frac{\text{Width of covrage (m) x length of streep (m)}}{\text{Time taken (h) x 10000}} \quad \text{.....(4)}$$

Field efficiency :

The field efficiency of the spreader was determined using following formula:

$$\text{Field efficiency (\%)} = \frac{\text{Effective field capacity}}{\text{Theoretical field capacity}} \text{x } 100 \quad \text{.....(5)}$$

FYM application rate :

The machine was calibrated for different manure application rate at different opening area. The manure application rate was calculated by using the equations given below.

$$AR = \frac{Q \times 10000}{w \times v} \quad \text{.....(6)}$$

where,
AR is manure application rate, kg/ha,
Q is the discharge of manure kg/s,
W is width of application, m
V is the forward speed of application, m/s.

Co-efficient of uniformity

The manure spreader uniformity was determined at different opening area by collecting the manure in the collecting pans placed at equal intervals.

$$Cu = 100\left(\frac{1.0 - \Sigma x}{mn}\right) \quad \text{.....(7)}$$

where,
Cu is co-efficient of uniformity, per cent,
m is average value of all observations g,
n is the total number of observations and
X is numerical deviation of individual observations from the average application rate g.

Swath determination :

The swath is the distance covered by the manure particles in the transverse direction. The measured distance covered by the manure particle from the edge of the spreading. The overlap value could be adjusted in the swath for uniform spreading.

Measurement of body temperature:

A digital thermometer was used for measurement of body temperature of bullocks.

Pulse rate:

Pulse rate was measured by placing the index or second finger on the coccygeal artery beneath the tail of bullocks and the number of beats per minute was counted. The pulse rate was measured at the start of work and at hourly interval in both the sessions.

Respiration rate:

The respiration rate was measured by counting the number of hot gushes exhaled per minute by placing the palm of hand near the nostrils of the bullocks. The respiration rate was measured at the start of work in both the session and thereafter every hour of work.

Body temperature:

The body temperature of the bullocks was measured by inserting the clinical thermometer 40 to 50 mm inside of the rectum of bullocks for two minute duration. The body temperature was measured at the start of work in both the session and thereafter every hour of work.

Physical symptoms:

In addition to physiological parameters, physical symptoms such as frothing, tongue protrusion, excitement and leg un-coordination were also observed to access the fatigue in bullocks.

Fatigue score card:

A fatigue score card suggested by Upadhyay and Madan (1985) was used to indicate comparative stage of fatigue of bullocks. The physiological parameters, namely, pulse rate, respiration rate and body temperature earn one fatigue point each which can accumulate to a maximum of 5 points for a particular parameter. Similarly five physical symptoms have also been related to fatigue in respect of frothing, leg un-coordination, excitement, inhibition of progressive movement and tongue protrusion. It has been suggested that when the grand total of such accumulated fatigue points is less than 20, an animal could be considered safe from physical stress.

EXPERIMENTAL FINDINGS AND ANALYSIS

The developed machine was tested for manure spreader cum cart by using a pair of red Kandhari breed of bullocks. The physical measurements and body dimensions of experimental bullocks are shown in Table 1.

Performance of manure spreader in field with no load:

After four replications it was observed that the speed of bullock varies from 3.1 to 2.78 km/hr in field with no load condition. Average draft requirement for manure spreader in no load condition was 399.5N and average power requirement was 0.33kW shown in Table 3.

According to field data, at no load condition draft requirement was directly proportional to speed of operation. As initially draft was lower and it increasedgradually with increase in speed during field operation. The relation between draft, speed and power at no load condition is shown in Fig. 1.

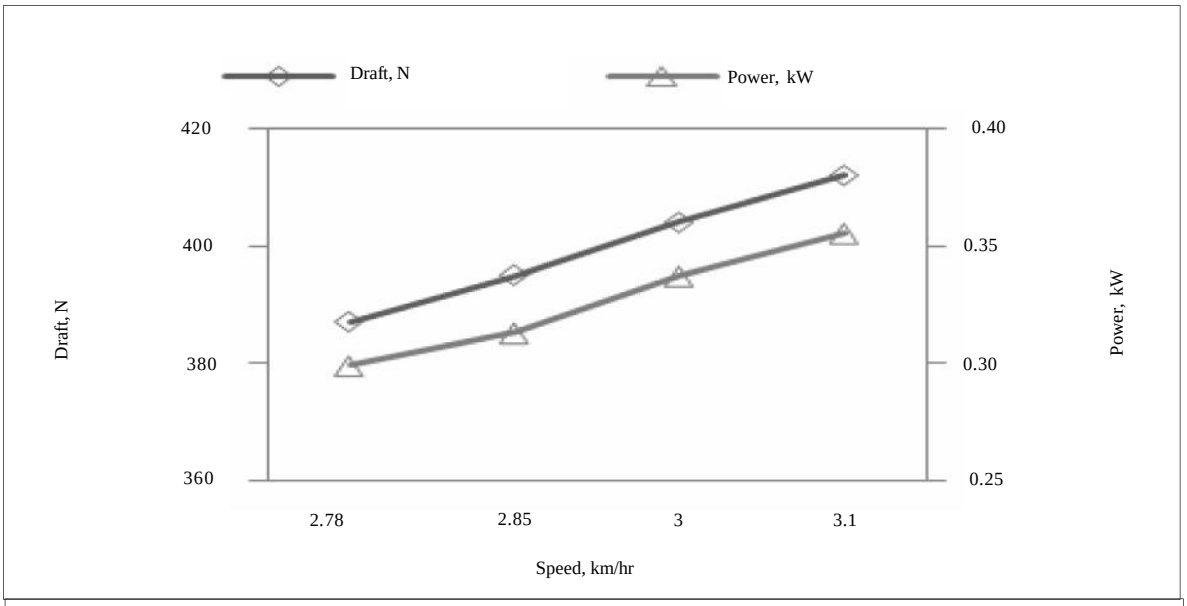

Fig. 1 : Relationship between draft, speed and power at no load condition in field

Table 1 : Physical measurements and body dimensions of experimental bullocks

Sr. No.	Particulars	RK bread of bullocks	
		B1	B2
1.	Average heart girth (mm)	1840	1880
2.	Average body length (mm)	1500	1550
3.	Average height at wither (mm)	1400	1470
4.	Body weight (kg)	445	460

Performance of manure spreader in field with 500 kg load:

The average application rate of manurewas observed 2.48 t/ha, 6.36 t/ha and 10.06 t/ha at opening area of 0.4 m^2, 0.8 m^2 and 0.16 m^2, respectively for 500 kg load in field. The co-efficient of variation was maximum at 0.04 m^2 and minimum at 0.016 m^2. The average speed of operation varies from 2.53 km/hr at 0.04 m^2 to 2.63 km/hr at 0.16m^2. Draft and power requirement for manure spreader with load of 500 kg varied from 669 N to 637 N and 0.47 kw to 0.46 kw, respectively. The draft and power requirement for manure spreader with 500 kg load is inversely proportional to the speed of operation as shown in Table 4.

Table shows that application rate of farm yard manure is 10 t/ha for opening area of 0.16 m^2 which is recommended for desired application rate.

Table 2 : Physical properties of farmyard manure at different moisture contents

Sr. No.	Moisture content % (w. b.)	Bulk density, kg/m^3	Dry matter content, %	Angle of repose, degree	Angle of friction, degree with	
					MS sheet	G I sheet
1.	20.5	292	80.5	32	33	33
2.	27.2	510	62.8	37	37	36
3.	36.4	680	63.6	39	39	38

Table 3 : Draft and power requirement for operating of manure spreader in field with no load condition

Sr. No.	Speed of operation, km/hr	Draft, N	Power, kW
1.	2.78	387	0.30
2.	2.85	395	0.31
3.	3	404	0.34
4.	3.1	412	0.35
Avg.	2.93	399	0.33

Table 4 : Application rate with respect to opening width adjusted by opening cover of rotating auger with 500 kg load

Sr. No.	Speed of operation, km/hr	Draft, N	Power, kW	Application rate, t/ha	Co-efficient of variation, %
Opening Area for discharge of manure(0.04 × 1) m^2= 0.04 m^2					
1.	2.32	658	0.42	2.67	22.1
2.	2.50	668	0.46	2.50	22.2
3.	2.60	674	0.49	2.45	22.3
4.	2.68	678	0.50	2.30	22.4
Avg.	2.53	669	0.47	2.48	22.25
Opening Area for discharge of manure(0.08 × 1) m^2= 0.08 m^2					
1.	2.44	642	0.44	6.48	19.9
2.	2.48	646	0.45	6.42	20.3
3.	2.57	654	0.47	6.30	20.8
4.	2.68	667	0.50	6.25	21.0
Avg.	2.54	652	0.46	6.36	20.5
Opening Area for discharge of manure(0.16 × 1) m^2= 0.16 m^2					
1.	2.5	625	0.43	10.17	18.0
2.	2.58	634	0.45	10.09	18.1
3.	2.63	640	0.47	10.03	18.2
4.	2.78	650	0.50	9.96	18.3
Avg.	2.63	637	0.46	10.06	18.15

From above observation it was cleared that draft requirement was directly proportional to the speed of operation for different openings of manure spreader (Fig. 2, 3 and 4).

Field performance of manure spreader:

The developed manure spreader was tested for manure application rate. The rotation of speed of manure spreading auger was 37 rpm. The quantities of manure collected in forward direction of travel were collected and weighed at opening width of 80 mm. this gave average manure delivery rate of 0.46 kg/s at bullock speed of 2.51 km/hr. The manure

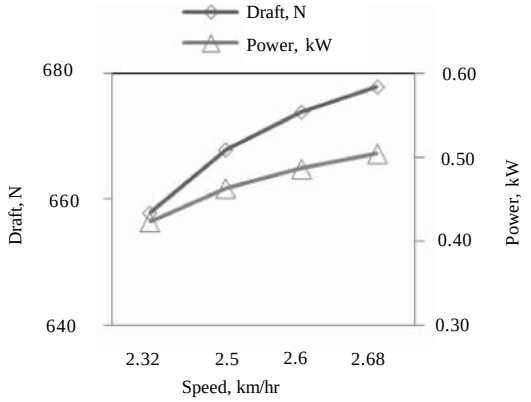

Fig. 2 : Relationship between draft, speed and power at 500 kg load for an opining area of discharge 0.4m²

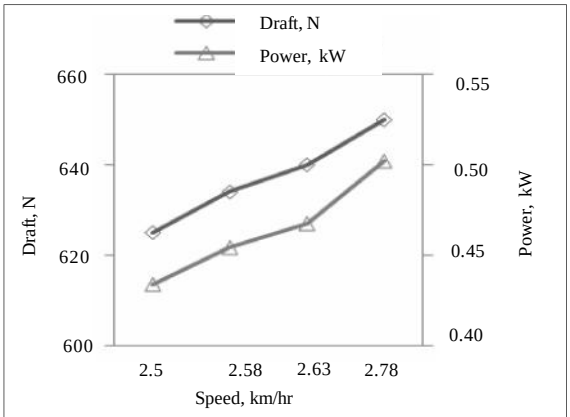

Fig. 4 : Relationship between draft, speed and power at 500 kg load for an opining area of discharge 0.16m²

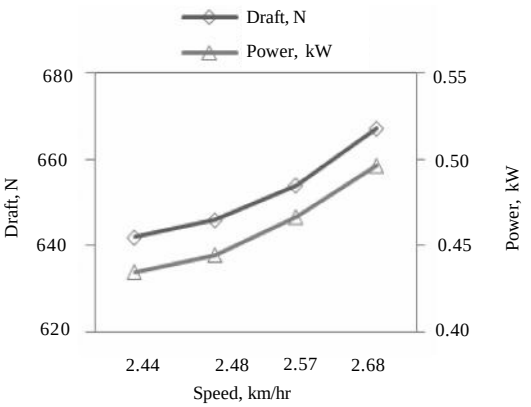

Fig. 3 : Relationship between draft, speed and power at 500 kg load for an opining area of discharge 0.8m²

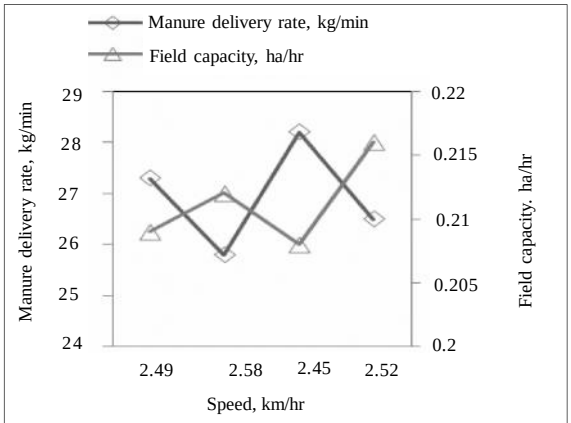

Fig. 5 : Relationship between manure delivery rate, speed and field capacity

Table 5 : Field performance of manure spreader at 80 mm opening width (Swath width = 1m)

Sr. No.	Manure delivery rate, kg/min	Speed, km/hr	Theoretical field capacity, ha/hr	Application rate, t/ha	Field capacity, ha/hr	Field efficiency, %
1.	27.3	2.49	0.249	6.57	0.209	84
2.	25.8	2.58	0.258	6.00	0.212	82
3.	28.2	2.45	0.245	6.90	0.208	85
4.	26.5	2.52	0.252	6.30	0.216	86
Avg.	27.8	2.51	0.251	6.44	0.211	84

delivery rate, application rate and field capacity of machine are given in Table 5 and presented in Fig. 5.

Testing of manure spreader for carting operation :

Testing of manure spreader for carting operation with no load condition on Tar road :

Respiration rate was increased during work with respect to time. Before work it was 20 and 21 and it was increased upto 43 and 46 after two hours for bullock 1 and bullock 2, respectively. Similarly pulse rate and body temperature were also increased with respect to time, initially pulse rate were 41 and 43 before work and it was increased upto 56 and 59 for bullock 1 and bullock 2, respectively. Body temperature was 36.9 and 37.6 before operation and during work it was increased upto 38.3 and 38.8 for bullock 1 and bullock 2, respectively. All the fatigue parameters were affected during work with respect to time (Table 6).

Testing of manure spreader for carting operation with no load condition on Kaccha road:

Respiration rate was increased during work with respect to time. Before work it was 20 and 22 and it was increased upto 46 and 50 after two hours for bullock 1 and bullock 2, respectively. Similarly pulse rate and body temperature were also increased with respect to time, initially pulse rate were 40 and 41 before work and it was increased upto 55 and 58 for bullock 1 and bullock 2, respectively. Body temperature was 36.6 and 37.4 before operation and during work it was increased upto 38.2 and 38.8 for bullock 1 and bullock 2, respectively. All the fatigue parameters were affected during work with respect to time (Table 7).

Table 6 : Physiological responses and fatigue score of red Kandhari bullock for cart operation with no load condition on Tar road

Parameters	Before work		After 30 min		After 60 min		After 90 min		After 120 min	
	B1	B2	B1	B2	B1	B2	B1	B2	B1	B2
Respiration rate (breath/min)	20 (0)	21(0)	26 (0)	29 (0)	32 (0)	34 (0)	39(1)	41(1)	43(1)	46 (1)
Pulse rate (beats/min)	41 (0)	43 (0)	44 (0)	46 (0)	47(0)	50 (0)	52 (1)	54 (1)	56 (1)	59 (1)
Body temp (^{0}C)	36.9 (0)	37.4 (0)	37.6 (1)	37.7 (0)	37.8 (1)	38 (1)	38 (2)	38.4 (2)	38.3 (2)	38.8 (2)
Frothing	0	0	0	0	1	0	1	1	2	2
Leg co-ordination	0	0	0	0	0	1	1	2	2	2
Tongue protrusion	0	0	0	0	0	0	1	1	1	2
Excitement	0	0	0	0	0	1	1	1	1	2
Inhibition of progressive movement	0	0	0	1	1	1	2	2	2	3
Total fatigue score	0	0	1	1	3	4	10	11	12	15

Table 7: Physiological responses and fatigue score of red Kandhari bullock for cart operation with no load condition on Kaccha road

Parameters	Before work		After 30 min		After 60 min		After 90 min		After 120 min	
	B1	B2	B1	B2	B1	B2	B1	B2	B1	B2
Respiration rate (breath/min)	20 (0)	22(0)	25(0)	28(0)	32 (0)	36 (0)	40(1)	45(1)	46(1)	50 (2)
Pulse rate (beats/min)	40 (0)	41 (0)	43 (0)	45 (0)	47(0)	50 (0)	50 (1)	54 (1)	55(1)	58(1)
Body temp (^{0}C)	36.6(0)	37.4(0)	37.1 (1)	37.8(0)	37.5(1)	38.2(1)	38(2)	38.6(2)	38.2(3)	38.8 (3)
Frothing	0	0	0	0	1	1	1	2	2	2
Leg co-ordination	0	0	0	0	0	1	1	2	2	2
Tongue protrusion	0	0	0	0	1	1	1	1	1	2
Excitement	0	0	0	0	0	1	1	2	2	2
Inhibition of progressive movement	0	0	1	1	1	1	2	2	2	3
Total fatigue score	0	0	2	1	4	6	10	13	14	17

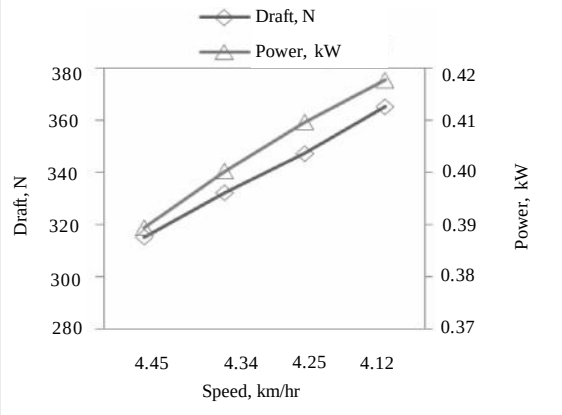

Fig. 6 : Relationship between draft, speed and power at no load condition on Tar road

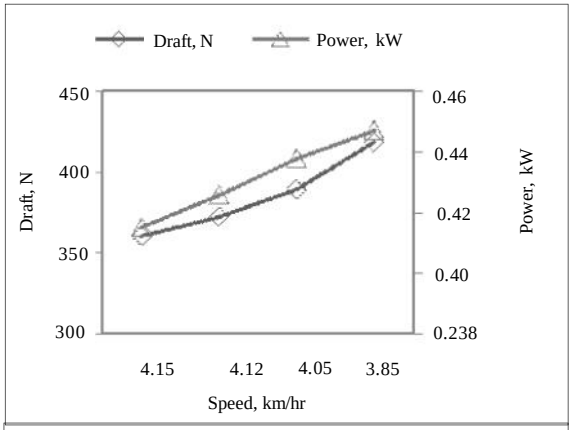

Fig. 7 : Relationship between draft, speed and power at no load condition on Kaccha road

The speed of bullock varies from 4.12 to 4.45 km/hr on Tar road and 3.85 to 4.15 km/hr on Kaccha road with no load condition. Average draft requirement for manure spreader was 340 N and 385 N, average power requirement was 0.40 kW and 0.43 kW with no load condition on Tar and Kaccha road, respectively (Table 8).

The draft and power requirement of manure spreader for carting operation with no load condition on Tar and Kaccha road inversely proportional to the speed (Fig. 6 and 7).

Testing of manure spreader for carting operation with 500kg load condition on Tar road:

Respiration rate was increased during work with respect to time. Before work it was 19 and 22 and it was

Table 8: Draft and power requirement of manure spreader for cart operating with no load condition on Tar road and Kaccha road

Sr. No.	Tar road			Kaccha road		
	Speed of operation, km/hr	Draft (N)	Power, kW	Speed of operation, km/hr	Draft (N)	Power, kW
1.	4.12	365	0.42	3.85	418	0.45
2.	4.25	347	0.41	4.05	389	0.44
3.	4.34	332	0.40	4.12	372	0.43
4.	4.45	315	0.39	4.15	360	0.42
Avg.	4.29	340	0.40	4.04	385	0.43

Table 9: Physiological responses and fatigue score of red Kandhari bullock for cart operation with 500 kg load condition on Tar road

Parameters	Before work		After 30 min		After 60 min		After 90 min		After 120 min	
	B1	B2	B1	B2	B1	B2	B1	B2	B1	B2
Respiration rate (breath/min)	19 (0)	22 (0)	26 (0)	27 (0)	32 (0)	33 (0)	40 (1)	43 (1)	49 (2)	52 (2)
Pulse rate (beats/min)	40 (0)	42 (0)	44 (0)	47 (0)	49 (0)	53 (1)	56 (1)	58 (1)	60 (2)	63 (2)
Body temp (^{0}C)	37.1 (0)	37.4 (0)	37.8 (1)	37.9 (1)	38 (1)	38.2 (1)	38.3 (2)	38.5 (2)	38.6 (3)	38.9 (3)
Frothing	0	0	0	0	1	1	1	2	2	2
Leg co-ordination	0	0	0	0	1	1	1	2	2	2
Tongue protrusion	0	0	0	0	1	1	1	1	1	2
Excitement	0	0	0	0	0	1	1	2	2	2
Inhibition of progressive movement	0	0	1	1	1	2	2	2	2	3
Total fatigue score	0	0	2	2	5	8	10	13	16	18

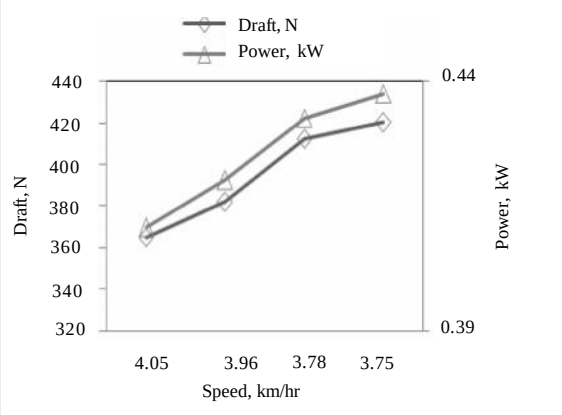

Fig. 8 : Relationship between draft, speed and power at 500 kg load condition on Tar road

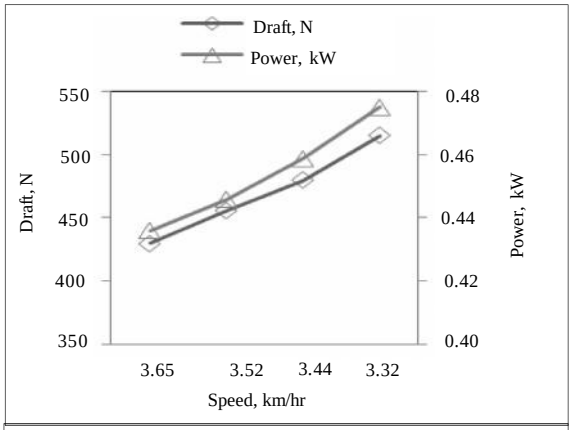

Fig. 9 : Relationship between draft, speed and power at 500 kg load condition on Kaccha road

increased upto 49 and 42 after two hours for bullock 1 and bullock 2, respectively. Similarly pulse rate and body temperature were also increased with respect to time, initially pulse rate were 40 and 42 before work and it was increased upto 60 and 63 for bullock 1 and bullock 2, respectively. Body temperature was 37.1 and 37.4 before operation and during work it was increased upto 38.6 and 38.9 for bullock 1 and bullock 2, respectively. And all the fatigue parameters were affected during work with respect to time (Table 9).

Testing of manure spreader for carting operation with 500kg load condition on Kaccha road:

Respiration rate was increased during work with respect to time. Before work it was 21 and 20 and it was

Table 10 : Physiological responses and fatigue score of red Kandhari bullock for cart operation with 500 kg load condition on Kaccha road

Parameters	Before work		After 30 min		After 60 min		After 90 min		After 120 min	
	B1	B2	B1	B2	B1	B2	B1	B2	B1	B2
Respiration rate (breath/min)	21 (0)	20 (0)	26 (0)	24 (0)	33 (0)	32 (0)	41 (1)	39 (1)	53 (2)	51 (2)
Pulse rate (beats/min)	41 (0)	42 (0)	44 (0)	46 (0)	49 (0)	52 (1)	57 (1)	59 (1)	62 (2)	64 (2)
Body temp (^{0}C)	36.9 (0)	37.1 (0)	37.5 (1)	37.8 (1)	37.9 (2)	38.2 (2)	38.4 (3)	38.5 (2)	38.7 (3)	38.9 (3)
Frothing	0	0	0	0	1	1	2	2	2	2
Leg co-ordination	0	0	0	0	1	1	1	2	2	2
Tongue protrusion	0	0	0	0	1	1	1	1	1	2
Excitement	0	0	0	1	1	1	2	2	2	3
Inhibition of progressive movement	0	0	1	1	1	2	2	2	3	3
Total fatigue score	0	0	2	3	7	9	13	13	17	19

Table 11 : Draft and power requirement of manure spreader for carting operation with 500 kg load condition on Tar road and Kaccha road

Sr. No.	Tar road			Kaccha road		
	Speed of operation, km/hr	Draft (N)	Power, kW	Speed of operation, km/hr	Draft (N)	Power, kW
1.	3.75	420	0.44	3.75	515	0.47
2.	3.78	412	0.43	3.78	480	0.46
3.	3.96	382	0.42	3.96	456	0.45
4.	4.05	365	0.41	4.05	430	0.44
Avg.	3.88	395	0.43	3.88	470	0.48

increased upto 53 and 51 after two hours for bullock 1 and bullock 2, respectively. Similarly pulse rate and body temperature were also increased with respect to time, initially pulse rate were 41 and 42 before work and it was increased upto 62 and 64 for bullock 1 and bullock 2, respectively. Body temperature was 36.9 and 37.1 before operation and during work it was increased upto 38.7 and 38.9 for bullock 1 and bullock 2, respectively. All the fatigue parameters were affected during work with respect to time (Table 10).

The speed of bullock varies from 3.75 to 4.05 km/hr on Tar road and 3.32to 3.65 km/hr on Kaccha road with 500 kg load condition. Average draft requirement for manure spreader was 395 Nand 470 N, average power requirement was 0.43 kW and 0.48 kW with 500 kg load condition on Tar and Kaccha road, respectively (Table 11).

The draft and power requirement of manure spreader for carting operation with 500 kg load condition on Tar and Kaccha road inversely proportional to the speed (Fig. 8 and 9).

For carting operation in Tar road and Kaccha road for both load and no load conditions, draft requirement was reduced with respect to increase in speed. As co-efficient of friction in axle bearing is considered negligible. Dynamic forces acting on the cart were higher due to increase in speed and due to this draft requirement was lower. But for lower speed dynamic forces were less and because of gravitational loads draft requirement were higher.

Conclusion :

The developed animal drawn manure spreader cum cart has capacity of 500 kg. Application rate of manure during manure spreader operation varies from 2.46 to 10.06 t/ha for different opening areas of cover from 0.04 m^2 to 0.16m^2, respectively.

– The co-efficient of variation in uniformity for manure distribution varied from 18 -20 per cent.

– The developed manure spreader cum cart has desired manure application rate of 9-10t/ha for 0.16 m^2 opining area of cover at the operational speed of 2.63 km/hr with the draft requirement of 637 N.

– The draft and power requirement of manure spreader were 637 N and 0.46 kW within the draft ability limit of pair of bullock.

– The field capacity and field efficiency of machine were 0.21 ha/hr and 84 per cent at operational speed 2.51 km/hr.

– When machine was used as cart, It was operated on the tar and Kaccha road for no load and 500 kg load conditions by red Kandhari bullocks. The draft observed for Tar road with no load and 500 kg load conditions by red Kandhari bullocks was 37 and 41 kg, respectively. The draft observed on Kaccha road for no load and 500 kg load conditions was 40 and 48 kg, respectively by red Kandhari bullocks.

– Speed observed on Tar road for no load and 500 kg load conditions by RK bullock was 4.29 and 3.88 km/hr, respectively. And speed on Kaccha road was 4.04 and 3.48 km/hr, respectively. Power observed for no load and 500 kg load conditions was 0.40 and 0.43, respectively for RK bullock on tar road. And 0.43 and 0.48 Kw for no load and 500 kg load conditions, respectively on Kaccha road for RK bullock. The increased respiration rate and pulse rate was observed after 2 hrs continuous work on Tar and Kaccha road is within the safe limit of fatigue score.

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