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Design and development of an animal drawn farmyard manure spreader

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In India bullock-carts / tractor-trailers are used to transport the farm yard manure (FYM) from the compost pit to the field and manure is stack piled in the field. The spreading of stack piled manure is performed manually with spade, which involves human drudgery. Therefore the existing bullock carts used for transport of manure to the field could be modified for FYM spreading operation also. Keeping all these facts in mind an animal drawn FYM spreader has been developed for uniform spreading of manure and eliminate the human drudgery involved in spreading of manure in the field. The developed farmyard manure spreader of 480 kg capacity and gave manure application rate of 5 to 10 t/ha for the manure delivery rate of 0.38 to 0.74 kg/s at the operational speed of 2.4 km/h, respectively.

Key words: Bullocks, manure, carts, spreader.

INTRODUCTION

Total farmyard manure available in the country is approximately 1200 million ton including availability of 268 MT dung from livestock and 5 MT poultry droppings for bio- methanation to produce biogas and manure of high quality. 50% FYM is used to improve soil fertility and remaining quantity is used for fuel. FYM supplies organic materials to the soil together with plant available nutrients (relatively small concentration compared to inorganic fertilizers) 0.4 to 0.8% N, 0.3 to 0.9% P_2O_2 and 0.3 to 1.9% K_2O. It increases microbial biomass, carbon content and an enzyme compared to the inorganic fertilizer and improves the soil quality by improving the soil-plant-environmental system (Lague et al., 1994; Alam et al., 2002). Integrated use of organic wastes and chemical fertilizers is beneficial in improving crop yield, soil pH, organic carbon and available NPK in soil as compared to continuous use of only chemical fertilizer (Hansen et al., 2004). In India tractor-trailer/bullock carts are used to transport the FYM from the storage pit/bin to the field and manure is stacked piled in the field (Singh and Singh, 2013). Farmyard manure (FYM) is mainly being applied through manual broadcasting, resulting more labours and time per unit area with poor application uniformity and wide variation of the application rate. Solid stack piled manure losses about 21% of its nitrogen to the atmosphere. Proper spreading and incorporation in the soil would reduce the loss only 5%. The spreading of stack piled manure is performed manually with spades, which involves human drudgery (Lague et al., 1994). Therefore an animal drawn cart cum manure spreading system is required for proper application rate and uniform spreading of FYM for the consistent results from a crop

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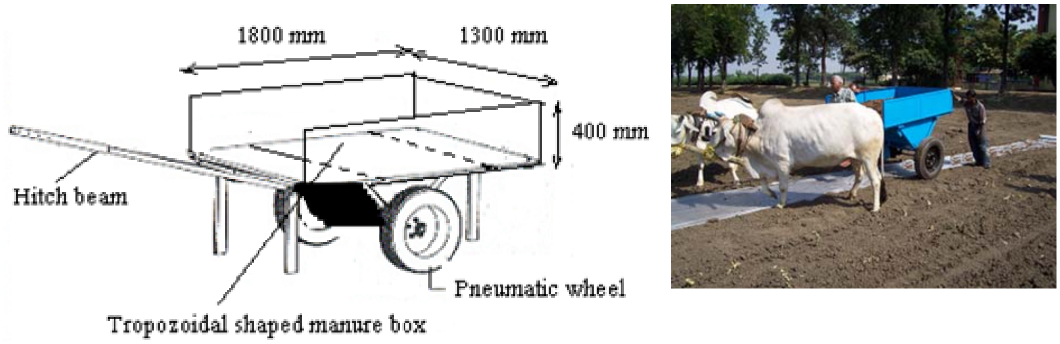

Figure 1. Schematic view of developed manure spreader.

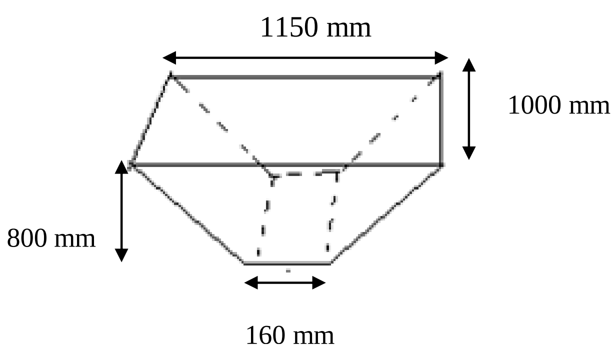

Figure 2. Trapezoidal shaped manure box,

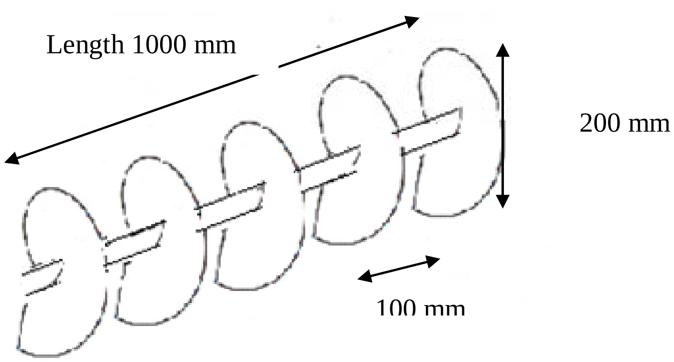

Figure 3. Details of spiral auger used for manure spreading. Spiral auger- disc size: Thickness = 2 mm; Pipe outside dia = 48 mm.

production system.

MATERIALS AND METHODS

A chassis for two-wheeled bullock cart was modified and adopted for animal drawn manure spreader (Figure 1). The chassis frame size (1800 × 1300 × 400 mm) was made of MS pipe of 40 mm inside and 48 mm outside diameter. The chassis frame was mounted on two sides frames, made of MS pipes of dia 48 mm and thickness 4 mm. The adopted axle of 300 mm diameter and 1500 mm was mounted on the both ends of side frames through the clamps. The distance between the side frames was kept 1000 mm. On the both ends of the body of chassis two MS sheet size of 400 × 1150 mm and 2 mm thickness were mounted and in the centre an open space of 1000 × 1150 mm was provided for manure box. A wooden platform of size 1000 × 1150 mm was used to cover the open space. Two pneumatic wheel size of 6 × 16 – 6 PR were provided at the both ends of axle. The track width of manure spreader was 1350 mm.

Manure box

The manure box was made of MS sheet of 2 mm thickness. The box has trapezoidal shaped body for storage and sliding the manure to the rotating auger for spreading (Figure 2). The side frames which gave the strength and support to the manure box made of 2 mm thickness MS sheet. Below the box a spiral auger was provided to spread the manure.

Spiral auger (spreading unit)

A manure-spreading auger made of mild steel spiral discs of 2 mm thickness was provided below the manure box (Figure 3). The diameter of disc is 200 mm. The discs are welded on MS pipe (of outside diameter 48 mm and inside diameter 40 mm) in such a way that the discs deliver the manure directly to the ground. The length of pipe was 1390 mm. At both ends of the pipe bearings have been provided for rotation of auger. It is used to crush the lumps and spreading the manure. Chain and sprocket arrangement have been provided for rotating the auger. To transmit the power from ground wheel to the auger shaft, a sprocket (17 teeth) on axle of cart has been connected with the sprocket (35 teeth) of auger shaft through the chain IS-10. The manure-spreading auger made 32 rpm (0.38 m/s) at cart speed of 2.5 km/h. A dog clutch was also provided to connect and disconnect the rotations of the rotating auger shaft from the ground wheel shaft.

Hitch beam

Two beams of MS pipe (V shaped) of inside diameter 40 mm and thickness 4 mm were used to pull the manure by a pair of bullocks. The length of beam was 2.4 m. Provisions were made for adjusting the angle of beam by lowering or raising the position of beams through changing the nut bolt on different holes on plates mounted on lower side of the body frame. The height of yoke from the

Figure 4. In field recording of pull and speed of operation with and without rotation of manure spreading auger

ground is 1.2 m. The yoke was made of babul wood of diameter 125 mm and length 1600 mm.

RESULTS AND DISCUSSION

The developed animal drawn cart cum manure spreading system was tested in the field for manure application rate and uniformity of manure distribution using a pair of Malvi breed of bullocks (Figure 4). The manure spreader was filled with the farmyard manure. The bulk density of manure was 492.5 kg m^{-3} at moisture content of 22% (d.b.) and manure clod size ranged from 10 to 110 mm with mean manure clod diameter of 46 mm. The manure spreader was operated in the field and time for 10 m travel was recorded.

After operation manure of 10 m length in the direction of line of travel was collected and weighed. Density of manure (kg/m^3) and the moisture content (%, dry basis) of farmyard manure were also determined. The manure application rate and coefficient of variation of uniformity of distribution were determined by using the Equations (1) and (2) respectively (Khurmi and Gupta, 2005).

$$AR = \frac{Q \times 10{,}000}{W \times V} \quad (1)$$

$$CV = 100\left[SD\left(\frac{\sum \times}{N}\right)\right] \quad (2)$$

Where, AR is the application rate in kg/ ha, Q is manure delivery rate in kg/s, W is width of application in m, V is the forward travel speed in m/s, CV is coefficient of variation of uniformity for manure distribution, %; SD is the standard deviation of a set of observations, Σ× sum of a set of observations, g.; and N is the total number of observations.

Measurement of draft and speed of bullocks

A pair of bullocks pulled the manure spreader, filled with the farmyard manure during the testing of manure spreader. The body weight of animal used to pull the manure spreader were determining by using an electronic weighing machine (capacity 0 to 1000 kg). The body size and weight of the experimental bullocks is given in Table 1.

The 21 X micrologger (Campbell Scientific, Inc. U. K.) with load cell (0-5000 N) were used to record the pull of animal. The angle of beam inclination (Ø) was measured by using an abeney level having marking for angles on its periphery. The speed of operation was determined by recording the time of travel of the bullocks for 20 m distance. The power out put of the bullock was determined by using the formula given below.

Draft = Pull × cos Ø
Power (kW) = Draft (kN) × Speed (km/h)/ 3.6

The power requirement for rotating auger and pulling the machine was calculated by using a pair of Malvi breed of bullock in the field. The draft required pulling the manure spreader without operation of auger (auger disengaged from the rotating axle through dog clutch) and with rotating auger for manure spreading (auger engaged with rotating axle through dog clutch) in the field was measured with the speed of operation.

Physical properties of FYM

Physical properties, that is, bulk density, dry matter content; moisture content and angle of friction of farmyard manure at different depth of manure pit of CIAE farm are shown in Table 2. The FYM is a heterogeneous

Table 1. Physical measurement and body dimensions of experimental bullocks.

S/N	Particulars	Malvi bread of bullocks	
		No. 1	No. 2
1	Average heart girth (mm)	1460	1570
2	Average body length (mm)	1480	1660
3	Average height at wither (mm)	1320	1380
4	Body weight (kg)	460	498

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

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
20.5	292	80.5	32	33	33
27.2	510	62.8	37	37	36
36.4	680	63.6	42	42	40

material and moisture content of its changes with the depth of storage pit. Hence angle of friction is more important for sliding the manure over a sheet as compared to angle of repose. On the basis of angle of friction slanting platforms were made from G I sheet. The platforms were fitted on the body of the trailer with an angle of 40° for sliding the manure from the top of the box to feeding auger. The moisture content of manure was determined on dry weight basis.

Design capacity

The design capacity of the developed spreader was calculated based on the density of FYM and volume of the developed spreader as given below. The volume of body frame of manure spreader was 0.96 m^2 and capacity was 253 kg considering the density of manure as 550 kg/m^3. The weight of manure in the box was calculated by using Equation (3).

$$V = \left[\left(\frac{l_1 + l_2}{2} \right) wh \right] \qquad (3)$$

Where, V is spreader box volume, m^3; l_1 and l_2 are top and bottom length of manure box (l_1 = 1.0 m and l_2 0.20 m); w is width of manure box (1.15 m); h is height of manure box (0.6 m); Substitution of values in Equation (3) resulted in the capacity of manure spreader box as 227 kg. Total capacity of manure spreader was 480 kg. The user could load 4 to 5 bags filled with manure over the leveled manure of the box for transporting to field. Specifications of developed manure spreader are given below.

Specifications

Over all dimensions (l× w × h)mm: 4200 × 1300 × 1400
Type of manure box: Trapezoidal shaped, volume = 0.42 m^3
Type of spreading unit: Spiral auger of 200 mm diameter and pitch 200 mm, length 1000 mm
Power transmission: Speed ratio ground wheel to auger (1:2). IS: 10, chain and sprocket drive for spreading unit at 32 rpm.
Pneumatic wheel: Pneumatic wheel size 6 ×16 '' – 6 ply
Ground clearance: 300 mm
Capacity: 480 kg
Width of spreading: 1.1 m
Unit Cost: Rs 25,000
Field capacity: 0.18 ha/h at 2.4 km/h speed
Cost of operation:Rs 70/h
Power source: A pair of bullocks
Suitable for:FYM spreading and transport of materials

Calibration of FYM spreader

The manure spreader was calibrated for manure delivery rate at forward speeds of 2.44, and 2.40 km/h. The manure delivery rate was varied by adjusting the opening width of cover of rotating auger. Manure delivery and application rate with respect to opening width adjusted by opening cover of rotating auger is given in Table 3.

Power requirement in the field

The power requirements for rotating auger and pulling the manure spreader filled with 500 kg were 0.18 and 0.27 kW at average bullock speeds of 0.76 and 0.68 m/s,

Table 3. Manure delivery and application rate with respect to opening width adjusted by opening cover of rotating auger.

Speed of operation (km/h)	Swath (m)	Manure delivery rate (kg/min)	Application rate (t/ha)	Coefficient of variation (%)
Opening area for discharge of manure (0.04 ×1) = 0.04 m^2				
2.38	1.1	8.76	2.22	22.2
2.55	1.1	9.34	1.99	22.4
Avg. 2.46	1.1	9.05	2.10	22.3
Opening area for discharge of manure (0.08 × 1) = 0.10 m^2				
2.36	1.1	22.68	5.13	20.3
2.52	1.1	23.20	5.02	19.9
Avg. 2.44	1.1	22.94	5.08	20.1
Opening area for discharge of manure (0.16 × 1) = 0.16 m^2				
2.26	1.1	42.20	10.12	18.3
2.55	1.1	46.65	9.96	18.1
Avg. 2.41	1.1	44.43	10.04	18.2

Moisture content of FYM = 21% (d b.)

Table 4. Draft and power requirement for operating of manure spreader in the field.

S/N	Draft (N)	Speed of operation (m/s)	Power (kW)	Power required for operation of auger, (kW)
Manure spreading, auger not working				
1	390	0.75	0.29	-
2	360	0.77	0.28	-
3	336	0.77	0.26	-
Avg.	362	0.76	0.27	-
Manure spreading, auger working				
1	650	0.70	0.46	0.17
2	682	0.68	0.46	0.18
3	695	0.66	0.45	0.20
Avg.	676	0.68	0.46	0.18

respectively. However power requirement for pulling the manure spreader in the field and spreading the manure was 0.46 kW at average speed of bullocks 0.68 m/s (Table 4).

Field performance of FYM spreader

The developed machine was tested for manure application rate by using a pair of Malvi breed of bullocks. The manure delivery rate, application rate and field capacity of machine are given in Table 5.

The variation of manure deliver rate at different levels of manure filled in the manure box is evident that the manure delivery rate has decreased from 24 to 21.8 kg/min as the level of manure has reduced from full level to 1/4th level in the box. The manure delivery rate decreased 9.2% as the manure level decreased from full level to ¼th level in the manure box of spreader.

The only limiting parameters for efficient operation of machine were moisture content of farmyard manure (range 10-30%) and the material would be free from plastic/cloth/wood/bricks and stone particles < 50 mm.

Conclusions

A bullock drawn farmyard manure spreader of 480 kg capacity was developed. The developed machine gave manure application rate of 5 to 10 t/ha for the manure delivery rate of 0.38 to 0.74 kg/s at the operational speed of 2.4 km/h, respectively. The coefficient of variation of

Table 5. Field performance of FYM spreader at different opening widths.

Manure delivery rate (kg/min)	Speed, (m/s)	Swath, (m)	Application rate (t/ha)	Field capacity (ha/h)	Field efficiency (%)
23.8	0.68	1.1	5.30	0.19	84
22.4	0.67	1.1	5.06	0.20	83
22.9	0.66	1.1	5.25	0.18	83
Avg. 23.0	0.67	1.1	5.18	019	83

Moisture content = 20% (db).

uniformity for manure distribution varied from 18 to 20%. The draft and power requirement of the manure spreader were 676 N and 0.46 kW within the draft ability of a pair of Malvi breed of bullocks (Body weight, 958 kg) (Srivastava, 2000; Upadhyay and Madan, 1985). The field capacity and the field efficiency of machine were 0.19 ha/h and 83% at operational speed of 4.1 km/h and the developed manure spreader reduced the drudgery involve in manure spreading over the conventional system.

Conflict of Interest

The authors have not declared any conflict of interest.

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