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DEVELOPMENT OF A MANURE SPREADER

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Abstract

A manure spreader was designed, constructed and evaluated. Cow dung collected from abattoirs was composted and used to test the machine in the field. Bulk density, moisture content, angle of repose and coefficient of friction of the composted dung were determined and found to be 791.9 kgm-3, 44%, 420 and 0.88 respectively. The developed machine was tested in the field using the organic manure and the following parameters were obtained: rate of application of 5.9 tha-1, field capacity of 0.6 hah-1, efficiency of discharge of 86% (when fed with a 75 kg of the manure) and operating width of 1.096 m.

1. Introduction

In any crop production system, application of fertilizer is important is one of the essential operations to be carried out. Fertilizer application is usually carried out in areas where the soil fertility is low and depends on factors such as texture of the soil, bulk density, stage of crop development, time of application, labour and equipment available.

Organic matter is a major source of nutrients for plants. Organic substances help in adsorption processes, improving soil structure, moisture retention capacity, water and air permeability and temperature. Both chemical and natural fertilizers can perform the above functions, although the latter is recommended. Overuse of chemical fertilizer over the years has been linked to nitrate contamination of rivers, lakes and wells due to leaching and runoff of excessive nitrogen. Excess nitrate levels in leafy vegetables like spinach and tomatoes are converted to nitrates which are toxic and are strongly linked to stomach cancer. This problem is avoided when compost and natural manure are used because they release their nitrogen slowly (Leonard, 1986).

In developing countries, there is limited use of organic manure due to its high labour requirement, scarcity of machines for spreading it and also due to introduction of chemical fertilizer, which is easier to handle (Leonard, 1986). Manual application of fertilizer by scattering or placement close to the plants may be very effective, but is laborious and can only be used where the land area is small (Archer, 1996).

Advancement in technology has brought about the development of different machines for the application of both chemical fertilizer and organic manure. Smith and Wilkes (1980) classified manure spreaders according to their driving method, namely, ground driven and P.T.O. driven. The ground driven manure spreader such as the trailer type manure spreader is operated by sprocket and chain from the land wheels. An example of the P.T.O. driven is the rotary spreader, which is simple in design and requires minimum maintenance (Lovegrove, 1968).

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The manure spreader is usually power driven by the tractor P.T.O. and employs the same basic principles as the spreading mechanism of the trailer spreader. Manure is first moved to the field and deposited in small heaps at regular intervals in rows of 360 – 450 mm apart. The machine is then driven down the rows, shredding the heaps.

The liquid manure spreader, according to Smith and Wilkes (1980), is meant to distribute the fertilizer through the use of mobile tank with a vacuum pump or centrifugal pump, which are both driven by the P.T.O.

Due to the increasing cost of chemical fertilizer and new Federal and State environmental laws, attention has been directed to the addition of animal dung to cultivated lands (John, 1979; Archer, 1996). The developed countries have been able to sustain the use of animal manure because of the availability of machinery for its handling. In Nigeria, the use of animal manure is not widespread because of high cost of machines and the tedious nature of collecting the manures. It is against this background that a manure spreader was designed and constructed for small and medium-scale farmers using locally sourced materials.

2. Materials and methods

The materials used for the construction of the machine were locally sourced machine and cow dung was collected from abattoirs in Kaduna, Nigeria. The cow dung was used for the preparation of the organic manure based on existing agronomic practices as given by Yawalkar *et al*. (1965).

2.1 Determination of properties of manure

In order to select the best machine parameters for the construction of the machine components such as hopper, power requirement and the spreading mechanism, four properties of the manure were determined namely, angle of repose, coefficient of friction, bulk density and moisture content.

2.1.1 Angle of repose

The angle of repose was used to select the angle at which the trapezoidal section of the hopper should be slanted. The angle of repose was determined by adapting the method given by Mohsenin (1978), in which an adjustable table was used to tilt 10 g of the prepared manure cubes placed in a container until the manure began to fall. The mean of 10 readings was taken as the angle of repose of the material.

2.1.2 Coefficient of friction

This was used to determine the flow of manure from the hopper. The readings earlier determined for the angle of repose were used to calculate the coefficient of friction (μ), as:

$$\mu = \tan\beta$$

Where β = angle of repose (friction).

Angles of repose (friction) were determined for metal, wood and rubber surfaces.

2.1.3 Bulk density and moisture content

Bulk density and the moisture content were used to determine the uniformity of distribution of the manure. The moisture content was determined by the oven-drying method at a temperature of 104^0C for 24 hours (Sidney, 1963).

After the determination of the properties of the manure, the design of the machine parameters and components were based on the procedures given by Bosoi *et al*. (1988), Lovegrove, (1968), Kepner *et al*. (1982) Shippen *et al*. (1980), ASAE (1998); Spivakovsky and Dyachkov (1983) and Reshetov (1978).

2.2 Design calculations

2.2.1 Power Requirement

The power (P) required to operate the spreading mechanism and the agitator was determined as follows:

$$P = \frac{C_0 QL}{367} \qquad (1)$$

where Q = Capacity, $kgmin^{-1}$
L = Length of Conveyer, m
C_o = Frictional factor

But $Q = 47\psi \int tnD^2 K$

where Ψ = Capacity factor
$\int$ = density of manure
D = Diameter of shaft
t = Pitch of conveyer = 0.5D
n = Speed of conveyor
K = Angle of rise

The power required at the agitator is the same as that of the spreading mechanism since they have the same width and the same formula is used.

2.2.2 The hopper

The hopper capacity (V_h) was determined by the relationship.

$$V_h = V_r + V_t$$

Where V_r = volume of the rectangular portion of the hopper, m^3
V_t = volume of the trapezoidal portion of the hopper, m^3

The hopper is slanted at 40^0 being the angle of repose of manure which varies between 38^0 and 50^0 (Bosoi *et al.*, 1988).

2.2.3 Power transmission

The spreader is powered by the tractor PTO using a belt-pulley arrangement (Figure 1).

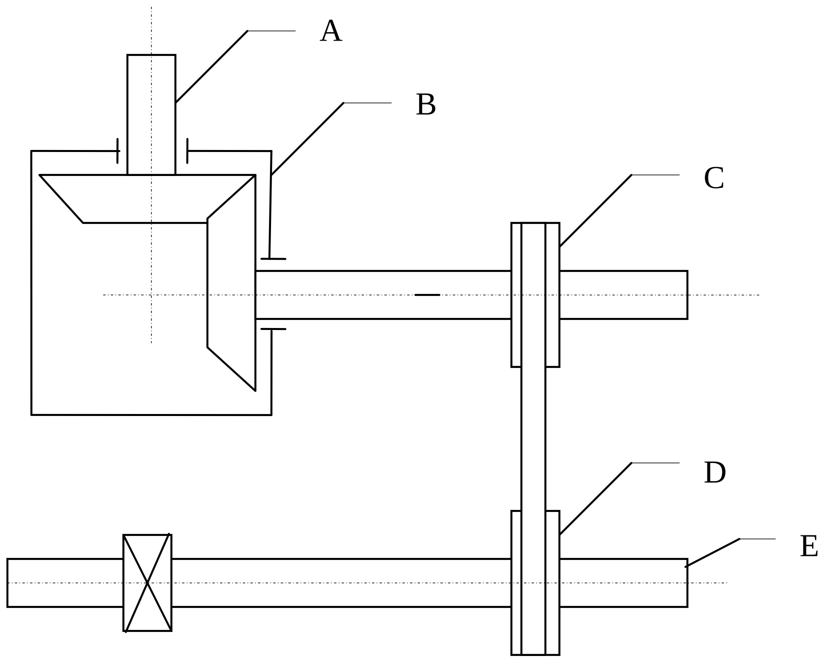

Figure 1: Layout of the power transmission
A = PTO of the tractor, B = Gear box, C = Driving pulley, D = Driven pulley, E = Flail rotor

2.2.4 The output shaft design

The diameter of the gearbox output shaft was calculated from the AMSE Code for the design of transmission shaft equation given below.

$$d^3 = \frac{16}{\pi \delta_s} \sqrt{(M_t K_t)^2 - (M_b K_b)}^2 \qquad 2$$

Where M_t, M_b = Torsional and bending moments, Nm
K_t, K_b = Fatigue and shock factors for torsional and bending moments
δ_s = allowable stress, Nm^{-2}

For torsional deflection of the shaft, the angle of twist was calculated as follows:

$$\theta_s = \frac{584 M_t L}{G_t d^4} \qquad 3$$

Where G_t = modulus of torsional shear, Nm^{-2}

The shaft of the spreading mechanism was also designed using Equations 2 and 3 above. Since the telescopic shaft is subjected only to torsional stress, the diameter of this shaft was calculated from Equation 4 below.

$$d^3 = \frac{16M_t}{\pi\delta_s} \qquad 4$$

2.3 Performance evaluation

The machine was loaded with 75 kg of composted manure and tested over a 100 m distance in the field. Rate of application, field capacity and field efficiency were evaluated using Equations 5 – 7 respectively. Spreading Pattern indicates the degree of uniformity of distribution of material across the swath and was determined by running the spreader over the test distance divided into ten (10) equal parts of 10m each and weighing the gathered quantity of manure spread on each of the parts. Ten test runs were carried out. The coefficient of variation (*CV*) was determined to express the uniformity of distribution.

$$R = \frac{QK}{LW} \qquad 5$$

$C = SW$ (Hunt, 1972): 6

$$E = \frac{Q}{Q_L} \qquad 7$$

Where Q = Weight of composted manure already spread, kg
W = Swath width, m
K = Constant
L = Distance covered, m
QL =

3. Result and discussion

3.1 Construction and principles of operation of the manure spreader

The main features of the spreader are the hopper, frame, power transmission unit, spreading mechanism and wheels. The hopper is rectangular in shape and tapers from the top to bottom and serves as the feeding chute to the spreading unit. It was constructed with a 2 mm thick metal sheet. The Power transmission unit consists of a telescopic shaft, a gearbox with bevel gears, three pulleys, bearings, shafts and V-belts. A 45 kW tractor, 540rpm P.T.O shaft of diameter 35mm with six splines, was used to drive the agitator and the spreading mechanism through the gear box. One pulley each was mounted on the gearbox output shaft, the agitator shaft and the spreader shaft. The manure agitator has 23 spikes welded at 35 mm spacing along its length to allow uniform flow of manure to the spreading mechanism that consists of a rotor carried on two bearings and attached to it in three rows. Along the entire length of the rotor are 36 flails fixed 35 mm apart. The flails are made of small pieces of mild steel bars welded to the rotor. The machine receives power from the tractor PTO through the telescopic shaft. The major components of the spreader are mounted on a frame made from rectangular steel 50 mm x 50 mm.

3.2 Manure and machine characteristics

Bulk density, angle of repose, coefficient of friction, pH and moisture content of the manure used were 791.9 kg/m^3, 42^o, 0.88, 7.7 and 44% respectively. The machine discharged an average of 64.54 kg out of the 75 kg fed into the machine for the ten test runs conducted. This gives the spreading efficiency of 86.05%. The distance was covered at an average interval of 66.06 seconds, and a spreading width of 1.09 m when the hopper discharge aperture was fully opened (Table 1). At the maximum opening of the hopper, the application rate was 5.9 tons/ha. Reducing the discharge aperture reduces both application rate and the spreading efficiency. A field capacity of 0.6 ha/h was achieved when the machine was operated at a speed of 1.5 m/s with a width of 1.09 m. Using the data for the spreading pattern (Table 2), the coefficient of variation obtained with this machine was 1.08% and this is within acceptable limit (Gomez and Gomez, 1986).

Table 1: Field test results with hopper aperture fully opened over a distance of 100 m and an initial weight of compost of 75 kg

S/no	Time (s)	Width of spreading, W (m)	Weight of material spread, Q (kg)
1	67.34	1.10	65.4
2	67.00	1.08	63.3
3	66.45	1.10	63.5
4	66.50	1.08	65.4
5	68.10	1.08	66.5
6	65.81	1.10	64.6
7	64.34	1.15	63.4
8	63.52	1.10	63.6
9	65.40	1.09	64.5
10	66.41	1.08	65.2
Mean	**66.06**	**1.10**	**64.5**

T able 2: Spreadiing pattern results

S/no	Weight of material spread, X_i (kg)	Square of deviation $(X_i – X_m)^2$
1	6.52	0.0004
2	6.50	0.00
3	6.46	0.0016
4	6.45	0.0025
5	6.40	0.01
6	6.42	0.0064
7	6.55	0.0025
8	6.63	0.0169
9	6.50	0.00
10	6.57	0.0049
Mean	**6.50**	**0.0452**

4. Conclusion

A manure spreader was designed, constructed and performance evaluation carried out on the developed machine in the field using cow-dung. The developed machine gave an efficiency of 86%, field capacity of 0.6 ha/hr and rate of application of 5.9 tons/ha. With proper selection of hopper size and the spreading mechanism, and selecting the appropriate tractor power requirement, the machine can be used by farmers in developing countries. The parts required for the development of such a manure spreader can be sourced locally and organic manure can also be found in abundance from abattoirs around Nigeria. The machine requires only one person (the tractor operator) to operate.

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