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Development and Performance Evaluation of a Tractor Powered Solid Manure Spreader

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Abstract: The objective of this study is to develop a tractor-powered manure spreader for various types of manure to facilitate manure spreading operation, reduce human drudgery and improve manure application uniformity for optimum crop growth. A rotating disc manure spreader was therefore developed to replace manual manure application and substitute the costly imported spreaders that are beyond the reach of an average Nigerian farmer. Major components of the spreader are hopper, agitator, spreading disc, flow rate control mechanism, frame, power transmission unit, and gear box. The spreader was evaluated both in the field and laboratory using cow dung. Laboratory test was conducted to determine the output [quantity in kilogram disposed per hour (kg/h)] at 3 levels of flowrate ($F_{1\,=}$ 15 cm, F_2 = 30 cm and F_3 = 45 cm) and 3 levels of disc peripheral speed at a stationary position. For the field evaluation, moisture content of manure was measured using the dry weight method; weights of 40 kg dung was measured and used for each experiment on a 100 m x 25 m field to determine the machine efficiency and effective field capacity. Results obtained show that the effective field capacity, effective width, efficiency of the spreader and spreading capacity ranges from 4.4-9.8 ha/hr, 7.5–10.4 m, 60.8-89.4 %, 1070-3938 1kg/hr, respectively. Manure application rate ranges from 3011.3-4082.1 kg/ha and Machine efficiency was 89.4%. Similarly, maximum spreading width, machine efficiency and effective field capacity were 9 m, 82.61%, and 9.8 ha/hr respectively. The cost of production of the designed manure spreader was ₦165,440.00.

Keywords: Application Rate, Drudgery, Manure, Flow Rate, Spreader

I. Introduction

Manures are natural substances that provide nutrients for the optimal growth of plants. It is termed as anything that is added to the soil to increase its fertility and enhance plant growth [1]. Manure is not just the urine and faeces from livestock, but also the bedding, runoff, spilled feed, parlour wash, and anything else mixed with it. In addition to nutrients, manure provides carbon and other constituents that affect soil humus content, organic matter and nutrients, biological activity and the physical structure of the soil [2, 3]. The method of manure application depends on the volume and consistency of the manure, hauling distance, planting pattern and existing equipment [4].

Most peasant farmers apply manure by band placement, manual broadcasting method or bullock-carts /tractor trailers [5]. These methods are labour intensive, wasteful and relatively time-consuming with low productivity. The application rate per unit area also results in non-uniformity in the application. Additionally, about 21% of its nitrogen is lost to the atmosphere through manual broadcasting of solid piled manure [6]. Although few mechanical manure applicators are available, the high cost associated with such equipment is above what most farmers can afford. The aim of this study is, therefore, to develop a tractor powered low-cost manure spreader capable of using various types of manure. This will facilitate manure spreading operation, improve manure application

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uniformity, reduced human drudgery and wastage at less cost for optimum crop growth.

II. Material and Method

A. Materials Used

The construction materials were selected based on availability locally, cost, durability, strength and resistance to corrosion. Angle iron of size 250 mm × 250 mm × 2 mm made of mild steel was chosen for the frame of the spreader, mild steel metal sheet made was used for hopper construction and copper material for the spreader disc. Instruments used during the course of the study were 100 kg capacity weighing balance (WT1000KF, 0.001 Accuracy; WANT Balance Instrument Co. Ltd - China), digital tachometer (RPM, 0.05% Accuracy; Sensotech Automation - China), stopwatch and 100m measuring tape.

i. **Components of the Spreader:** The manure spreader consists of the following components: hopper, agitator, spreading disc, flow rate control mechanism, frame, power transmission unit, screen and gear box as shown in Figure 1.

a) **Hopper:** This is a pyramidal container attached to the topmost part of the spreader for temporarily holding the manure before being metered onto the spreading disc by gravity. It was made of mild steel sheets. It was designed to ease movement of manure towards the metering aperture. The hopper has a capacity of 0.56 m^3

b) **Agitator*:*** This is a stirring device made from metal rod of 210 mm in length and 21 mm in diameter with three spikes of metal rod attached. The length of the spikes was 41 mm spaced at a distance of 100 mm on the agitator shaft. Its function is to mechanically stir and prevent agglomeration of manure at the tail end of the hopper. The agitator is fixed to the spreader disc rotates in the same direction as the spreader disc.

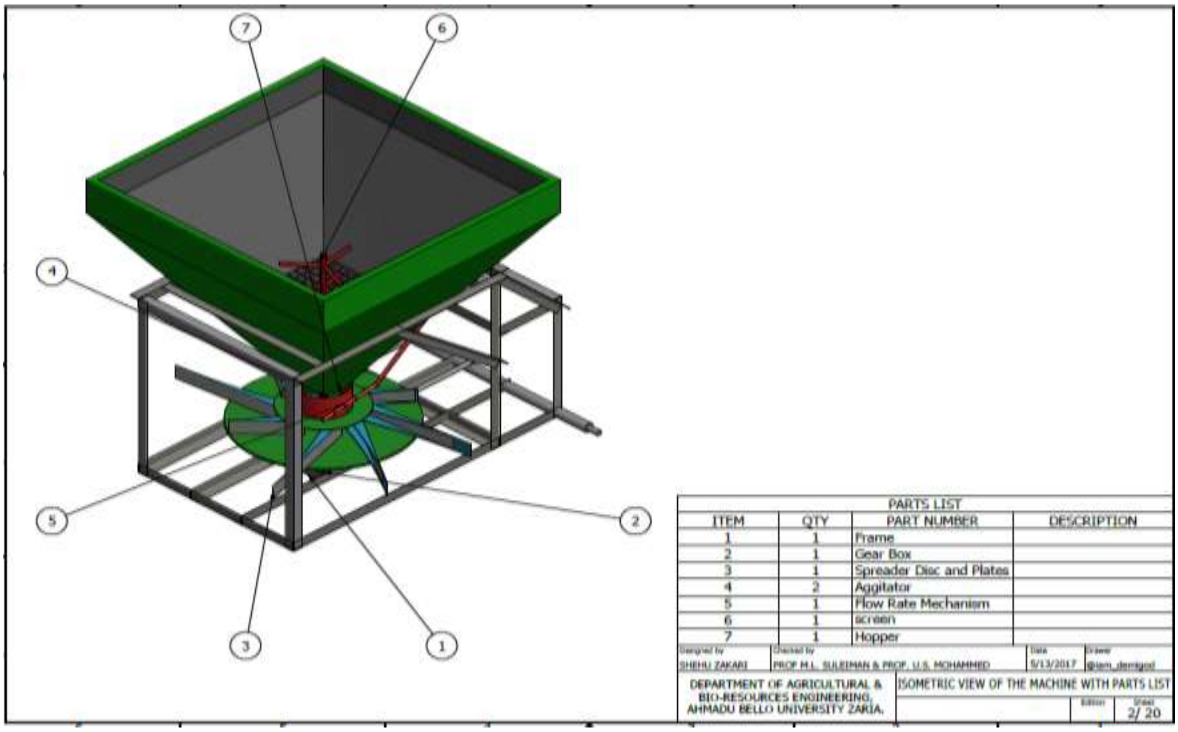

Figure 1: Pictorial View of the Manure Spreader

c) **Spreading Disc:** The spreading disc is a circular disc of 340 mm diameter of steel material that is mounted at the bottom of the hopper just below the aperture openings of the twin pyramidal frustum. It has 8 equally spaced pegs in which six of them (major) are of 490 mm length while the other two (minor) are of shorter length of 257 mm. The function of the minor fins is to spread to shorter distances while the major fins are expected to reach far distances. Both fins are of 60 mm width.

d) **Flow Rate Control Mechanism:** A suitable flow rate control mechanism with a locking device was provided at the tail end of the hopper opening to control the flow of manure through the aperture to the spinning discs. The mechanism is manually controlled.

e) **Frame:** The main frame is the skeletal structure of the manure spreader on which all other components are mounted. Factors considered in the determination of the material required for the frame are weight and strength. Mild steel angle bar of 40 mm x 40 mm and 5mm thickness and galvanized steel pipes were used to give the required rigidity.

f) **Power Transmission Unit:**The unit comprises of the PTO which transmits power to the spreading mechanism by connecting shaft from the PTO to the gear box.

g) **Screen:** The helps to sieve out unwanted materials such as large stones, bottles and pieces of metals. It also helps in trapping large clods of manure which can be broken into smaller pieces.

h) **Gear Box:** This consists of a pair of bevel gears of transmission ratio 1:1. The input shaft takes power from the PTO shaft while the output shaft drives the spreader disc and the agitator.

B. Experimental Procedure

The tractor-powered manure spreader wasevaluated both in the field and laboratory. Laboratory test was first conducted to determine the output [quantity in kilogram disposed per hour (kg/h)] at 3 levels of flowrate (F_1 = 15cm, F_2 = 30cm and F_3 = 45cm) and 3 levels of disc peripheral speed at a stationary position in order to determine the uniformity of manure spread. While in the field, the moisture content of manure (cow dung) was measured by dry weight method. Weights of 40 kg dung was measured and used for each experiment on a 100 m x 25 m field. After uploading the measured manure into the hopper, the stop watch starts simultaneously as the spreading begins, effective time, delay and total time are recorded. The swath width was also recorded at intervals.

C. Design Calculations

i. Determination of the Hopper Capacity

The hopper design was based on the volume of tripozodial container with a square area attached to its base. The volume of the container was obtained by the principle of determining volumetric and gravimetric capacity of hopper [7]:

$$(V_h) = \frac{l^2}{3}h + l^2 \times b \qquad (1)$$

where:

V_h = Capacity of the hopper (m^3)

l = Length of the base end (m)

h = Height, distance of the line segment strectching from the "point" of the pyramid to the plane of the base at perpendicular angles to both (m)

b = height of the base

The hopper capacity was determined to be 0.56 m^3

ii. Determination of Manure Weight in the Hopper

$$N_w = M_m g \qquad (2)$$

where:

N_w = Normal force (weight of the manure),
g = acceleration due to gravity (9.8 m/s^2)
M_m = Mass of manure filled to the hopper brim (kg)

$$M_m = \rho_m \times V_h \qquad (3)$$

where:

V_h = Capacity of the hopper (m^3) as determined in equation (1)
ρ_m = Bulk density of manure (kgm^{-3}), average bulk density of farmyard manure as noted by Singh and Singh (2006)ρ_m = 260 kgm^3

The Mass of manure full to the hopper (M_m) was computed as 145.6 kg (from Eqn. 2)

iii. Determination of Mass of the Spreader Disc Assembly

$$M_{Ts} = \rho V \qquad (4)$$

where:
M_{Ts} = mass of spreader disc (kg)
ρ = density of the disc material (Steel) (kg/m^3)
V = total volume of disc material (m^3)

But

$$V = At = V_c + V_{lf} + V_{sf} + V_d \qquad (5)$$

where:
A = total area of material (m^2);
t = thickness of material (m);
V_c = Volume of circular disc material beneath the fins;
V_{lf} = Volume of longer fins (six in number);
V_{sf} = Volume of shorter fins (two in number);
V_d = Volume of circular disc material above the pegs;
ρ = 7850 kg/m^3

The mass of spreader disc (M_{Ts}) was determined as 3.07 kg

iv. Determination of Mass of the Agitator

$$M_{Ta} = \rho V \qquad (6)$$

where:
M_{Ta} = total mass of agitator assembly (kg)
ρ = density of the agitator material (Steel) (kg/m^3)
V = total volume of the material (m^3)
But

$$V = Al \qquad (7)$$

where:
A = total area of material (m^2)
l = total length of material including length of spikes (m)

$$A = \frac{\pi d^2}{4} \qquad (8)$$

ρ = 7850 kg/m^3

From Eqn. (6), mass of agitator assembly (M_{Ta}) = 7850 × 3.07 × 10^{-4} = 2.41 kg

v. Determination of Mass of Manure at a Point During Spreading

The mass of manure was determined by collecting manure weight available on the disc when not in motion, the weight collected at rest will be much than the weight during spreading.

M_{Tm} = mass of manure on spreading disc at a point during spreading

$$M_{Tm} = 495g \cong 500g$$

vi. Determination of Weight of Spreader Disc, Agitator and some Manure on Disc

The weight of the spreader disc and agitator will be determined in order to know the amount of load being exerted on the gear by both the spreader disc and agitator. The total weight of the spreader disc assembly and the agitator is given in Equation (9)

$$W_T = M_T g \quad (9)$$

$$M_T = M_{Ts} + M_{Ta} + M_{Tm}$$

where:

$W_T =$ total weight of the spreader disc, agitator assembly and manure on disc (N)
$g =$ acceleration due to gravity (9.8 m/s^2)
$M_T =$ total mass of spreader disc and agitator assembly and manure on disc (kg)
$M_{Ts} =$ mass of spreader disc (kg) as determined in eq (4)
$M_{Ta} =$ mass of the agitator assembly as determined in eq (6)
$M_{Tm} =$ mass of manure on disc at a point during spreading as determined in (8)

vii. Determination of the Centrifugal Force Developed by the Rotating Disc Agitator and Manure

Centrifugal force on a rotating disc was determined from the equation below [8]:

$$F_c = \frac{M_T w^2 D}{2} \quad (10)$$

where:
F_c = centrifugal force (N)
$M_T =$ total mass of spreader disc and agitator assembly and manure on disc (kg), as computed in (9)
$w =$ angular velocity of the spreader disc assembly (rad/s)
But

$$w = \frac{2\pi N}{60} \quad (11)$$

where:
N = maximum speed of the spreader disc in rpm
$D =$ diameter of spreader disc (m)
Thus, the force developed by the rotating disc agitator and manure (F_c) = $6499.67\mathrm{N}$

viii. Determination of Peripheral Speed of the Spreader Disc

The peripheral (linear) speed of the spreader disc was related to the revolution per minute and the effective diameter of the spreader disc as given by equation (12)

$$V = \frac{\pi N}{60} D \quad (12)$$

where:
$V =$ pheripheral speed of the spreader disc assembly (m/s)
$N =$ revolution per minute of the spreader disc assembly (rpm)
$D =$ effective diameter of spreader disc (m)
The speed of the spreader disc (V) = 19.22 m/s

ix. Determination of Stress on the Walls of Agitator per unit area

The formula for determining the stress per unit area on the wall of the agitator established by [9] was utilized.

$$\delta_b = \frac{2W_{Ta}}{\pi {d_k}^2} \quad (13)$$

where:
$\delta_b =$ stress on the wall of the agitator material per unit area (N/m^2)
$d_k =$ diameter of the agitator rods (m)
$W_{Ta} =$ total weight of agitator assembly (N).

$$W_{Ta} = M_{Ta} g$$

where:
$M_{Ta} =$ total mass of agitator assembly (kg), as computed in equation (6)
$g =$ acceleration due to gravity (9.8m/s^2)
Therefore, the stress on the wall of the agitator (δ_b) = $15.035(d_k)^{-2}$N/m^2

x. Determination of the Diameter of the Agitator Shaft

In order to withstand the stress on the agitator, the diameter of the agitator has to be determined to prevent avoidable system failure. Kreg [9] stated that the diameter of an agitator to withstand the stress is a function of the unit stress that acts on the agitator, the diameter of the agitator shaft and the maximum permissible stress of the material expressed by Equation (14). Using [10] code for steel which gives the steel permissible stress (δ_p),

δ_p = permissible stress of the agitator material (42×10^6 N/m^2)

$$d_k = \frac{\delta_b D_h}{2\delta_p} \qquad (14)$$

where:

d_k = diameter of the agitator rods (m)

δ_b =stress on the wall of the agitator material per unit area (N/m^2),

δ_p =permissible stress of the agitator material (N/m^2)

D_h =diameter of hopper bottom (m)

The diameter of the agitator (d_k) = 5.12 mm

xi. Torque Required to Turn the Spreader Disc and the Agitator

The torque required to turn the spreader disc and agitator was given by equation (15) by [8]. This include:

i. The force required to turn the disc, agitator and amount of manure on the disc
ii. Agitation work (resistance of the manure to agitation)

$$T = (F_c + F_{rm}) \times r \qquad (15)$$

where:

T =torque of the spreader disc and agitator (Nm)

F_c = Force required to turn the spreader and agitator (N),

$F_{rm} = \mu N_w$ = Resistance force of manure to agitator (N)

r = radius of the spreader disc assembly (m)

μ = Coefficient of friction, μ = 0.4 average value for farmyard manure [5]

N_w = Normal force (weight of the manure),

The Torque required to turn the spreader disc and the agitator = 1202.07 N

xii. Determination of Shaft (spindle) Size Carrying the Disc and Agitator

$$d^3 = \frac{16M_t}{\pi\tau_a} \qquad (16)$$

where:

d = spindle size (m)

M_t = Torsional moment (N-m)

τ_a = Allowable shear stress of material (N/m^2) [8]

The shaft (spindle) size carrying the disc and agitator = 52 mm

xiii. Power Required to move the Manure to the Desired Swath Width

The power required to spread the manure was determined by [8] as given in equation (17)

$$P = \frac{2\pi N_{pn} T}{60} \quad (17)$$

where:

P = power required (Watt)

N_{pn} =speed of the spreader disc in rpm

T =torque of the spreader disc and agitator (Nm),

$$P = 68.02 \text{ kW}$$

xiv. Determination of the Rate of Manure Discharge

The rate of manure discharge determines the rate of spread/swath width of manure being dispersed. The rate of manure discharge and spread is determined by equation 18

$$Q = VA \qquad (18)$$

where:

Q = Discharge rate (m^3/s)

A = Area of manure delivery hole (4.42 m^2)

V = Speed at which manure is delivered and spread (19.22 m/s),

$Q = 0.085\ m^3/s$

xv. Determination of Field Efficiency of the Spreader

The spreading efficiency of the spreader was determined using Equation (19) and (20). It gave the actual time required to perform the operation. Time loss due to overlap, turning, loading and unloading the materials were duly accounted.

$$FE = \frac{T_t - T_d}{T_t} \quad (19)$$

$$T_t = (T_e + T_d) \quad (20)$$

where:

FE = Field efficiency

T_t = Total time required to spread manure including delayed time (min)

T_e = Total effective time in spreading manure (min)

T_d = Total delay time required for cleaning, turning, reloading and repair, min

xvi. Determination of Effective Field Capacity of the Spreader

The effective field capacity of the spreader was calculated using Equation (21).

$$C_{eff} = \frac{SW}{10} \times FE\ , ha/h \quad (21)$$

Where ha/h is the unit of the effective field capacity.

Where:

C_{eff} =Effective Field Capacity of the manure spreader, ha/h

S = Optimum forward speed of the tractor during the operation, km/h

W = Effective swath width of the manure spreader, m

FE = Field efficiency

xvii. Determination of Field Efficiency of the Spreader

The spreading efficiency of the spreader was determined using Equations (22) and (23). It gave the actual time required to perform the operation. Time loss due to overlap, turning, loading and unloading the materials were duly accounted.

$$FE = \frac{T_t - T_d}{T_t} \quad (22)$$

$$T_t = (T_e + T_d) \quad (23)$$

where:

FE = Field efficiency

T_t = Total time required to spread manure including delayed time (min)

T_e = Total effective time in spreading manure (min)

T_d = Total delay time required for cleaning, turning, reloading and repair, min

xviii. Determination of Effective Field Capacity of the Spreader

The effective field capacity of the spreader was calculated using Equation (24).

$$C_{eff} = \frac{SW}{10} \times FE \quad (24)$$

where:

C_{eff} =Effective Field Capacity of the manure spreader (ha/h)

S = Optimum forward speed of the tractor during the operation (km/h)

W = Effective swath width of the manure spreader (m)

FE = Field efficiency

III. Results and Discussion

The tractor-powered manure spreader was designed and constructed (Figures 2) and mounted on a tractor via the 3-point linkage (Figure 3). It was also evaluated both in the laboratory and in the field (Figure 4) to determine the uniformity of the spreader, effective width, field efficiency and effective field capacity of the spreader.

Performance Evaluation Parameter for the Developed Manure Spreader

i. Laboratory Evaluation

The spreader was evaluated at stationary position. It was run at a selected gear speed of 8 km/hr. Results obtained shows that the average spread capacity of the spreader was 4082.13 kg/hat a flow mechanism setting of 'F3' with swath width of 10.37 m. while the lowest average spread capacity was 3011.31 kg/h with a swath width of 7.50 m at flow rate setting 'F1' (Table 1)..

Figure 2: Developed Manure Spreader

Figure 3: Manure SpreaderMounted on Tractor

Figure 4: Developed Manure Spreader in Operation

The results obtained indicates an increase in the height of flow mechanism increases the amount of manure deposited per unit time with a corresponding increase in swath width length

ii. Effective Field Capacity of Developed Spreader

The Result of the analysis of variance (ANOVA) of the effects of height of flow mechanism and disc speed on effective field capacity is presented in Table 2. The effect of height of flow of mechanism and the disc speed was highly significant on effective field capacity of the developed spreader. The interaction effect was also significant on the effective field capacity. Further analysis using Duncan Multiple Range Test (DMRT) to assess the effect of disc speeds and heights of flow mechanism and their interaction on effective field capacity were presented in Tables 3 and 4 respectively.

Table 3 showed an increase in effective field capacity as disc speed and height of flow mechanism increased. Higher effective field capacity of 8.6 and 8.5 ha/h were obtained at 450 rpm and 45 cm respectively and lower with 14.1 and 16.1 ha/h at 150 rpm and 15 cm respectively. This could be attributed to the increase in manure discharge as the speed increased. The effects of levels of speeds and height of flow mechanism were statistically different.

The effect of interaction between disc speeds and height of flow on effective field capacity is shown in Table 4. Higher effective field capacity of 9.8 ha/h was obtained at 45 cm height of flow mechanism and 450 rpm disc speed and lowest at 15 cm height of flow mechanism and 150 rpm disc speed with effective field capacity of 4.4 ha/hr. The effective field capacity were statistically the same at 30 and 45 cm height of flow mechanism and for 300 and 450 rpm disc speeds. The table showed as the height of flow increases the machine effective field capacity increases.

Table 1: Spread Capacity, Time and Swath Width of the Developed Spreaders.

Flow rate settings	**Rep**	**Time (min)**	**Machine Capacity (kg/h)**	**Swath Width (m)**	**Average Time (min)**	**Average Capacity (kg/h)**	**Average Swath Width (m)**
	1	1.27	2862.02	7.37			
F1	2	1.25	3105.92	7.70	0.92	3011.31	7.50
	3	1.06	3065.98	7.43			
	1	1.27	3634.10	8.70			
F2	2	1.26	3587.11	9.10	0.85	3706.37	9.01
	3	1.21	3897.89	9.23			
	1	1.23	4109.93	10.50			
F3	2	1.23	4005.05	10.33	0.82	4082.13	10.37
	3	1.09	4131.41	10.27			

Table 2: Effect of Disc Speed and Height of flow mechanism on Effective Field Capacity

Source	DF	SS	MS	F-value	Pr>F
Speed (S)	2	376.1927463	188.0963731	304.34**	<.0001
Height of Flow (F)	2	183.0955130	91.5477565	148.12**	<.0001
S*F	4	4.8964259	1.2241065	1.98*	0.0495
Error	18	11.1248167	0.6180454		
Total	26	575.3095019			

*= Significant at ($P \leq 0.05$), **= Significant at ($P \leq 0.01$)

Table 3: Effect of Disc Speeds and Heights of Flow on Effective Field Capacity

Treatment	Effective Field Capacity (ha/h)
Speed (rpm)	
150	5.31c
300	8. 2b
450	8.6a
SE±	0.262
Height of Flow (cm)	
15	6.4c
30	7.5b
45	8.5a
SE±	0.262

*= Significant at ($P \leq 0.05$) s followed by the same letter(s) in the column are not different statistically at *P=0.05* using DMRT.

Table 4: Effect of Interaction between Disc Speeds and Heights of Flow Mechanism on Effective Field Capacity

Treatment	Effective Field Capacity (ha/h) Speed (rpm)		
	150	300	450
Height of Flow (cm)			
15	4.4f	6.4d	7.5c
30	5.3e	8. 2b	8.6b
45	6.5d	9.4a	9.8a
SE±	0.454		

s followed by same letter(s) in the same column and row are not different statistically at *P=0.05* using DMRT

Table 5: Effect of Disc Speeds and Heights of flow Mechanism on Machine Efficiency

Source	DF	SS	MS	F-value	Pr>F
Speed (S)	2	17.166881	8.583440	0.01NS	0.9897
Height of Flow (F)	2	7396.876632	3698.438316	4.44*	0.0270
S*F	4	2135.451343	533.862836	0.64NS	0.6400
Error	18	14986.71979	832.59554		
Total	26	24536.21465			

NS= Not significant, *= Significant at ($P\leq0.05$)

iii. Field Efficiency of the Developed Spreader

The result of analysis of variance (ANOVA) of the effect of heights of flow mechanism and disc speeds on machine efficiency is presented in Table 5. The effects of disc peripheral speed and the effect of interaction for speed/height of flow mechanism on the machine efficiency were not significant on the field efficiency of the developed spreader. But the effect of heights of flow mechanism is significant at ($P\leq0.05$).

Further analysis using Duncan Multiple Range Test (DMRT) to assess the effect of heights of flow mechanism is presented in Table 6. The effect of heights of flow mechanism was statistically the same at 15 cm and 45 cm with an efficiency of 89.4 % and 100% respectively. It was statistically lower at 30 cm

Table 6: Effect of Heights of Flow Mechanism on Field Efficiency

Treatment Height of Flow (cm)	Field Efficiency (%)
15	89.4a
30	60.8b
45	100.0a
SE$\pm$	9.618

NS=Not significant s followed by the same letter(s) in the column are not different statistically at *P=0.05* using DMRT.

IV. Conclusion

A tractor-mounted manure spreader was developed and evaluated using three levels of disc speeds, three levels of heights of flow mechanism. Laboratory evaluation of the spreader obtained shows an average spread capacity of the spreader was 4082.13 kg/h with a swath width of 10.37 m; while its field results of the spreader were 82.61 %, 22 kg/ha, and 2734.9 kg/h for machine efficiency, effective field capacity and spread capacity, respectively. This was against the 76.20 %, 21.42 kg/ha, and 2527.50 kg/h for machine efficiency, effective field capacity and spread capacity, respectively obtained from the imported spreader of similar capacity. The estimated cost of production of the manure spreading machine is ₦165,440.00 as against ₦1, 006,500 for an imported spreader of similar capacity.

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References

[1] Boller, E. and Hani, F. "Manures and Soil Amendments", *Ideal book on functional biodiversity at the Farm level*, 2004, pp. 4-8.

[2] Wagner, E. and George, H. "Legume Green Manuring", *Ecology*, vol.35, 2004, pp.12

[3] Haynes, R., Pressey, J., Jen and Mondy, N. "Field Assay for Nitrogen Evaluation", *Journal of Food Science*, vol. 54, no.3, 1989, pp.64-69.

[4] Davis, J.G., Ahnstedt, B. and Young, M. "Soil Characteristics of Cropland Fertilized with Feed Lot Manure in the South Platte River Basin of Colorado",*J. Soil Water Conservation,*vol. 52, 1997, pp. 327-331.

[5] Singh, R.C. and Singh, C.D "Design and Development of an Animal Drawn Farmyard Manure Spreader",*African Journal of Agricultural Research*,8337, vol. 9, no. 44, 2014, pp. 3245-3250.

[6] Lague, C., Roy, P.M., Chenard, L. and Lagace, R."Wide Span Boom for Band Spreading of Liquid Manure",*Appl. Eng. Agric.*, vol. 10, no. 6, 1994, pp. 759-763.

[7] Harris, J.W. and Stocker, H."Frustum of Regular Pyramid",§4.32 in *Handbook of Mathematics and Computational Science.* New York: Springer-Verlag, 1998pp. 99.

[8] Khurmi, R.S., and Gupta, J.K. "Machine design (14th ed.)"*S. Chand & Company Ltd.*, Ram Nagar, New Delhi-110055,2005, pp. 434-1101.

[9] Kreg, E. "Stress in Centrifuge: Principles of Sugar Technology", *Elsver, Armsterdam*, vol. III,1975,pp. 3-17

[10] American Society of agricultural and Biological Engineers(ASABE) "Agricultural engineer's yearbook",*Agric. Mach. Mgt. Data*: EP 391 and D230.3 St. Joseph, MI, USA, 2003,pp. 12-16