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Development and Performance Evaluation of a Spinning Disc Spreader Using Four Organic Manures

Bello Raphael Segun and Nebo Ephraim Ugochukwu

Department of Agricultural and Bioenvironmental Engineering Technology, Federal College of Agriculture, Ishiagu, Ebonyi, Nigeria

ABSTRACT

Background and Objective: Manual application of manure directly to the field is hazardous, uneconomical and inefficient due to attendant health, uneven distribution and high labor involvement. To considerably minimize these challenges, mechanical spreading had become popular. This study, therefore, investigates the performance of a developed tractor-mounted spreader consisting of a disc with two conventional vanes, a reduction gear attached to the tractor PTO shaft, an agitator, a hopper and points of attachment to the tractor. **Materials and Methods:** The machine was constructed of locally sourced materials from scrap metals and tested for field performance. The spreader was calibrated and evaluated for field performance using four organic manures, poultry, cow dung, pig and goat droppings. **Results:** The developed tractor-drawn manure spreader has desirable functional and field performance results with hopper discharge efficiency of 99.99%, a maximum disc width throw of 4.84 m at an angular velocity of 12.57 rad, particle velocity of 138.2 m sec^{-1} and a discharge capacity range of 828.11 and 934.12 kg hr^{-1} for all manure samples. The particle size distribution characteristics and density of the selected manures showed that poultry dropping has a larger percentage of fine particles and the least coefficient of variation (0.95). Cow dung has the highest coarse particle sizes, highest coefficient of variation (1.38) and particle density (1785.33 kg m^{-2}). **Conclusion:** The spreader provided technical solutions to the challenges of hazards in manure application, uniformity in distribution and low cost of equipment acquisition. Cow dung has the best uniformity spread, while poultry droppings had the least uniformity spread.

KEYWORDS

Manure spreader, spinning disc, swath, discharge rate, application rate, tractor

INTRODUCTION

Fertilizer application is an artificial way of enriching the soil through the introduction of nutrient-supplying organic or chemical substances known as fertilizer or manure[1]. Fertilizer application is an aspect of crop management practice involving the introduction of organic and inorganic manure to farmland to improve its soil fertility (nutrients) and organic matter contents. To maximize the benefits of manures and fertilizers, efficient and even distribution on the soil surface is important. Other essential considerations include application technique and varying fertilizer requirements including material composition, effective

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application techniques and equipment. Handling fertilizer, especially field distribution is dangerous, especially when there are huge quantities involved and manual handling practices are used. Farmers who use fertilizers frequently complained about allergies, including stinging sensations, blisters, itching, irritations and redness of the skin. To minimize body contact, mechanical distribution has become popular, especially when chemical fertilizers are involved. Furthermore, commercial mechanical spreaders are not readily available in Nigeria. On the one hand, broadcasters that are driven by tractors are highly expensive for intermediate and small-scale agricultural producers to buy and maintain and on the other, the manual technique of applying fertilizer is characterized by uneven fertilizer distribution, slow application and high energy consumption.

Fertilizer application is predominantly done manually, which is a labor-intensive, tedious process and non-uniformity in application[2,3]. Thus, to make fertilizer application safer, uniform and efficient locally developed fertilizer spreaders are essential. An increase in the demand for agricultural goods has prompted the emergence of various machinery for various farming-related activities. Efficient fertilizer application studies have gained increased attention within academia, which promotes the development of different technologies including variable-rate or intermittent fertilization technologies[4,5] which have improved traditional fertilization, improved efficiency of operation and rate of utilization of fertilizers. Since the 1980s, when the kinetic properties of granular fertilizer on the spreader disc and in the air were first discussed[4], several studies have been done on detailed mathematical and empirical examination of centrifugal fertilizer applicators. According to Mohammad *et al.*[6], manual broadcasting (topdressing) and centrifugal machines are the two most common methods of applying fertilizer. A spreader for utilization in sugarcane plantations in India was invented by Chaudhari *et al.*[7] having an initial cost that is lower than conventional fertilization machinery. Birajdar *et al.*[8] focused on fertilizer use in agriculture, while Manda *et al.*[2] experimented with dropping fertilizer through impeller discs. To improve the uniformity of the spread pattern, Kweon and Grift[9] suggested the technique of drop location to control fertilizer particles on a spinner disc. The system had an optical sensor as a feedback mechanism that monitored discharge velocity and position as well as particle sizes.

Spreader development has also expedited modern agricultural long-term growth to support high-yield, better-quality output and maintain adequate conservation of the environment[10,11]. Machine construction features and other machine-based parameters, such as axial and longitudinal tilts, etc., are crucial to machine performance but difficult to set because they depend on a variety of variables, particularly the physical and chemical characteristics of fertilizers, as well as geometric and kinematic characteristics of the discs. The impact of vane height on the distribution pattern with various flow rates was examined by Yildirim and Kara[12]. It was further stated that it is impossible to compare the performances of combined factors of different spreaders and fertilizer type[13] due to unpredictable external factors, such as wind and field conditions. Lv *et al.*[14] suggested a method for conducting optimization research on the design of a fertilizer spreader using granular fertilizer and Outer Groove Wheel Fertilizer Spreaders (OGWFS). To study the impact of spin on the travel path of fertilizer grains in air and dropping positions, three-dimensional ballistic models were created in addition to CAD models. The simulations showed a significant impact on the landing places of individual grains, although the amount was dependent on the spreader and fertilizer application-specific characteristics[15].

To effectively distribute fertilizer on agricultural land, it is important to provide alternatives to manual fertilizer application systems for solid fertilizer distribution, a machine that is capable of handling the demands of small-scale and intermediate-level farmers must be developed. Development of machines that are user friendly and less time-consuming not causing any health hazards to the farmers becomes imperative. The fertilizer spreader has a unique simple distributing mechanism that ensures uniform spreading of fertilizer over a large area with provisions for application rate control, discharge rate and uniformity of spread. This study, therefore, reported the development of tractor mounted spinning-disc fertilizer spreader with the mentioned attributes.

MATERIALS AND METHODS

Study area and duration: This research was carried out at the Department of Agricultural and Bioenvironmental Engineering Technology, Federal College of Agriculture Ishiagu in Ebonyi State, Nigeria, for a period of five months, from the month of May, 2021 through October, 2021.

Considerations for the selection of materials for construction: The major material is the organic manures which include poultry droppings, cow dung, pig dung and goat dropping. These materials were locally sourced within the College animal farmhouses. The major engineering consideration for the selection of materials is the chemical reactivity of components that will be in direct contact with the manure. Organic manure has some acidic or alkaline components that are corrosive to engineering materials, hence the choice of the material and parts selected were based on the factors such as:

- Corrosive action of the material to be handled (manure)
- Simple metering and discharge mechanism
- Material strength, dependability and accessibility for production when necessary
- Financial and ergonomic factors, such as the operator's safety
- System flexibility in terms of operation and modification

Therefore, the ideal material for the hopper is a plastic mold or other non-reactive metals, which are very expensive. Based on economic considerations, metal plates were selected as favorable material within the limits of economic considerations. Other materials used include fabrication equipment and characterization equipment such as a Rupson mechanical sieve shaker (manufactured by Fritsch® Germany) with stacked sieves of American Society for Testing and Materials (ASTM) mesh numbers #8, 12, 20, 35 and 40 with aperture sizes: 2.360, 1.700, 0.850, 0.500 and 0.425 mm, respectively). To determine the weight and relative proportions of different particle sizes, an SF-400 precision electronic weighing scale (5 kg capacity and 1 g accuracy) manufactured in Zhejiang, China was used. A 0.01 mm accuracy Rider Digital Vernier Calliper (Model RDDC 706, EMC, China was used to measure particle lengths.

Methodology

Manure collection and preparation: Samples of poultry droppings, pig droppings and cow dung were sourced and collected in sacks from the Federal College of Agriculture, Ishiagu animal farm sites. The materials were sun-dried to average moisture of 15-18% for handling and characterization. The dried samples were stored in sacks for experimentation.

Design considerations and equations: Three critical design considerations observed in this study include machine factors, field operating conditions and operator characteristics.

Material and machine considerations: The following material and machine factors were taken into consideration:

- Material should be dry and not moist
- Spreader should be able to reduce lump manure sizes into sizes that can be handled before spreading
- Spreader should to a large extent conveniently uniformly spread solid manure
- Simple and efficient spreading mechanism
- Spreader should be able to perform optimally over a wide range of environmental conditions
- Manufacturing costs and costs associated with the manure-spreading process should be minimal

Field operating conditions: The technical and operational qualities of the apparatus, the physical characteristics of fertilizer used and the conditions of the environment in which the process occurs are the three key elements that determine how efficiently fertilizer could be distributed across the field[16,17]. According to El-Sheikha and Hegazy[15], factors such as spreader velocity, blade diameter, spreader dip angle, fertilizer variety and field conditions like terrain, soil surface condition and atmospheric variables (such as wind speed, humidity), as well as product properties (such as granule size, granule structural integrity and granule size homogeneity), as well as varying ground speed, can affect fertilizer distribution uniformity. According to Tawfik and Khater[18], an oval layout works best for fertilizer spreaders that have one or two discs. Salama *et al.*[19] demonstrated that a high degree of uniformity could be attained by employing a spinner speed at 500 rpm, a C-shaped blade with a 15° rake angle, a spinner dip angle of 0° and a spinner height of 500 mm.

Operator considerations: Tractor operators should have a lot of control, especially over how much manure will be distributed, how comfortable they are while operating and how willing they are to work.

Spreader design assumptions: The following assumptions were taken into consideration in the design of various machine elements:

- Fertilizer particles roll down to the vanes radially
- Inter-particle interactions are neglected
- Spreading disc rotates at constant angular velocity ω_d (sec^{-1})
- Fertilizer particles are perfect homogeneous spheres
- Particle travels smoothly along the vane
- Bouncing impact of particles on the disc and its vanes is ignored
- Rotating disc member distributes particles uniformly

Machine components design and equations

Spreader hopper design: The hopper for centrifugal spreaders is mostly conic-frustum in shape with an orifice at the base. The capacity of the hopper is dependent on the size of the field, the material to spread and the cost. The hopper has dimensions' height and upper and lower base diameter The volume of the hopper: The hopper is the frustum of a conical cylinder (Fig. 1) with a closed lower end and an opening for fertilizer metering. The size of the chamber is evaluated by El-Sheikha and Hegazy[15] as the volume and expressed as:

$$V = \frac{1}{3}\pi(R^2 - r^2) \times h(m^3) \quad (1)$$

Where, h is 40 cm is the height and is the radius of the upper and lower base of the cylinder, respectively.

Disc and vane design: Consider a centrifugal spreader hopper with a single disc shown in Fig. 1, the fertilizer particles move under gravity from the hopper down to the orifice at the bottom, then ejected onto the disc spinner at t specified distance from its axis of rotation. The particles come in contact with one of the attached vanes rotating with the disk and traced a particle trajectory until its ejection into the air.

According to El-Sheikha and Hegazy[15], the ejected particle speed has a direct relationship to the angular speed of the disc ω_d (Fig. 2) d (Fig. 2) and other design variables as described:

- Disc radius r_d, =11 cm
- Dertilizer feed-point radius r_0, 8 cm
- Pitch angle, β_0 and
- Rotating disc cone angle

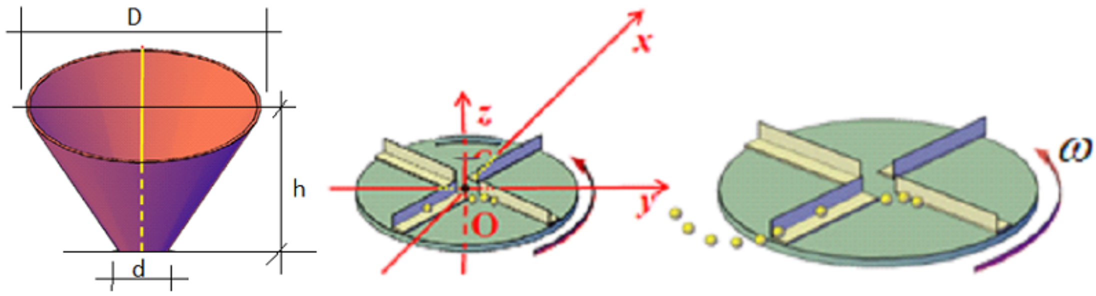

Fig. 1: Hopper, flat disc and straight vane configurations[15]

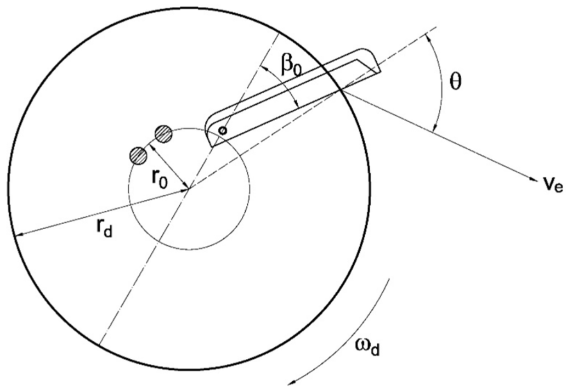

Fig. 2: Spreader disc and vane geometry

The velocity of fertilizer particles leaving the impeller or vane is expressed as:

$$V = r_d \times \omega_d \quad (2)$$

where, ω_d is the angular velocity of the disc expressed by El-Sheikha and Hegazy[15] as:

$$\omega_d = \frac{2\pi N_i}{60} \text{ (rad)} \quad (3)$$

N_i is the speed of the disc in rpm. The speed ratio of the reduction gear is 1/3 of the speed of the tractor PTO (360 rpm). Therefore:

$$N = (1/3)\times \text{PTO} = 120 \text{ rpm}$$

Fertilizer displacement: The fertilizer horizontal distance traveled (X) concerning the height of the f disc vane (Y=3 mm) is given by the following expressions[20]:

$$X = \sqrt{\frac{2\times V_i^2 \times Y}{g}} \quad (4)$$

Torque and traction force calculation: The torque required to drive the system is:

$$T = F\times\left(\frac{d_t}{2}\right) \text{Nm} \quad (5)$$

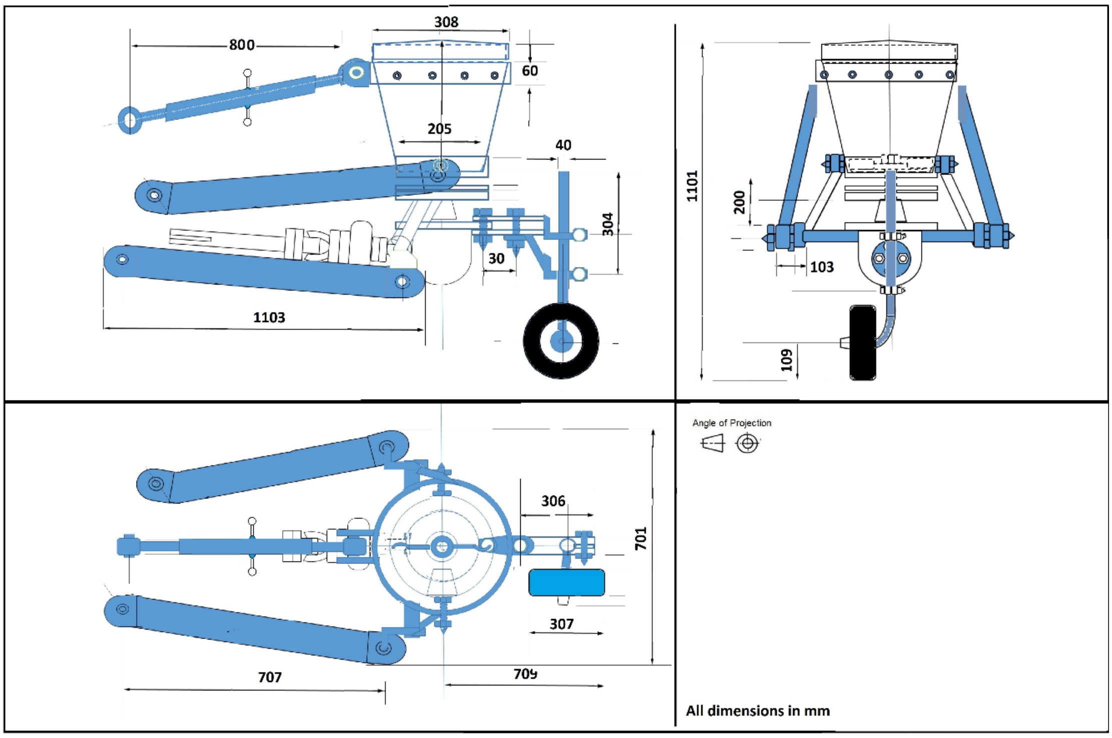

Fig. 3: Orthographic drawing of a machine

where, d_t is the diameter of the driving wheel, 0.64 m, F is force required to pull the equipment. The required traction (tractive) force is given as:

$$F = \mu \times M \times g \tag{6}$$

where, μ is frictional resistance to motion, M is net weight of the tractor+attached equipment. Figure 3 shows the engineering drawings of the machine.

General description and operation of fertilizer spreader: The spreader fertilizer spreader consists of a disc with two conventional vanes, a reduction gear attached to the tractor PTO shaft, an agitator, a hopper and points of attachment to the tractor. The hopper is conic in shape with a frustum base having a discharge outlet and an agitator that supplies manure to the disc under gravity. Usually, the fertilizer is thrown away from the disc as it made contact with the rotating disc. The length or distance of the throw is assisted by the vanes with a speed ranging between 15-70 m sec^{-1}, in some cases, at high relative velocity to the working widths[15]. A spring-loaded adjuster controls the rate of manure discharge from the hopper to the disc assembly. In operation, power is transmitted from the tractor PTO to the distributor gear through the PTO shaft. The machine is mounted on the 3-point hitch of the tractor which powers the PTO and transmits the power to the spinning disc. At engagement, the shaft turned the disc and the agitator inside the hopper, which in turn sets the material in motion, thereby pulverizing the manure and at the same time discharging it by pushing it past the discharge slot and subsequently dropping it onto the spinning disc for distribution.

Machine operation: In operation (Fig. 4), the spreader attached to the tractor's 3-point hitch operated at a PTO speed of 360 rpm turned the shaft connected to a reduction gear which in turn rotated the pinning disc with two sets of vanes. An agitator within the hopper reduces the clods as it channels the material through a discharge slot with an adjustable aperture. The materials dropped on the disc and the vanes propelled it in a trajectory uniformly on the field.

Fig. 4(a-b): Developed machine and field test

Spreader field performance evaluation

Manure physical characteristics: The physical characteristics of sample manures (poultry manure, pig manure, cow dung and goat droppings) for performance evaluation were carried out using sieve analysis procedures to determine the particle distribution and size in three replicates[21,22]. The diameter of the sieve, the quantity of manure, the proportions of manure retained on each sieve after vibration and the percentage of a particle passing through each sieve are determined using standard equations by Kpalo *et al.*[23] and Maharani *et al.*[24]. The percentage of samples passing through the sieve represents a cumulative percentage distribution of each sample. The density was evaluated by determining the mass of fertilizer contained in the hopper from the mass-volume ratio:

$$\rho = \frac{\text{Mass}}{\text{Volume}}\ \text{kg m}^{-2} \qquad (7)$$

For most dry fertilizers, the density varied between 900 to 1600 kg m^{-3} (for all types of dry fertilizers). Considered the maximum density for design.

Machine performance: The following performance indicators manure delivery rate, application rate, uniformity of distribution and field capacity were measured using four manures (poultry, cow dung, pig and goat droppings).

Discharge/flow rate: Material flow rate describes the ability of the manure or fertilizer particles/granules to move relative to each other. The discharge or delivery rate of the spreader was evaluated as the quantity of material discharged (20 kg) from the hopper opening per unit time (120 sec). The discharge rate Q (kg sec^{-1}) is evaluated by:

$$Q = \frac{\text{Quantity discharged from opening (kg)}}{\text{Unit time (sec)}} \qquad (8)$$

The discharge rate should be proportional to the forward speed of the implement and be adjustable in small increments. There should be no appreciable cyclic variations in discharge rate. The flow rate was controlled by adjusting the sliding plate made from the MS sheet inserted below the agitator to control the manure delivery rate. The sliding plate adjusts the opening area in the manure box. The rate of manure delivery varied according to the size of the orifice in weight per second.

Manure application rate (AR): Manure application rate (AR) was determined using the expression in Eq. 9:

$$AR = \frac{Q \times 10000}{WxV} \text{ kg ha}^{-1} \quad (9)$$

Where:

AR = Application rate kg ha^{-1}
Q = Manure delivery/discharge rate (0.168 kg sec^{-1})
W = Width of application, 6.84 m
V = Forward travel speed, 25 km hr^{-1} (0.694 m sec^{-1})

Uniformity of spread: Uniform spread is an acceptable pattern that will produce an even spread of fertilizer across multiple swaths when delivered to the whole field. The uniformity of the spreader is determined primarily by the performance of the spreader disc. Manure uniformity spread is measured by setting collection boxes (e.g., 200 g capacity cups) on the ground at predetermined intervals of (400 mm) to collect materials caught at intervals. The uniformity spread was measured by the coefficient of variation of uniformity determined using the expression:

$$CV = \left[\frac{SD}{\bar{X}}\right] 100x \quad (10)$$

$$\bar{X} = \frac{1}{n}\sum_{i=1}^{n} X_i \quad (11)$$

$$SD = \sqrt{\frac{\sum (X_i - \bar{X})^2}{n-1}} \quad (12)$$

Where:

CV = Coefficient of variation of particle distribution (%)
$\bar{X}$ = Average weight of fertilizer particles of all boxes
X_i = Weight of material in each box i.e., the quantity of fertilizer particles in the ith (1, 2, 3, 4...) collection box g
n = Total number of collection pan/boxes
SD = Standard deviation of a set of observations

Spreader field calibration: To determine the actual capacity of the spreader, field calibration was carried out using four manure samples. To measure the amount of product applied in the spreader, the hopper was filled half-full with manure, then the hopper opening was adjusted to a low, then to medium and then full discharge and operate the spreader at a steady speed replica of the field speed through the marked off distance. Pack the product from the pavement and weigh it. The product weight was recorded and repeated the procedure 3 more times or until consistent results are obtained.

Statistical analysis: Descriptive statistics and correlation analysis were used to analyze data collected from particle size distribution and uniformity index respectively. Correlation analysis was used to establish the uniformity index at a 95 percent confidence interval and $\alpha_{0.05}$ significance level.

RESULTS AND DISCUSSION

Physical characteristics manure samples used for machine evaluation: The percentage of samples passing through the sieve from Table 1 shows that no particle passed through sieve #40, while a greater proportion of each material passed through sieves #8 to #20. This implied that the material particle diameter ranges from 2.36 and 0.085 mm. However, greater proportions of the materials are within the 2.36 mm, which will significantly be favorable to the uniform distribution of manure on the field.

Particle distribution analysis: Particle distribution analysis for each manure was represented in a plot of the percentage mass retained on each sieve against the sieve size as shown in Fig. 5. A greater proportion (51.60%) of the particle sizes are retained on the sieve number #35 with diameter 0.05 mm. This indicates that poultry droppings have a higher percentage of fine particles than other particle sizes. This can be explained by the feed ration composition which is largely cereal grains and by-products. Larger proportions of the particle sizes are coarse with zero percentage of fine particles.

Particle density: The mass-to-volume (density) relationship was used to determine the manure sample densities using the mean values of three replicate samples as shown in Table 2. The mean material particle density showed the same range of values for the replicate samples, respectively.

Developed machine performance: Figure 4 showed the developed machine mounted on the tractor for testing, while Table 3 showed the summary of the parameters determine in the development of the machine. The machine effectively discharges manure from the hopper and evenly distributed it to the ground. The machine performance tests were evaluated based on its functionality (ability to perform designed functions), components' reliability and field performance.

Table 1: Particle size distribution of different manure samples

		Poultry		Cow dung		Dip dropping		Goat dropping	
Sieve number	Diameter (mm)	A	B	A	B	A	B	A	B
#8	2.36	11.1	88.9	31.2	68.8	35.5	64.5	39.6	60.4
#12	1.7	12.1	76.8	18.5	50.3	27.0	37.6	32.9	27.5
#20	0.085	24.1	52.7	26.9	23.4	34.6	3.0	20.1	7.4
#35	0.05	51.6	1.1	23.3	0.1	2.9	0.0	7.4	0.0
#40	0.04	1.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Pan		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

A: Percentage manure retained on sieve (%) and B: Percentage manure passing (%)

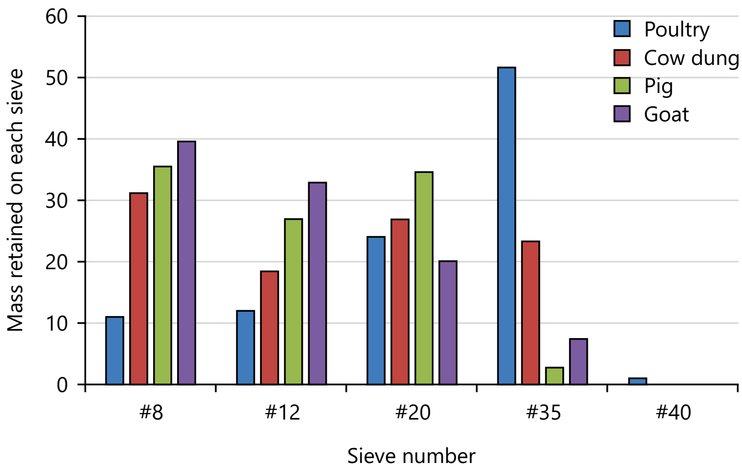

Fig. 5: Percentage mass retained distribution pattern on each sieve

Table 2: Particle density of samples

Sample	Mass (g)	Volume (cm^3)	Density ($kg\ cm^{-3}$)
Poultry dropping	567	900	0.63
Cow dung	900	1200	0.75
Pig dropping	800	1150	0.70
Goat dropping	1000	1357	0.74

Table 3: Developed machine specifications

Machine component	Design value	Machine component	Design value
Hopper volume	0.013 m^3	Particle velocity	1.38 $m\ sec^{-1}$
Disc radius r_d	0.11 m	Width of spread	4.84 m
Feed point radius	0.08 m	Tractor forward speed	25 $km\ hr^{-1}$ (0.694 $m\ sec^{-1}$)
Pitch angle	Variable	Discharge rate	0.168 $kg\ sec^{-1}$
Disc angular velocity	12.57 (rad)	Application rate	353.90 $kg\ ha^{-1}$

Table 4: Spreader calibration table

Manure	Quantity applied (kg)	Area covered (m^2)	Time taken (sec)	Product quantity/ area covered	Calculated product quantity/10, 000 m^2
Poultry dropping	85.45	450	0.088	189.89	1898.89
Pig dropping	75.32		0.09	167.38	1673.78
Cow dung	80.34		0.85	178.53	1785.33
Goat dropping	78.3		0.10	174.00	1740.00

Table 5: Mean machine material capacity

Manure	Quantity loaded (kg)	Quantity discharged (kg)	Material retained (kg)	Discharge duration (hr)	Material capacity ($kg\ hr^{-1}$)
Poultry dropping	85.45	84.70	0.75	0.088	962.5
Pig dropping	75.32	74.53	0.79	0.09	828.11
Cow dung	80.34	79.4	0.94	0.85	934.12
Goat dropping	78.3	74.30	0.87	0.10	743.00

Machine test at no-load and load conditions: The machine ran satisfactorily at idle operation without component failure and subsequently during the field test. Vibration and noise levels were not above the sound of the tractor, therefore within tolerable levels. At full load capacity, all parts including the agitator performed satisfactorily.

Spreader field calibration: Table 4 showed the results of field calibration of the equipment.

Field performance evaluation: Field performance evaluation was carried out to test the machine field capacity, field efficiency and field coverage or material capacity. The machine material capacity is measured by the quantity of material handled per hour. Table 5 showed the mean triplicate replications of the material capacity of the machine working with different manures. Variations in the material capacity were due to manure moisture contents, disc configuration and material coefficients of frictions[17]. From the results, the machine material capacity is very high for all the material handled. This implies that the machine discharged almost all the material fed into the machine. Machine performance efficiency was measured by the percentage recovery of useable material from the machine. The material retained after each test was insignificantly small with a material discharge efficiency of approximately 99.99%.

Uniformity of spread: Uniform spread occurred when products are evenly distributed across the field in multiple swaths. The uniformity of the spreader was determined by measuring the materials contained in the collection boxes set on the ground at predetermined intervals of (400 mm) to collect materials caught at intervals. Table 6 showed the uniformity spread measured by the coefficient of variation of uniformity. Good spread uniformity requires that the coefficient of variation should be less than 8.0%[2], however, other reports considered CVs up to 20% as satisfactory for granular fertilizers[25]. Poultry droppings have the least

Table 6: Coefficient of variation for manure samples

Manure	Mean passing (%)	STDEV	CV
Poultry dropping	43.9	41.66503	0.95
Pig dropping	28.52	30.59472	1.07
Cow dung	21.02	29.04225	1.38
Goat dropping	19.06	25.70385	1.35

Table 7: BEME for the developed fertilizer spreader

			Cost (NGN)	
Material	Specification	Quantity	Unit	Total
MS plate and shaft	1200×600×2 mm	1	12, 000.00	12,000.00
Disc assembly and PTO shaft	-	1	18,000.00	18000.00
Clutch and gear assembly	-	1	16,000.00	16,000.00
Machining cost	Shaft turning, disc milling	-	15, 000.00	15,000.00
Tractor fueling	Diesel	30 L	350.00	10,500.00
Miscellaneous		-	-	5,000.00
Total				NGN76, 500.00

coefficient of variation of 0.95 and cow dung had the highest CV of 1.38, which implied that there is little variation in individual measured quantities compared with the average values. This could be explained by the particle size, composition of manure and disc average velocity[17]. The coefficient of variation increased with a decrease in manure delivery rate, in agreement with Manda *et al.*[2] report.

Machine cost valuation: The cost analysis for the developed fertilizer spreader Table 7 showed that the total cost of fabricating the machine is approximately NGN76, 500.00. A public survey of current trends in economic reality and the inflationary economy showed this value to be far less expensive compared to other locally fabricated spreaders and subsequently, imported boom spreaders whose costs are astronomically high considering the current exchange rate and high cost of import duties in Nigeria. This indicates that the cost of the machine is relatively cheap and affordable by small and intermediate-holder farmers.

By implication, the spreader is low-cost and has the potential for utilization in spreading manure from different sources without a reduction in efficiency and capacity. A major limitation of this study is the low capacity of the hopper, which invariably increased the time spent loading and spreading over a large area of land. From the standpoint of further enhancing the efficiency of spreader efficiency, additional studies are required on the product performance to improve the application efficiency and mitigate factors affecting low hopper capacity, mean disc radius and knife angular positioning.

CONCLUSION

A cost-effective tractor-drawn manure spreader was developed and evaluated with desirable functional and field performances. The spreader discharge rate ranges between 828.11 and 934.12 kg hr^{-1} for cow dung and poultry dropping, respectively and meeting up with the economic realities of acquiring new spreaders.

SIGNIFICANCE STATEMENT

Fertilizer application is a vital aspect of agricultural mechanization that enhances productivity. However, most prevalent among rural farmers is the application of manure manually, which is hazardous, not efficient, wasteful due to non-uniform distribution and labor-intensive. To proffer a solution to these challenges, a tractor-drawn manure spreader was developed, constructed and evaluated using four manures (poultry droppings, cow dung, pig and goat droppings). The developed machine increased agricultural production within the area and has high-performance efficiency, uniform distribution and low labor input compared to imported spreaders. Sampling economic implications and government policy on the importation, the spreader is appropriate for small and medium-scale farmers.

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