Global Scientific JOURNALS

GSJ: Volume 12, Issue 5, May 2024, Online: ISSN 2320-9186

www.globalscientificjournal.com

DEVELOPMENT OF A TRACTOR MOUNTED FERTILIZER BROADCASTER FOR SOIL HEALTH MANAGEMENT

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ABSTRACT

The most valuable resource for humanity is healthy soil. Human life depends on the generosity of the soil. However, addressing soil degradation and containing the numerous risks it poses to safety and security of food worldwide requires immediate action. To this end, a fertilizer broadcaster of 300 kg h^{-1} capacity was designed and developed for granular or powdery fertilizer application for soil health management. The main components are hopper, spread plate, spreader shaft, gear-box, coupling and control lever. The machine was designed to spread fertilizer evenly over a large area of ground. It is powered by the PTO of the tractor. As the tractor moves forward, the fertilizer is dispensed from the hoper and falls on the spreader plate where it is afterwards broadcasted on the field. Linear regression was the statistical model used to understand the relationship between the two variables of evaluation, the predictor x (gate valve clearance) and the response variable y (spreading capacity). Since significance F (0.000307182) and p value (8.74366 E^{-06}) are less than 0.05, there is 95% confidence that there is linear relationship between gate valve clearance and the spreading capacity of the machine. Model equation from evaluation work is therefore given as $y = 1.97\,x + 214.62 \pm 3.24$ and R^2 being 0.992. The highest width of coverage (2.54 m) and field capacity (4.55 ha h^{-1}) were attained at highest gate valve clearance (50 mm). The direct implication of this is that the broadcaster can favorably cover 36 hectares in a day (of 8 hours operation) with an application rate 2.5 tonnes of fertilizer per day. The machine was developed at an affordable cost of ₦320,000.00 ($199.24). The machine is applicable for both granular organic and inorganic fertilizer. It can as well be used for grains seeding. The machine is less stressful to operate and economical to run and maintain. If the machine is widely adopted for use by farmers, soil heath will be maintained and food security will be ensured.

***Keywords**: Soil health, fertilizer broadcaster, coupling, field capacity, application rate.*

INTRODUCTION

Nigeria faces intricate problems relating to food security. Some of the problems are growth in population, poor road network, lack of storage facilities, climate changes, agricultural practices that cannot meet the needs of her teaming population, poverty, lack of access to credit, market price volatility, food loss and waste, poor soil health, etc. (Ahmad et al, 2021, FAO, 2023). Lower crop yields, food poverty, and in certain situations famine can result from unhealthy soil.

Promoting sustainable farming practices is necessary to alleviate some of these problems. The techniques used to improve soil health include utilizing soil testing to analyze nutrients, applying crop-specific targeted fertilizer, developing nutrient management plans, and adding organic amendments to improve soil health. Farmer education and training programs can be crucial for optimizing agricultural yields, mitigating environmental impact, and promoting optimal fertilizer use.

The factual evidence obtained thus far indicates that the largest food crisis in modern history is currently unfolding globally. Hunger has not increased to such dangerous proportions since the UN launched the World Food Program (WFP) in 1963. Every day, millions of people are in greater risk of starvation due to growing food and fuel costs, the worsening effects of the climate disaster, and the advent of new wars (WFP, 2023). Given that there will be more than 9.7 billion people on the planet by 2050, traditional agriculture might not be able to meet the growing demand for food on its own (FAO, 2023).

Soil health is crucial for ensuring food security since it affects crop yields in terms of quality, quantity, and resilience. Plants depend on the nutrients and water that healthy soil provides to produce nutrient-dense food. To maintain healthy soil, there is need to implement practices that support natural processes and increase the soil's ability to retain water, minerals, and organic matter. A few examples of these techniques are crop rotation, cover crops, less tillage, and replenishing the soil with organic matter or compost.

The main source of food availability is the soil; only thriving, healthy soils can produce food that is high in nutrients and suitable for animals to eat. Over the past 50 years, population expansion, rising food prices and improvements in agricultural technology have put growing strain on our soils. The potential of the land to provide enough food to feed future generations is under jeopardy due to soil depletion caused by the intensive crop production practices used in many countries (FAO, 2015).

Since the world's population is predicted to reach over 9 billion people by the year 2050, it is imperative to enhance food quality and yields from the soils that are now being farmed in order to ensure food security for the future. Farmers' efforts, at all levels, are crucial in this regard. Agroforestry, organic farming, conservation agriculture, agricultural ecology, zero tillage farming, and organic farming are a few agricultural strategies that help manage soils sustainably while boosting output (FAO, 2015).

The purpose of this research innovation is to boost crop productivity by developing a fertilizer broadcaster. The fundamental functioning of a standard fertilizer broadcaster comprises filling the hopper with granular fertilizer (which can be either organic or inorganic), modifying the spread width and application rate parameters, and subsequently pushing the broadcaster across the targeted fertilization region. The material is uniformly distributed throughout the ground by means of the revolving spinner disk. With the help of the deflector plate, the material is distributed as intended. Adjusting the broadcaster's settings and speed of movement will help to guarantee that the fertilizer or other components are distributed evenly to support healthy plant development or seeding.

Fertilizer is any substance applied to plants or soil to provide essential nutrients and encourage plant development. Nitrogen, phosphorus, and potassium—all of which are frequently contained in these nutrients—are necessary for plant growth. Fertilizers can be naturally occurring or synthesized from resources such as manure and compost. There are numerous methods for applying them, including broadcasting, top-dressing, and injecting into the ground. They come in many different forms, including liquids, powders, granules, and spikes. Fertilizers are crucial to gardening, horticulture, and agriculture because they replenish soil nutrients that may have been lost due to farming practices. Thus, the goal of this research project is to develop a tractor-mounted fertilizer broadcaster of 300 kg h^{-1} capacity for fertilizers in granular or powdery form. Proper application and responsible management of fertilizers are essential for sustainable agriculture and protecting the environment.

MATERIALS AND METHOD

Design Consideration

In order to minimize replacement costs, the fertilizer broadcaster's design and development took into account a number of pertinent factors, such as fertilizer type, capacity, distribution mechanism, efficiency, effectiveness, safety in agricultural operation, operator comfort, gear use safety, noise and vibration control, weather consideration, accuracy, and drive pattern. The construction of the hopper was made of 2 mm stainless steel to prevent corrosion resistance and to offer a longer lifespan than hoppers made of other materials.

When designing fertilizer broadcasters, efficiency, versatility, and ease of use should be the primary priorities, among other things. It is expected that the design will optimize the speed pattern to give uniform coverage, reducing the likelihood of over-fertilizing some areas and under-fertilizing others. This can be accomplished by ensuring that the spread width is continuous and adjustable, as well as by using components such as spread pattern deflectors or interchangeable deflector plates.

A well-designed system will support varying fertilizer types and application rates. To effectively handle a variety of sizes and densities, the broadcaster design will work with several types of granular fertilizers. In addition, it will allow adjustments to the rate of dissemination so that users can apply fertilizer at different rates depending on the specific demands of the soil.

Additionally, a straightforward and simple-to-understand design that makes it easy for operators to use was considered in the design of the broadcaster. The lightweight and agility of the broadcaster will allow operators to easily go through a variety of terrains and locales. Simple cleaning and maintenance will be facilitated by easily accessible parts and minimal downtime.

The broadcaster is probably going to get features like guards or shields around moving equipment that lessen the chance of accidents or injury. In addition, it is anticipated that a secure hopper closure mechanism will be incorporated to prevent spillage during operation. The device will also have prominently displayed warning labels and easy-to-follow operation instructions.

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Design Philosophy

Using the centrifuge principle, the machine distributes granular fertilizer. When a tractor's PTO shaft is engaged, the coupling that is connected to it transfers rotational motion to the reduction gear at the hopper's base for speed reduction and subsequently power transmission to the spreader plate, which spreads the fertilizer out onto the field by broadcasting when the hopper is filled.

Component Parts of the Machine

The following are the major components of the fertilizer broadcaster: shaft, hitching point, frame, broadcasting disc, hopper, cross gear, and frame support.

i. Hopper: The hopper serves as a holding tank for the granules or fertilizer that will be applied. For the purpose of directing the material into the spreading mechanism, it usually features a funnel-shaped bottom.

ii. Broadcasting disc: A broadcasting disc, often located at the bottom of the hopper, rotates and flings the material outward in a circular pattern.

iii. Frame: Fertilizer broadcasters are mounted on frame, allowing them to be pushed, pulled, or towed behind a vehicle. The design of the frame may vary depending on the intended use and capacity of the broadcaster.

iv. Handle or Hitch: Many handheld or walk-behind spreaders have a handle for manual operation, while tow-behind spreaders are equipped with hitches to connect to a tractor, ATV, or other vehicles.

v. Frame Support: The frame or support structure holds the hopper and spreading mechanism in place and provides stability.

vi. Cross Gear: It gear reduction used to slow down the rotation of the spreading mechanism to achieve the desired spreading rate and coverage while applying the necessary force to distribute the granular material evenly.

vii Shaft: The shaft transmits power from the input source (e.g., a tractor's power take-off or a manual crank) to the spreading mechanism, allowing it to rotate and distribute fertilizer.

Material Selection

The materials needed to develop the broadcaster assembly subcomponents are listed in Table 1. The table also included the dimensions, comments, and selection criteria for those parts.

Table 1: Material Selection

Machine component	Criteria for material selection	Machine selected	Dimension	Remark
Hopper	Must be strong and able to acquire more material	Stainless steel of 2 mm thickness	Top Section: 609.6 mm x 609.6 mm x 2 mm thickness Bottom Section: 150 mm x 150 mm x 2 mm thickness	It does not twist and has ability to occupy more material (fabricated)
Gate Valve	Ability to	Stainless steel	150 mm x 150	Durable (fabricated)

	withstand weight of fertilizer and impact both centrifugal force and impact force on the material to be broadcasted	of 2 mm thickness	mm x 2 mm thickness	
Transmission Shaft	Must be strong	Stainless steel	820 mm long and ф 30 mm	It was machined
Frame	Must be strong and able to be pushed or towed behind the tractor	Mild steel of 12 mm thickness	980 mm x 905 mm x 925 mm high	It was machined
Reduction Gear (Cross Gear)	Ability to increase and decrease the speed of the PTO shaft	Cast iron of 8 mm thickness	Ratio 1 : 5	Available (bought readymade)
Coupling	Must have strong shaft sufficiently long enough to transmit power from PTO to reduction gear of the broadcaster. It must be able to give allowance for free movement of hitching points.	Chain	Ø 34 mm	Stable (bought readymade)
Cross Gear	Ability to have a good wear property	Mild steel	150 mm x 75 mm	Bought readymade

Channel	Must be able to withstand dead load imposed by the self-weight of the shredder	Angle iron of 6 mm thickness	1047 mm x 365 mm x 80 mm	Constructed
Bolts and nuts	Must be hard and durable	Alloy Steel	Various sizes ranging from 13 mm to 24 mm	Bought readymade
Prime mover	Must be a medium or high speed engine	PTO Power	PTO Shaft Ø 30 mm	Harnessed from Tractor Assembly
Spread Plate	Must be able to distribute fertilizer by broadcasting	Stainless Steel plate	Ø 55 mm	Fabricated

Machine Description

A fertilizer broadcaster is a machine or equipment used to evenly distribute or spread fertilizers, seeds, or other granular materials onto a field or garden. It typically consists of a hopper or container where the materials are held, a spreader plate or disc that distributes the materials, and mechanisms such as gearbox or impeller to control the rate and distance of spreading. Attached to the bottom of the hopper is a spinning disc or spreader plate. This plate is responsible for dispersing the granular materials in a controlled manner. It is usually made of a stainless steel material to withstand exposure to the granular substances and environment. The spinning disc is connected to a mechanism for rotation. In manual models, this may involve a handle or crank that the user turns to activate the spreading action. In more advanced models, the rotation of the disc may be powered by an engine, electric motor, or by connecting it to a tractor's power take off (PTO).

To control the spread pattern and with, the broadcaster has adjustable settings (gate valve). These settings allow the user to modify the rate at which the material is released and the distance over which it is spread. This includes sliders that can be easily adjusted according to the desired application rate and field conditions. It is typically a PTO propelled machine or hand held device with a hopper that holds the fertilizer. The broadcaster is designed to distribute the fertilizer in a controlled manner, spreading it evenly across the ground as the user moves forward. It consists of a hopper, a spreader plate and a spreader chute. The hopper is the container where the material is stored prior to spreading. The spreader plate is located underneath the hopper and rotates as it releases the fertilizer or seed. Figures 1, 2 and 3 respectively show the isometric view, orthographic view and exploded view of the machine assembly.

Fig. 1: Isometric View of the Fertilizer Broadcaster

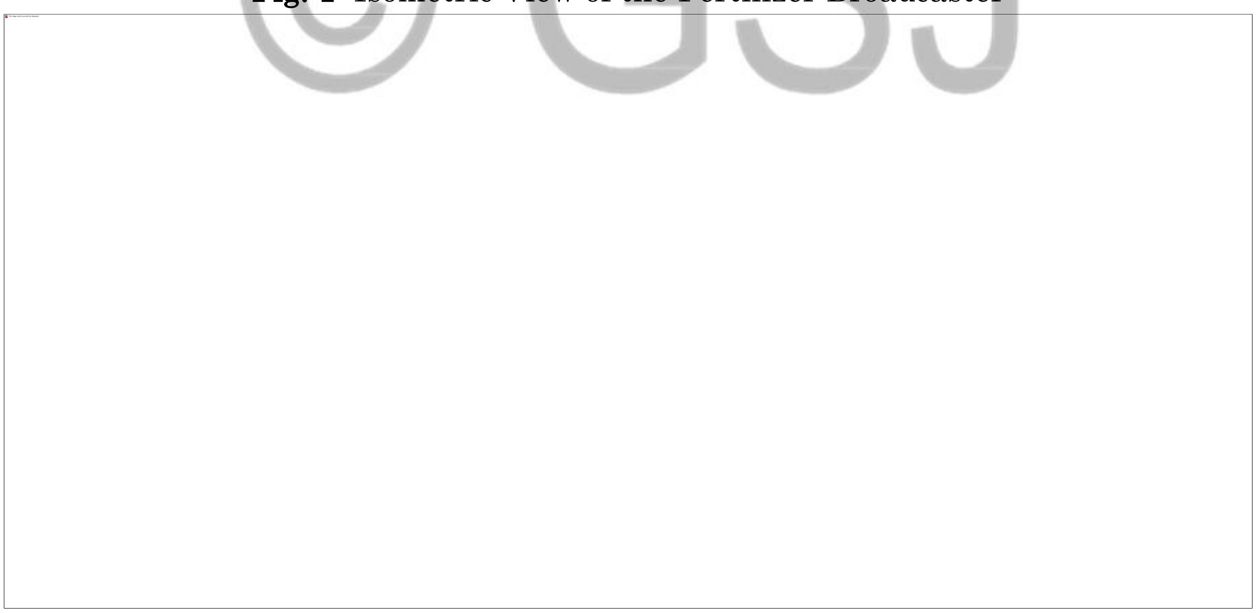

Fig. 2: Orthographic View of the Fertilizer Broadcaster

Fig. 3: Exploded View of the Fertilizer Broadcaster

3.6 Design Calculation

3.6.1 Hopper Design

Volume of the Hopper, $Vh = \frac{1}{3}\ x\ h\{A1 + A2\sqrt{A1 + A2}\}$ **(1)**

Where, A_1 = Area of top base in m^2

A_2 = Area of bottom base in m^2

h = Height of hopper in m = 251 mm = 0.251 m

V_h = Volume of hopper in m^3

$A_1\ \frac{609.6\ x\ 609.6}{10^6} = 0.372\ m^2$

$A_2 = \frac{150\ x\ 150}{10^6} = 0.0225\ m^2$

$Vh = \frac{1}{3} x\ 0.251\{0.372 + 0.0225\sqrt{0.372 + 0.0225}\}$

Volume of hopper, V_h-= 0.0323 m^3

Angle of Repose

Angle of repose, $\emptyset$ is otherwise known as angle of pour. It is a function of coefficient of both sliding friction(μs) and rolling friction (μr).

$\emptyset = \tan^{-1}(\mu s)$ **(2)** (Khurmi & Gupta, 2004)

μ_s is 0.65 (Engineering Toolbox, 2004, Manikyam et al, 2022) for inorganic fertilizer.

By using equation 2, the angle of repose can then be found.

$\emptyset = \tan^{-1}(0.65) = 33.02^0$.

Angle of repose is therefore 33.02^0

Weight of fertilizer in the hopper

Density of inorganic fertilizer, $\rho = \frac{mass}{volume}$ **(3)**

$Weight\ of\ fertilizer\ in\ the\ hopper = \rho\ x\ Vh$
$Wt = 1{,}112\ x\ 0.0323 = 35.92\ kg = 352.4\ N$
Hence, the weight of NPK fertilizer the hopper can take per batch of operation is 352.4 N.

Impeller disc location design

The impeller disc location can be estimated using equation 4 below.

$H = \{A * \frac{\sin[\theta-(\sin^{-1}(r*\sin\theta/A))]}{\sin\theta}\}$ **(4)** Chaudhari (2017)

Where:
H = horizontal distance that the fertilizer travel through into the air = ?
A = vertical height on which the disc is located
r = radius of the disc = 27.3 mm = 0.0273 m
θ = angle in degree = 30^0
If horizontal distance is assumed to be 1270 mm, it implies that vertical height on which the disc is located can be found using equation

$1.27 = \{A * \frac{\sin[30-Sin^{-1}(0.0273\ x\ \sin 30/A))]}{\sin 30}\}$

$1.27 = A\ x\ \frac{\sin(30-Sin^{-1}(0.01365/A)}{sin30}$

$1.27 = 2A\ x\ Sin\{(\ 30 - Sin^{-1}\left(\frac{0.01365}{A}\right)\}$

$\frac{1.27}{2A} = Sin\{(\ 30 - Sin^{-1}\left(\frac{0.01365}{A}\right)\}$

$\frac{1.27}{2A} = Sin\{\left(\ 30 - Sin^{-1}\left(\frac{0.01365}{A}\right)\right\} = Sin30\cos\{Sin^{-1}\left(\frac{0.01365}{A}\right)\} - Cos30\ sin\{Sin^{-1}\left(\frac{0.01365}{A}\right)\}$

$\frac{1.27}{2A} = 0.5\mathrm{Cos}\{Sin^{-1}\left(\frac{0.01365}{A}\right)\} - 0.866\left(\frac{0.01365}{A}\right)\}$

$\frac{1.27}{2A} + 0.866\left(\frac{0.01365}{A}\right)\} = 0.5\mathrm{Cos}\{Sin^{-1}\left(\frac{0.01365}{A}\right)\}$

$\frac{1.27+(2\ x\ 0.866\ x\ 0.01365)}{2A} = 0.5\mathrm{Cos}\{Sin^{-1}\left(\frac{0.01365}{A}\right)\}$

$\frac{1.27+0.02364}{2A} = 0.5\mathrm{Cos}\{Sin^{-1}\left(\frac{0.01365}{A}\right)\}$

$\frac{0.6468}{A} = 0.5\mathrm{Cos}\{Sin^{-1}\left(\frac{0.01365}{A}\right)\}$

$\frac{1.2936}{A} = \mathrm{Cos}\left\{Sin^{-1}\left(\frac{0.01365}{A}\right)\right\} = \sqrt{}\{1 - x^2\}$

Where x = $\frac{0.01365}{A}$

Therefore, $\frac{1.2936}{A} = \mathrm{Cos}\left\{Sin^{-1}\left(\frac{0.01365}{A}\right)\right\} = \sqrt{}\{1 - (\frac{0.01365}{A})^2\}$

$\frac{1.2936}{A} = \sqrt{}\{1 - (\frac{0.01365}{A})^2\}$

$\left(\frac{1.2936}{A}\right)^2 = 1 - (\frac{0.01365}{A})^2$

$\left(\frac{1.2936}{A}\right)^2 + (\frac{0.01365}{A})^2 = 1$

$$\left(\frac{1.2936^2}{A^2} + \frac{0.01365^2}{A^2}\right)^1 = 1$$

$$\left(\frac{1.6734}{A^2} + \frac{0.00186}{A^2}\right)^1 = 1$$

$1.6358 = A^2$

$A = \sqrt{1}.6358 = 1.2789$ m

Hence, vertical height, A on which the disc is located is 1,279 mm.

Weight of rotating disc

The weight of rotating disc can be calculated using equation 5 below.

$$w = \frac{\pi}{4} * d^2 * t * \rho * g \qquad \textbf{(5)} \qquad \text{Chaudhari (2017)}$$

Where,

d = diameter of rotating disc = 109.2 mm = 0.1092 m

t = thickness of rotating disc. = 2 mm = 0.002 m

ρ = density of stainless steel = 7,500 kg m^{-3}

g = 9.81 ms^{-2}

$$w = \frac{\pi}{4} x\ 0.1092^2 x\ 0.002\ x\ 7{,}500\ x\ 9.81 = 1.379\ kg$$

Design of drive mechanism

Belt drives, power screws, gear drives, chain drives, and direct coupling are the most widely utilized drive mechanisms. The two drive mechanisms used in the broadcaster design are gear drive and direct coupling. A coupling is a mechanical device that connects like or dissimilar shafts in machinery to transmit power and movement while gear drives use gears to transmit motion and power from one shaft to another. Direct coupling was used to transmit power from the PTO shaft to the transmission shaft of the centrifuge disc that broadcast fertilizer. The reduction gear assists in reducing the speed of rotation (540 rpm) N_{pto} coming from the PTO shaft with a ratio of 1: 5. From equation 6, the centrifuge disc speed, N_{cent} can be estimated.

$$Ncent = \frac{Npto}{Speed\ ratio} \qquad \textbf{(6)}$$

$$Ncent = \frac{540}{5} = 108\ rpm$$

$$Vcent = \omega\ r = \frac{\pi DNcent}{60{,}000} \qquad \textbf{(7)}$$

$$Vcent = \frac{\pi\ x\ 30\ x\ 108}{60000} = 0.169\ ms^{-1}$$

Where V_{cent} is the linear speed of spinning disc.

Input Power Requirement

To determine the input power measurement, information can be obtained from the name plate of the prime mover that drives the machine. It may also be determined using the transmission shaft drive of the machine. This initiative computed the broadcaster input power according on the torque needs of the transmission shafts.

The power needs for the driving and driven shafts were calculated using the formula in equation 8.

$P = \frac{2\pi NT}{60,000}\ (KW)$ **(8)** P is the power, T shaft torque, and N is the speed of rotation Belonio (2004)

Where N = final speed of rotation of transmission shaft in rpm = 108 rpm

T = torque requirement of the transmission shaft = 9.0 Nm. (See equation 9 for details)

$P = \frac{2\pi\ x\ 108\ x\ 9}{60,000} = 0.102\ KW = 102\ W$

Torque Requirement

T = F x r **(9)** Where F is the total load on the shafts and r is the radius of the shaft (Ossian, 2023)

If the total load on the shaft per batch is estimated to be 600 N

F = 600 N

$r = \frac{30}{2\ x\ 1000} = 0.015\ m$

$T =$ F x r $= 600\ x\ 0.015 = 9\ Nm$

Transmission Shaft Design

In order to guarantee adequate strength and rigidity when the shaft is transmitting power under varied operating and loading situations, the main task of shaft design hinges on determining the proper shaft diameter. Shafts can be solid or hollow and typically have a cross-section. In this study brief, a solid cylindrical shaft was taken into consideration for design (see figure …… for details).

The ASME code equation for solid shaft diameter is as given in equation in equation 9

$\boldsymbol{d^3 = \frac{16}{\pi\ Ss}\sqrt{\{(KbMb)^2 + (KtMt)^2\}}}$ **(10)** (Hall etal, 2017)

The shaft diameter can be estimated using the following parameters:

The maximum permissible stress for a solid shaft is 40 MNm^{-2}, the fatigue factors for a solid shaft are K_b = 2.0 and K_t = 2.0, the torsional moment is derived from the prime mover's name plate, and BM = 8.19Nm is derived from the computation of the bending moment.

$d^3 = \frac{16}{\pi\ Ss}\sqrt{\{(KbMb)^2 + (KtMt)^2\}}$

$d^3 = \frac{16}{\pi\ Ss}\sqrt{\{(KbMb)^2 + (KtMt)^2\}}$

$d^3 = \frac{16}{\pi\ x\ 40\ x\ 10^6}\sqrt{\{(2\ x\ 8.19)^2 + (1.5\ x\ 9)^2\}}$

d = $\sqrt[3]{\{}\ \frac{16}{\pi\ x\ 40\ x\ 10^6}\sqrt{\{(2\ x\ 8.19)^2 + (2.0\ x\ 9)^2\}}\}$

d = $\sqrt[3]{\{}0.127\ x\ 10^{-6}\ x\ \sqrt{\{16.38^2 + 13.5^2}$

d = $\sqrt[3]{\{}0.127\ x\ 10^{-6}\ x\ \sqrt{\{592.}3044\}$

d = $\sqrt[3]{3.0991}\ x\ 10^{-6}$

d = $1.46\ x\ 10^{-2}$ m

d = 14.6 mm

d ≈ 15 mm

Diameter of shaft section for each shaft can be taken as 20 mm and above

Shaft Design for Torsional Rigidity

The allowable angle of twist serves as the basis for rigidity. The allowable twist varies from approximately 0.3^0 per meter for machine tool shafts to approximately 30 per meter for line shafting, depending on the specific application.

SAME claims that for a solid circular shaft,

$$\theta = \frac{584MtL}{Gd^4} \qquad \textbf{(11)}$$

$\theta = angle\ of\ twist\ (degree)$

L = length of shaft (m) = 820 mm - designed

Mt =torsional moment (Nm) = 1.47 Nm (name plate)

G = torsional modulus of elasticity (Nm^{-2}) = 80 x 10^{12} Nm^{-2} - standard

d = shaft diameter = 30 mm - Calculated

R = D/2 = 30/2 = 15 mm = 0.015 m

$$\theta = \frac{584\ x\ 1.47\ x\ 0.82}{80\ x\ 10^{12} x\ 0.015^4} = 0.000174^0$$

$\theta = 0.000174^0$. Since the value is less than 0.3^0 per meter (0.3^0 / m >>> 0.000174^0/m), angle of twist of the 0.82 m long transmission shaft is within permissible range.

Shear force and bending moment analysis

Force Analysis

The weight of the spinning disc is resting on the transmission shaft (See figure 4)

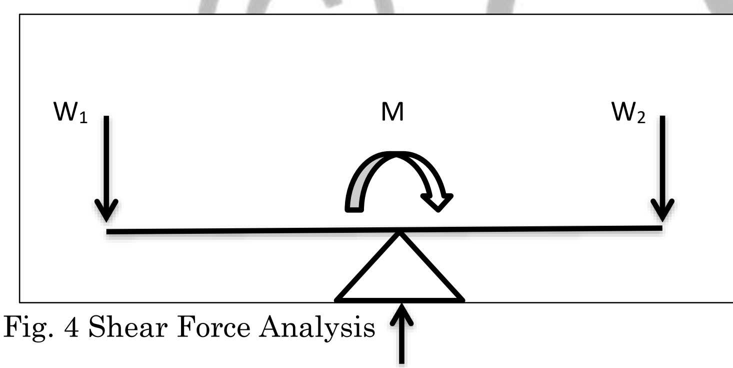

Fig. 4 Shear Force Analysis

Figure 4: Force analysis on the transmission shaft

Finding reactions R_A and R_B at the bearing section:

Weight of spinning Disc and fertilizer, W_1 = 300 N;

Weight of spinning Disc and fertilizer, W_2 = 300 N;

The reaction $\mathbf{R_0}$ at the support (the bearing section) = $W_1 + W_2$ = 600N

ΣM about $R_0 = 0$,

$$\Sigma M\ (CCW) = \Sigma M\ (CW) \qquad \textbf{(12)}$$

Where CW is clockwise moment and CCW is anticlockwise moment. Anyakoha (2016)

$R_0 = W_1 + W_2$ **(13)** Where R_0 and R_Q is reaction at the support Anyakoha (2016)

$\mathbf{R_0}$ = $W_1 + W_2$ = 600N (See figure 5 for details)

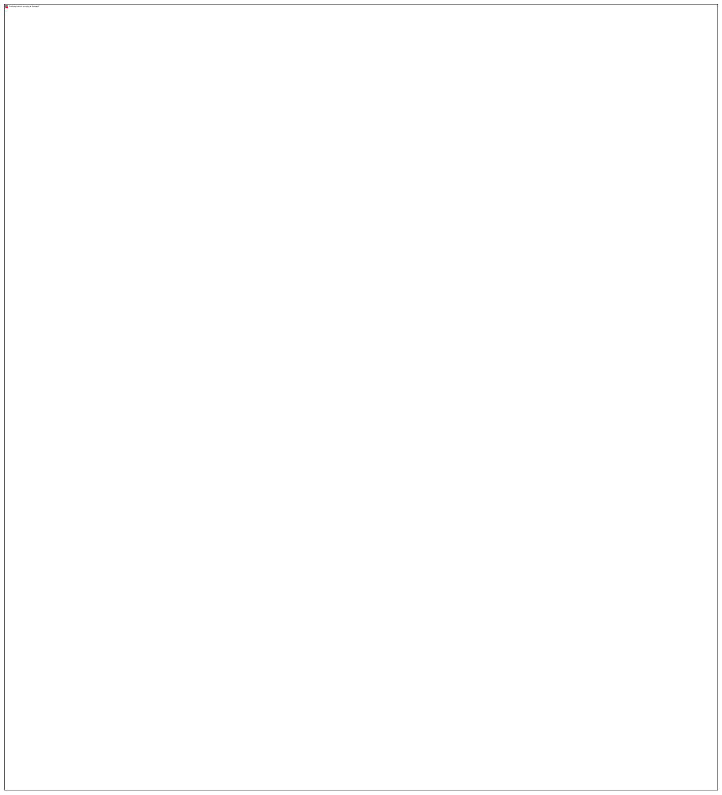

Fig. 5: Shear Force and Bending Moment Diagram

Materials for Evaluation and Variables Considered

The following materials are utilized to evaluate the fertilizer broadcaster: organic fertilizer, inorganic fertilizer (urea), stop watch, recording materials, sensitive measuring scale, and standby tractor. The gate valve clearance, rotational speed, and broadcaster coverage area are variables that are taken into account throughout the evaluation process.

Performance Evaluation

Using both organic and inorganic fertilizers at different gate valve clearances, the machine's performance was evaluated. The spinning blade rotated at a speed of 108 revolutions per minute via the transmission shaft. An electronic weighing balance was used to calculate the weight of the assessment materials. In an effort to determine how many kilograms of materials will pass through the machine in an hour, this was done. The width of coverage of the broadcaster was also measured with a stop watch. By tabulating and analyzing the results from each material that was evaluated, the spreading capacity in an hour or a day of eight hours of operation was computed.

Method of Analysis of Results

Regarding the variables in question, the null hypothesis is Ho: $0.5 \leq r \leq 1$, and the alternative hypothesis is H1: $r < 0.5$. Two-way Linear regression was the statistical model used to determine the connection between the predictor and the response variable. The response variable is Y, the model error is ε, the predictor is X1 / Xn, the regression coefficient is ß1 / ß n, and the intercept on the y axis is ßo. Variable X, the predictor, is the gate valve clearance, and variable Y, the response variable, is the spreading capacity in kilograms per hour (kg h-1). The Analysis Tool-Pak in Microsoft Excel was used to look at the relationship between the predictor and the response variable. The general model for bivariate and multivariate linear regression analysis is shown in Equation 14.

$$y = \beta o + \beta 1X1 + \beta nXn + \varepsilon \quad \textbf{(14)}$$ (Zach, 2020, Statology)

Cost Estimation of Broadcaster Fertilizer

Technical items, such as the fertilizer broadcaster that was recently manufactured, can be classified as either direct or indirect expenses according on their pricing (Hasiehurst, 1981). The cost of the newly designed and built shredder was ascertained using the detailed factorial estimate approach (Sinnot, 1993). This is so that it is possible to estimate and dissect each individual component part in depth because the machine has been fully built. Table 2 shows the cost analysis of the machine.

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Table 2: Bill of Engineering Quantity and Measurement (BEME)

S/N	Materials	Specification	Quantity	Unit Price (N)	Total Amount (N)
1	Propeller Shaft	Ø 35 mm & 820 mm long	1	25,000	25,000
2	Plate (stainless steel)	2 mm	1	80,000	80,000
3	Spinning Disc Shaft	Ø30 mm	1	10,000	10,000
4	Reduction Gear	Ratio: 1: 5	1	70,000	70,000
5	Flange	8 mm thick	1	17,500	17,500
6	Bar (Thick) for Member Frame	15 mm	1	15,000	15,000
7	Bearing	-	2	3,250	7,500
8	Welding and Turning	-	-	20,000	20,000
9	Bolt & Nut	-	-	3,000	3,000
11	Blade	269/74 mm	6	1,670	10,000
12	Transport	-	-	7,000	7,000
13	Miscellaneou	-			12,500

s	
TOTAL	**277,500**

i. Materials Cost = ₦ **277,500**
ii. Direct Labour Cost: (Machining of Main Shaft , Bending, painting) = ₦ 15,000
iii. Indirect/Overhead Cost: = 20% of ₦ **277,500**= ₦ **55,500**

Grand-total = Material cost + Labour cost + Overhead cost **= ₦ 277,500 + ₦ 15,000 + ₦ 55,500 = ₦ 348,000**

At $ 1.00 = ₦ 1200

₦ **348,000** = $ 290.00

RESULTS AND DISCUSSION

The designed and fabricated broadcaster was tested at 108 revolutions per minute while using inorganic fertilizer. The ideal clearance for spreading capacity was determined by varying the gate valve clearance for every batch that was processed. The findings are displayed in table 3 below. For each gate valve clearance test, the processing time of the materials was maintained constant. At a 50 mm clearance, the largest coverage area and spreading capacity were noted. Tables 4, 5, and 6 give the statistical analysis of the evaluation outcomes.

Table 3: Evaluation of Fertilizer Broadcaster Using Inorganic Fertilizer (Urea)

S/N	Duration (hr.)	Weight of Fertilizer (kg)	Fertilizer Width of Coverage (m)	Field capacity (ha h^{-1})	Gate Valve Clearance (mm)	Machine Spreading capacity (Kg h^{-1})
1.	1.0	237.40	1.55	3.02	10	237.40
2.	1.0	250.80	1.71	3.36	20	250.80
3.	1.0	273.50	1.98	3.72	30	273.50
4.	1.0	291.20	2.23	4.14	40	291.20
5.	1.0	315.70	2.54	4.55	50	315.70

Referring to Table 3, the broadcaster's lowest and highest spreading capacities are 237.4 kg h-1 and 315.7 kg h-1, respectively. Invariably, 5 bags to 7 bags of NPK fertilizer (a bag being 50 kg) will be sufficient for fertilizing 1 ha of farm land. The gate valve clearance at which the lowest and highest spreading capacity were obtained are respectively 10 mm and 50 mm. It was equally observed that as the gate valve clearance increases, the spread width and field capacity increases considerably. More also, the machine was found to be versatile for grains seeding.

The statistical model utilized to analyze the relationship between the response variable (broadcaster spreading capacity) and the explanatory variable (gate valve clearance) was bivariate linear regression. The spreading capacity of each material that was treated was calculated using the formula in equation 15.

$$Spreading\ Capacity\ or\ Application\ Rate \ = \frac{m}{t}\ (kgh^{-1}) \qquad (15)$$ (Manda et al, 2018)

m is the mass of material broadcasted in kilogram -
t is the time it took to broadcast the material – it is measured in hour.

Table 4: Statistical Analysis of Evaluation Results (Regression)

Regression Statistics	
Multiple R	0.99596773
R Square	0.991951718
Adjusted R Square	0.989268958
Standard Error	3.239753077
Observations	5

Five observations were employed for the predictor and response variable model, as indicated by the results displayed in Tables 4, 5, and 6. The application rate accounts for 99.1% of the variation in gate valve clearance, according coefficient of determination in table 4 (R square = (0.991). The explanatory variable (clearance) and response variable (application rate) have a good level of correlation or linear relationship, as indicated by the multiple R value of 0.996. It also means that the defined null hypothesis is within admissible bounds. The coefficient of the predictor (clearance), which is 1.97 mm, is less than the standard error, 3.24. The observed value of the predictor, on average, deviates 3.42 from the regression line.

Table 5: Analysis of Variance
ANOVA

	df	SS	MS	F	Significance F
Regression	1	3880.9	3881	369.7503811	0.000307182
Residual	3	31.488	10.5		
Total	4	3912.388			

The regression statistics' analysis of variance (ANOVA) is displayed in Table 5. Since the regression degree of freedom (df) in the table is 1 and the total df is 4, it is also possible to deduce that the number of independent variables in the model is 1. Table 5 shows a F value of 369.75 and a Significance F of 0.000307182. The independent variable's zero slope hypothesis is tested with the help of the F value. The p value for the null hypothesis is another name for the Significance F. It helps to verify whether the independent variable's coefficient is zero. Given that the p-value is less than 0.05, it may be concluded with 95%

confidence that the regression line's slope is not zero. As a result, the broadcaster's application rate and the gate valve clearance in millimeters have a strong linear relationship.

Table 6: Model Coefficients

	Coefficients	Standard Error	t Stat	P-value
Intercept	214.62	3.397881693	63.163	8.74366E-06
Gate Valve Clearance (mm)	1.97	0.102449988	19.229	0.000307182

For individual p-value in table 6, it can be inferred that the predictor (clearance) is statistically significant – meaning the predictor is applicable for the model. The model equation is therefore $\boldsymbol{y} = 1.97\,\boldsymbol{x} + 214.62 \pm 3.24$

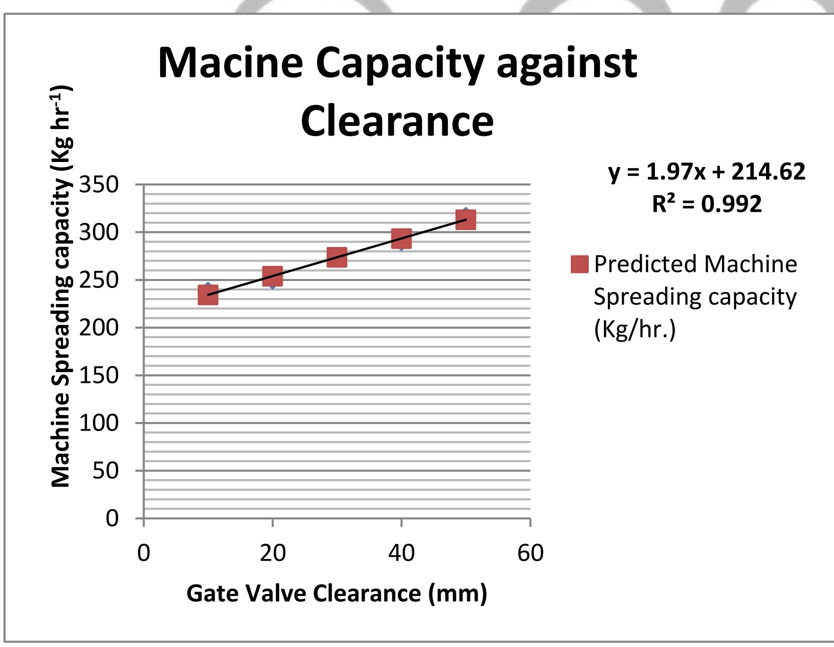

Fig. 6: Plot of Machine Capacity and Gate valve Clearance

The relationship between spreading capacity and gate valve clearance for material flow is depicted in the application rate charts in Figure 6. Based on the graph, it can be inferred that an increase in gate valve clearance corresponds to a rise in the amount of material flow per unit of time. 237.40 kg of material are broadcast in an hour with a 10 mm clearance. The amount broadcast rose along with a significant increase in clearance. In one hour, 315.7 kg was transmitted at 50 mm. On 8 hectares of land, the machine can effectively broadcast 56 bags weighing 50 kg (2.8 tons a day) if it is run for eight hours a day at the maximum observed clearance. The model has the gate valve clearance as variable X1, the machine's application rate or spreading capacity as variable Y, the model error as ε, and the intercept on the y axis as ßo.in kilograms per hour.

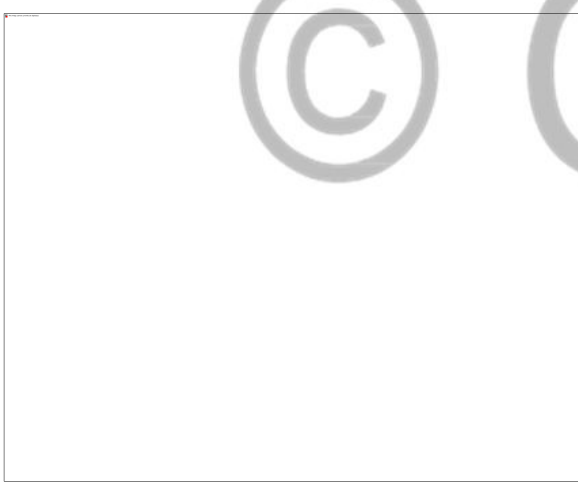

Fig. 7: Coupling of Fertilizer Broadcaster to Hitching Point of a Tractor

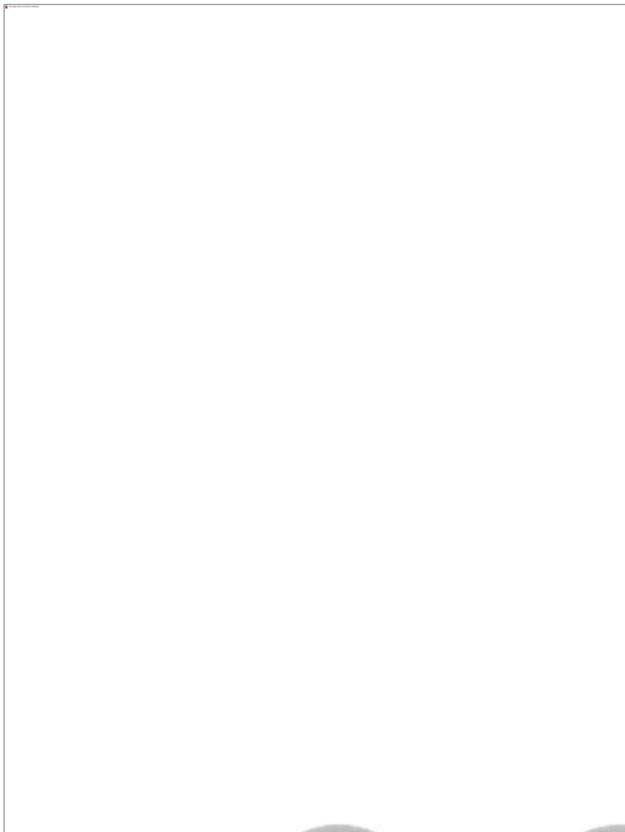

Fig. 8: Machine Evaluation Exercise

The pictures of the machine assembly during evaluation exercise and product of evaluation are as shown in figures 7 and 8.

CONCLUSION AND RECOMMENDATION

Conclusion

A fertilizer broadcaster is an essential piece of machinery for precise and effective dispersal of granular ingredients. In addition to ensuring adequate nutrient distribution and reducing waste or over-application, it saves labor and time. The type of fertilizer broadcaster developed and tested in this research brief can be mounted on tractor 3 point linkage and powered by tractor's PTO shaft. The speed of rotation of the spinning disc was estimated to be 108 rpm while the machine application rate or spreading capacity is 315.7 kg h^{-1}. The highest width of coverage (2.54 m) and field capacity (4.55 ha h^{-1}) were respectively attained at highest gate valve clearance (50 mm). it can be inferred that the broadcaster can favorably cover 36 hectares in a day of 8 hours operation. The machine was also found to be applicable for seeds that are planted by broadcasting like grains and vegetables.

Soils must be managed sustainably in order to alleviate the demands brought on by growing population. Encouraging sustainable use of our finite soil resources through the use of the most up-to-date scientific research is an essential need at all levels. The ability of farmers in increasing agricultural productivity and ensuring food quality on already cultivated land will determine how secure our food supply chain will be both now and in the future.

Recommendations

The following recommendations are given about the machine while in operation:
i. The machine can be adopted for use by farmers at all levels to promote high yield at harvest.
ii. In order to optimize the process, the machine should be used for additional evaluation tasks.
iii. More research should be conducted to provide additional equipment for efficient soil management.

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