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Research Paper

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Development of a Low-Cost Seed Drill for Sowing Amaranth Seed

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Abstract- The elementary necessities for planting using tools or machines are in its simplicity, design model and knowledge which are adaptable used for diverse farm tasks. Single row amaranth seed planter was established toward increasing productivity with moderate technique to plant Amaranth. The study is aim to design, construct and asses a low-cost amaranth seed drill. The amaranth seed drill comprises of feeder hopper, metering device/chamber, wheels, discharge sprout, furrow opener, covering device and push handle. It was calibrated in the workshop for spacing, metering and check damaged seeds in rows. Calibration involves loading the hopper with 50 g (with sand) of amaranth seeds. Error bars was used for analysis and highest metering efficiency was 92.3% with machine speed of 1.8 m/secs for (3) holes metering device; and 83.3% with 1.9 m/secs speed for one (1) hole metering device; this was obtained at low speed. The ANOVA performed shows that speed has significant effect on the metering efficiency one (1) hole with P-value of 0.000 and no significant effect on (3) holes metering efficiency 0.563. The tukey's test showed that 1.8 m/secs and 1.9 m/secs performed better than other speeds for one (1) hole; while all speeds are of the same range for (3) holes. In conclusion the metering device increases seed planting and accuracies at low speeds. Fabricated with locally sourced material making it affordable to commercial farmers to lessen drudgery.

Keywords: Amaranth seed, seed drill, metering efficiency, speed, planting

I. INTRODUCTION

Amaranth jointly known as *Amaranthus*, it's a yearly perennial plant which fit in *Amaranthaceae* family [1]. About 60 species globally with 40 species mostly found in Asia, America, Africa and Europe, [2] [3] these species are with eatable leaves and [4] grain amaranths. These varieties are originating in both temperate and tropical climates, and classified as vegetables, weed, grain and ornamental. It's not a grass, cereal or true grain, but identified as "Pseudo-cereal" for its flavor and taste with species display comparisons to grain. Amaranth seeds comprise whole sources for protein and minerals (copper, manganese phosphorus and iron). It's mostly cultured and consumed for its leaves because they are nourishing leaf vegetable, being used for cooking. Hence, it is termed "grain of the future" for its worthy nutritive worth [5]. For 8,000 years back, studies on various planting methods on many Amaranthus species have been done [6] and has been fast increasing with a huge amount of information have been acknowledged [7] but no seeder for amaranth seed. Poor planting reduces viability and productivity. Most planting is done by broadcasting because of its grain sizes and its wasteful. There is a need for seed-drill that allows seed drilling without prior tilling and planting in rows. Planting of seeds are carried out using broadcasting, animals-drawn planter and seed drills. Seeder efficiency lies on seed quality for effective metering, there is considerable rises in planting level to compensate for small seed sustainability which can be damaged by seed meters, mostly precision seed metering devices [8] [9] [10]. Examples of planter classification are hand-held, human-powered, broadcast planter, trailed, tractor-powered drill planter, and precision planter dibble planter [11].

II. RELATED WORK

Amaranth seed sizes are about 1/16 inches; this feature made it difficult to develop mechanical planters specific for amaranth grains multi-grain seeders. However, amaranth seed can be sown using vegetable seeders [12], sugar beet planter, standard grain drill [13], or using insecticide in-furrow applicators [14]. A drum seeder was developed by [15] for small grains like millet ad amaranth. [16] designed a seeder which allows metering devices to be changed and enables it to grow wheat, amaranth, groundnut, black gram, maize and groundnut which is powered manually.

III. METHODOLOGY

Design Principle for Amaranth Planter

It's considered to help as a middle equipment between the cruel tools and the tractor drawn planter for sowing amaranth seeds; it's designed for local farmers nurturing less plot. It is a push type and operates in a single row. Amaranth seeds were mixed with sand and fed into the hopper; then placed at the anticipated initial point, and pushed. The machine drops five seeds per furrow through the chute. The furrow opener constantly opens the soil and gently dropped seeds into the opened furrow which are concurrently covered by the furrow coverer.

Specification of Planter component

A. Hopper design capacity

The hopper is like a cone truncated and it functions as a feeder unit. It was designed using [17] method to offer plane quantity of amaranth seed delivered into the metering compartment as shown in Figure 1.

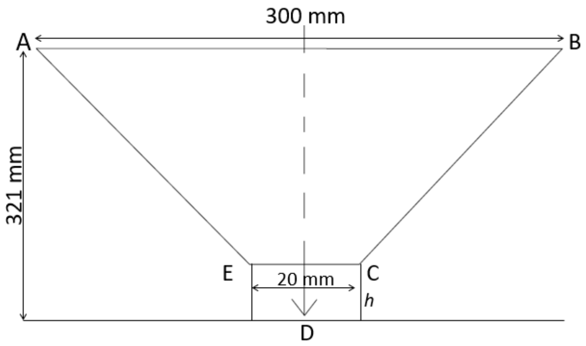

Figure 1. Hopper Design

Considering AMB,

$$\frac{EM}{AM} = \frac{h}{h+300}$$

h=21 mm (h is base height)

H=21+300= 321 mm. (H is total height)

Hopper capacity = πrlh

Where l=250 mm, h=321 mm

Volume = 3.142 x 300 x 321 = 302575 mm^3

B. Shaft Design Calculations and Stress Analysis

The analysis of the linear relationship between the machine shaft loading and stress driving the shaft in the metering unit and the proper sizing members to safely withstand the maximum stress induced within machine members when subjected to separate or combined bending, torsional, axial or transverse loads.

These broken down into two phases the first being the stress resulting from each separate loads/ moment and second, the combined stresses to give a resultant stress.

Determination weight of Auger

Outer Auger diameter (D)=7cm= 0.070 m

Thickness of Auger (T)=4 mm=0.0040 m

Inner diameter of Auger(Di)=6.5cm=0.0650 m

Length of Auger(L)=100 cm =1 m

Outer radius (R)= 4 cm =0.040 m

Inner radius (r)= 3.75 cm=0.0375 m

From the data above

Volume of metering Auger could be calculated as:

Volume of metering Auger $= \pi r^2 L$

$=6.0868 \times 10^{-4} m^3$

Density of a material is given as accord

$$\text{Density}=\frac{Mass}{Volume} \quad (2.1)$$

A relationship for mass therefore could be derived as

Mass = Density of galvanized Steel x Volume of the auger

Since mild steel was used to construct the roller

Density of wood (ρ)=160 kg/m^3

Therefore: Mass of auger = 7800 x 0.0006868

= 4.8076 kg

Weight of auger (W_1) = mass x acceleration due to gravity

= 4.8076 x 9.81 =47.16 N

Therefore, total weight acting on each shaft

= Weight of Auger + Weight of chamber + Assumed weight of amaranth seeds (viability of 4) = (27.16 + 1.96 + 15) N = 44.12 N

Machine Shaft Design

It's a part used for transmitting power and motion from one point to the other, for this research a solid shaft was consider due to the following reasons:

i. ease conveyance of amaranth seeds; and
ii. increase torsional strength;

Determining loading

The following were considered;

i. torsional moment, and
ii. bend

While designing the safety factor μ = 1.5 is assumed

Reacting forces are caused by the following;

i. Weight wheel
ii. The Bearing Reaction
iii. The point loads of the cylindrical metering device

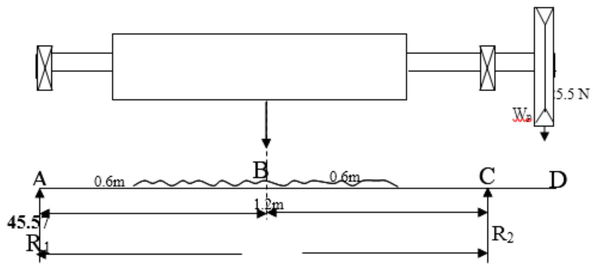

Figure 2. Forces acting on the Shaft

where:

W_1 = Weight of the Auger acting vertically

W_w = Weight of wheel.

The weight of wheel is derived thus:

W_w = Ma = 2.6 kg x 9.81 = 25.5 N

The sum of horizontal forces ($\sum fx$) = 0

Therefore, $R_1 - W_1 + R_2 - W_p = 0$

$R_1 - 94.12 + R_2 - 25.5 = 0$

$R_1 + R_2 = 119.62$ N

Taking moment at R_1

$W_1 \times 0.6 - R_2 \times 1.2 + W_P \times 1.27 = 0$; $94.12 \times 0.6 - 1.2 \times R_2 + 25.5 \times 1.27 = 0$

$56.472 - 1.2 R_2 + 32.385 = 0$

$R_2 = \frac{-88.857}{-1.2}$; $R_2 = 74.05$ N

Therefore, since $R_1 + R_2 = 119.62$ N; $R_1 = 119.62 - 74.05$ N; $R_1 = 45.57$ N

(a) Shear Force

Starting from point A
Shear Force at point A = 45.57 N
Shear Force at point B = 45.47 – 94.12 = -48.65 N
Shear Force at point C = - 48.65 + 74.05= 25.4 N
Shear Force at point D = 25.5N – 25.5N= 0 N

(b) Bending Moment

Calculating Bending Moment;

At A, $BM_A = 0$
At point B, $BM_B = 45.47 \times 0.6 = 27.282$ Nm
At point C, $BM_C = 45.47 \times 1.2 - (94.12 \times 0.6) = -1.908$ Nm
At point D, $BM_D = 45.47 \times 1.27 - (94.12 \times 0.67) + (74.05 \times 0.07) = 0$ Nm

Maximum bending moment (M_b) = 27.282 Nm

(c) Determination of Moment due to Torsion

It is expressed using [18] equation 2.2;

$$M_t = \frac{60\,P}{2\pi N} \quad (2.2)$$

Where P = Power = 750 W
N = Maximum speed of shaft = 700 rpm

Therefore,
$M_t = 750 \times 60 / 2\pi * 700$
$M_t = 10.24$

(d) Shaft Diameter

Shaft diameter is given by [18] equation;

$$d^3 = \left(\frac{16}{\pi S_s}\right)\left[\sqrt{(K_b + M_b)} + \sqrt{(K_t + M_t)}\right] \quad (2.3)$$

Where d = Diameter of the shaft
$S_s = 55 \times 10^6$ N/m^2 (Allowable Shear stress for shaft without keyway)

Bending moment, K_b = 1.5 (fatigue factor and combined shock)
Torsional moment, K_t = 1 (combined shock and fatigue factor)
M_b = 27.282 N/m, M_t =10.23

Therefore,

$$d^3 = \frac{16}{\pi \times 55 \times 10^6}\sqrt{(1.5 \times 27.282)^2 + (1 \times 10.23)^2}$$

$$d^3 = \frac{16}{\pi \times 55 \times 10^6}\sqrt{1674.69 + 104.65}$$

$$d^3 = \frac{16}{\pi \times 55 \times 10^6}\sqrt{1779.34}$$

d = 0.0157m

Applying an assumed factor of safety (μ) of 1.5
0.0157m x 1.5 =0.0235 m=23.5 mm
Based on this calculation, a steel shaft 25 mm was selected

Design Drawings

The designs were done using AutoCAD 16 as shown in figures 3-4.

S/N	DESCRIPTION	QTY	S/N	DESCRIPTION	QTY
1	HANDLE	1	8	FURROW OPENER	1
2	HOPPER	1	9	SPOUT	1
3	SHAFT KEY	1	10	WHEEL	2
4	COVER PLATE	1	11	BEARINGS	2
5	SHAFT	1	12	METERING CHAMBER	1
6	METERING DEVICE	2	13	FURROW COVERER	1
7	FURROW OPENER BASE	1	14	HANDLE ADJUSTER	1

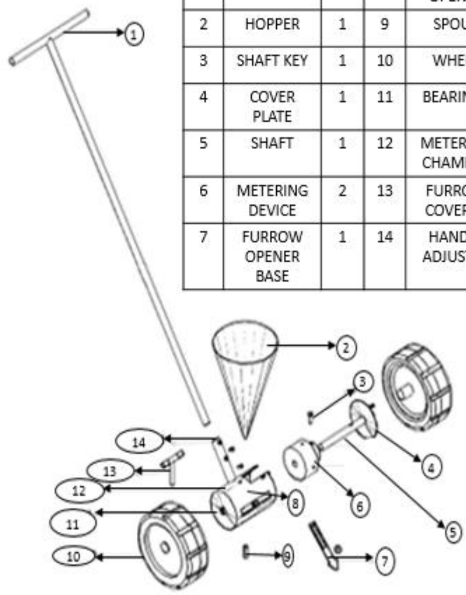

Figure 3. Exploded view of Seed Drill for Amaranth seed

Figure 4. Isometric view of Seed Drill for Amaranth seed

Experimental setup

The fabricated machine as shown in Figure 6 was standardized in the workshop to regulate seed discharge, uniformity of seeds arrangement in rows and damaged seeds. Calibration of the planter involves loading the hopper with 50 g of amaranth grains. The machine was seized on bench vice to allowed the moving unit of the planter and remove the wheels. Chalk was used to mark a point on the wheel to calculate speed when in motion and a bowl used for discharged. A slow speed was used to calibrate the machine with 50 rotations over a time measured by a watch. The seeds discharged into a bowl and weighed using a weighing balance with the same process repeated 5 periods for clarity. To get uniformity of seed space in ratio 1:50 g (sand and seeds) was used to increase visibility on the cardboard on the ground. The hopper was feed with the mixture for test run over a plain cardboard prepared on the floor. The planter was pushed to observe the seeds dropped and the distance between point as shown in Figure 5.

To determine the performance (percentage seed damage, metering efficiency and field efficiency) of the machine at different wheel speed and different metering device field test were conducted**.**

Performance Test to be carried out

Equation (3.1) was used to calculate field efficiency of the machine;

$$\eta_f = \frac{T_a}{T_t} \times 100 \quad (3.1)$$

Here, T_a is operation time for actual planting; T_t is engaged time.

Using equation (3.2);

$$ME = \frac{T_s - T_0}{T_s} \times 100 \quad (3.2)$$

ME is planter metering efficiency, T_s is total number of spot with viable seeds while T_o is total number of spots without viable seeds

Data Analysis

Minitab 12 was used to perform some mathematical calculations and results obtained was be subjected to ANOVA and Tukeys test.

Figure 5. Fabricate planter for Amaranth seed

Figure 6. Experimental Test carried out on Amaranth Seed Planter

IV. RESULTS AND DISCUSSION

Designed Components

Metering device: It function is to collect certain seed amount place it in the soil at a required depth. It was machined and a 5 mm hole drill on it with 10 cm in between the three (3) holes. Each hole on the device can take up four to five seeds with design 10 cm spacing. Metering device is powered by the wheel through a shaft with key.

Discharge tube: The tube is located under metering chamber. Seeds are dropped in the furrow made a long line of travel. The selected material was a 30 mm diameter by 50 mm steel pipe

Furrow opener: It's design like shovel with adjustable hand, use to open up the soil. The teeth of the opener are sharp so as to cuts and moves through the soil to avoid obstacles. The following was considered; angle of cut, condition of soil and soil type. The adjustable feature allows planting at different depth. The dimension of the opener is 300 mm x 5 mm of mild steel material

Furrow coverer: it's also designed like a packer which is adjustable and positioned at the back of the discharge tube. This allows it to cover the soil with gentle compaction. A 25 mm x 3 mm mild steel was selected.

Traction Wheel: Rubber type wheel with punch edges was selected; and this helps to reduce motion resistance particularly during planting on slack soil by griping surface. It provides drive through rotation of the wheel.

Metering Chamber: The metering chamber was made to be closed and adjustable. The opening at one side helps for ergonomics, so as to help in the keying device. The thickness was 3 mm, 32 cm in length and 22 cm in diameter.

Push lever: Hollow pipe with dimension 90 cm x 31 cm x 3 mm was selected. This gives the required motion/push energy to the machine. It has adjustable lever to help with ergonomics of the operator.

Hopper: Volume of hopper with a conical shape calculated was 302575 mm^3 secure at angle 30^0.

Using equation 3.1, the machine has 84.7% field efficiency.

$$\eta_f = \frac{T_a}{T_t} \times 100 \quad (3.1)$$

T_a actual period engaged 50 secs , T_t total period engaged 59 secs;

$$\eta_f = \frac{50}{59} \times 100 = 84.7\%$$

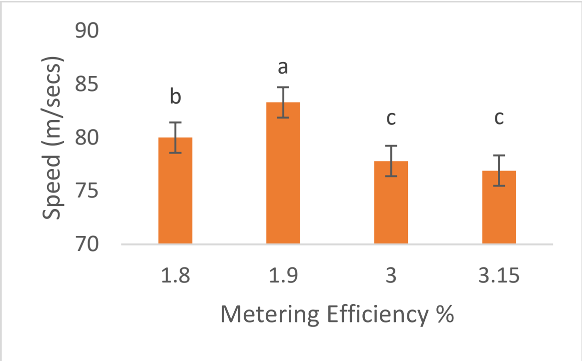

Figure 7. Metering Efficiency with three (3) Holes at different speeds

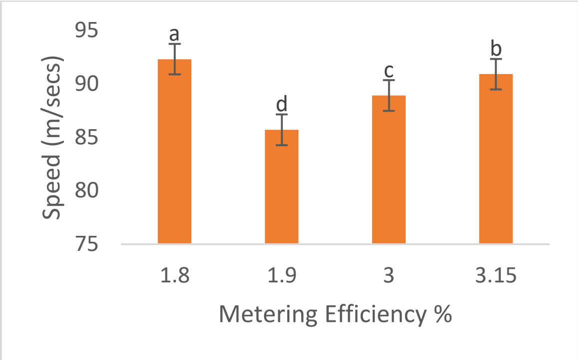

Figure 8. Metering Efficiency with three (3) Holes at different speeds

The metering efficiency was 92.3% with machine speed of 1.8 m/secs as shown in Figures 7-8.

$$ME = \frac{T_s - T_0}{T_s} \times 100 \quad (3.2)$$

DISCUSSION

The metering efficiency was graphically expressed as shown in Figures 7-8, the highest metering efficiency was observed as 83.3% with speed of 1.9 m/secs for one (1) hole metering device while for three (3) holes metering device the highest metering efficiency of 92.3% was observed at 1.8 m/s using error bars standard error. The ANOVA Tables 1-2 shows that the speed of the machine as significant effect on the metering efficiency with P-value of 0.000 for three (3) holes metering device while for one (1) hole metering device show no significant effect with p-value of 0. 563. This is in agreement with [19] that forward speed affects the metering efficiency of significantly. Figures 9-10 shows a box-plot representation of the effect of speed on metering efficiency, the means are not symmetry which means there is significant effect for three (3) holes metering device while for one (1) hole metering device the means are symmetry this means there is no significant effect. The Tukey pairwise comparisons shows that speed 1.8 m/s and 1.9 m/s gives the best metering efficiency compared to other speeds for three (3) hole metering device while there was no significant effect for one (1) hole metering device. Figures 11-14 shows the different view of the developed planter.

Table 1. ANOVA effect of speed on metering efficiency with one (1) hole

Source	DF	Adj SS	Adj MS	F-Value	P-Value
speed	3	77.77	25.9245	37.25	0.000
Error	16	11.14	0.6960		
Total	19	88.91			

Table 2. Tukey Pairwise Comparisons

Speed(m/sec)	N	Mean	Grouping		
1.8	5	91.920	A		
1.9	5	90.480	A	B	
3	5	89.040		B	
3.15	5	86.580			C

Means that do not share a letter are significantly different

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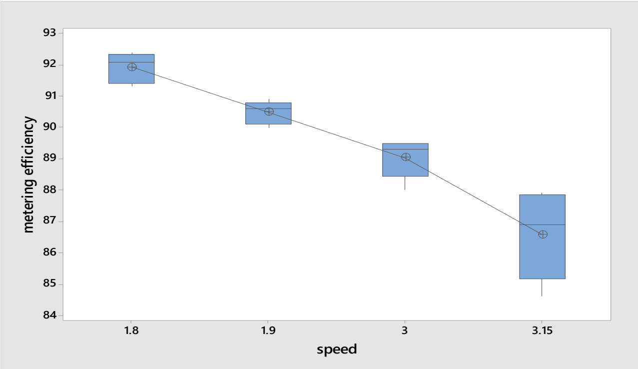

Figure 7. Box-plot showing effect of speed on metering efficiency with three (3) hole.

Table 3. ANOVA effect of speed on metering efficiency with three (3) holes

Source	df	Adj SS	Adj MS	F-Value	P-Value
speed	3	35.87	11.96	0.71	0.563
Error	16	271.25	16.95		
Total	19	307.12			

Table 4. Tukey Pairwise Comparisons

Speed(m/sec))	N	Mean	Grouping
3	5	83.78	A
1.9	5	83.48	A
3.15	5	82.50	A
1.8	5	80.36	A

Means that do not share a letter are significantly different.

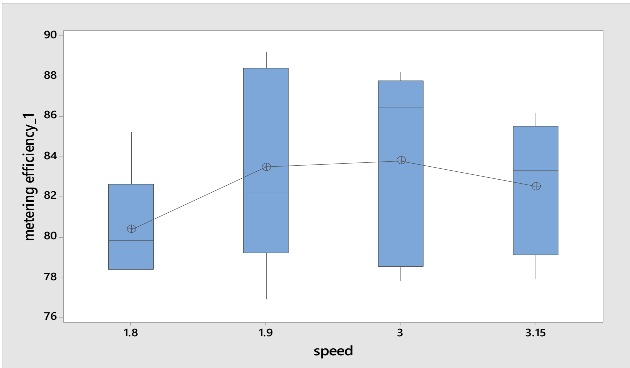

Figure 8: Box-plot showing effect of speed on metering efficiency with one (1) hole.

Figure 11. Testing of the Fabricated Seed Drill planter

Figure 12. Side View showing the marker on the wheel

Figure 13. Front View showing the hopper, wheels and furrow opener

Figure 14. Top View

V. CONCLUSION AND FUTURE SCOPE

A low-cost seed drill for sowing amaranth seed has been designed, constructed and tested which can be adopted by small scale farmers to reduce drudgery. The seed drill with three holes was effective in planting average of 5-8 seeds. The machine was fabricated using locally available materials. The results obtained showed that the highest metering efficiency of 92.3% observed at 1.8 m/secs for first metering device with three (3) holes and 83.3% with 1.9 m/secs for second metering device with one (1) holes. Field efficiency of 84.7% was determined for the seed drill. The ANOVA (analysis of variance) shows that speed as significant effect on metering efficiency. This machine is affordable (₦35,000) and require less skill to plant amaranth. The machine can be improved to have more rows and automated.

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