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Research Article

# Development of a Low Cost Two-Row Groundnut Planter

**Adewale Moses SEDARA[ID][a]* Roseline LANWO[ID][a] Oluwadunsin Seun SEDARA[ID][a]**

[a]*Department of Agricultural and Environmental Engineering, School of Engineering and Engineering, The Federal University of Technology, Akure, Nigeria, PMB 704,*

*(*): Corresponding author, adewale.sedara@gmail.com, Tel: +2348188068438*

## ABSTRACT

The groundnut seed composed of approximately equal weight of fatty and non-fatty oil. The groundnut cake (kulikuli- Hausa name in Nigeria) contains concentrated protein, minerals, and vitamins in addition research finding revealed that no part of the nut is a waste. The kernel without the nuts can be used as hay to feed animals like, horse or ash manure. Planting machine or planter that is normally required to produce more food is beyond the buying capacity of smallholder's farmers, which result in low productivity especially in the production of grains. An improved manual two-row groundnut planter was developed and evaluated for its performance using locally sourced materials which can be adapted for gardens and smallholder farmers. The machine has the following parts which are furrow opener, handle, frame, hopper, discharge tube, metering unit, and roller housing. The machine was evaluated for field capacity and metering efficiency (3 hole metering devices) at different forward speeds. It was observed that the machine field capacity efficiency of was 82%. Using standard error bars the highest metering efficiency of 92% was observed at 0.7 m s$^{-1}$ machine speed. The ANOVA (analysis of variance) shows that speed as significant effect on metering efficiency with a p-value of 5.44E-18. The planter could plant an average of five seeds per point. It is simple, cheap and the ergonomics of the machine was considered which makes it easy to operate.

**RESEARCH ARTICLE**

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- Groundnut,
- Planter,
- Metering efficiency,
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- Planting efficiency

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## INTRODUCTION

Groundnut (*Arachis hypogea*) is a species in the legume or beans family. Groundnut originated from South America and is mainly produced in the tropical and subtropical regions of the world. It is cultivated on subsistence and commercial bases for food and industrial purposes (Thakur *et al.,* 2013; Mohammed *et al.,* 2018). Groundnuts take about 3-5 days to germinate and emerge from the soil at 30 °C. Groundnut seeds contain 40-50% oil and 20-50% protein. The groundnut seed composed of approximately equal weight of fatty and non-fatty oil. The general productivity of groundnut in Africa is comparatively low, compare to that of America due to a number of constraints such as biological, undulating climate, socio-economic factors, pests and diseases (Zongo *et al.,* 2019). The average output of groundnut in Africa (902.6 kg $ha^{-1}$) is very low comparative to the American output of 33381.4 kg $ha^{-1}$ (FAOSTAT, 2018). The average yield of groundnut in Africa is about ¼ of that of the America's and about ½ of the yield of Asia due to low mechanization, pressure of pest and diseases and low yielding varieties among others (Desmae and Sones, 2017). Groundnut is considered as the most valuable crop among legumes, grown in West Africa because of its economic, dietary and industrial advantages (Sugri, 2020). Farm machinery is an important element for agricultural development and crop production in many developed countries. The use of machines for agricultural operations has been one of the outstanding developments in the global agriculture during the last decade (Abdalla, 2007). The type of crop, soil condition and available power are considered in the selection of planters (Hunt, 1995). Planters can give different types of distribution and precision pattern, depending on the machine that is being used (Abdalla, 2007). Some researchers have worked on row planters (Ashoka *et al.,* 2012) the twin or two-row groundnut planter and the 48-row planter by John Deere (Russnogle, 2009). As our population continues to increase, it is necessary that we must produce more food, but this can only be achieved through some level of mechanization. It is therefore necessary to develop a low-cost planter that will reduce drudgery and enable smallholder farmer to produce more foods. The specific objectives are to design and fabricate a manually operated two row groundnut planter and evaluate the performance of the planter.

## MATERIALS and METHODS

### Design principle

The planter is designed to serve as an intermediate technology between the hand tools and the tractor drawn multi-row planters; mainly for smallholder farmers cultivating less than two hectares of land. This is necessary considering that more than half of the farming population in the country cannot afford either to buy or hire tractor drawn planting machinery, given their level of income and size of farm. The planter is intended to minimize drudgery by eliminating continuous bending down and standing up, time wasting, hand method of seed metering, furrow opening, closing, and fatigue that generally characterize traditional seed planting by most Nigerian farmers. The design and material selection also ensured that the machine will be easy to construct, affordable to the target end users, with most of the component parts made with locally available materials, and low technology requiring little or no training for operation and maintenance. The planter is a double row push type working on the principle of fluted roller. To operate it, seeds are poured into the hopper; the planter is then positioned at the desired starting point and pushed along the row. About two seeds are picked up by the metering plate and introduced into the chute. The furrow opener continuously opens the soil and the seeds metered into the chute fall into the opened furrow, which are simultaneously closed by the furrow closer. As the planter is pushed along the row, it plants continuously at 30 cm intra row spacing, until the seeds in the hopper will finish to a level requiring refilling the hopper.

**Mechanical factors considered for the design planter**

The recommended seed spacing, and depth of seed placement vary from crop to crop and for different agro-climate conditions to achieve optimum yields. The following are considered which can affect emergence of seed;

a) Uniformity of depth of placement of seed.
b) Uniformity of distribution of seed along rows.
c) Transverse displacement of seed from the row.
d) Uniformity of soil covers over the seed.

Machines that place the seed in the soil and cover it in the same operation create definite number of seed dropped into the soil.

**Description of groundnut planter**

The developed planter consists of the handle, seed hopper, furrow opener, seed discharge tube, main body (frame) and metering roller housing. The machine was powered by the rotation of the wheel and its motion was transmitted through the shaft to the metering unit. The average mean diameter of groundnut used was 9.23 mm. The seed tube was made of hollow cylindrical metal designed from the hopper to the seed meter. A 25 mm diameter hole on the metering device houses the seed to be planted. Seeds picked from the hopper pass through the upper hole at the open and close castellated metering mechanism to the lower hole into the discharge tube which deposits the seeds into the opened furrow.

Metering disc: the metering mechanism was constructed from the principle of bicycle braking system where the seed-metering component is linked to the regulator handle. Applying the regulator handle causes the seed meter to open for a seed from the hopper to pass through the lower slot tube, into the opened furrow.

**Design considerations**

The design of manually operated groundnut planter with two rows was based on the following considerations

e) The ease of fabrication of component parts.
f) The safety of the operator
g) The operation of the machine should be simple for small scale or rural farmers.
h) The materials available locally were used in the fabrication of the components.
i) Availability and cost of the materials for construction.
j) Viability of the seed
k) Nature of the seed (orientation of the seed and moisture content)

**Design Analysis and Specification of Planter Component**

**Determination of the capacity of the Hopper**

The hopper is a truncated cone which serves as the input unit, so it was designed to provide smooth supply of groundnut seed into the metering chamber.

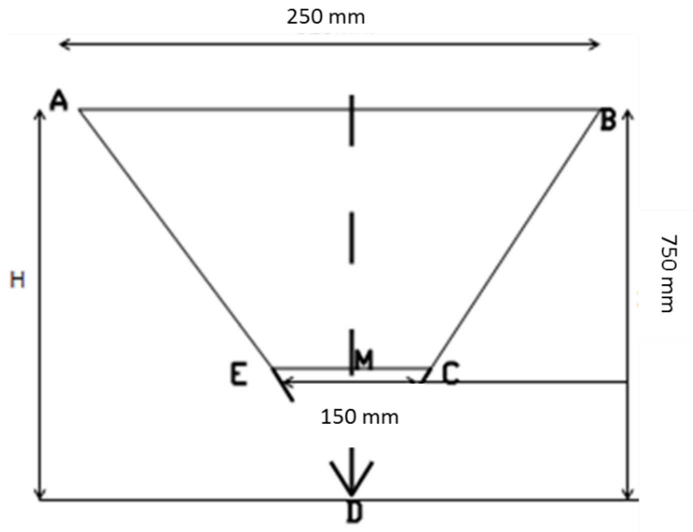


**Figure 1.** Hopper design

Considering AMB,

$$\frac{EM}{AM}=\frac{h}{250+h}$$

$$\frac{30}{150}=\frac{h}{260+h}$$

h=52 mm

Therefore, the total height H=52+250= 302 mm.

Volume of hopper = Volume of cone = π l h

Where l=250 mm, h=302 mm

Volume = 3.142 x 250 x 302

= 237221 $mm^3$

**Shaft Design Calculations and Stress Analysis**

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

The stress analysis is broken down into two phases the first being the stress resulting from each separate loads/ moment and second, the combined stresses acting at a point to give a resultant stress.

**Determination weight of Auger**

| | | |
|---|---|---|
| Outer diameter of Auger (cm) (D) | = | 8 |
| Thickness of Auger (cm) (T) | = | 5 |
| Inner diameter of Auger (cm) (Di) | = | 7.5 |

| | | | |
|---|---|---|---|
| Length of Auger (cm) | (L) | = | 100 |
| Outer radius (cm) | (R) | = | 4 |
| Inner radius (cm) | (r) | = | 3.75 |

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 according to Khurmi and Gupta, (2005) = $\frac{mass}{volume}$ (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 groundnut seeds (viability of 3) = (47.16 + 1.96 + 45) N = 94.12 N

**Machine Shaft Design**

A shaft is a rotating machine part used for transmitting power and motion from one point to the other, in this design consideration, a solid shaft is used because of the following reasons:

i. to ease the conveyance of the cassava tubers;
ii. to increase the torsional rigidity of the shaft; and
iii. to withstand the axial loads acting on the shaft.

**Determining the loading on the shaft**

The following are the loading on the shaft:

i. torsional load imposed from the energy input, and
ii. bending load imposed by various loading points along the shaft.

While designing the shaft, a factor of safety μ = 1.5 is assumed

Forces acting on the shaft are:

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

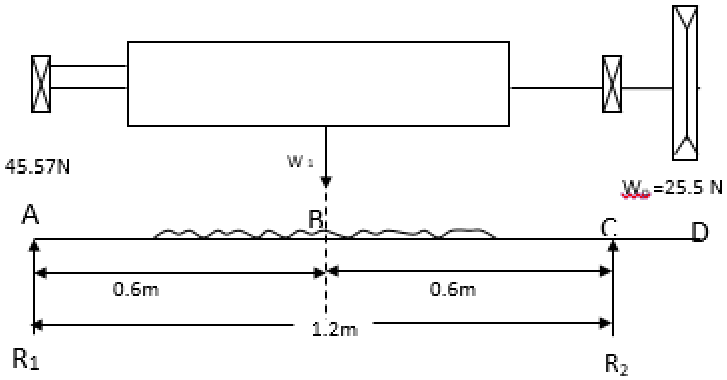


**Figure 2**. Forces acting on the shaft

where; $W_1$ is weight of the Auger acting vertically and $Ww$ is weight of wheel.
The weight of wheel is derived thus:

$W_w = Ma = \quad 2.6kg \times 9.81 = 25.5$ N

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

Therefore, $\quad R_1 - W_1 + R_2 - W_p = 0,\ R_1 - 94.12 + R_2 - 25.5 = 0,\ R_1 + R_2 = 119.62$ N

Taking moment at $R_1$

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

$56.472 - 1.2\ R_2 + 32.385 = 0$

$R_2 = \dfrac{88.857}{1.2};\ R_2 = 74.05$ N

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

**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

**(a) Bending Moment**

Calculating Bending Moment;

At A, $BM_A = 0$

At point B, $BM_B = 45.47 \times 0.6 = 27.282$ N m

At point C, $BM_C = 45.47 \times 1.2 - (94.12 \times 0.6) = -1.908$ N m

At point D, $BM_D = 45.47 \times 1.27 - (94.12 \times 0.67) + (74.05 \times 0.07) = 0$ N m

Maximum bending moment $(M_b) = 27.282$ N m

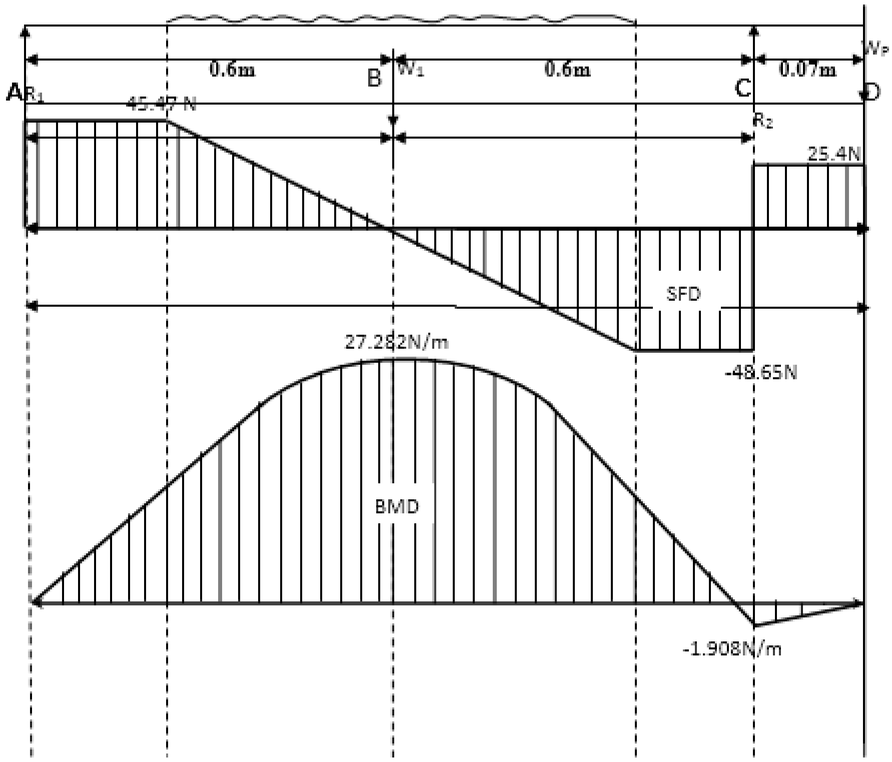


**Figure 3.** Bending and shear force diagram

**(b) Determination of Torsional Moment**

The torsional moment acting on the shaft can be calculated from Khurmi and Gupta, (2005) equation;

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

Where P = Power = 750 W (power require to push the planter)

N = Maximum speed of shaft = 700 rpm

Therefore,

$$M_t = \frac{750 \times 60}{2\pi \times 700}$$

$M_t$ = 10.24

**Shaft Diameter**

Shaft diameter is given by Khurmi and Gupta, (2005) equation;

$$d^3 = \frac{16}{\pi S_s}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad (3)$$

Where d = Diameter of the shaft

$S_s$ = 55 x $10^6$ N $m^{-2}$ (Allowable Shear stress for shaft without keyway)

$K_b$ = 1.5 (combined shock & fatigue factor applied to bending moment)

$K_t$ = 1 (combined shock & fatigue factor applied to torsional moment)

$M_b$ = 27.282 N $m^{-1}$

$M_t$ = 10.23

Therefore,

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

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

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

$$d = 0.0157 \text{ m}$$

Applying an assumed factor of safety (μ) of 1.5

$$0.0157\text{m} \times 1.5 = 0.0235 \text{ m} = 23.5 \text{ mm}$$

Based on this calculation, a steel shaft 25 mm was selected for the peeling tools.

## Design Conception

The conceptual design details of the two-row groundnut planter are shown in Figure 4. The machine was designed using AutoCAD 13 software.

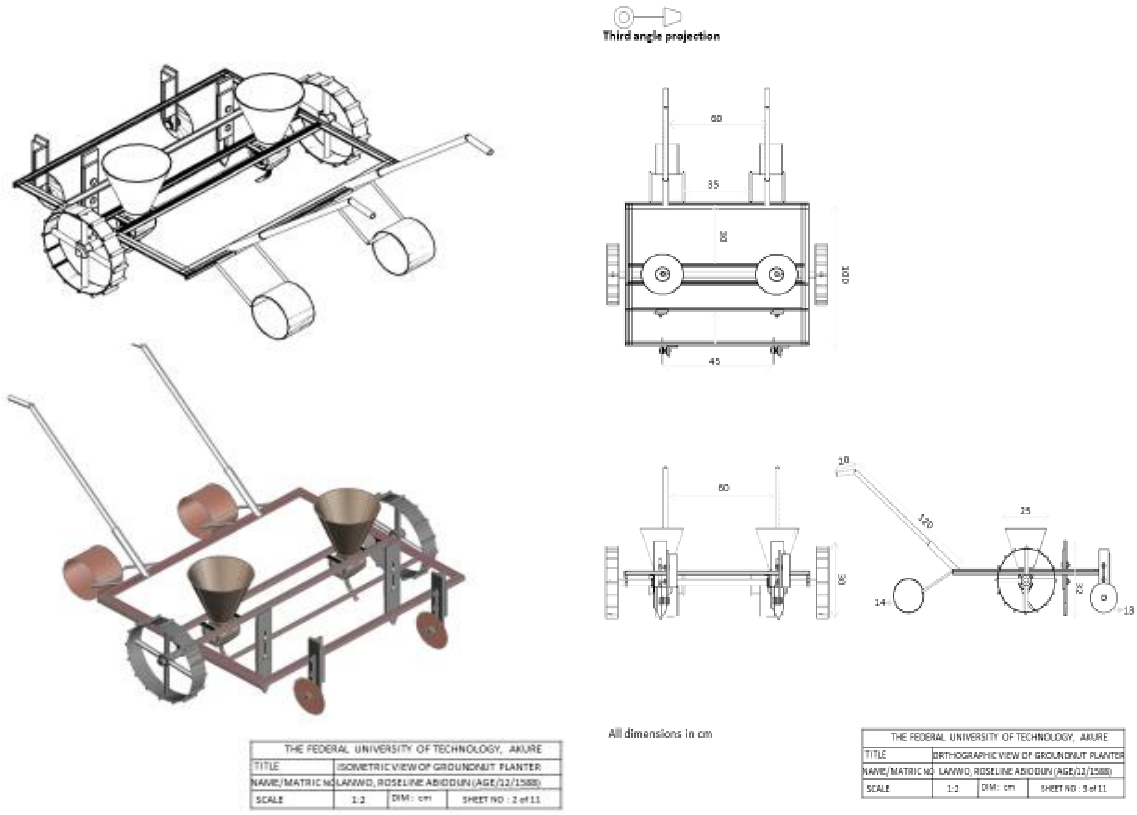


**Figure 4.** Preliminary design of showing the isometric views and orthography view

## Performance Evaluation

Figure 5 shows the fabrication of the groundnut planter in the workshop after which the machine was calibrated using a stopwatch to measure time and making a mark on the wheel to measure the revolution of the wheel. During experimentation the groundnut seeds were dropped at points, this point were marked as shown in Figure 6 and the distance between the points was measured to know the intra row spacing while counting numbers of holes filled with more than five (5) seeds. Three (3) samples of experiment was performed to evaluate metering efficiency of the machine by varying speed and time. In preparation of the plot, the land must be a flat surface, minimum tillage (using cutlass and rake) should have been done before planting as shown in Figure 7 and Figure 8 shows the testing of the machine on the prepared plot.

The field efficiency of the planter was determined using Equation (4) according to Ani *et al.* (2016).

$$\eta_f = \frac{T_a}{T_t} \times 100 \qquad (4)$$

where, $T_a$ is the time taken for actual planting operation; $T_t$ is the total time taken. The metering efficiency of the planter would be determined using Equation (5) according to Ani *et al.* (2016).

$$ME = \frac{T_s - T_O}{T_s} \times 100 \qquad (5)$$

*ME* is the metering efficiency of the planter, $T_s$ is the total number of holes in the tested farmland while $T_o$ is the total number of holes with no seed in the tested farmland.

**Data Analysis**

Results obtained were subjected to analysis of variance (ANOVA) to get Mean differences and standard error bars to get the range of the effect of speed on metering efficiency.

**Figure 5**. Fabrication of the two-row planter

**Figure 6.** Calibration of the two-row planter

**Figure 7.** Preparation of the Plot for Testing of the two-row planter

**Figure 8.** Testing of the two-row planter (minimum tillage using cutlass and rake for land preparation)

## RESULTS and DISCUSSION

### Component Designs

**Hopper:** The hopper is conical on the inside and constructed to have a conical shape. The shape is informed by the nature and location of the seed metering mechanism. To ensure free flow of seeds, the slope of the hopper was fixed at $45^0$, which is modestly higher than the average angle of repose of the seeds. The material used for the hopper design was 2 mm thick mild steel sheet metal. The capacity of the hopper was 237221 $mm^3$.

**Furrow opener:** The type of furrow opener used for this design is the adjustable 'shovel type' furrow opener which gives a 'v' shaped furrow opening and is suitable because it cuts and displaces the soil sideways for easy planting. The material used for the furrow opener design was mild steel angle iron with dimension 10 mm x 32 mm x 5 mm thickness while the angle of curvature was $35^0$.

**Furrow closer:** The furrow closer was also designed to allow for proper covering and compaction of the soil over the seeds in the furrows. The material used for the design was mild galvanized flat plate of 20 mm x 3 mm thickness, fabricated as a packer positioned at the back of the chute.

**Seed metering mechanism:** The metering mechanism is an essential component in a planter. It picks the required number of seeds and delivers them into the soil through the chute at required depths created by furrow openers. The diameter is 200 mm and 280 mm in length; the metering device as three (3) holes with distance of 120 mm each. The cells were designed to pick an average of five seeds and drop them at an intra-row spacing of 120 mm and inter-row spacing of 200 mm. The metering device is attached vertically on a horizontal shaft driven by the front wheel.

**Seed chute:** The chute is a tube through which the seeds metered out by the cells travel before they are deposited into the furrow. The material used for the design is a cylindrical funnel made of mild steel pipe with a dimension of 22 mm x10 mm x 12 mm.

**Wheel:** Wheels of larger diameters are to reduce rolling resistance especially in the case of traction wheels. In this research, the wheel is designed to be a traction wheel to enhance movement on loose soils. The diameter of the wheel is 30 mm with 110 mm connecting rod, which cut across the two-row planter. It has edges for effective gripping on the ground surface. The wheel provides a drive for the metering mechanism through rotation of the wheel.

**Metering chamber:** the metering chamber was made to be closed on one side and adjustable on the other side. The opening at one side helps for ergonomics, to help in the keying of the metering device. The thickness was 3 mm, 320 mm in length, and 220 mm in diameter.

**The handle:** The handle is used to provide the push force from a human operator to move the planter from point to point during planting operation. The handle is adjustable to take care of differences in height of operators. The hollow pipe was chosen for the handle because of its high strength and rigidity properties to prevent bending or breaking during operation. The 30 mm x 100 mm x 3 mm dimension was selected because of weight considerations to enable ease of operation.

**Figure 9.** Different Views of two-row Groundnut Planter

**Table 1.** Result on the Metering Efficiency of the two-row planter

| Test | Time (s) | Speed ($m\ s^{-1}$) | Number of holes with seeds | Numbers of holes without seeds | Metering efficiency (%) |
|---|---|---|---|---|---|
| 1 | 15 | 0.7 | 13 | 1 | 92.8 |
| 2 | 20 | 0.45 | 14 | 2 | 87.5 |
| 3 | 25 | 0.4 | 17 | 2 | 89.5 |
| 4 | 30 | 0.28 | 21 | 3 | 87.5 |
| 5 | 35 | 0.29 | 25 | 2 | 92.6 |
| 6 | 40 | 0.25 | 28 | 3 | 90.3 |
| 7 | 45 | 0.22 | 32 | 3 | 91.4 |

**Determination of field efficiency**

The field efficiency of the planter was determined as 82% using equation 6;

$$\eta_f = \frac{T_a}{T_t} \times 100 \quad (6)$$

$T_a$ is the actual time taken for the planting operation 45 secs , $T_t$ is the total time taken 55 secs

$$\eta_f = \frac{45}{55} \times 100 = 82\% \quad (7)$$

**Metering efficiency**

Table 2 shows the relationship between the machine speed and metering of the machine. The metering efficiency was determined using Equation 5; for the metering device with 3 holes. The highest metering efficiency of the planter was 92.8% with machine speed of 0.7 m $s^{-1}$.

Table 2 shows that the speed of the machine as significant effect on the metering efficiency with P-value of 5.44E-18. Figure 10 shows how the speed affects the metering efficiency graphically and standard error bars, it was observed that at the highest speed of 0.7 m $s^{-1}$ the metering efficiency is the highest at 92.8% compared to other speed. The lowest metering efficiency of 87.5% was observed at 0.45 m $s^{-1}$ and 0.28 m $s^{-1}$ respectively. This means the machine can perform effectively at high speed and improve the sowing quality.

The manual two-row groundnut planter machine has considerable potential to greatly increase productivity in Nigeria, helping the farmers to reduce drudgery. Other countries of the world where the two-wheel tractor is the main traction unit in farming it can also be in cooperated. The main task now is to promote this technology and have available to farmers at an affordable price because the materials used for fabrication are locally sourced. The manual two-row groundnut planter machine can be readily made from local sourced components and fabricated in the Agricultural Engineering workshop, FUTA. The only specialized items required are the seed-metering device.

**Table 2.** ANOVA Table for the effect of speed on metering efficiency of the machine
ANOVA: Single Factor

| SUMMARY | | | | | | |
|---|---|---|---|---|---|---|
| *Groups* | *Count* | *Sum* | *Average* | *Variance* | | |
| Speed(M/Secs) | 7 | 2.59 | 0.37 | 0.027933 | | |
| Metering Efficiency (%) | 7 | 613.788 | 87.68399 | 7.543948 | | |
| ANOVA | | | | | | |
| *Source of Variation* | *SS* | *df* | *MS* | *F* | *P-value* | *F crit* |
| Between Groups | 26683.07 | 1 | 26683.07 | 7047.936 | 5.44E-18 | 4.747225 |
| Within Groups | 45.43129 | 12 | 3.785941 | | | |
| Total | 26728.5 | 13 | | | | |

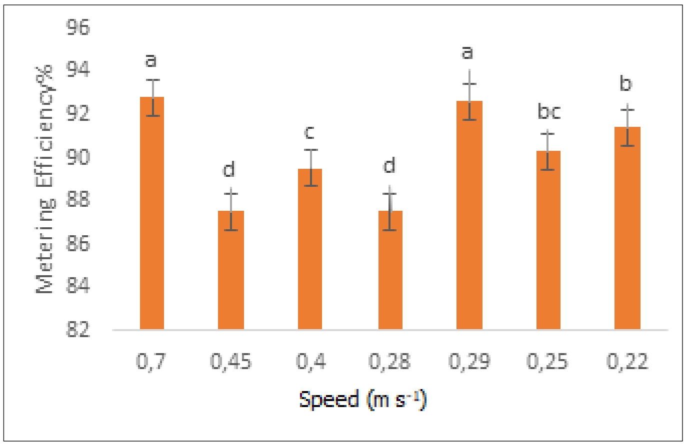


**Figure 10.** Relationship between metering efficiency and machine speed

**Table 3**. Comparable table for manual planter, tractor and seed sowing machine

| S/N | Parameter | Manual | Tractor | Seed sowing machine |
|---|---|---|---|---|
| 1 | Man power | More | Moderate | Less |
| 2 | Time required | More | Less | Less |
| 3 | Sowing technique | Manually | Automatically | Automatically |
| 4 | Distance between seed | Not Fixed | Fixed | Fixed |
| 5 | Wastage of seed | Moderate | More | Less |
| 6 | Required Energy | High | Very high | Less |
| 7 | Cost of machine | Less | Very high | Very less |

Table 3 shows the comparison between the developed planter, tractor-mounted planter and seed sowing machine. The planter has more improvement in metering efficiency of 92.8% and field efficiency of 82%, which corresponds to the research of Ani *et al.,* 2016 with the field test results showed that the planter has a metering efficiency of 88.94% and field efficiency of 71.86%. This means that there would be an increase in crop yield, cropping reliability and cropping frequency because of the good metering efficiency. The machine was made of durable and cheap material affordable for the small-scale peasant farmers with lesser maintenance cost with overall production cost of ₦65,480. The seeds can be placed at any required depth because the furrow opener is adjustable; with this plant, germination can be improved. The requirement of labor also decreased. It consumes less time for sowing. Seed can be placed uniformly in a row with the required distance between plants as reported by Kyada and Patel, 2014. The furrow coverer covers the soil properly and provides proper compaction over the seed.

The planter was tested on a prepared plot to plant groundnut, Figure 12 shows groundnut plant growth three (3) weeks after planting.

**Figure 12.** Groundnut plant growth three (3) weeks after planting

## CONCLUSION

A low cost two-row groundnut planter has been designed, constructed with locally sourced materials and tested which is adapted for gardens and smallholder farmers. The planter could plant an average of five seeds per point. It is simple, cheap and the ergonomics of the machine were considered which makes it easy to operate. Two-row planter has the highest metering efficiency of 92.8% with 0.7 m $s^{-1}$ machine speed using standard error bars with a field capacity efficiency of was 82%. The ANOVA (analysis of variance) shows that speed is a significant effect on metering efficiency with p-value of 5.44E-18. This planter is economical and can be adopted for planting different cultivar of groundnut by commercial farmers.

## DECLARATION OF COMPETING INTEREST

The authors affirm that there is no conflict of interest.

## CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

**Adewale Moses Sedara** contributed to the manuscript in conceptualization, writing original draft and review.

**Roseline Lanwo** contributed in the aspect of investigation and experimentation.

**Oluwadunsin Seun Sedara** is the project supervisor and contributed in editing of the original draft.

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