# DEVELOPMENT OF A MOTORIZED TWO-ROW MULTISEED GRAIN WALKING PLANTER

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## ABSTRACT
*Addressing the challenges of low crop yields and labour intensive planting processes, a motorized two-row multiseed grain walking planter was designed and fabricated. This innovative equipment enables small and medium-scale farms to enhance their productivity efficiently. Key features of the motorized two-row multiseed grain planter include a robust design suitable for small and medium-scale farms, adjustable settings for optimal seed-soil contact, efficient planting mechanism for increased productivity, and suitable for planting multiple types of grains. The motorized two-row multiseed grain planter was designed to operate effectively under various field conditions in order to ensure improved crop yields and reduced labour requirements for farmers. Laboratory and field tests were both conducted on the planter to evaluate the planter's performance. Test results revealed significant improvements in planting efficiency, crop yields, and reduced labour requirements. This innovation has the potential to transform the agricultural sector, particularly for small and medium-scale farmers, by increasing productivity, efficiency, and profitability.*

**Keywords:** Planter, Productivity, Efficiency, Grain, Farming, Crop, Yields, Labour, Mechanization

## 1. INTRODUCTION
Cereal crops, often known as grain crops, are members of the grass family (Gramineae) and are primarily produced for their starchy, edible seeds. Examples of cereal crops are barley, rye, oats, soybeans, millet, wheat, rice, and maize (corn). Cereals are used for various purposes in Nigeria, which includes the making of akamu, agidi, nrioka, tuwo shinkafa, and then tuwo masara. They are also used for livestock feed and fodder. Cereal stems are used in some regions of Nigeria to make traditional shelters using structural designs. Protein content in cereal grains is comparatively low, particularly for the important amino acids. Legumes and proteins are necessary supplements for them (Adesoye and Mary, 2015). Grains planting operation in Nigeria are quite low because a large number of farmers still plant their crops with their hands or make use of hand tools as shown in Figures 1 and 2.

Nevertheless, the manual method of seed sowing causes the farmer to experience unbearable back discomfort, inadequate spacing, and poor seed placement, thereby restricting the amount of land that can be cultivated. Furthermore, it requires a lot of time and labour to plant by hand; eight persons are required to cultivate one hectare of land (Dela Cruz and Bobier, 2016). Majority of Nigerian farmers roughly 95% of them have small land holdings whereby they often struggle to escape poverty. The seed planters that are available in the market are expensive, made especially for large-scale farms, imported, and unsuited to the local environment. Purchasing expensive imported farming supplies and equipment can be difficult for a peasant farmer (Wahid and Khadatkar, 2023) The promptness of activities is a critical aspect that can be attained solely through the recommended utilization of agricultural machinery (Salokhe and Oida, 2003). Nonetheless, the diminished operational efficiency and elevated labour intensity of this planter render it unattractive in contemporary contexts. The manual nature of the technique renders it labourious.

Figure 1. Conventional Agricultural Method
Source: Ahmed (2022)

Figure 2. Women planting manually
Source: FAO/CIMMYT (2018)

With a history dated back to centuries, the evolution of agricultural machinery such as grain planters has been marked by ongoing innovation aimed at boosting efficiency and productivity in farming practices. The advent of mechanized agriculture revolutionized the industry, enabling farmers to cover larger areas in less time while achieving greater planting accuracy. Early motorized grain planters were rudimentary, often consisting of simple seed dispensers attached to horse-drawn carts or tractor. The initial designs established a foundation for future innovations, facilitating the creation of more advanced and efficient planting machinery. Manual and animal traction grain planters are often compact in design, lightweight, and easy to operate. These planters are primarily designed for limited plots of land, mountainous terraces, or inclined terrains (Chapagain and Raizada, 2017).

The development of a motorized two-row multiseed grain walking planter is a pivotal advancement in agricultural machinery, transforming the methods of grain planting and cultivation. This advanced equipment embodies a synthesis of state-of-the-art technology and conventional agricultural methods, providing farmers with a flexible and effective means to improve their planting processes. The motorized two-row multiseed grain walking planter exemplifies a new era of agricultural efficiency and sustainability through the integration of precision planting mechanisms and multifunctionality. This development aims to optimize planting operations while enhancing productivity and resource efficiency. The two-row arrangement facilitates the concurrent planting of two rows of grains, practically doubling the planting capacity relative to conventional single-row planters. This expedites the planting process while guaranteeing consistent spacing and depth, resulting in enhanced crop emergence and overall production potential. The agriculture sector has adopted mechanical processes to varying degrees, reflecting the variable conditions throughout different regions of the country. A prevalent characteristic of mechanization is planting. It is the procedure of sowing seeds in the soil to optimize germination outcomes. Planting commenced with manual techniques and evolved to incorporate stones, hand tools, and machines (Yasir et al., 2012). Adejuyitan *et al.* (2012) assert that the essential criteria for small-scale cultivation technology are suitability for small farms, a user-friendly design, enhanced planting efficiency, and reduced labour compared to manual planting methods. A row planter was engineered to achieve 88% field efficiency and a planting rate of 0.20 hectares per hour.

The cultivable field is constrained by the manual seed planting technique, which results in suboptimal seed placement and spacing efficiencies, leading to significant back pain for the farmer. It is essential to create an economical planter that reduces monotony and labour, enabling smallholder farmers to enhance food output sustainably and environmentally beneficially. Various design types have emerged historically, each employing distinct methodologies with specific advantages, disadvantages, and constraints.

## 2. MATERIALS AND METHODS

### 2.1 The Concept of The Machine and Working Principle

The principal design considerations for the development of the motorized two-row multiseed grain walking planter include power requirement, types of grains to be sown, farm's dimensions, scale of the operation, and selection of seeds.

#### 2.1.1 Power requirement

Human assistance is necessary to direct the planter during its movement over the land.

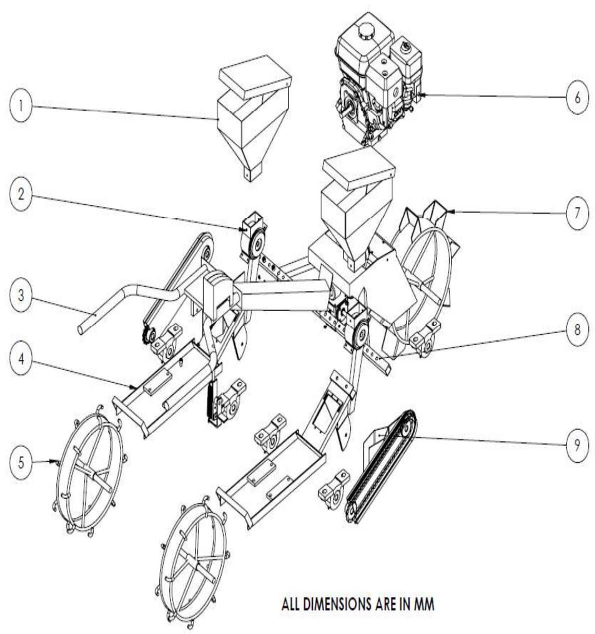
#### 2.1.2 Crop varieties

This aim at obtaining an average plant spacing distance as specified by the planter as shown in Table 1.

Table 1. Grains with different planting inter-row and intra row spacing distances

| S/No. | Grain | Inter-row spacing (cm) | Intra-row spacing (cm) |
|---|---|---|---|
| 1. | Maize | 75 | 30 |
| 2. | Soya bean | 75 | 30 |
| 3. | Wheat | 30 | 25 |
| 4. | Groundnut | 25 | 25 |
| 5. | Guinea corn | 90 | 40 |

The motorized two-row multiseed grain walking planter consists of fundamental components which include the primary frame, seed metering system, seed hoppers, ground wheels, furrow openers, and furrow coverer. The principal parameters of this two-row multiseed grain walking planter encompass the dimensions of length, width and height measuring 1,845 mm, 1,015 mm, and 1,495 mm, respectively; plant-to-furrow spacing within rows varying from 25 to 40 cm and between rows from 20 to 90 cm; and an integrated handle for maneuvering the planter during operation. The planter's seed metering system is placed vertically which was incorporated with few holes designed for the specified seed sowing distance. A transmission system has been developed to regulate seed placement and minimize movement between the 39 cm diameter planter's wheel and the feeding mechanism, controlling the number of seed drops per revolution using metering seed plates at a sprocket ratio of 1:1. The front column features a stationary furrow opener that enables the adjustment and modification of the furrow's depth. The closing mechanism consists of two cage wheels that compress the seeds into the soil as the planter advances. Presented in Figure 3 is the seed planter's exploded view which presents the part list. Presented in Figure 4 is the seed planter's 3D view.




| Item number | Part number |
|---|---|
| 1 | Hopper |
| 2 | Metering device |
| 3 | Handle |
| 4 | Rear wheel frame |
| 5 | Back cage wheel roller |
| 6 | Prime mover |
| 7 | Front cage wheel |
| 8 | Adjustable frame |
| 9 | Chain and sprocket drive |

Figure 3. Seed planter's exploded view containing the part list

Figure 4. Seed planter's 3D view

## 2.2 Design Calculations

### 2.2.1 Assessment of the mass of the hopper material

Presented in Figure 5 is the sectional view of the seed planter's hopper in its inverted orientation.

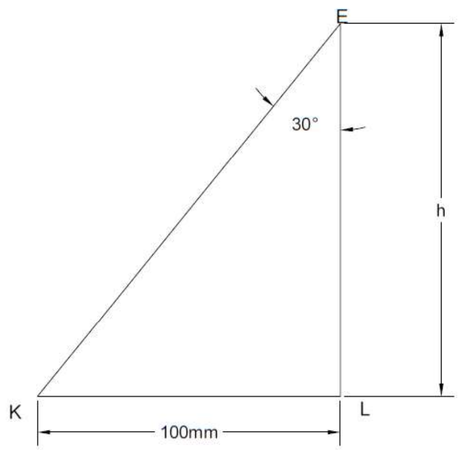



Figure 5. Illustrating the seed planter's hopper in its inverted orientation

The length EK was determined using the Pythagoras theorem as follows:

$$EK^2 = EL^2 + LK^2 \quad (1)$$

Recall from Fig. 5, that LK = 100 mm (0.1 m) and EL = h

Substituting these values into Equ. (1), we have

$$EK^2 = h^2 + (0.1)^2 \quad (2)$$

$$EK^2 = h^2 + 0.01 \quad (3)$$

$$EK = \sqrt{h^2 + 0.01} \quad (4)$$

$$\text{Area EKL} = \frac{1}{2} \times EL \times LK \quad (5)$$

By substitution method from Figure 5, this implies

$$\text{Area EKL} = \frac{1}{2} \times h \times 0.1 \quad (6)$$

$$\text{Area EKL} = 0.05h \text{ m}^2 \quad (7)$$

where h, could be expressed from Fig. 5 as:

$$h = \frac{0.1}{Tan\ 30^o} \quad (8)$$

h = 0.17322 m

Area EKL = 0.17322 x 0.05

Area = 0.008661 $m^2$

### 2.2.2 Determination of the weight of grain

From Figure 6, using Pythagoras theorem, the lengths EG and AC are determined as follows:

It can be deduced from Fig. 6, that EG is twice the distance of EQ and likewise AC is twice the distance of RA.

In determining the length of EG, there is need to consider triangle PEQ. From Pythagoras theorem,

$$PC^2 = PQ^2 + QE^2 \quad (9)$$
$$QE^2 = PE^2 - PQ^2 \quad (10)$$
$$QE = \sqrt{PE^2 - PQ^2} \quad (11)$$

Since EG is twice the distance of QE, therefore

$$EG = 2(\sqrt{PE^2 - PQ^2}) \quad (12)$$

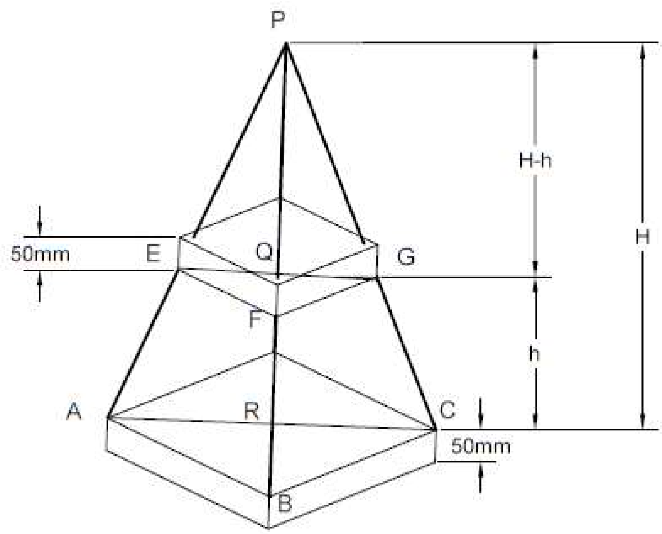



Figure 6. Schematic representation of the planter's hopper in its inverted orientation

In determining the length of AC, there is need to consider triangle PAR. From Pythagoras theorem,

$$PA^2 = PR^2 + RA^2 \quad (13)$$
$$RA^2 = PA^2 - PR^2 \quad (14)$$
$$RA = \sqrt{PA^2 - PR^2} \quad (15)$$

Since AC is twice the distance of RA, therefore

$$AC = 2(\sqrt{PA^2 - PR^2}) \quad (16)$$

Utilizing the principle of similar triangles, one can ascertain the overall height of the frustum as follows:

$$\frac{PQ}{PR} = \frac{QG}{RC} \quad (17)$$
$$PQ = PR \times \frac{QG}{RC} \quad (18)$$
$$H - h = H \times \frac{QG}{RC} \quad (19)$$
$$H - \frac{QG}{RC} H = h \quad (20)$$
$$H\left(1 - \frac{QG}{RC}\right) = h \quad (21)$$

$$H = \frac{h}{\left(1 - \frac{QG}{RC}\right)} \tag{22}$$

The hopper's volume can be derived from the subsequent expression.

$$V_H = \frac{1}{3}\lfloor(\text{area of frustrum base}) \times \text{overall height of frustrum}\rfloor$$

$$V_H = \frac{1}{3}[(\text{area of truncated frustrum base}) \times \text{height of trucated frustrum}] + \text{volume of the square extension at the top and bottom of hopper} \tag{23}$$

$$M_G = V_H \times P_G \tag{24}$$

$$W_G = M_G \times \text{Acceleration due to gravity} \tag{25}$$

where,

$V_{H=}$ Volume of hopper
$M_G$ = Mass of grain
$P_G$ = Density of grain
$W_G$ = Weight of grain

2.2.3 Determining the shaft diameter

The primary aim of shaft design is to determine the ideal shaft diameter to provide successful power transmission under various operating and loading conditions while preserving adequate strength and rigidity. The strength-based design of ductile material shafts is governed by the maximum shear theory. The shaft consists of a mild steel rod. The diameter of a shaft under minimal axial loading can be calculated using the ASME code equation as given by Natarajan (2000) as:

$$d^3 = \frac{16}{\pi S_a}\sqrt{(K_b M_b)^2 + (K_t K_t)^2} \tag{26}$$

*where,*

d = Diameter of the shaft (mm)
$M_b$ = Bending moment ( KN − m)
$M_t$ = Torsional moment (Nm)
$K_b$ = Combined shock and fatigue factors applied to bending moments (Km)
$K_t$ = Combined shock and fatigue factor applied to torsional moment (Kt)
$S_a$ = Allowable stress (N/m2)

According to Natarajan (2000), when a load is abruptly imparted to rotating shafts under minor shock, the following terms applies:

$K_{b\,=}$ 1.5 *to* 2.0
$K_{t\,=}$ 1.0 *to* 1.5
For shaft without key way, allowable stress $S_a = 55MN/m^2$
For shaft with key way, allowable stress $S_a = 40MN/m^2$

For computations, the diameter of shaft $d$ = 14.87 mm

2.2.4 Determining the maximum draught of the planter

The soil resistance faced by the machine and the contact area between the furrow opener and the soil determines the planter's maximum draught. The maximum draught of the planter can be calculated using the expression in Equation (27).

$$D_{FM} = R_S \times A_{FO} \times \text{Acceleration due to gravity} \tag{27}$$

where,

$D_{FM} =$ Maximum draught (N)

$A_{FO} =$ Surface area of furrow opener in contact with the soil ($cm^2$)

Rs = soil resistance ($kg/cm^2$)

$$A_{FM} = \text{Recommended depth of cut} \times \text{Thickness of furrow opener} \tag{28}$$

2.2.5 Determining the capacity of the planter

The area of land cultivated or the number of seeds sown during a planting session can be utilized to determine a planter's capability. This expression as expressed in Equation (29) can be utilized to ascertain the planter's capacity.

$$C_{PA} = \frac{\text{Area covered by planter}}{10000\ m^2}(\text{hectare/time}) \tag{29}$$

where,

$C_{PA} =$ Capacity of planter in hectare per time

$$\text{Area covered by planter} = (\text{inter} - \text{row spacing}) \times (\text{Distance covered by planter}) \text{in } m^2 \text{ per time} \tag{30}$$

$$\text{Distance covered by planter} = (\text{speed of planter}) \times (\text{Time of planting}) \text{in m/time} \tag{31}$$

The planter's speed can be determined through empirical experimentation. The planter's capacity is so determined as follows:

$$C_{PN} = \frac{\text{Distance covered by planter per time}}{\text{Intra-row spacing}} \times \text{Number of seeds per hole (seeds/time)} \tag{32}$$

where,

$C_{PN}$ = capacity of planter in terms of seed per time

2.2.6 Depth of sowing

Each grain has specific planting requirements regarding seed depth, spacing, and soil conditions, necessitating careful consideration and management during the planting process. Successful grain planting contributes to robust crop establishment, healthy growth, and ultimately, a bountiful harvest essential for sustaining global food systems (Technology *et al.*, 2021).

Table 2. Grains with different planting depths

| **S/No.** | **Grain** | **Planting depth (cm)** | **Reference** |
|---|---|---|---|
| 1. | Maize | 5 to 10 | Molatudi and Mariga (2009) |
| 2. | Soya bean | 5.08 | Purcell *et al.* (2014) |
| 3. | Wheat | 4 to 8 | Alwan *et al.* (2022) |
| 4. | Groundnut | 5 to 7 | Howlader *et al.* (2009) |
| 5. | Sorghum/Guinea corn | 5 to 10 | Reddy *et al.* (2012) |

2.2.7 Determination of planter's driving wheel diameter of the ground wheel

This was calculated by using the expression given in Equation (34).

$$\text{From } V = \frac{\pi D_w N}{60} \tag{33}$$

Therefore, the driving wheel diameter, $D_w$ can be expressed as follows:

$$D_w = \frac{V \times 60}{\pi N} \tag{34}$$

where,

V = speed of operation (m/s)
N = Number of revolutions per min by the ground wheel (rev/mins)
Dw = Diameter of the ground wheel (m)

2.2.8 Determination of the numbers of seed cell on the metering device

The seed cells were manufactured in accordance with specifications about the quantity of seeds needed to sow a given crop. The diameter of the ground wheel determines the rotation of the metering device, rendering this information crucial for determining the quantity of seed cells on the metering device. The standard plant spacing is determined. Dw = 600 mm as calculated, S = 600 mm plant spacing (Umar, 2022) and N = Number of seed cell on the metering device. Hence,

$$\text{Circumfrerence of the metering device (mm)} = \pi d \tag{35}$$

2.2.9 Measurement of the diameter of the metering apparatus

Considering the availability of the materials used in constructing the metering device. This has provided 3 holes or seed cells on it with 300 mm spacing due to the small size of the metering device which result to the approximately half of the standard spacing of planting maize, which is 600 mm. Hence, calculating the diameter of the metering device.

Given values:
Circumference of the metering device (mm)
Total planting space = 3 cells x 600 = 1,800 (mm)
Standard diameter = 572.88 mm (for a full planting space)
Half of the planting space = 3 x 300 = 900 mm

The maximum height of the seed must be known in designing the seed cells with dimensions exceeding the maximum height of the seed. The dimension of ten samples of maize was analyzed by Umogbaia and Shehu (2009). The planter's metering device was designed with a seed cell depth of 16.5 mm, which corresponds to the average height of the seeds being planted.

2.2.10 Design of handle

The planter's handles were designed to accommodate different heights of people either being a male or a female operator so that each operator could adjust the handle to suit his/her own height. To ensure operator comfort, the adjustable handle was designed with a length corresponding to the standard standing elbow height. The handle was fabricated by welding a mild steel square sheet and circular pipe to the frame. The adjustable handle assists the operator in maneuvering the planter during operation.

## 2.3 Material Selection and Fabrication of Machine Components

The motorized two-row multiseed grain walking planter was designed and fabricated using various materials. The pictorial view of the seed planter is presented in Figure 7. The hopper of the seed planter was formed using a 2 mm thick mild steel sheet. The shafts, with a diameter of 14.87 mm for both base diameters, were fabricated from a mild steel rod of 20 mm diameter and length size of 304.8 mm. A mild metal plate of 10 mm and 2 by 2 feet was cut, machined, and used to form the seating of the prime mover and the gear reduction unit. The frame was fabricated using flat bars of

50 mm. All the fabrication processes, including marking out, machining, cutting, joining, drilling, and fitting, were performed at the Centre's wokshop located at the TEFEDEC building.

The planter's components, including the metering mechanism, were constructed from mild steel, while the seed metering plate was composed of Teflon. The selection of Teflon for the seed plate was due to its lower coefficient of restitution, which significantly reduces seed bouncing and safeguards the seeds from impact-related harm. The primary structure of the seed planter was constructed from 3 mm mild steel sheet and 5 mm mild steel flat bar. The planter's adjustable handle was constructed from a 1.5-inch mild steel circular pipe measuring 1219.20 mm in length, while the adjustable furrow opener was made from a 60 mm x 5 mm mild steel flat bar. The planter's ground wheels were constructed from a combination of 3 mm mild steel sheets and 12 mm rods.

The specification of the materials used for constructing the motorized two-row multiseed grain walking planter is presented in Table 3.

Table 3. Specification of the construction material

| S/No. | Component | Material |
|---|---|---|
| 1. | Primary frame work | MS square tubing |
| 2. | Seed chamber | Galvanized sheet |
| 3. | Bearings | Steel |
| 4. | Chain and sprocket | Steel |
| 5. | Ground wheel | MS sheet |
| 6. | Cage wheel traction | Mild steel bar |
| 7. | Seed plate roller | Teflon |
| 8. | Handle | Galvanized pipe |
| 9. | Furrow opener | MS sheet |

Figure 7. Pictorial view of the seed planter

## 3. CONCLUSİON

The requirements of underprivileged smallholder farmers have been met by developing a motorized multiseed grain walking planter at the National Centre for Agricultural Mechanization (NCAM), Ilorin. This planter will enable farmers to efficiently and successfully sow their seeds in the field. However, many crops possess different requirements for seed planting in the field. This project concentrated on the design and construction of an economically viable motorized operated two-row multi-crop walking planter that is affordable, easy to maintain, and requires minimal labour to operate. The planter will significantly enhance the appeal of farming and augment agricultural productivity. All components of the planter were constructed from mild steel, with the exception of the metering mechanism which was manufactured from high-quality Teflon material. The seed metering mechanism employed in this study was the nylon wheel type including peripheral cells. The design feature involving a drive shaft which directly operates the seed metering mechanism, helps to eliminate the need for a power transmission system, reduce complexities and costs, and enhance efficiency at a significantly lower expense.

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