

# DEVELOPMENT AND PERFORMANCE EVALUATION OF A MANUALLY OPERATED TWO-ROW PLANTER FOR SORGHUM (GUINEA CORN)

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## ABSTRACT

*Manually operated two-row sorghum planter was designed and constructed in the department of Agricultural and Environmental Engineering of the Modibbo Adama University of Technology, Yola, based on the relevant physico-mechanical properties of sorghum seeds. The developed planter consisted of a hopper, seed metering device, seed tube, land wheel, frame, chain and sprocket. Field Performance evaluation of the planter showed that the efficiency was 51%, the theoretical filed capacity was 4.8 ha/hr, effective field capacity was 3.6 ha/hr and field capacity was 3.4 ha/hr, while the seed rate was 0.030kg/hr.*

**Key words:** Planter, Sorghum, Performance, Rows, and Manual

## 1 INTRODUCTION

Sorghum is a member of the sub family Panicoidea, tribe Andropogoneae. It originated in Africa but has become popular in Asia, China, U.S.A. and Australia. It grows well in semi desert regions and in areas where maize would fail to establish. Sorghum is among the world's staple food crops and consumed by more than half of the sub-Saharan African people and parts of Asia and Latin America [1]. It requires a field temperature of 18°C for germination the optimum soil moisture for germination is 20 – 50% of field capacity. The soil requirement for sorghum is a well-drained, lightly alkaline sandy loam and spacing between rows and plants of 75 cm and 28 cm respectively. The seeds are sown about 4 – 10 per hole at a depth of 2 – 4cm [2]. Nigeria like all other developing countries is yet to attain the optimum level of mechanization. Most farmers use the simple traditional tools such as hoes, cutlasses etc. for planting and weeding operations on their farms. This makes planting of sorghum a tedious and time consuming exercise. The high dependence on manual labour places a premium on the farm size a farmer and his family could effectively maintain. This has negative implications for agriculture, food security and poverty alleviation in less developed countries.

One of the most laborious and time consuming operation in sorghum production is planting, which is traditionally done with human power using hoe, cutlass or bare foot. This does not only consume energy, but it takes a lot of time to plant large piece of land and for those doing it bare footed it exposes them to danger of cuts from shrapnel, metals, bottles etc. Sowing is one of the most important farm operations after soil preparation because the time of sowing and the way in which it is done influences timeliness of operation, and seed germination. Planters are machines that have provisions that can be used to vary the spacing between plants on the same row or ridge (in addition) these can vary the spacing between rows. A planter like a seed drill can be either single row or multi-row depending on the power available. Germination of seeds may be adversely affected if the seeds are sown at shallow depth of 2 – 4 cm as done in irrigated areas. To get high yields the right amount

of seeds should be placed at the right time at a predetermined depth and spacing [2]. The factors that affect seed emergence include the seed quality, the soil characteristics and the planting tool used. The differences in power requirements for a planter are primarily due to the design of the openers, the weight of the planter and the number of rows, and contact surface area of the residue-cutting and groove-opening components. The prices of farm machinery are beyond the reach of the ordinary farmer, it is therefore desirable to undertake a study of designing and construction of a planting device for sorghum that would alleviate the drudgery in this operation and be adoptable and affordable to the farmer. Therefore, the objective of this work is to (1) Design and construct a manually operated two-row planter for sorghum using locally available material. (2) Evaluate the performance of the planter.

## 2 MATERIALS AND METHODS

### 2.1 Design Analysis

The chain length was determined from the relationship given by [3].

$$L = K \times P \quad (1)$$

Where L = length of chain, K = number of chain links, P = pitch of chain (cm)

While number of chain links is calculated using the expression

$$K = \frac{T_2 + T_1}{2} + \frac{2x}{P} + \frac{T_2 + T_1}{(2x)^2} \times \frac{P}{x} \quad (2)$$

Where,  $T_1$  = number of teeth on the smaller sprocket,  $T_2$  = number of teeth on larger sprocket

P = pitch of the chain (cm), x = height of the teeth.

Velocity ratio of the gears is given by equation 3.

$$VR = \frac{N_1}{N_2} = \frac{T_2}{T_1} = \frac{D_2}{D_1} \quad (3)$$

Where,  $N_1$  = speed of rotation of smaller sprocket in rpm,  $N_2$  = speed of rotation of larger sprocket in rpm,  $T_1$  = number of teeth on the smaller sprocket,  $T_2$  = number of teeth on the larger sprocket,  $D_1$  = pitch diameter of smaller sprocket (cm),  $D_2$  = pitch diameter of larger sprocket (cm) [3].

Pitch diameter of sprockets was determined using equation 4.

$$D = \frac{PC}{\sin\left(\frac{180}{T}\right)} \quad (4)$$

D = pitch diameter of sprockets in cm, PC = pitch length of chain in cm, T = number of teeth on sprocket

$$D_R = \frac{\pi C_L}{V_R} \quad (5)$$

Where  $D_R$  = diameter of fluted roller in mm,  $C_L$  = circumference of land wheel,  $V_R$  = velocity ratio

The number of cells on a fluted roller was calculated using equation 6;

$$N_C = \frac{\pi D_L}{a} \quad (6)$$

$N_C$  = number of cells,  $D_L$  = diameter of land wheel (cm), a = spacing between plants (cm)

The number of revolutions of land wheel (N) was determined using equation 7;

$$N = \frac{L}{\pi D_L} \quad (7)$$

Where,  $D_L$  = diameter of land wheel, L = length of travel (cm)

The planter hill distance was calculated from equation 8;

$$H_D = \frac{D_{LW}}{N_C} \quad (8)$$

Where,  $H_D$  = hill distance in (cm),  $D_{LW}$  = distance travel by land wheel in (cm),

$N_C$  = number of cell on fluted roller

The power transmitted by the chain was estimated from equation 9;

$$P = \frac{WB \times V}{n \times K_S} \quad (9)$$

Where,  $WB$  = breaking load in (N),  $V$  = velocity of chain in (m/s),  $K_S$  = service factor

$(K_1 \times K_2 \times K_3)$ ,  $n$  = factor of safety,  $n = \frac{WB}{W}$ ,  $W$  = total load on the chain (N)

The capacity of the hopper was calculated using equation 10

$$C = \rho V \quad (10)$$

Where,  $C$  = capacity of hopper (kg),

The bulk density was obtained from equation 11;

$$\rho = \frac{M}{V} \quad (11)$$

$\rho$  = bulk density of sorghum ( $\text{kg/m}^3$ ),  $V$  = volume of hopper ( $\text{m}^3$ ), Mass of sorghum (kg)

Determination of angle of repose of the sorghum was done using an incline plane device and substituting measured parameters into the equation 12;

$$\tan \theta = \frac{H}{R} \quad (12)$$

Where,  $\theta$  is the angle (degree) of the incline plane,  $H$  is the height in (cm),  $R$  is the horizontal distance (cm).

## 2.2 Description of the Sorghum Planter

The two-row planter consists of components as presented in figure 1, a seed box or hopper (1) that contains the sorghum seeds, the seed metering device (3) is celled at an interval of  $90^\circ$  along the circumference and is mounted on a shaft which runs below the seed hopper. The seeds fall into the fluted roller cells by gravity and are discharged via the seed tubes (5) to the opened furrow (4) as the fluted roller rotates. The seed covering device is behind to cover the seeds that were dropped in the furrows made by the furrow opener. The planter is powered manually through chain and sprocket. The cut-off prevents the seeds from falling out when only part of the fluted roller is exposed to the seed hopper opening. The supporting frame is made of metallic pipe. Orthographic projection of the planting machine is shown in Figure 1, Isometric view of the sorghum planter in Figure 2 while Plate 1 shows the developed two row sorghum planter.

## 2.3 Design Consideration and Analysis

The agronomic factors considered during the design of the sorghum planter include inter crop spacing between the sorghum plants which was given as 15 – 16 cm, inter-row spacing of 30cm, 5 -8 number of seeds per hole and planting depth of 2 – 4cm as reported [4]. Reduction in time and energy spent in planting sorghum; ease of maintenance and construction using locally available materials were some of the factors considered.

## 2.4 Performance Evaluation

Testing the performance of the planter involved evaluation of the machines capacities and efficiencies. The parameters investigated include; capacity (ha/hr) and field efficiency (%), average depth of placement of seeds, evenness of seed spacing in the field and ease of setting, operation and adjustment. Preliminary testing of the planter was conducted in the workshop to remedy some of the

design deficiencies observed before testing on the field. This was done by rotating the land wheel of the planter ten times in suspended position and using wetted textile materials to collect seeds falling from the flute in order to determine the regularity of seed spacing.

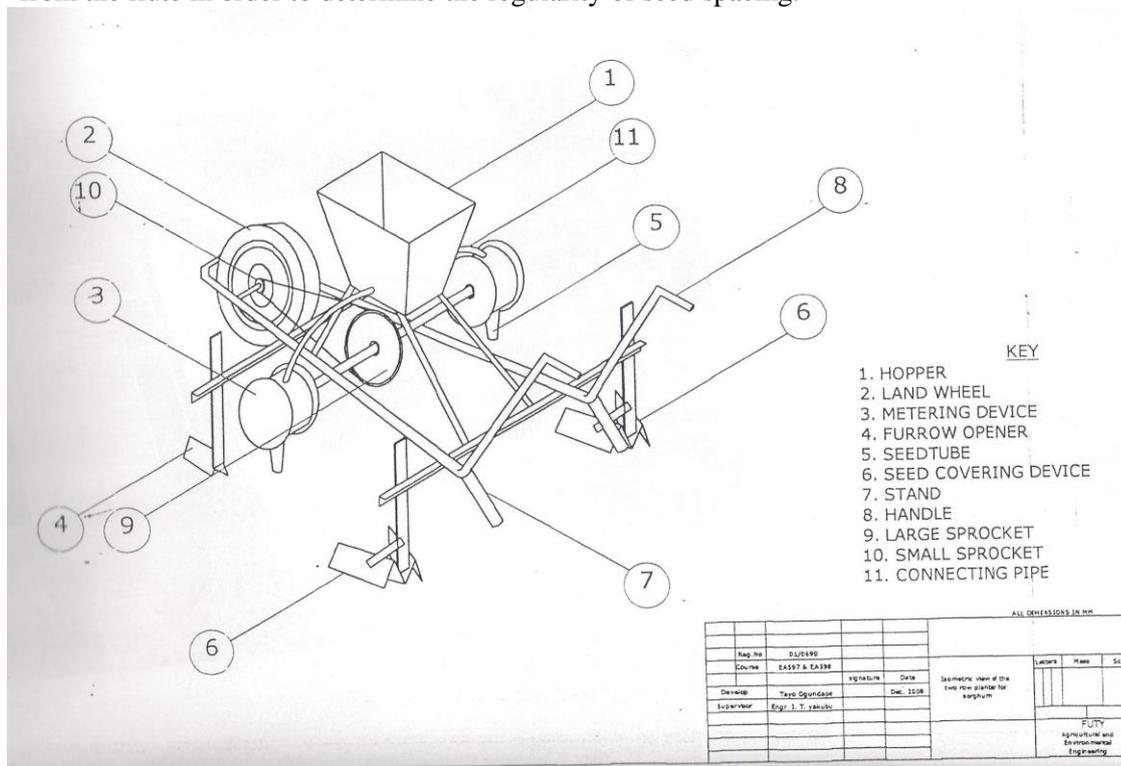


Figure 1. Orthographic Projection of the Sorghum Planter

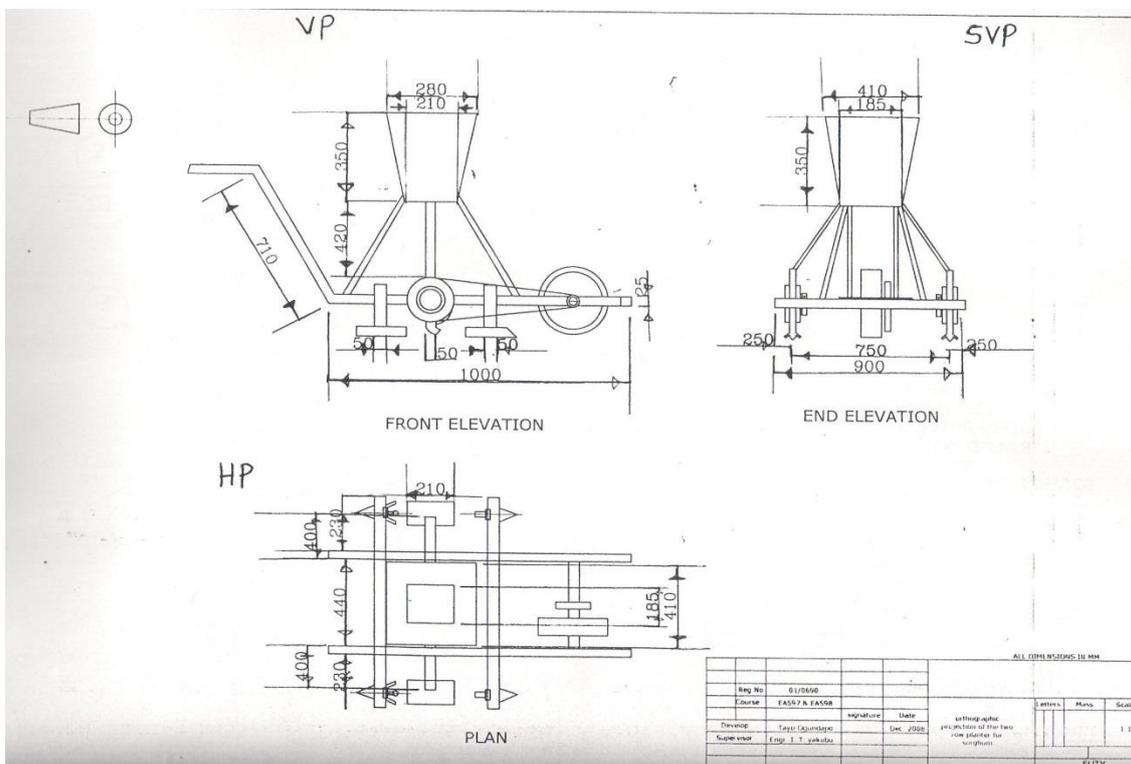
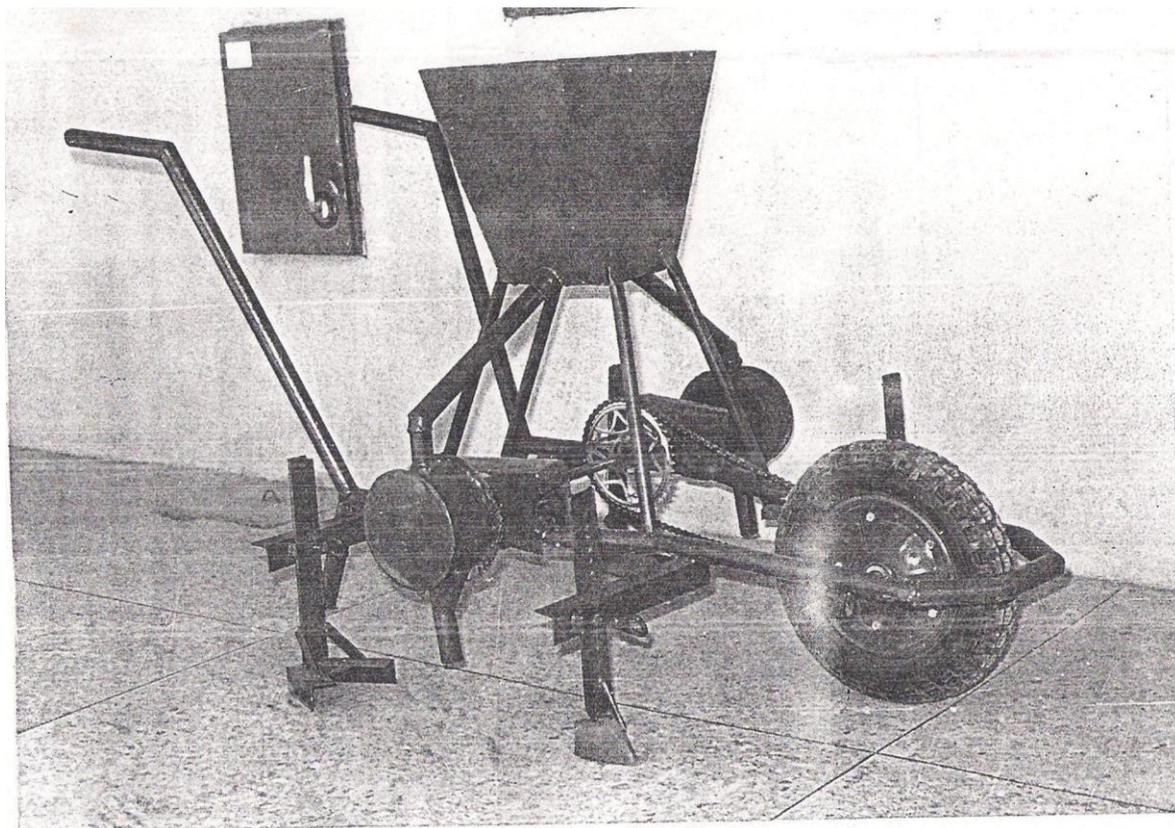


Figure 2. Isometric Projection of the Sorghum Planter



*Plate 1: Shows the developed two row sorghum planter*

Distribution pattern and the standard deviation of the planter were determined using procedures and standards of evaluating planters as reported by [5] and [6]. A piece of harrowed land measuring 25m x 25m was used for the field data collection. The machine was run without furrow opening so as to determine the speed of operation and to allow for measuring distance between stands and the average depth of placement. The machine was then operated to plant the seeds on the field. The time taken to cover the land was noted using the stop watches. One stop watch record the time losses and the other records the time during which the planter performed the actual intended operation. The machine's performance parameters were evaluated using the equations (13) and (14) below:

$$C_a = \frac{A}{T} \quad (13)$$

$$E_f = T_a/T \times 100 \quad (14)$$

Where,  $C_a$  = Actual field capacity (ha/hr);  $E_f$  = Field efficiency (%);  $A$  = area covered (ha);  $T$  = total time covered on the field (hr);  $T_a$  = actual time for intended work operation.

### **3 RESULTS AND DISCUSSION**

Table 1 shows some measured physical properties of sorghum used in the design of the planter like hopper, seed per grove and angle of discharge chute. Table 2 presents the various components of the seed metering device used in the planter while Table 3 shows the data obtained from the machine used to evaluate the machine's performance presented in Table 4. The distance between stands was found to be 15 cm, number of seeds per hole is six and average depth of planting

is 3.24cm, the mass of seed planted was 1.45kg on an area of 625m<sup>2</sup>. The seed rate was 21.56kg/ha. This compares favourably with values of (21-22kg/ha) obtained by [7].

Table 1. Some physical properties of sorghum (Guinea Corn)

S/n	Parameters	Average value
1.	Geometric mean diameter (cm)	0.12
2.	Sphericity (%)	0.96
3.	Bulk density (kg/m <sup>3</sup> )	1386.6
4.	Repose angle (degree)	25
5.	Coefficient of friction (degree)	34
6.	Arithmetic mean	0.12
7.	Length(cm)	0.11
8.	Width (cm)	0.13
9.	Thickness (cm)	0.11

Table 2. Components and Dimension of Metering Mechanism

S/N	COMPONENTS	DIMENSION
1.	Effective diameter of fluted roller (cm)	15.1
2.	Diameter of fluted roller (cm)	14.9
3.	Depth of the cell (cm)	0.2
4.	Diameter of the cell (cm)	0.8
5.	Number of cells on the fluted roller	4.0
6.	Consecutive angle between cells (degree)	90 <sup>0</sup>

Table 3. Data obtained from field measurement of machine

Theoretical time (T <sub>o</sub> )hr/ha	operating time (T <sub>c</sub> )	Effective operating time (T <sub>c</sub> )	Fraction of implement width actually used (K)	Time lost per hectare (T <sub>1</sub> ) hr/ha
0.25		0.37	0.70	0.16
0.31		0.43	0.70	0.12
0.29		0.41	0.70	0.11
0.27		0.40	0.70	0.17
0.28		0.40	0.70	0.14

Table 4. Results of Field Performance Evaluation

S/N	PARAMETERS	
1.	Effective Field Capacity (ha/hr)	2.50
2.	Theoretical Field Capacity (ha/hr)	3.60
3.	Field Capacity (ha/hr)	2.52
4.	Field Efficiency (%)	51.10
5.	Depth of planting (cm)	3.5
6.	Plant spacing (cm)	28
7.	Spacing between rows (cm)	75

#### 4 CONCLUSION

The manually operated two row sorghum planter developed using locally available materials was found to operate at a field capacity of 2.50 ha/hr with an average spacing of 15.24cm. The planter was able to effectively meter six seeds per hole, the machine was simple to operate and

maintain. The planter has potential to mechanize sorghum planting, which will reduce drudgery; labour cost and time spend in planting this crop.

The performance of the planter shows that there is little or no variation in the recommended requirements of sowing sorghum in terms of seed per hole and the spacing with the traditional manual planting.

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