Manually operated vertical seed-plate maize planter

B. O. Soyoye, O. C. Ademosun and E. O. Olu-Ojo

(Agricultural and Environmental Engineering Department, School of Engineering and Engineering Technology, Federal University of Technology, P. M. B. 704 Akure Ondo State Nigeria)

Abstract: Maize has been of great importance in providing food for man, feed for livestock and raw materials for some agro-based industries. It constitutes a stable food in many regions of the world. Studies in maize production in different parts of Nigeria have shown an increasing importance of the crop amidst growing utilization by food processing industries and livestock feed mills. A manually operated vertical seed-plate maize planter was designed, fabricated and tested. The research was aimed at developing a planting machine that is simple in operation, easy to maintain and affordable by peasant farmers. Design criteria, calculations and analysis of various components of the machine were critically considered and determined in the cause of the development. The laboratory and equivalent field investigations were carried out, these include: the seed metering performance tests, number of seed discharge per meter length, the average distributive seed spacing test and functioning speed efficiency. The planting population was analyzed with average depth between 35 mm and 45 mm, average spacing of 313.5 mm, with optimum speed of 1.38 ms-1 and the sowing efficiency was determined to be 89.7% with planting capacity of 1.53 ha hr-1.

Keywords: maize, planter, laboratory evaluation, field test

Citation: Soyoye, B. O., O. C. Ademosun, and E. O. Olu-Ojo. 2016. Manually operated vertical seed-plate maize planter. Agricultural Engineering International: CIGR Journal, 18(4):70-80.

1 Introduction

The global importance of grain crops to the human diet and agriculture cannot be over emphasized. Grains are the fruit of plants belonging to the grass family Gramineae (Migton, 1985). Nutritionally, they are important sources of dietary protein, carbohydrates, the B complex of vitamins, vitamin E, iron, trace minerals, and fiber. It has been estimated that global grain crops consumption directly provides about 50% of protein and energy necessary for the human diet, with cereals providing an additional 25% of protein and energy via livestock intermediaries. Some cereals, notably wheat, contain proteins that form gluten, which is essential for making leavened bread. Although dried cereal grains constitute living cells that respire, when kept in an appropriate environment, whole grains can be stored for many years. Major cereal crops produced worldwide include wheat, rice, maize and barley. Other major grain crops produced include sorghum, soybean, oats, millet and rye. Asia, America, and Europe produce more than 80% of the world's cereal grains. Wheat, rice, sorghum, and millet are produced in large quantities in Asia; corn and sorghum are principal crops in America, and barley, oats and rye are major crops in the former USSR and Europe (Stoney, 1999; Khawar et al., 2007). Seed planting machine is a device which helps in the sowing of seeds in a desired position hence assisting the farmers in saving time and money. The basic objective of sowing operation is to bear the seed, put the seed in rows at desired depth and seed to seed spacing, cover the seeds with soil and provide proper compaction over the seed (Chetan, 2014). The old traditional way of sowing still predominate the cropping system in the country, especially the peasant farming method. About 95% of the

Received date: 2016-08-05 **Accepted date:** 2016-09-06

***Corresponding author: B. O. Soyoye,** Agricultural and Environmental Engineering Department, School of Engineering and Engineering Technology, Federal University of Technology, P. M. B. 704 Akure Ondo State Nigeria. Email: soyoye2002@yahoo.com, bosoyoye@futa.edu.ng.

Nigerian farmers have small land holding and are much below living standard. It is very difficult for them to have costly agricultural machinery and equipment (Odumal et al., 2014). The traditional way of sowing still predominate the cropping system in the country, especially the peasant farming method. Since that is the principal farming system of the country, about 95% of the Nigerian farmers have small land holding and are much below living standard. It is very difficult for them to have costly agricultural machinery and equipment (Odumal et al., 2014).

1.1 Objective of the research

The main aim of this research is to design, fabricate, assemble and test a durable and easy to operate manually operated maize planter for the use of peasant farmers. The specific objectives of the research are to:

i. Design the components of the planter

ii. Fabricate, assemble and test the planter

iii. Determine the optimum operating parameters of the planter.

1.2 Justification of the research

The old (traditional) seed placing method include the use of stick to open the soil and the heel or toe to dig and cover the seed firmly. It results in improper placement of the seed into the soil at the correct soil depth, failure to properly keep the seeds firmly in the soil, uneven placement of the seed at the correct interval of row, and incidence of bird and rodent attack on improperly planted seeds. Small scale farming and local peasant farmers are the dominant of the country's system of farming. In that regards, the acquisition or hiring of tractor and other machines to carry out planting operations has remain a major problem. Therefore, an attempt to solving this problem brings about the development of a locally made planter with the use of locally available materials.

2 Main body

2.1 Maize crop

Maize constitutes a stable food in many regions of the world. It is a basic stable for large population groups particularly in developing countries. Grain crops produced in Nigeria are maize, rice, cowpea, soybean, sorghum, millet and groundnut (Adekunle and Nabinta, 2000). The greater proportion of this grain is maize because of its ability to thrive under different ecological conditions. FAO (1989) figures show a consistent increase in production of these crops in Nigeria. Adekunle and Nabinta (2000) also reported sustained increase in their output. Maize is the most important staple food in Nigeria (Nweke, 2006). Maize (Zea mays L.) is a member of the grass family (gramineae). It originated from South and Central America. It was introduced to West Africa by the Portuguese in the 10th century. Maize is one of the most important grains in Nigeria, not only on the basis of the number of farmers that engaged in its cultivation, but also in its economic value. Maize is a major important cereal being cultivated in the rainforest and the derived savannah zones of Nigeria. Maize has been in the diet of Nigerians for centuries. It started as a subsistence crop and has gradually become a more important crop. Maize has now risen to a commercial crop on which many agro-based industries depend for raw materials (Iken and Amusa, 2004). Maize is becoming the miracle seed for Nigeria's agricultural and economic development. It has established itself as a very significant component of the farming system and determines the cropping pattern of the predominantly peasant farmers, especially in the Northern States (Ahmed, 1996). Maize has been of great importance in providing food for man, feed for livestock and raw materials for some agro-based industries. Studies in maize production in different parts of Nigeria have shown an increasing importance of the crop amidst growing utilization by food processing industries and livestock feed mills (Ogunsumi et al., 2005; Khawar et al., 2007; Abaduhaman and Kolawole, 2008). The crop has thus grown to be a local 'Cash crop' most especially in the southwest part of Nigeria where at least 30% of the cropland has been put to maize production under various cropping systems (Degrande and Duguma, 2000).

Growing maize in farms of 1 to 2 hectares can overcome hunger in the household and the aggregate effect could double food production in Africa.

2.2 Grain crop planter

Bamgboye and Mofolasayo (2006) designed, fabricated and carry out performance evaluation on a manually operated two-row okra planter by conducting field and laboratory tests. The laboratory investigation included the determination of the variation in weight of seeds discharged from the two hoppers, percentage damage of seeds, and average intra-row spacing of seeds. The field tests comprised the determination of effective field capacity, average depth of placement of seeds in the furrows, and mean spacing of seeds within each row. A percentage difference between the weights of seeds discharged from the two hoppers of 4.97% was obtained during testing; while the seed rate was 0.36 kg hr^{-1}. A reduction in percentage damage of 3.51% was attained with spacing varying from 59 cm to 70 cm, and an average depth between 8 mm and 9 mm. The overall average efficiency of the planter was recorded to be 71.75%. In the same trend, Adisa and Braide (2012) designed and developed a template row planter to improve planting efficiency and reduce drudgery involved in manual planting method. They also recorded that the row planter increased seed planting, seed/fertilizer placement accuracies and it was made of durable and cheap material affordable for the small scale peasant farmers. The operating, adjusting and maintaining principles of the planter were made simple for effective handling by unskilled operators (farmers). The planting rate of the template row planter was found to be 0.20 ha hr^{-1}. Template seed filling efficiency was found to be 88% and draft requirement was found to be 85 N at average speed of 2.16 km hr^{-1}. Ugwuoke, et al. (2014) designed and fabricated a single row maize planter for garden use. They focused their work on the design and fabrication of a manually operated single row maize planter capable of delivering seeds precisely in a straight line with uniform depth in the furrow, and with uniform spacing between the seeds. The work demonstrates the application of engineering techniques to reduce human labour specifically in the garden. The results obtained from their trial tests showed that the planter functioned properly as expected with a planting capacity of 0.0486 hectare hr^{-1}. It was also recorded that visual inspection of the seeds released from the planter's metering mechanism showed no visible signs of damage to the seeds.

3 Materials and methods

3.1 Design considerations

The following factors were considered for the design of the planter:

i. Simplicity in design, construction and operation;

ii. Safety and light in weight; for safe and easy transportation;

iii. Easy to operate and low maintenance; components parts easily dismantled for replacement of parts;

iv. Use of locally available materials;

v. Correct seed-box or feed hopper to bear the seed and feed the metering device;

vi. Control of planting depth and spacing;

vii. Accurate placement of seeds without damage by the metering device;

viii. Aesthetics: the beauty of the machine;

ix. Cost affordability; the total expenditure to complete the machine is of low cost.

3.2 Design analysis

The machine was made up of the following components: The frame, feeding hopper, metering seed-plate, seed-plate covers, the shaft, bearings, rear wheels, furrow opener, chain furrow cover and front wheel (Figure 1).

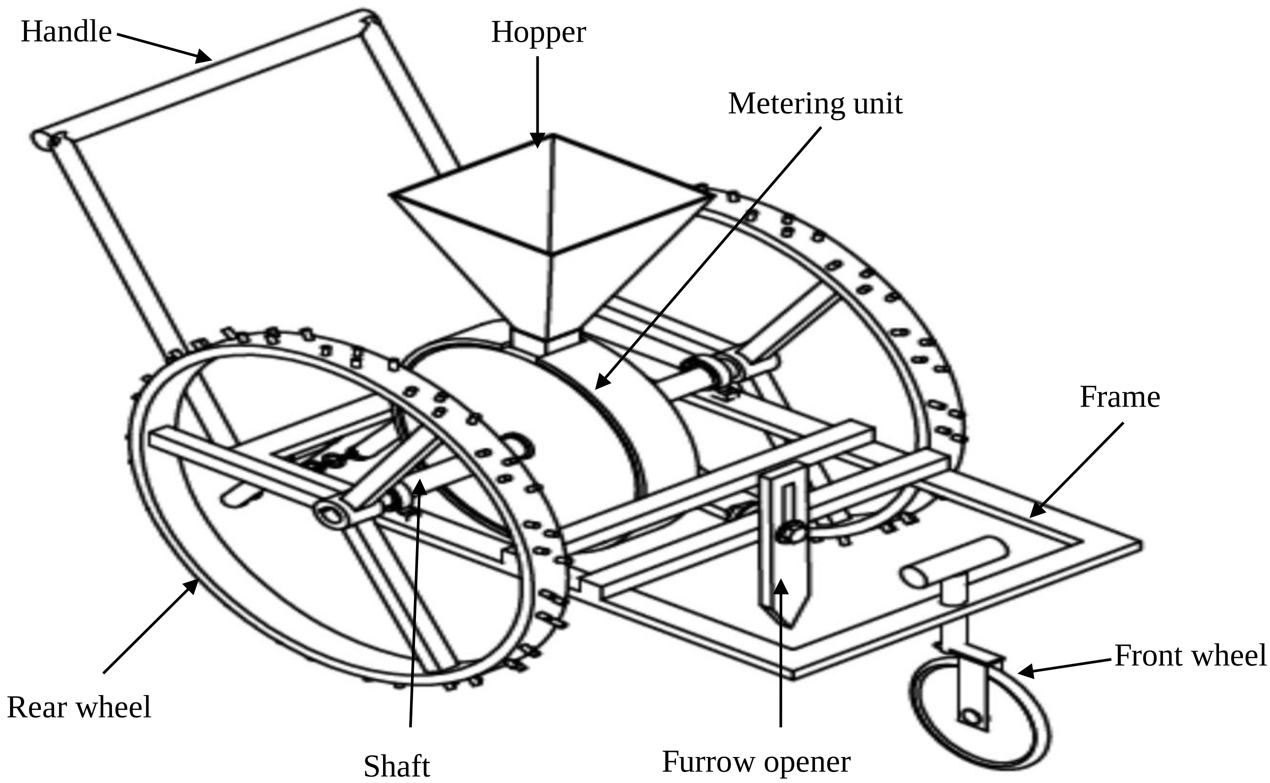


Figure 1 Conceptual design of the planter

3.2.1 The machine frame

The frame is the skeleton/structural component on which the machine body or other components were built, supported or attached. The major frame acting as the machine bed was made from 50 mm by 50 mm angle iron. The bar was cut into the required sizes of 500 mm length and 296 mm width. The minor frame was made from the same materials but, it was integrated to form supportive structures for the furrow opener and the seed plate cover. It was cut to the required sizes of length 280 mm, width 85 mm and height 55 mm. All, these iron pieces were welded together by electric arc welding machine to form a rigid machine frame.

3.2.2 The feeding hopper

The feeding hopper was developed from a steel metal plate forming a hollow frustum of a triangular prism with bottom base area of 28 mm × 28 mm and top area of 200 mm × 200 mm, the height was 162 mm while the slant height was 183 mm. The hopper was designed with the consideration of the grain's angle of repose. The angle of repose (α) for maize grain at 16% moisture content is 30° approximate (Mohammad, 2010). Therefore, the slanting angle to the horizontal was calculated to be 62° which was greater than the angle of repose. Some of the basic reasons for choosing a slanting angle greater than the angle of the repose were to minimize piling, to make sliding easy and to overcome the coefficient of friction. Also, connected to the hopper is an extended hollow cuboid joined to the hopper base. This helped to fit and feed the hopper and seeds respectively to the metering device housing. It was formed from steel metal plate, with 28 mm × 28 mm base and 23 mm high. The shape design of the hopper is shown in Figure 2.

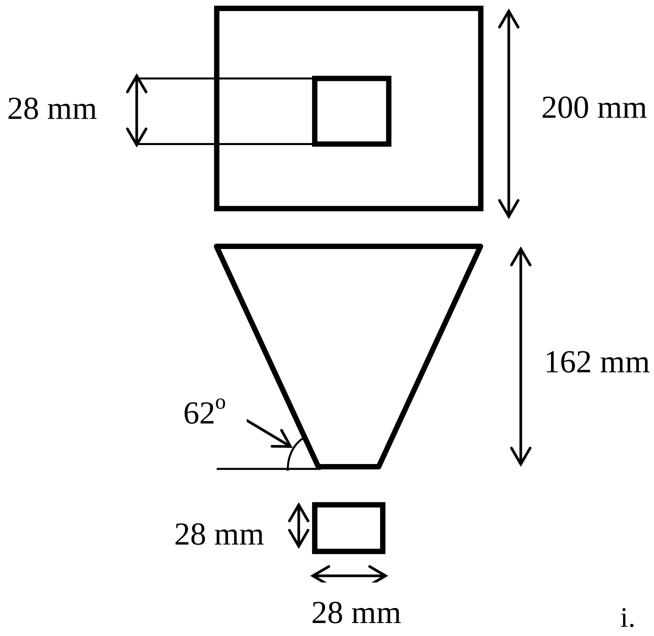


Figure 2 Dimensions of the hopper

The hopper capacity is the number of seeds or quantity of seeds the hopper can bear.

$$Capacity\ of\ the\ hopper = \frac{Total\ volume\ of\ the\ hopper}{Average\ volume\ of\ a\ maize\ seed}$$

The volume of an average maize grain at 16% (wb) moisture content used is $234.34 \pm 29.47\ mm^3$ (Mohammad, 2010). The volume of an average grain can also be determined going by this Equation Jain and Bal (1997).

$$V = 0.25\left[\left(\frac{\pi}{6}\right) L(W+T)^2\right]$$

Where; *V*- volume of grain, *L*- length of the grain, *W*- width or breadth of the grain, *T*- grain's thickness.

$$Max. number\ of\ seeds\ the\ hopper\ can\ bear = \frac{Total\ volume\ of\ the\ hopper}{Average\ volume\ of\ a\ maize\ seed}$$

$$= \frac{2.50 \times 10^6\ mm^3}{255\ mm^3}$$

$$= 9{,}804\ Seeds\ per\ volume$$

$$Max. number\ of seeds\ or\ Capacity\ of\ the\ hopper = (9804 + 71)$$

$$= 9{,}875\ Seeds\ per\ volume$$

The factor of safety of 71 was added to take care of the seed in the feeding tube:$\left({}^{18{,}032}/_{255}\right)$.

3.2.3 Total machine weight

The machine is composed of parts such as the main frame, opener adjustable bed, furrow opener, seed plate covers, and the hopper all made up the body of the machine. The weight of these components is important so as to design for the shaft size and other component bearing the load of the entire machine.

i. Mass of the main frame

$$Mass = Density \times Vo$$

$$Volume\ of\ the\ frame's\ lengths = 2[L(2B)T]$$

Where; *L*- length of the frame, *B*- width of the frame's length, *T*- thickness of the frame's length, V_l – volume of frame's length.

$$V_l = 2[700(200v)3] = 420{,}000\ mm^3$$

$$Volume\ of\ the\ frame^{\prime}\ s\ breadths = 2[L(2B)T]$$

$$V_b = 2[370(2700)3] = 222{,}000\ mm^3$$

The furrow opener adjusting bed is of the same materials and of equal dimensions as the main frame's breadth, therefore they have equal volume.

$$Volume\ of\ the\ furrow\ opener\ adjusting\ bed = 222{,}000\ mm^3$$

Combine volume of the frame $= (420{,}000 + 222{,}000 + 222{,}000) = 864{,}000 mm^3 or\ 8.64 \times 10^{-4}\ m^3$

Density is 7850 kg m^{-3}, the density of steel material.

$$Weight\ of\ the\ frame = (7850 \times 8504810^{-4}\ kg)$$

$$= 6.7824\ kg = 66.5\ N$$

ii. Design of the furrow opener

The furrow opener is typically design like tine with an arrow head or pointed tip (Figure 3).

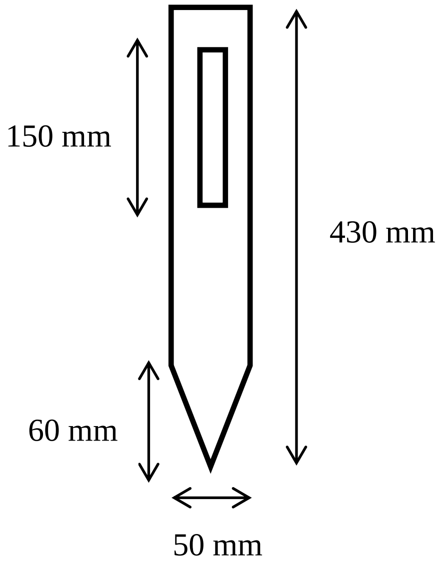


Figure 3 Dimensioned furrow opener

Volume of the furrow opener = (Total surface area × thickness)

Volume of the furrow opener

$$= \left[\left[\frac{1}{2} BH_t + L_r B\right] - (lb)\right] T$$

Where, L_r - length of the rectangle (430-60) mm, B - the width of the tool (50 mm), T - thickness of the tool (4 mm), H_t - height of the triangular tip (60 mm), l - length of the cut part of the opener, b - breadth of the cut part of the opener.

$$Volume = \left[\left[\left(\frac{1}{2} \times 50 \times 00\right) + (430-60)50\right] - (150 \times 50)\right] 4$$

$$Volume = 74{,}000 mm^3 \; or \; 7.40 \times 10^{-5} m^3$$

The mass of the furrow opener

$$= \text{Density} \times \text{Total volume of the furrow opener}$$

Density of the material used for the designing of the furrow opener is 7 850 kg m^{-3}.

$$Mass \; of \; the \; furrow \; opener = 7850 \times 7.40 \times 10^{-5} \, kg = 0.581 kg = 5.70 \, N$$

iii. Analyzing the Draft Force of the Furrow Opener

Draft = Soil resistance × Furrow cross-section

Furrow cross-section = Width of furrow × Working depth

Taking soil resistance as 0.8 kg cm^{-2} and working depth (planting depth) as 3.5 cm

Width of furrow (width of furrow opener) = 2.5 cm

$$Draft = 0.8 \times 2.5 \times 3.5 = 7 \, kg$$

$$Force \; or \; draft \; pull = 7 \times 9.81 = 68.67 \, N$$

iv. Mass of the seed plate covers

$$Volume \; of \; the \; covers = \frac{2(\pi d^2 t)}{4} + (\pi dt)w$$

Where,

t - thickness of the materials used = 3 mm;

d - Diameter of the cover = 220 mm;

w - Width of the cover = 35 mm.

$$Volume = \frac{2(\pi \times 220^2 \times 2)}{4} + (\pi \times 220 \times 3)35$$

$$Volume \; of \; the \; seed \; plate \; covers = 3.01 \times 10^{-4} \, m^3$$

$$Mass \; of \; the \; seed \; plate \; cover = 7850 \times 3.01 \times 10^{-4} kg = 2.36 kg = 23.2 \text{ N}$$

Having established the weights of each component that make up the body of the planter, therefore, the combined weight of the machine was calculated to be 128.42 N.

v. Mass of the metering device

The seed metering plate is one of the component acting on the shaft. Therefore, it is important to determine it effect on the shaft.

$$Volume \; of \; the \; metering \; device = surface \; area \times thickness = \frac{\pi d^2}{4} t$$

Where, d and t are the diameter and thickness, respectively.

$$Volume = \frac{\pi \times 190^2 \times 20}{4} = 567{,}057.47 mm^3 \; or \; 5.67 \times 10^{-4} \, m^3$$

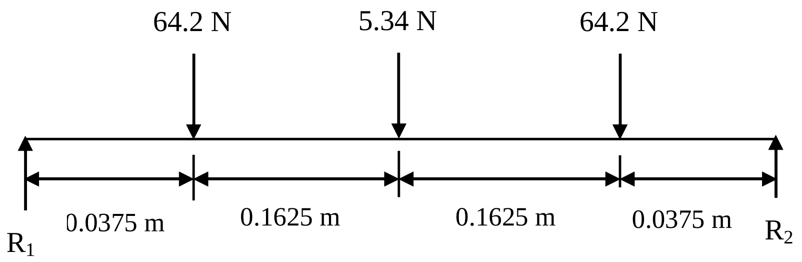
$$Mass \; of \; the \; device = Density \times Volume$$

The material used for this device is wood. However, the density of the material was carefully considered and selected due to the various differences in varieties (Iroko, Bamboo, Teak, Mahogany, Ebony, etc.) and densities. Considering the factor of safety, the variety with the highest density was selected. The density of the material used is assumed 960 kg m^{-3}.

$$Mass\ of\ the\ device\ = 960kg\ m^{-3} \times 5.67 \times 10^{-4} m^3$$
$$= 0.544\ kg$$
$$Weight\ of\ the\ metering\ device\ = 0.544 \times 9.81$$
$$= 5.34\ N$$

3.2.4 Shaft design

The shaft will be subjected to fluctuating torque and bending moments during the operation, and therefore combined shock and fatigue factors were taken into account.



Taking moment about R_1;

$$R_2 \times 0.4\ = 64.2 \times 0.0375 + 5.34 \times 0.2 + 64.2 \times 0.3625$$
$$R_2 = 66.87\ N$$

Upward forces equal to downward forces;

$$66.87 + R_1 = 133.74$$
$$R_1 = 66.87\ N$$

At point A, Bending moment (BM) = 0

Point B, BM = $(66.87\ B, BM\ ) =\ 2.51\ Nm$

Point C, BM = $(66.87\ C,) - (64.27\ C, BM) =$ 2.94 Nm

Point D, BM = $(66.87\ D, BM\ ) - (64.27\ D, B) - (5.347\ D, BM) = 2.51\ Nm$

Point E, BM $= (66.87\ E,) - (64.27\ E, BM) - (5.347\ E,) - (64.27\ E, BM) = 0\ Nm$

The maximum bending moment (M_b) is 2.94 Nm.

$$Torsional\ moment (M_t) =\ \frac{P}{2\pi N}$$

Where, *P*- total power required pushing or operating the machine, *N*- speed (revolution per second).

$$Power\ required\ to\ push\ the\ wheel = \tau.\omega$$
$$\tau = force(reaction\ at\ the\ whee\quad) \times radius\ of\ the\ wheel$$

Reaction at the wheel = 66.87 N, Radius of the wheel = $\frac{350\ mm}{2}$ = 175 mm, τ- Torque

$$\tau = 66.87 \times 175$$
$$= 11{,}702.25\ Nmm\ or\ 11.702\ \ Nm$$

$$\omega = 2\pi N$$

Taking N as 1rev per second;

$$\omega = 2\pi = 6.28 rad sec^{-1}$$
$$Power\ required\ to\ push\ the\ wheel = 11.702 \times 6.28$$
$$= 73.50\ W$$
$$Power\ required\ to\ push\ the\ wheels\ (the\ two\ wheels) = 147.00\ W$$

Power required to roll the seed plate $= \tau.\omega$

Weight of the seed plate = 5.34N, radius of the seed plate = $\frac{190mm}{2}$ = 95 mm,

$$\omega = 2\pi = 6.28\ rad\ sec^{-1}$$
$$Power\ required\ to\ roll\ the\ seed\ plate$$
$$= 5.34 \times 0.095 \times 6.28 = 3.19\ W$$

Total power required to pushing the machine = (147.00 + 3.19) = 150.19 W

$$M_t = \frac{150.19}{6.28} = 23.92\ Nm$$
$$d^3 = \frac{16}{\pi Ss}\sqrt{(\mathrm{K_b M_b})^2 + (K_t M_t)^2}$$
$$d^3 = \frac{16}{\pi \times 40 \times 10^6}\sqrt{(1.540 \times .5)^2 + (14540 \times 4)^2}$$
$$= 3.1010^{-6}$$
$$\mathrm{d} = 0.01458\ \mathrm{m\ or\ 14.58\ \ mm}$$

Factor of safety of 3.0 was chosen for the shaft with mild steel material and a steady load application. A shaft diameter of 45 mm was selected for the design.

3.2.5 Calibration of the metering device

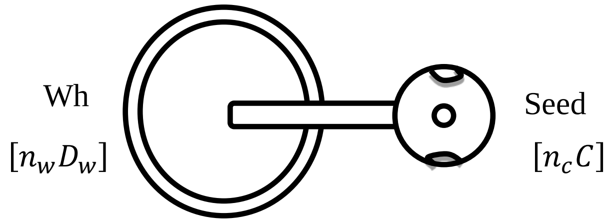


Figure 4 The wheel and the metering device

$$\frac{\pi D_w n_w}{S} = n_c C$$

Where,

S is the ground spacing (300 mm);

D_c is the diameter of the seed plate (190 mm);

C the number of cells (unknown);

D_w is the diameter of the wheel (350 mm);

n_w is the number of revolution of wheel;

n_c is the number of revolution of cell, but, $n_c = n_w = n$ (number of revolution).

Since the wheel and the seed plate are on the same shaft, they rotate at the same number of revolution (n). D_c is also considered instead of D_w due to the same reason of having a common shaft.

$$C = \frac{\pi D_c}{S}$$

$$C = \frac{\pi \times 19\ cm}{30\ cm}$$

$$C \cong 2$$

The metering of the planter has two (2) cells. Before the seed planter was taken to the field, it was important to get calibrated under laboratory conditions. Calibration is important to control the quantity of seeds to be sown. The calibration details are as follows:

Area of land to be experimented = 4 m^2

Circumference of ground wheel π D = π × 35 cm = 110.0 cm = 1.10 m

Number of revolution it takes the ground wheel running 2 m length

$$= 2/1.10\ \cong 2\ revolutions$$

Width of seed planter = Number of furrow opener × width of seed drill

$$= 1 \times 0.4\text{ m} = 0.4\text{ m}$$

Area covered for one revolution = Circumference of ground wheel × Width of seed drill

$$= 1.1\text{ m} \times 0.4\text{ m} = 0.44\ m^2$$

Number of turns required/ha= $10{,}000\ m^2/0.492\ m^2$ = 20,325 revolution per hectare

Number of grains dropped = the seed cell capacity (no of seeds /cell) × No of cell/revolution

$$= 2 \times 2 = 4\ seeds/revolution$$

The number of seeds required to plant a hectare of land by the designed planter = 4 × 20,325 = 81,300 seed / hectare or 21.95 kg/ha (Taking the average mass of a maize as 0.27 g).

3.2.6 Machine testing

The planter was fabricated and tested in workshop of the Agricultural and Environmental Engineering Department, Federal University of Technology Akure, Ondo State (Figure 5). Digital caliper was used for measuring seed dimensions, the seeds were weighed using an electronic balance. A measuring tape (50 m) was used to measure the distances. A stopwatch was used to estimate the time requirements of different operations and maize seeds were used in these tests. Seed distribution tests were conducted to determine the number of seeds per meter length in row, and the distance among the seeds in the rows. Two sets of tests were conducted: (a) seed metering devices performance tests and (b) seed distribution tests.

Figure 5 Fabricated planter

The driving wheels were suspended and the metering device was rotated by turning the wheels. Fifteen revolutions of the wheel were made and the numbers of seeds dropped were counted and recorded.

The number of seeds per meter length was also determined. Finally, the machine was tested on a 4 m^2 field and the width of the field was divided into four rows. The number of seed dropped and the average seed distributive spacing were determined. The seeds received on the ground were counted per meter length. The visible seed damaged was also estimated, by operating the planter at three different speeds.

Figure 6 Measurement of seed dimensions

Figure 7 Measurement of seed spacing

4 Results and discussion

The planter covers a distance of 16.50 m in 15 revolutions of the wheel. The revolutions were recorded at different time and speeds, the time taken and corresponding speed are 10 s, 12 s ,15 s, 1.65 ms^{-1}, 1.38 ms^{-1} and 1.10 ms^{-1} respectively.

Expected points of planting $E_p = \frac{Distance\ covered}{Calibrated\ spacing} = \frac{16.50}{0.30} = 55\ points$

The speed of 1.38 ms^{-1} was discovered to have the best functioning efficiency of delivering close to the fed seeds. Therefore, this speed was used further in performing the seed metering device performance test and the results are shown in Table 1.

Table 1 Seed metering test

Tests	No of Seeds discharged	No of Seeds damaged	Functional efficiency, %
1	106	4	96.4
2	109	1	99.1
3	105	5	95.5
4	106	4	96.4
Average	106	4	96.9

Average seed planted received per meter length = ${}^{106}/_{16.50} = 7 seeds/m$

Percentage of damaged seed = 3.6%

The seed distribution test was performed by dividing a 4 m^2 field into four rows. The speed that gave the best performance of seed metering device and functional efficiency (1.37 ms^{-1}) was maintained while conducting this test (Table 2).

Table 2 Seed distribution test

Rows	No of seed dropped/spacing	Spacing, cm	Retained/damaged seed
	2		
		29.5	
1	2		1
		30.5	
	1		
Average	2	30	
	3		
		30.5	
2	1		0
		32.5	
	2		
Average	2	31.5	
	2		
		29	
3	2		0
		30	
	2		
Average	2	29.5	
	2		
4		29	2
	2		
Average	1	29	

Estimated Mean spacing $= \frac{30 + 31.5 + 29.5 + 30.5}{4} = 30.38\ cm$

Average number of seed discharged per spacing $\cong 2$.

The seed population was determined using the formula.

$$P_a = n\left[\frac{LB}{S_r S_c}\right]$$

Where, *Pa* – actual seed population, *N*- Average number of seed discharged seed, *LB*- area of the field and *SrSc* - Inter-row and intra-row spacing, respectively. *LB* = 4 m^2 (L is 2 m, B is 2 m), *n* = 2, *Sr* = 0.32m, *Sc* = 0.5 m.

$$P_a = 2\left[\frac{4}{0.32 \times 0.5}\right] = 50\ seeds$$

The expected planting population using the same formula with the designed spacing of 30cm is 50seeds. The sowing efficiency of the machine in regard to the considerable field area is 92.6%. Therefore, the total sowing efficiency of the machine is the product of the functioning efficiency and the sowing efficiency which is (0.969×0.926) and is equal to 89.7%.

In one (1) revolution of the wheel, the planter covered an area of 0.44 m^2; in 15 revolutions of the wheel the planter would have covered an area of 6.6 m^2. The planting capacity of the planter was calculated to be 1.53 ha hr^{-1}.

5 Conclusions

The manually-operated vertical seed plate planter developed from locally available materials to suit the need of the peasant farmers was found to operate at a sowing efficiency of 89.7% with an average spacing of 31.5 cm. The planting machine was averagely able to meter two seeds per hole with a negligible percentage of damaged seeds. The simplicity of operation and ease of maintenance is appreciable by an average local farmer. The average seeds spacing recorded were 30.38 cm which was nearer to the calibrated spacing designed for the machine (30.0 cm). The sowing efficiency of the machine in regard to the considerable field area is 92.6%. Therefore, the total sowing efficiency of the machine is the product of the functioning efficiency and the sowing efficiency which is equal to (0.969×0.926) 89.7%. The planting capacity of the planter was 1.53 ha hr^{-1}.

References

Abdulrahaman, A. A., and O. M. Kolawole. 2006. Traditional preparations and uses of maize in Nigeria. *Ethnobotanical Leaflet,* 10:6-11.

Adekunle, O. A., and R. T. Nabinta. 2000. Indigenous storage structure of cereals, by women farmers in kaltungo area of Gombe State, Nigeria. *Journal of Rural Economics and Development*, 14(1):47-54.

Adisa, A. F. and F. G. Braide. 2012. Design and development of template row planter. *Transnational Journal of Science and Technology August 2012 Edition,* 2(7):44-50.

Ahmed, B. 1996. Economic analysis of fertilizer used in maize production in the Northern Guinea Savannah of Nigeria. Unpublished Ph.D Thesis. Department of Agric. Economics and Rural Sociology, Ahmadu Bello University, Zaria: Nigeria.

Ayeni, A. O. 1991. Maize production in Nigeria: problems and prospects. *Journal of Food and Agriculture,* 2(1):123-129.

Bamgboye, A., and A. Mofolasayo. 2006. Performance evaluation of a two-row okra planter. *CIGR Journal.* Manuscript PM 06 002. Vol. VIII. July, 2006.

Degrande, A., and B. Duguma. 2000. Adoption potential of rotational hedge row intercropping in the humid lowlands of Cameroon. *Agricultural Research and Extension Network,* 103:1-7.

Food and Agricultural Organization (FAO), 1989. *Production Year Book Statistical Series*, 142(85):159-172.

Iken, J. E., and N. A. Amusa. 2004. Maize research and production in Nigeria. *African Journal of Biotechnology*, 3(6):302-307.

Jain, R. K., Bal, S. 1997. Physical properties of pearl millet. *Journal of Agricultural Engineering Research,* 66(2):85-91.

Khawar, J., A. Zahid, and Muhammad F. 2007. Maize: cereal with a variety of uses. DAWN–Business. http://wwwdawn.com/2007/03/12/ebr5.htm.

Migton, C. O. 1985. Planting of Grain Crops. *Journal of Agricultural Engineering Research,* 2(2):20-25.

Mohammad, R. S. 2010. The moisture content effect on some physical and mechanical properties of corn. *Journal of Agricultural Science*, 2(4):125-134.

Nweke, F. 2006. New challenges in the cassava transformation in Nigeria and Ghana. *EPTD Discussion Paper*, No. 118. *International Food Policy Research Institute 2033 K Street, NW*. Washington, D.C. USA.

Oduma1, O., J. C. Ede, and J. E. Igwe. 2014. Development and performance evaluation of a manually operated cowpea precision planter. *International Journal of Engineering and Technology,* 4(12):693-699.

Ogunsumi, L. O., S. O. Ewuola, and A. G. Daramola. 2005. Socio-economic impact assessment of maize production technology on farmers' welfare in southwest, Nigeria. *Journal of Central European Agriculture*, 6(1):15-26.

Stoney, E. A. 1999. Study on grain crops and their properties. *Journal of Agricultural Engineering Research,* 7(3):105-111.

Ugwuoke, I. C., A. Gbabo, and I. B. Ikechukwu. 2014. Design and fabrication of a single row maize planter for garden use. *Journal of Advancement in Engineering and Technology*, Volume 1. ISSN: 2348-2931.