

Design and evaluation of a motorized multi-grain crop planter

Babatunde Oluwamayokun Soyoye

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

Abstract: The economic importance of grain crops such as maize, soybean, cowpea and groundnut to the growing population of Nigeria, demands that an urgent measurement be undertaken to ensure improved productivity to meet food and other requirements by man and animals. The pre-design experimentation was carried out on yellow maize (*Zea mays*), Ife Brown cowpea (*Phaseolus vulgaris*), Seed soybean (*Glycine max*) and groundnut (*Arachis hypogaea* L). Some properties of the used grain crops were determined to design, fabricate and assemble a locally made motorized vertical seed-plate planter. Design criteria, calculations and analysis of various components of the machine were critically considered and determined in the course of the development. The geometric mean diameter of 8.26 mm, 8.72 mm, 9.51 mm and 6.52 mm were recorded for maize, cowpea, groundnut and soybean grains respectively, with respective groove depths of 8 mm, 7 mm, 9 mm and 6 mm. It was revealed from the results that the planter had a uniform discharge rate and application rate. When operated manually, the optimum planter metering device speed was 24 rpm (0.69 m s^{-1}), while the calculated field capacity of the planter is 0.187 ha hr^{-1} , average performance efficiency of 95.5% with the average discharge and application rates of 7.86 kg hr^{-1} and 42.1 kg ha^{-1} respectively. When the planter was electrically operated, it has the highest efficiency of 98% with the average discharge and application rates of 14.28 kg/hr and 54.96 kg/ha respectively at a metering speed of 40 rpm (1.15 m/s).

Keywords: grain crop, planter, motorize, design and fabrication

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1 Introduction

Planting is an art of placing seeds in the soil to have good germination. Planting began with the use of hands and later the use of stones, hand tools and mechanized form of planting (Yasir et al., 2012). Manual methods of planting resulted in low seed placement, low spacing efficiency, and health issues for the farmer considering the size of the farm land (Kumar et al., 2015; Soyoye et al., 2016). Seed planting machine is a device which helps in the sowing of

seeds in a desired position, thereby assisting the farmers in saving time and reducing cost. 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 (Odumal et al., 2014; Soyoye et al., 2016). However, in fabricating the form of this mechanized planting equipment, some properties of the plant which is to be planted must be determined in order to accurately specify the design considerations (Jouki and Khazaei, 2012). The physical properties such as size, shape, axial dimensions, roundness and sphericity helps to determine the maximum size of the cup in the seed plate, the weight help in the material selection for the frame of the planter, the bulk density and moisture content helps to know the interaction between the

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***Corresponding author:** Babatunde Oluwamayokun Soyoye, Ph.D. P. M. B. 704. Akure Ondo State Nigeria. Email: soyoye2002@yahoo.com; bosoyoye@futa.edu.ng, Tel: +234(0)8036577499.

seed and the material used for the hopper of the planter at maximum heat level (Jayan and Kumar, 2004). The mechanical properties such as the angle of repose helps to ensure free flow of seed in the hopper (Jayan and Kumar, 2004), the terminal velocity helps to determine the flow of the seed in air between the point of discharge and impact on the soil. The shear stress and impact stress helps to determine the amount of pressure the seed plate should apply on the seed. These properties help in specifying the design considerations of planting equipment because it will be a waste of time, resources, effort and money if after fabricating, the machine fails to deliver up to expectation.

To successfully establish crops, a planter should be able to:

- i Open a furrow;
- ii Meter the seed;
- iii Deliver the seed to, and place the seed appropriately in, the furrow;
- iv Cover the seed in the furrow;
- v Firm the seedbed; and
- vi Perform other functions as required, e.g. weed control, apply crop chemicals, etc.

These functions must be performed at an acceptable forward speed and with a high degree of reliability. Not all planting machines are capable of performing, or necessarily need to perform, all the functions. Nevertheless, the ability to perform all functions improves planter flexibility and prospect of crop establishment, particularly when sub-optimal conditions for crop establishment exist at the time of planting (Murray et al., 2006).

1.1 Aim of the research

The aim of this research is to develop a motorized grain crop planter that would be suitable for planting operation in tropical soils.

The specific objectives are to;

- i design the components of the planter for precision planting;
- ii fabricate and assemble the components of the planter using locally available materials;
- iii test the performance of the planter.

1.2 Project justification

The economic importance of grain crops such as maize, soybean, cowpea and groundnut to the growing population of Nigeria, demands that an urgent measurement be undertaken to ensure improved productivity to meet food and other requirements by man and animals. The insufficiency in the production level of these grain crops could be attributed to low productivity from grain crop farms or that farmers have not adopted improved technologies for their production. As a result of competition for the crops by both man and animal, there is the need to increase the supply level of the grains. Since the manual, hand push and animal driven methods of grain planting result in low seed placement, low spacing efficiencies and serious drudgery for the farmers which limit the size of field that can be planted. The design and production of tractor mounted planters has eliminated most of the limitation attached to the manual and animal driven methods but the innovation is very expensive and not in the reach of peasant farmers. Thus, the need for appropriate technology to deliver optimal yield while using fewer resources is very essential.

2 Main body

2.1 Existing planting methods and equipment

The early planters consisted of hoe with a small container. After digging a hole, the farmer releases the seed and presses it firmly into the soil with his foot (Deere, 1981; Kepner et al., 1978). The mechanical planters in Nigeria are either hand or power operated. Gupta and Herwanto (1992) reported the various versions of existing hand operated planters, which included “Jab” planter, rotary injection planter, auto feed “punch” planter, and hand-operated precision planter. The limitation of the conventional “Jab” planter is the time required by the user to select and deposit into the planter funnel the correct number of seeds and the desirability of locating seed in the base point of the opener at the correct time of “Jabbing”. Metering of the desired number of seeds remains the problem of rotary injection planter.

Kumar et al. (1996) designed a manually operated seeding attachment for animal-drawn cultivator. A moderately accurate metering of seed was designed for proper distribution of seed in furrows and minimum number of moving parts was ensured so that farmers may operate and maintain the machine easily. Bamgboye and Mofolasayo (2006) carried 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 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 8mm and 9mm. 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.

Yasir et al. (2012) designed and tested a tractor mounted pneumatic precision metering device for wheat which was applied to wheat seeding to overcome seed damage, seed loss and non-uniform distribution. The performance of the device, including quality of feed index, multiple index, miss index and seed rate expressed in number of kernels per meter length, was investigated under laboratory conditions in Wuhan using a test stand with camera system. The results revealed that the rotating speed and negative pressure and their interactions had a significant effect on these variables. 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.

Precision planting is defined as providing accurate placement of seeds within each row (Singh et al., 2005). There are two common types of precision seeders: belt and vacuum (Karayel et al., 2004). Precision planters differ from other seeding machines in that they have single seed metering devices. According to Hunt (2001), these mechanisms must be able to select as many seeds per minute that are of variable size and shape without causing damage to the seeds that would prevent germination. According to Srivastava et al. (2006), the horizontal seed plate planter was the most popular precision planter until the mid-1960s. The air planter was the next major innovation in precision planting (Srivastava et al., 2006). This type of planter uses a ground driven seed drum that is pressurized by a fan. Seeds are gravity fed into the drum from a central hopper (Data, 1974; Guarella et al., 1996; Karayel et al., 2004; and Singh et al., 2005). Planters that meter individual seeds provide the most precise control of seeding rates (Singh et al., 2005); however, according to Hunt (2001), field tests of planters show substantial variability of seed spacing in a row.

3 Research methodology

3.1 Pre-design experimentation

The seeds used for the experimentation work include DMR-LSR yellow maize (*Zea mays*), Ife Brown cowpea (*Phaseolus vulgaris*), TGX 1740-IF-Seed soybean (*Glycine max*) and groundnut (*Arachis hypogaea*). These seeds were procured at the Institute of Agricultural Research and Training Obafemi Awolowo University, Nigeria. A pair of vernier caliper was used to measure the axial dimensions of the material including the length, breadth and thickness. The model used is the Gilson Vernier Caliper with calibration of 20 cm with error of 0.05 mm. Two measuring

cylinders (Spyrex EX 20°C with calibration of 250 mL ± 2 ml and a measuring cylinder with 100 mL; 20°C) were used to determine the bulk volume of the materials. The weighing can was used to hold the materials in the oven when determining the moisture content of the material. It was also used when weighing in bulk. The weighing balance was used to measure the weight of materials in grams. The weighing balance used was the Electronic Precision balance with model JA303P, number 1505601, Max weighing 310 g and readability 0.001 g. The sliding box was the equipment used to determine the friction angle and the coefficient of friction. It was made of ply-wood and a protractor was used for calculating the angle. The dimension is 0.3 m × 0.6 m.

3.1.1 Geometric mean diameter

As described by Tarighi et al. (2011), the geometric mean diameter (mm) was determined using Equation 1;

$$D_g = (LWT)^{1/3} \quad (1)$$

where; D_g is the geometric mean diameter, L is the length, W is the width and T is the thickness.

3.1.2 Surface area

The surface area (mm²) was determined using the Equation 2;

$$S = \pi D_g^2 \quad (2)$$

where; S is the surface area and D_g is geometric mean diameter.

3.1.3 Roundness

The roundness of the materials was determined using the Equation 3 (Jayan and Kumar, 2004);

$$Roundness = \frac{A_p}{A_c} \quad (3)$$

A_p is the largest projected area of the object in its natural rest position and A_c is the area of the smallest circumscribing circle.

3.1.4 Sphericity

It was determined using the Equation 4 as described by Jouki and Khazaei (2012);

$$\Phi = \frac{(LWT)^{1/3}}{L} \quad (4)$$

3.2 Design considerations

The following factors were taken into consideration:

- i Simplicity in construction so that it can be made locally, using locally available materials;
- ii Developing a planter with moderate weight to reduce soil compaction;
- iii Selecting the best design criteria which creates provision for effective performance of the planter using moderate power;
- iv Considering the shape of the planter and the furrow openers for minimum and maximum depth of operations;
- v The disc coulter was spring loaded for it to ride on stones, roots and soil pediments without remarkable damage to the disc;
- vi Metering attachments were made versatile so that the machine can accommodate different seeds;
- vii The hopper was designed to ensure free flow of grain into the metering unit after proper consideration had been given to the seeds' angle of repose;
- viii Chain and sprocket mechanism was considered for the power transmission to ensure accuracy of metering and the prevention of slippery.

3.3 Conception of the planter

The motorized planter is a machine that was designed to tackle the major constraint and challenges encountered in the use of the existing planters and planting systems (low productivity, drudgery, cost, safety etc.). The metering device is the key component of the precision grain crop planter. A ground wheel was used to provide the drive to the metering device in the existing planters. However, the wheel bears high resistance and easily slips. Therefore, an electrically driven motor was incorporated into the designed planter. The seeder of the planter was designed using two separate seed boxes, one for each row (Figure 1). Seeds were distributed and metered by vertical seed plates with peripheral seed cells. The seeding mechanism was mounted on a metal frame supported on the chassis. It was also made versatile to accommodate different types of grains through the inter-row spacing adjustment mechanism thereby enhancing the acceptability of the planter by peasant

farmers. The frame was constructed from a hollow square pipe to maintain rigidity of the planter and at the same time making it lighter in order to reduce its weight so as to eliminate the problem of compaction. The constructed frame was mounted and supported on the four wheels of the planter (two rear and front wheels). The furrow openers were in two adjustable states; one for on-the-road

transportation with the seed furrow openers above the wheels, and the other for on-the-field seeding with the seed furrow openers below the wheels. In order to enhance the performance of the planter chisel openers were used, in front of which were couler discs to cut straw ahead the furrow openers and to aid easy penetration of the furrow openers.

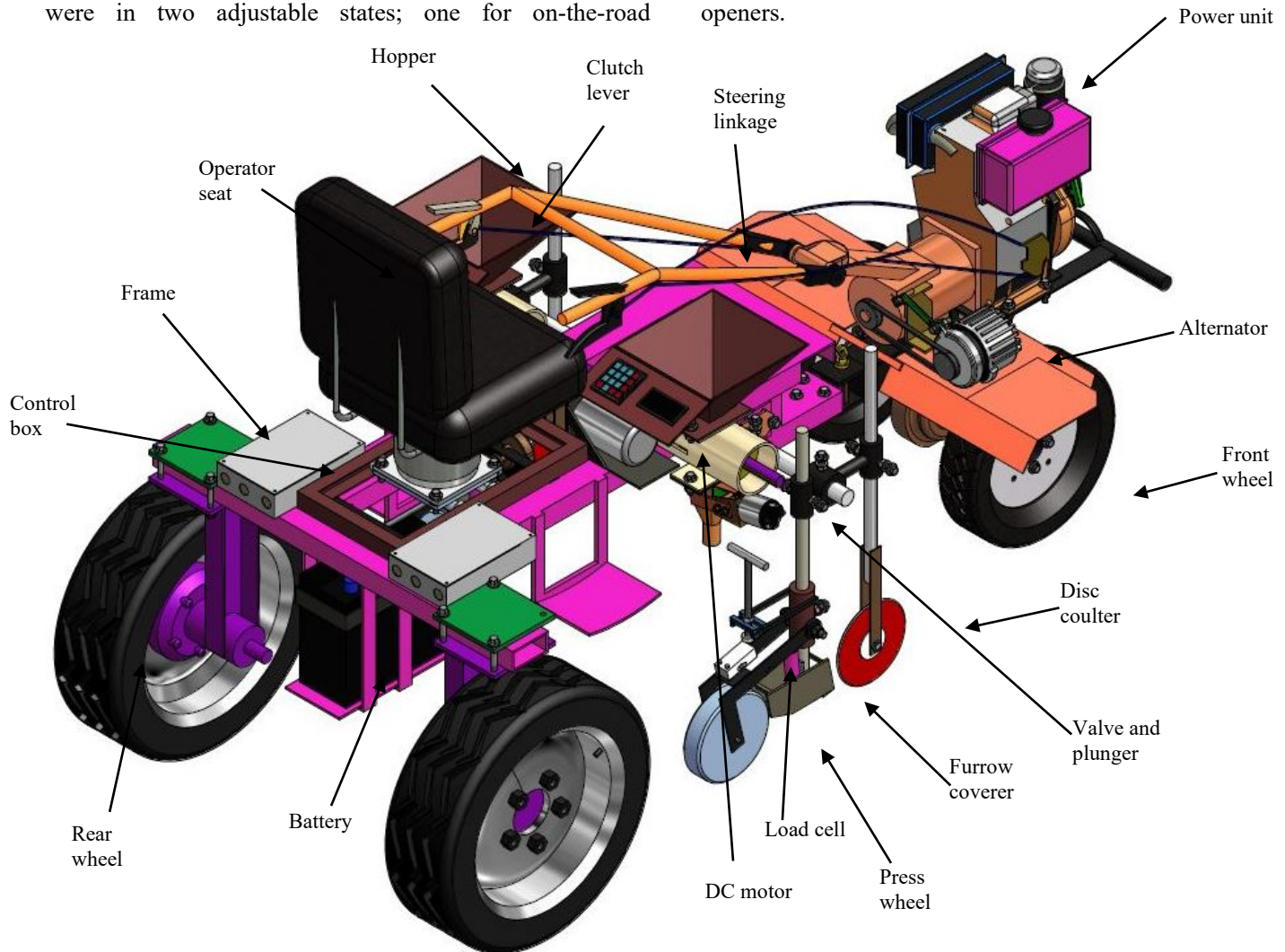


Figure 1 The designed motorized planter

3.4 Design analysis

The innovative information obtained from literatures, thesis, models, laboratory experiments along with experience and innovative ideas were applied in the conception of the machine described in Figure 1.

3.4.1 Disc couler

The disc is a plain circular plate cut from a medium carbon steel of 5 mm thickness and 100 mm diameter. The edge was chamfered to aid self-sharpening and improve

cutting action of the disc. The surface of the disc was hardened to reduce wear. The formula (Equation 5) proposed by Morrison et al. (1996) and Šarauskiš et al. (2013) was used in the determination of the resistance force acting upon the disc couler blade.

$$F_1 = S\sigma = \delta\Delta/\sigma \quad (5)$$

where; S is the area of the disc couler blade (mm^2), σ is the normal stresses of plant residue (Mpa), δ is the

thickness of the disc coultter blade (mm) and Δl the length of disc coultter blade at the time of contact with plant residue (mm).

3.4.2 Furrow opener

The furrow opener was designed in form of tine with an arrow head or pointed tip. The soil strength parameters are part of the factors affecting the draught requirement of tillage implements (Ademosun, 1990). It was desired that the furrow opener blade be strong enough to operate well at depth of up to 80 mm and at the high rake angle of 30°. The blade in operating position and at maximum depth has the draught force per unit width of blade (H) and the vertical force per unit width (V) given by Agbetoye (2000) as (Equations 6 and 7):

$$H = P \sin(\alpha + \delta) + C_a \cos \alpha \quad (6)$$

$$V = P \cos(\alpha + \beta) + C_a \sin \alpha \quad (7)$$

According to Ashrafizadeh and Kushwaha (2003), the passive force per unit width of the tine (P) is given as (Equation 8):

$$P = (pgd^2 N_p + cdN_c + qdN_q)w \quad (8)$$

where; C is the soil cohesion (N m⁻²), C_a is soil adhesion (N m⁻²), α is rake angle (°), δ is soil/metal friction angle (°), ρ is soil density (kg m⁻³), g is acceleration due to gravity (m s⁻²), w is tool width (m), d is the maximum working depth (m), ϕ is the angle of shearing resistance (°), N _{γ} , N_c, and N_q are factors read out using identity in Equation 9.

$$N_{\gamma,c,q} = N_{\delta=0} \left(\frac{N_{\delta=\phi}}{N_{\delta=0}} \right)^{\delta/\phi} \quad (9)$$

3.4.3 Traction force

Traction can be defined as the ability of the vehicle tractive element to generate enough forces to overcome all types of vehicle resistance to motion (Raymond et al., 1984). The traction mathematical modeling (the state of failure in soils) is generally expressed by well-known Mohr-Coulomb failure criterion (Yong, 1982) and can be written as (Equations 10):

$$\tau = C + \sigma \tan \phi \quad (10)$$

where; τ is the soil shear stress (N m⁻²), C is soil

cohesion (N m⁻²), σ is soil normal stress (N m⁻²) and ϕ is soil friction (°).

Assuming a uniform pressure distribution at the tyre-soil interface, according to Raymond et al. (1984), the maximum traction forces (N) can be calculated as (Equation 11):

$$F = CA + W \tan \phi \quad (11)$$

F is the traction force, C is soil cohesion, A is tyre-soil contact area, W is tyre load, ϕ is soil internal friction.

3.4.4 Hopper

The hopper is a compartment in the machine through which the grains to be planted were fed into the seed metering chamber. The feeding hopper was developed from a steel metal plate forming a hollow frustum of a rectangular trapezoidal trough with bottom base area of 30 × 70 mm and top area of 350 × 300 mm, the height was 300 mm. The hopper was designed with the consideration of the grain's angle of repose. The angle of repose for the grains considered falls between 38° and 50° (Soyoye, 2018). 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.

The hopper capacity is the number of seeds or quantity of seeds the hopper can bear, and it was determined using Equation 12 proposed by Mohammad (2010):

$$\text{Capacity of the hopper} = \frac{\text{Total volume of the hopper}}{\text{Average volume of a grain}} \quad (12)$$

The volume of the hopper was determined using equation 12 (Udo et al., 2015);

$$\text{Volume}(V) = \frac{(h)[WL + (W + a)(L + b) + ab]}{6} \quad (13)$$

where; V is the total volume of the hopper; W is the width of the top trough; L is the length of the top of the trough; a is the width of the base trough; b is the length of the base of the trough and h is the height of the hopper.

The volume of an average grain can also be determined going by Equation 14 (Jain and Bal, 1997).

$$V = 0.25 \left[\frac{\pi}{6} L(W + T)^2 \right] \quad (14)$$

where; V is volume of grain, L is length of the grain, W is width or breadth of the grain, T is grain's thickness.

3.4.5 Metering plate

The seed metering device used for this work is the vertical plate type with cells on its periphery. The material used for the metering plate is Teflon (*Polytetrafluoroethylene*) having a diameter of 100 mm and length of 500 mm. The size and number of cells on the plate depend on the type of grain and size of seed. In this design, the seeds in the plate were released through the cells and dropped into the seed funnel and were then conveyed to the opened furrow through the seed tube. The number of cells on the seed metering plate was obtained using Equation 15 (Reza, 2014; Soyoye et al., 2016):

$$\text{Number of cells} = \frac{\pi \times D \times t_2}{S \times t_1} \quad (15)$$

where; D is the wheel diameter (m), t_1 is the number of teeth on the wheel sprocket, t_2 is the number of teeth on the seed plate sprocket and S is the intra row spacing (m).

Based on calculations, the number of cells selected is 6, 7, 9 and 9 for maize, cowpea, soybean and groundnut respectively, with a spacing of 0.3 m for maize, 0.25 m for cowpea and 0.20 m each for soybean and groundnut.

3.4.6 Metering shaft

The metering shaft has chain and sprocket arrangement through a DC motor;

$$M_t = F_t R = \frac{F_t D}{2} \quad (16)$$

Where; F is force acting on the chain sprocket (N), D_1 is pitch diameter of the sprocket (m) = 0.05 m, T_1 is number of teeth on the smaller sprocket = 40 and P is power delivered from the DC motor (m)

$$F = \frac{\text{Power transmitted}(W)}{\text{Velocity}(m/s)} \quad (17)$$

$$V = \frac{\pi DN}{60} = \frac{\pi \times 0.05 \times 240}{60} = 0.628 m/s \quad (18)$$

$$F = \frac{746}{0.628} = 1187.90 N \quad (19)$$

$$M_t = \frac{FD}{2} = \frac{1187.90 \times 0.05}{2} = 29.70 Nm \quad (20)$$

The chain and sprocket arrangement on the metering shaft was aligned horizontally; the horizontal component of the force acting on the shaft is the force due to the chain and sprocket arrangement while the vertical components of the force acting on the shaft are the weight of the metering plates and the self-weight of the chain and sprocket (58.85 N).

The metering plate was selected from Teflon material with diameter of 0.10 m and total length of 0.5 m while the sliding shaft that carries the metering plate is made from hollowed mild steel material with length of 0.25 m. the volume of the Teflon used is $7.07 \times 10^{-4} m^3$ with density of $2200 kg m^{-3}$. The masses of the metering plate and the sliding shaft used were calculated to be 1.56 kg (15.30 N) and 1.25 kg (12.25 N) respectively.

3.5 Machine fabrication and assembly

The components of the planter were fabricated in the Agricultural and Environmental Engineering Departmental workshop of the Federal University of Technology Akure, Ondo State Nigeria. The planter consisted of the following components; soil engaging unit, metering unit, power transmission unit and instrumentation unit. The planter was fabricated in accordance with the design specifications. Marking out of the materials for fabrication was carried out using steel rule and scribe. Operations like cutting, drilling, machining, slotting, welding and milling were done using the appropriate machines as available in the workshop. The components of the planter were assembled and mounted on the fabricated frame as shown in Figure 2. The frame was mounted on two wheels and attached to the power tiller where the whole system was checked and gauged for alignment. The operator seat was mounted on the frame and proper adjustment opportunity was made available with respect to the steering handle to enhance the ergonomic factor of the planter.

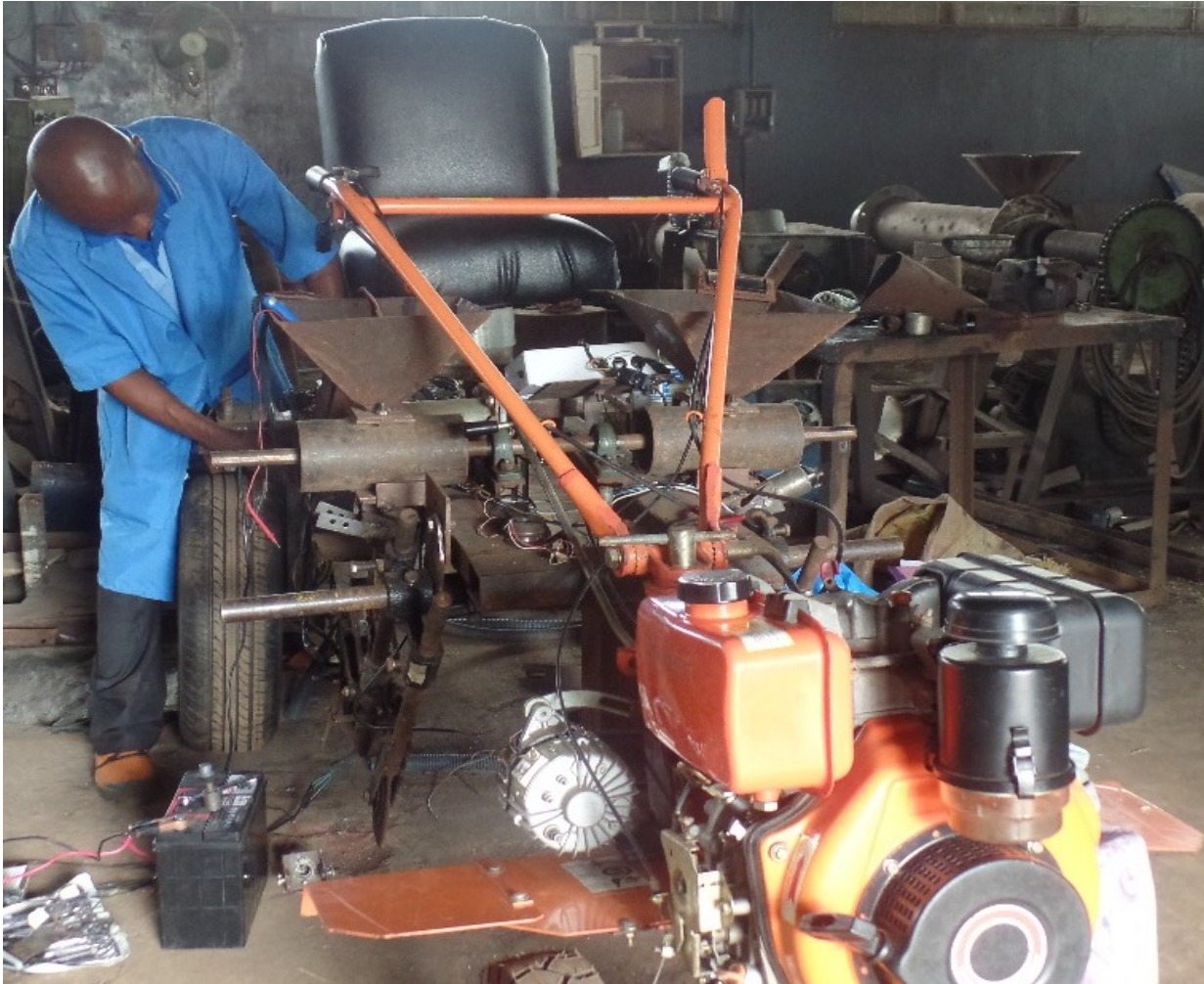


Figure 2 Machine Assembly in Progress

3.6 Machine testing

The assembled machine (Figure 3) was tested in the Laboratory where experiments were conducted to test the metering mechanism manually and electrically. During the manual testing, the metering shaft was turned and the time taking to make 20 complete revolutions was noted and recorded. The planter was tested electrically by connecting a dc motor to the metering shaft using a chain and sprocket connection of ratio 1:1. The motor was allowed to rotate and the quantity of seeds received over a period time was counted, weighed and recorded. The seed visible damage was also estimated, by operating the planter at various speeds. The planter was also operated at different levels of seeds in the hopper. It was evaluated in the following hopper conditions;

i When the hopper was filled with seeds at its full

capacity

ii When the hopper was filled with seeds at its 75% capacity

iii When the hopper was filled with seeds at its 50% capacity

iv When the hopper was filled with seeds at its 25% capacity

The effect of these hopper capacities on the seed discharge and application rates was noted, recorded and tabulated. At each instance, Equations 21 and 22 were used to calculate the discharge and application rates respectively.

$$\text{Discharge rate} = \frac{\text{Quantity of seed dropped}}{\text{Time taken}} \quad (21)$$

$$\text{Application rate} = \frac{\text{Quantity of seed dropped}}{\text{Area of land covered}} \quad (22)$$



Figure 3 The Assembled Planter

4 Results and discussion

4.1 Grain crops dimensional analysis

Table 1 shows the summary of the dimensional analysis carried on the grain crops. It was revealed from the table that the Geometric Mean Diameters (GDM) are 8.26 mm, 8.72 mm, 9.51 mm and 6.52 mm for maize, cowpea, groundnut and soybean respectively. Since it was desired to drop a single seed per hole, the cell geometry of the individual metering plate was designed following the seed dimensional analysis as tabulated in Table 1. The cell diameters of 10 mm, 11 mm, 12 mm and 8 mm were chosen for maize, cowpea, groundnut and soybean grains respectively, with respective groove depth of 8, 7, 9 and 6 mm in accordance with Sricastava et al. (2006).

Table 1 Dimensional analysis of the tested crops

Dimension	Maize	Cowpea	Groundnut	Soybean
Major diameter, a (mm)	10.43	11.54	12.34	7.37
Intermediate diameter, b (mm)	8.83	8.02	8.92	6.37
Minor diameter, c (mm)	6.12	7.17	7.80	5.90
Geometric Mean Diameter, GMD (mm)	8.26	8.72	9.51	6.52

4.2 Planter performance

The capacity of the planter was evaluated based on the discharge rate and application rate of the planter. These parameters were in turn used to determine the optimum operation conditions of the planter. Table 2 shows the average capacity of the planter when the planter was turned manually 20 times. It was revealed from the table that the total seed discharged (dropped) at the seed tube increased with decrease in the speed of the planter (metering plate speed). This is due to the fact that at high speed the seeds

do not have enough time to drop into the cell groove thereby resulting in the rebound of the seeds. The implication of operating the planter at high speed is that it results in high missing index on the field. The optimum speed of the planter was chosen to be the point of interception between the discharge rate and the application rate; it is taken to be 24 rpm (Figure 4). It was revealed that at all the hopper capacities the highest efficiency was recorded at the metering speed of 24 rpm at the linear speed of 0.69 m s⁻¹. The calculated field capacity of the planter is 0.187 ha hr⁻¹ with the average discharge and application

rates of 7.86 kg hr⁻¹ and 42.1 kg ha⁻¹ respectively. The result could be compared with what was recorded by Karim et al. (2015) when they evaluated a drum seeder with urea super-granule application and recorded an optimum roller speed of 23 rpm when the seeder was manually pulled. On the other hand, Hossein et al. (2012) recorded a metering speed of 41.5 rpm at the planter travel speed of approximately 1 km hr⁻¹ during the determination of some design parameters for roller type seed metering device such as roller speed, travel speed, length and depth of groove for tomato seeds precision planting.

Table 2 Planter performance under different metering shaft turns

S/N	Time (s)	Speed (rpm)	Total seed dropped (kg)	Seed damage (kg)	Speed (m s ⁻¹)	Discharge rate (kg hr ⁻¹)	Application rate (kg ha ⁻¹)	Efficiency (%)	Field Capacity (ha hr ⁻¹)
1	20	60	0.0352	0.0034	1.7286	6.3360	16.9697	90.3409	0.37341
2	30	40	0.0544	0.0042	1.1524	6.5280	26.2259	92.2794	0.2489
3	40	30	0.0902	0.0040	0.8643	8.1180	43.4849	92.5654	0.1867
4	50	24	0.1109	0.0067	0.6914	7.9848	53.4642	93.9585	0.1493
5	60	20	0.1105	0.0082	0.5762	6.6300	53.2714	92.5792	0.1245
6	70	17.14	0.1127	0.0088	0.4939	5.7960	54.3320	92.1917	0.1067
7	80	15	0.1168	0.0099	0.4321	5.2560	56.3085	91.5240	0.0933
8	90	13.33	0.1163	0.0102	0.3841	4.6520	56.0675	91.2296	0.0830

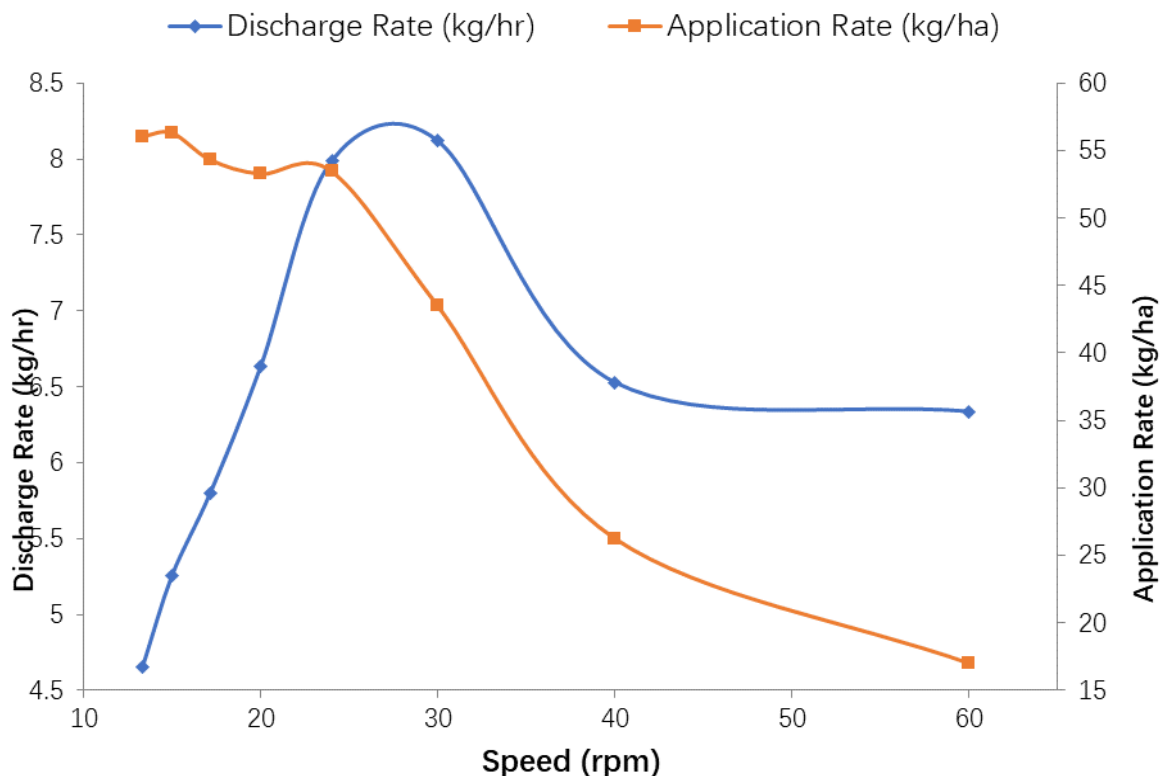


Figure 4 The discharge and application rates of the planter

Table 3 Planter performance under the electrically operating

S/N	Speed (rpm)	Speed (m s ⁻¹)	Total seed dropped (kg)	Seed damage (kg)	Discharge rate (kg h ⁻¹)	Application rate (kg ha ⁻¹)	Efficiency (%)	Field capacity (ha h ⁻¹)
1	80	2.305	0.214	0.0189	12.84	25.79	91.17	0.50
2	70	2.017	0.232	0.0136	13.92	31.96	94.14	0.44
3	60	1.729	0.251	0.0106	15.06	40.33	95.78	0.37
4	50	1.441	0.272	0.0063	16.32	52.45	97.68	0.31
5	40	1.152	0.262	0.0059	15.72	63.15	97.75	0.25
6	30	0.864	0.202	0.0049	12.12	64.92	97.57	0.19
7	20	0.576	0.134	0.0045	8.04	64.60	96.64	0.13
8	10	0.288	0.067	0.0024	4.03	64.79	96.43	0.06

The effect of speed of rotation of the metering plate on the discharge rate (kg hr⁻¹), application rate (kg ha⁻¹) and the planter efficiency (%) were determined electrically using the electric motor as the power source (Table 3). The linear increment of the discharge rate with the speed of operation revealed the steadiness of the electric motor with respect to the speed. The planter when operated electrically has the highest efficiency of about 98% at a metering speed

of 40 rpm with the field capacity, discharge and application rates of 0.25 ha hr⁻¹, 14.28 kg hr⁻¹ and 54.96 kg ha⁻¹ respectively. It was shown from the Figure 3 that the discharge rate and the application are inversely related. The optimum speed of the planter was chosen to be the point of interception between the discharge rate and the application rate; it was taken to be 40 rpm (Figure 5).

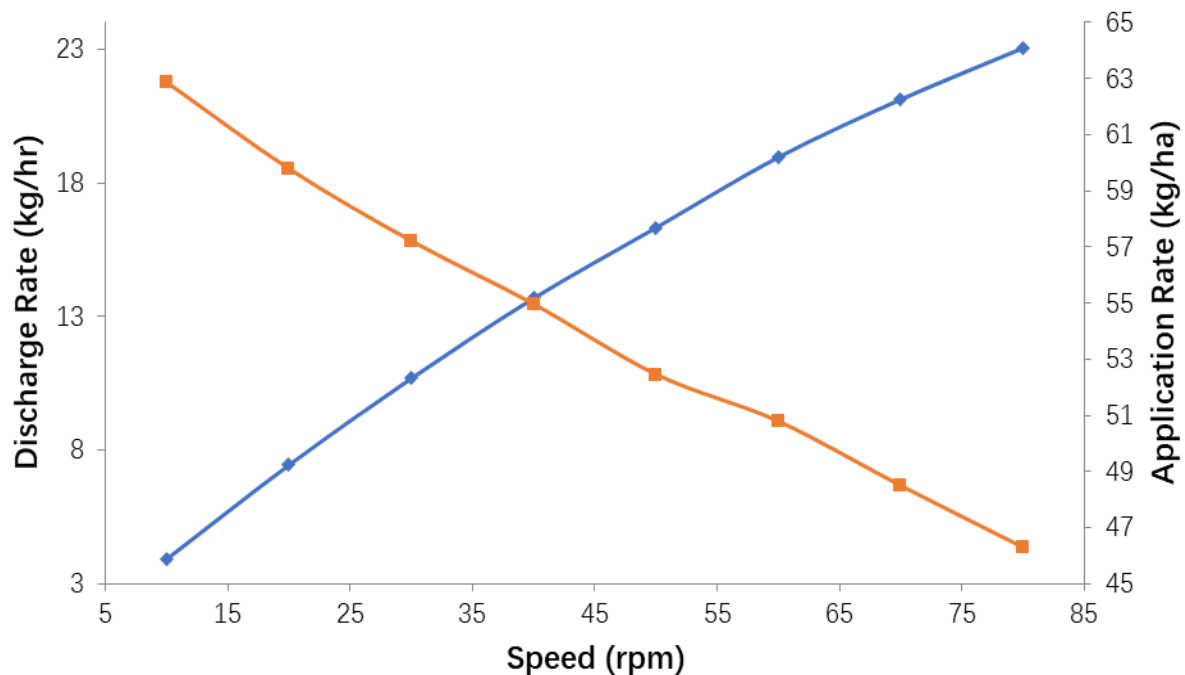


Figure 5 The discharge and application rates of the planter when electrically operated

5 Conclusions and recommendation

5.1 Conclusions

An indigenous multi-grain crop planter was designed, fabricated and assembled using locally available materials. The planter was tested to determine its optimum working

parameters and based on the results, the following conclusions were made.

- i The designed planter had uniform discharge and application rates.
- ii The optimum rotational speed of the metering unit

of planter when operated manually was 24 rpm while it was 40 rpm when operated electrically.

iii The damage on the seeds was not significant at low speed.

5.2 Recommendation

For further research work it is recommended that cameras should be installed at the seed tube to monitor the patterns and orientations of seed flow.

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References

- Ademosun, O. C. 1990. The design and operation of a soil-tillage dynamics equipment. *The Journal of the Nigerian Society of Engineers*, 25(1): 51-57.
- Adisa, A. F., and F. G. Braide. 2012. Design and development of template row planter. *Transnational Journal of Science and Technology*, 2(7): 27-33.
- Agbetoye, L. A. S. 2000. The design and operation of a model cocoyam harvester. *Journal of Science and Technology*, 9(1): 147-151.
- Ashrafizadeh, S. R., and R. L. Kushwaha. 2003. Soil failure model in front of a tillage tool action, a Review. *The Canadian society for Engineering, Food and Biological System, CSAE*, 3(210): 1-28.
- Bamgboye, A., and A. Mofolasayo. 2006. Performance evaluation of a two-row okra planter. *CIGR Journal*, 2(8): manuscript PM 06 002.
- Data, R. K. 1974. Development of some seeders with particular reference to pneumatic seed drills. *Indian Institution of Technology*, 16(1): 26-29.
- Deere, J. 1981. *Fundamental of Machine Operations: Planting*. 1st ed. Moline, Illinois: Deere and Com.
- Guarella, P., A. Pellerano, and S. Pascuzzi. 1996. Experimental and theoretical performance of a vacuum seed nozzle for vegetable seeds. *Journal of Agricultural Engineering Research*, 64(1): 29-36.
- Gupta, C. P., and T. Herwanto. 1992. Design and development of a direct paddy seeder. *Agricultural Mechanization in Asia, Africa and Latin America (AMA)*, 23(1): 23-27.
- Hossein, N., R. G. Hamid, and M. Mohammad. 2012. Determination of some design parameters for roller type seed metering device. *Journal of Agricultural Science and Technology*, 2(6): 845-850.
- Hunt, D. 2001. *Farm Power and Machinery Management*. Ames, IA: Iowa State University Press.
- Jain, R. K., and S. Bal. 1997. Physical properties of pearl millet. *Journal of Agricultural Engineering Research*, 66(2): 85-91.
- Jayan, P. R., and V. J. F. Kumar. 2004. Planter design in relation to the physical properties of seeds. *Journal of Tropical Agriculture*, 42(1-2): 69-71.
- Jouki, M., and N. Khazaei. 2012. Some physical properties of rice seed. *Research Journal of Applied Sciences, Engineering and Technology*, 4(13): 1846-1849.
- Karayel, D., Z. B. Barut, and A. Ozmerzi. 2004. Mathematical modeling of vacuum pressure on a precision seeder. *Biosystems Engineering*, 87(4): 437-444.
- Karim, M. F., M. Alam, R. Ali, and O. Kozan. 2015. Design and development of a drum seeder with urea and supergranule application for rural farmers in Bangladeshi. *CIGR Journal*, 17(3): 61-71.
- Kepner, R. A., R. Bainer, and E. L. Banger. 1978. *Principle of Farm Machinery*. 3rd ed. Westport: AVI Publishing Company.
- Kumar, A., S. C. Moses, and K. Khan. 2015. A survey on the design, fabrication and utilization of different types of foods and vegetables dryer. *IOSR Journal of Agricultural and Veterinary Science I*, 8(4): 2319-2372.
- Kumar, K., N. K. Naresh, and T. P. Ojiha. 1996. Design, construction and performance evaluation of manually operated seeding attachment for an animal drawn cultivator. *Agricultural Mechanization in Asia, Africa and Latin America (AMA)*, 27(2): 35-38.
- Mohammad, R. S. 2010. The moisture content effect on some physical and mechanical properties of corn. *Journal of Agricultural Science*, 2(4): 125-134.
- Morrison, J. E., J. G. Hendrick, and R. L. Schafer. 1996. Soil forces on coulter and disc-opener combinations. *Transactions of the ASAE*, 39(2): 369-376.
- Murray, J. R., J. N. Tullberg, and B. B. Basnet. 2006. Planters and their components: types, attributes, functional requirements, classification and description. *ACIAR Monograph No. 121*. ISBN 1 86320 462 8.
- Odumal, 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.
- Raymond, N. Y., A. F. Ezzat, and S. Nicolas. 1984. *Vehicle Traction*

- Mechanics, Developments in Agricultural Engineering*. Montreal, Canada: Geotechnical Res. Centre, McGill Univ.
- Reza, A. 2014. Modified design of a precision planter for a robotic assistant farmer. M.S. thesis, Saskatoon: Dep. of Mechanical Eng, Univ. of Saskatchewan Saskatoon.
- Šaraukis, E., K. Romaneckas, A. Sakalauskas, E. Vaiciukevičius, K. Vaitauskiene, D. Karayel, and R. Petrauskas. 2013. Theoretical analysis of interaction of disc coulters and straw residues under no-tillage conditions. *Agronomy Research*, 11(1): 89-96.
- Singh, R. C., G. Singh, and D. C. Saraswat. 2005. Optimization of design an operational parameters of a pneumatic seed metering device for planting cottonseeds. *Biosystems Engineering*, 92(4): 429-438.
- Soyoye, B. O., O. C. Ademosun, and E. O. Olu-Ojo. 2016. Manually operated vertical seed-plate maize planter. *CIGR Journal*, 18(4): 70-80.
- Soyoye, B. O. 2018. Development and performance evaluation of an instrumented motorized multi-grain crop planter. Ph.D. diss., Federal Univ. of Technology Akure.
- Srivastava, A. K., C. E. Goering, R. P. Rohrbach, and D. R. Buckmaster. 2006. Crop planting. In *Engineering Principles of Agricultural Machines*, ed. A. K. Srivastava, 231-268. St. Joseph: American Society of Agricultural Engineers.
- Tarighi, J., A. Mahmoudi, and A. Naser. 2011. Some mechanical and physical properties of corn seed. *African Journal of Agricultural Research*, 6(16): 3691-3699.
- Udo, S. B., A. F. Adisa, S. O. Ismaila, and S. B. Adejuyigbe. 2015. Development of palm kernel nut cracking machine for rural use. *CIGR Journal*, 17(4): 379-388.
- 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*, 1(2): 2348-2931.
- Yasir, H, Q. Liao, J. Yu, and D. He. 2012. Design and test of a pneumatic precision metering device for wheat. *CIGR Journal*, 14(1): 16-25.
- Yong, R. N. 1982. Track/grouser-soil interaction studies. *Technical report to the Defence Res. Establishment*, Suffield: 125. Vehicle mobility laboratory, McGill Univ., Montreal.