DEVELOPMENT AND PERFORMANCE EVALUATION OF A SINGLE-ROW MANUALLY OPERATED GRAIN PLANTER

SANI, A., MOHAMMED, U.S., SALEH, A.* AND YUNUSA, S.U.
Department of Agricultural and Bio-Resources Engineering
Ahmadu Bello University, Zaria

ABSTRACT

Increase in demand for functional and affordable planters due to inability of the Nigerian peasant farmers to purchase imported planters necessitated the development and performance evaluation of a locally developed single-row manually operated planter that could contribute in addressing the challenges encountered in grain planting. The developed planter consists of hopper, seed metering device, delivery tube, furrow opener, covering device, press wheel, frame, handle and traction wheel. The planter was evaluated both in the laboratory and the field using maize as test crop in the Department of Agricultural and Bio-Resources Engineering, Ahmadu Bello University, Zaria-Nigeria. Parameters determined while evaluating the planter were planting speed, seedling emergence, plant-to-plant spacing, effective field capacity, germination count, planting efficiency, seed delivery rate, number of seeds per hole and percent seed damage. A combination of three planting speeds; 2, 1.1 and 0.8m/s and three different seed weight levels; 2.9, 2.2 and 1.1kg were used for the performance evaluation. Results obtained showed that seed delivery rate was 24.8kg/ha and effective field capacity was 0.12ha/ha. Similarly, the highest germination count of 83% was obtained at 0.8m/s planting speed and 2.9 kg seed weight. Optimum value of planting efficiency of 86.4% was obtained at 1.1m/s planting speed and 2.9kg seed weight. Plant to plant distance of 26.4cm was obtained at 2m/s planting speed and 2.2kg seed weight. One seed per hill was obtained at the all combinations. The developed planter has proved to be suitable for eliminating the limitations associated with manual planting methods and imported planters.

Keywords: Field Capacity, Grain Planter, Performance Evaluation, Planting Efficiency, Operating Speed
***Correspondence:** salehaminu@gmail.com +234803 577 4780

INTRODUCTION

To establish crops over a wide range of area in a desired position such that it saves cost and time, a planting machine that would be capable of opening a furrow, meter seed, deliver and place seed covers the seed and firmly compresses the soil on the seedbed is required [1]. Increase in crop yield, cropping reliability and crop returns depend on uniform and timely establishment of optimum plant populations [1]. This is subject to good planting operation.

Most Nigerian farmers still practice traditional manual planting methods which are tedious and time consuming, thus requiring several men – hours per day. This causes delay in planting operation which is detrimental to the crop yield. Timeliness in sowing helps in taking full advantage of the soil moisture [2]. Sultan and Gupta [3] reported that human labour is fast becoming more expensive every year in developing countries due to rural-urban drift. Manual method of seed planting results in low seed placement, poor spacing and causes serious back ache, thereby limiting the size of field to be planted [4].

About 95% of the Nigerian farmers have small land holdings, low crop yield and therefore live far below the standard of living. Seed planters available in the market are imported, specifically designed to operate on large farms. They are usually expensive, difficult to operate/maintain and often unsuitable for local conditions. Hence, the difficulty for peasant farmers to acquire such planters for profitable crop production. [5].

The objective of this paper is to develop and evaluate the performance of a single – row manually operated planter which will contribute in addressing the challenges being encountered by farmers in grain planting. The estimated cost of the planter was ₦21,000:00.

MATERIALS AND METHODS

Materials

The materials selected for constructing the planter were based on strength, availability, durability and cost effectiveness. These include: angle iron of 50 mm x 50 mm of mild steel, gauge 16 and 18 mild steel sheet metal cast iron, 25 mm diameter mild steel bar, 25 mm diameter bearing and 3 mm x 50 mm flat bar.

Description of the planter

The planter consists of the following components; frame, handle, traction wheel, hopper, seed plate with edge cells, furrow opener, delivery tube and bevel gears. The pictorial view of the planter is shown in Plate 1.

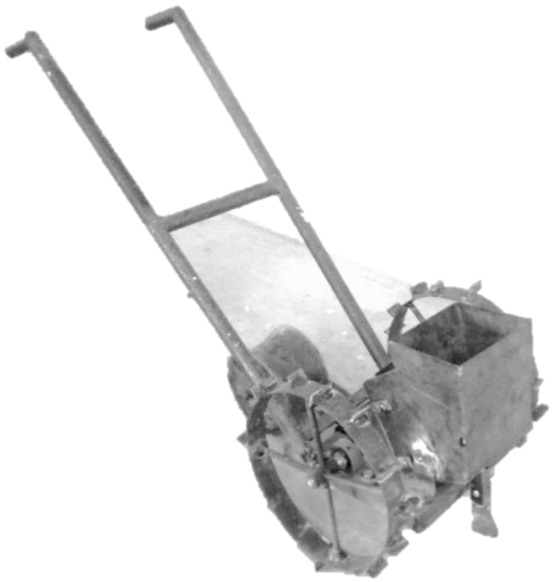


Plate 1: Pictorial view of the developed planter

Frame-The frame is the component on which all other components are attached. The frame is made of mild steel of 40x40 mm square pipe.

Handle-The handle is made of mild steel flat bar of round pipe with height of 85 cm, internal external diameter of 2.6 cm and 3.2 cm respectively.

Traction wheel-The traction wheel is made up of mild steel of 3 mm flat bar. It has a 350 mm diameter with six bars made from mild steel each welded on a hollow pipe placed at the center of the traction wheel. There are two wheels located at the sides of the frame.

Hopper-The hopper is made up of mild steel sheet metal of 1.5 mm thickness. It is trapezoidal in shape at the top but slanted at 45 degree, with height of 180 mm and length of 120 mm and bottom width is 160 mm, respectively.

Seed metering mechanism- The seed metering device is a major component of the planter. It picks the required number of seeds and delivers them into the soil through the delivery tube at a predetermined depth created by the furrow opener. The metering device is made up of cast steel material of 240 mm diameter and 4mm thickness with 5 edge cells.

Delivery Tube-The seed delivery tube is located below the metering compartment into which metering plate releases the seeds picked from the seed box/hopper and deposited into the opened furrow. The delivery tube is made of 15 mm diameter flexible rubber pipe of 100 mm length.

Furrow Opener- The furrow opener is a shoe- shape mild steel angle iron of 50 mm thickness and length of 300 mm.

Press Wheel - The press wheel is fixed at the back end of the planter. It is designed to cover the seeds and establish good seed-to-soil contact. It has a 150 mm diameter with a hole drilled in the rod that support it, and a cotter pin is placed on the front and back side of the wheel to hold it in place (Figure 1). When the furrow-opening operation is disengaged, the press wheel supports the weight of the planter and is being trailed behind the main frame.

Determination of design parameters

The following design parameters of the planter were determined

Number of cells - The numbers of the cells were determined using the expression given by [6]:

Number of cells = $\frac{\pi d_w}{s_c}$……………………………………… (1)

Where: d_w= diameter of the planter traction wheel = 350 mm

s_c= intra row spacing of the seed = 250 mm given by [6]:

π = 3.142

Therefore, the number of cells = 4.

Seed population - The seed population was determined using equation 2 reported by [7]

p_s =n$\left[\frac{A}{s_r s_c}\right]$………………………………(2)

where;
p_s = actual number of seed discharge
n = average number of seed discharge
A = area of the field, m
s_r= inter row spacing, m
s_c = intra row spacing, m
$n = 1,\ A = 45\ m \times 9\ m, s_r = 0.75\ m, s_c = 0.25\ m$

$$p_s = 2160\ seeds$$

Seed delivery rate R_s (kg/ha) - The seed delivery rate was determined from equation 3 given as reported by [8]

$R_s = \frac{Q_p}{A}$………………………………… (3)

where;
Q_p = Quantity of planted seed (kg)
A = Area of planted field (ha)
R_s= Seed delivery rate (kg/ha)
For maize
Q_P = 1.02kg, A= 0.041 ha
R_S = 24.8 kg/ha

Seed damage D_s (%) - The percent seed damage was determined from expression 4 as reported by [8]

$D_s = \frac{Q_d}{Q_p}$ x 100……………………………….. (4)
where:
Q_d= Quantity of damaged seed (kg)
Q_p = Quantity of planted seed per unit time (kg)
D_s = Seed damage (%)
The percent seed damage = 0%

Weight of the planter - The weight of the planter is the sum of the weights of the planter components:

$$W_o = W_h + W_{f+W_{pw}} + W_{sp} + W_H + W_{tw} + W_{dt} \quad (5)$$

where;
Wp = Total weight of the planter
W_h= Weight of the hopper (49 N)
Wf = Weight of the frame (24.7 N)
W_{pw}= Weight of the pressing wheel (38.1 N)
W_{sp} =Weight of the seed plate (1.2 N)
W_H= Weight of the handle (17.9 N)
W_{tw} = Weight of the traction wheel (1.2 N)
Wdt = Weight of delivery tube (0.2 N)
Wp = 49 + 24.7 + 38.1 + 1.2 + 17.9 + 1.2 = 132.3 N

Total torque– the total torque was determined from equations 6 and 7:

$$T = H_m \times r_w \quad (6)$$

$$H_m = C\,A + W tan\theta \quad (7)$$

where:
H_m= Maximum thrust kN
r_w= Radiusof the traction wheel (0.225 m^2)
C = Soil cohesion, 30^0 for clay sand [9]
W = Weight of the planter (0.52 kN/m^2)
θ = Soil frictional resistance, 13.5kPa for clay sand [9]

Therefore, H_m= 3.5 kN

Forces exerted on the shaft due to bevel gear drive - The force acting on the shaft due to bevel gear drive is calculated using the expressions given in equation 8 [10]:

$$F_l = F_t tan\theta \times cos\alpha \quad (8)$$

where;
F_L= Lateral force
F_t= tangential force = T/R
θ = pressure angle (22^0) [10]
α = bevel gear angle (45^0) [10]
T = total torque on the shaft (0.79 Nm)
R = pitch radius (0.015 m)

Shaft diameter - The shaft diameter was determined using the relationship given by [10] for shaft loading consisting of only torsion and bending

$$d^3 = \frac{16}{\pi\tau_s} \text{ x } \sqrt{[(K_b M_b)^2 + (K_t M_t)^2]} \ldots\ldots\ldots\ldots (9)$$

where; d = shaft diameter
K_b and Kt = combine shocks and fatigue factors applied to bending and torsional moment respectively
M_b and M_t = bending and torsional moment respectively (N/m^2)
τ_s= allowable stress of the steel shaft (N/m^2)

Allowable shear stress for shaft without keyways, τ_s= least value of 0.3 NM/m^2 yield strength and 0.18 NM/m^2 ultimate strength of the shaft material [10]. The least value multiply by 0.75 to account on a keyways. The material selected for the shaft is mild steel (C1040) with ultimate and yield strength of 770 and 580 MN/m^2 respectively.

0.3(580) = 174 MN/m^2
0.18(770) = 138.6 MN/m^2
The smaller value is 138.6 MN/m^2 and further reduced by 25% due to the presence of the keyway 0.25(138.6) = 34.65 NM/m^2
Allowable shear stress for the shaft, τ_s = 34.65MN/m^2

K_b = 1.5 to 2.0 and K_t= 1.0 to 1.5

$$d^3 = \frac{16}{\pi\tau_s} \times \sqrt{[(K_b M_b)^2 + (K_t M_t)^2]}$$

$$d^3 = \frac{16}{\pi\,x 34.56\,x\,10^6} \times \sqrt{}[(2\,x\,0.0062)^2 + (1.5\,x\,0.00079)^2]$$

d= 0.00130 m

Planter evaluation
The planter was evaluated both in the laboratory and the field.

Laboratory test
Laboratory testing was undertaken to determine and check functionality and defects in the design of the planter as suggested by [11]. During the test, the planter was suspended on a vice. As the wheel is turned, it rotates the metering device. For each trial, the drive wheels were rotated 10 times at low speed. A stop clock was used to record the time taken to complete the revolutions. The hopper was loaded with 400g of maize seeds while the number of seed discharged per outlet and number of damaged seeds, seed rate and seed spacing were noted and recorded. The seed discharged were weighed on a weighing balance and the procedure was repeated three times.

Field test

The planting of the seeds was conducted directly on a plot of 45x 9m area (405m^2) marked out on the field. The plot was prepared for planting. The planting operation was carried out using three different levels of speed (2 m/s, 1.1 m/s and 0.8 m/s) and three different seed weight (2.9 kg, 2.2kg and 1.1kg) in the hopper to determine and examine the distribution pattern i.e. the distribution of seeds along rows were examined to observe the number of seeds discharged and planted per stand and also observe the missing point along, seed spacing and percentage germinations i.e. the total number of germinated seeds was expressed against the total expected plant stand in each of the row to obtain the percentage germination. The plant population of $2160\ seeds$ was obtained.

Experimental design and analysis

A 3x3 factor factorial in a Randomized Complete Block Design (RCBD). Three levels of working speed (2 m/s, 1.1 m/s and 0.8 m/s) and three different seed weight (2.9 kg, 2.2 kg and 1.1 kg) were used. The experimental procedure was repeated three times and the average values of dependent variables were determined. However, the performance indication data were subjected to analysis of variance using Statistical Analysis Software (SAS). The effect of variation between the independent variables and their interaction were assessed at 5% and 1% levels of significant. Significant variables were further analyzed using Duncan Multiple Range Test (DMRT) to validate the results obtained.

RESULTS AND DISCUSSION

Results of laboratory evaluation

Table 1 shows the result obtained with regards to the percentage of seed damage. No seed damage was reported (i.e. 0% seed damage). This shows that the planter is mechanically efficient in the delivery of seeds to the soil without damage. Broken seeds reduce the number of seedlings emergence. The higher the number of damage seeds, the lower the plant population in a planted field. Therefore, the planter has the ability to maintain maximum plant emergence after population.

Table 1: Result of per count seed damage (maize)

Trial	Number of seed discharged for 20 revolutions	Number of seed damaged	Percentage damaged (%)
1	40	0	0.0
2	20	1	5.0
3	20	0	0.0
4	20	0	0.0
5	40	0	0.0
6	20	0	0.0
Average			0.8

Tables 2 and 3 show the result of tests conducted on seed metering device of the planter and the result of the ground wheel travel speed respectively. From the wheel travel speed and metering tests, it was found that the planter 1 seed per hole and has an average travel speed of 0.78 m/s, average plant to plant distance of 25.7 cm. These values are likely to be affected while working in the field as the conditions on the field are not the same as with the laboratory. The speed obtained is in agreement with the findings of [12] who reported that planters that are not tractor trailed have not been able to reach the 1 m/s operation speed on the field as reported by [12]. The number of seeds delivered per point agrees with design consideration. This may also be affected on the field since there could be a wide range variation in soil moisture content. It has earlier being reported that soil moisture tends to hinder the smooth movement of any equipment that depends of the soil for traction 13].

Table 2: Results of seed metering test on planter with maize as test crop

Trial	Plant to plant distance (cm)	Number of seed dropped
1	25	1
2	25	1
3	27	1
Average	**25.7**	**1**

Table 3: Result of ground wheel travel speed

Trial	Distance(m)	Time taken (secs)	Travel speed (m/s)
1	20	16	0.80
2	20	15	0.75
3	20	15	0.75
Average			0.76

Effects of interaction between planting speed and seed weight

Table 4 shows the effect of interaction between seed weight and planting speed on germination count of maize. Generally, there was a significant increase (P≤0.05) in germination count with varying planting speeds and seed weights. At 0.8 m/s planting speed varying the seed weight, there was a significant increase in germination count from 47 to 80%. This result shows that seed weight has influence on germination count of maize plant. However, at 1.1 m/s and 2.0 m/s planting speed there was a decrease from 1.1 kg (0.73 to 0.60) to 2.2 kg (0.67 to 0.60) seed weight in germination count with further increase from 2.2 kg to 2.9 kg seed weight respectively. The highest germination count of 83% was recorded at 0.8 m/s planting speed and 2.9 kg seed weight. This result shows that the planter performs better in terms of germination count when compare with the value of 53.86% obtained by [14]. While the lowest germination count of 47% was recorded from 0.8 m/s and 1.1 kg seed weight.

Table 4: Interaction between seed weight and planting speed on the performance on germination count using maize

	Seed Weight (kg)		
Treatments	**1.1**	**2.2**	**2.9**
Planting Speed (m/s)			
0.8	0.47c	0.73ab	0.83a
1.1	0.73ab	0.60bc	0.63abc
2.0	0.67abc	0.60bc	0.67abc
SE±		0.063	

Means followed by same letter(s) in the same column and row are not different statistically at *P=0.05* using DMRT

Interaction between the variables

The results for interaction between seed weight and planting speed on planting efficiency of the developed planter using maize seeds are presented in Table 5. Generally, there was a significant increase (P≤0.05) in planting efficiency with varying planting speeds and seed weights. At 0.8 m/s planting speed there was a significant increase (P≤0.05) in planting efficiency and this is because there is direct relationship between planting efficiency and germination count from 1.1 kg seed weight to 2.9 kg seed weights respectively. However, at 1.1 m/s and 2.0 m/s planting speed, there was an initial decrease in planting efficiency from 1.1 kg to 2.2 kg of seed weight which later increase from 2.2 kg to 2.9 kg of seed weight. The planting efficiency ranges from 47.7% to 85.0% (Table 5). This result is in conformity with the result obtained by [14], the overall efficiency of the planter was 71%.

Table 5: Interaction between seed weight and forward speed on the performance on planting efficiency using maize

	Seed Weight (kg)		
Treatments	**1.1**	**2.2**	**2.9**
Forward Speed (m/s)			
0.8	47.7c	75.0ab	85.0a
1.1	75.0ab	61.3bc	64.3abc
2.0	68.0abc	61.0bc	68.0abc
SE±		6.521	

Means followed by same letter(s) in the same column and row are not different statistically at *P=0.05* using DMRT

CONCLUSION

A one-row manually operated planter was designed, constructed and evaluated using maize as test crop. The highest germination count for the single-row manually operated planter of 83% was obtained at 0.8 m/s planting speed and at seed weight of 2.9 kg. Planting efficiency of 85% was obtained at 0.8m/s planting speed and 2.9kg seed weight indicating that the seed weight and speed of planting have significant effect on the seedling emergence. The average plant to plant distance was 25.7 cm while one seed per hill was obtained in all combinations of the variables. The developed planter has proved to be suitable for eliminating the limitation associated with manual planting methods and imported planters.

ACKNOWLEDGEMENT

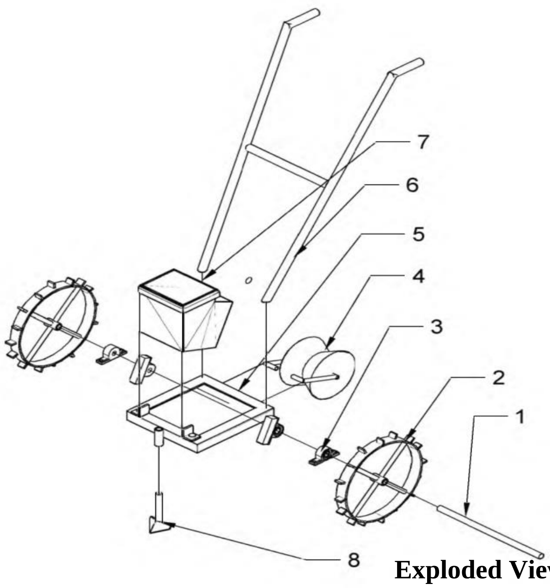
The authors are grateful to the staff of both Processing Laboratory and the Crop Protection Machinery Laboratory of the Department of Agricultural and Bio-resources Engineering, Ahmadu Bello University Zaria for their assistance during the research.

REFERENCES

1. MURRAY, J.R., TULLERG, J.N. & BASNET, B.B. (2006). Planters and their Components; Types, Attributes, Functional Requirements, Classification and Description. School of Agronomy and Horticulture, University of Queens land, Australia. P: 135-137.
2. ISIAKA, M., EL-OKENE, A.M.I. & MUHAMMAD U.S. (2001). Development of two-row Animal drawn seed planter. *Savannah Journal of Agricultural Mechanization*, **2**(1): Pp 2.
3. SULTAN, A. & GUPTA, C.P. (1994) *Agricultural Mechanization in Asia*, *Africa and Latin America*, **25**(2): 3.
4. KYADA, A.R. & PATEL, D.B. (2014). Design and Development of Manually Operated Seed Planter Machine. *5th International and 26th All India Manufacturing Technology*, Design and Research *Conference (AIMTDR)* Guwahati, Assam, India. Pp 591-597.
5. OLAYE, J.O. & BOLUFAWI, S.J. (2001) Design, Fabrication and Performance of a Multi-Purpose Row Planting Machine. *Journal of Sustainable Environment*, **3**(1): 7-20.
6. IBUKUN, B.I., AGIDI, G. & UGWUOKE, I.C. (2014). Design and Fabrication of a Single Row Maize Planter for Garden Use. *Journal of Advancement in Engineering and Technology*, **1**(2): 1-7.
7. SOYOYE, B.O., ADEMOSUN, O.C. & OLU-OJA, E.O. (2016). Manually Operated Vertical Seed – Plate Maize Planter. *Agricultural Engineering International: CIGR Journal*. **18**(14): 70-80.
8. DESHPANDE, S.D., BAL, S. & OJHA, T.P. (1993). Physical Properties of Soybeans, J. of Agric: Engineering Res 56: 89-98.
9. FOODS AND AGRICULTURAL ORGANIZATION (FAO) (1994). *Testing and Evaluation of Agricultural Machinery and Equipment*: *Principles and Practices*; FAO Agric. Services Bulleting 110: 150-169.
10. MUHAMMAD, G. (2010) Landslide Susceptibility Mapping to Inform Land Use Management Decision in an Altered Climate. Msc thesis submitted to the Department of Civil and Environmental Engineering, Washington State University. Pp 21.
11. KUMAR, K., NAARESH, N.K. & OJHA, T.P. (1986). Design, Construction and Performance of a Manually-Operated Seeding Attachment for an Animal Drawn Cultivator. *Agricultural Mechanization in Asia*, *African and Latin America*,, **17**(2): 35-38.
12. CHRISTIANSON, L.L. & ROHRBACH, R.P. (1986). Design in Agricultural Engineering. *Design in Agricultural Engineering*, (1). Pp 2.
13. BAMGBOYE, A.I. & JEKANYINFA, S.O. (2006). Energy Consumption Pattern in Palm Kernel Oil Processing; *Agric. Eng. Int.: CIGR e-journal* (3): pp10, www.goole.com/academic journals Retrieved August 2009.
14. UPAHI, E.J. (2017). Development and Performance Optimization of a Two – Row Engine Propelled Seed Ridge Planter; PhD Thesis submitted to the Department of Agric, and Bio-Resources Engineering, Ahmadu Bello University; Unpublished: 209 Pp.
15. ABUBAKAR, L.G. (1994). A Multiple Rotary Jab Planter for Sandy Loam Soils. An MSc. Thesis Submitted to the Department of Agricultural Engineering, Ahmadu Bello University, Zaria Unpublished: 168 Pp.

APPENDIX

Exploded View of the Planter



Part Table		
Item no.	Description	Material
1	Shaft	Steel
2	Drive wheel	Flat bar
3	Bearing	Cast iron
4	Press wheel	Steel
5	Frame	Angle iron
6	Handle	Round pipe
7	Seed compartment	Metal sheet
8	Furrow opener	Angle iron

Exploded View of the Planter

Estimated Cost of the Developed Planter

S/N	Material	Quantity	Unit Cost (#)	Total Cost (#)
1	Bevel Gears	1	10,000	10,000
2	204 Pillor Bearing	1	1,000	1,000
3	1.5’’ Angle Iron	1	2,000	2,000
4	2’’ Flat Bar	2	500	1,000
5	1’’ Round Pipe	1	1,000	1,000
6	204 Shaft	2ft	1,000	1,000
7	½’’ Rod	1	500	500
8	Bolt and Nut	5	20	1,000
9	Chain and Sprocket	1	2,000	2,000
10	Electrodes	½ pack	1,000	1,000
11	Cutting Disc	1	400	400
	Total			**#20,900**