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DEVELOPMENT OF A FOUR-ROW-ANIMAL-DRAWN PRECISION MAIZE PLANTER

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ABSTRACT
Crop planting is an indispensable farm operation to increase production through the proper facilitation of optimum plant population per area as well as reducing unnecessary competition among crops. The excessive inaccurate placement of seed at a required depth and intra - row distance, low field capacity and seed damage due to metering all envisage the need for a locally developed and cost effective multi-row animal drawn precision seed planter. This study focused on the design, fabrication and performance evaluation of a four row animal drawn maize seed planter. The fabrication was carried out at the Department of Agricultural and Bio-Resources Engineering Workshop, Ahmadu Bello University Zaria. The machine was evaluated in the experimental field of the department during the 2019 raining season. Three levels of planting speed ‘S’, three levels of hopper seed quantity ‘W’ and two levels of planting depth ‘D’ were assessed. The field experiment was designed in a 3×3×2 randomized complete block design (RCBD). The results showed that the effects of planting speed, seed quantity and planting depth were significant on the planting performance of the machine. The highest mean seed spacing, germination counts, field capacity and seed delivery rate of 23.50 cm, 88.5 %, 0.54 ha/hr and 20.7 kg/ha respectively were obtained. The developed planter has successfully eliminated the limitations associated with manual planting method, most locally developed planters, imported tractor drawn planters as well as increasing the field capacity of the planting operation.

Keywords: Animal Drawn, Field capacity, Planter, Planting, Seed delivery rate,

INTRODUCTION
Planting is one of the basic and most important operation in crop production. Improvement in the planting techniques could ensure adequate establishment of uniform crop stands and make subsequent operations easier and effective; and thus, increase yield (Gambari *et al.,* 2017). The objective of planting operation is to put the seed in rows at desired depth and intra-row spacing, cover the seeds with soil and provide proper compaction over the seed (Kyada and Patel, 2014).
Planters are fabricated as simple or multi-rows depending on the design and targeted power source. Planters may be powered by human effort, work animal, self-propelled engine and tractors power (Murray *et al*., 2006). Philip *et al*. (1988) reported that the use of animal technology for agricultural practices is potentially useful and an appropriate means of improving the efficiency of the traditional farming system. It would reduce labour requirement per unit area and allow an increase in the area under cultivation as well as helping to resolve bottleneck in weeding and reduce the drudgery of manual labour (Hailu, 1990).
The planting operation in Nigeria is still characterized by direct labour input resulting in high level of drudgery, non-uniformity of intra-row spacing and depth of plant, low rate of seed emergence, high energy expenditure in operation and losses due to seed scattering (Upahi, 2017). Most small and medium scale farmers in Nigeria still practice traditional manual planting methods which is tedious, time consuming, requiring several man – hour per day. This causes delay in planting operation which is detrimental to the yield of crop. The locally developed planters are challenged with the inability to effectively plant on both ridged and flat land, covering a wider area in one pass (Abubakar, 1994) and seed placement at required distance and depth. The tractor drawn planters is out of reach of financial capability of the peasant farmer (Isiaka, *et al.,* 2000) and lack of technical know – how to operate and maintain the equipment (Isiaka, *et al.,* 2001). Some of the modern equipment are generally not suitable nor economical for small plot sizes and often – fragmented farm land as obtains in our farming system (Mandal *et al*., 2013).
As local peasant farming is 90 % dominant of the country’s system of farming (FMARD, 2006), the desire for increase food production necessitates that the scale of production must be increased. This increase will be brought about by mechanical practices. Currently, Nigeria has abundant animal which could be adopted to power our implements in farming operation. Also, the increase in scale of production subsidizes the cost of using the locally made and imported tractor drawn planters. To address these challenges, there is need to develop a planter that will eliminate the limitations associated with manual planting method, locally developed planters (manual/tractor drawn type), imported tractor drawn planters as well as increasing the field capacity of the planting operation. The aim of this study is therefore, to develop four-row- animal-drawn precision maize planter using a pair of Bull in order to bridge the gap observed.

MATERIALS AND METHODS
The construction materials were selected based on strength, availability, durability, cost effectiveness, and suitability. These materials were 50 mm × 50 mm mild steel angle iron, gauge 16 and 18 mild steel sheet metal, 3 mm × 50 mm flat

bar, 25 mm round mild steel bar, 25 mm diameter bearing, Black Afara wood plank 40 mm in thickness and 193 mm in diameter. The instrument used for the determination of the design related seed properties and field evaluation were; 5 kg electric weighing balance, 100 mm Vernier caliper, stop watch, 100 m steel measuring tape, 300 mm plastic ruler, 300 mm long wooden peg.
The four-row-animal-drawn planter is being designed and developed in the fabrication workshop of the Department of Agricultural and Bio-Resources Engineering, Ahmadu Bello University Zaria. Its main components are: hopper, frame, metering mechanism, furrow opener, delivery tube, furrow coverer, traction wheel

Description of the planter

The planter comprised of the following components; hopper, frame, metering mechanism, furrow opener, delivery tube, furrow coverer, traction wheel and press wheel. The detailed description of the components of the planter are presented below:

Hopper

The hopper was made from a steel metal plate of gauge 16 (1.5 mm) forming a hollow frustum of a triangular prism with bottom base area of 60 mm × 40 mm and top area of 230 mm × 200 mm, the height is 250 mm. The hopper was designed with the consideration of the grain's angle of repose. It had a slant base which enable seeds flow through the outlet.

Frame

The frame is a component on which all other components are attached. The frame was made of 2 inch × 2 inch × 3 mm angle iron. The material of the main frame was selected based on weight, strength, reliability and availability of the material.

Metering mechanism

The metering mechanism was made of wooden disc of 193 mm diameter and 40 mm thickness. It had six equally spaced holes at the circumference of the plate, the disc was enclosed in a faced ring pipe of length 50 mm with internal and external diameter of 195 mm and 202 mm respectively. The holes (cells) pick only one seed when the disc rotates in a vertical plane at the bottom of the hopper. It is mounted on a horizontal shaft which is driven directly by the side traction wheel.

Furrow opener

The Furrow opener is made of 3 mm mild steel sheet with a length of 240 mm. The angle bar iron was fabricated to knife edge like structure to facilitate an easy cut through the soil and as well attached with a seed coverer made from sheet metal of same thickness which opened at an angle of 90˚. Threaded shaft is used to fasten the device to the frame through a hole drilled on the frame.

Delivery tube

This is a rubber syphon of 1-inch diameter and 200 mm length made from polyethylene through which the seeds metered is out and deposited into the furrow. The seed delivery tube is located below the metering casing into which the metering plate releases the seed after picking the seeds from the bottom of the hopper.

Connecting bar

This is a bar on which the four row planters are mounted and also adjustable for ridge spacing. The individual planter units were attached to the bar with a U-bolt through a connecting frame protruding out at an angle of 180^0. The connecting bar was constructed by welding two mild steel angle iron of 50 mm × 50 mm to form a hollow square pipe.

Traction Wheel

The wheel was made of a 3 mm × 50 mm mild steel flat bar cut and folded into a wheel of 477 mm diameter. Small pieces of ¾ flat bars were attached throughout the circumference of the wheel to provide lugs for effective traction.

Design Calculation

Hopper capacity

Hopper capacity was determine using equation 1 as suggested by Soyoye and Ademosun (2016).

$$H_c = \frac{TVH}{AVS} \quad (1)$$

Where: H_c = Total number of seed in the hopper
TVH = total volume of the hopper (0.00365 m^3)
AVS = average volume of seed (0.00000022 m^3)
H_c = Hopper Capacity (17232 seeds)

Therefore, at 90 % hopper capacity, a total of 15509 seeds was obtained. For the four planters, a total of 62036 seeds was computed.

Determination of number of cells

Provided the speed ratio between the traction wheel and the metering plate is one, the number of cells could be determined using the expression below given by Ibukun *et al*. (2014).

$$\text{Number of cells} = \frac{\pi d_w}{S_c} \quad (2)$$

Where: d_w = diameter of the planter ground wheel (477.4 mm)
S_c = intra row spacing of the seed (250 mm)
Therefore, the number of cells on the metering plate was 6 holes.

Weight of the Planter

The weight of single planter component acting on the wheel was determined as 12.38 kg. Considering four row planter, the net weight was determined as 65.60 kg.

Power Required to Push the Planter

The power required to push the wheel of the planter was determined as expressed below (Khurmi and Gupta 2005);

$$P = T \times w \quad (3)$$

Where; T = torque on the shaft (1196.862 Nm)
w = angular velocity (0.105 rad/sec)
P= power required to push the planter (125.67 W)

Determination of the shaft diameter

The shaft size was selected using the relationship given by Hall and Hallowenko (1982) as;

$$d^3 = \frac{16}{\pi \tau_s}\sqrt{(K_b M_b)^2 + (K_t M_t)^2} \quad (4)$$

Where: M_b and M_t = bending and torsional moment (0.0006 N/m^2 and 299.22 N/m^2)
K_b and K_t = combine shocks and fatigue factors applied to bending and torsional moment respectively (1.5 and 1.0)
τ_s = allowable stress of the steel shaft (103.95 N/m^2)

d = shaft diameter (0.0253 m)

Determination of seed population

The seed population was determined by using equation as reported by Soyoye *et al.* (2016)

$$Ps = n[\frac{A}{SrSc}] \quad (5)$$

Where: n = average number of seed discharge per hole (1 seed)

A = area of the field (2.255 m × 5 m)

S_r = inter row spacing (0.75 m)

S_c = intra row spacing (0.25 m)

P_s = actual seed population (20 seeds)

For the four rows, the total actual seed population of 80 seeds was determined.

Working principle of the planter

The machine consists of a circular vertical metering plate enclosed in a metallic case fixed below a hopper. The circumference of the plate is drilled at center with six equally spaced cells near and flushing with the circumference of the plate in such a way that each cell picks up single seeds at a time. In front of the plate is an attachment of the Furrow opener attached with covering device which opens the Furrow for the seeds and at the same time covers the seed. As the ground wheel rotates, the plate also rotates below the hopper and the seed is picked up by the cell of the plate and carried until it is drop by gravity into the seed discharge tube and finally fall into the opened Furrow. The covering device covers the opened furrow and then compacted by the pressing wheel after the seed deposition on the seed, and the process continues.

Plate I: Four-row-animal-drawn planter Plate II. Planting process

Performance evaluation of the machine

The performance evaluation of the planter was carried out on the field. The procedures prescribed by FAO (2000) on testing and evaluation of agricultural machinery and equipment was adopted. The parameters determined in the field tests include seed spacing, field capacity, Germination count and Seed delivery rate.

Seed delivery rate

The seed delivery rate was determined from the express given below

$$R_s = \frac{Q_p}{A} \quad (6)$$

Where: Q_p = Quantity of planted seed (kg)

A = Area of planted field (ha)

R_s = Seed delivery rate (kg/ha)

Effective field capacity

The Theoretical field capacity was determined from the equation

$$C_{eff} = \frac{SWe}{10} \quad (7)$$

Where: S = planter forward speed

W = planter effective width

e = field efficiency

***Germination count* C_g (%)**

The germination count was obtained from the expression given below

$$C_g = \frac{S_g}{S} \times 100 \quad (8)$$

Where: S_g = Germinated seed

S = Total seed planted

Experimental design

The experiment comprised of three levels of working speed (S_1 = 0.6, S_2 = 0.8 and S_3 = 1 m/s), three levels of seed quantity (W_1 = 25, W_2 = 50, W_3 = 100 %) and two levels of planting depth (D_1 = 1.5, D_2 = 2.5 m). The experiment was laid in a Randomized Complete Block Design (RCBD) with three replicates. Data obtained from the experiment was subjected to

Analysis of Variance (ANOVA). However, in the case of significant effect, the mean differences were assessed using Duncan Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Seed spacing

The result of the analysis of variance (ANOVA) showed that the effect of planting speed is highly significant on seed spacing while seed quantity and planting depth is not significant. The result of the Duncan Multiple Range Test (DMRT) to assess the effect of planting speed, seed quantity and planting depth on seed spacing is presented in Table 1. The result indicated that the mean seed spacing among planting speed 0.6, 0.8 and 1m/s were significantly different and were the same among the seed quantity of 25, 50 and 100 % full as well as between planting depth of 1.5 and 2.5 cm. The highest seed spacing of 23.5 cm was obtained at 0.8 m/s and least spacing of 22.82 cm at 0.6 m/s which shows nearly accurate seed spacing with moderate forward speed and irregular seed spacing with higher forward speed. This result agrees with the findings of Isiaka (2000) and Wondwosen (2021) having better seed planter performance at 0.8 m/s planting speed.

Table 1: Effect of planting speed, seed quantity and planting depth influence on seed spacing.

Mean Seed spacing (cm)		
Treatment	**Seed spacing**	**IAR Recommended spacing**
Planting speed (PS) (m/s)		
0.6	22.82b	25 cm
0.8	23.50a	
1.0	21.77c	
SE±	0.123	
Seed quantity (SQ) (%)		
25	22.64	
50	22.78	
100	22.66	
SE±	0.123	
Planting depth (PD) (cm)		
1.5	22.69	
2.5	22.69	
SE±	0.101	

Means followed by same letter(s) in the same column are not different significantly at *P=0.05* using DMRT. **= Significant at ($P \leq 0.01$)

Germination counts

The result of the Duncan Multiple Range Test (DMRT) to assess the effect of planting speed, seed quantity and planting depth on seed germination count is presented in Table 2. The mean seed germination counts among planting speed (0.6, 0.8 and 1 m/s) as well as planting depth (1.5 and 2.5 cm) were significantly different. The mean seed germination count was the same between the seed quantity of 25 and 50% but statistically different at 100 % seed quantity. The highest germination counts of 88.5, 82.8 and 83.4 was obtained at 0.6 m/s planting speed, 100% seed quantity and 1.5 cm planting depth respectively, and the least germination count of 74.8, 80.1 and 79.1 at 1 m/s planting speed, 50% seed quantity and 2.5 cm planting depth respectively. Evidently, this result showed good plant population at a low speed, high hopper seed quantity and shallow furrow opening of the soil.

Table 2: Effect of planting speed, seed quantity and planting depth influence on germination count

Mean Germination count (%)		
Treatment	**Germination count**	**IAR Recommended**
Planting speed (PS) (m/s)		
0.6	88.5a	100 % (53333 seeds/ha)
0.8	80.9b	
1.0	74.8c	
SE±	0.518	
Seed quantity (SQ) (%)		
25	80.9b	
50	80.1b	
100	82.8a	
SE±	0.518	
Planting depth (PD) (cm)		
1.5	83.4a	
2.5	79.1b	
SE±	0.423	

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

Field capacity

The result shows that the effect of planting speed, seed quantity and planting depth are highly significant on field capacity. The result of the Duncan Multiple Range Test (DMRT) to assess the effect of planting speed, seed quantity and planting depth on field capacity were presented in Table 3. The result showed that the mean field capacity was significantly different among the planting speed, seed quantity and planting depth. The highest mean field capacity of 0.54, 0.48 and 0.47 ha/hr at 1 m/s, 50 % and 2.5 cm respectively, were recorded and the least mean field capacity of 0.34, 0.41 and 0.44 ha/hr at 0.6 m/s, 100 % and 1.5 cm respectively were obtained. This conform with the field capacity obtained by Oduma *et al* (2014) and Upahi (2017) having 0.26 ha/hr with planting depth of 2.22 cm and 0.22 ha/hr and planting speed of 0.55 m/s respectively. The high mean field capacity was as a result of larger width of operation (i.e. four row).

Table 3: Effect of planting speed, seed quantity and planting depth on field capacity.

Mean Field capacity(ha/hr)	
Treatment	**Field capacity**
Planting speed (PS) (m/s)	
0.6	0.34c
0.8	0.47b
1.0	0.54a
SE±	0.004
Seed quantity (SQ) (%)	
25	0.46b
50	0.48a
100	0.41c
SE±	0.004
Planting depth (PD) (cm)	
1.5	0.44b
2.5	0.47a
SE±	0.003

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

Seed delivery rate

The result shows that the effect of planting speed, seed quantity and planting depth are highly significant on seed delivery rate. The result of the Duncan Multiple Range Test (DMRT) to assess the effect of planting speed, seed quantity and planting depth on seed delivery rate is presented in Table 4. The mean seed delivery rate among the planting speed 0.6, 0.8 and 1 m/s were statistically different, and significantly the same between the seed quantity of 25 and 50% but different at 100 % seed quantity as well as between planting depth of 1.5 and 2.5 cm. The highest mean seed delivery rate of 20.7, 19.4 and 19.5 kg/ha were obtained at 0.6 m/s planting speed, 100% seed quantity and 1.5 cm planting depth and the least seed rate of 17.5, 18.8 and 18.5 kg/hr at 1 m/s, 50% and 2.5 cm respectively were recorded. This conform with the result obtained by Upahi (2017) with average seed delivery rate of 19.8 kg/ha at planting speed of 0.55 m/s.

Table 4: Effect of planting speed, seed quantity and planting depth influence on seed delivery rate

Seed rate(Kgha^{-1})		
Treatment	**Seed delivery rate**	**IAR Recommended**
Planting speed (PS) (m/s)		
0.6	20.7a	20 kg/ha
0.8	18.9b	
1.0	17.5c	
SE±	0.137	
Seed quantity (SQ) (%)		
25	18.9b	
50	18.8b	
100	19.4a	
SE±	0.137	
Planting depth (PD) (cm)		
1.5	19.5a	
2.5	18.5b	
SE±	0.112	

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

CONCLUSION

The development and performance evaluation of the four-row animal drawn precision seed planter was done in the Department of Agricultural and Bio-resources Engineering, Ahmadu Bello University, Zaria. The selected planting speed (0.6, 0.8 and 1 m/s), hopper seed quantity (25, 50 and 100 %) and planting depth (1.5 and 2.5 cm) influenced the field performance of machine. The seed spacing was influenced by planting speed but not affected by seed hopper quantity and planting depth. The best spacing was achieved at moderate planting speed. Germination count, Field capacity and Seed delivery rates were also affected by planting speed, seed hopper quantity and planting depth. Better germination was achieved with decreasing planting speed and planting depth as well as increasing seed hopper quantity. Field capacity increases with increase in planting speed, planting depth and moderate seed quantity. Lastly, the performance of the planter on seed delivery rate was increased with decreasing planting speed, planting depth and increasing seed hopper quantity. It is therefore concluded that planting at 0.6 and 0.8 m/s, with 50 and 100 % seed hopper full and 2.5 cm planting depth result in maximum planting performance.

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