Development and Performance Evaluation of a Manually Operated Two-Row Maize Planter

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Abstract- A two-row maize planter was designed, fabricated and evaluated for its performances.
The forward speeds of operation used in the evaluation were: 2.2 km/hr, 1.6 km/hr and 1.3 km/hr. The average draft of the planter was 500.31 N. The measurements of the performance of the two-row maize planter are: The theoretical field capacity, effective field capacity, field efficiency, planting efficiency and labour requirement. The theoretical field capacity was 0.198 ha/hr, 0.144 ha/hr and 0.117ha/hr, the effective field capacity was: 0.180ha/hr, 0.131 ha/hr and 0.166ha/hr: the planting efficiency were: 71 %, 82 % and 76 %: and the labour requirement were: 1man-0.152 hr/ha, 1man-0.164 hr/ha and 1man-0.852 hr/ha, for the speed of 2.2 km/hr, 1.6 km/hr and 1.3 km/hr respectively. The field efficiency of 91 % was constant for the speed.

Keywords: effective field capacity, field efficiency, planter efficiency, labor requirement, speed of operation, two- row maize planter.

1. Introduction

Maize; (*zea may* L.) is the most important cereal crop produced in Nigeria. It is also the most widely consumed staple food in Nigeria. The production of maize in Nigeria has been increasing since 1965 {FAO Statistical Databases; 2008; morries *et al* 1999}. In Nigeria, maize is produced predominantly by small holder resource poor farmer under rainfed conditions. The crop is planted mainly manually, using hoes, cutlasses or dibblers depending on local tradition (Adjei *et al*., 2003; Tweneboah; 2000) resulting in high labour requirements drudgery. Because of the seasonality of rainfed farming, maize farming is often late resulting in considerable losses in crop yield.

Planting is one of the major labour demanding operations in the production of grains (maize, millet, sorghum e.t.c.) and pulses (cowpea, groundnut, soya bean, e.t.c.). Traditionally, it is done with the use of various devices such as sticks, hoes and cutlasses. Hand and heel of the foot are equally used. In a large field; most of the planting work is done by women and children, some of who are inexperienced in proper placement and covering of the seeds using that device. Also, this method of planting suffers from low output per man-hour and fatigue, due to the bending posture which has to be assumed for efficient operation (Isiaka *et al.,* 2000).

There are many manual and animal drawn planting equipment in existence. However, the manual planters have low work rate apart from tremendous effort that is required to operate them in the field. In the case of animal drawn planters, they are mostly single row with equally low work rate. Also, they are complex, costly, lack spare parts and under-utilized the power of the draught animal. In large mechanized farms, the use of tractors drawn planters are already in existence, but this method of planting is above the reach of financial capacity of the peasant farmers that constituted 90 percent of the farming population in Nigeria (Nwuba, 1986).

Improvement in the planting techniques can ensure adequate establishment of uniform crop stands and make subsequent operations more effective and thus increase yield. Variable climatic condition in many area of the West Africa Savannah regions cause available water to be a limiting factor

and thus make timely planting an important operation. The slow traditional hand planting method limits the area that a farmer can plant at the optimum time. In addition, the traditional method is physically demanding: most farmers retire home after a day's planting with serious back pains. (Choudhury,1985).

However, the replacement of the primitive tools used for planting namely; stick, cutlass, hoes, e.t.c., with a simple mechanical device to boosting the productivity of small scale farmers as limited effort would be required to accomplish planting within a specified period of time. The introduction of a mechanical planting device will eliminate the problems associated with planting; such as reduction in drudgery, time, energy consumption, and pains due to constant bending posture (Yusuf and Gbadamosi, 2010).

2.0   Description of the Machine

The two-row planter consists of a mainframe, ground driving wheels, seed hopper, furrow opener, covering device, handle, chain device, sprocket and delivery passage. The metering device which is rotor type made of wood, meters the seed. Different types of rotors are used to sow different crops by changing it. Figure 1 below shows the assembled two-row maize planter while figure 2 below shows the machine components as labeled in the pictorial display of the two-row maize planter.
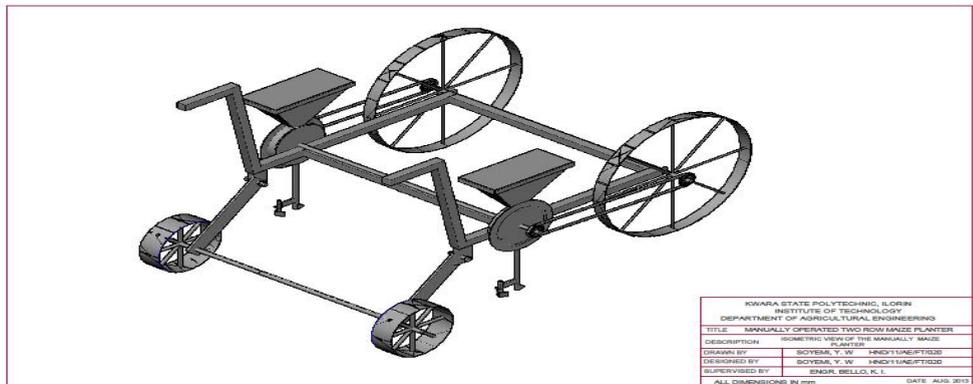
Figure 1, The two row maize planter.
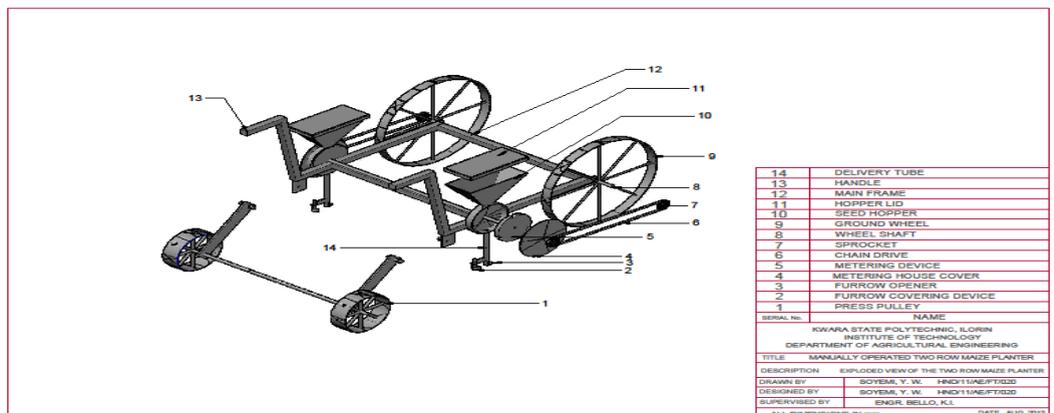
Figure 2, Exploded view of the two row planter.

2.1   Design Consideration

The basic design consideration is developing the two-row maize planter were power requirement, types of crops, seed of operation, and size of operation, size of the farm and selection of materials. Power Requirement; It requires human power and one operator is considered for its operation. Type of Crops; It is meant to sow maize at average plant spacing of 600 mm. Speed of Operation; this considered steel slow pace movement of the operation.

Size of the farm; It is designed for small scale farming of between 0.1 ha to 10 ha of land.

Selection of Materials; This considered the strength, rigidity, lightness and availability of the materials.

3.0   Methodology

3.1   Design Calculations

The component parts of the two-row maize planter were designed based on specification obtained during design calculation of the machine.

3.2   Depth of Sowing

This is based on the type of seed. Sowing depth for maize is 20 – 40 mm, that of cotton is 10-30 mm, and for groundnut 40-50 mm (Yusuf and Gbadamosi, 2010).

3.3   Determination of Planter's Driving Wheel

Diameter of the ground wheel; This was calculated by using the expression below

$$V = \frac{\pi D_w N \text{ m/sec}}{60}, \qquad D_w = \frac{V \times 60}{\pi N} \tag{1}$$

$$= 3.7 \text{ km/h (Afzal, 1992)}, \quad \text{i.e} \quad \frac{3.7 \times 1000}{60 \times 60} = \frac{3700}{36} = 1.02 \approx 1.0 m/s$$

Where: V = speed of Operation(m/s)

 N = Numbers of revolution per min by the ground wheel, i.e speed of the ground wheel   which is 32.0 rpm (NCAM, 1997)

D_w =   Diameter of the ground wheel;

$$D_w = \frac{1.0 \text{ m/s} \times 60}{3.142 \times 32.0} = \frac{60}{100.53} = 0.5968m = 0.5968 \times 1000 = 596.8mm$$
(2)

Approximated to the reasonable dimension, i.e 600 mm for the ground wheel diameter as labeled in figure 2 above.

Circumference of the ground wheel; Circumference of a circle = πd

 Forward travel = πdw

 Forward travel   = 3.142 x 600   = 1885.2 mm

3.4   Determination of the Numbers of Seed cell on the Metering Device

The seed cells were machined to specification as regard the number of seed required for planting for a particular crop. To determine the number of seed cell on the metering device, the diameter of the ground   wheel must be known, since it is the determinant of the metering device revolution. The standard plant spacing is determined. Dw = 600 mm as calculated, S = 600 mm plant spacing (Yusuf and Gbadamosi, 2010) and N = Number of seed cell on the metering device.

$$\text{Therefore} = N\frac{\pi D_w}{S}; = \frac{3.142 \times 600}{600} = 3.1423 \text{ seed cells}$$

(3)

Hence the number of the seed cell that was designed on metering device for the planter was   3.

3.5   Determination of the Diameter of the Metering Device

Considering the availability of the materials used in construction of the metering device. This has provided 3 holes or seed cells on it with 300 mm spacing due to the small size of the metering device which result to the approximately half of the standard spacing of planting maize, which is 600 mm, (Yusuf and Gbadamosi, 2010). Hence,

Circumference of the metering device = πd_m;   (4)

C_{md} = 3 cells x 600 = 1800mm, d_m = , d_m = 572.88 mm (for standard)

πd_m = 3 x 300 (for half of the plant spacing), πd_m = 900, d_m = , = 286.44 mm

Therefore, the diameter of the constructed metering device (C_{md}) is 286 mm.

3.6   Determination of the Dimension of Seed on the Metering Device

The maximum height of the seed must be known so as to design the seed cells with the dimension which is greater than the maximum height of the seed. The dimension of ten samples of maize as analyzed by (Oyewumi, 2010).

Therefore, the planter was designed with the seed cell on the metering device of 16.5 mm depth as the average height of seed.

3.7   Principle of Operation

The pushing force applied via the handle sets the ground wheel into motion which through the transmission shaft transfers rotary motion to the metering device shaft through a gear arrangement with chain device to the both shaft (i.e. ground driving wheel shaft and metering device shaft). As the ground driving wheel rotates which in turn derives or rotates the metering device enables seed in the hopper to pass through the funnel to the soil and drop to the soil via the delivery tubes as the furrow opener opens up the soil. The covering device covers the seeds with soil as planter is pushed along, and lastly, the wheel press/firm the soil around the seeds to the proper degree for the particular crop involved.

3.8   Sample Preparation

Field tests were conducted at Kwara State Polytechnic on an 81 meter-square   selected area plot of land. The minimum tillage operation was done on the land in order to evaluate the performance of the two row-maize planter. The planter was tested using one operator.

3.9   Experimental Design and Layout

A portion of land 9m by 9m was then divided into three runs of 5 meter each. The planter was run three times at three replications per run for each selected speed. The number of seed drop was recorded for each replication. The time taken to cover 9 m run was varied over 15 seconds, 20 seconds and 25 seconds for the runs. To determine the actual speed for each time, the distance of each run was divided by each time in seconds, resulting to speeds of 0.6 m/s 0.45 m/s and 0.36 m/s. the speeds were then converted to km/hr giving 2.2 km/hr, 1.6 km/hr and 1.3 km/hr.

3.10   Output Parameter

The following measurements were taken which include**;** Seed spacing = 600 mm, Weight of the machine = 45 kg**,** Width of the machine = 900 m, Seed rate (seed/ha)   =23,333.3 seeds/ha, = 36 kg/ha**,** Number of seed drop per 81 m^3 = 66 = 189 seeds. Expected number of seed per 81 m^3 = 243 seeds**,** Labour requirement (hours/ha) = man – 0.152 hr/ha, man – 0.169 hr/ha and 0.852 hr/ha.

The following performance parameters are to be determined from the field test results.

i. Planting efficiency %, ii. Theoretical field capacity (C_T) ha/hr, iii. Effective field capacity (C_E) ha/hr, iv. Field efficiency (η) %, v. The draft of the machine N.

Table 1, shows the details of the seed droppings at each selected speeds of operation. Number of seed drop per 9 m length run = 63 seeds, 189 seeds weigh with scale=0.09 kg

Number of seed drop at 81 m^3 of three trials run =63x3 runs=189 seeds

Average trial speed of the two-row maize planter. = .

Expected number of speed per 9 length = Number of seed drop per cell x number of seed   cell" x"
distance covered = 3 x 3 x 9 = 81 seed

Expected number of speed at $81m^2$ = 81 seeds x 3 runs = 243 seeds, and Seeds Weight = 0.12 kg
Seed rate is computed from the analysis below
Since 10,000 m^2 = 1 ha, 81 m^2 =
Seed rate =, Seed rate = 400 x 0.09 kg = 36 kg/ha.

Table 1, Seed dropping at selected speeds of the planter.

Runs	Distance (cm)	Speed of operation 2.2 km/hr at timing of 15 secs			Average of 3 replication	Speed of operation 1.6 km/hr at timing of 20 secs			Average of 3 replication	Speed of operation 1.3 km/hr at timing of 25 secs			Average of 3 replication
		1	**2**	**3**		**1**	**2**	**3**		**1**	**2**	**3**	
1	9	56	54	58	56	68	74	68	70	65	59	63	62
2	9	50	61	50	54	50	59	62	59	74	52	70	65
3	9	45	67	61	58	51	76	70	70	58	54	67	60
Average					**50.0**				**66.3**				**62.3**

4.0 Analysis of Test Result
(i)   Planting Efficiency =
(5)

The two-row maize manually operated planter was test run at various speeds and correspondent planting efficiency was deduced as shown in table 2 below.

Table 2, Computed planting efficiency (%) at selected speeds of the two-row maize planter.

Planting speeds (km/hr)	2.2	1.6	1.3
	$\frac{56.7}{81} \times 100\%$	$\frac{66.3 \times 100\%}{81}$	$\frac{62.3 \times 100\%}{81}$
Planting efficiency (%)	= 70.5	= 81.8	= 76.9

(ii)   Theoretical Field (C_T),
$$= \frac{\text{Width of the machine (m) x forward speed (km/hr)}}{10,000},$$

(6) $C_T = \frac{W(m) \times S (km/hr) \times 1000 (ha/hr)}{10,000}$; $C_T = \frac{W \times S \, ha/hr}{10}$ (kepner *et al,* 1978).

The table 3 gives the computed theoretical field capacity of the two-row maize planter at selected speed of 2.2km/hr, 1.6km/hr, 1.3km/hr with a corresponding values of theoretical field capacities at each forward speed of operation.

Table 3, Computed theoretical filed capacity result for each planting speed of the planter.

Planting speed (km/hr)	2.2	1.6	1.3
	$\frac{0.9 \times 2.2}{10}$	$\frac{0.9 \times 1.6}{10}$	$\frac{0.9 \times 1.3}{10}$
Theoretical field capacity	0.198ha/hr	0.144ha/hr	0.117ha/hr

(iii). Effective Field Capacity (C_E)

$$C_E = C_r \times \eta;$$

(7)

t_o = Theoretical time per hectare, $= , \quad 1/c_T, \quad = \frac{t_o \times 100}{k}$

(8)

k= % width of the machine that is actually used. And since the full width of the machine was used then $t_o = t_e$ (Kepner, *et al*, 1978).

t_a = time lost per hectare that is proportional to the area such as turning at ends, loading etc. Assume 10 % of 't_o'. As shown in Table 4.

Table 4, Computed effective operation time; t_o (hr/ha) for each planting Speed of the Planter.

Planting speed (km/hr)	2.2km/hr	1.6km/hr	1.3km/hr
	$\frac{1}{0.198}$	$\frac{1}{0.144}$	$\frac{1}{0.117}$
Theoretical field capacity(%)	5.05ha/hr	6.44ha.hr	8.55ha/hr

owing that for t_m = time lost per hectare that is not proportional to the area , $t_m = 0$.

Table 5 shows the computed t_a $_{values}$ at different selected speeds of 2.2km/hr,1.6km/hr, and 1.3 km/hr with equivalent values of t_a as obtained respectively in the table below.

Table 5, Computed t_a (hr/ha) for each planting forward speed.

Planting speed (km/hr)	2.2 km/hr	1.6 km/hr	1.3 km/hr
	$\frac{10 \times 5.05}{100}$	$\frac{10 \times 6.94}{100}$	$\frac{10 \times 8.555}{100}$
t_a values (hr/ha)	0.51 hr/ha	0.70 hr.ha	0.86 hr/ha

Assuming there is no time lost; Therefore, $\eta = \frac{t_o}{t_e + t_a + t_m} \times 100\%$.

(9)

Table 6 and 7 shows the computed field efficiency and effective field capacity for each planting speed respectively. More so table 8 presents the summary of planting and field efficiencies at each planting forward speed of operation of the planter. While table 10 gives the cumulative result of field trials at planting speed of the two-row maize planter.

Table 6, Computed field efficiency (%) for each planting forward speeds.

Planting speed (km/hr)	2.2	1.6	1.3
	$\frac{5.05}{5.05+0.51+0} \times 100\%$	$\frac{6.94}{6.94+0.70+0} \times 100\%$	$\frac{8.55}{8.55+0.86+0} \times 100\%$
Field efficiency (%)	$\frac{5.05}{5.55} \times 100\%$	$\frac{6.94}{7.64} \times 100\%$	$\frac{8.55}{9.41} \times 100\%$

Hence $C_E = C_T$ x .

Table 7, Computed effective filed capacity C_E(hr/ha) for each planting speed.

Planting speed (km/hr)	2.2	1.6	1.3
	$\frac{0.198 \times 91}{100}$	$\frac{0.144 \times 91}{100}$	$\frac{0.177 \times 91}{100}$
C_E (hr/ha) values	0.180ha/hr	0.131ha/hr	0.106ha/hr

Table 8, The summary of planting and field efficiencies at each planting forward speed of the planter.

Planting speed (km/hr)	2.2	1.6	1.3
Planting efficiency, η (%)	71	82	77
Field efficiency, η (%)	91	91	91

(iv) The Draft of the Machine

Since draft is the horizontal components of pull, it is given as

$$Draft\ (Force) = \frac{Power}{Velocity}(N)(Kepner,\ et\ al, 1974) \tag{10}$$

$$Where, Power = \frac{Workdone}{Time\ Taken}(Okeke, 1990) \tag{11}$$

$$= \frac{Force \times Distance\ (w)}{Time\ Taken} \tag{!2}$$

And force = mass x acceleration (N), Draft (force) = (mass of the machine + mass of seeds) acceleration

Average time taken in sec = $\frac{15+20+25}{3} = \frac{60}{3} = 20\ secs$. Average time in hour $= = \frac{20}{60 \times 60} = 0.0056\ hr$

Draft (force) = (45kg + 6kg) x 9.81, then the Draft force = 51kg x 9.81 = 500.31 N

(v) Labour Requirement (hours/ha) $= \frac{Total\ time\ (hr)\ x\ 10,000m^2}{25\,m^2\ (selected\ area)}$ (13)

The analysis of the labour requirement at each speed is show in table 9 while table 10 shows the summary of results of the field trials.

Table: 9, The analysis of the labour requirement at each speed of the two row planter.

Planting speeds (km/hr)	2.2	1.6	1.3
	$\dfrac{0.009km}{2.2\ km/hr}$	$\dfrac{0.009km}{1.6\ km/hr}$	$\dfrac{0.009km}{1.3\ km/hr}$
	0.0041 hr	0.0056 hr	0.0069 hr
Labour requirement(hr/ha)	$\dfrac{1ha \times 0.0041}{0.0081\ ha}$	$\dfrac{1ha \times 0.0056}{0.0081\ ha}$	$\dfrac{1ha \times 0.0069}{0.0081\ ha}$

Table 10, Summary of result of field trials at planting speed of the two-row planter.

Planting speed (km/hr)	2.2	1.6	1.3
Planting Efficiency (%)	71	82	76
Theoretical Field Capacity (ha/hr)	0.198	0.198	0.117
Effecting field Capacity (ha/hr)	0.180	0.131	0.106
Field Efficiency (%)	91	91	91
Working Width (mm)	900	900	900
Weight of the machine (kg)	45	45	45
Weight of the materials involved (kg)	6	6	6
Planter Drive Force	500.31	500.31	500.31
Labour Requirement (man-hr/ha)	0.152	0.169	0.852

The figure 3, below gives the relationship between planting/field efficiency and the selected forward speeds of operation with shows that at time lost which is proportional to the area the graph reaches its maximum performance before retarding after efficient performance initially, like at speed of 2.2km/hr the maximum effective planting /field efficiency is maintain at approximately 91%.
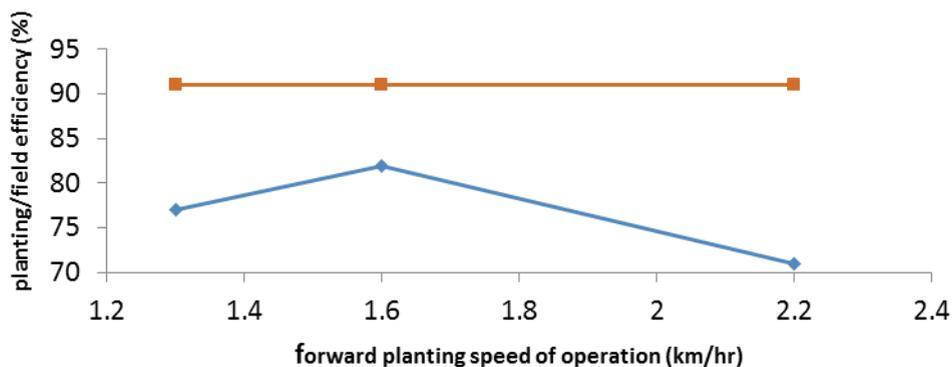
Figure: 4.1 Relationship between planting/field efficiency and forward field of operation

— at lost proportional to area   — at lost not proportional to area

Figure 3. Relationship between planting/field efficiency and forward field of operation

5.0 Conclusion

From the information and design values obtained in this study; it has be found that the designed two-row maize planter after its efficient performance test gives a remarkable and improved precision planting of maize on rows per stand at low seed loss. It reduces human labour input on the field and it performed effectively with an improved planting efficiency of 70.5% at 2.2 km/hr speed of operation.

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