DESIGN MODIFICATION, FABRICATION AND TESTING OF FOUR ROW TRACTOR DRAWN MULTI-SEED PLANTER WITH FERTILIZER APPLICATOR

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ABSTRACT
The problem of planting is a major challenge for farmers all over the world for a long time. This has led to demand from various farmer groups and societies through the various states ADPs for an improved, effective and faster means of carrying out the planting operation since the imported planter are majorly beyond the purchasing power of an average farmer in Nigeria. In response to the demands NCAM developed a tractor drawn multi-seed planter with aim of solving the problem and encouraging farmers to increase their production scale. The planter was designed for planting seed crops namely maize; beans and guinea corn and the crops were used to test the three available seed plates for the machine. The field test was carried out gave a seed metering efficiency of 85%, field efficiency of 75.68%,effective field capacity of 0.7675 ha/h, at an average planting depth of 2.53cm, and an average spacing of 48 cm intra row. The result showed that NCAM developed multi-seed planter performed satisfactorily when subjected to field operation and can as well reduce drudgery faced by Nigerian farmers during planting operation.

Keywords: *planting, tractor drawn, seed planter, developed, testing*

1. INTRODUCTION
Grains are small, hard, dry seeds, with or without hulls/covering. There are two classes of grain producing crops namely cereal and legume crops. Examples of cereal crops are wheat, rice, maize etc. and legume crops are soybeans, cowpea, groundnut etc. After harvesting, dry grains are more durable than other staple foods like plantain, breadfruit and tubers like yam, arish potatoes and cassava. Grains are vital food component of humans and animals. Eating grains, especially whole grains, provides health benefits and also gives strength. It is a well-known fact that people who eat grains as part of healthy diet have reduced risk of some chronic diseases. Grains are used in producing most animal feeds so the importance and awareness continues to increase. Khan *et al*. (2015) reported that it is necessary that more grains be produced and this can only be achieved through some level of mechanization of which planting activity is a very important process which needs mechanization.

Maize also referred to as corn is a popular staple food in Nigeria as well as an important raw material for industries. It is processed in different forms as livestock feed. Maize is an important source of carbohydrate, protein, iron, vitamin B, and minerals. Nigerians and other Africans consume maize as starch base in a wide variety such as porridges, pastes, grits, and beer.

The first activity in crop farming after land preparation is planting. The importance of this operation cannot be over emphasized. A seed planter is a sowing device that sows seed in rows with high precision and accuracy. This implement carries out an important operation that determines the successful germination of planting process.

The planter ensures precise positioning of seeds in the soil, to a large extent not more than two seeds per hole/stand and their adequate covering with soil. Specific features that need to be well addressed in planting are, distance between plant stands, distance between rows, depth of planting and covering of the planted seeds with soil. Before the invention of seed planters, planting was done by hand (manually), this was time consuming, wasteful, tedious and made planting without precision. According to Bamgboye and Mofolasayo (2006), the traditional planting method is tedious, causing fatigue and backache due to the longer hours required for careful hand metering of seeds if crowding or bunching is to be avoided. Planting machines are normally required to increase production but they are beyond the buying capacity of small-scale farmers (Kalay *et al.,* 2015).

In Nigeria, various types of planters have been designed and developed at different levels to solve specific problems as they arise using different approaches. Aniekwe *et al*. (2014) reported that most of the existing planters in Nigeria are manually operated, whereas, tractor drawn planters are usually preferred in large farms. Olajide and Manuwa (2014) also designed, fabricated and tested a low-cost grain planter capable of planting three types of grains- maize, soybean and cowpea. The planter had an average field capacity of 0.36 ha/h and efficiency of 71% with a percentage seed damage of 2.58%, spacing of 50.2 cm and an average depth of 4.28.

However, in this research work, a tractor drawn multi-seed planter was developed and evaluated to overcome the challenges in seed planting faced by farmers and as well improve food security in Nigeria.

2. MATERIAL AND METHODS

2.1 Description of the Seed Planter

The four-row tractor drawn multi-seed planter comprises of seed hopper, metering mechanism, ground wheel made from mild steel, chains and sprocket, furrow opener and closer, handles and frame. Figs. 1 and 2 show the orthographic and exploded view of the planter.

i. Seed hopper - This component holds the seeds being planted.
ii. Metering device - This controls the efficient delivery of seeds during the planting operation, thus ensuring the right number of seeds are planted per stand and the spacing within rows is effectively maintained.
iii. Delivery chute/ pipe - This directs the seed from the metering device accurately into the marked soil.
iv. Furrow opener and closing devices – The furrow opener opens the soil at the point of planting and the closing device closes it after the seed has been delivered into the soil.
v. Ground wheel - This supports the whole assembly and controls the planting distance.
vi. Transmission Assembly - This operation connects the metering device with the ground wheel and control seed droppings. In doing its operation, the precision in number of seed per stand and distance from one stand to the other is uniform and standardized. The transmission is a manual process.

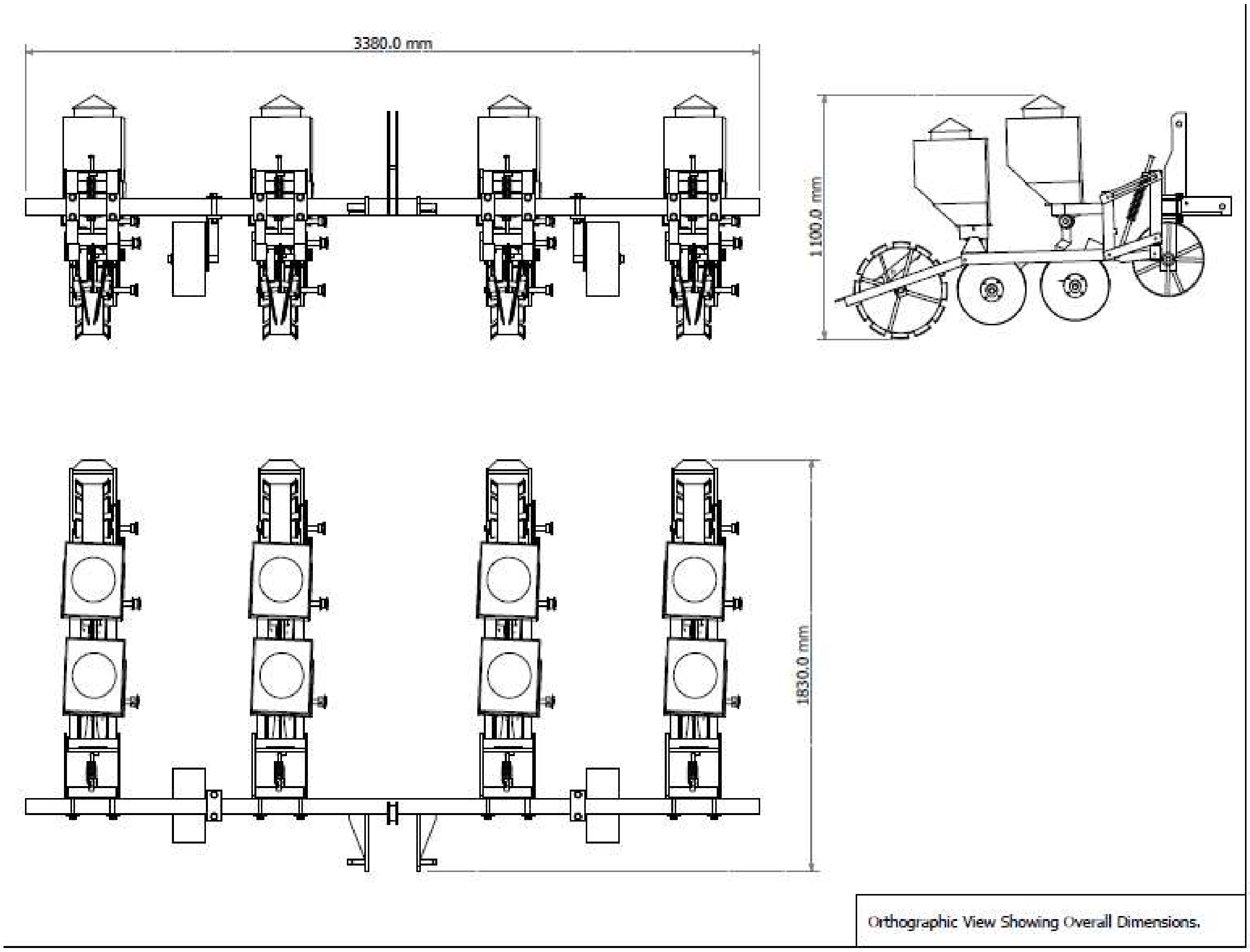

Fig. 1. Orthographic view of the Seed Planter

PARTS LIST			
ITEM	QTY	PART NUMBER	DESCRIPTION
1	1	Frame of Planter	
2	4	Angle Iron	
3	8	Flat Bar	
4	8	Flat Bar	
5	4	Frame	
6	4	Part3	
7	4	Frame 2	
8	4	Spring Shaft	
9	4	Fertilizer Metering Unit	
10	16	Plate 1	
11	16	Wheel 1	
12	4	Shaft 2	
13	4	Support	
14	8	Roller Chain Sprocket11	
15	8	Hopper Base	
16	8	Hopper	
17	4	Auger	
18	8	Part6	
19	4	Grain Metering Device	
20	4	Bevel Gear 1	
21	4	Bevel Gear2	
22	4	Rolling bearing 23	Rolling Angular ball bearings
23	4	Stopper 1	
24	4	Stopper 2	
25	4	Stopper 3	
26	4	Seed Meter	
27	4	Part1	
28	4	Wheel	
29	8	Hopper Cover	
30	4	Roller Chain Sprocket12	
31	8	Part3	
32	16	ISO 7089 - 140HV	Plain washers - Normal series
33	16	ISO 4014 - M18 x 100	Hexagon head bolt -
34	2	Part of Wheel	
35	2	Wheel 2	
36	2	Part1 2	
37	2	Part7 1	
38	8	ISO 7092 140 HV	Plain washers grade A
39	4	ISO 4014 - M18 x 120	Hexagon head bolt
40	4	ISO 4034 - M18	Hexagon nuts - grade C

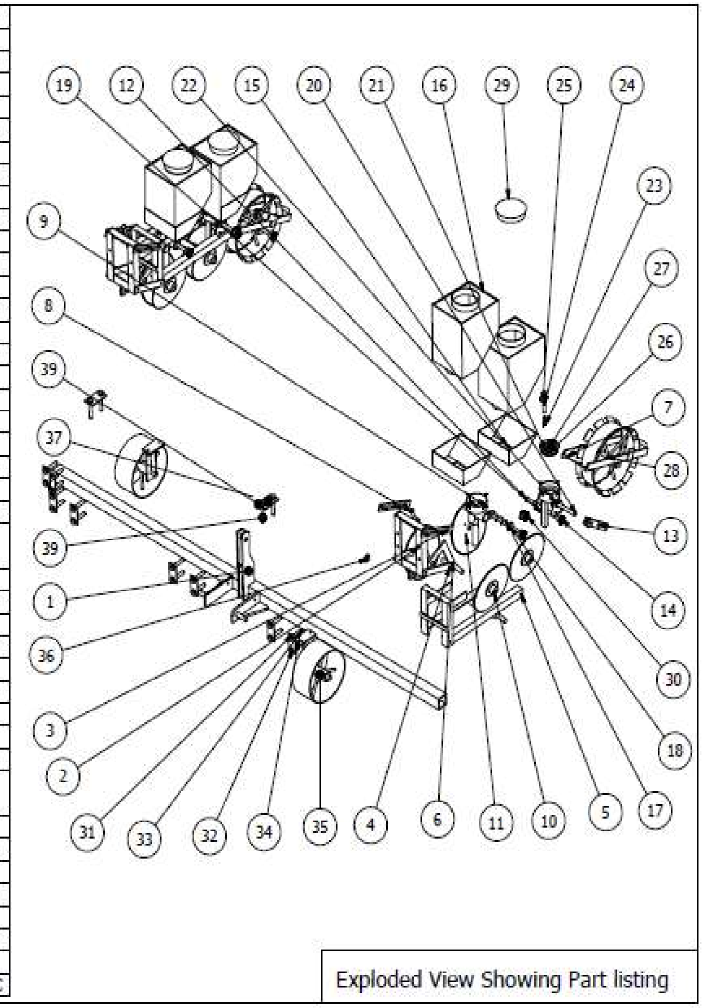

Figure 2. Exploded view of the Planter showing component names

2.2 Design Consideration

The design of the planter is based on the following considerations.

i. The ease of fabrication of component parts.
ii. The safety of the operator
iii. The operation of the machine simplified for small scale or rural farmers to handle easily.
iv. The materials used for the fabrication of the machine are locally available to ensure ease of getting the spare parts.
v. The materials used for construction are readily available and cheap thereby making the machine components/spare parts affordable.

2.3 Design Calculations

2.3.1 Seed hopper

The seeds hopper as the name implies is a device in which the seeds to be planted are kept (transitionally) before their gradual release into the furrowed tunnel. The hopper is trapezoidal on the inside with the shape of a frustum of a pyramid truncated at the top as shown in Figure 1. To ensure free flow of seeds, the slope of the hopper was fixed at 30^o, which is modestly higher than the average angle of repose of the seeds. The seed hopper also has a lid, with a handle on top to ease opening. Volume of the hopper is 252,665 cm^3.

$$V = \frac{h}{3}[A_1 + A_2 + \sqrt{A_1}A_2] \quad (1)$$

2.3.2 Seed metering mechanism

The metering mechanism is a major component in a planter. It picks required number of seeds and delivers them into the soil through the chute at required depths determined by the adjustments on the furrow openers. The metering mechanism of the planter also controls/determines seed spacing in a row. For efficient performance of a planter the following were put into consideration, the size of the seed, the intra and inter row spacing for each seed, which usually differs from one crop to another, and for different desired plant populations.

Different seed plates were designed for different types of seeds. The seeds are maize, guinea corn and soybeans. Proper design of the metering device is an essential element for satisfactory performance of the seed planter. The number of cells on the seed plate may be obtained from the expression given in Equation (2).

$$Number\ of\ cells = \frac{\pi \times Diameter\ of\ the\ planters\ ground\ wheel}{Intra-row\ spacing\ of\ seeds} \quad (2)$$

2.3.3 Determination of the shaft diameter

Shaft design consists primarily of the determination of the correct shaft diameter to ensure satisfactory strength and rigidity when the shaft is transmitting power under various operating and loading conditions. Design of shafts of ductile material based on strength is controlled by maximum shear theory. The material for the shaft is mild steel rod. For a shaft having little or no axial loading, the diameter may be obtained using the ASME code equation given as:

$$d^3 = \frac{16}{\pi Sa}\sqrt{(k_b\, m_b\,)2 + (k_t\, m_t)2} \quad (3)$$

where,

d = Diameter of the shaft

M_b = Bending moment

M_t=Torsional moment

K_b= Combined shock and fatigue factor applied to bending moment

K_t= Combined shock and fatigue factor applied to torsional moment

S_a= Allowable stress

For rotating shafts, when load is suddenly applied (minor shock):

K_t = 1.5 to 2.0 k_t = 1.0 to 1.5

For shaft without key way, allowable stress S_a = 55MN/m^2

For shaft with key way, allowable stress S_a = 40MN/m^2

2.3.4 Sprocket

This is one of the power transmitters to both the metering device and the fertilizer auger. The power is considered, the speed of the driver and the driven, and centre distance are all considered. The permissible working stress of the thickness of a tooth of the sprocket was determined using Equation (4).

$$\sigma_w = My/I \quad (4)$$

where,

σ_w= Permissible working stress
M= Maximum bending moment at the critical section BC which is the same as t =W_t x h
W_t = Tangential load acting at the tooth,
h = Length of the tooth,
y = half the thickness of the tooth (t) at critical section BC= t / 2,
I = Moment of inertia about the centre line of the tooth = b.t^3 /12,
b = width of gear face.

When the value of 'y' is independent of the size of the tooth and depends only on the number of teeth on a gear and the system of teeth.

y = 0.124 - $\frac{0.684}{T}$ for $14^{1/2}$ composite and full depth involute system.

2.3.5 The furrow opener

This consist of a disc positioned in a v shape to make a open to the soil as it travels. It has a hub with a bearing in it to rotate the disk as it travels. The bearing; the dynamic load rating for the furrow opener was determined using Equation (5).

$$L = \left(\frac{C}{W}\right)^k \times 10^6 \quad (5)$$

where,

L = Rating life
C = Basic dynamic load rating which is c=w $(l/10^6)^{1/k}$
W = Equivalent dynamic load rating
K=3 for ball bearings

2.3.6 The ground wheel

This is the source of power to the metering device and the fertilizer auger. It also determine the distance at which the metering device will drop seed with a revolution. The circumference of the wheel is determined using Equation (6).

$$C = \pi d \quad (6)$$

Since the diameter of the wheel is 52cm then the circumference is:

$$C = 3.142 \times 520$$
$$C = 1633.84\, mm$$

2.3.7 Frame

This is made of a 5mm angle iron, flat bar, and 1mm flat sheets. Which are cut, and welded together to form a desirable structure, that houses and carry other components of the implement. On the main frame is the hatching point.

3. PRELIMINARY TEST

Maize seed was the main seed used for the performance evaluation of the planter and the seed was procured from the Farm Management unit of the Centre. The standard code suggested by Mehta *et al.* (1995) for seed drill performance test as reported by Bamgboye and Mofolasayo (2006) was adopted in the evaluation of the machine performance. Laboratory and field tests were conducted to determine the performance of the machine.

Laboratory tests were carried out on the fabricated planter to determine the seed dropping rate and spacing efficiency. The test was done on a flat soil surface with a tractor driving the plantet to set and do the necessary adjustment for effective working of the mechanisms. Three different types of crop seeds were used.Two varieties of each seed crop was used, that is the large and small size respectively. These are, Maize, beans and guineacorn using the seed plate specified for each of the seeds. For each of the three seed types the machine dropped seeds between two and three per stand.

Further test was conducted on a piece of land of dimensions 10m by 50m to ascertain that the main functional parts are working as expected. Two runs of the tractor on a 50m stretch were used to ascertain the effective functioning of the operational components like the soil opener, the closer, the seed delivery chute and the rolling parts. The planter hopper was filled with maize seeds and right adjustments effected appropriately on each of the 4-row gang and the planter used to plant the measured area. Number of seeds dropped per planting point and seeds damaged were noted and recorded by picking samples and other functionality component determined. Time of operation was measured using a stop watch.

4. RESULTS AND DISCUSSION

The picture of the four-row tractor drawn multi-seed planter shown in Plate 1. Planting tests were carried out to ascertain that the main functional parts are working as expected and it was observed that the planter could successfully plant an average of two seeds per hole. The metering mechanism could successfully pick the required number of seeds from the hopper; deliver them into the chute through which the seeds are dropped along the rows at about 30cm intra row spacing. The ground wheel transmitted power to the metering device through the chain and sprocket system.

Plate 1. Picture of four-row tractor drawn multi-seed planter

4.1 Determination of Field Efficiency

The field efficiency of the planter was determined as 75.68% using Equation (7).

$W = T_a$ (7)

T_a is the time taken for actual

$T_t \backslash T_a$

where,

T_a is the time taken for actual planting operation;
T_t is the total time taken.

4.2 Determination of Effective Field Capacity

The effective field capacity, is a function of the theoretical field capacity and field efficiency. The effective field capacity was determined as 0.7675 ha/h using the expression given by Oyelade and Oni (2011) as:

$$D = E\frac{(3600)}{F} \quad (8)$$

where,

D = effective field capacity (ha/h)
E = area of field (ha)
F = total time taken in completing the whole tillage operation (sec)

Table 1. Laboratory calibration of Tractor drawn four row seed Planter

Replications	Weight of seeds discharged	Time for 100 rev. (sec)	Speed (rpm)
1	505.5	310	7.5
2	520.5	305	6.2
3	490.0	287	5.9
4	530.0	313	6.4
5	510.0	303	6.2
6	505.5	307	6.3
7	510.0	300	6.1
8	520.5	312	6.4
9	505.5	304	6.2
10	510.0	300	6.1
TOTAL	5177.5	341	63.3
MEAN	5.17.0	304	6.33

Table 2. Determination of seed rate and planting distance of the machine

Rep	kg/trip in stretch (kg/h)	Speed (km/h)	Laboratory Spacing (cm)	Field Spacing (cm)
1.	1.3	0.2	38.0	45.0
2.	1.3	0.2	44.0	44.0
3.	1.3	0.2	57.0	48.0
4.	1.3	0.2	46.0	40.0
5.	1.3	0.2	39.0	43.0
6.	1.3	0.2	46.0	52.0
7.	1.3	0.2	38.0	51.0
8.	1.3	0.2	45.0	50.0
9.	1.3	0.2	41.0	55.0
Mean row spacing	1.3	0.2	43.8	47.6

Table 3. Percentage seed damage rate of the planter

Replication	Time for 20 rev. (sec)	Weight of seed discharged (g)	Weight of broken seed (g)	Percentage of damages (%)
1.	73	20.7	0.4	0.03
2.	65	20.5	0.6	0.04
3.	58	22.7	1.2	0.08
4.	55	17.2	0.5	0.03
5.	60	20.0	6.4	0.43
6.	57	15.4	2.4	0.16
7.	50	16.0	1.8	0.12
8.	60	19.2	0.8	0.05
Total	42.08	151.68	14.08	0.96
Mean	5.26	18.96	1.76	0.12

4.3 Test Result

During the laboratory test, the planter was tested for seed discharge rate as reported in table 1.It was found to be an average of 5seeds at a speed of 6.33rpm. And test for seed spacing by the planter was found to be an average of 44cm between ridges in the laboratory and in the field an average of 48cm on the ridge i.e., between stands, as shown in table 2. The row to row spacing is standard as this is adjustable by setting the ridge gang within the main frame of the planter.

From Table 3, the rate of damages of the planter was found to be 0.12% of the full load of the planter when the planter was operated at the forward speed of 1.25 m/s. The moisture content and the bulk density of the soil during the test were found to be 10.3 per cent (db) and 2.36 Mg/m^3. The average draft required during operation was 2300 N and the percentage of missing points obtained for planter was 3.50 per cent.

5. CONCLUSION

A four row tractor drawn seed planter was replicated in NCAM using locally available materials thus making it cheaper, and with spare parts available and affordable than the imported version. An extensive performance evaluation test was carried out on it using maize on a clay-loamy soil to get its performance rate. It has seed metering efficiency of 85%, field efficiency of 75.68%, effective field capacity of 0.7675 ha/h, planting depth 2.53cm and planting rate of two seed per stand. The planter is economical and simple to use with handling made less cumbersome compared to the imported version.

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