International Journal of Scientific Engineering and Applied Science (IJSEAS) - Volume-1, Issue-4, July 2015
ISSN: 2395-3470
www.ijseas.com

Development of a Revolving Wooden Disc Single-Row Grains Planter

Agidi, Gbabo[1], Blessing Ibukun[2], Ibrahim Mohammed Gana[3]

1. Engineering Department, National Cereals Research Institute, Badeggi-Bida, Niger State, Nigeria
2. Department of Agricultural &Bioresources Engineering Department, Federal University of Technology Minna, Niger State Nigeria
3. Department of Agricultural & Bio-Environmental Engineering Department, Federal Polytechnic Bida, Niger State Nigeria

ABSTRACT

A manually operated single-row multi-crop planter was developed for planting of different agricultural seeds such as maize, cowpea and soya beans. The major components of the planter include seed hopper, metering device, adjustable furrow opener and closer, drive wheels and seed tube. The planting operation is achieved by feeding seeds into the hopper. The planter was pushed forward in the direction of travel at an average speed of 0.15m/s, the furrow opener penetrated the soil creating a furrow for seeds to be placed. The planter's ground wheel is connected directly to the seed metering device, and as the ground wheel rotates, the seed metering device placed at the bottom of the hopper also rotates, thereby releasing two or three seeds depending upon the size of the cells or the size of the seeds. These seeds are then conveyed to the furrow through the seed tube. The furrow was then closed by the furrow closer. The planter was designed to be operated manually by one operator. It was tested to plant maize, cowpea and soya bean seeds. The result showed that the planter covered the largest area of 486 m^2/h when planting maize seeds and least area of 270 m^2/h when planting soya beans. The capacity of the planter in terms of area covered was found to be high (0.0486 m^2/hec) when planting maize and less when planting soya beans(0.027m^2/hec) this could be as result of least inter-row spacing between soya beans plant compared to the other grains under the study. The least time(20.78hrs) and number of days (2.6 days) required to plant one hectare of land were obtained when planting maize, while the highest time(37.037 hrs) and number of days (4.6 days) required to plant one hectare of land were obtained when planting soya beans. The successful development of this planter will provide a cheap, easily affordable planter for the rural farmers. It will also go a long way in making farming more attractive to the youths, reducing the problem of urban migration by youths in search of white collar job, saving tremendous amount of time during farming, ensuring capacity utilization of available farmland, and finally increasing agricultural output

Key Words: Manually, single-row, multi-crop, planter, maize, cowpea and soya beans

1.0 INTRODUCTION

Over eighty percent of mankind diet is provided by the seeds of some plants species. The root of seed cultivation is believed to have begun in the areas of the present day Turkey and the Middle East about 10,000 years ago. This was where the evidence of people taking wild grasses, using the seeds for food and planting some for the next year's food, was first discovered. These seeds are what is now known as cereals and make up large percentage of the world food supply (Binswanger, 1986). Early seed planting was carried out manually through broadcasting method. This method simply involves throwing the seeds randomly onto the ground. Due to the fact that the seeds are planted without any specific control on the mode of seed placement on the soil, it is more difficult to weed and harvest the crops and in most cases birds eat up most of the seeds before germination. Later, a board with holes evenly spread apart known as dibbler was used. This involves pushing a stick through the holes in the box to create holes in the soil and placing the seeds accordingly. This method which was first used in Mesopotamia in 1500B.C was very effective but tedious and time consuming. In 1970, JethroTull invented the first seed drill (Mayne, 1956). The implement cuts small channels into the soil and the seed was then dropped into the channel and covered. Advantages recorded with by this planting method over the previous systems include higher percentage of seed germination, less seed losses to birds or other animals, easier to weeding and harvesting operations. However, the invention was met with scepticism and was not really accepted till after JethroTull's death in 1741. Later this technology was modified to drill seeds in several ways either manually or pulled by animals.

The advent of the industrial revolution in the 18th century especially with the invention of the steam engine by James Watts brought about massive and dramatic changes in cultivation technologies during which the tractor was invented. The manufacture of the tractor gave room for dramatic changes in farm cultivation; as a result, tractor drawn seed drills having multiple rows were manufactured (Ehui and Polson, 1992). Successful crop production requires optimum planting performance and substantial preparation. Ninety percent of this is accomplish through proper sowing. Although high yield in crop production certainly requires field scouting and management inputs during the planting season, problems created by poor planting cannot be corrected during the season. Poor seed spacing and depth uniformity may affect yield potential as much as plant population. The development of this machine would provide a cheap and affordable manually operated single-row multi-crop planter with an interchangeable wooden cell seed metering mechanism to accommodate the different varieties and types of seeds. The development will also increase agricultural output, reduce production cost and makes farming more attractive to youths. Thus, this paper is presentation of development of a manually operated single-raw multi-crop planter developed at the Agricultural and Bioresources Engineering Department of the Federal Unversity of Technology Minna, Nigeria

2. MACHINE DESCRIPTION

The Planter was designed to be made up of the following major parts as shown in fig 1 and plate 1 to 3.

i. Main Frame: This is the skeletal structure of the seed planter on which all other components are mounted. It is made of mild steel angle bar of the following dimension 50.8mm x 50.8mm x 4mm

ii. Adjustable Handle: This was designed to be adjustable for the different height of individuals in order to reduce drudgery. The handles help the operator to push the planter while in operation. It is made of combination of 1 inch mild steel square pipe, ¾ inch mild steel square pipe, and 1 inch mild steel angle bar.

iii. Seed Hopper: This is a device in which the seeds to be planted are kept (transitionally) before their gradual release into the furrowed tunnel. It has the shape of a frustum of a pyramid truncated at the top as shown in Figure1.This is 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 container also has a lid, with a handle on top to ease opening. The material used for the design was 2mm thick mild steel sheet metal.

iv. Seed Metering Mechanism: This distributes seeds uniformly at the desired application rates. It is of wooden roller type with cells on its periphery as shown in Plate I. The wooden roller lifts the seeds in the cells and drops these into the seed funnel which is conveyed to the open furrow through the seed tube. For varying the seed rate and sowing different seeds, three separate rollers were provided.

v. Adjustable Furrow Opener: This permits planting at each variety's ideal ground depth. It is of pointed bar type capable of forming narrow slit under heavy soils for placement of seeds at medium depths. It is made of 50mm x 5mm mild steel flat bar. It is shown in Fig 1 and Plate II

vi. Adjustable Furrow Closer: This was designed to be adjustable and of shoe type. It was designed to allow for proper covering and compaction of the soil over the seeds in the furrows. It is made of 50mm x 5mm mild steel flat bar. It is shown in Fig 1 and Plate II

vii. Drive Wheels: These are located at both ends of the frame. They are circular in shape containing 1 inch square pipes which serves as spokes. These spokes are used to support the centre bushing or hub. The spokes are arranged in such a way that it braced the wheels circular circumference and also gives it necessary radial support. It is made of combination of both 1 inch mild steel square pipes and 3mm thick mild steel flat bars. It is shown in Fig 1.

viii. Seed Tube: This was the channel through which seeds are conveyed to the furrow. It is made of a conical funnel with a rubber hose. The outlet diameter is 1 inch. It is shown in Fig 1 and Plate II

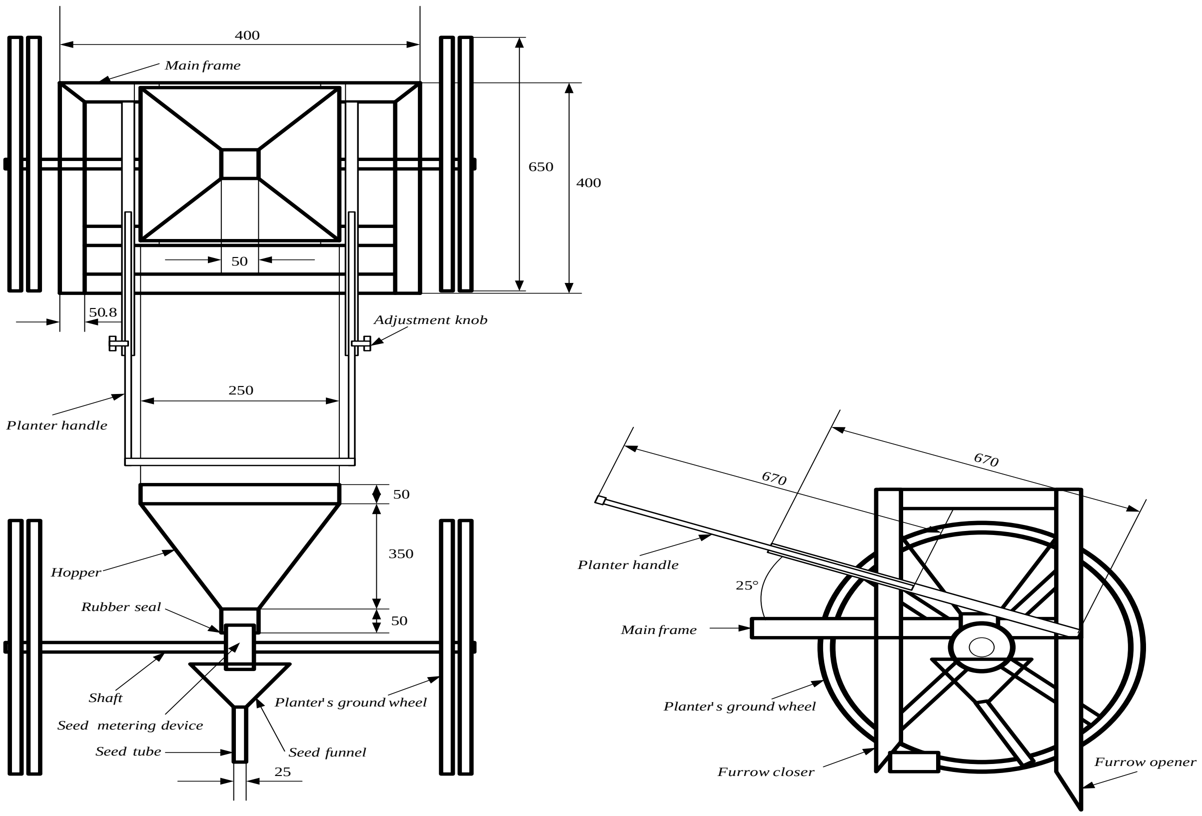

Fig. 1: Diagram of the seed planter showing all the necessary Parts

Plate I: Seed Metering Device

Plate I1: The Seed Tube,

Adjustable Furrow Opener and Closer

Plate II1: The Developed Manually Operated Single-Row Multi-Crop Planter

3. Working Mode of the Machine

The hopper was filled with seeds. The filling of the hopper depends on how much area of the field to be covered. As the multi-crop planter was pushed forward in the direction of travel at an average speed of 0.15m/s, the pointed bar type furrow opener penetrated the soil creating a furrow for seeds to be placed. The planter's ground wheel is connected directly to the seed metering device, and as the ground wheel rotates, the seed metering device placed at the bottom of the hopper also rotates, thereby releasing two or three seeds depending upon the size of the cells or the size of the seeds. These seeds are then conveyed to the furrow through the seed tube. The furrow was then closed by the shoe type furrow closer.

3.1 DESIGN ANALYSIS

The following design analysis were carried out in order to select the various machine parts:

Determination of the Weight of the Hopper Material

The weight of the hopper is essential in determination of the power required to move and operate the planter and is given as

$W_{HM} = M_{HM}\,g$(Gbabo,1988).………………………………..1

$W_{HM} = V_{HM}\,\rho_{HM}\,g$(Gbabo,1998) ………………………………2

$W_{HM} = \rho_{HM}\,A_{HM}\,t_{HM}\,g$ (Gbabo, 1988) …………………………3

Where, W_{HM} is weight of the material used for construction of the hopper

M_{HM} is mass of the hopper material

A_{HM} is surface area of the hopper material

V_{HM} is volume of the hopper material

t_{HM} is thickness of the hopper material

ρ_{HM} is density of the hopper material

Determination of the Weight of the Main Frame Material

The weight of the frame is essential in determination of power required to move and operate the machine and using the conventional method of weight and mass determination given as

$V_{MFM} = A_{MFM} \times t_{MFM}$ ……………………………………4

$W_{MFM} = M_{MFM} \times g$ ……………………………………..5

$W_{MFM} = V_{MFM}\,g\rho_{MFM}$ ………………………………………6

Where, A_{MFM} = Surface area of the main frame material

V_{MFM} = Volume of the main frame material

t_{MFM} = Thickness of the main frame material

M_{MFM} = Mass of the main frame material

ρ_{MFM} = Density of the main frame material

W_{MFM} = Weight of the main frame material

g is the acceleration due to gravity

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.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 (Khurmi and Gupta, 2005) given as

$$d^3 = \frac{16}{\pi S_a}\sqrt{(k_b M_b)^2 + (k_t M_t)^2} \text{ (Khurmi and Gupta, 2005)}\ldots\ldots\ldots\ldots\ldots\ldots 7$$

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) (Khurmi and Gupta, 2005): $k_b = 1.5 \text{ to } 2.0$ $k_t = 1.0 \text{ to } 1.5$ and for shaft without key way, allowable stress $S_a = 55 MN/m^2$, For shaft with key way, allowable stress $S_a = 40 MN/m^2$

Determination of the Maximum Bending Moment

Figure 2 shows the load distribution on the shaft. The maximum bending moment may the obtained from the following expressions

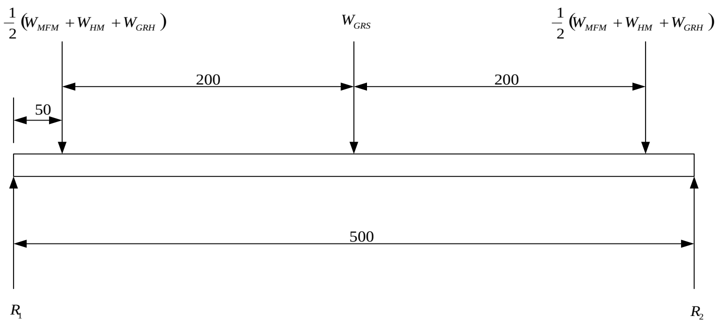

Fig.2: Load distribution on shaft

The following expressions where used for calculation of the reactions at the support

$$R_1 + R_2 = 2 \times \frac{1}{2}(W_{MFM} + W_{HM} + W_{GRH}) + W_{GRS} \text{ (Gbabo,1988)}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 8$$

$$R_1 = \frac{1}{0.5}\left[\frac{1}{2}(W_{MFM} + W_{HM} + W_{GRH}) \times 0.45 + W_{GRS} \times 0.25 + \frac{1}{2}(W_{MFM} + W_{HM} + W_{GRH}) \times 0.05\right] \ldots\ldots 9$$

Where, R_1, R_2 = *Reactions at the support*

W_{GRH} = *Weight of grain resting on the hopper*

$W_{GRS} = Weight\ of\ grain\ resting\ on\ the\ shaft$

Using the method of sectioning(Gbabo,1988)., the following expressions were obtained for the bending moment

$M_{b1} = R_1 \times 0.05$ ……………………………………………………10

$M_{b2} = R_1 \times 0.25 - \frac{1}{2}(W_{MFM} + W_{HM} + W_{GRH}) \times 0.20$ …………………..11

$M_{b3} = R_1 \times 0.45 - \frac{1}{2}(W_{MFM} + W_{HM} + W_{GRH}) \times 0.4 - W_{GRS} \times 0.2$ ………..12

The maximum value in equation 10, 11, and 12 is taken as the maximum bending moment M_b for the shaft.

$V_{GRS} = 0.45 \times (EF \times FG)$………………………………………13

$M_{GRS} = V_{GRS} \times \rho_G$ ……………………..14

$W_{GRS} = M_{GRS} \times Acceleration\ due\ to\ gravity$ ……………………………15

$W_{GRH} = W_G - W_{GRS}$ ……………………………………………………….16

$Where, V_{GRS} = Volume\ of\ grain\ resting\ on\ the\ shaft$

$M_{GRS} = Mass\ of\ grain\ resting\ on\ the\ shaft$

3.8 Determination of the Force Required Pushing the Planter

Figure 3 gives the free body diagram showing all the forces acting on the planter. the force required to push the planter may be obtained from the following expressions given by Gbabo (1988)

$\sum F_x = F_P \cos\theta - R_S \cos\phi - F_R = 0$ ………17

$\sum F_y = R_S \sin\phi - F_P \sin\theta - W_P = 0$ …………18

$Where, F_P = Planter\ push\ force$

$F_R = Horizontal\ soil\ resistance\ force$

$R_S = Soil\ frictional\ resistance\ force$

$\phi = Angle\ of\ friction$

$\theta = Angle\ between\ planter\ handle\ and\ the\ horizontal\ plane$

$W_P = Weight\ of\ planter$

International Journal of Scientific Engineering and Applied Science (IJSEAS) - Volume-1, Issue-4, July 2015
ISSN: 2395-3470
www.ijseas.com

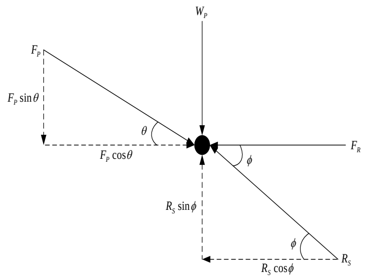

Fig.3: Free body diagram showing all the forces acting on the planter

From equation 17

$$F_P = \frac{R_S \cos\phi + F_R}{\cos\theta} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 19$$

Substituting equation 18 into equation 19, one obtains

$$R_S = \frac{F_R \tan\theta + W_P}{(\sin\phi - \cos\phi \tan\theta)} \ldots\ldots\ldots\ldots\ldots\ldots 20$$

The maximum draft on the planter is a function of the soils resistance on the machine and the area of contact of the furrow opener with the soil. Data for the different soil resistance is presented in table 3.3 (Gbabo, 1988). The maximum draft on the planter is the horizontal component of push parallel to the line of motion in order to overcome the soil resistance on the planter (Gbabo,1988). The maximum draft may therefore be obtained from the following expression

$$D_{FM} = R_S \times A_{FO} \times g \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 21$$

D_{FM} = Maximum draft

R_S = Surface area of furrow opener in contact with soil

$A_{FO} = \text{Re}\,commended\ depth\ of\ cut \times Thickness\ of\ \ furrow\ opener$

g =Acceleration due to gravity

4. TESTING OF MACHINE

4.1 Materials and Methods

30kg of maize seeds were obtained from Bida central market in Bida LGA, Nigeria. The grains were divided into three samples each. The planter was first run under no load condition in order to ascertain the smoothness of operation for the machines rotating parts.

Two plots of fields adjacent to each other measuring 50m x 90m each were ploughed and harrowed. Each of these plots were sub divided further into three plots of 50mx30m each. One of the plots was planted up manually while the other one was planted up with the machine using three (3) different speeds of 0.6m/sec, 0.8m/sec and 1.0m/sec. The planting operations were replicated three times for each crop. Agronomically recommended planting spacing of 90cm x 25cm for maize was used. The seeds were left in the field to germinate and allowed to establish for 6 weeks. Planting and seed germination data were collected for both machine and manually planted up plots and the following data were analysed and results obtained are presented in table 1:

Machine Capacity: This is the area covered by the planter in a given time usually expressed as ha/hr. This was computed by recording the time used to plant up the 50m x 30m plot. The planter's capacity was then computed as follows:

$$Cm = \frac{Ac}{t}$$

Where Cm is Machine capacity (ha/hr)

Ac is area covered by machine (ha)

t is time spent (hr)

- **Furrow opening and covering efficiencies:** This is the effectiveness with which the machine was able to open the soil and cover the seeds after the seeds were dropped into the furrow. The length of the furrow effectively opened and covered by the planter within a marked out plot of 5m x 10m was computed as ratio to the whole length of the rows expected to be marked out within the marked out plot. The values obtained were then expressed in percentage as shown:

$$Foe = \frac{Lo \times 100\%}{Lt} \quad \text{-----------------------------------}$$

$$Fce = \frac{Lc \times 100\%}{Lt} \quad \text{------------------------------------}$$

Where Foe is furrow opening efficiency (%)
Fce is furrow covering efficiency (%)
Lo is length of furrow opened by the furrow opener (m)
Lc is length of furrow covered by the furrow coverer (m)
Lt is Length of the row expected to be opened up (m)

- **Seed dropping efficiency:** This is an indication of the effectiveness of the seed dropping mechanism. This was computed by measuring a given area (5m x 10m), counting the seeds dropped by the planter within the area and comparing the value to the expected seed rates for each crop:

$$Sd = \frac{Qs}{Qe}$$

Where Sd is Seed dropping efficiency (%)

Qs is Quantity of seed dropped (kg)

Qe is Expected or recommended quantity of seeds (kg)

- **Seed damage rate:** This is an indication of the quantity of seeds that got damaged in form of bruises or cutting as a result of the friction generated by the revolving wooding disc and the stationary cushioning walls of the machine. This was computed by recording the damaged seeds within a 5m x 5m area and relating it to the total seeds released by the machine which is expressed in percentage:

$$\mathbf{Sda} = \frac{Da}{St}$$

Where Sda is Seed damage (%)

Da is Damaged seeds (kg)

St is total quantity of seeds (kg)

- **Plant establishment rate:** This the rate at which the plants germinated and established in the field. It is expressed as a ratio of the number of established seeds to the total number of seeds expected to be established under normal circumstances:

$$\mathbf{Ep} = \frac{Ne}{Nx}$$

Where Ep is Plant establishment (%)

Ne is Number of established plants

Nx is Number of plants expected to be established

Table 1: Performance of Planter for planting maize and soybeans compared with manual planting

Functional Machine Parameters	Average Performance values at different machine speeds	
	Maize	Soybeans

	Machine Operation			Manual	Machine Operation			Manual
	0.6m/sec	0.8m/sec	1.0m/sec	Normal	0.6m/sec	0.8m/sec	1.0m/sec	Normal
Machine capacity (ha/day)	0.38	0.42	0.5	0.03	0.25	0.35	0.40	0.02
Furrow Opening Efficiency (%)	82.3	78.5	73..8	92	81.0	80.5	74.2	91.5
Furrow Covering Efficiency (%)	74.2	72.4	67.5	90.8	73.6	70.8	66.8	90.2
Seed Dropping Efficiency (%)	96.3	94.5	85.4	96.4	98.0	95.2	84.7	95.3
Seed Damage Rate (%)	0.02	0.02	0.03	0.00	0.18	0.02	0.03	0.00
Plant Establishment (%)	92.6	90.4	87.8	9I.3	94.1	94.3	95.8	95.7

RESULTS AND DISCUSSIONS

The observations made from testing the machine are presented as follows:

Machine Capacity: The capacity of the machine was found to generally increase with increase in the speed of the operator. The highest machine capacity of 0.5 ha/ day was obtained by planting maize at 0.8m/sec while the least capacity of 0.25ha/day the machine was observed when it was used to plant soybean. This due to the fact that the inter row spacing used for planting maize was 90cm while that of soybean was 50cm.Comparatively, manual mode of planting had 0.03ha/day and 0.02ha/day for maize and soybean. This indicates that about 10 people would be required to plant the same area of land planted up by the machine at its lowest speed of 0.6m/sec and 18 people for the same area of land at the highest speed of 0.8m/sec.

Furrow Opening and Covering Efficiencies: The furrow opening and covering efficiencies of the planter was generally high ranging from a. The performance of the furrow openers and coverers were found to reduce from an average of 82.0% to 74.0% for furrow opening and 74.0% to 67.0% for furrow covering as the planter's speed increased 0.6m/sec to 1.0m/sec for planting both maize and soybean but did not show variation in the performance for planting the two crops.

Seed Dropping Efficiency: The seed dropping efficiency of the planter was also very high in planting the maize and soybean seeds. Although the dropping efficiency reduced from about 96.0% t0 85.0% as the planter's speed increased from 0.6m/sec to 1.0m/sec. No specific variation in the performance of the seed dropping mechanism for the maize and soybean seeds.

Seed Damage Rate: The seed damage rate very minimal with the lowest speed of 0.6m/sec recording the least damage percent of 0.00% and the highest speed of 1.0m/sec recording the highest rate of 0.03% for both seeds, maize and soybean.

Plant Establishment Rate: The plant establishment rate of the planter was also very high, ranging from 87.8% to 96.2% for maize and 94.3% to 95.7% for soy beans. This variation for maize and soybean could be as a result of the difference in the viability of the seeds. In planting both maize and soybean, the plant establishment was higher at the lowest speed of 0.6m/sec.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions are made from the work carried out on the development of the planter:

i) The planter using horizontal disc metering mechanism work effectively in planting maize and soybean. It can still be useful in planting other grains such as cowpea, sorghum, rice etc by interchanging the seed metering disc with an appropriately calibrated one

ii) The minimum field capacity of the machine, approximately 0.4 ha/day at the lowest operator's speed of 6m/sec is a desirable outcome compared with the manual planting capacity of 0.03 ha/day. This indicates that the machine can do the work of 13 labours in a day

iii) The furrow opening, dropping and covering mechanisms were also effective as their efficiencies were over 70%

iv) The maximum seed damage rate of 0.03% was also very low which also resulted to the high plant establishment rates ranging from 87.8% – 95.8%.

v) The optimum working speeds which are recommended for operation of the planter is 0.6m/sec and 0.8m/sec because the planter performed best at these speeds

vi) Despite the fact that the furrow opening and covering mechanisms performed appreciably, more work is recommended to be done further to improve their efficiencies.

REFERENCES

Gbabo, A. (1988): Design and construction of a two-row cowpea and maize planter. Maintenance and Repair Unit, Agricultural Engineering Section, National Cereals Research Institute, Badeggi.

Jayan, P.R. and Kumar, V.J.F. (2004): Planter design in relation to the physical properties of seeds. Journal of Tropical Agriculture, 42(1-2): 69-71.

Khurmi, R.S. and Gupta, J.K. (2005): A textbook of machine design. Eurasia Publishing House (Pvt.) Ltd., Ram Nagar, New Delhi-110055, India, pp. 509-557.

Mayne, J.E. (1956): Progress in the mechanization of farming in Colonial territories", Tropical Agriculture, 33(4): 272-277.