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Development and Evaluation of a Manual Multi - crop Planter for Peasant Farmers

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ABSTRACT

Farming today has gone beyond subsistence farming that produces for the farmer and his household. Research shows that the consumption of grains or cereal crops is at an alarming rate in the world, so to encourage small farm holders a manually operated multi-crop hand push planter with changeable metering devices for cowpea, maize and soybean was designed, fabricated and evaluated to improve planting efficiency and reduce drudgery involved in manual planting method. The laboratory and field tests were conducted to determine weight of seeds discharged from the planter, seed percentage damage, field capacity, average depth of placement of seeds in furrow, average inter-row spacing of seeds and the emergence of the seedlings. Results revealed that the planter had field efficiency and field capacity of 76.3% and 0.39 ha/hr with seed rate of 0.25 kg/ha, 0.18 kg/ha and 0.21kg/ha respectively for cowpea, maize and soybean. Percentage difference between the seed damage of 3.54%, 2.32% and 1.32% of cowpea, maize and soybean respectively obtained was from an average spacing of 40.8cm and depth of 3.98cm. The single-row multi-crop planter is very simple to use and it is maintenance free, except for the bearings which needs to be lubricated from time to time to allow the planter's ground wheel to move freely. For this design, the drive shaft directly controls the seed metering mechanism which eliminates completely attachments such as pulleys, belt systems, and gears thereby eliminating complexities which increase cost, and increasing efficiency at a highly reduced cost which is the focus of this project work. The planter can be easily maintained without any technicality and all materials used for the fabrication are locally available in the case of worn - out parts.

Introduction

Grain crops are interchangeably called cereals crops which belongs to the grass family (Gramineae), generally grown for their edible starchy seeds. Cereal crops includes; wheat, rice, maize (corn), barley, rye, oats, soybean and millet etc. In Nigeria, uses of cereals range from "Akamu," "Agidi", to "Nrioka", "tuwo shinkafa" and "tuwo masara". They are used as animal feed and fodder. In some parts of Nigeria, cereal stems find uses in structural designs in the construction of local huts. Cereal grains are relatively low in proteins especially the essential amino acids. They require supplements with legumes and proteins (Henry, 2005).

There are many factors responsible for low agricultural yields. These include use of low yielding varieties, and inadequate cultural management practices particularly in the area of fertilization, insect, diseases, weed control and most importantly, planting operation. Planting operation is one of the most important tasks that grains growers undertake. Planting operation of grains in Nigeria is at low level as many farmers still use bare hands or hand tools to plant their crops. However, manual method of seed planting, results in low seed placement, spacing efficiencies and serious back ache for the farmer which limits the size of field that can be cultivated. Moreover, manual planting is tedious and time consuming; a hectare of land requires eight-man (Cruz, 2007). About 95% of the Nigerian farmers have small land holdings and are much below living standard. Seed planters available in the market are imported, specifically designed to operate in large farms, expensive and not suited to local conditions. It is difficult peasant farmers to acquire costly imported agricultural machinery and equipment (Olaoye and Bolufawi, 2001; Odigbo, 1981; Odigbo, 1983). Timeliness of operations is one of the most important factors which can only be achieved if appropriate use of agricultural machines is advocated (Salokhe and Oida, 2003).

Many types of implements have been developed for seed planting. Some cereal crops are planted by broadcasting seeds, scattering the seeds over a wide area. Machines for broadcasting usually consist of a long seed box mounted on wheels and equipped with an agitator to distribute the seeds. Broadcast seeds are not always covered by a uniform or sufficient depth of soil, so seeding is more often done with drills, which produce continuous furrows of uniform depth. Specialized implements called planters are necessary for sowing crops that are planted in rows, such as maize, cowpea soybean. Corn planters and other similar machines have a special feed wheel that picks up small quantities of grain or separate kernels and places them in the ground. Singh et al. (1985) developed a two row ridge planter for planting winter maize and evaluated in the field over an area of 0.4 ha. Average seed distance was found to be 0.198 m, row to row spacing 0.60 m and the average ridge height was 0.25 m. The capacity of the planter was 0.10 ha/hr at a forward speed of 2.5 kmph. Braide and Njidda (1989) developed a combined jab planter which was found to be 73.4% efficient and was three times faster than manual planting with hoes and cutlass. Braide and Ahmadu (1990) developed a transplanter for some selected crops in Guinea Savannah of Nigeria which has 0.19ha/h field

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capacity and 20% field efficiency. Olaoye and Bolufawi (2001) developed a tractor drawn planter for planting grains both on flat lands and ridges. Plant spacing, uniformity and emergence rate are the most common characteristics used by producers to evaluate planter performance. (Staggenborg et al., 2004). The main objective of this study was therefore to design and fabricate a simple multi-crop hand push planter for cowpea, maize and soybean with locally available materials, evaluate the machine with maize, cowpea and soybean and determine its capacity and efficiency.

Material and Methods

Machine Description

The planter was designed to be made of the following parts as shown in Figures 1 to 6.

Seed hopper

The feed hopper is made of mild steel having a trapezoidal shape. The design capacity of the hopper is 200 cm^3. The dimension of the hoppers is 210mm x 90mm x 200mm

Metering disc

The metering disc or flute roller is made of 5 mm plastic (Teflon). On the flute are two cylindrical cells bored equidistant from each other along the periphery. The dimension of the flute is 10mm x 5mm with a hollow opening of 3mm

Drive wheels

The drive wheels are made of mild steel and are integral parts of the seed metering mechanism. The wheels have spindles that bear bolts and rotate the metering device. The surfaces of the drive wheels are fixed with 10 mm long steels cut from10 mm diameter iron rod that provide necessary soil rolling resistance during forward movement of the machine.

Discharge spout

The discharged spout has an opening beneath the hollow pipe from the metering housing. The seed drops directly into the furrow.

Furrow opening device

The furrow opener (adjustable) was made of 50 mm mild steel angle iron with a length of 390 mm. The mild steel is slightly beveled at the lower edge (5^o) to facilitate an easy cut through the soil. To facilitate the attachment of the furrow – opening device to its support, a pipe of 50 mm and 390 mm long was drilled to accommodate an 8mm diameter bolt with the nut welded on the periphery of the drilled hole. The pipe was then welded at the underside of the top portion of the furrow opening device.

Furrow covering device

The furrow - covering device is made of mild steel angle iron rectangular plate of dimension 195 mm x 95 mm. The rod for attachment to the support was welded to the middle of the upper edge of the plate. The covering device is inclined at an angle of 45^o with a spring to the direction of travel for optimum covering of the soil.

Handle

The handle consists of a hollow pipe of 9 mm internal diameter, length 900 mm x 420mm. a bushing of 21 mm internal diameter was welded in a horizontal position to accommodate the handle. The handle can meet the heights of various operators.

Bracer

The bracer is used to create support between the wheel and the housing bearing the shaft.

Fig 1. Side view of the wheel

Fig 2. Furrow opener and closer, discharge spout

Fig 3. Metering device, shaft, bracer and pin

Fig 4. View of an empty housing

Fig 5. Back view of furrow closer

Fig 6. Multi crop hand- push planter

Design Assumptions

The following assumptions were made in the design of the planter: the linear sowing speed of the manually operated planter, 5m/s; the exposed surface of the roller, 28cm; the bulk density of soybean, maize, and cowpea are 640.7, 716.2 and 768.8 kg/m^3, respectively; and the seed rate per hectare for cowpea (0.25kg/ha), maize (0.18kg/ha), and soybean (0.21kg/ha). The sustainable input to any human-power in the form of simulated working or pedaling at about 30 to 40 rpm is considered to be 75W. Therefore; it is assumed that the power requirement for pushing the planter is 50 watts.

Determination of physical and mechanical properties of soybean, maize, and cowpea

The range of shapes and sizes of agricultural grain crops and their physical properties like bulk density grain length, width and thickness as determined by Ndirika and Oyeleke (2002), Shephered and Bhardwaj, 1986, Mohammed (2002) Deshpande and Ali, 1988 and Oyeleke (2002) were made used in designing grain cell sizes on the seed metering unit.

Design calculations

Determination of shaft diameter

The shaft diameter of the planter was determined using standard formula for calculating the diameter of shaft and is given as follows:

$$d^3 = \left[\frac{16}{\pi}S_s\right] \times \left[(K_b M_b)^2 + (K_t M_t)^2\right]^{1/2}$$ (Gupta and Khurmi, 2005) (1)

Where; d = diameter of the shaft, m, M_t = torsional moment, Nm, M_b = bending moment, Nm, K_b = combined shock and fatigue factor applied to bending moment, K_t = combined shock and fatigue factor applied to torsional moment, S_s = axial stress, N/m^2, S_b= bending stress, N/m^2, γ_{XY} = torsional shear stress, N/m^2

Determination of maximum draft of planter

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. The maximum draft is expressed as follows:

$$D_{FM} = R_S \times A_{FO} \times \text{Acceleration due to gravity} \quad (2)$$

Where; D_{FM} = Maximum draft, R_S = Surface area of furrow opener in contact with soil, A_{FO} = Recommended depth of cut X Thickness of furrow opener

Determination of seed rate requirement and the volume of hopper

The seed rate requirement, according to Gupta and Herwanto (1992) is given as follows:

$$SR = \frac{1000}{W \times S_c} \times \frac{1}{1-S} \times SW_{IR} \quad (3)$$

$$W_{IR} = Zab \times \frac{q}{1000} \quad (4)$$

Where; W = Working width (0.90 m as the inter row spacing, commonly used in the study area).

S_C = Circumference of the ground wheel, S = Slip expressed in fraction, W_{IR} = Weight of seeds fallen for one revolution or driving wheel, Z = Number of grooves (maximum value of 4, from machine assumption), a = number of grains per stand (2-3), b = number of rows (1), and, q = weight of 1000 grains (242.8g cowpea, 256.9g maize and 200g soybean from the assumed value of bulk density)

The volume of hopper was determined using Eq. (5)

$$V = \frac{SR}{n \times BD} \quad (5)$$

Where; SR = seed rate per hectare, BD = bulk density, n = number of refilling per ha

Determination of the force required to push the planter

The force required to push the planter was derived from Eq. (6) and (7):

$$F_P = \frac{R_S \cos\emptyset + W_p}{\cos\theta} \quad (6)$$

Where; F_P = Planter push force, F_R = Horizontal soil resistance force,

R_S=Soil frictional resistance force; $R_S = \frac{F_R \tan\theta + W_P}{(\sin\emptyset - \cos\emptyset\tan\theta)}$ (7)

Ø = Angle of friction, θ = Angle between planter handle and horizontal plane, W_P = Weight of planter.

Determination of planter capacity

The capacity of the planter was determined from the following expression:

$$C_{PA} = \frac{\text{Area covered by planter}}{10000m^2}\left(\frac{\text{hectare}}{\text{time}}\right) \quad (8)$$

Where; C_{PA} = Capacity of planter in hectare/time,

Area covered by planter = (Inter-row spacing) x (Distance covered by planter) (m^2/time)

Distance covered by planter = (Speed of planter) x (Time of planting) (m/time)

Principle of operation

The principle of operation of the machine is very simple and requires only one man to operate. Planting is accomplished by just pushing the device in a pre-established furrow. Since the seed hopper is directly attached to the wheel shaft, it will rotate once the wheel rotates. As the seed hopper rotates, seeds will automatically drop into the soil thru the seed outlet by means of gravity. After seeding, the furrow will be covered with soil using a spike-toothed harrow.

Testing and Evaluation

Laboratory Tests

Laboratory testing was undertaken to determine and check any malfunctioning parts and defects in the design as suggested by Christianson and Rohrbach (1986), discovering any defect will lead to changes and improvement in the design. During the test, the number of seed discharged per outlet and number of damaged seeds were noted and recorded.

The hopper was loaded with 333g of cowpea seeds, 311g and 317g of maize and soybean respectively. The planter was suspended on a vice and turning the wheel rotates the metering device. For each investigation, the drive wheels were rotated 25 times at low speed. A stop clock was used to record the time taken to complete the revolutions. The seed discharged were weighed on a weighing balance and the procedure was repeated five times.

Table 1. Calibration Result from Laboratory Experiment of planter (COWPEA)

Trail	Wt. discharged(g)	Time for 25(rev/sec)	Speed (rev/min)
1	4.40	50	30.0
2	4.56	47	28.2
3	5.01	45	27.0
4	4.65	49	29.4
5	4.08	50	30.0
	22.7	48.2	28.92

Table 2. Calibration Result from Laboratory Experiment of planter (MAIZE)

Trail	Wt. discharged(g)	Time for 25(rev/sec)	Speed (rev/min)
1	4.80	48	28.8
2	3.96	50	30.0
3	4.93	47	28.2
4	4.00	53	31.8
5	4.51	49	29.4
	22.2	49.4	29.64

Table 3. Calibration Result from Laboratory Experiment of planter (SOYBEAN)

Trail	Wt. discharged(g)	Time for 25(rev/sec)	Speed (rev/min)
1	5.01	46	27.6
2	4.44	53	31.8
3	4.63	43	25.8
4	4.28	40	24.0
5	4.85	41	24.6
	23.21	44.6	26.76

Table 4. Field Efficiency and Field Capacity Determination of the planter

Trail Activity	Time for 1/10 hectare(s)	Time/hectare(min)
Turning at field ends	50	8.3
Removal of stump	120	20
Adjustment	50	8.3
Actual planting	710	118.3
Total Time	930	154.9

Table 5. Percentage Seed Damage (cowpea)

Trail	No. of seeds discharged	No. of seed damage	Time for 20(rev/sec)	Speed (rev/min)	Percentage damaged (%)
1	75	4	48	28.8	5.3
2	70	3	46	27.6	4.3
3	73	2	43	25.8	2.7
4	76	3	41	24.6	3.9
5	68	1	47	28.2	1.5

17.7%

Average damage = 3.54%

Table 6. Percentage Seed Damage (maize)

Trail	No. of seeds discharged	No. of seed damage	Time for 20(rev/sec)	Speed (rev/min)	Percentage damaged (%)
1	50	1	44	26.4	2.0
2	54	2	40	24.0	3.7
3	50	2	41	24.6	4.0
4	56	1	41	24.6	1.8
5	52	1	45	27.0	1.9

13.4%

Average damage =2.6%

Table 7. Percentage Seed Damage (soybean)

Trail	No. of seeds discharged	No. of seed damage	Time for 20(rev/sec)	Speed (rev/min)	Percentage damaged (%)
1	65	0	47	28.2	0
2	62	1	42	25.2	1.6
3	60	2	41	24.6	3.3
4	64	0	46	27.6	0
5	60	1	44	26.4	1.7
					6.6%

Average damage =1.32%

Table 8. Average Depth of Placement of seeds

Trial	Depth measured for furrow (cm)
1	3.6
2	3.8
3	4.5
4	4.0
5	4.0

Average depth of placement of seeds (cm) = 3.98

Table 9. Distance between Successive Seedlings

Trial	Distance between Seedlings (cm)
1	46
2	41
3	38
4	41
5	38

Average distance (cm) = 40.8

Table 10. Seedlings emergence percentage at day (s) 21

Seeds	R1	R2	R3	Average plant stands	Percentage emergence (%)
Cowpea	23	24	25	24	32
Maize	21	18	20	19.7	36.5
Soybean	19	21	21	20.3	31.7

Damage Test

The test for percentage seed damage was done with the planter held in the same position as described above; the hopper was loaded with 1.0 kg of cowpea seeds, 1.3 kg and 1.1kg of maize and soybean respectively. The wheel was rotated 20 times in turns and the time taken to complete the revolution recorded with the aid of stop clock. The seeds discharged from the spout were observed for any visible external damage.

Field Test

The planting of the seeds was conducted directly on a plot of 10m x 10m area (100m^2) was marked out on the field. The plot was ploughed and harrowed to get a flat bed. The planting operation was carried out 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 plant stand and also observe the missing point along row, the emergence of the seeds planted, effective field capacity, field efficiency and percentage of 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 effects of method of preparation of the field on which the seeds were to be planted, hopper loading capacity and the types of seeds were examined on the field with three replications.

The investigation into the field efficiency and effective field of the planter involved continuous observation and timing of each activity involved in the planting operation. Two persons were involved in the determination of the field efficiency, one person operated the planter on the field while the other person observed and recorded the time for the activities. The time losses were recorded such as turning at field ends, removal of stump and adjustments (change of metering device). Field efficiency and field capacity of the planter was determined as follows

Field efficiency =

$$\left(\frac{Time\ for\ actual\ planting\ operation}{Total\ time\ taken}x100\right) \quad (9)$$

$$\text{Field capacity} = \left(\frac{Area\ cover}{Total\ time\ taken}\right) \quad (10)$$

The average depth of the seeds placement was determined by running the planter at a tilted angle 45^o to the soil surface to and fro over an area of 10 m without the furrow covering closing the hole with a moderate setting of the furrow opener. The time taken to go across the length of the field was recorded to get the average depth; five rows were selected to take the depth using a steel rule to measure. The distances between successive seedlings within row were measured using measuring tape.

Seedling emergence percent

It is the ratio of the number of seeds which emerge from the soil to the number of seeds planted. Emergence counts for this study were taken after three weeks of seeds planting by using Eq. (11).

$$G_p = \frac{P}{S} x\ 100 \quad (11)$$

(Abd El-Tawwab et al., 2007)

Where; G_p = the emergence percent, P = Average plant number per 10m along the sowing row,

S = Average number of delivered seeds per 10m along the planting row.

Result Analysis

Results of laboratory and field Tests

Tables 1, 2 and 3 show the results obtained from the calibration of the planter for cowpea, maize and soybean. It was observed from the Table that the weight of seed discharged were 4.54g, 4.44g and 4.64g respectively. The total average weight of seeds discharged during calibration was 13.62g while the mean discharge was 4.54g. This is within the range of ±7 recommended for optimums inter furrow variation (Bamgboye and Mofolasayo, 2006). The planter effectively discharged 2-3 seeds per hole on the average. The planter design performance was satisfactory because the expected number of seeds were discharged from the metering device.

Determination of field efficiency and field capacity

From Table 4, field efficiency was observed to be 76. 3% from the average values of field efficiency trials. This shows a good and satisfactory performance as it was within the range of values obtained for planting operation by investigators (Kepner et al, 1978; Bamgboye and Mofolasayo, 2006). Also, the effective field capacity of the planter was 0.39 ha/hr. This value agrees with that reported by Bamgboye and Mofolasayo (2006) and has a higher value than that of the manually operated seeding attachment of 0.28 ha/hr. for an animal drawn cultivator developed by Kumar et al., (1986) and that of template row planter developed by Adisa and Braide (2012). This satisfactory result is due to its maneuverability which saves time in moving and turning the planter from one point to another. Also Braide and Njidda (1989) developed a combined jab planter which was found to be 73.4% efficient and was three times faster than manual planting with hoes and cutlass. Olajide and Manuwa (2014) the effective field capacity of the planter was 0.36ha/hr. and efficiency to be 71%.

Tables 5, 6 and 7 show the average percentage of seed damaged (cowpea, maize and soybean) of 3.54%, 2.68% and 1.32%. The hopper incurred seed damage rate of 17.7%, 13.4% & 6.6% respectively. It was observed the second and third average value of percentage seed damage in this work is low compare to 3.15% damage obtained by Bamgboye and Mofolasayo (2006). Seed damage can be due to minimal clearance between the metering devices (flute) and its housing and also due to low speed at which the planter wheels was rotated during the laboratory tests.

Tables 8 and 9 show the depth measurements observed in the determination of the average depth of furrow opener and the distance between successive seedlings. The mean depth of furrow opened at the moderate setting of the opener was 3.98 cm. The distance between successive seedlings of 40.8cm was obtained. These values fall within the recommended sowing depth of 3 -5 cm and a distance of 50 cm respectively (Akinsanmi, 1975; Sule and Ohanwe, 1999; Ojomo and Ale, 2008). The operation of this planter on the field was without much difficulty due to the condition of the soil preparation. The furrow opening device was easily adjustable as the topography of the land demanded.

Determination of seedlings emergence percentage

Table 10 show that maize have higher emergence percentage (36.5%) compare to others. Soybean has the least emergence percentage (31.7%). This research was carried out before planting season of soybean; this may have led to low emergence of soybean as observed in this study.

Conclusion and Recommendations

Conclusion

The design and fabrication of a manually operated multi - crop hand push planter was successfully carried out and evaluated to determine its performance. This multi – crop planter was primarily designed to cater for the need of small farm holders. The overall cost of production was minimal and would be affordable for intended end users, it is easy to maintain and require less labour to use. This planter will go a long way in making farming more attractive. All parts of the planter were fabricated from mild steel material except for the metering devices which were made from good quality plastic (Teflon).

The seed metering devices used for this work was plastic roller type with cells on its periphery. The shaft directly controls the metering devices which eliminate completely attachment such as pulleys, belt systems, gears and thereby eliminating complexities which increase cost and increasing efficiency at a highly reduced cost. The results obtained from the trial test showed that the planter functioned properly as expected with the expected field efficiency of 76.3%. The planter was able to meter 2-3 seeds per hole with a minimum damage to the seeds

The multi-crop planter was able to plant on a flat seed bed at average field capacity of 0.39ha/hr. and field efficiency of 76.3% which will be quite adequate for small scale farming. The total cost of production is twenty-two thousand, five hundred naira only (N22, 500). The machine can be easily maintained without any technicality. Before planting with this planter, the seed must be properly selected and also ensure the seeds are viable.

Recommendations

This project is recommended for further improvement in the following areas;

1. Mechanical power should be introduced to this planter to further reduce drudgery from improve hand technology and increase field operation.
2. The working condition of the planter should be improved whereby the planter can plant on a ridge furrow not only on flat beds,
3. The hopper design of the planter can be modify to increase its capacity during,
4. The planter should be improved whereby fertilizer can be added instantly along planting operation. A fertilizer applicator could be incorporated into this planter.
5. The seed metering device can be modify by increasing the number of cells and also create a proper clearance between the housing and metering to avoid seed damage.

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