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Development and Performance Evaluation of a Two-Row Yam Sett Planter

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---***ABSTRACT***---
A tractor mounted two-row ridge yam sett planter was developed and its performance evaluated. The main features of the planter are: land wheel, metering device, hopper, opener, coverer and frame. The planters' performance was conducted on the field at tractor forward speeds of (2.8, 3.8 and 5.7) km/h respectively. Parameters determined were the effect of speed on planting distance and depth, evenness of planting, rate of operation and metering efficiency. The physical properties such as size and weight, Impact force of yam setts on the soil were also determined.Results showed that the metering device had 100 % efficiencies for all speeds. The planter had a mean planting distance of 0.9 m with dropping evenness of 92 %. Similarly, average theoretical capacities of (0.14 ha/h), effective field capacities of (0.27 ha/h) and field efficiencies of (50 %) of the planter increased with increasing forward speeds. The average length and diameter of the yam setts were 150 mm and 100 mm respectively, while the average weight of the yam setts was 0.35 kg. Experiment on the Impact force of the yam sett on the soilshowed that the distance of fall of 250 mm was suitable for planting the yam setts without causing bruises. The ANOVA results at $p \leq 0.05$ showed that speed had no significant effect on the planting distance and depth. The optimum performance of the planter was at the tractor forward speed of 5.7 km/h and a rate of operation of 2182 yam setts per hour.

KEYWORDS:*Yam, Yam-Sett, Planter, Tractor, Efficiency, Metering, Planting depth, Planting distance and Impact Force*

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I. INTRODUCTION

Yams have a long history of cultivation, dating as far back as 8000 B.C., and have various ritual uses in African cultures. Yams are still important for survival in Africa, and are a primary agricultural commodity in Sub-Saharan Africa, particularly West Africa. Of the total 2010 global production, 47.7 million metric tons commercially harvested from 4.8 million hectares, Nigeria accounted for 61 % of the harvest, with Ghana, Cote d'Ivoire, and Benin also among top producers. Yams can be grown on the flat soil, holes, ridges or mounds, it is traditionally planted on mounds in Nigeria and the sizes of the mounds vary from place to place depending on the size and the hydromorphic nature of the soil [5]. The production of yam is labour intensive, since almost all yam farmers use the traditional method of planting (hoe-cutlass technology) with little size of farm holdings. As a result of its demand for labour, many farmers are majorly old people and if mechanization is not done, yams might go into extinction. A good number of researchers have attempted to mechanize the planting of yam setts using planting machines but without much success as a result of clogging/blockage of yam setts at the hopper throat and metering problems[2]. In recent years, yam is becoming expensive and relatively unaffordable and its production has not been encouraging. The production has not kept pace with population growth and its demand exceeds supply. Consumers are turning more and more to the less expensive cassava even though they prefer yam [3].

To be able to satisfy the growing domestic demand for yam, both as food and as an agro-industrial raw material require the urgent development of a mechanization package for all phases of its production of which the development of a two-row yam-sett planter is considered a necessary step. Also, is the total elimination of drudgery in the making of mounds, as the planting of the yam setts will now be on ridges.

II. METHODS

2.1Description of the Two-Row Yam Sett Planter.

Fig. 1 is the view of the fabricated two-row yam sett planter, while Fig. 2shows the orthographic view of the planter showing the plan, front and the end views in 3rd angle projection and detailed drawings of the device. The planter is tractor mounted by first attaching it to the frame of the ridger which is then hitched to the three-point linkage of the tractor. The device has a cylindrical hopper (part no 16) which is 150 mm high with a diameter of 500 mm. The cylinder is made from mild steel sheet which is 3 mm thick. Inside the cylinder is an arrangement of metal sheets demarcated into 9 segments at 40^{o} (metering element; part no. 3). The metal sheets are arranged in a nonagonal pattern in the cylinder in order to ensure effective metering of the yam setts. It is mounted on a fixed platform attached to the furrow opener (part no. 13) to ensure easy movement and dropping of the yam sett into the ground by gravity.

Figure 1: View of the Fabricated Two-Row Yam-Sett Planter.

The metering mechanism is mounted on a fixed platform made of mild steel and the chute (part no. 8) is attached to this platform by the aid of bolts and nuts. The fixed platform has a diameter of 500 mm, with a thickness of 3 mm. An opening/orifice is made on the fixed platform which links the metered yam to the chute. The chute is made from rubber and has a thickness of 8 mm and it shields/guides the yam without falling off the ridges when it drops. The furrow opener is a component which opens the ridges to enable the yam setts sit properly on the ridges. It is made of mild steel 8 mm thick and was constructed with a "V" shaped pointed head to enable it penetrate the soil during draft. The movement of the metering device is controlled by a land wheel (part no. 10) made from mild steel with lugs to enhance trafficability. From the land wheel is an assembly of simplex chain drive which is used to connect the land-wheel to the shaft of the pinion which drives the main gear that rotates the metering device.

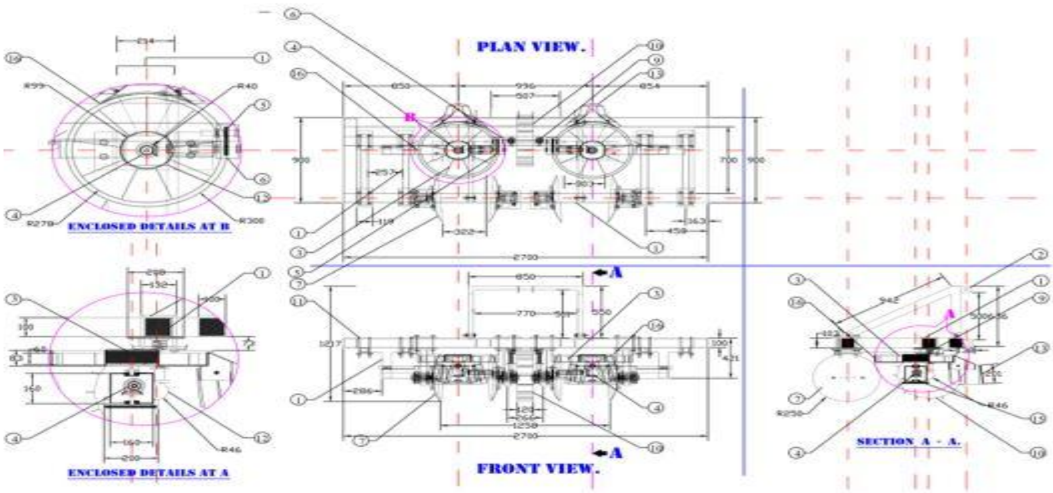

Figure 2: Orthographic View of the Planter Showing the Plan, Front and the End Views in 3rd Angle Projection

The chain drive is facilitated by sprockets, with the driven sprocket having more number of teeth than the driver, and also the driven gear having twice the number of teeth of the driver. The choice of teeth is to reduce speed of rotation of the metering device in order to achieve evenness in the intra-row planting space.
Metering unit is driven by land wheel and can meter two yam setts per revolution of the land wheel at an average planting space of 900 mm. The land-wheel has a diameter of 600 mm and a distance of 1.88 m in a revolution allowing two yam setts to be planted.

2.2Method of Administering Planting

Firstly, the tractor will take a pass with the ridger to make ridges then a second pass attaching the planter to the tractor for planting to be carried out. As the land-wheel rotates and transmits power to the metering unit through chain, sprocket (part no. 5) and bevel gear arrangement (part no. 4). Yam setts loaded in the cylindrical metering unit flows in a continuous circular pattern where it eventually drops in the space that links the chute directly into the ridge at a depth of 150 mm. The furrow opener is a component attached to the orifice of the metering device and it is adjustable to suit the farmers planting depth specification. It opens the ridge by making a groove along the ridges, so that yam setts that drop on the ridges do not fall off to the bare ground. The chute also guides the yam safely into the groove created by the opener. When the yam sett drops in the groove, the coverer (part no. 7) completes the planting by burying the yam sett with soil. The coverer consists of four discs (two for a ridge) adjusted at an angle of 45^o and 30^o respectively, such that the 30^o disc first collects the soil to partly cover the yam sett then the 45^o disc collects the soil that finally buries the yam sett. Table 1 shows the specification of the yam-sett planter.

Table 1:Specification of the Two-Row Yam Sett Planter

Parameter	Specification
Weight of Frame	224 kg
Overall length of machine	2700 mm
Overall width of machine	1300 mm
Overall height of machine	1055 mm
Overall weight of machine	430 kg
Diameter of solid shaft connecting bevel gears	
Hopper capacity	50 mm
Weight of metering device +	16 yam setts
hopper + yam setts	23 kg
Height of Ridges	0.9 – 1.2 m
Width of Ridges	0.9 – 1.0 m
Furrow Spacing	0.9 – 1.0 m
Power requirement to drive the Planter	12 kW

2.3Determination of Physical and Mechanical Properties Relevant to Planting

Yam sett physical properties were determined and used to design the hopper of the planter. Yam sett properties determined were average sizes of yam setts and average weights of yam setts. The mechanical property determined was the impact force, which is the force that can bruise the setts during planting.

2.3.1Size of yam sett

Yam tubers were bought from North-bank market (Makurdi) and sliced into required planting sizes. The various dimensions of the sliced yam sett were taken and recorded using measuring rule.

The average length of the yam sett provided the necessary information required to achieve the length of the metering device in the hopper, while the average diameter of the yam sett provided information on the spacing between the metering device that could accommodate one yam sett at a time.

2.3.2 Weight of yam sett

A weighing balance was used to determine the weight of yam sett. 48 yam setts were measured on the balance one by one and the weight noted and recorded for each yam sett. This information on average weight of the yam setts was used to determine the bearing capacity of the hopper.

2.3.3 Determination of impact force

48 yam setts were released at a height of 200 mm, 250 mm, 300 mm and 350 mm, respectively, to fall on the soil. The aim of the exercise was to ensure that there was minimal or no bruises on the yam setts during impact on the soil in the process of planting. It also provided information on height difference (clearance) between the hopper and the ridges.

The impact force (FI) was calculated using equation 1,

$$FI = M_{av} \cdot g \qquad (1)$$

Where, M_{av} = average mass of yam setts (kg),

g = acceleration due to gravity (m/s^2)

2.4Evaluation of Planter

The planter was evaluated on a field layout of 100 m by 100 m that was earlier ploughed and harrowed. The evaluation was replicated 3 times at the tractor forward speeds of 2.8, 3.8 & 5.7 km/h at 21 m length of run in order to determine the effect of speed on planting distance, rate of operation, depth and metering efficiency. The theoretical and effective field capacities & efficiency were also determined.

2.4.1 Determination of metering efficiency

The metering efficiency (η_m) was calculated using equation 2.

$\eta_{m=\{}s_m/s_{e\}} \times 100$ % (2)

Where;

η_m is the metering efficiency (%)

S_m is the number of yam sett metered

$S_e$is the number of yam sett expected

2.4.2 Determination of evenness of planting

The evenness of dropping/planting of yam setts from the developed two-row planter was calculated using equation 3.

$$E = \frac{Y - S_d}{Y} \times (100\ \%) \quad (3)$$

Where;

E is the evenness of dropping/planting of yam setts (%)

Y is the distance between two dropped/planted yam setts (m)

2.4.3 Determination of rate of operation of planter

The rate of operation of the planter (R) was determined using equation 4.

$$R = \frac{P_y}{T} \quad (4)$$

Where;

P_y = No. of yam setts planted

T = Time taken (s)

2.5Determination of Planter Capacities and Efficiency

The planter capacities were determined by calculating the theoretical and effective field capacities, while the planter efficiency was determined by calculating the ratio of the effective and theoretical field capacities.

2.5.1 Theoretical field capacity

This is the rate of field coverage possible if the machine works all the time at the recommended speed and utilizes its entire width of operation (it takes into account all the times used for planting, turning and resting among others). The theoretical field coverage is determined at the tractor forward speed of 2.8, 3.8 and 5.7 km/h and is accomplished on a 100 m by 100 m field layout in three replications. Its unit is in hectare per hour. This was calculated using equation 5.

$$T_{fc} = T_l + T_p + T_t + T_r \quad (5)$$

Where,

T_{fc} = theoretical field capacity (ha/h)

T_l = rate of field coverage for loading (ha/h)

T_p = rate of field coverage for planting (ha/h)

T_t = rate of field coverage for turning (ha/h)

T_r = rate of field coverage for resting (ha/h)

2.5.2 Effective field capacity

This is the actual rate of coverage by the machine. It represents the time taken to carry out the actual planting only. The unit is also in hectare per hour. It was calculated using equation 6.

$$E_{fc} = T_p \quad (6)$$

Where,

E_{fc} = effective field capacity (ha/h)

T_p = rate of field coverage for planting (ha/h)

2.5.3 Field efficiency

This is the ratio of effective field capacity to theoretical field capacity. This was calculated using equation 7.

$$F_e = \frac{T_{fc}}{E_{fc}} x \frac{100}{1} \quad (7)$$

Where;

F_e is field efficiency (%)

E_{fc} is effective field capacity (ha/h)
T_{fc} is theoretical field capacity (ha/h)

III. RESULTS AND DISCUSSION

Table 2 showed the theoretical field capacity, effective field capacity and field efficiency of 0.1302 ha/h, 0.2677 ha/h and 48.66 %, respectively at the tractor forward speed of 2.8 km/h. Tractor forward speeds of 3.8 km/h gave a theoretical field capacity, effective field capacity and field efficiency of 0.1358 ha/h, 0.2743 ha/h and 49.51 %, while that of 5.7 km/h gave a result of 0.1413 ha/h, 0.2806 ha/h and 50.36 %, respectively. Comparing the 3 forward speeds, 5.7 km/h speed gave the best field efficiency than that of 2.8 km/h and 3.8 km/h. The effective field capacity for manual rate of planting yam sett is 80 h/ha (i.e. 10 days to plant on a hectare) [2], which compares very poorly to the effective field capacity of the developed planter of 3.5 h/ha. The device is capable of accomplishing what a farmer (working at 8 hours per day) can do in 10 working days within 3.5 hours. It also showed summary of metering efficiency at various speeds. The table showed that metering efficiency remained constant at the various tractor forward speeds. The metering efficiency remained at 100 % as the tractor forward speed increased from 2.8 km/h to 5.7 km/h. This implies that the different tractor forward speeds do not affect the metering efficiency. The metering efficiency of 100 % obtained is a great improvement over the 73 % metering efficiency obtained by [2]. It also surpassed the metering efficiency of 98 % [4] for a minisett planter, and 82 % for metering equipment for mechanized yam sett planting [1].

Table 2:Summary of Field Results at Various Tractor Forward Speeds

	Field parameters				
Speed (km/h)	**Theoretical field capacity (ha/h)**	**Effective field capacity (ha/h)**	**Field efficiency (%)**	**Metering efficiency (%)**	**Evenness of planting (%)**
2.8	0.1302	0.2677	48.66	100	92
3.8	0.1358	0.2743	49.51	100	92
5.7	0.1413	0.2806	50.36	100	92

The Table also carried information on the evenness of planting at various tractor speeds. The average distance of planted yam sett was 0.9 m with an evenness of planting of 92 % irrespective of the tractor speed. This showed that speed had no influence on the distance of planting yam setts and evenness of planting.

Table 3 showed the impact analysis of yam setts on the soil. Yam setts were released at a certain height to fall on the soil. Heights considered were 200, 250, 300 and 350 mm. It was discovered that at the height of 200 mm, there were no bruises on the yam setts, but the hopper was too close to the opened ridges, thereby disrupting the orientation of the ridges. At the height of 250 mm, there were no bruises on the yam setts and there was a clear distance between the hopper and the opened ridges. At heights 300 and 350 mm, there were little bruises on the yam setts but the clearance between the hopper and the opened ridges was good. In conclusion, 250 mm was recommended as the height suitable for planting and it is the height between the hopper and the point where the yam sett is planted.

Table 3: **Impact Analysis of Yam Setts on the Soil**

Distance of fall (mm)	**Observation** 1st Test	2nd Test	3rd Test
200	-No bruises -Hopper: ridge clearance too close	-No bruises -Hopper: ridge clearance too close	- No bruises -Hopper: ridge clearance too close
250	-No bruises -Hopper: ridge clearance is good	-No bruises -Hopper: ridge clearance is good	-No bruises -Hopper: ridge clearance is good
300	-Little bruises -Hopper: ridge clearance is good	-Little bruises -Hopper: ridge clearance is good	-Little bruises -Hopper: ridge clearance is good
350	-Little bruises -Hopper: ridge clearance is good	-Little bruises -Hopper: ridge clearance is good	-Little bruises -Hopper: ridge clearance is good

Table 4 showed the rate of the planter operation at the different tractor forward speeds of 2.8, 3.8 and 5.7 km/h to be 58, 59, 62 (%), respectively. 5.7 km/h had the highest number of yam sett planted per second. Therefore, the tractor forward speed of 5.7 km/h is preferable for planting since it had the highest rate of operation.

Table 4:Rate of Planter Operation at Various Speeds

Tractor forward speed (km/h)	No. of yam setts planted	Average Time taken (s)	Rate of operation (yamsett/s)
2.8	48	83	0.58
3.8	48	79	0.60
5.7	48	76	0.63

Table 5 showed the summary of the ANOVA test on the effect of various tractor forward speeds on the planting distance and depth. The table showed that speed had no significant effect on the planting depth and on the planting distance.

Table 51: Summary of ANOVA of the Effect of Tractor Forward Speed on the Planting Distance and Depth

Factors	SV	Df	SS	MS	Fcal	Ftab
Planting distance	Speed	2	0.0002	0.0001	8.00^{ns}	6.94
	Error	4	0.00005	0.0000125		
	Total	8	0.0003			
Planting depth	Speed	2	0.0017	0.0009	0.900^{ns}	6.94
	Error	4	0.0040	0.001		
	Total	8	1.0054			

ns = not significant at $p \leq 0.05$

IV.CONCLUSIONS

4.1 Conclusions

It was concluded that:

1. The two-row yam sett planter was developed and its performance evaluated successfully.
2. The yam sett parameters for length, width and weight were 150 mm, 100 mm and 350 g, respectively.
3. The planter has a 100 % metering efficiency.
4. Speed had no significant effect on depth of planting and planting distance.
5. The planter has a mean planting distance of 0.9 m with an evenness of planting of 92 %.
6. The planter has a maximum field efficiency of 50.36 % at tractor forward speed of 5.7 km/h.

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