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Effect of Tractor Forward Speed on Metering Efficiency and Evenness of Planting of a Device for Mechanized Yam Sett Planting

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Abstract

A tractor mounted yam (Dioscorea spp) metering device was designed and fabricated and its performance evaluated. The device was designed to minimize the clogging of yam setts at the throat of the hopper, a problem that has adversely affected mechanization of yam planting. The main features of the developed device are the hopper, the metering mechanism, delivery chute, and frame and land wheel. The metering device was evaluated on a flat field at forward speeds of 2.8, 3.8, 5.7 and 7.5 km/h. The field evaluation determined the evenness of dropping at the various forward speeds. The theoretical field capacity (ha/h), effective field capacity (ha/h) and field efficiency (%) were determined. The dropping rate of the device was determined and compared with manual rate of planting yam setts using the traditional "hoe-and machete" technology. Analysis of variance (ANOVA) at $P \leq 0.05$ was used to determine if speed had any significant effect on metering efficiency and evenness of dropping. Results obtained show that the highest metering efficiency of 73% was obtained at the forward speed of 2.8 km/h. The metering efficiency decreased with increasing forward speeds. The ANOVA showed that speed had a significant effect on the metering efficiency and the spacing between dropped yam setts. The yam setts were dropped at a mean spacing of 1.2 m apart with evenness of dropping of 88%. Similarly the theoretical field capacity, effective field capacity and field efficiency of the device decreased with increasing speed. The manual planting rate was 144 yam setts per hour which is equivalent to 1152 setts for a farmer working at 8 h per day. Correspondingly, the device dropped 782 setts per hour, which is equivalent to 6255 setts if the device also works at 8 h per day. When the device runs for 13.2 h, it is capable of doing what a farmer working at 8 h per day can do in 10 working days. The device cannot be operated in reverse direction and is recommended to be operated at a forward speed of 2.8 km/h. This device can, therefore be used to enhance the mechanization of yam planting when opener and covering mechanisms are attached.

Keywords: *Efficiency, Mechanized, Metering, Planting, Sett, Speed, Tractor and Yam*

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I. INTRODUCTION

Yam is a tropical root crop. It belongs to the Genus: *Dioscorea* and occurs in different species such as white yam (*D.rotundata*), yellow yam (*D.Cayenensis*) water yam (*D.alata*), Chinese yam (*D. esculenta*) and aerial yam (*D.bulbiteria*). Yam is a staple food crop in West Africa second to cereals [1]. Small- scale farmers who use the "hoe-and machete" technology are the major producers of yams. Yam production in West Africa is decreasing at an annual rate of about 1% [2]. 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 yams [1].

Traditionally, yams are planted manually on soil that is mounded from 50-100 cm in height. Yams are sometimes planted in previously prepared holes or trenches, with the soil then covered flat, mounded or ridged depending on the locality. The orientation of yam setts does not affect their emergence since many parts of the setts will sprout under favorable conditions [3] and [4]. Manual planting of yams entails very heavy back-breaking work which coupled with the very high labor intensity of all the other phases of its cultivation severely limits the development of large scale yam production in Nigeria. Yam planting materials include seed yams and mini setts or yam setts Seed yams are small whole tubers, which usually weigh between 100 g and 150 g. The number of setts used varies according to the species and the cultivar, but for most large-tuber yams 10,000-15,000 per hectare are used, requiring a sett application rate of at least 2.5 t/ha [5]. Yam setts are culturally accepted, readily available and constitute the main planting material used by the small scale farmers.

[6] reported that stanchion (vertical pole) ridges were used for mechanizing yam planting.[7] reported that in the development of a yam planter, the metering mechanism represents the major work of innovation because of the choking and blockage at the throat of the hopper, which is the section where material discharges from the hopper. [8] reported the importance of developing a mechanical yam sett planter that will overcome the traditional agronomic practices and will be culturally acceptable to farmers

Earlier efforts at developing yam planting device were made by [9] and [10]. These devices had varied performances, some performed very poorly, some better than others in metering efficiency and evenness of planting. The objective of this study was to determine the effect of tractor forward speed on the metering efficiency and evenness of dropping of a device for mechanized yam sett planting

II. MATERIALS AND METHODS

Description of planting device

A metering device was designed and constructed for a tractor mounted mechanized yam setts dropping (Fig.1) while some hidden parts of the device were showed in (Fig.2). The device is tractor mounted by hitching it to the three-point hitch of the tractor. The device has a trapezoidal hopper (fig.1). Inside the hopper is an arrangement of metal sheets inclined at 58^0 and these metal sheets are arranged in a serpentine (zigzag) pattern in order to reduce yam setts clogging and ensure easy movement of yam setts to the picker (fig. 2) riveted on the belt to pick one yam sett at a time.

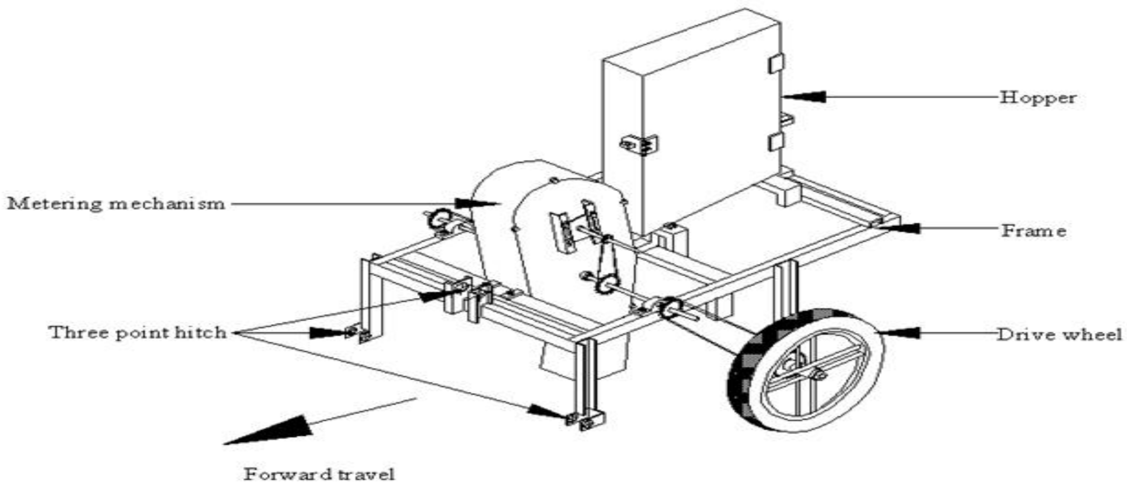


Figure 1: Isometric Drawing of the Yam Metering Device. To show components, safety shields on chain drives have been removed

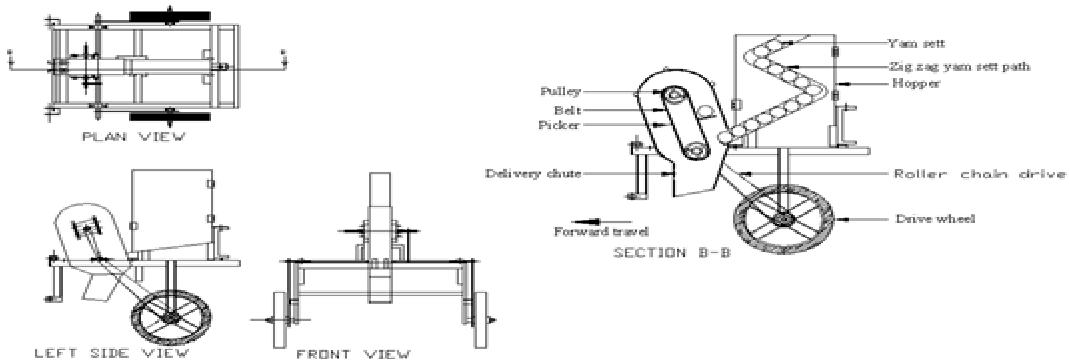


Figure 2: Orthographic views of the Metering Device in 3rd angle projection. To show components, safety shields on chain drives have been removed

The hopper has a capacity of 40 - 70 yam setts. The hopper end projects into the metering unit. The projected sheet metals in the metering unit are strips of metal cut to allow pickers to pass through freely and lift yam setts. On the flanges are stop rods welded to wedge yam setts from further movement and prevent contact of yam setts with the conveying belt.The metering unit is driven by a land wheel and one revolution of the land wheel, meters two yam setts at an average dropping space of 1010 mm.

Yam setts loaded in the hopper flow along the zigzag channel to the metering unit where they are picked by pickers which rotate upward and lift yam setts out of the hopper load relief platform. Yam setts fall and flow into the delivery chute. Figure 3 shows the metering device loaded with yam setts and hitched to a tractor on flat ground for field test. Specifications of the metering device are shown in Table 1.

Figure 3: Field test of yam metering device on flat ground.

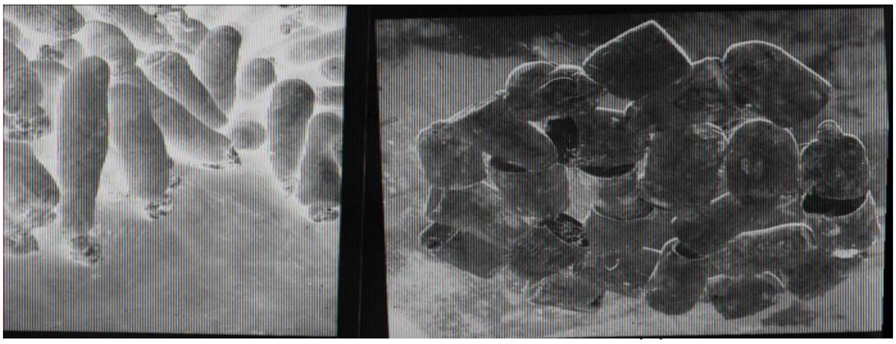
Table: 1. Physical Specification of the Metering Device

Parameter	Specification
Overall length of machine	1500 mm
Overall width of machine	1000 mm
Overall height of machine	1904 mm
weight of machine	177 kg

2.1 DETERMINATION OF YAM SETT PROPERTIES

Yam sett properties were determined and used to design the hopper of the metering device. Yam sett lengths, diameters, and weights were determined and the angle of repose was measured.

Yam tubers (fig. 4a) were bought from the Wurukum market in Makurdi, Nigeria and sliced into average planting sizes of 100 mm long and yam setts (fig. 4b) used in the design of the device hopper, allowed for some days for drying of the sliced surfaces before dropping to avoid rotting.



(a) (b)

Figure 4: Yam tubers (a) and yam setts

Weighing balance was used to determine the weight of fifty yam setts. The yam setts were put on the balance one by one and the weight noted and recorded for each yam sett.The angle of repose of yam sett was determined using fifty yam setts from the angle of repose measuring device developed by the Department of

Agricultural Engineering University of Agriculture at Makurdi, Nigeria. A simple device having two arm of wooden material hinged together with a protractor attached to one of the arms which stands vertically. The other arm which carried the yam sett was moved along the graduation of the protractor and watched closely to see when the yam sett will start to slide or roll easily down the length of the arm. The angle at which the sliding of yam sett occurred was noted and recorded as the angle of repose for the yam sett.

2.2 FIELD EVALUATION

The field evaluation of the device was undertaken to determine the metering efficiency, theoretical field capacity, effective field capacity, field efficiency and evenness of planting. These parameters were determined at the tractor forward speeds of 2.8, 3.8 and 5.7 km/h for a distance of 30 m. The metering efficiency, percentage of broken tuber and evenness of dropping were determined from equations 1, 2, and 3, respectively [11]. The theoretical field capacity, effective field capacity and field efficiency where determined from equation 4, 5, and 6 respectively [11].

2.3 METERING EFFICIENCY

$$_m | s_e \} \times 100\% \qquad (1)$$

The number of bruised tubers was calculated using

$$l\ tuber = \left[\frac{S_b}{S_m}\right] \times 100\% \qquad (2)$$

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
S_b is the number of yam sett bruised

2.4 DETERMINATION OF EVENNESS OF DROPPING

$$- \times 100\% \qquad (3)$$

Where:
E is the evenness of dropping of yam setts (%)
Y is the mean spacing between two dropped yam setts (m) and
S_d is the standard deviation of Y.

2.5 THEORETICAL FIELD CAPACITY

This is the rate of field coverage possible if the device works all the time at the recommended speed and utilizes its entire width of operation (it takes into account all the times used for dropping, turning and resting among others). The theoretical field capacity was determined from equation 4 [11].

(4)

Where T_{fc} is the theoretical field capacity (ha/h)
T_l is the total time for loading yam setts into the hopper (h)
T_d is the total time for drooping yam setts (h)
T_t is the total time for turning of tractor (h)
T_r is the total time for resting (h)

2.6 EFFECTIVE FIELD CAPACITY

This is the actual rate of coverage by the device. It represents the time taken to carry out the actual placement of yam on the ground only. The effective field capacity was determined from equation 5 [11].

(5)

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

2.7 FIELD EFFICIENCY

This is the ratio of effective field capacity to theoretical field capacity. The field efficiency was determined from equation 6 [11].

$$\times 100 \qquad (6)$$

Where F_e is field efficiency (%)

2.8 DETERMINATION OF MANUAL PLANTING RATE

The manual planting rate was determined by planting of yam sett per mound using the hoe technology on four different farms located in Makurdi, Nigeria. Planting was done on each of the farms by male farmers of average age of 45 years, height of 1.65m and weight of 69kg. A stop watch was used for timing the planting operation, while a measuring tape and weighing scale was used to measure the height and weights of the farmers respectively. The manual planting rate was determined as the number of planted yam setts in an hour. Figure 5 is a flow chart showing manual yam planting procedure.

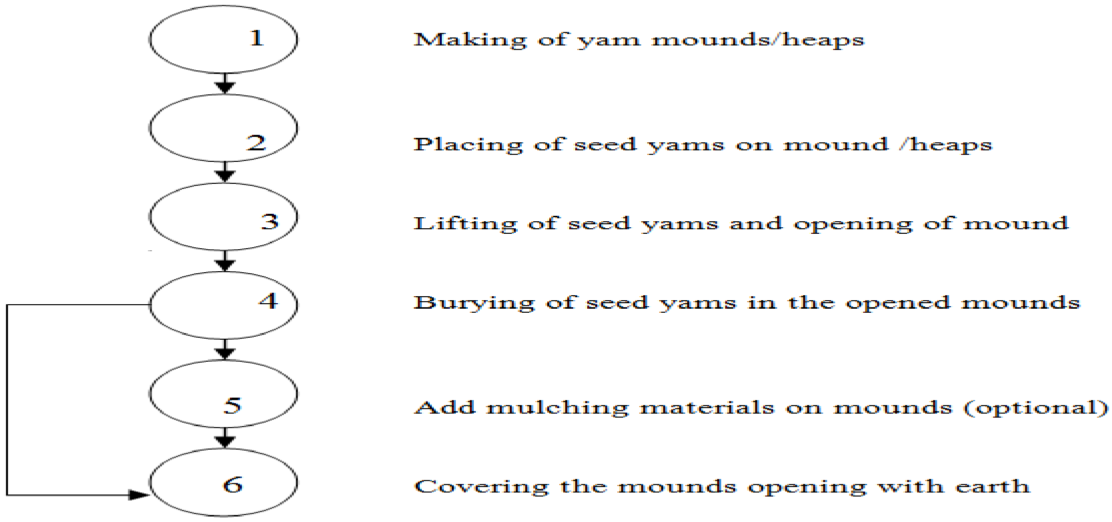


Figure 5 Flow chart of manual planting of yam Seeds

2.9 MEASUREMENT OF DRAFT

The total draft of the device was measured using a set of two tractors. In the first instance the combined draft of the tractor and the planting device was recorded from the dynamometer. The planting device was then disconnected and the draft of the tractor alone was determined using the same dynamometer at the same speed of run. The draft was calculated as the difference in the two readings.

2.10 ANALYSIS OF RESULTS

Randomized complete block design at four different dropping speeds with three replications was adopted to determine the metering efficiency while dropping spacing and evenness of dropping was determined from randomized complete block design at three different speeds with three replications. ANOVA tables were used to test for significant effects at $p \leq 0.05$. Simple mean and percentage was used to analysis results from manual rate, yam sett properties, theoretical field capacity, effective field capacity and field efficiency

III. RESULTS AND DISCUSSION

The average length, width, weight and angle of repose of yam setts used in this study was 15 cm, 10 cm, 450 g and 58^0 respectively (Table 2). Plant able yam setts may weigh as much as 100 to 150 g with diameters, of 4.5 to 10.0 cm, and length, varying from 15 to 25 cm [5],[12] & [7]. The hopper of the device was inclined at 58^0 according to the determined angle of repose. The determined size of yam sett and angle of repose were used to design the zigzag structure that contained the yam setts in the hopper. This arrangement may have accounted for eliminating the well-known problem of clogging at the throat of the hopper of existing yam planters.

Table 2: Selected mean physical propert ies of yam setts (Species *Dioscorearotundata;* Cultivar: *Gbangu*)

Parameter	Item
Yam Sett Size	
Length	150 mm
Diameter	100 mm
Weight	450 g
Angle of Repose	58°

Summary of metering efficiency of the device at various speeds is presented in Table (6). The figure showed that metering efficiency decreased with increasing tractor forward speed. The metering efficiency decreased from 73% to 63% as the tractor forward speed increased from 2.8 km/h to 5.7 km/h. The best metering efficiency of 73% was obtained at the tractor forward speed of 2.8 km/h. This is lower than the metering efficiency of 98% [7] for a minisett planter, and 82% [9] for metering equipment for mechanized yam sett planting. This may be because these machines used minisetts, which had relatively smaller size, shape and frictional characteristic compared to the yam setts used in this device. Also, the planter developed by [9] employed a conveyor in its metering.

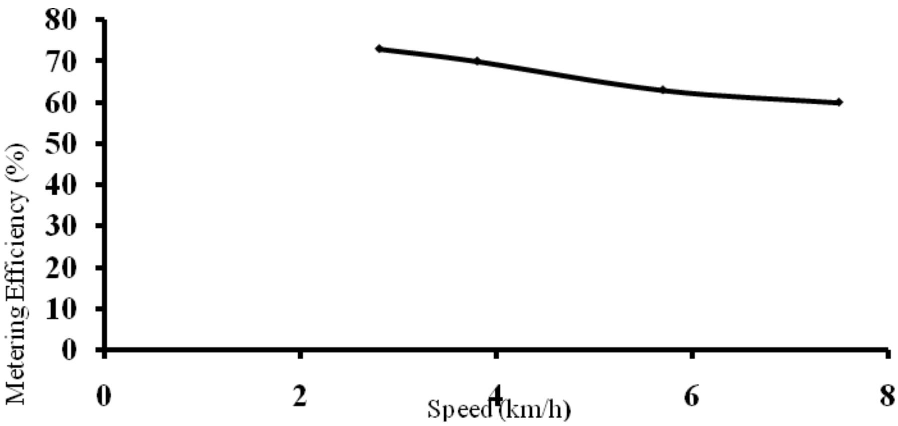


Figure 6 Metering Efficiency at various Speeds

Table 3 shows Theoretical Field Efficiency, Effective Field Capacity, Field Efficiency, Distance and Evenness of Spacing at Various Tractor Forward Speeds. When the device runs for 13.2 h, it is capable of doing what a farmer working at 8 h per day can do in 10 working days.

Table 3: Summary of field results at various speeds

Parameters	Speed (km/h)		
	2.8	3.8	5.8
Theoretical Field Efficiency (ha/h)	13.0	12.0	12.0
Effective Field Capacity (ha/h)	1.5	1.2	1.0
Field Efficiency (%)	11.0	10.0	9.0
Mean Dropping spacing (m)	1.20	1.20	1.18
Evenness of dropping (%)	88	88	88

Mean spacing between dropped yam setts was 1.2 m with evenness of dropping of 88% at all the speeds investigated. Hypotheses Tests for metering efficiency and dropping spacing at $P \leq 0.05$ (Table 4) showed that speed had significant effect on metering efficiency and the spacing between dropped yam setts. The significant difference in spacing between dropped yam setts may have been because the metering mechanism was ground-driven and could be affected by wheel slip.

Table 4: Tests of hypotheses for metering efficiency and dropping spacing

Parameters	Source	Ff	SS	MS	F-value	Pr >F
Metering Efficiency	Speed	3	15	5	5*	4.76
	Replicates	2	2	1	1	
	Error	6	6	1		
	Total	11	23			
Dropping Spacing	Speed	2	0.0014	0.0007	14*	3.33
	Replicates	2	0.0002	0.0001	2.0	
	Error	4	0.0002	0.00005		
	Total	8	0.0018			

*significant at $p \leq 0.05$

The mean manual planting rate was 144 yam setts per hour.(Table 5) This represents a field capacity of 0.002 ha/h, which compares very poorly to the effective field capacity of the developed metering device of 1.5 ha/h at the speed of 2.8 km/h (Table 3) and (Table 6).

Table 5: Manual Planting Rate

Farm Plot	Number of yam setts planted	Time Taken to Plant(h)	Planting Rate (setts/h)
A	400	3.4	118
B	400	3.0	133
C	400	3.4	188
D	400	2.9	138
Mean	400	3.2	144

The technical specification of the device (Table 6) has a draft of 52 N, mean dropping space of 1.2 m, evenness of dropping of 88%, theoretical field capacity, effective field capacity and field efficiency of 0.076 ha/h, 0.667 ha/h and 11% respectively.

Table 6: Technical Specifications of the Device

Parameter	Value
Evenness of dropping	88%
Mean dropping space	1.20 m
Draft	52 N
Theoretical Field Capacity	0.10 ha/h
Effective Field Capacity	0.70 ha/h
Field Efficiency	11%

IV. CONCLUSIONS

[1] It can be concluded that:-
[2] The device was capable of eliminating clogging/blockage at the throat of the hopper.
[3] The metering efficiency decreased with increasing forward speed of the tractor. Metering efficiency decreased from 73% to 60% as tractor forward speed increased from 2.8 km/h to 7.5 km/h.
[4] The theoretical, effective field capacities and field efficiency decreased with increasing tractor speed.
[5] Speed had a significant effect on metering efficiency and spacing between dropped yam setts
[6] The mean spacing between dropped yam setts was 1.2 m with evenness of dropping of 88% and
[7] When the device runs for 13.2 h, it is capable of doing what a farmer working at 8 h per day can do in 10 working days.

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