Indian Journal of Design Engineering (IJDE)
ISSN: 2582-8584 (Online), Volume-1 Issue-2, August 2021

Field Capacity and Efficiency of a Turmeric Rhizome Planter in Response to Machine Speeds and Some Selected Crop Parameters

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***Abstract**: This study present variation in field capacity and efficiency of a turmeric rhizome planter in response to the machine speed and some selected turmeric parameters (dimension); turmeric rhizome length and diameter. This was done with a view to ascertaining the best condition under which the planter could perform optimally. The land area covered in a specific duration by the planter depends largely on the field capacity. The turmeric rhizome planter consists of trapezoidal hopper, grooved cylindrical metering devise, ground wheels made of mild steel, chain/sprocket drive system, three linkage point and frame. The experiment was randomized in a factorial design of three levels of rhizome lengths of 30, 45 and 60 mm, diameter of 25, 30 and 35 mm and operational speeds of 8, 10, and 12 kmh-1. The result of the study shows that increase in planter operational speed resulted in an increase in field capacity and efficiency of the planter, and had a significant effect on them. The turmeric rhizome lengths and diameter were found to have insignificant effects on the field capacity and efficiency of the planter.*

***Keywords**: Dimension, Planter, Speed, Turmeric.*

I. INTRODUCTION

Turmeric (*Curcuma longa linn*) belongs to the same family as ginger (*Zingiberaceae*). It grows in the same hot and humid tropical climate. The rhizome is deep bright yellow in colour. Turmeric was derived from Latin word terra merita (merited earth) [1]. India is the largest producer, consumer and exporter of turmeric. Indian turmeric has been known to the world since ancient times. It has been used as a dye, medicine and flavouring since 600 BC [2]. In spite of increasing demand for derived products of turmeric in Nigeria which makes its large-scale production attractive, it is still cultivated mainly in small plots around homes. In Nigeria, turmeric has not gained the desired attention that will boost its large-scale production. According to [2], turmeric has little or no mechanization in its production processes from planting to harvesting in Nigeria. Turmeric, if fully mechanized, will ensure timeliness of operation in the farm and reduce cost and drudgery associated with planting, mulching and harvesting. In an attempt to address this turmeric planter was developed at Federal University of Technology, Minna, Niger State, Nigeria. The field capacity of the machine is expressed as the area of field covered in given time. The differences between field capacity in relation to the planting speed may be related to the other variables that are occurring and not being considered such as turmeric rhizome length and diameter for the optimal performance of the mechanism.

The objective of this study is to investigate the influence of machine speed, as well as turmeric rhizome length and diameter on field capacity of a tractor-drawn turmeric rhizome planter.

Manuscript received on 11 June 2021 | Revised Manuscript received on 29 July 2021 | Manuscript Accepted on 15 August 2021 | Manuscript published on 30 August 2021.

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II. MATERIALS AND METHODS

A. Materials

Turmeric Rhizome Sample

A turmeric rhizome sample and a demonstration plot at the Department of Agricultural and Bioresources Engineering, Federal University of Technology, Minna, Nigeria were used for the study.

Equipment

A turmeric rhizome planter (Figure 1) developed at the Department of Agricultural and Bioresources Engineering, Federal University of Technology, Minna, Nigeria, was used in the study. The planter consists of the ground drive wheel, hopper, metering system furrow opener, residue cutting edge, furrow closing device press wheel and power transmission mechanism. A 75mm x 75mm x 6mm angle iron was used for the construction of the frame and also the 3-point hitching linkages system. The hopper was made from 1.5 mm thick mild steel sheet. It has a trapezoidal shape (340 mm x 340 mm) top and (70 mm x 40 mm) lower end. A rubber seal was fixed round the lower end to avoid bruising of the rhizomes. The metering device was constructed in a circular disc. The circular disc has six grooves of 70 mm x 60 mm x 50 mm. The disc is slightly touching the hopper which is standing vertically above the metering device. This is to ensure that the rhizomes fall into the grooves of the metering system. The power generated by the ground wheel rotates the metering system through a chain transmission system.

Retrieval Number:100.1/ijde.B8002081221
DOI: 10.54105/ijde.B8002.081221
Journal Website: www.ijde.latticescipub.com

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The metering disc on rotation drops the rhizome into the delivering system. The delivery system is made up of lower and upper parts. The upper part of the delivery system was made of flat stainless plate curved in a frustum shape. The upper end of the plate was fastened to the frame and passed through to the metering system. The lower end of the flat plate was fastened into a 3 inches PVC pipe. The 400mm length PVC terminated behind the furrow opener and was suspended by a circular metallic ring formed with 8 mm rod. The design of the furrow opener of this planter has height adjustable length. The adjustment was provided to ensure control of 5 – 10 cm planting depth as recommended in the agronomic practice of turmeric production. It was made from 8mm thick mild steel flat bar and has horizontal V shape with a sharp edge attached to serve as residue cutting device. The V shape of the furrow opener prevents soil from falling back into created furrow. It is fastened to the machine frame using 17mm size standard bolts and nuts. The furrow closing device was designed from a 6mm thick mild steel flat bar to form an expanded horizontal U – shape. A 6mm thick mild steel angular bar with holes at the lower end for height adjustments was braced perpendicular to the planter frame downward. A similar angular bar was braced to the U – shape closing device and fastened to the perpendicular angular bar with bolts and nuts. The press wheel was constructed in the shape of a car tyre rim. It has a diameter of 200mm with the two edges rolling on the ground. The centre of the rim was designed to curve inward. The inward curved allow some quantity of soil to be packed and pressed on top of the turmeric rhizome for good sprouting. It also ensures that the air spaces around the seed inside the soil are covered. The ground drive wheels are made up of larger diameters in order to reduce rolling resistance especially in the case of traction wheels [3]. The circumference of the drive wheel was formed with 12mm mild steel rod. An angular mild steel of 4mm was used to brace the two circular flat bar at an interval of 50mm round the drive wheel. A 12mm rod was used to design the spokes. These spokes are used to support the center bushing or hub. The spokes are arranged in such a way that they braced the circumference and also give it necessary radial support.

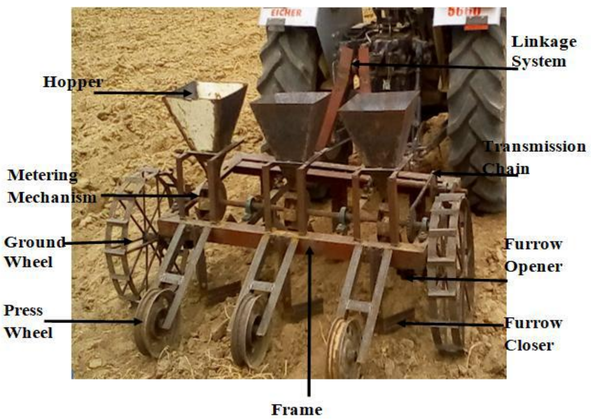

Fig. 1. The Developed Planter.

The two wheels are connected to the two shafts which are suspended in two sets of bearing. The wheels transmit power obtained from the pull of the tractor. The power transmission system reduces the ground speed of the tractor to a permissible level that is suitable for the operation of the turmeric rhizome metering system. It is comprised of chain and two sprockets of predetermined sizes. A big sprocket (42 teeth) fitted to the shaft of the drive wheel and a smaller sprocket (15 teeth) connected to the shaft that was fastened to the frame of the planter with two pillow bearings. From that point, power was taken to the metering device shaft with the aid of chain and two sprockets (34 teeth). Chain and sprockets are used to transmit power in the drive so as to prevent power loss during transmission.

B. Design of experiments

The experimental design was designed as a function of the tractor speed, rhizome length and diameter (independent variables) using Box-Behnken design. In order to obtain the required data, the range of values of each of the three variables (k) was determined as reported by [4] and is presented in Table 1.

C. Statistical analysis

A Minitap software package was used for the regression and graphical analysis as reported by [5]. Analysis of variance (ANOVA) was carried out to estimate the effects of main variables and their potential interaction effects on the field capacity and efficiency.

D. Determination of parameters

The performance parameters were determined based on field capacity and efficiency

Effective Field Capacity

The effective field capacity was the actual average time consumed during planting operation (lost time + effective time). It was determined as reported by [6] and is given in equation 1.

$$F_{ec} = \frac{A_C}{T_t} \qquad (1)$$

where, F_{ec} is the effective field capacity (ha/hr), A_c is the actual area covered (m^2), T_t is the total time (hr)

Field Efficiency

This was calculated by using the values of the theoretical field capacity and effective field capacity rates as reported by [6].

$$F_{eff} = \frac{C_{ef}}{C_{th}} \times 100 \qquad (2)$$

$$C_{th} = \frac{S \times W}{1000} \qquad (3)$$

III. RESULTS AND DISCUSSION

Results

The results of the influence of machine speed, turmeric length and diameter on the field capacity and efficiency of the tractor-drawn turmeric rhizome planter is presented in Table 1. The field capacity ranges from 1.08 ha/hr to 0.63 ha/hr. The highest value of 1.08 ha/hr was obtained from combination of tractor speed of 12 km/hr, turmeric rhizome length and diameter of 60 mm and 30 mm respectively while the low value of 0.63 ha/hr was obtained from combination of tractor speed of 8 km/hr,

Retrieval Number:100.1/ijde.B8002081221
DOI: 10.54105/ijde.B8002.081221
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Published By:
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Table- I: Matrix transformation of three levels- three factors factorial design of the experiment

Std Order	Run Order	Coded Value			Tractor Speed (km/hr)	Length (mm)	Diameter (mm)	Field Capacity (ha/hr)	Efficiency (%)
		X_1	X_2	X_3					
9	1	0	-	-	10	30	25	1	90.83
2	2	+	-	0	12	30	30	1.06	96.29
14	3	0	0	0	10	45	30	0.95	86.3
12	4	0	+	+	10	60	35	1.05	95.38
15	5	0	0	0	10	45	30	0.98	89.02
5	6	-	0	-	8	45	25	0.63	57.23
7	7	-	0	+	8	45	35	0.63	57.23
11	8	0	-	+	10	30	35	1.00	90.84
10	9	0	+	-	10	60	25	1.05	95.38
6	10	+	0	-	12	45	25	0.96	87.2
1	11	-	-	0	8	30	30	0.75	68.13
4	12	+	+	0	12	60	30	1.08	98.12
3	13	-	+	0	8	60	30	0.74	67.22
13	14	0	0	0	10	45	30	0.95	86,23
8	15	+	0	+	12	45	35	0.96	87,20

Turmeric rhizome length and diameter of 45 mm and 25 mm respectively. The efficiency ranges from 57.23% to 98.12%. The highest efficiency of 98.11% was obtained from combination of tractor speed of 12 km/hr, turmeric rhizome length and diameter of 60 mm and 30 mm respectively while the low value of 57.23% was obtained from combination of tractor speed of 8 km/hr, turmeric rhizome length and diameter of 45 mm and 25 mm respectively.

Discussion

Effects of the tractor speed and rhizome length on field capacity

The result of statistical analysis of variance (ANOVA) of the experimental was presented in Table 2.

The value of Probability > F less than 0.0500 indicated that model terms were significant. In this case A, A2, and B2 were significant model terms with P-values of < 0.0001 each. It can be clearly observed that only A (speed of the tractor) had significant effect on field capacity. The regressed model equation to predict the field capacity was presentenced in equation 4, the insignificant terms were removed and the regressed model was reduced to equation 5 [7]. The coefficient of determination R value of 0.9975 indicated that the model was able to predict 99.75 % of the variance and only 0.25 % of the total variance was not explained by the model [8].

Table- II: Name of the Table that justify the values

Source	Coefficient of estimate	Standard error	F – value	P- value Prob >F	R- Squared	
Model	-3.375	0.556	420.53	< 0.0001	0.9951	Significant
A-Speed (rpm)	0.777	0.056	193.15	< 0.0001		
B-Length (cm)	-0.037	0.006	37.89	0.002		
C-Diameter (cm)	0.570	0.249	5.25	0.071		
AB	0.0003	0.0002	0.69	0.443		
AC	-0.0000001	0.00000001	0.00	1.000		
BC	0.0000001	0.00000001	0.00	1.000		
A^2	-0.0353	0.00235	226.67	< 0.0001		
B^2	0.0004	0.000042	89.49	< 0.0001		
C^2	-0.0950	0.0375	6.41	0.052		
Lack of Fit			1.14	0.499		

The regressed field capacity model equation is given as

$$F_C = -3.375 + 0.7769A - 0.03708B + 0.570C 0.000250AB - 0.00000CA + 0.00000\,BC - 0.03531A^2 + 0.000394\,B^2 - 0.0950\,C^2 \quad (4)$$

Where, F_C is the field capacity, A is the speed, B is the length, C is the diameter.

The model equation was improved by removing insignificant model terms. The values that are greater than 0.1000 implies that they are not significant, since these terms are insignificant the model was reduced to equation 5, in order to improve it [5]. The fitted field capacity model equation is given as

$$F_C = -3.375 + 0.7769A - 0.03531A^2 + 0.000394\,B^2 \quad (5)$$

It is important to add that the variable A in the model had positive co-efficient implying a direct proportionality. That is independent increase in A increased the field capacity.

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The effects of the tractor speed on field capacity indicated that the capacity increased significantly from 0.75 ha/hr to 1.05 ha/hr as the speed increases from 8 km/hr to 10 km/hr and then remain constant with further increased in speed to 12 km/hr (Figure 2).

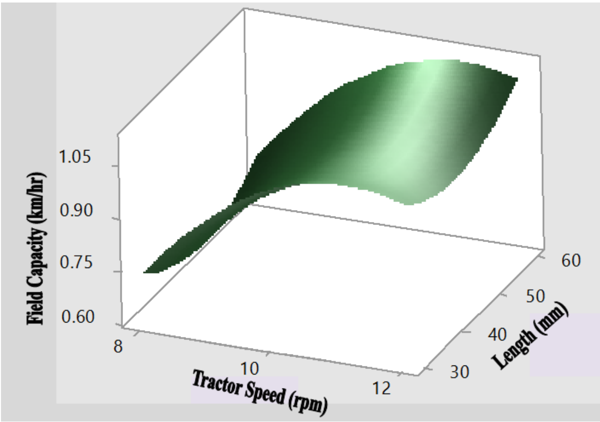

Fig.1. Response Surface for Field Capacity with respect to Tractor Speed and Length

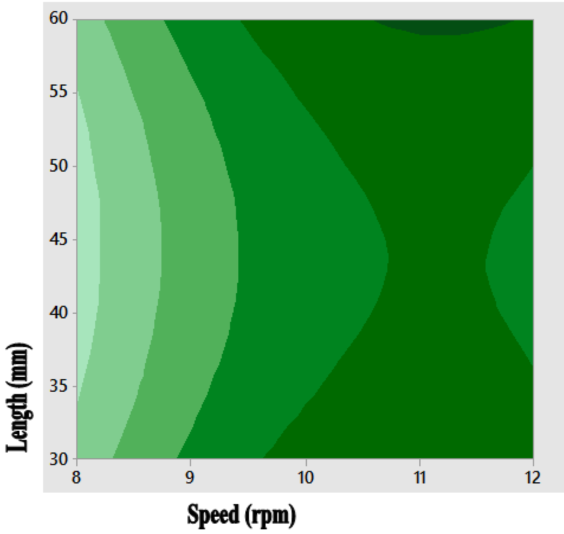

Fig.3. Contour Plot for Field Capacity with respect to Tractor Speed and Length

Effects of the tractor speed and rhizome diameter on field capacity

The effects of the tractor speed on field capacity indicated that the capacity increased significantly from 0.5 ha/hr to 1 ha/hr as the speed increases from 8 km/hr to 10 km/hr and then remain constant with further increased in speed to 12 km/hr (Figure 2). This could be due to increase in area covered with increased in tractor speed. This is in agreement with results of similar studies conducted by [9] which indicated that increasing the forward speed resulted to increase in field capacity. On the other hand the field capacity remains constant with variation turmeric diameter, this indicated the diameter have no any significant effects on the field capacity.

This could be due to increase in area covered with increased in tractor speed. This is in agreement with results of similar studies conducted by [9] which indicated that increasing the forward speed from 1.0 to 4.0 km/h at a constant moisture content of 22 %, increased field capacity from 0.31 to 1.14 fed/h using Yanmar combine. On the other hand the field capacity remains constant with variation turmeric length, this indicated the length have no any significant effects on the field capacity

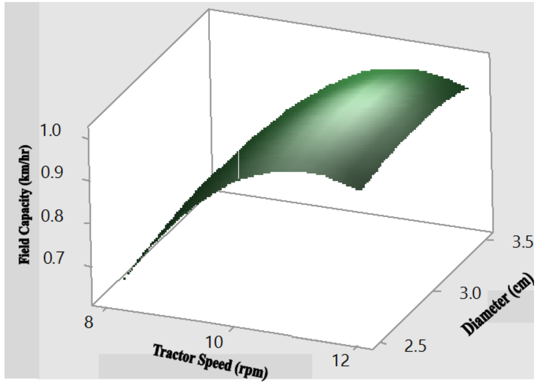

Fig.4. Response Surface for Field Capacity with respect to Tractor Speed and Diameter

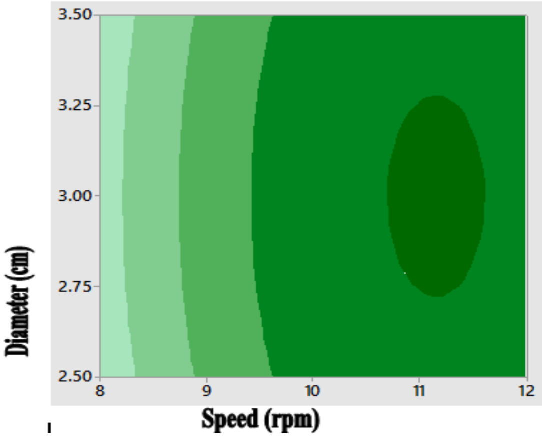

Fig.5. Contour Plot for Field Capacity with respect to Tractor Speed and Diameter

Effects of the tractor speed and rhizome length on field efficiency

From Figures 6 and 7, the effects of the tractor speed on field efficiency indicated that the efficiency increased from 67% to 95% as the speed increased from 8 km/hr to 10 km/hr and then remain constant with further increased in speed to 12 km/hr.

This is in agreement with results of similar studies conducted by [9] which indicated that increasing the forward speed increased the field efficiency. But the length of the turmeric rhizome has no any significant effects on the field efficiency.

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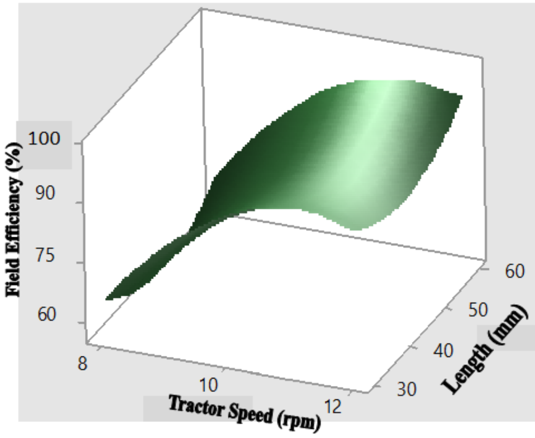

Fig.6. Response Surface for Field Efficiency for Tractor Speed and Tumeric Length

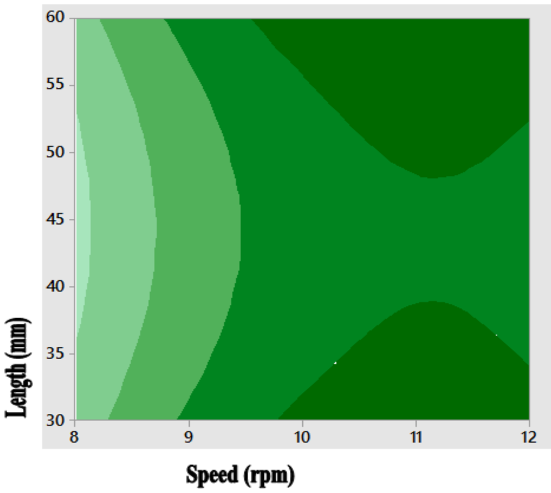

Fig.7. Contour Plot for Field Efficiency for Tractor Speed and Tumeric Length

The regressed field efficiency model equation is given equations 6 and 7

The regressed field efficiency model equation is given as

$$F_{ef} = -305.9 + 70.50A - 3.374B + 51.6C + 0.0228\,AB - 0.000001CA + 0.000001\,BC + 0.03589A^2 - 8.60\,B^2 - 8.60\,C^2 \quad (6)$$

Where, F_{ef} is the field efficiency (%), A is the speed (rpm), B is the length (mm), C is the diameter (cm)

The model equation was improved by removing insignificant model terms. The values that are greater than 0.1000 implies that they are not significant, since these terms are insignificant the model was reduced to equation 7 from equation 6, in order to improve it [5].

The fitted field efficiency model equation is given as

$$F_{ef} = -305.9 + 70.50A + 0.03589\,A^2 - 8.60\,B^2 \quad (7)$$

IV. CONCLUSION

The result of this study provides the best condition under which the tumeric planter could perform optimally. This would increase production, save planting time, utilization, help in creating employment and ensure proper planting operation.

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