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Design and Development of a Tractor-Powered Turmeric Rhizome Planter

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Abstract: Turmeric is a significant spice crop that generates substantial foreign cash for our nation via the export of its goods. By decreasing manufacturing expenses Increasing the benefit per acre. The excavation of turmeric crops at the appropriate maturation level is a crucial agricultural activity; nonetheless, it is laborious, time-consuming, and expensive. The lack of skilled labor and their higher wage demands for manual harvesting have resulted in significant field losses and crop damage. This situation underscores the necessity for the development of an appropriate mechanical tuber crop harvester specifically for turmeric, aimed at mechanizing the digging operation for this crop. The tuber crop harvester comprises a main frame, a soil cutting blade, a webs/windrowing unit, and a three-point linkage. The maximum turmeric rhizome miss index of 35% was observed for a rhizome length of 30 cm at a machine operational speed of 10 km/h, while the minimum miss index of 15% was recorded for a rhizome length of 60 cm at a speed of 12 km/h. The operating speed of the machine and the dimensions of the turmeric rhizomes influence the machine's field capacity. The maximum capacity of 0.96 ha/h was observed at the peak operating speed of 12 km/h. The minimum field capacity of 0.63 ha/h was observed at the lowest machine speed of 8 km/h. The created equipment could alleviate the toil associated with manual turmeric planting and save a significant quantity of labor and operational time.

Keywords: *Development, testing, tractor-drawn turmeric, planter*

INTRODUCTION

Turmeric (Curcuma longa Linn) is a tuberous stem crop. It is a member of the Zingiberaceae family and thrives in the same hot and humid tropical environment. The rhizome has a vivid yellow hue. Turmeric originates from the Latin term terra merita, meaning "merited earth." In Nigeria, turmeric is mostly farmed on a subsistence basis in around 19 states (Nwaekpe et al., 2015). The subterranean rhizome imparts a unique flavor to food and is also used to bestow a deep, lasting orange hue (FAO, 2004). Contemporary medicine has acknowledged its significance, as shown by more than 3,000 papers on turmeric released in the last 25 years (Sahdeo and Bharat, 2011).

A nutritional analysis revealed that 100 g of turmeric comprises 390 kcal, 10 g of total fat, 3 g of saturated fat, 0 mg of cholesterol, 0.2 g of calcium, 0.26 g of phosphorus, 10 mg of sodium, 2500 mg of potassium, 47.5 mg of iron, 0.9 mg of thiamine, 0.19 mg of riboflavin, 4.8 mg of niacin, 50 mg of ascorbic acid, 69.9 g of total carbohydrates, 21 g of dietary fiber, 3 g of sugars, and 8 g of protein (Balakrishnan, 2007; Sahdeo and Bharat, 2011). The cultivation of turmeric has been a difficulty for farmers in Nigeria owing to the lack of planting machinery.

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The farmers are relegated to use ancient methods of planting using hoes and machetes. This approach is time-consuming, labor-intensive, burdensome, and requires significant human effort. It was observed that "time is the essence of farming," and any assistance that reduces the duration needed for planting would mitigate the impact of unfavorable weather (Ajitet al., 2006). To attain food security via extensive mechanized agricultural production.

Harvesting is the most labor-intensive procedure within the agriculture industry.The temporal factors and labor availability dictate the cost of the harvest. Turmeric is a crop that occupies around 234,000 hectares of land in India (M. Saimurugan et al., 2021), establishing the nation as the leading producer and consumer of this spice. Notwithstanding the monopoly in turmeric manufacturing, no equipment exists that encompasses the full harvesting process of the spice. The current harvesters remove the rhizome and deposit them behind as they advance, where they are subsequently separated from the soil and gathered by laborers. The project focuses on designing and developing a harvester that can execute the whole harvesting process and is suitable for Indian agricultural lands. The apparatus is designed as an accessory for any compact tractor (24HP) (M. Saimurugan et al., 2021). Zate et al. (2018) indicated that farmers cultivate turmeric and ginger on elevated beds. The preparation height is 20 to 30 cm and the width is 75 to 100 cm, with a recommended length and a minimum spacing of 30 cm between two rows of turmeric on the beds. Munde et al. (2010) indicated that the mother rhizome or finger rhizome is cultivated either on elevated beds of 60 to 90 cm in width and 15 cm in height on ridges and furrows, or in a flat system.

MATERIAL AND METHODS

Design of Rhizome Seed Metering Device

The accurate design of the metering device, achieved by the calculation of the number of holes, is crucial for the optimal operation of the planter. It was designed to consistently disperse seeds at the specified application rate and regulate seed spacing. Consequently, the quantity of apertures on the measuring apparatus was established as documented by Khan et al. (2015), as follows:

$Ng = \pi Dwi \times x$ (3)

Where: Dw= diameter of the drive wheel

i = drive ratio

x = intra raw spacing (m)

Determination of the Angular Speed of the Drive Wheels (Rpm)

The planter's driving wheels convey power to the metering mechanism using a chain drive system. The angular velocity of the drive wheel, identical to that of the smaller sprocket, is crucial in the design of chains and sprockets, as well as in the assessment of power transfer via chain drive.

The angular velocity of the planter's driving wheels was calculated using Equation 4 (Maxmillan, 2002).

$$V = \pi D Nw \quad (4)$$

Where V =operational speed (m/h)

D = diameter of drive wheel (0.6m)

Nw= rotational speed of drive wheel (rpm)

Determination of the Torque of the Planter's Wheel

The torque of the planter's wheel is crucial for calculating the power supplied to the metering shaft and for establishing the minimum diameter necessary for both the wheel shaft and the metering device shaft. It was derived using Equation 6 as documented by Khan et al. (2015).

$$Tw = Kw \times Ww \times Rw \quad (6)$$

Where: Tw = torque of the wheel

Kw = rolling resistance coefficient of wheel (0.3 for metallic wheel)

Wp = Weight on the drive wheel

Rw = Radius of the wheel

Description of the Machine

Machine Frame

This is the skeleton framework of the planter onto which all other components are affixed. It was fabricated from 75 mm × 75 mm x 6 mm carbon steel angle iron. Provisions are established for the 3-point hitch couplings to facilitate tractor attachment to the machine. During road transportation and relocation between fields, the whole frame is securely affixed to the tractor; however, during the planting process, the planter's frame is supported by the drive wheel. The frame's construction is seen in Figure 1.

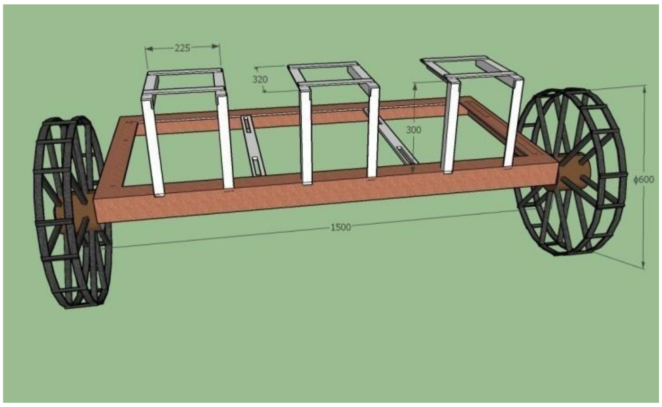

Figure1. *Machine frame*

Hopper

The cane seed hopper was constructed from 1.5 mm thick mild steel sheet. The object has a trapezoidal configuration with dimensions of 340mm x 340mm at the top and 70mm x 40mm at the bottom end. A rubber seal was affixed around the bottom end to prevent damage to the rhizomes. It decreased friction between the revolving measuring apparatus and the hopper's edge, while temporarily retaining the turmeric rhizomes for planting as the machine traverses the field. The hopper is seen in Figure 2.

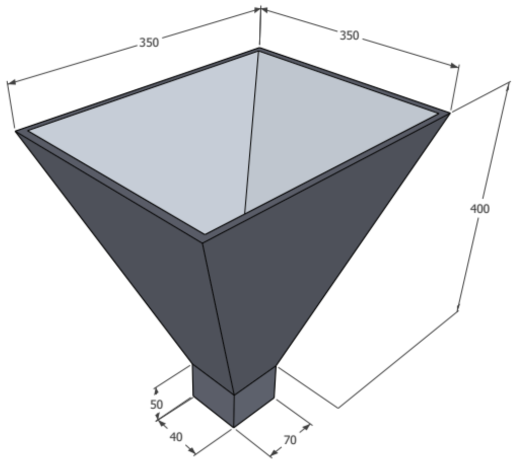

Figure2. *Hopper*

Ground Drive Wheel

Larger diameter wheels are designed to minimize rolling resistance, particularly for traction wheels (Bharat and Sidharth 2014; Ani et al 2016).The circumference of the drive wheel was constructed using a 12mm mild steel rod, as seen in figure 3.6. A 4mm angular mild steel bar was used to support the two circular flat bars at 50mm intervals around the drive wheel. A 12mm rod was used to fabricate the spokes. These spokes serve to reinforce the central bushing or hub. The spokes are intended to reinforce the circular circumference while providing essential radial support. The two wheels are linked to the two shafts, which are supported by two sets of bearings. The wheels convey power derived from the tractor's draw.

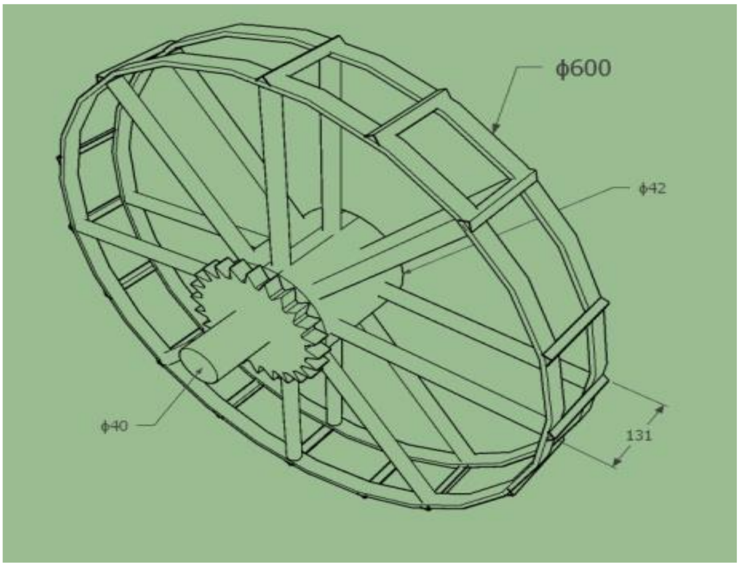

Figure8. *Ground wheel*

Power Transmission System

The power transmission system (figure 3.9) functions to decrease the tractor's ground speed to an acceptable level for the functioning of the turmeric rhizome metering system. It consists of a chain and two sprockets of specified dimensions. A large sprocket (42 teeth) is affixed to the driving wheel shaft, while a smaller sprocket (15 teeth) is attached to the shaft secured to the planter frame with two pillow bearings. Subsequently, power was transmitted to the metering device shaft using a chain and two sprockets with 34 teeth each. Chains and sprockets are used to convey power in the drive, hence minimizing power loss during transmission.

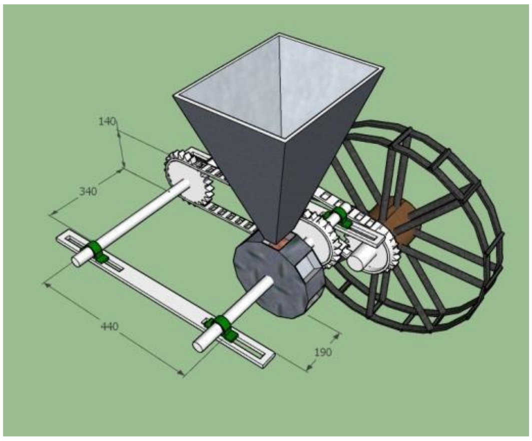

Figure9. *Power Transmission System*

TESTING OF MACHINE

A 90m × 90m area at the Federal University of Technology, Minna agricultural site was cultivated and tilled. The area was then partitioned into sections of 30m by 30m. Turmeric rhizomes were sourced from the National Root Crops Research Institute (NRCRI) Nyanya Sub Station in Abuja. The rhizomes were cleansed and categorized into lengths of 30mm, 45mm, and 60mm to ascertain the length that yields optimal performance. The planter was filled with turmeric rhizomes and then planted in 30 m × 30 m subplots at three distinct operating speeds of 8 km/h, 10 km/h, and 12 km/h for each group.

A three-variable, three-level factorial design (N = 33) serves as the framework for the investigation. The experimental design used a split-plot framework based on the principles of factorial experimentation. The three speed levels were allocated to the subplot, while the three lengths of turmeric rhizome were allotted to the split-plot. The data underwent Analysis of Variance (ANOVA) using specialized design software, and the following parameters were calculated:

Miss Index

Misses or skips occur when seed grooves do not effectively capture and transport seeds to the delivery funnels. Misses are recorded along a randomly chosen 15-meter segment of each planted row with the covering devices removed. The missing percentage is represented by an index known as the miss index (MI), which denotes the proportion of spacing exceeding 1.5 times the theoretical spacing (Katchman and Smith, 1995).

MI =nsN 100 (11)

Where: ns = number of skips

N = Total number of spacing

Field capacity of Planter: The field capacity of the planter is the total area of land that was covered. It is expressed as the area of field covered in given time and was obtained as follows:

CM =.AfT (12)

Where CM = machine capacity (ha/h)

Af= area of field covered (m2)

T = time taken (h)

RESULTS AND DISCUSSION

Miss Index

Table 1 illustrates the machine's performance regarding the miss index. The results indicate that the proportion of misses diminishes as the length of turmeric rhizome increases. This observation contradicts the conclusions of Singh and Gautam (2015). The planter's findings indicate that there was no consistent trend in the fluctuation of the miss index relative to the growth in turmeric rhizome length and machine operating speed. The maximum turmeric rhizome miss index of 35% was observed for a rhizome length of 30 cm at a machine operational speed of 10 km/h, while the minimum miss index of 15% was recorded for a rhizome length of 60 cm at a speed of 12 km/h. This tendency arises because shorter rhizomes are more prone to dislodgment, as many turmeric rhizomes often escape from the hopper into the metering system.

Table1. Effect of machine operational speed on miss index for different lengths of turmeric rhizome

Levels	**Machine speed (km/h)**	**Percentage of miss index for different turmeric rhizome lengths (%)**		
		30	45	60
1	8	30	35	30
	10	35	25	20
	12	30	15	25

2	8 10 12	35 30 35	30 20 30	20 25 20
3	8 10 12	35 30 30	35 25 35	25 25 20

Field Capacity

The results of the test conducted to assess the planter's field capacity at various operating speeds are shown in Table 2. The field capacity of planters are contingent upon the operating velocity. The findings indicate that an increase in machine operating speed led to an enhancement in field capacity for all lengths of turmeric rhizomes, corroborating the conclusions of Khan and Moses (2017). The field capacity ranged from 0.63 to 0.65 ha/h for all turmeric rhizome lengths at the minimum operating speed of 8 km/h, while the maximum field capacity of 0.95 to 0.96 ha/h was achieved for the different lengths of turmeric rhizome at the maximum machine speed of 12 km/h. The optimal planting field capacity of the turmeric rhizome planter was achieved with a rhizome length of 45 cm at an operating speed of 12 km/h.

CONCLUSION

The apparatus was successfully fabricated and assessed. The machine's performance test was conducted to determine the miss index and field capacity of the planter at three operating speeds: 8, 10, and 12 km/h, and three lengths of turmeric rhizomes: 30, 45, and 60 mm. The operational speed of the machine significantly influences the miss index of the turmeric rhizome prototype planter ($P < 0.05$), although the classification of turmeric rhizomes by length does not significantly affect the miss index. No consistent trend was seen in the variation of the miss index with respect to the length of turmeric rhizomes and the operating speed of the machine.

The planter's field capacity mostly relied on operating speed. The dimensions of the cane seeds (diameter and length) did not influence the machine's field capacity. The maximum capacity of 0.96 ha/h was seen at an operating speed of 12 km/h, while the minimum field capacity of 0.63 ha/h was noted at a machine speed of 8 km/h.

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