

Development and Evaluation of Tractor Operated Semi-Automatic Two Row Turmeric Planter

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ABSTRACT

Keywords

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Turmeric planting in India is largely carried out using conventional manual methods, which are labour-intensive, time-consuming, and costly. To address these limitations, tractor operated semi-automatic two row turmeric planter was designed and fabricated at the department of Farm Machinery and Power Engineering, College of Agricultural Engineering and Technology, RPCAU Pusa. The developed planter consists of a mild steel main frame, trapezoidal hopper, horizontal disc-type seed metering mechanism with ten slots, semi-cylindrical seed dropping tubes, ground-driven power transmission system, adjustable ridger bottoms, and an operator seat for manual feeding. Laboratory evaluation showed that the planter achieved a rhizome application rate of 2201.40 kg/ha. The highest rhizomes average spacing was 286 mm at the speed of 1.25 km/h for 2.0:1 gear ratio whereas minimum spacing was 186 mm at the speed of 0.75 km/h for 1.6:1 gear ratio. Maximum missing index was observed 17.68 % at the speed of 1.25 km/h for 2.0:1 gear ratio while minimum missing index was 8.76 % at the speed of 0.75 km/h for 1.6:1 gear ratio. Maximum multiple index was observed 19.07 % at the speed of 1.25 % for 1.8:1 gear ratio while minimum multiple index was recorded 10.15 % at the speed of 0.75 km/h for 2.0:1 gear ratio. The effective field capacity was found 0.059, 0.077, 0.09 ha/h at the speed of 0.75, 1.00 1.25 km/h respectively. The average fuel consumption of the tractor was 4.3 l/ha.

Introduction

Turmeric (*Curcuma longa*) is a perennial herb, which is used as spice. It's known as Indian saffron, and *Haldi*. Turmeric production is estimated to be over 11 lakh tonnes per year worldwide. India dominates the global production picture, accounting for 80% of total output, followed by China (8%), Myanmar (4%), Nigeria and

Bangladesh (3%) each. Because turmeric is an important component of many Indian dishes and traditional remedies, India is the largest producer and exporter of turmeric and turmeric-based products. In India, roughly 2.54 lakh hectare of turmeric were planted in 2019-2020 with production of 12.29 lakhs tones. The total turmeric production of India has reduced from 1.13 MT in 2018 to 0.95 MT in 2020 (Dept. of Agri. and Farmer Welfare-

2020). Andhra Pradesh, Tamil Nadu, Orissa, Karnataka, West Bengal, Maharashtra, and Assam are the most prominent turmeric-growing states in India.

The total area under turmeric in Bihar is 3384 ha, with an annual production of 8237 tonnes.

Turmeric is primarily farmed as a significant spice crop in Bihar's north western districts, including Muzaffarpur, Samastipur, Vaishali, East Champaran, Madhubani, Sitamarhi, Bhagalpur, and Begusarai.

Planting method is an important soil management practice that influences plant growth and yield (Kandiannan *et al.*, 2006). According to Gill *et al.*, the number of tillers per plant, number of leaves per plant, plant height, turmeric rhizome weight, and fresh turmeric yield were significantly higher under the ridge planting method compared to the flat planting method. Wider plant spacing maximizes the yield potential of individual plants, whereas closer spacing maximizes yield per unit area due to greater competition among plants (Parkash and Brar, 2015). The type and weight of planting material influence plant vigour, crop yield per unit area, and the overall cost of production (Brar *et al.*, 2021).

To design agriculture machinery the engineering and physical properties of agricultural produce must be determined and improve processes for harvesting, postharvest operation and storage (Kumar and Kumar, 2016).

Turmeric is frequently cauterized by its physical dimensions (length, width and thickness) and density because these properties are used for sorting and grading (Jahromi *et al.*, 2018). The spacing between rows is approximately 45 to 60 cm and 15 to 20 cm between plants. One hectare required a seeding amount of 2500 kg of turmeric (Jayashree *et al.*, 2016).

Planting turmeric takes time and effort. This is tedious task as workers have to manually dig the soil and sow the seed on the ground. In the current economic environment, the shortage of skilled workers makes it very difficult to increase turmeric production. It associated with human drudgery, human energy intensive and back breaking tasks due to regular bending posture at the time of sowing. With the above stated reason there is need of tractor drawn turmeric sowing implements. The objective of this research is to develop a tractor operated semi-automatic two row turmeric planter.

Materials and Methods

General Description

Turmeric can be grown on raised beds as well as on flat fields. About 2000 - 2500 kg of seed rhizomes per hectare is required for planting, depending on the size of the rhizomes. The recommended row-to-row spacing for turmeric is 40-60 cm and plant-to-plant spacing is 15-20 cm. Accordingly, the row-to-row spacing was fixed based on agronomic recommendations, while the plant-to-plant spacing was maintained by varying the gear ratio of the metering mechanism. To determine the width of the planter, it was decided that the machine should be capable of planting two rows on a raised bed. The planting depth was maintained at 5-7 cm, as recommended for proper rhizome emergence and crop establishment.

Development of the Turmeric Planter

Main frame: MS square pipe was used to fabricate rectangular frame. The main frame was strong enough to withstand all types of loads during working condition. All the other parts of the planter were supported by the main frame. Due to induced draft the planter frame is subjected to bending moment and torsion. Determination of forces acting on main frame.

$$\text{Draft per tyne} = \text{soil resistance} \times \text{width} \times \text{depth} \dots(i)$$

$$\text{Torque produced on frame (T)} = \text{draft} \times \text{ground clearance} \times \text{no. of tynes} \dots(ii)$$

Hopper: The planter's hopper was fabricated using an angle bar frame and enclosed with a 2.2 mm thick mild steel sheet. To minimize frequent refilling during operation, the seed box was designed to hold an adequate quantity of turmeric. Its capacity was determined based on the volumetric requirements, angle of repose, and bulk density of turmeric. Determination of capacity of hopper

$$\text{Capacity of hopper} = \frac{\text{seed rate}}{n \times \text{bulk density}} \dots(iii)$$

Seed metering mechanism: The seed metering mechanism was fabricated from mild steel flats and was driven by two ground wheels mounted on either side of the frame. The metering disc was provided with ten slots, equally spaced along its periphery. It was mounted on a

set of bevel gears, which enabled horizontal rotation of the disc. This horizontal disc-type metering unit operates as a manually fed seed metering device. Diameter of metering disc was determined by:

$$\text{Diameter of metering disc} = \frac{\text{Number of cell per metering disc} \times \text{Peripheral distance between two cells}}{\pi} \dots(\text{iv})$$

Number of cell/slots on metering disc was determined by:

$$\text{Number of cell per metering disc} = \frac{\text{actual distance travelled by ground wheel}}{\text{gear ratio} \times \text{rhizome spacing}} \dots(\text{v})$$

Seed dropping mechanism: The seed dropping mechanism was fabricated by a mild steel sheet half-cylindrical form. The turmeric seed will be placed in the cell by the operator then the turmeric will be passed through a half cylindrical tube and dropped in between the two ridgers.

Ground wheel: The ground wheel was fabricated from high-carbon steel and mounted on both sides of the frame, connected through a shaft. A total of 22 lugs, each 10 mm in diameter and 100 mm in length, were welded at equal intervals along the outer rim of the wheel. The wheel featured 12 spokes made of mild steel rods between the hub and the inner rim, which were welded at both the central hub and the inner rim. Additionally, 7 spokes were provided between the inner and outer rims and were securely welded to the rim structure.

$$\text{Determination of number of revolutions of drive wheel} = \frac{\text{No. of revolution per hectare}}{10000} = \frac{\pi D \times \text{working width of planter}}{\dots} \dots(\text{vi})$$

Where, D is diameter of drive wheel

Ridger bottom: The ridger bottom was attached to the turmeric planter frame to create uniform sized ridges. As the planter was developed for two rows therefore three ridgers were provided. The ridger bottom consists of a shovel, tyne, and wing. The ridger bottom was developed with adjustable curved wings shaped. At the lower end shovel was bolted with the tyne.

Operator Seat: The seat was fabricated by an angle iron and flat that was attached to the back side of the frame. The dimensions of the operator seat were 640 mm length

and 770 mm width. Back support was provided in the seat for back support and safety. MS flats were welded between the two angle iron for sitting and back support. 5 MS flats were welded between angle iron for sitting and 4 MS flats were welded between angle iron for back support. The two operators will get together seated in the operator seat to feed the turmeric into the metering mechanism.

Power transmission system: The power is transmitted from the ground wheel to the shaft fitted above the main frame. The shaft rested on 3 US bearings, two at the end and one at the middle of the shaft. From the shaft fitted on the main frame, the drive is transmitted to the bevel gears fitted on the shaft of the turmeric metering mechanism with a gear ratio of 1.8:1. The bevel gear fitted on the turmeric metering shaft drives the metering disc.

Laboratory evaluation of turmeric planter

Laboratory test was carried out to assess planter functional performance under controlled conditions before field testing. The planter was tested for key parameters such as metering mechanism efficiency, rhizome rate and rhizome spacing uniformity at different forward speed.

Performance Evaluation of Turmeric Planter

The performance evaluation of the planter was carried out using three level of forward speed (0.75, 1.0, and 1.25 km/h) and three level of gear ratio (1.6:1, 1.8:1, and 2.0:1) as independent parameters, resulting in nine combinations, while rhizome spacing, missing index, multiple index, and quality of feed index were considered as dependent parameters.

Missing index

When the spacing is greater than 1.5 times the recommended spacing (S) it indicates missing. That is given below, (Gbabo *et. al.* 2020; Gautam, 2016).

$$I_{\text{miss}} = \frac{n_1}{N} \times 100 \dots(\text{vii})$$

Where,

n_1 = number of spacing in the region > 1.5 S
N = total number of observations

Multiple index

It is the proportion of spacing that is less than half of the recommended spacing (S). That is given below,

$$I_{\text{mult}} = \frac{n_2}{N} \times 100 \quad \dots(\text{viii})$$

Where,

n_2 = number of spacing in the region $<0.5S$

N = total number of observations

Rhizome spacing

Rhizome spacing was measured during the field trial using a measuring tape at randomly selected locations in the field.

Theoretical field capacity

The theoretical field capacity was calculated by taking planter's working width and travel speed into account.

$$\text{Theoretical field capacity, ha/h} = \frac{\text{width of operation (m)} \times \text{speed (km/h)}}{10} \quad \dots(\text{viii})$$

Effective field capacity

During field tests, time losses for each event, such as turmeric refilling in the planter and turning losses, were recorded.

$$\text{Effective field capacity, ha/h} = \frac{\text{length of field (m)} \times \text{width of field (m)}}{10000 \times \text{time (h)}} \quad \dots(\text{ix})$$

Field efficiency

Field efficiency was expressed as percentage and measured by using below formula, (Kepner *et al.*, 1978)

$$\text{Field efficiency, \%} = \frac{\text{Effective field capacity}}{\text{Theoretical field capacity}} \times 100 \quad \dots (\text{x})$$

Fuel Consumption

Fuel consumption was measured using, top fill method. Fuel tank was filled to full capacity before and after the field test. Amount of refuelling after the test was recorded.

Statistical Analysis

The obtained data were statistically analysed using a two-factor design with Design-Expert software. Analysis of variance (ANOVA) and levels of significance was reported.

Result and Discussion

Laboratory Test Result

From the calibration of the planter, the rhizome rate was observed 2201.40 kg/ha, which satisfies the recommended seed rate. The mean spacing of rhizomes was observed 214 mm.

Field Test Result

Effect of forward speed and gear ratio on rhizomes spacing

The rhizome spacing was increased as increased in forward speed and gear ratio as shown in figure 4. The spacing between rhizome observed 186, 192, 197 mm at the speed of 0.75 km/h, 230, 232, 238 mm at the speed of 1.0 km/h and 264, 277, 286 mm at the speed of 1.25 km/h for gear ratio 1.6:1, 1.8:1 and 2.0:1 respectively. Analysis of variance indicate that the forward speed significant effect on rhizome spacing.

The rhizome spacing also increased with the increase in gear ratio. The rhizome spacing was 186, 230, 264 mm for 1.6:1 gear ratio, 192, 232, 277 mm for 1.8:1 gear ratio and 197, 238, 286 mm for 2.0:1 gear ratio at speed 0.75, 1.0, 1.25 km/h respectively. Analysis of variance indicate that the gear ratio significant effect on rhizome spacing.

Effect of forward speed and gear ratio on missing index

The missing index increased with increase in forward speed as shown in figure 5. The missing index observed was 8.76, 10.86, 12.65 % at the speed of 0.75 km/h, 10.15, 12.03, 14.25 % at the speed of 1.0 km/h and 13.24, 15.33, 17.68 % at the speed of 1.25 km/h for gear ratio 1.6:1, 1.8:1 and 2.0:1 respectively.

Analysis of variance indicate that the forward speed significant effect on missing index.

Figure.1 Metering disc

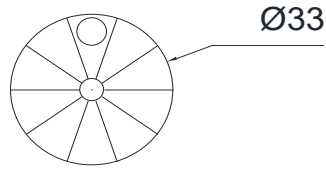


Figure.2 Power transmission

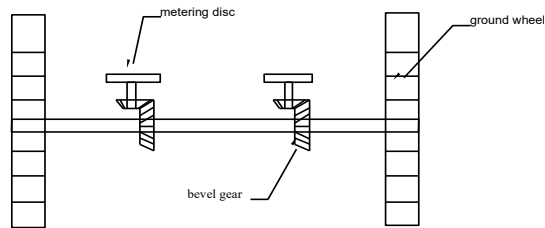


Figure.3 Turmeric planter



Figure.4 Effect of forward speed and gear ratio on rhizomes spacing

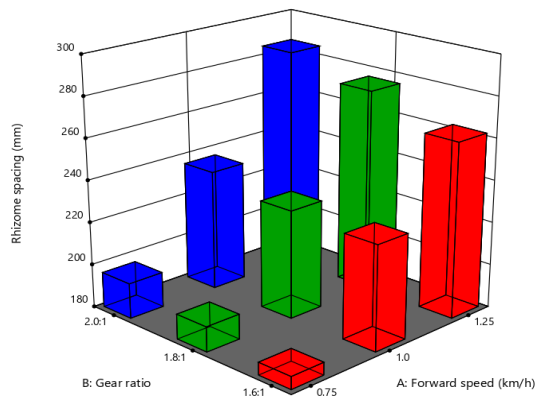


Figure.5 Effect of forward speed and gear ratio on missing index

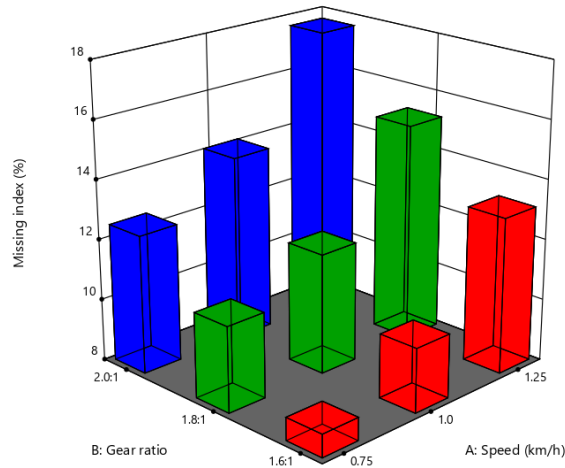
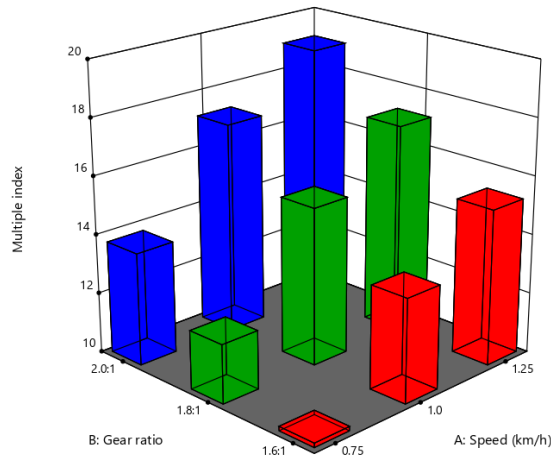


Figure.6 Effect of forward speed and gear ratio on multiple index



The missing index increased with increase in gear ratio. The missing index observed was 8.76, 10.15, 13.24 % for 1.6:1 gear ratio, 10.86, 12.03, 15.33 % for 1.8:1 gear ratio and 12.65, 14.25, 17.68 % for 2.0:1 gear ratio at speed 0.75, 1.0, 1.25 km/h respectively. Analysis of variance indicate that the gear ratio significant effect on missing index.

Effect of forward speed and gear ratio on multiple index

The multiple index increased with increase in forward speed as shown in figure 6. The multiple index observed was 10.15, 12.02, 13.89 % at the speed of 0.75 km/h,

13.56, 15.43, 17.30 % at the speed of 1.0 km/h and 15.37, 17.25, 19.07 % at the speed of 1.25 km/h for gear ratio 1.6:1, 1.8:1 and 2.0:1 respectively.

Analysis of variance indicate that the forward speed significant effect on multiple index.

The multiple index increased with increase in gear ratio. The multiple index observed was 10.15, 13.56, 15.37 % for 1.6:1 gear ratio, 12.02, 15.43, 17.25 % for 1.8:1 gear ratio and 13.89, 17.30, 19.07 % for 2.0:1 gear ratio at speed 0.75, 1.0, 1.25 km/h respectively. Analysis of variance indicate that the gear ratio significant effect on multiple index.

Field capacity

Theoretical field capacity increased with an increase in speed. The theoretical field capacity was 0.067, 0.09, and 0.112 ha/h at the speed of 0.75, 1.00 and 1.25 km/h respectively. The effective field capacity was 0.059, 0.077 and 0.09 ha/h at the speed of 0.75, 1.00 and 1.25 km/h respectively. The field efficiency was 88.05, 85.55 and 80.35% at the speed of 0.75, 1.00 and 1.25 km/h respectively.

Fuel Consumption

The planter was operated in an area of 0.45 ha. The fuel consumption and time for the test area was measured. The fuel consumption obtained was 4.3 l/ha.

In conclusion, A tractor operated semi-automatic two row turmeric planter was successfully designed, fabricated, and evaluated. Performance of the planter was evaluated at three different forward speed levels (0.75, 1.0, and 1.25 km/h) and with three different levels of gear ratio (1.6:1, 1.8:1 and 2.0:1). The dependent parameters were rhizome spacing, missing index, multiple index and quality of feed index. The observed data were statistically analysed by Design Expert software.

The highest rhizomes average spacing was 286 mm at the speed of 1.25 km/h for 2.0:1 gear ratio whereas minimum spacing was 186 mm at the speed of 0.75 km/h for 1.6:1 gear ratio. Missing index was increased as increase in forward speed and gear ratio. Maximum missing index was observed 17.68 % at the speed of 1.25 km/h for 2.0:1 gear ratio while minimum missing index was 8.76 % at the speed of 0.75 km/h for 1.6:1 gear ratio. Maximum multiple index was observed 19.07 % at the speed of 1.25 % for 1.8:1 gear ratio while minimum multiple index was recorded 10.15 % at the speed of 0.75 km h⁻¹ for 2.0:1 gear ratio.

The quality of feed index was decreased with increase in forward speed and gear ratio. The effective field capacity was found 0.059, 0.077 and 0.09 ha/h at the speed of 0.75, 1.00 and 1.25 km/h respectively. The average fuel consumption of the tractor was 4.3 l/ha. The results demonstrate that the developed planter is a cost-effective and efficient solution for turmeric planting, capable of reducing labour requirement and improving planting uniformity compared to conventional methods.

Author Contributions

Akhilesh Bariha: Investigation, formal analysis, writing—original draft. Er. Manoranjan Kumar: Validation, methodology, writing—reviewing. Anuradha Yadav:—Formal analysis, writing—review and editing.

Data Availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethical Approval Not applicable.

Consent to Participate Not applicable.

Consent to Publish Not applicable.

Conflict of Interest The authors declare no competing interests.

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