

Original Research Article

Investigation of Physical Properties of Turmeric Rhizomes About to Design a Metering Mechanism for Turmeric Planting

ABSTRACT

Aims: Turmeric production is facing the labour shortage during peak operations like planting and harvesting. There are different methods in turmeric planting which require different amount of manual energy. The objective of the study was to investigate the physical properties of turmeric seed rhizomes and to optimize the design parameters of Automatic turmeric planter.

Place and Duration of Study: The study was carried out in the Department of Farm machinery and power engineering, Dr NTR CAE Bapatla, Andhra Pradesh during the year 2021-22

Methodology: Turmeric seed material is not available directly in the market like other seeds or seedlings. There is some procedure is followed by farming community for turmeric seed rhizome preparation. To design a metering mechanism of a turmeric planter, information related to geometrical properties such as length, breadth, thickness and density are necessary. Frictional parameters are also measured to design hopper of the planter which facilitates free flow of seed rhizomes during planting operation.

Results: The length of finger rhizome used as seed material in turmeric cultivation ranged from 3.7 to 5.5 cm. Average breadth and thickness of seed rhizomes are 2.1 and 1.7 cm respectively. Average weight of turmeric seed rhizome was found to be 15.5 g with an equivalent diameter of 2.45 cm. Bulk density and true density of seed rhizome was found to be 640 and 1040 kg m⁻³, respectively. Angle of repose was noted as 36.80°. The coefficient of static friction on mild steel sheet for different varieties found to varied between of 0.75–0.85.

Conclusion:

Familiarization of turmeric planting methods and seed material preparation procedures helps in proper investigation of seed rhizomes. By measuring all these physical properties, optimum values for the design of a turmeric planter which delivers the required seed rate at desired plant spacing was obtained.

Keywords: Turmeric seed rhizome, geometrical properties, density and frictional parameters

1. INTRODUCTION

India is a leading producer and exporter of turmeric in the world. Since ancient times, turmeric is being cultivated in India as a significant spice. Indian turmeric is regarded as the greatest quality one, as it contains a lot of curcumin. Among various costs involved in turmeric cultivation, seed and labour costs account for 34.22% and 29.42% of the total cost of cultivation [1]. Due to improved industrial and urban livelihood opportunities, labour availability has decreased to a great extent in agriculture sector. Increase in wage rate of human labour has led to influence in the cost of cultivation drastically reducing the net income.

Rise in the wage rate is not specific to turmeric cultivation alone as agricultural wages rose steeply after 2007-08. Hence, the key in reducing the cost of cultivation of turmeric is by reducing the dependence of human power which can be achieved by increased mechanization [2].

Most of the farmers depend on the bullock drawn plough with manual seed dropping and semi-automatic planters for turmeric planting. In bullock drawn plough method two passes of plough is required in turmeric planting. First pass is used to make the ridge and furrows in the field, after that turmeric rhizome seeds manually dropped in furrows. In second pass dropped seeds were covered by braking the ridge. In Semi-automatic planter's operation, one manual laborer required for each row. Planting of turmeric rhizome on raised beds is more advantageous in Telangana and Andhra regions. It supports drip irrigation, controls rhizome rot disease, creating drainage during high rainfall times [3]. By developing automatic turmeric planter, dependency on labour force can be reduced in planting and irrigation operations.



a. Manual seed dropping in furrows



b. Covering the seed furrows by braking the ridge

Fig. 1 Bullock drawn plough with manual turmeric seed rhizome dropping



Fig. 2 Semi-automatic planter's turmeric seed rhizome planting

In view of these, a research work has been undertaken to develop a tractor drawn automatic turmeric seed rhizome planter suitable for raised bed cultivation of different turmeric varieties. As a part of above-mentioned research, the turmeric seed rhizome physical properties have been determined to optimize the design parameters of turmeric planter.

2. MATERIALS AND METHODS

The present investigation was undertaken during the year 2021-22 to study the physical parameters of the selected varieties of turmeric cultivation. To design a turmeric planter that includes metering mechanism and seed box, one should obtain the design values of turmeric seed rhizome in terms of geometrical properties (length, breadth and thickness), gravimetric properties (bulk density, true density and porosity) and frictional properties (angle of repose and coefficient of friction). Geometrical properties, gravimetric properties and frictional properties combinedly termed as Physical properties seed materials.

Physical properties such as length, breadth and thickness are essential to design a suitable metering mechanism [4]. Proper size and shape of the metering mechanism can be identified by measuring the physical properties [5]. Gravimetric properties like bulk density and true density helps in designing the seed box dimensions and selection of seed box material. Frictional properties like angle of repose and coefficient of friction are useful in seed box design. These properties help in smooth movement of seeds in seed box during planting operation.

2.1 Preparation of turmeric seed rhizomes

In turmeric cultivation there is no separate seeds for plant propagation. A part of whole rhizome i.e. mother rhizome and finger rhizomes are used as seeds for plant propagation. Many farmers are not using the mother rhizome as seed material as it is also becoming less economical on comparing with finger rhizome. Mother rhizome based crop also facing many pest and disease problems, so all over the country only finger rhizome is being used as seed material. Finger rhizomes are cut into pieces of certain length are used as planting material [6]. Farmers select the healthy finger

rhizomes and cut it into pieces by using traditional knives. Those cut pieces is technically called as turmeric seed rhizomes. While cutting seed rhizome into pieces (i.e. seed rhizomes) care must be taken that each seed rhizome must contain two nodes.

After **planting** the seed rhizome in the soil, the plant germination starts from nodes of the rhizome. The length of cut pieces i.e. seedrhizomes varies significantly which depends on the health of the finger rhizome.

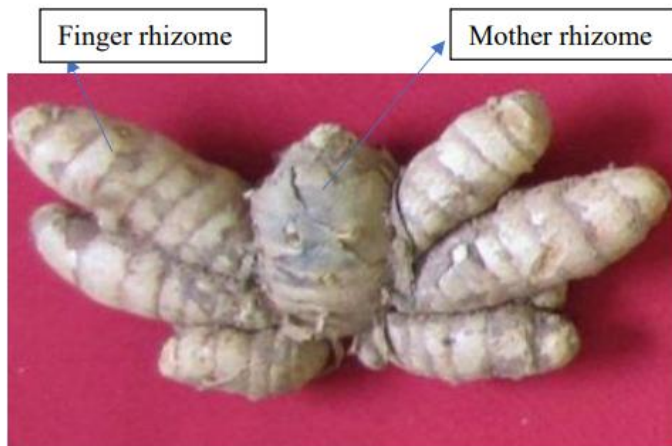


Fig. 3 Whole turmeric rhizome



Fig. 4 Turmeric seed rhizomes

Size of the turmeric rhizome varies with moisture content. Moisture content of the turmeric rhizome decreases on the passage of time from the time of harvest. Moisture content of the seed rhizomes measured by using Oven-drying method [7]. The moisture content of seed rhizome during **planting** season is varied between 20-25 per cent. Geometrical properties like length, breadth and thickness decreases with moisture content of the rhizome [8]. Generally turmeric crop is harvested in **f**ebruary and **m**arch whereas plantation takes place in the period of **j**une to **a**ugust.

2.2 Equivalent diameter

Length, breadth and thickness of the seed rhizome **were** measured using Vernier caliper (least count 0.01 cm) [9]. Breadth **was** measured as the diameter of the rhizome along major axis. Thickness **was** measured as diameter of the rhizome along minor axis.

Equivalent diameter, also known as geometric mean diameter of seed rhizome is defined as the cubic root of length, width and thickness (not necessary that the three intercepts should intersect with each other).

$$\text{Equivalent diameter} = (lbt)^{1/3} \dots [10]$$

Where l, b and t are the length, breadth and thickness of rhizome

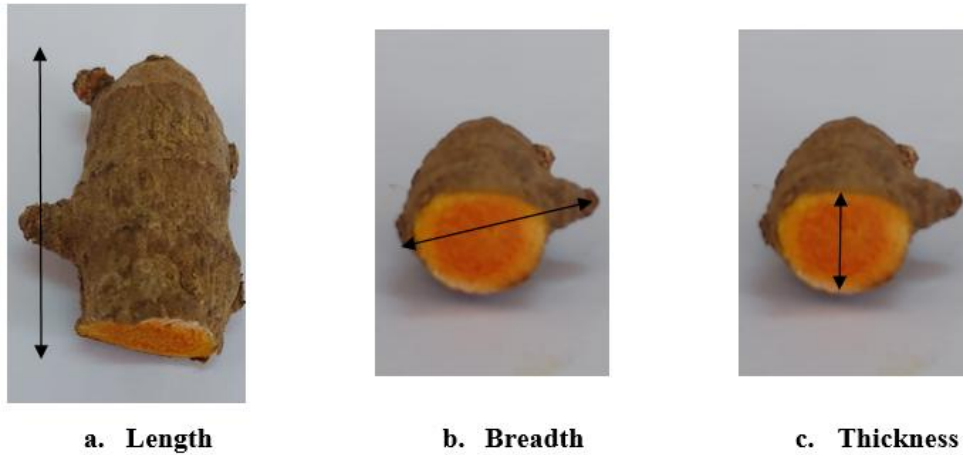


Fig. 5 Geometric parameters of turmeric seed rhizome

2.3 Density

Density is determined as the weight of the turmeric seed rhizome divided by its volume, expressed in kg m^{-3} [11]. Both bulk density and Apparent density were measured following the similar procedure. A 1000 ml volume empty cylindrical beaker was taken and filled it with the seed rhizomes. By measuring the weight of the filled rhizomes bulk density was measured. To measure the Apparent density, turmeric rhizomes were gently pressed into the beaker and refilled the empty space of beaker with rhizomes. New weight of seed rhizomes measured and apparent density was calculated. An Electronic weighting balance is used to measure the rhizome weights.

$$\text{Density} = \frac{\text{Weight}}{\text{Volume}}$$

True density is measured using toluene solution and measuring cylinder. A 100 ml toluene solution was filled in measuring cylinder and the single turmeric rhizome of known weight was dropped in it. Change in the volume of toluene solution is the volume of turmeric rhizome.

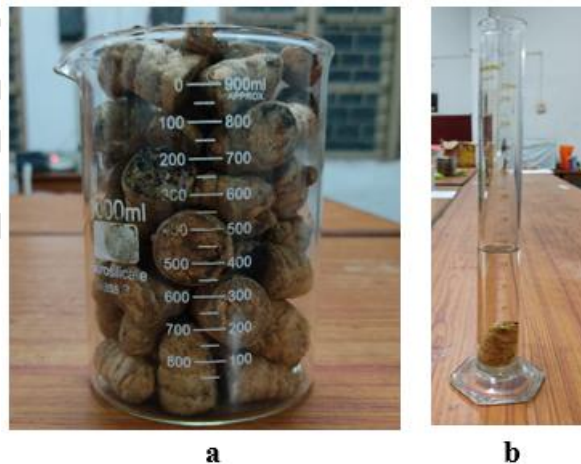


Fig. 6(a) Bulk density and (b) True density measurement

2.4 Angle of repose and coefficient of friction

Angle of repose and coefficient of friction are necessary to design a seed hopper of a planter. Properly designed hopper assures controlled free flow of seeds during planting [12]. The angle of

repose can be measured by angle of repose apparatus. Angle of repose of seeds was calculated using the following expression.

$$\theta = \tan^{-1} \frac{2H}{D} \dots [13]$$

Where θ , H, D are Angle of repose ($^{\circ}$), Height of rhizome heap (cm) and Diameter of circular plate (cm) respectively.

For determination of coefficient of friction of turmeric rhizomes, a tilting table top setup was used. Set up consisted two levelled surfaces in which one is constant to horizontal plane and other is movable in vertical plane. Turmeric rhizomes were kept on movable surface and raised it to the point where the rhizomes start to moving by rotating screws. The angle of tilt was measured. The tangent of angle with the horizontal is called as static coefficient of friction.

2.5 Comparison of physical parameters for local grown turmeric varieties

Physical parameters of few selected local grown turmeric varieties were needed to optimize the design of turmeric planter. Different parameters considered for the study were density, geometrical properties like length, breadth and thickness and frictional properties like angle of repose and coefficient of friction. Local grown turmeric varieties (Andhra and Telangana regions) viz., **Mydkur (Kadapa), Duggirala and Nizamabad** were selected to collect the information during rhizome planting stage. Measurements were taken from 5 randomly selected seed rhizomes of each variety.

3. RESULTS AND DISCUSSION

Physical properties of turmeric rhizomes play an important role in the design optimization of metering mechanism. Variety of the turmeric rhizomes were not given any attention while measuring the physical properties since all rhizomes are similar in size and shape.

3.1 Equivalent diameter

Equivalent diameter was the indirect property which indicates about length, breadth and thickness variations. Equivalent diameter was calculated by measuring the major, minor and intermediate axis dimensions of a seed rhizome. It increased with the weight of the rhizome and average equivalent diameter was calculated to be 2.45cm. Among length, breadth and thickness, Variation in length is more significant which is affecting the equivalent diameter and design of metering mechanism. Based on the results obtained a laboratory model was designed. Different metering cups were designed to check the planting efficiency.

3.2 Density

Density plays an important role in design of proper seed hopper. A hopper should facilitate storage of seed for longer time during planting work on field and at a time it should not be over weighted. Bulk density and true density were found to be 640 and 1040 kg m⁻³ respectively. During field work, there may be a change in seed density because of jerks and vibration. Bulk density changes are analysed by knowing Tapped density. Tapped density of seeds also measured as 680 kg m⁻³. All these density measurements were used in designing the seed hoppers of laboratory models and prototype of turmeric planter.

Table.1 Gravimetric properties of turmeric rhizomes

S. No.	Turmeric Variety	Bulk Density (kg m ⁻³)	True Density (kg m ⁻³)	Tapped Density (kg m ⁻³)	Moisture Content (%)
1	Mydkur (Kadapa)	649	1057	703	22.5
2	Duggirala	632	1026	662	20.5
3	Nizamabad	639	1037	675	21.5
4	Average	640	1040	680	21.5

3.3 Physical parameters for local grown turmeric rhizome seed varieties

Observation related to the physical properties of locally grown turmeric rhizome varieties during planting stages enabled us to find a proper design of metering mechanism and hopper. Major turmeric varieties cultivated in Andhra Pradesh and Telangana regions are Mydkur (Kadapa), Duggirala and Nizamabad were chosen for the study. All these varieties shape is similar i.e. oblong, but there is a little difference in lengths and breadths. Among all these varieties, Mydkur (Kadapa) variety rhizome is longer and broader than other varieties.

Table.2 Geometric properties of local grown Turmeric varieties

Parameters	Length (cm)	Breadth (cm)	Thickness (cm)	Angle of repose (°)	Coefficient of friction on MS sheet
Mydkur (Kadapa)					
Minimum	3.9	1.9	1.5	31	0.75
Maximum	5.5	2.5	2	42	0.85
Mean	4.38	2.12	1.76	36.6	0.812
Median	4.1	2	1.8	36	0.82
SD dev	0.67	0.26	0.21	4.15	0.04
Duggirala					
Minimum	3.8	1.7	1.5	31	0.76
Maximum	5.5	2.5	1.9	41	0.82
Mean	4.29	2.1	1.68	35.4	0.79
Median	4	2.2	1.6	35	0.8
SD dev	0.7	0.3	0.16	3.8	0.02
Nizamabad					
Minimum	3.7	1.65	1.5	30	0.75
Maximum	5.4	2.4	1.9	36	0.82
Mean	4.22	2.09	1.7	32.8	0.79
Median	4	2.1	1.7	33	0.8
SD dev	0.67	0.32	0.15	2.38	0.03

3.4. Design of Laboratory Model

Based on these physical properties, a metering mechanism for turmeric rhizome was designed which assist all the local varieties. A Laboratory model was developed by incorporating results of all the physical properties. This model was designed to work in Soil-Bin set up where it offers similar field conditions and speedy testing. Different types of rhizome metering cups were designed to check their seed picking efficiency.

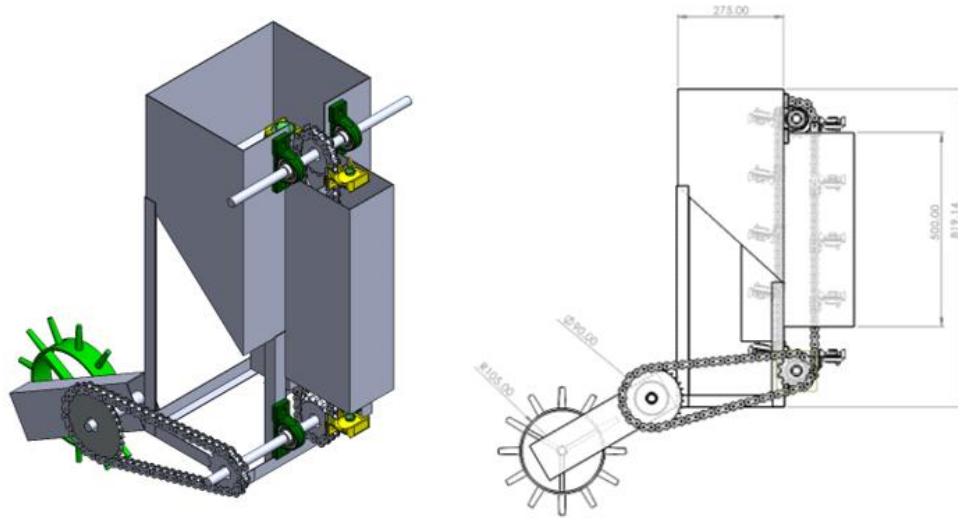


Fig. 7 Laboratory model of Turmeric planter

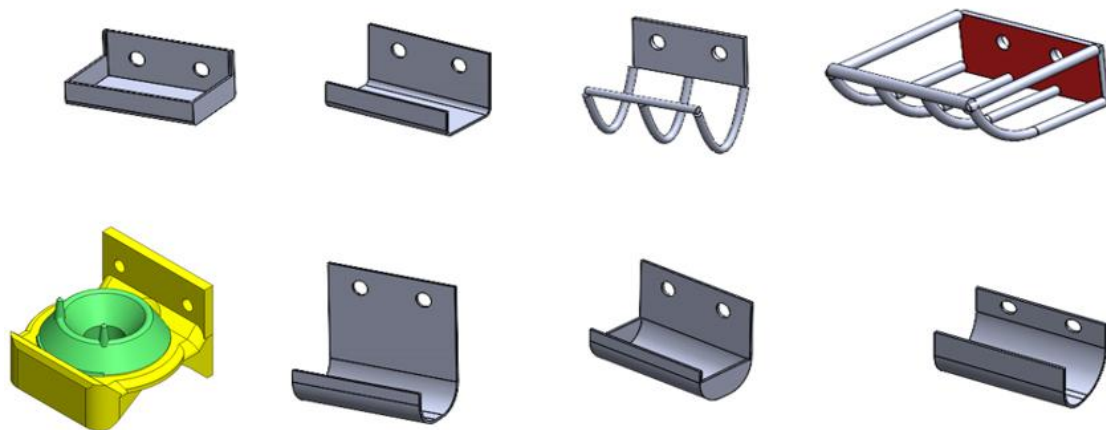


Fig. 8 Different rhizome metering cups designed for Laboratory model

4. CONCLUSION

Different turmeric planting methods were briefly discussed in Introduction of this article. Turmeric seed material preparation procedure is clearly explained in materials and methods of this article. Physical properties of turmeric seed rhizomes are investigated as a primary objective in developing Automatic turmeric planter. Average weight of turmeric seed rhizome was found to be 15.5 g with an equivalent diameter of 2.45cm. Bulk density and tapped density of seed rhizomes found to be 640 and 680kg m⁻³, respectively. From rigorous lab studies in various turmeric varieties, average seed rhizome length was noted to be 4.29cm. Average breadth and thickness were noted as 2.1 and

1.7 cm, respectively. The length of finger rhizome used as seed material in turmeric cultivation is ranges from 3.7 to 5.5 cm. By utilizing all these physical properties results proper design of a turmeric planter models were made to develop a turmeric planter.

RESEARCH CATEGORY

Agricultural Engineering, Farm Machinery and Power Engineering

CONSENT

As per international standard or university standard, Participants' written consent has been collected and preserved by the author(s).

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