Original Research Article

ENGINEERING PROPERTIES OF FOXTAIL MILLET SEEDS FOR DEVELOPMENT OFPLANTER FOR MILLET CROP

Abstract

Millets are drilled using conventional tools and seeded using broadcasting. By using these tools, seeds were not distributed uniformly, which led to an excess of plants and irregular spacing. Furthermore, if seed is sown in a line rather than a spread pattern, harvesting and threshing activities become more efficient. In keeping the views of above facts, planter for millet seeds was developed.A study was carried out to measure the engineering properties of foxtail millet seeds for development of planter for millet crop.Engineering properties helps in design of machine parameters like type of seed metering mechanism, size of cell and hopper capacity *etc*. The engineering properties such as mean linear dimensions viz., length, width and thickness are 2.20 mm, 1.23 mm and 1.11 mm respectively. The physical properties like geometrical mean diameter, bulk density and true density of are 1.43 mm, 670.33 kg m^{-3}, 1156.2 kg m^{-3}respectively. The frictional properties such as angle of repose, co-efficient of internal and external friction are 24.30 degrees, 1.23 and 0.45 degrees respectively.In developing the millet planter, these measured engineering parameters were taken into account.

Keywords: Millet planter, physical properties and frictional properties.

Introduction

Millets are among the oldest cultivated crops and are highly nutritious compared to refined cereals (Kiple, 2001). Global millet production stands at 28.45 million metric tons, covering approximately 30.11 million hectares of cultivated land (Anon, 2015). India leads the world in millet cultivation, with 8.9 million hectares under cultivation, producing 11.56 million metric tons, and achieving a productivity rate of 1,299 $kgha^{-1}$. Millets are adaptable to various soil types, rainfall patterns, and environmental conditions, thriving in a range of thermal and photoperiod regimes. Their resilience enables them to flourish in different ecological settings, making them essential for rainfed, tribal, and hill agriculture where crop substitution is challenging (Michael Raj & Shanmugam, 2013). Despite these benefits, the area dedicated to millet cultivation has been declining in recent decades, likely due to the lower market value, reduced cultivation area, and limited mechanization in production processes (Sims *et al.*, 2016).

Millet crops are becoming increasingly significant in India due to their rich nutritional profile and economic value. These grains offer a valuable source of energy, proteins, fatty acids, vitamins, minerals, dietary fiber, and polyphenols, making them highly versatile for various food applications. Foxtail millet, in particular, contains between 8.0% and 18.2% protein, 3% to 5% fat, 59.3% to 69.5% carbohydrates, 1.2% to 2.8% fiber, 1.5% to 2.7% ash, and 2.0% to 2.7% sugar (Adebowale et al., 2012). Additionally, millets are abundant in phytochemicals, antioxidants, and micronutrients such as phenolic acids, glycated flavonoids, and key vitamins like niacin, B6, folacin, calcium, iron, magnesium, and zinc (Thilagavathi*et al.*, 2015). Their consumption has been associated with several health benefits, including cancer prevention, reduced risk of cardiovascular disease, weight loss support, tumor reduction, blood pressure regulation, improved cholesterol levels, slowed fat absorption, and enhanced metabolic function (Gupta *et al*., 2012).

Foxtail millet is cultivated in both tropical and temperate regions and thrives in areas with an annual rainfall of around 750 mm. This grain crop, which has a growing period of approximately 100 days, is well-suited to regions with low to moderate rainfall, typically between 500 to 700 mm. It can also be cultivated at higher altitudes, reaching up to 1830 meters above sea level, and is a vital food source in the Himalayan foothills. The crop is grown throughout the year in different regions of India, with about 90% of its cultivation concentrated in the lower Deccan Plateau, particularly in the highlands of Andhra Pradesh, Karnataka, and Tamil Nadu. In the hilly regions of North India, foxtail millet is often intercropped with other kharif crops, maturing within two months to provide food during periods of scarcity. In states like Punjab, Himachal Pradesh, and Uttar Pradesh, it is sown between June and July and harvested from September to October, often as a border or mixed crop alongside other kharif crops (Vilas *et al*., 2016).

In India, millets are traditionally sown using broadcasting and drilling methods with conventional tools. However, these methods often lead to uneven seed distribution, resulting in overcrowded plants and irregular spacing. Moreover, harvesting and threshing processes are more efficient when the seeds are sown in rows rather than scattered through broadcasting(Nandede*et al.*, 2018).

A precise sowing process involves ensuring the correct number of seeds per unit area, proper sowing depth, and appropriate spacing both between rows and individual plants, which can be achieved using seed drills and planters. These tools not only minimize labor and reduce costs but also help in timely operations. To optimize the performance of seed drills and planters, the field must be well-prepared with finely pulverized soil. Seed drills distribute seeds in furrow lines continuously, but with uneven spacing between individual seeds. They can be used for sowing in single or multiple rows. In contrast, planters are designed for larger seeds that seed drills cannot handle. They ensure uniform row-to-row and plant-to-plant spacing by performing key functions: opening furrows, metering seeds, placing them in the furrows, and covering them with soil (Alaamer&Alsharifi, 2020).

Material and methods

1. Size of seeds

The dimensions of foxtail millet seeds (length, width, and thickness) were determined using a micrometer with an accuracy of 0.001 mm. Measurements were taken from 20 randomly selected grains and the average values were recorded (Shivabasappa*et al.*, 2012).

2. Geometrical mean diameter of seeds

The geometric mean diameter was calculated by using the formula given below.

Geometric mean diameter,

$$D_m = [LBT]^3$$

Where,

L = Longest intercept (length),
B = Longest intercept normal to L (width) and
T = Longest intercept normal to L and B (thickness)

3. Bulk density of seeds

The bulk density is defined as the ratio of a sample's weight to its total volume. In this experiment, bulk density was measured using a 100-ml glass beaker. The beaker was first weighed, then filled with foxtail millet seeds up to the 100-ml mark, and the weight of the seeds in kilograms was recorded. This process was repeated three times, and the average weight was used for the final measurement. The bulk density was then calculated using the following formula(Alsharifi and Ameen, 2018).

$$\text{Bulk density (kg m}^{-3}\text{)} = \frac{\text{Weight of foxtail millet let filled in 100 ml glass beaker (kg)}}{\text{Volume of 100 ml beaker (m}^3\text{)}} \times 100$$

Where,

Volume of 100 ml glass beaker (m^3) = $(\pi/4) \times D^2 \times H$
D = Diameter of the 100 ml glass beaker, m
H = Height of the 100 ml glass beaker, m

4. True density of seeds

The true density represents the ratio of a grain sample's mass to the solid volume it occupies. In this experiment, 50 ml of toluene was placed in a 100 ml measuring cylinder, and 10 g of foxtail millet was added. The rise in toluene volume, representing the actual volume of the millet without voids, was noted. This procedure was conducted three times, and the average value was used. The true density of the foxtail millet was then determined using the following formula(Soyoye*et al.*, 2018).

$$\text{True density (kg m}^{-3}) = \frac{\text{Weight of foxtail millet (kg)}}{\text{Change in volume of toulene in 100 ml glass beaker (m}^{3})} \times 100$$

Where,

Change in volume of toluene in 100 ml glass beaker (m^3) = (π/4) × D^2 × H

D = Diameter of 100 ml glass beaker, mm

H = Height of 100 ml glass beaker, mm

5. Angle of repose of seeds

The angle of repose refers to the angle between the base and the slope of the cone formed when foxtail millet is freely poured onto a horizontal surface (as shown in Fig. 1). The experimental setup included a hopper containing 1 kg of foxtail millet seeds and a circular iron platform supported by iron legs. The seeds were released from the hopper onto the platform, forming a natural pile. The angle of repose was calculated using the height and diameter of the pile, following a specific formula. All measurements were taken in triplicate, and the average values were recorded.

$$\text{Angle of repose, } \Phi = \tan^{-1}\frac{H}{r}$$

Where,

Φ = Angle of repose, degrees φ

H = Height of heap, mm

r = Radius of heap, mm

Fig. 1. Measurement of angle of repose of foxtaill millet seeds

6. Co-efficient of friction of seeds

The coefficient of internal friction refers to the resistance between grain particles when they move against each other. In the experiment described, a box with dimensions of 10×10×10 cm was tied to a cord that passed over a pulley and connected to a pan. The surface was covered with a layer of foxtail millet seeds to a depth of 1 cm (Fig. 2). Weights (W_1) were added to the pan until the empty box began to slide across the millet surface. The box was then filled with 200 g of foxtail millet (W), and weights (W_2) were again added to the pan until the filled box started sliding. This process was repeated three times, with the average values recorded (Shivabasappa*et al*., 2012).

$$\text{Co-efficient of internal friction } (\mu_i) = \frac{W_2 - W_1}{W}$$

Where,

W_1= Weight to cause sliding of empty box, g

W_2 = Weight to cause sliding of grain filled box, g

W = Weight of foxtail millet inside box, g

The coefficient of external friction, which measures the sliding friction between grain and a horizontal surface, was evaluated for foxtail millet using galvanized iron and cardboard test surfaces. A 10×10×10 cm box was suspended by a cord over a pulley, with a pan attached to the opposite end of the cord. Weights (W_1) were added to the pan until the empty box began to slide. Subsequently, the box was filled with 200 grams of foxtail millet (W), and additional weights (W_2) were added to initiate sliding of the filled box. The weights needed to slide the filled box were recorded, and the procedure was repeated three times to obtain an average value (Shivabasappa*et al.*, 2012).

$$\text{Co-efficient of external friction } (\mu_e) = \frac{W_2 - W_1}{W}$$

Where,

W_1 = Weight to cause sliding of empty box, g

W_2 = Weight to cause sliding of filled box, g

W = Weight of foxtail millet inside box, g

Fig. 2 Measurment of frictional properties of foxtaill millet seeds

Results and discussion

The engineering properties of foxtail millet seeds which are necessary for the development of millet planter components were measured.Moisture content of the seeds during the measurement of properties was noted as 11.06 ± 0.09 %. The results obtained are presented in the Table 1.

1. Size of seed

Physical dimensions, length, width and thickness of foxtail millet seeds were 2.20 mm, 1.23 mm and 1.11 mm respectively. These values helped in the design of cells size on the seed plate for flow of seeds. The cell size on the metering plate must be appropriate for the seed size to ensure accurate and consistent seed pickup, transport, and release. The size of the seed directly influences the design of the cell size on the metering plate of sowing equipment.The cell should be large enough to accommodate the seed but not so large that it allows multiple seeds to be picked up at once. Based on the size of the seeds we developed the metering plate for easy flow of seed metering mechanism.

2. Geometrical mean diameter of seed

Geometrical mean diameter of the selected foxtail millet seed was obtained as 1.43 mm.It helped in determining the dimension of the cell on the seed plate. Seeds plates with cell size 10, 20 and 30 per cent greater the maximum diameter of seed was developed for the sowing equipment.

3. Bulk density of seeds

The bulk density of the foxtail millet seeds was found to be 670.33 kg m^{-3}**.**Ithelps in the design of the seed hopper in sowing equipment by determining its size, shape, and capacity to ensure efficient seed flow, prevent clogging, and maintain a consistent seed supply to the metering mechanism. Hoppers must accommodate seed to provide optimal volume for storage and flowability and enhancing equipment performance.

4. True density of seeds

The true density of the foxtail millet seeds was found to be 1156.20 kg m^{-3}. It determines the hopper's capacity, shape, and flow characteristics, ensuring consistent seed flow, preventing bridging, and minimizing seed damage during planting operations.

5. Angle of repose of seeds

Angle of repose of the selected foxtail millet seeds was determined and the value was found to be 24.30 degrees.It helps in deciding the slope of hopper to be provided for the easy flow of seeds**.** The hopper slope must be steeper than the seedsangle of repose to facilitate continuous movement toward the metering mechanism. This design consideration minimizes interruptions in seed flow and maintains planting efficiency.

6. Co-efficient of friction for seeds

The co-efficient of internal and external friction of foxtail millet seed were obtained as 1.23 and 0.45 degrees respectively.A low friction coefficient helps seeds move easily through the hopper, while a higher coefficient may require steeper hopper walls or surface treatments to facilitate consistent seed flow. By considering co-efficient of friction values, we have selected material for hopper construction, which ensures smooth flow of seeds to seed metering mechanism.

Table 1. Engineering properties of selected foxtail millet seed for millet planter

Sl. No.	Properties	Values
1	Physical dimensions	
	a. Length (mm)	2.20 ± 0.16
	b. Width (mm)	1.23 ± 0.04
	c. Thickness (mm)	1.11 ± 0.18
2	Geometrical diameter (mm)	1.43 ± 0.16
3	Bulk density (kg m^{-3})	670.33 ± 17.48
4	True density (kg m^{-3})	1156.00 ± 83.72
5	Angle of repose (degrees)	24.30 ± 1.70
6	Coefficient of internal friction	1.23 ± 0.07
7	Coefficient of external friction	0.45 ± 0.01

Conclusions

Seed dimensions and properties are much essential in development of the sowing equipment. Hence, for design and development of bullock drawn millet planter the engineering properties are the required parameters. The average values of length, geometrical mean diameter, bulk density, true density, angle of repose, co-efficient of internal and external friction of foxtail millet seeds are 2.20 mm,1.43 mm, 670.33 kg m^{-3}, 1156.20 kg m^{-3}, 24.30, 1.23 and 0.45 degrees respectively.

Disclaimer (Artificial intelligence)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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