Original Research Article

ENGINEERING PROPERTIES OF FOXTAIL MILLET SEEDS FOR DEVELOPMENT OF BULLOCK DRAWN PLANTER FOR MILLET CROP

Abstract

Millets are sown by broadcasting and drilling by traditional implements. The use of such implements resulted innon-uniform distribution of seeds which in turn gave excessplant population and uneven spacing. Further, harvesting andthreshing operations becomes more effective if sowing is donein line rather than broadcasting. In keeping the views of above facts, planter for millet seeds was developed. A study was carried out on investigation on bullock drawn planter for millet crop at College of Agricultural Engineering, Raichur.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. These measured engineering parameters were considered for the development of millet planter.

Keywords: Millet planter, physical properties and frictional properties.

Introduction

Millets are one of the oldest cultivated food crops known to humans (Kiple, 2001) and are highly nutritive grains compared to fine cereals. World's millet production is 28.45 Mt from cultivated area about 30.11 M ha (Anon, 2015). India is the leading country in the world growing in an area of 8.9 M ha with production of 11.56 Mt and the productivity being 1299 kg h^{-1}. Millets are grown in diverse soils, varying rainfall regimes and in areas widely differing in thermos and photoperiods. The resilience exhibited by millet crops is helpful in adjusting themselves to different kinds of ecological niches because of their eco-friendly nature. All these have made them quite indispensable to rain fed, tribal and hill agriculture where crop substitution is difficult (Michael raj and Shanmugam, 2013). Despite having various advantages, total area harvested is declining from few decades. It may be due to the lower cost of the produce, area under cultivation and lower level of mechanization in all production operations (Sims *et al.*, 2016).

The millet crops are gaining more importance in India. Millets are good source of energy, protein, fatty acids, vitamins, minerals, dietary fiber and polyphenols. It has great potential for being utilized in different food systems by virtue of its nutritional quality and economic importance. Foxtail millet contains 8.0 to 18.2 % protein, 3 to 5 % fat, 59.3 to 69.5 % carbohydrate, 1.2 to 2.8 % fiber, 1.5 to 2.7 % ash and 2.0 to 2.7 % sugar (Adebowale *et al.*, 2012). Millets are rich sources of phytochemicals, micronutrients and anti-oxidants, such as phenolic acids and glycated flavonoids, also in vitamins, especially niacin, B6 and folacin, calcium, iron, magnesium and zinc (Thilagavathi *et al.*, 2015). Several potential health benefits such as preventing cancer and cardiovascular diseases, reducing heart attack risk, helps in weight loss, reducing tumor incidence, lowering blood pressure, risk of heart disease, cholesterol and rate of fat absorption and delaying gastric problems and aids in metabolic rate of the body (Gupta *et al.*, 2012).

The foxtail millet is cultivated in both tropical and temperate regions. The crop can be grown successfully in areas receiving 750 mm of annual rainfall. Foxtail millet is essentially a grain crop of about 100 days duration suited to conditions of low and moderate rainfall ranging from 500 to 700 mm. It can be grown in higher altitudes (up to 1830 m above MSL) and is an important food grain in the foothills of Himalayas. It is a crop grown almost throughout the year in different parts of the country. Cultivation of foxtail millet in the lower Deccan Plateau including high lands of Andhra Pradesh, Karnataka and Tamil Nadu account for about 90 per cent of the area in the country. In the hilly regions of North India, foxtail millet is sown with other kharif crops and matures in about 2 months, providing food during scarcity periods. In Punjab, Himachal Pradesh and U.P. it is grown from June-July to September-October either as a border or as a mixed crop with several kharif crops(Vilas *et al.*, 2016).

India, millets are sown by broadcasting and drilling by traditional implements. The use of such devices resulted innon-uniform distribution of seeds which in turn gave excessplant population and uneven spacing. Further, harvesting andthreshing operations becomes more effective if sowing is donein line rather than broadcasting (Khan and Sahrigi, 1990).

A perfect sowing gives, correct number of seed per unit area, correct depth of sowing, correct spacing between row-to-row, plant-to-plant and correct seed rate which can be achieved by use of seed drill and planters. Use of these implements not only reduces human drudgery and labour cost but also ensures the timeliness of operation. Proper field preparation with finely pulverized soil is a pre requisite for better performance of seed drill and planter. In seed drill seeds are dropped in the furrow lines of the drill in a continuous stream and covering them with soil. But the spacing between the seeds is not uniform. The number of rows may be one or more. Planter is sowing equipment used for sowing those seeds which are larger in size and cannot be handled by seed drills. Row to row, plant to plant spacing is maintained in planter. Function of planter is to open the furrow, meter the seed, deposit the seed in the furrow, covering the seed with soil (Nandede *et al*., 2018).

Material and methods

1. Size of seeds

The size of foxtail millet seeds (length, width and thickness) was measured by using a micrometer to an accuracy of 0.001 mm. The randomly selected 20 grains were measured and average value was recorded (Shivabasappa *et al.,* 2012).

2. Geometrical mean diameter of seeds

The geometric mean diameter was calculated by using the relationship.

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 the ratio of the weight of the sample to total volume of the sample. The bulk density was determined using a 100 ml glass beaker. The glass beaker was weighed, then filled with the foxtail millet seeds up to 100 ml and measured the weight of foxtail millet occupied in kg. The experiment was repeated thrice and the average value was recorded. The bulk density was calculated using the following formula (Mohsenin, 1986).

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

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 is the ratio of the mass of the grain sample to the solid volume occupied by the sample. 50 ml of toluene were taken in a 100 ml measuring jar. 10 g of foxtail millet sample were poured into the measuring jar and rise in the toluene level (ml) was recorded as the true volume of the foxtail millet without void space. The experiment was repeated thrice and the average value was recorded. The true density of the foxtail millet was calculated by using the following formula (Mohsenin, 1986).

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

Where,

Change in volume of toluene in 100 ml glass beaker (m^3) = $(\pi/4) \times D^2 \times H$
D = Diameter of 100 ml glass beaker, mm
H = Height of 100 ml glass beaker, mm

5. Angle of repose of seeds

Angle of repose is the angle between base and slope of the cone formed on a free vertical fall of foxtail millet on to a horizontal plane (Fig. 1). It was determined by following the method described by Sahay and Singh (1994). The apparatus consisted of a hopper filled with 1 kg of foxtail millet seeds and circular iron platform supported by iron legs. The foxtail millet seeds were allowed to flow from the hopper over the circular iron platform. A heap of foxtail millet was formed on a circular iron plate. From the height and diameter of foxtail millet heaped in natural pile, the angle of repose was calculated by using the following formula. All the measurements were replicated thrice 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 is the friction between the grain mass of kernels against each other. A box of size 10×10×10 cm tied by a cord passing over pulley was attached to a pan. The surface was filled with foxtail millet seeds to a depth of 1 cm (Fig. 2). The weight (W_1) was put into pan until the empty box started to slide on foxtail millet surface. Later, the empty box was filled with 200 g of foxtail millet (W) and again the weights were put into pan and were allowed to slide. The weights (W_2) required to slide the filled box on the foxtail millet surface was recorded (Shivabasappa *et al.*, 2012). The experiments were repeated thrice and the average values were recorded.

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

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

Coefficient of external friction (metal and seeds) is the sliding friction between the grain and the horizontal plane against the wall. The coefficient of external friction was determined for foxtail millet using test surfaces of galvanized iron and card board. The box of the size 10×10×10 cm was tied by cord passing over pulley and a pan was attached to the other end of the cord. The weights (W_1) were put into pan until the empty box started to slide. Later, the box was filled with 200 g of foxtail millet (W) and again the weights were put into pan to cause it sliding. The weights (W_2) required to slide the filled box was recorded (Shivabasappa *et al.,* 2012). The experiments were repeated thrice and the average value were recorded

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

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. 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.

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