Original Research Article

Assessment of Physical Properties of Black Gram and Green Gram Seeds in Relation to the Design of Seed Metering Mechanisms

ABSTRACT

In 2023, a comprehensive study was carried out at the Department of Agricultural Engineering, IARI, New Delhi, India, focusing on the investigation of vital physical properties encompassing size, sphericity, test weight, bulk density, true density, coefficient of static friction, and angle of repose for black gram and green gram seeds. Black gram seeds were characterized by mean dimensions of 4.90 mm (length), 3.74 mm (breadth), 3.57 mm (thickness), and a geometric mean diameter of 4.02 mm. In contrast, green gram seeds exhibited corresponding values of 5.08 mm, 4.06 mm, 3.99 mm, and 4.45 mm. Sphericity percentages were quantified as 82% for black gram and 86% for green gram. Mean bulk density measurements of 0.86 g/cc (black gram) and 0.87 g/cc (green gram) were accompanied by true density values of 1.36 g/cc and 1.38 g/cc, respectively. The mean angle of repose measurements were recorded as 24.06° (black gram) and 23.94° (green gram). The mean coefficient of static friction exhibited variability across different materials: 0.50 (aluminum), 0.45 (mild steel), 0.47 (galvanized iron), and 0.60 (plywood) for black gram seeds; while for green gram seeds, corresponding values were 0.48, 0.43, 0.45, and 0.57. Additionally, the mean thousand-grain weight was found to be 41.82 g for black gram and 46.18 g for green gram.

Keywords: Angle of Repose, Coefficient of Static Friction, Geometric Mean Diameter, Physical Properties, Seed Metering Mechanism

1. INTRODUCTION

"Population of India is growing at a fast pace. Thus, it is necessary to increase the productivity of the agriculture sector to meet the food requirement of growing population. India stands as the world's leading producer (26%), consumer (27%), and importer (15%) of pulses. Pulses account for around 20% of the area under food grains and contribute 7-10% of the total food grain production in the country"[1]. "Pulses are cultivated in both the Kharif and Rabi seasons, with Rabi pulses contributing over 60% of the total production" [2,3]. "The major pulse crops grown in India are chickpea, pigeon pea, green gram (Mungbean) and black gram (Uradbean) in that order of importance. Green gram occupies 4.4 million hectares with an annual yield of 2.56 million tonnes. Similarly, black gram is cultivated on approximately 4.1 million hectares, yielding around 2.42 million tonnes" [4]. Substantial shares of pulse imports, including chickpeas, pigeon peas, mung beans, and urad beans, originate from Myanmar, Canada, and Australia. For reducing the import, there is need to increase the production of pulses particularly in our country.

"Seeding or planting is one of the most important critical operations in agriculture which influence the production of crops. Use of seed drill for pulses enables farmers to cover large areas in a relatively short period" [5]. "Besides, sowing by seed drill leads to uniform crop stand and row spacing which facilitates intercultural operations. Seed rate and spacing between seeds are not maintained efficiently while sowing with conventional seed drill which causes hindrance in mechanizing subsequent operations" [6]. There is a need to develop efficient seed meterring mechanism for pulses which should meet the need of farmers with precision as well as affordability.

The physical characteristics of seeds, such as size, shape, angle of repose, thousand-grain weight, and bulk density, play a crucial role in the design of seed metering unit. These factors also substantially impact the performance of seed metering mechanisms used in planters or seed drills. Jayan and Kumar, 2006 [7], conducted research to gauge the physical characteristics of maize, red gram, and cotton seeds. Their findings indicated that both sphericity and roundness influenced seed flow through different planter components. Variations in average unit mass, volume, thousand-seed mass, bulk density, true density, bulk density, and porosity exist among seed varieties, affecting seed metering mechanism performance [8,17]. In a study by Ajay *et al.,* 2021 [9], focusing on three maize varieties (Rasi-3033, NMH-589, and KMH-2589), the investigation aimed to optimize seed metering unit design parameters. Their outcomes underscored the criticality of physical properties in developing efficient planter components for effective functionality. While several researchers have reported on diverse seed physical characteristics, there is still a lack of research exploring the correlation between these properties and metering system design, particularly for green gram and black gram. To address these issues, a study was undertaken to investigate the different physical properties of the selected black gram and green gram seeds in relation to the design of seed metering mechanisms.

2. MATERIAL AND METHODS

The physical characteristics of seeds, including size, shape, bulk density, angle of repose, and thousand-grain weight, play a crucial role in the performance of the seed metering mechanism. These properties were thoroughly examined and the data is used for the design of an efficient seed metering system. The size property was used to determine the groove length, depth, and the number of seeds required on the groove surface. The shape property ensured the smooth and uniform flow of selected pulse seeds from the groove. The bulk density and true density values aided in designing the appropriate seed hopper volume and thickness. The angle of repose and coefficient of friction were considered to establish the optimal slope for the free flow of selected pulse seeds from the hopper. The coefficient of static friction was measured to select a suitable hopper material that allows uniform and free flow of seeds. Additionally, the thousand-grain weight played a key role in calculating the number of seeds needed per meter area to achieve the desired seed rate.

All experiments were conducted in the laboratory of the Division of Agricultural Engineering at IARI, New Delhi, using an experimental set-up to determine the aforementioned physical properties. The experimental procedure for determining the aforementioned physical properties of the selected seed varieties is outlined below.

i) Size and shape

The size and shape of black gram and green gram seeds were two significant factors that influences the determination of the shape and size of the seed metering plate. To accomplish this, a random sampling of seeds was conducted, and their length (*l*), breadth (b), and thickness (t) were measured in three mutually perpendicular directions using a digital vernier caliper with a least count of 0.01 mm (Fig 1(a). The size of the seed is expressed as the geometric mean dimension (Dg), determined using the relationship proposed by [10,11].

$$\text{Geometrical mean} = \sqrt[3]{l \times b \times t}$$

Where,
l = length of seed, mm
b = breadth of seed, mm
t = thickness of seed, mm

Sphericity (Ø) plays a significant role in ensuring the smooth and even flow of pulse seeds from the groove surface of the metering plate. Sphericity serves as the parameter to define the shape of the seed. The calculation of sphericity (Ø) follows the method proposed by [10].

$$\text{Ø} = \frac{\sqrt[3]{(l \times b \times t)}}{l}$$

ii) Bulk density

Bulk density and true density measurements are utilized in the design of the seed hopper. To determine the bulk density, a cube of size 10x10x10 cm was used. The cube was filled with pulse seeds without any compaction, and the weight of the seeds inside the cube was subsequently measured (Fig 1(b). The bulk density was calculated by dividing the weight of the seeds by the volume of the cube, using the following relationship [12].

$$\rho = \frac{W}{V}$$

Where,
ρ = Bulk density, g cc^{-1}
W = Weight of the seed, g
V = Volume of the sample, cc

iii) True density

The true density of pulse seeds was determined using the hexane displacement method (Mohsenin, 1986). The volume and true density were assessed for 10 samples of seeds, with the weight of each sample being recorded. Each sample was immersed in a jar filled with hexane liquid (Fig 1(c)), and the volume of displaced hexane was measured for each sample. The true density was then calculated as the ratio of the weight of each sample to its corresponding volume [13]

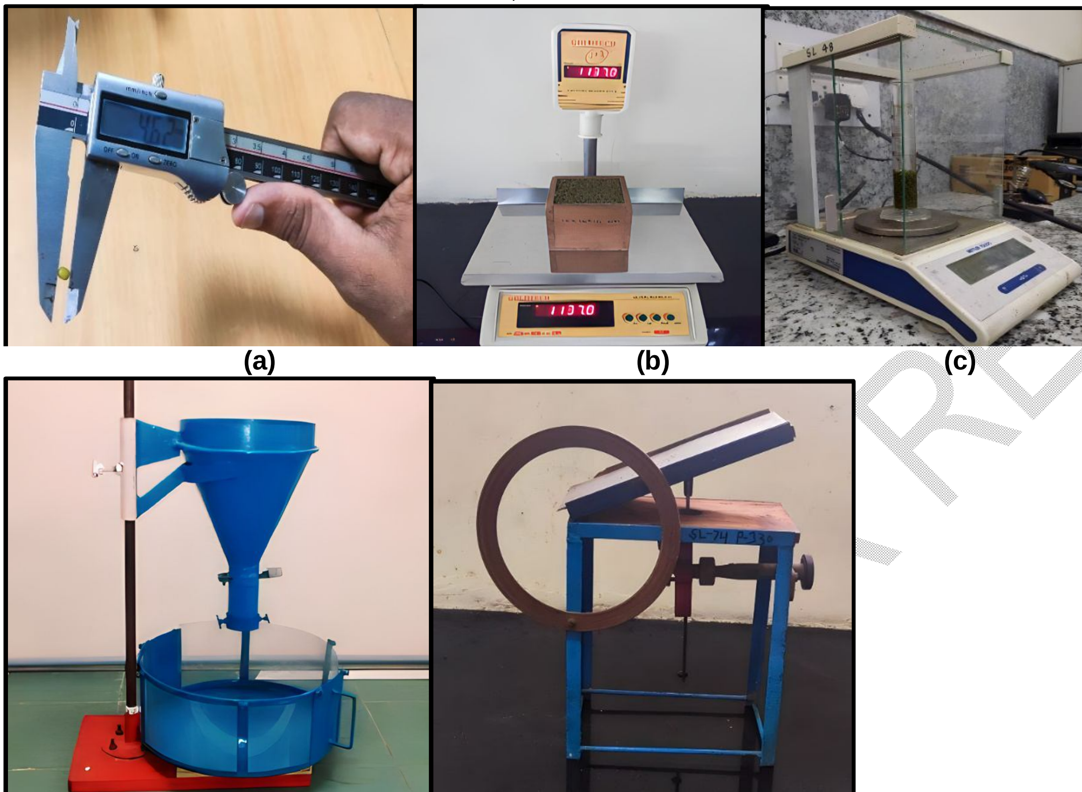
iv) Angle of repose

The equipment used to measure the dynamic angle of repose comprised a funnel with a throat opening that could be adjusted, and it was mounted on a stand (Fig 1(d). Inside the funnel, there was a circular plate with centering arms positioned above the adjustable throat. To begin the measurement, the funnel was filled with seeds, while keeping the adjustable throat closed. Then, the throat was fully opened, allowing the seeds to flow freely over and around the plate inside the funnel. This resulted in the formation of a heap of seeds on the plate. The base diameter and height of the seed heap were measured.The angle of repose was calculated using the following equation [14,18,18].

$$\theta = tan^{-1}\left(\frac{2H}{D}\right)$$

Where,

ϴ = Angle of repose, degrees
H = height of cone, cm
D = base diameter, cm



(a) (b) (c)

(d) (e)

Figure 1. Measurement of (a) seed size (b) bulk density (c) True density (d) Angle of repose and (e) Coefficient of static friction

v) Coefficient of static friction

The inclined plane method (Fig 1(e))was utilized to measure the coefficient of static friction for pulse seeds. The procedure involved placing the material on a horizontal surface and gradually increasing the slope. The angle (α) at which the seeds were on the verge of sliding was recorded. The coefficient of static friction was then determined as tanα. This process was repeated twenty times, and the mean value was calculated [15]. The experiment was replicated with various samples of black gram and green gram seeds.

vi) Thousand-grain weight

"The key factor used to determine the desired seed rate of green gram and black gram seeds was the weight of one thousand seeds. Ten random samples, each containing one thousand seeds, were selected from chosen seed varieties. These samples were then weighed using an electronic balance, and the average weight was calculated" [16].

3. RESULTS AND DISCUSSION

The design of the seed metering mechanism involved evaluating the physical characteristics of selected seed varieties, such as black gram and green gram seeds. These characteristics included size, shape, bulk density, angle of repose, and coefficient of static friction. The resulting observations are outlined below:

Table 1 illustrates the spatial dimensions of the seeds of black gram and green gram. The mean length of the chosen black gram seeds was 4.90 mm, while that of green gram seeds was 5.08 mm. Correspondingly, the average breadth for black gram and green gram seeds measured 3.74 mm and 4.06 mm, respectively. The average thickness of black gram and green gram seeds were 3.57 mm and 3.99 mm, respectively (Fig. 2). Furthermore, the geometric mean diameter for black gram and green gram seeds were 4.02 mm and 4.45 mm, respectively (Fig. 2). The sphericity of pulses seeds was analyzed to ascertain their shape. The sphericity of black gram and green gram seeds were 82 and 86%, respectively (Table 1).

Table 1. Variations in size dimensions of black gram and green gram seeds

Crop	Descriptive Statistics	Length (mm)	Breadth (mm)	Thickness (mm)	Geometric mean diameter (mm)	Sphericity (%)
Black gram	Range	4.01-5.43	3.10-4.23	2.88-3.95	3.29-4.49	74-89
	Mean	4.91	3.74	3.57	4.02	82
	CV (%)	8.12	8.16	7.38	4.75	4.43
Green gram	Range	4.07-5.83	3.49-4.60	3.47-4.48	3.75-4.83	79-94
	Mean	5.08	4.06	3.99	4.35	86
	CV (%)	10.21	8.26	8.93	8.35	6.41

The angle of repose for black gram and green gram was found to be in the range of 22.33° to 25.25° and 22.40° to 24.90°, respectively (Table 2). The mean values of the angle of repose for black gram and green gram were 24.06° and 23.94°, respectively. In all cases, the coefficients of variation were less than 3%. The mean values of the coefficient of static friction for aluminum, mild steel (MS), galvanized iron (GI), and plywood were 0.50, 0.45, 0.47, and 0.60, respectively, for black gram seeds. In the case of green gram seeds, the values were measured to be 0.48, 0.43, 0.45, and 0.57, respectively (Fig. 3). Overall, the coefficient of friction was least for MS compared to aluminum, GI, and wood. Thus, MS was selected as the material for seed hopper fabrication with a maximum angle of selected material to ensure the free flow of seeds.

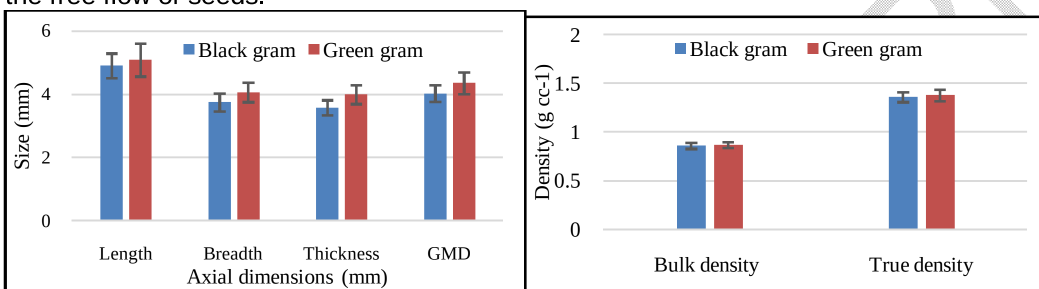


Figure 2. (a) Size dimensions (b) Bulk density and true density of black gram and green gram

Table 2. Angle of repose and frictional properties of black gram and green gram seeds

Crop	Descriptive Statistics	Angle of repose (°)	Coefficient of static friction			
			Aluminum	Mild steel	Galvanized Iron	Plywood
Black gram	Range	22.33-25.25	0.47-0.51	0.43-0.49	0.45-0.49	0.58-0.64
	Mean	24.06	0.5	0.45	0.47	0.6
	CV (%)	3	2	4	3	3
Green gram	Range	22.40-24.90	0.46-0.50	0.41-0.45	0.42-0.48	0.53-0.62
	Mean	23.94	0.48	0.43	0.45	0.57
	CV (%)	3	2	3	3	5

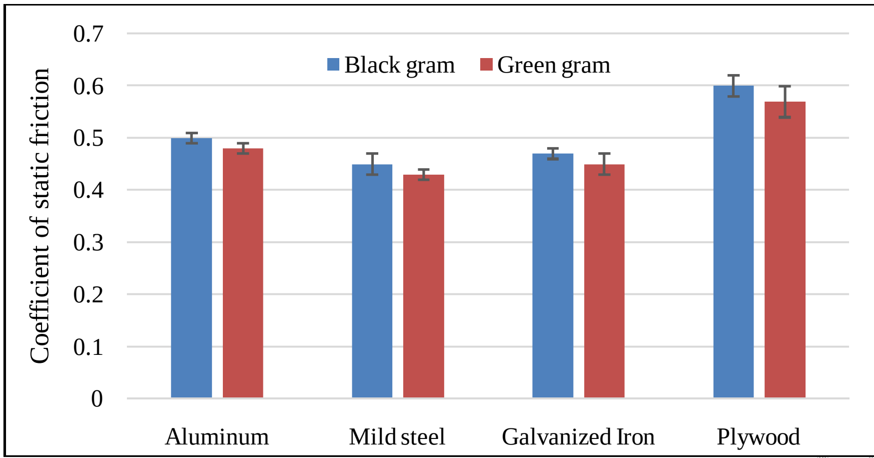


Figure 3.Coefficient of static friction of black gram and green gram

The mean thousand-grain weight for black gram seeds was found to be 41.82 g, while for green gram seeds, it was 46.18 g. This thousand seed weight is crucial in calculating the seed rate and determining the number of seeds to be placed along the rows.

Design values of seed metering mechanism: The average dimensions of length, breadth, and thickness for pulse seeds played a pivotal role in the design of the seed metering Plate. Based on the respective average geometric mean diameter ranges of 3.29-4.49 mm for black gram and 3.75-4.83 mm for green gram, the optimal groove diameter was determined to be between 5 to 6 mm, ensuring the precise release of one seed per hill. As a result, three groove diameters for the metering plate were selected within this 5 to 6 mm range.

The coefficients of friction, ranging from 0.41 to 0.49, were identified for both types of pulse seeds when in contact with mild steel material. This observation facilitated the material selection process, leading to the choice of mild steel for the hopper's design due to its less frictional properties with the seeds.

The average angle of repose for pulse varieties, specifically black gram and green gram, exhibited values within the range of 22.33-25.25 degrees. These angle of repose values were instrumental in determining the appropriate slope of the hopper to facilitate the uninterrupted free flow of pulse seeds. Consequently, the minimum value of 25.25 degrees was selected in design of the hopper.

4. CONCLUSION

The assessment of physical properties in selected seed varieties is a fundamental criterion for designing any seed metering unit. Observations indicate minimal dimensional differences between black gram and green gram seeds. A size range of 5 to 6 mm was employed to design the plate groove diameter. Sphericity values averaged 0.74 to 0.89 for black gram and 0.79 to 0.94 for green gram, influencing the slope design of the seed transfer cup to enable free seed movement. The lowest coefficient of friction, 0.45, was associated with mild steel material, guiding the selection of mild steel for hopper design. Utilizing angle of repose values determined a suitable hopper slope, facilitating unrestricted seed flow, with observed angles of 22.33 to 25.25 degrees for both black gram and green gram seeds. The bulk density values of the chosen varieties were found to be in the range of 0.86 to 0.87 g/cc this value is used for calculating volume of the hopper.

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