STUDY ON PHYSICO-ENGINEERING PROPERTIES OF COTTON SEED FOR DESIGNING OF METERING MECHANISM OF PNEUMATIC PLANTER

ABSTRACT

Understanding the physical properties of seeds is essential for designing efficient seed metering systems in precision planting. This study focuses on the characterization of Bt cotton seeds (variety: Rudra-666), widely cultivated in Andhra Pradesh, to assist in the development of a robotic pneumatic planter (Bapatla, Andhra Pradesh, Jun-Jan). A total of 100 seeds were analysed under laboratory conditions. The average length, width, and thickness of the seeds were 8.94 mm, 4.48 mm, and 4.69 mm, respectively. The arithmetic mean diameter was 6.04 mm, and the geometric mean diameter was calculated as 5.86 mm. The seeds exhibited a sphericity of 64.11% and an aspect ratio of 50.10%, indicating a moderately elongated shape. The 100-seed weight was recorded at 10.4 grams. Bulk density and true density were found to be 733.02 kg/m³ and 1038.4 kg/m³, respectively, with a porosity of 29.40%. The angle of repose measured at 41.40°, reflecting fair flowability of the seeds. The terminal velocity was recorded at 8.01 m/s, relevant for pneumatic separation and delivery. The moisture content ranged from 7.05% to 8.60%, with an average of 7.83% on a wet basis. These parameters provide critical input for optimizing the seed handling and placement systems in robotic and precision-based sowing technologies.

INTRODUCTION

Cotton is a crucial fiber and cash crop in India, playing a significant role in both the agricultural and industrial economy of the country. It is cultivated in about 60 countries across the globe, but nearly 85% of the total production comes from just ten major producers: India, China, the United States, Brazil, Pakistan, Russia, Turkey, Egypt, Mexico, and Sudan.

According to the USDA (United States Department of Agriculture), the global cotton cultivation area for 2023–24 was estimated at 31.8 million hectares, yielding around 113 million bales, each weighing 217.72 kg. China led with an estimated 27.5 million bales grown on 2.95 million hectares, followed closely by India with 25.5 million bales. Brazil, the United States, and Pakistan followed with 14.6, 12.1, and 6.7 million bales respectively. India has emerged as the world's largest producer of cotton, ranking first in area and second in production.

The Government of India's third advance estimates for 2023–24 project cotton production at 343.11 lakh bales, slightly higher than the 337.60 lakh bales recorded in the previous year. By December 28, 2023, cotton had been sown on 124.69 lakh hectares across the country, compared to 129.47 lakh hectares during the same time the previous year, according to data from (1). Cotton in India is mainly cultivated in three zones: The North Zone (Punjab, Haryana, Rajasthan), the Central Zone (Maharashtra, Madhya Pradesh, Gujarat), and the Southern Zone (Telangana, Andhra Pradesh, Karnataka). Around 65% of the total cotton area is rainfed, making it highly dependent on monsoon rains. The majority of India's cotton almost two thirds is produced in the states of Maharashtra, Gujarat, Andhra Pradesh, and Telangana, often referred to as the "Cotton Basket of India." (cotcorp.org.in)

The thorough knowledge on physical properties of cotton seed id help full in the design of seed metering mechanism and suction regulation of equipment for planting operation and useful for the new machinery development related for cotton crop the current inquiry is to study some physical properties of Rudra-666 (ICAR-CICR 23-BT variety which is mostly growing in the districts of Andhra Pradesh state.

2. MATERIALS AND METHODS

2.1 Preparation of seeds

The physical parameters of cotton seed variety, Rudra-666 (ICAR-CICR 23-BT), were examined which are commonly grown in Andhra Pradesh. The seeds were cleaned and graded to remove foreign materials such as dust, debris, stones, and any immature, broken, or uneven seeds. The experiments were carried out the laboratory at Dr. Nandamuri Taraka Rama Rao college of agricultural engineering in Bapatla.

Plate.1 seed metering unit

2.2 Measurement of physical properties of cotton seed

The physical properties are important for designing diameter of seed metering units of planter. Rudra-666 (ICAR-CICR 23-BT) is selected for this study and is popular in the Andhra Pradesh. The listed properties were determined using standard techniques.

Table 1. physical properties of cotton seed

Independent parameters Variables	**level**	**details**	**dependent**
Cotton seed	1	Rudra-666 (icar-cicr 23-bt)	Parameters
			Axial dimensions
			Sphericity
			Aspect ratio
			Moisture content (%)
			Terminal velocity m/s
			Bulk density (kg m-3)
			True density (kg m-3)
			Hundred seed weight (g)

			Porosity (%)
			Angle of repose (º)
Replications	3		

2.2.1 Axial dimensions

The axial dimensions of cotton seeds, such as length, width, and thickness, can be represent in a reference seed format. For the Rudra-666 (ICAR-CICR 23-BT) varieties, these dimensions were determined using a digital vernier calliper with a least count of vernier calliper of 0.01 mm. To increase measurement accuracy, a random selection of 100 seeds was taken from a 1-kilogram sample of variety. These measurements offer essential data for seed classification, processing, and optimizing planting efficiency. The recorded axial dimensions contribute to a better understanding of cotton seed characteristics

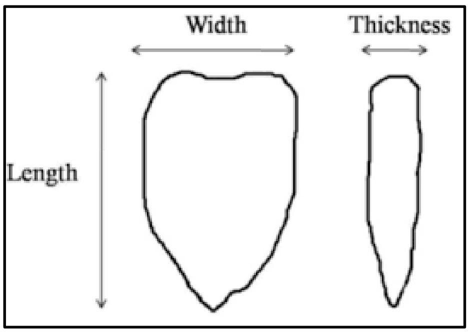


Fig 1. Dimensions of reference seed

(a) **(b)** **(c)**

Plate. 2. measurement of axial dimensions of cotton seed (rudra-666) (a) length (b) width (c) thickness

2.2.2 Sphericity (φ)

Sphericity is a measure used to determine how closely a seed's shape resembles a sphere. It is calculated as the ratio of the surface area of a sphere with the same volume as the seed to the actual surface area of the seed. This property helps in understanding the uniform flow of cotton seeds across a surface. The sphericity of cotton seeds is determined using the equation provided by (Mohsenin.1970).

$$\Phi = \frac{(\mathrm{LB}t)^{\frac{1}{3}}}{l} \times 100$$

Φ = sphericity

L = length, mm

B = width, mm

t = thickness, mm

2.2.3 Aspect ratio

The aspect ratio is equivalent to a proportion of the width of the seed to the length of the groundnut seed. The aspect ratio is calculated using the following relationship given below (3).

$$\text{Aspect ratio} = \frac{W}{L}$$

W = width of cotton seed, mm

L = length of cotton seed, mm

2.2.4 Moisture content (mc)

Moisture content of cotton seeds were resolute by using oven dry method. Three sample of cotton seed each having weight of 10 gram was placed in container and weighed on digital weighing balance. The three samples after weighing were kept in the dry oven machine at 103°±2°C for 17 hours. After 17 hours the seed samples were removed and cooled in desiccators. The dried cotton seeds again weighed on the weighing balance. The moisture content of seeds was calculated by using following equations (5)

$$Mc\ (db), \% = \frac{wa - wb}{wb} \times 100$$

Where,

Mc = moisture content, %

W_a = weight of sample before drying, g

W_b = weight of sample after drying, g

Plate. 3. measurement of moisture content of sample using hot air oven

2.2.5 Terminal velocity

Terminal velocity is an important factor in determining how much air suction is needed for seed metering in pneumatic planters. To measure the delinted cotton, a laboratory experiment was conducted using a simple setup. The setup included a clear glass tube, allowing easy observation of the seeds as they moved in the air. A small container (hopper) at the bottom of the tube released the seeds in a controlled way. A wire mesh was placed just above the air inlet to help manage the airflow. Each test, about 100 grams of seeds were added to the hopper.

Air was then blown from below the mesh, moving upward to lift the seeds into the air. The airflow was adjusted using a control knob to find the point where most of the seeds stayed suspended for about 30 seconds. Lighter seeds were carried upward and collected in a container, while heavier ones fell into a pan at the bottom. The airflow was gradually increased until the mostly the seeds were lifted by the moving air flow rate was varied till the air stream lifted most of the seeds. The rate of air flow velocity calculated by using described by (8). The air velocity which kept the seeds in suspension and calculated using termed equation as terminal velocity of cotton seed.

$$Vt(m/s) = \frac{air\ flow\ rate\ for\ suspending\ the\ material\ m^3h^{-1}}{area\ of\ the\ cylinder\ m^2 \times 3600}$$

2.2.6 Bulk density (ρb)

The bulk density of cotton seeds was determined through three replications. Bulk density indicates the portion between weight of the specimen to the known capacity of the container. A container of known volume was filled with seeds until it reached the top, and any excess seeds were removed. The combined weight of the seeds and the container was then measured. To find the mass of the seeds, the weight of the empty container was subtracted from the total weight of the seeds and container. Bulk density calculated by the below equation (3,4)

$$\text{Bulk density } (\rho b) = \frac{weight\ of\ sample}{known\ weight\ of\ the\ container}$$

Where, ρb = bulk density, kg m^{-3}

Plate. 4. measurement of bulk density

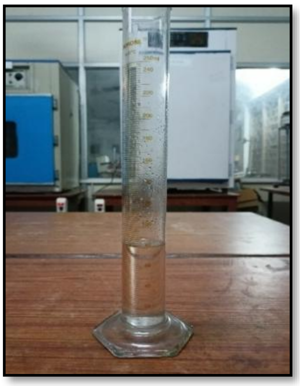
2.2.7 True density

The true density of cotton seeds was measured using the volume displacement method with toluene as the liquid. True density is defined as the ratio of the seed sample's mass to the actual volume of toluene displaced. To determine this, a measuring cylinder filled with toluene up to a specific level. A known quantity of cotton seeds was addition to the cylinder, and the ensure in the toluene level was recorded. This change in volume was used to find the true density of the seeds. It was obtained using toluene displacement method (2).

$$\text{True density } (\rho t) = \frac{weight\ of\ sample}{true\ volume\ of\ toluene}$$

Where,

Pt = true density, kg m^{-3}



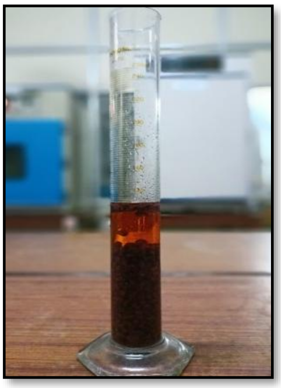


Plate. 5. Before seeds put into toluene **Plate. 6. After put seeds into toluene**

2.2.8 Hundred seeds weight

The weight of 100 seeds is measured using a digital weighing balance with 0.01g precision, recorded three times for accuracy (4). This measurement plays a key role in designing the hopper size to increase proper seed flow and storage. A correctly sized hopper helps prevent blockages and increase smooth machine operation. Accurate weight estimation also contributes to improving the efficiency and performance of seed-handling machines.

2.2.9 Porosity

Porosity refers to the measure of voids spaces or pores within the material. Porosity is expressed as a percentage. Porosity is calculated by the relationship between bulk density and true density by using the below equation (3,4).

Porosity (%) = $1- \frac{bulk\ desity}{true\ density} \times 100$

Bulk density, kg m^{-3}

True density, kg m^{-3}

2.2.10 Angle of repose

The angle of repose helps determine the slope of a seed hopper. To measure it, a box was loaded with delinted cotton seeds and placed on a flat surface. The seeds were then released onto a circular disc below, forming a pile. The base radius and height of the pile were measured, and the angle of repose measured by using formula. (7)

$$\Theta = \tan^{-1} \frac{h}{r}$$

Θ = angle of repose

H = height of heap, mm

r = diameter of heap, mm

Plate. 7. Measurement of angle of repose of groundnut seeds

3. RESULTS AND CONCLUSION

100 seeds were selected randomly from the variety to determine some of physical properties like Axial dimensions, Sphericity, Aspect ratio, Moisture content (%), Terminal velocity m/s, Bulk density (kg m^{-3}), True density (kg m^{-3}), Hundred seed weight (g), Porosity (%), Angle of repose (°)

3.1 Axial dimensions

The results indicated that three axial dimensions namely, length, width, and thickness of cotton seed are represented below graph. The avg length value of rudra-666 cotton seeds are 8.94 mm. The avg values of width of seeds are 4.48 mm, and while the thickness given as 4.69 mm.

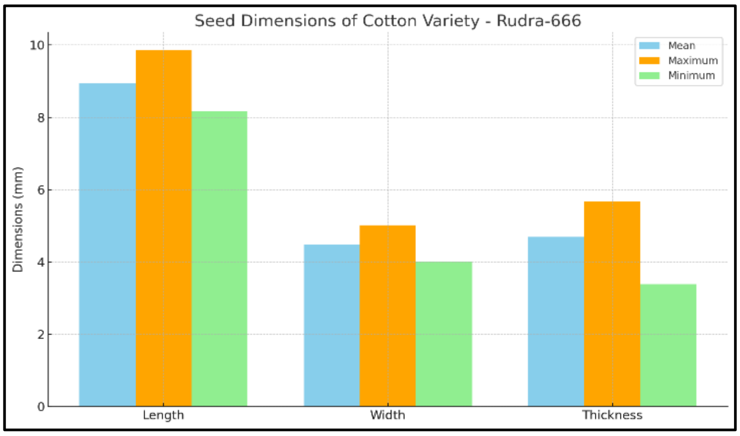


Fig.2 axial dimensions of rudra-666 cotton seed varieties

3.2 Sphericity

The sphericity values of Rudra-666 variety of 100 samples are obtained.

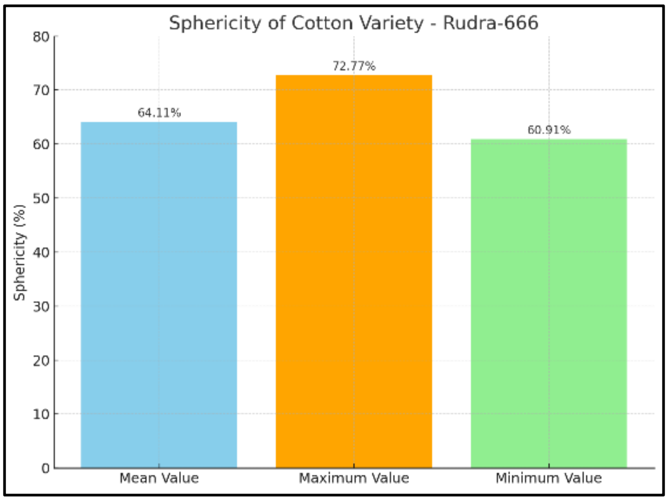


Fig.3 sphericity of rudra-666 cotton seed varieties

3.3 Aspect ratio

The aspect ratio of cotton seed (Rudra-666) is obtained as and aspect ratio the mean, maximum and minimum values of aspect ratio of rudra-666 verity are shown below in the graph.

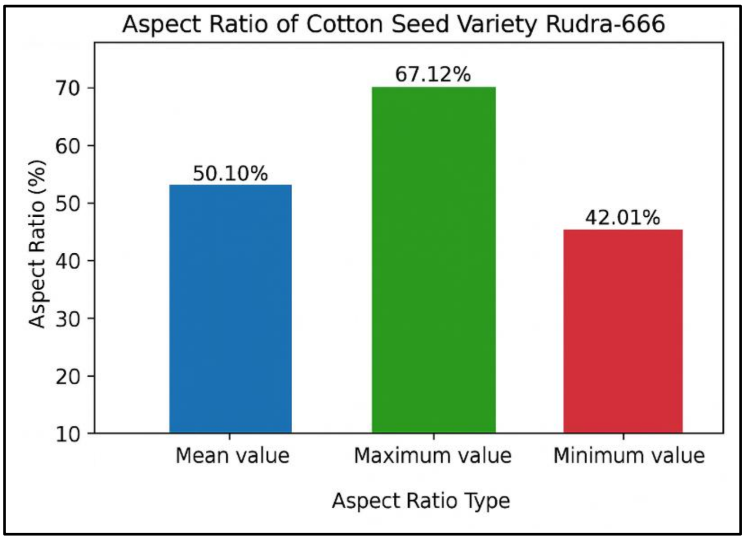


Fig. 4 Aspect ratio of rudra-666 cotton seed varieties

3.4 Moisture content of cotton seed (rudra-666)

The average value of moisture content of cotton seed (Rudra-666) in three replications are obtained as 7.86 %, 8.60 % and 7.05 % moisture content.

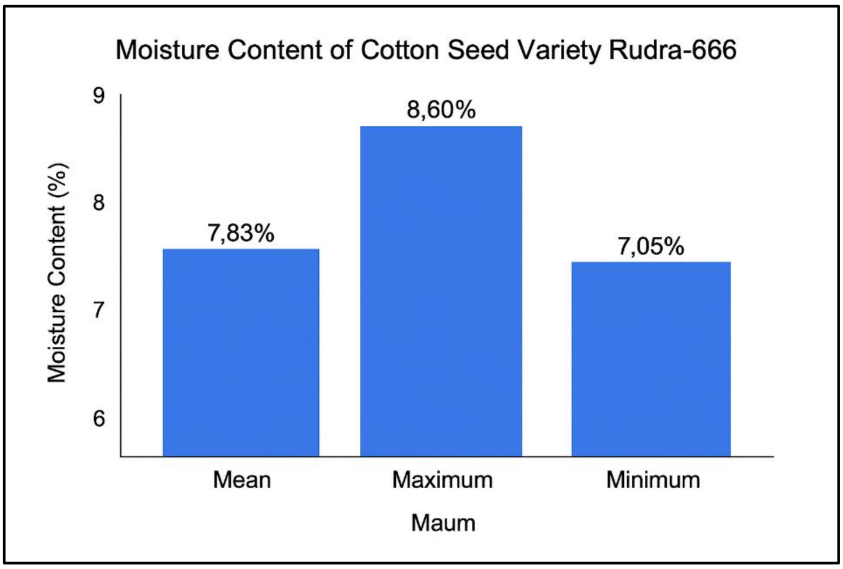


Fig.5 Moisture content of rudra-666 cotton seed varieties

3.5 Terminal velocity

Average maximum and minimum values of cotton seeds terminal velocity determined in this study. It is evident that the terminal velocity decreased as the lint content increased. We conducted this experiment in three replications, recording terminal velocity values of 8.60 m/s, 7.95 m/s, and 7.50 m/s. The mean, maximum, and minimum values of the cotton seed's terminal velocity are provided in the below graph.

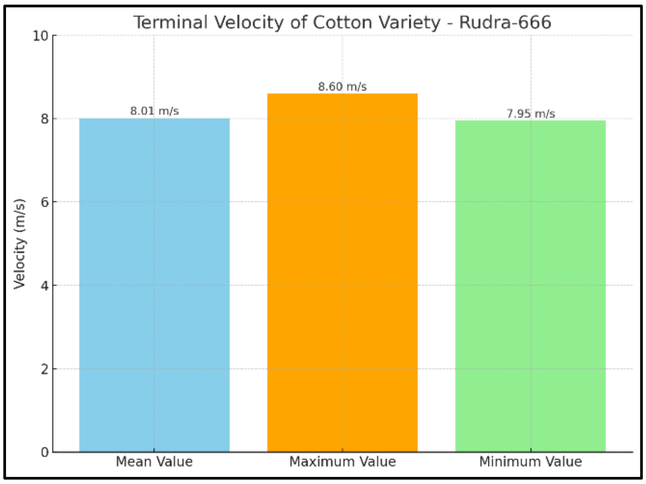


Fig.6 Terminal velocity of rudra-666 cotton seed varieties

3.6 Bulk density

The bulk density of seeds plays a crucial role in determining the box capacity and optimizing the seed rate for the crop. The average bulk density values of rudra-666 variety were determined by using equation mention in previous chapter were found 733.02 kg/m^3.in

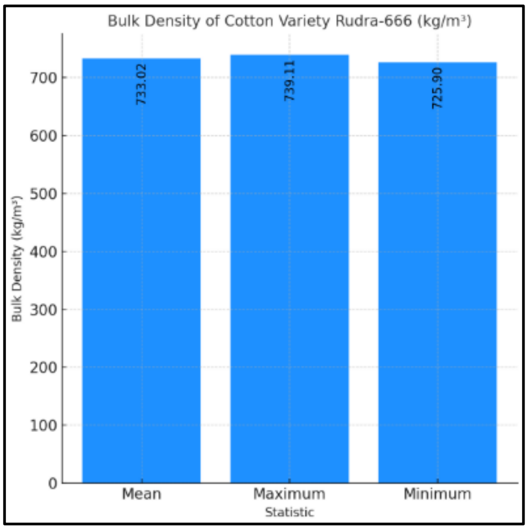


Fig.7 Bulk density of rudra-666 cotton seed varieties

3.7 True density

This measurement provides the apparent volume of seeds by eliminating any voids within a cylinder. The average density of Rudra-666 cotton seed was observed 1038.4 kg/m^3.

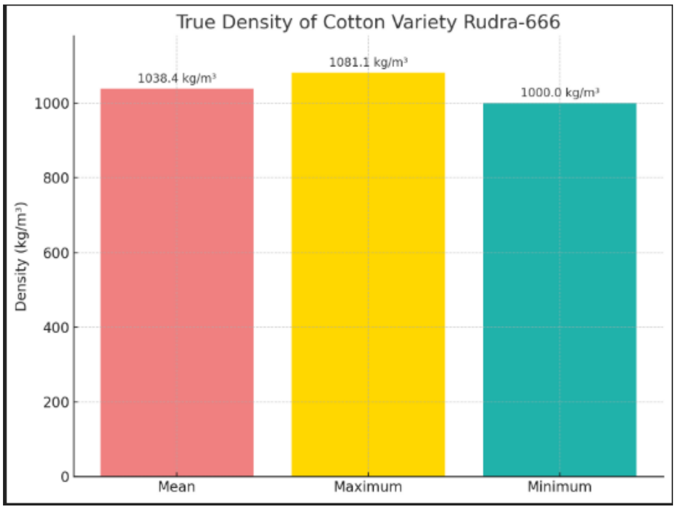


Fig.8 True density of rudra-666 cotton seed varieties

3.8 Hundred seed weight

The average 100 seed weight of rudra-666 variety was represented in table. The average hundred seed weight varied form 10.1g to 11.2g. In given below graph mention mean and maximum and minimum values of hundred seed weight of rudra-666 variety.

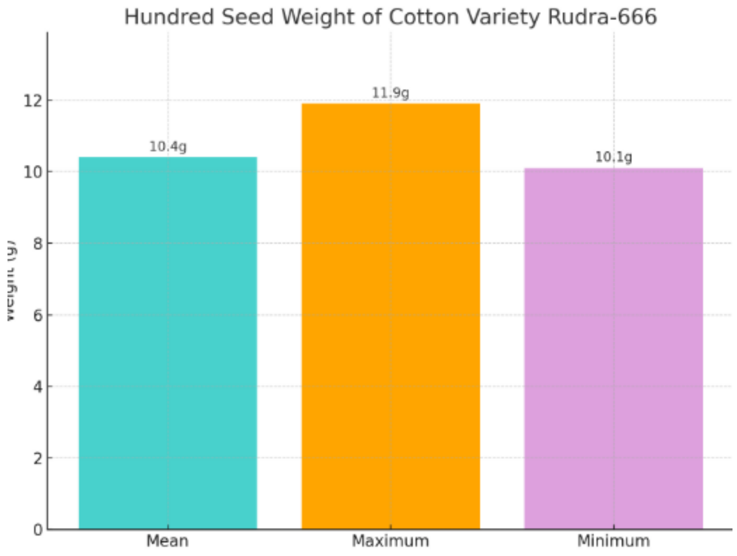


Fig.9 Hundred seed weight of rudra-666 cotton seed varieties

3.9 Porosity

The average porosity of rudra-666 variety obtained show in graph. Mentioned mean, maximum and minimum values.

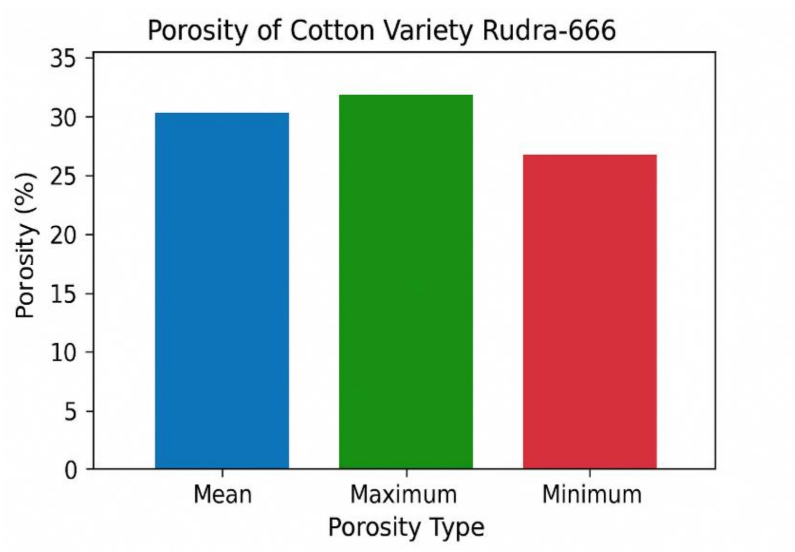


Fig.10 Porosity weight of rudra-666 cotton seed varieties

3.10 Angle of repose

The angle of repose is the steepest angle at which cotton seeds can pile up without sliding. It’s an important factor in making the slope of a seed hopper to make sure the seeds flow smoothly and don’t get stuck. The average angle of repose was measured by using formula mentioned in previous chapter and it was obtained by 41.4^0

4. CONCLUSION

The study focused on evaluating the key physical properties of Rudra-666 cotton seeds, which are vital for the development and performance of seed handling, storage, and sowing equipment. Based on measurements from 100 randomly selected seeds, the mean seed length was found to be 8.94 mm, the width 4.48 mm, and the thickness 4.69 mm. These dimensions showed moderate variation, with the length ranging from 8.17 mm to 9.86 mm, width from 4.01 mm to 5.02 mm, and thickness from 3.39 mm to 5.67 mm.

Shape characteristics like sphericity and aspect ratio were also studied. The mean sphericity was 64.11%, while the aspect ratio averaged 50.10%. These values suggest that the seeds are not perfectly spherical and have an elongated shape, which is dominent for designing equipment that ensures uniform seed flow and accurate placement during planting.

The moisture content of the seeds averaged 7.83%, ranging from 7.05% to 8.60%, indicating they were within a safe range for storage and mechanical handling. The average terminal velocity of 8.01 m/s (ranging from 7.50 m/s to 8.60 m/s) provides insights into how the seeds would behave in air-assisted or pneumatic planting systems.

Density measurements showed a bulk density of 733.02 kg/m³ and a true density of 1038.4 kg/m³. These values helped determine a porosity of 29.4%, which influences how seeds settle in containers and bins. The average weight of 100 seeds was 10.4 grams, with values between 10.1 g and 11.9 g, which can help calculate seed rates for sowing.

The angle of repose was recorded at 41.40°, indicating that the seeds have relatively good flowability, an important consideration in designing hoppers and seed boxes. Overall, the Rudra-666 cotton seed variety exhibits physical characteristics that are favourable for mechanical sowing. The data obtained from this study can be effectively used for planning and improving the design of planting machinery and storage systems to ensure efficiency and reliability in agricultural operations.

REFERENCES

1. https://angrau.ac.in/downloads/AMIC/OutlookReports/2023_24/Cotton%20outlook%20-June%20to%20May%202023-24.pdf

2. Singh Kp, Mishra Hn and Saha s, 2010. Moisture-dependent properties of barnyard millet grain and kernel. Journal of food engineering 96(4): 598-60

3. Davies, R.M. 2009. Some physical properties of groundnut grains. Research journaof applied sciences, engineering and technology. 1(2): 10-13.

4. Gojiya, D.K., Dobariya, U.D., Pandya, P.A and Gojiya, K.M. 2020. Studies on physical properties of peanut seed. Acta scientific agriculture. 4(3): 1-5.

5. Sahay, K. M. and Singh, K. K. 1994. Unit operations of agricultural processing. *Vikas publishing house pvt. Ltd*.

6. Mohsenin, N. N. 1970. Physical properties of plant and animal materials (2nd edn.). *Gordon and breach science publications*, new york, usa.

7. Vasuki, g. and Tajuddin. A. 2015. A study on physical properties of cotton seeds for developing a high-density cotton planter. *International journal of agricultural science and research (ijasr)*, *5*(4):49-52.

8. Kachru RP, Gupta RK and Alam A. 1994. Physico - chemical constituents and engineering properties of food crops. Scientific publishers, new delhi, india