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Studies on engineering properties of selected paddy varieties for design of seed planting equipment

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Abstract
Engineering properties aids in developing agricultural machines and equipment for many agricultural operations including planting and drilling. Size, geometric mean diameter, sphericity, aspect ratio, bulk density, true density, porosity, thousand seed weight, angle of repose, coefficient of static friction and hardness are some engineering attributes that are vital in sowing machine were investigated in the present study. The grain length varied from 6.62 to 8.26 mm, with a breadth of 1.82 to 2.40 mm and a thickness of 1.42 to 1.84 mm. The 1000 grain weight ranges from 14.0 to 15.3 g, an angle of repose of 27.40 to 28.10 º. The average coefficient of friction values was 0.38 and 0.36 in plastic, 0.40 and 0.40 in glass, 0.42 and 0.46 in mild steel sheet, 0.47 and 0.45 in fibre, and 0.51 and 0.53 in plywood and a bulk density of 577.63 to 605.16 kgm^{-3}, with a true density of 1000 to 1043.15 kgm^{-3}. The average values of moisture content, hardness of BPT 5204 and BPT 2766 paddy varieties were 9.10% (d.b.), 12.78 kg and 10.2% (d.b.), 13.17 kg respectively.

Keywords: Rice, physical properties, sowing equipment, BPT 5204, BPT 2766, Frictional properties, mechanical properties

Introduction
Rice, the utmost staple crop is the basis of livelihood for millions of rural people in India. It plays a vital role in nation's food security. It is usually cropped in puddled fields with transplanting method. However, direct seeded rice is an alternate method that demands less water and labor requirement than transplanting method. Direct seeded rice refers to the process of seed sown directly in the pulverized field, rather than transplanting seedlings from nursery. Sowing, the art of placing seeds in the soil aims at improving the yield at field. Method of sowing progressed from sowing using hands, stones, hand tools and now with mechanized drills/ planters. Manual seeding methods have resulted in poor seed placement, reduced row spacing and health problems for the farmer due to the size of the arable land (Kumar *et al.*, 2015) [6].

The demand for increasing production, improve the quality of locally produced rice and become more competitive compared to imported one were done by mechanization. Various factors have been identified that explain these variable traits. One of it are, poor physical attributes (Oludare *et al.*, 2012). The seed metering mechanism is at the heart of a sowing machine, and its job is to evenly distribute seeds at the desired application rates, along with control and regulate seed spacing in a row in seed planters. A seed planter may be needed to drop the seeds at various rates. The seed hopper can be designed using the angle of repose and the coefficient of static friction. As a result, investigations were attempted to pick the optimum planter design parameters by studying the relevant physical and mechanical attributes of two distinct types of paddy seeds.

Inview of the importance of engineering properties for design of seed planter, the proposed study was conducted to investigate the properties of paddy, namely, size, shape, sphericity, cylindricity, 1000 seed mass, bulk density, true density, porosity, angle of repose, static coefficient of friction and hardness.

Methodology
Two paddy varieties namely BPT 5204 and BPT 2766 were procured from the agriculture research farm of ANGRAU, Bapatla, Andhra Pradesh, India. The seeds are cleaned by removing the foreign matter manually and evaluated in the department of processing and food engineering, CAE, ANGRAU, Bapatla, Andhra Pradesh, India. Fig: 1 shows the selected varieties of paddy seeds under study.

Fig 1: BPT 5204 and BPT 2766 paddy varieties

Physcial properties

The moisture content (m.c.) is determined using ASAE standard method (ASAE, 2006) [2]. Axial dimensions i.e., length, width, and thickness of paddy is measured using digital vernier calipers (Fig. 2). 30 seeds picked randomly from 100 g sample are used to measure axial dimensions. Geometric mean diameter (D_e), Sphericity (ø), aspect ratio (R_a) is determined from the measured axial dimensions using the formulas reported in Kenghe *et al.*, 2015 [5] and Ravi *et al.*, 2015 [9] respectively.

$$\text{m. c. } (\%) = \frac{W_0 - W_1}{W_1} \times 100 \quad (1)$$

Where,
W_0 – Initial weight of the grains before drying, g
W_1 – Final weight of the grains after drying, g

$$D_e = (lbt)^{\frac{1}{3}} \quad (2)$$

Where,
D_e – Geometric mean diameter, mm
l - Length, mm
b - width, mm
t – Thickness, mm

$$ø = \frac{(lbt)^{\frac{1}{3}}}{l} \quad (3)$$

where,
ø – Sphericity
l - Length, mm
b - width, mm
t – Thickness, mm

$$R_a = \frac{w}{l} \quad (4)$$

Where,
R_a - Aspect ratio
w - Width of paddy seed, mm
l - Length of paddy seed, mm

Fig 2: Determining of Physical attributes

Gravimetric properties

Bulk density is defined as the ratio of the mass of the paddy to its total (bulk) volume. It is determined by filling a circular container of known volume with paddy seeds without compaction. The true density (ρ_t) is the ratio of the mass of the paddy to its true volume. It is determined using the toluene displacement method. Toluene (C_7H_8) was used in place of water because paddy absorbed toluene to a lesser extent. (Ravi *et al*. 2015) [9]. Porosity is defined as a measure of voids or space of the volume within the substance that occupied the total volume. It is determined by using the relationship between bulk density and true density (Muralidhar *et al.* 2012).

Thousand grain weight

Thousand-grain weight was determined by using the electronic balance of accuracy 0.001g (Fig: 3). A thousand seeds kernels are determined by counting the 1000 seeds and weight them (Zareiforoush *et al.* 2009) [11].

$$\rho_b = \frac{m}{v} \quad (5)$$

Where,
ρ_b – Bulk density, kg m^{-3}
m – Mass of paddy seeds, kg
v – Volume of paddy seeds, m^3

$$\varepsilon = (1 - \frac{\rho_b}{\rho_t}) \quad (6)$$

Where,
ε – Porosity, (%)
ρ_b – Bulk density, kg m^{-3}
ρ_t – True density, kg m^{-3}

Fig 3: Determination of gravimetric properties

Frictional properties

The angle of repose (θ) is considered as the angle in degrees with the horizontal at which the material will stand forming a heap. The angle of repose was calculated from the measurement of the height of the heap at the center and the base diameter of the heap (Chidanand *et al.* 2015) [4]. The coefficient of static friction simply indicates the frictional forces acting between two bodies under stationary conditions (Muralidhar *et al*. 2012). Mild steel sheets, plywood, glass, fiber, and plastic are the materials utilized. With the help of a screw attached to the instrument, the structural surface with

the cylinder resting on it was gradually inclined until the cylinder just began to slide down. The procedure was repeated five times, and the data was recorded. The coefficient of static friction between the test surface and the rice grain has been calculated by using tangents at the above angle (Fig: 4).

$$\theta = tan^{-1}(\frac{2h}{d}) \quad (7)$$

Where,
θ - Angle of repose, º
h – height of the pile, cm
d – diameter of the pile, cm

$$\mu = tan\theta \quad (8)$$

Where,
μ - Coefficient of static friction
θ – Angle measured between the horizontal surface and inclined surface

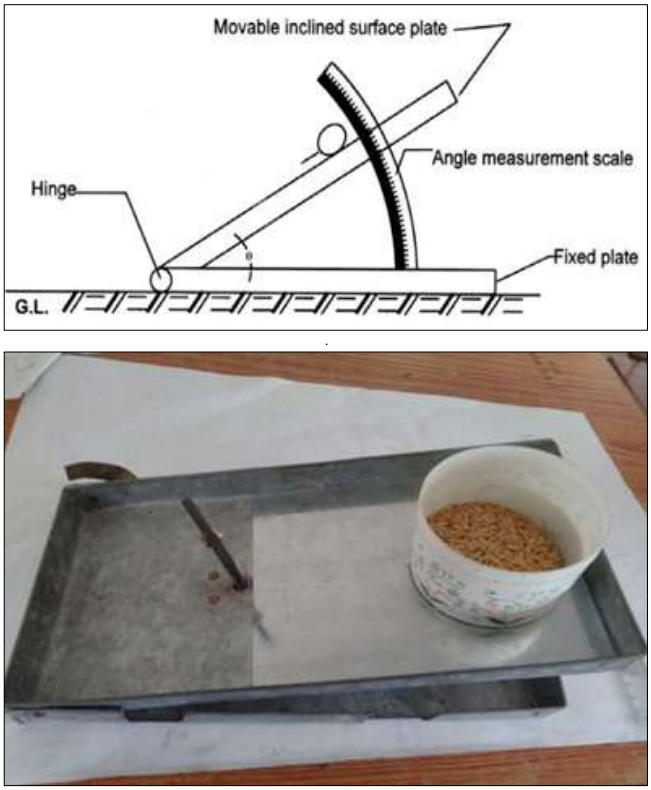

Fig 4: Determination of frictional properties

Mechanical properties

Hardness is defined as the first fracture point due to the peak force applied during the first bite of compression where force falls off. It is expressed in Kg or g or N force (Muralidhar *et al*. 2012).

Results and discussions

Physical attributes

The average moisture content of the BPT 5204 and BPT 2766 paddy varieties are 9.10 % and 10.2% (d.b.), respectively. The average values of length, width, and thickness are found to be 7.67, 2.15, and 1.65 mm for paddy BPT 5204 variety and 7.66, 2.19 and 1.70 mm for paddy BPT 2766, respectively. The geometric mean diameter of BPT 5204 and 2766 was observed to be 3.00 and 3.05 mm respectively. The complete data was tabulated in Table 1.

The sphericity of the BPT 5204 and BPT 2766 paddy varieties are obtained as 39.01 and 39.88 respectively. The lowest sphericity is observed in BPT 5204paddy variety due to its axial dimensions. The aspect ratio (R_a) is used for the classification of paddy shape and is observed as 27.95 for BPT 5204 paddy variety and 28.65 for BPT 2766 paddy variety respectively.

Size and shape of the paddy had significant effect on the design parameters of grooves (i.e., groove size, groove shape). Seed metering grooves are designed from data recorded for the physical attributes. Similar trend of results are reported by Jadhav *et al.* (2020), Bangale *et al.* (2019) [3] and Rajaiah *et al.* (2015) [10], respectively.

Gravitational attributes

The bulk density of seeds is a significant consideration while designing box capacity and optimizing the crop's seed rate. The bulk density of paddy BPT 5204 and BPT 2766 was 583.20 kg m^{-3} and 596.13 kg m^{-3}, respectively. By eliminating the voids in a cylinder, the apparent volume of seeds is achieved. The average density of BPT 5204 and BPT 2766 paddy seeds was 1069.50 kg m^{-3} and 1077.64 kg m^{-3}, respectively. The rice seeds had an average porosity of 45.5 % for BPT5204 and 35.1 % for BPT 2766, respectively.

Table 1: Mean values of engineering properties of BPT 5204 and BPT 2766 paddy varieties

Property	BPT 5204		BPT 2766	
	Range	Mean	Range	Mean
Length (mm)	6.62-8.26	7.67	6.77-8.17	7.66
Width (mm)	1.82-2.40	2.15	1.92-2.41	2.19
Thickness (mm)	1.42-1.81	1.65	1.50-1.84	1.70
Geometric mean diameter (mm)	2.72-3.17	3.00	2.79-3.22	3.05
Sphericity (%)	35.85-44.37	39.18	37.90-42.02	39.88
Aspect ratio	23.81-35.05	27.95	25.70-30.99	28.65
Bulk density (kgm^{-3})	585.03-605.15	596.13	577.63-591.12	583.20
True density (kgm^{-3})	1042.9-1143.15	1077.64	1000-1136.10	1069.50
Porosity (%)	42.68 – 47.06	44.64	42.0 – 48.0	45.5
Hardness (kg)	12.1 – 13.4	12.78	12.5 – 14.2	13.17

Thousand seed weight

A thousand seeds of paddy BPT5204 and BPT2766 were determined by manually counting 1000 seeds and weighing them on an electric balance. A thousand seeds of BPT 5204 and BPT 2766 weighed 14 and 15.3 g, respectively, and observing the obtained results show that the weight of BPT 2766 was greater than that of BPT 5204.

Frictional Properties

The peak angle of a pile of grain in the horizontal plane is defined as the angle of repose. The slope of the seed hopper must be determined to allow seeds to keep flowing. BPT 5204 and BPT 2766 had an average angle of repose of 28.10 and 27.40 degrees, respectively. BPT 5204 and BPT 2766 coefficient of friction were examined in different materials, including plywood, mild steel sheet, fiber, plastic, and glass. The average coefficient of friction values was 0.38 & 0.36 in plastic, 0.40 & 0.40 in glass, 0.42 & 0.46 in mild steel sheet, 0.47 & 0.45 in fibre, and 0.51 & 0.53 in plywood, respectively. As a result, plywood had the highest coefficient of friction while plastic had the lowest. Fig: 5 gives the variation of the coefficient of static friction on different materials used.

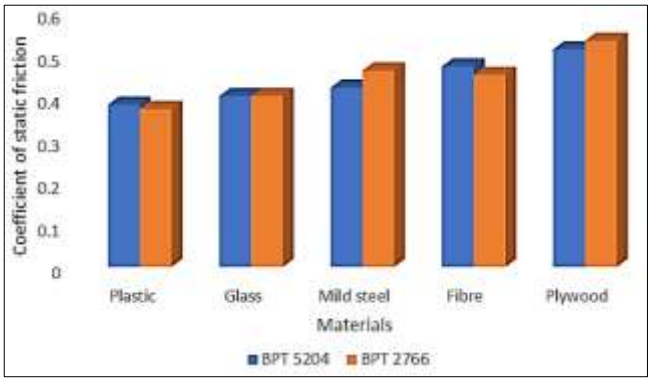

Fig 5: Variation of coefficient of friction on different materials

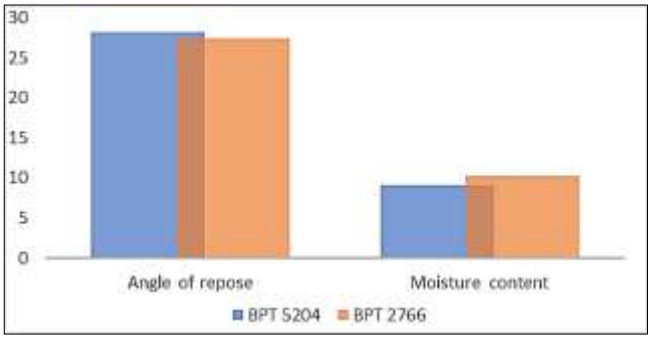

Fig 6: Variations of angle of repose with moisture content

Hardness

The hardness of paddy grains is a function of the moisture content present in them. It is increased from 12.5 to 14.2 kg for BPT 2766 and 12.1 to 13.4 kg for BPT 5204.

Conclusion

The observed values can be used to construct seed metering cells with cell sizes ranging from 7 to 10 mm for selected varieties. The seed metering discs thickness and cell radii were calculated based on breadth and length. Thus, average values of angle of repose and coefficient of friction can be used to design the hopper. To ensure the free flow of seed, the maximum angle of repose found in BPT 5204 can be used to design a seed hopper slope of 30º. Plastic had a lower coefficient of friction than glass, mild steel, fiber, and wood surfaces in all of the tested kinds. As part of agricultural equipment, a mild steel sheet was selected as a material for seed hopper fabrication for the free flow of seeds by analysing several recommendations. It was concluded that a minimum angle of 30º can be used to design a hopper by selecting the low friction mild steel sheet.

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