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# Role of physical and engineering properties of rice (*Oryza sativa*) cultivars for designing of precision planter

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ABSTRACT

The paper describes the effect of physical and engineering properties of five rice (*Oryza sativa* L.) cultivars, viz. Pusa 1121, Pusa 44, BPT 5205, MTU 7209 and MTU 1010 on the design parameters of precision planter for direct sowing of rice seeds in drylands. The properties were determined in three conditions of seeds, viz. dry condition, 1-day soaking and two day soaking condition. In all the five selected varieties, no significant difference in length was found between dry and soaked seed, while breadth and thickness of the seeds were found slight increase in all varieties. It was observed that the grain length varied from 7.32±0.61 to 13.79±0.93 mm, breadth 2.16±0.21 to 2.58±0.06 mm, sphericity, 43.66±2.45 to 30.56±3.49, 1000 grain-weight 14.37 to 32.6 g, angle of repose 25.25 to 33.68° and bulk density 524.6 to 667.56 kg/m$^3$.The observed values can be used to fabricate the seed metering cells for different varieties with cell diameter ranging from 10 mm to 14 mm. Thickness and cell diameters of the seed metering discs were designed in reference to the maximum breadth and length. Based on the results, it can be revealed that flow rate from the hopper can be affected due to angle of repose and coefficient of friction for rice grains. Thus, to design the hopper the average values of angle of repose and coefficient of friction can be taken. The highest angle of repose observed in PUSA 1121 can be used to have a seed hopper slope of 35° to ensure free flow of seed. The coefficient of friction in all the selected varieties was less with mild steel as compared to galvanized-iron and wood surfaces. It was concluded that a minimum angle of 30°and a plate thickness of 4 mm can be used to design a hopper by selecting the low friction mild steel sheet. The measured bulk density and size values can be used to design a hopper of required capacity and seed metering plate cell size for required number of seeds/hill.

**Key words**: Engineering property, , Physical characteristics, Planter design, Rice cultivars

The direct seeded rice (DSR) is an emerging production system in Asia in the face of looming water and labour scarcity, and the energy crisis. Direct seeding rice (*Oryza sativa* L.), a common practice before green revolution in India, is becoming popular once again due to its potential to save water and labour (Gupta *et al.* 2006). Direct seeded rice removes puddling, drudgery of transplanting and saving of water. The success of DSR mainly attributed to timely sowing, reduced cost of cultivation as compared to transplanting (labor, puddling costs, water for puddling-12-15%; diesel 15-16 L, etc), reduced seed rate (8-12 kg per acre as against 25-30 kg per acre required for transplanting), saves 35-40% water and thereby helps to increase more area under irrigation, reduced fertilizer (25-30%) and pesticide use etc., equal or higher yields with reduced production costs and higher net farm income (Mahajan *et al.* 2013). The area of direct seeded rice in India is 7.2 m ha. At present, 23% of rice is direct-seeded globally (Rao *et al*. 2007). The dry-seeded rice is primarily done under labour shortage situation, and is currently practiced in Malaysia, Thailand, Vietnam, Philippines, and Sri Lanka. About 95% of the rice grown in Sri Lanka is direct-seeded (wet- and dry-seeding) (Pandey and Velasco 2002, Weerakoon *et al.* 2011).

Direct seeding by manual methods requires high seed rate, consumes more time per unit area could be overcome by using tractor drawn precision seeders with properly designed metering plate mechanisms. In direct seeding of rice, the seed is to be soaked in fungicide solution for 24 hr to manage soil borne diseases and allowed for shade drying for 3 hr to make it suitable for drilling with planter. The knowledge about physical and engineering properties of paddy kernels is very much essential in design of hopper, seed metering mechanisms and other components of any planter/seeder.

Hence the present study was carried out to determine the effect of physical and engineering properties of rice seeds of five varieties, on the design parameters of the precision planter for direct-sowing.

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## MATERIALS AND METHODS

Presently, among different planting techniques, precision planting is the preferred method since it provides more uniform seed spacing than other methods. Accurate planting of single seed at pre determined seed to seed and row to row spacing in soil ensures saving in costly seeds, reduces the problem of thinning and higher crop yield as each plant gets the desired quantity of sunlight, water and nutrients. The precision in a planter can be achieved by proper design of cell size in seed metering plate and seed hopper for which the knowledge of physical properties namely, length (l), breadth (b), thickness (t), equivalent diameter ($d_e$), sphericity ($\phi$), bulk density ($\gamma$), true density ($\rho$) and 1000 seed weight (w) and engineering properties, Angle of repose ($\theta$) and Coefficient of friction ($\mu$) is essential. Therefore, the present study under taken to determine the physical and engineering properties of five paddy varieties, $V_1$, $V_2$, $V_3$, $V_4$ and $V_5$ in the laboratory. The seeds were cleaned in an air screen cleaner to remove all foreign matter such as dust, dirt, stones, chaff and immature and broken seeds. The seeds were categorized into three treatments as dry, one-day soaked and two day soaked. The one-day soaked and two-day soaked seeds were obtained after putting the seeds in water for 24 hr and 48 hr respectively and later allowed for shade drying for three hours. The samples were placed into polyethylene bags and sealed. The sealed samples were used for determination of physical properties using following methods.

*Moisture content:* The moisture content affects the physical and engineering properties of paddy grains used for designing of components. Moisture content of the paddy was determined by oven dry method. Three samples of paddy were taken and kept in oven at 105° for 24 hr. Thereafter, samples were taken out and their dry weight was determined using electronic balance. The moisture content was calculated by the following relationship.

$$\text{Moisture content, \%(db)} = \frac{\text{w1} - \text{w2}}{\text{w2}} \times 100 \qquad (1)$$

where, $w_1$= wet weight of paddy (g) and $w_2$= oven dry weight of paddy (g).

*Size:* Geometrical mean size of a paddy grain affect the groove length, depth of rotor in seed metering plate and the number of seeds require on groove surface. The size of paddy was determined in terms of its geometric length (l), width (b), thickness (t) and equivalent diameter ($d_e$) measured with the help of vernier caliper having a least count of 0.02 mm. A sample of 100 was taken and data was averaged out for determining the average size. The size of rice grain was expressed in terms of geometric mean as determined by the following relationship.

$$\text{Geometrical mean} = {}^{1/3}\sqrt[3]{l \times b \times t} \qquad (2)$$

where, l = length of paddy (mm), b = breadth of paddy (mm), and t = thickness of paddy (mm).

*Shape:* Sphericity ($\phi$) will affect the uniform free flow of paddy grains from the metering plate groove surface. In order to define the shape of seeds, sphericity ($\phi$) was calculated by utilizing the values of physical dimensions of seed using the following relationship.

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

*Thousand grain weight:* Thousand grain weight will decide the number of grains required per meter area. Three samples, each comprising of one hundred paddy grain were taken. The weight of each sample was determined using electronic balance having a least count of 0.1g. The average of all three samples was taken to determine the average weight of thousand seeds.

*Bulk density:* Bulk density and true density values are required to design the seed hopper. Bulk density was determined using a cube of size 10×10×10 cm. The cube was filled with paddy grains without any compaction and later on the seeds filling the cube were weighed. The bulk density was calculated as the ratio of weight of the seeds and volume of cube was calculated as

$$\rho = \frac{w}{v} \qquad (4)$$

where, $\rho$ = bulk density (g/cc), w = weight of the paddy (g), and v = volume of the sample (cc).

*True density:* The true density of paddy was determined by toluene displacement method using a measuring cylinder of 100 cc. A 10 g sample was immersed in a jar containing toluene liquid. The displaced volume of toluene was recorded for each sample and true density was calculated as the ratio of weight of the sample to its volume displaced.

*Porosity:* Bulk density and true density values determined from previous methods were used to calculate the percent porosity of the paddy grain. The porosity of the paddy grain was calculated using the following expression

Porosity, % = (True density – Bulk density) × 100/(True density) (5)

*Angle of repose:* The angle of repose is defined as the angle made by heap of a material while piled up with the horizontal. It is required to find minimum slope for free flow of paddy grains from the hopper. It was measured by an apparatus consisting of a conical hopper mounted above a circular base plate of 33 cm diameter. A scale was attached to this set up for measuring the height of heap above the base. A sample of paddy grain was taken and poured to form a conical heap above the base plate. The pouring was continued till the base plate was completely filled and paddy just started sliding outward. The height of the heap was measured by using the attached scale. The angle of repose was determined using the following relationship (Sahay and Singh 1994).

$$Ø = \tan^{-1}\frac{2h}{d} \qquad (6)$$

where, Ø = angle of repose (deg), h = height of heap (cm), and d = diameter of base plate (cm).

*Coefficient of static friction:* Coefficient of static friction helps in finding out resistance for uniform and free flow for paddy grains. The coefficient of static friction on three different surfaces, i.e. mild steel, galvanized iron and wood was measured for the paddy grain by inclined plane method. The paddy grain was kept on a horizontal surface and the slope was increased gradually. The angle (ø) at which paddy starting sliding was recorded. The coefficient of static friction was computed using the following relationship.

$$\mu = \tan ø \quad (7)$$

where, $\mu$ = coefficient of static friction, and ø = angle of static friction (degree).

## RESULTS AND DISCUSSION

The various properties like size, shape, bulk density, angle of repose and coefficient of static friction for five varieties were determined. The observed dimensions were used to determine the range of the design values of different components of the metering mechanism in terms of groove length, size of roller, hopper capacity and angle of hopper wall.

*Size of the paddy grain*

The observed results presented in Table 1 revealed that the average length of selected paddy varieties, $V_1$, $V_2$, $V_3$. $V_4$ and $V_5$ varied from 12.08 to 12.2 mm, 8.84 to 8.93 mm, 7.77 to 7.87 mm, 7.31 to 7.48 mm and 9.2 to 9.35 mm respectively in dry, one-day soaked and two-day soaked conditions. Breadth of varieties of paddy were in the order of 2.35 to 2.4 mm, 2.39 to 2.58 mm, 2.16 to 2.26 mm, 2.38 to 2.55 mm and 2.29 to 2.37 mm respectively. Similarly, the mean thickness of paddy grain were 3,7 to 3.82 mm, 3.43 to 3.59 mm, 3.0 to 3.59 mm, 3.13 to 3.31 mm and 3.43 to 3.57 mm respectively (Table 1). In all the 5 selected varieties, no significant difference in length was found between dry and soaked seed. The breadth and thickness of the seeds were found slight increase in all varieties (Fig 1). The observed values can be used to fabricate the seed metering cells for different varieties with cell diameter ranging from 10 to 14 mm.

*Shape of grain*

The measurement of sphericity and aspect ratioofgrainsare important parameters to express the shape of paddy grain. The sphericity and aspect ratio of grains gradually increased for paddy varieties $V_1$, $V_2$, $V_3$, $V_4$ and $V_5$ with the soaking time (Fig 2). The sphericity was found to vary from 30.7 to 31.4%, 38.85 to 40.19%, 38.67 to 40.05%,

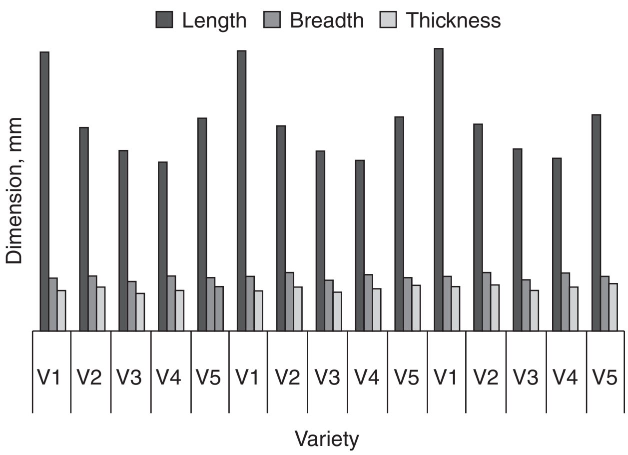


Fig 1 Dimension variations of paddy seeds

Table 1 Dimensions of paddy seeds

| Variety | Treatment | Length (mm) | | Breadth (mm) | | Thickness (mm) | | Equivalent dia. (mm) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Range | Mean | Range | Mean | Range | Mean | Range | Mean |
| T1 | $V_1$ | 9.91-14.13 | 12.08 | 2.0-3.03 | 2.35 | 1.17-2.23 | 1.78 | 3.09-4.17 | 3.70 |
| | $V_2$ | 7.35-9.90 | 8.84 | 2.05-2.91 | 2.39 | 1.10-2.20 | 1.91 | 2.74-3.78 | 3.43 |
| | $V_3$ | 6.58-8.48 | 7.77 | 2.0-2.59 | 2.16 | 1.04-1.87 | 1.62 | 2.62-3.26 | 3.00 |
| | $V_4$ | 6.13-8.10 | 7.31 | 1.84-2.75 | 2.38 | 1.51-2.06 | 1.76 | 2.62-3.39 | 3.13 |
| | $V_5$ | 7.84-10.20 | 9.20 | 2.02-2.69 | 2.29 | 1.24-2.12 | 1.91 | 2.88-3.69 | 3.43 |
| T2 | $V_1$ | 10.49-13.41 | 12.12 | 2.02-2.86 | 2.38 | 1.19-2.50 | 1.79 | 3.22-4.30 | 3.75 |
| | $V_2$ | 7.80-9.91 | 8.91 | 2.09-2.80 | 2.55 | 1.61-2.17 | 1.94 | 3.20-3.78 | 3.48 |
| | $V_3$ | 6.73-8.49 | 7.83 | 2.00-2.67 | 2.22 | 1.19-1.98 | 1.73 | 3.20-3.78 | 3.48 |
| | $V_4$ | 6.19-7.88 | 7.39 | 2.16-2.71 | 2.48 | 1.54-2.09 | 1.83 | 2.96-3.43 | 2.95 |
| | $V_5$ | 7.72-1027 | 9.28 | 2.02-2.60 | 2.34 | 1.33-2.33 | 1.99 | 3.08-3.81 | 3.51 |
| T3 | $V_1$ | 10.37-13.79 | 12.2 | 2.00-2.80 | 2.40 | 1.63-2.07 | 1.92 | 3.52-4.04 | 3.82 |
| | $V_2$ | 7.60-9.78 | 8.93 | 2.50-2.69 | 2.58 | 1.70-2.20 | 2.01 | 3.33-3.76 | 3.59 |
| | $V_3$ | 7.41-8.56 | 7.87 | 2.05-2.97 | 2.26 | 1.46-1.96 | 1.76 | 3.33-3.76 | 3.59 |
| | $V_4$ | 7.01-8.19 | 7.48 | 2.16-3.07 | 2.55 | 1.69-2.20 | 1.91 | 3.05-3.58 | 3.31 |
| | $V_5$ | 8.55-10.31 | 9.35 | 2.08-2.61 | 2.37 | 1.61-2.18 | 2.06 | 3.37-3.76 | 3.57 |
| | | | 9.10 | | 2.38 | | 1.86 | | 3.20 |

T1: Dry, T2: 1-day soaked; T3: 2-day soaked

42.84 to 44.37% and 37.31 to 38.26% in dry, one-day soaked and two-day soaked conditions respectively (Table 2). The sphericity was found to be highest for $V_4$ variety of paddy grain.

*Bulk density and true density of grain*

The bulk density and true density of $V_1$,$V_2$,$V_3$,$V_4$ and $V_5$variety paddy grains varied from 524.6 to546.16 kg/m$^3$, 626.79 to 648.74 kg/m$^3$, 604.23 to 667.56 kg/m$^3$, 633.94 to 647.29 kg/m$^3$ and 593.12 to 637.42 kg/m$^3$and true density 1165.03 to 1206.62 kg/m$^3$, 1125.56 to 1240.24 kg/m$^3$, 1186.88 to 1265.45 kg/m$^3$, 1181.41 to 1262.46 kg/m$^3$, and 1205.25 to 1280 kg/m$^3$with average values of 596.10 kg/m$^3$ and 1202.5 kg/m$^3$ for dry, one-day soaked and two-day soaked conditions respectively (Table 3). It was found that the bulk density and true density of paddy seeds increased significantly with the soaking time (Fig 3).

Table 2 Shape parameters of paddy seeds

| Variety | Treatment | Sphericity | | Aspect ratio | |
|---|---|---|---|---|---|
| | | Range | Mean | Range | Mean |
| T1 | $V_1$ | 26.14-35.42 | 30.70 | 15.01-25.02 | 19.66 |
| | $V_2$ | 32.51-45.69 | 38.85 | 21.72-35.97 | 27.16 |
| | $V_3$ | 34.11-42.57 | 38.67 | 24.17-34.63 | 27.86 |
| | $V_4$ | 39.50-46.03 | 42.84 | 27.27-37.60 | 32.65 |
| | $V_5$ | 32.81-41.29 | 37.31 | 21.86-30.22 | 25.00 |
| T2 | $V_1$ | 26.55-37.91 | 31.01 | 16.54-23.97 | 19.66 |
| | $V_2$ | 36.23-42.87 | 39.06 | 23.83-33.04 | 27.35 |
| | $V_3$ | 33.57-43.40 | 39.72 | 24.97-33.63 | 28.36 |
| | $V_4$ | 40.63-49.53 | 43.70 | 28.65-40.87 | 33.69 |
| | $V_5$ | 34.19-41.39 | 38.16 | 22.66-29.08 | 25.51 |
| T3 | $V_1$ | 28.62-34.73 | 31.40 | 15.47-23.44 | 19.71 |
| | $V_2$ | 37.40-43.82 | 40.19 | 25.56-35.13 | 28.91 |
| | $V_3$ | 37.19-44.35 | 40.05 | 25.32-38.47 | 28.74 |
| | $V_4$ | 41.00-48.05 | 44.37 | 29.23-40.37 | 34.19 |
| | $V_5$ | 35.20-41.48 | 38.26 | 21.67-29.25 | 25.60 |
| Mean | | | 44.95 | | 25.6 |

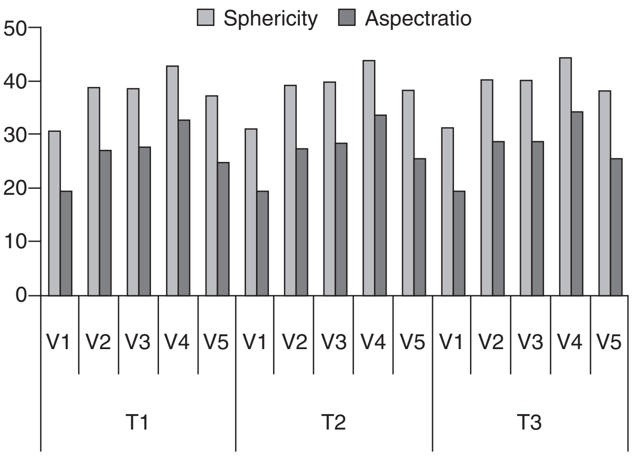


Fig 2 Shape parameters of paddy seeds

*Thousand grain mass*

The grain mass for each size of $V_1$,$V_2$,$V_3$,$V_4$ and $V_5$ varieties was determined for 1000 grains. The average grain weight of five paddy varieties was observed to vary from 23.87 to 32.6 g, 28.13 to 27.7 g, 14.37 to 18.2 g,18.0 to 21.27 g and 23.63 to 27.47 g for dry, one-day soaked and two-day soaked conditions respectively (Table 6). The highest value of 32.6 g was observed in two day soaked $V_1$ variety and lowest was 14.37 g in dry $V_3$ variety.

*Angle of repose and coefficient of friction*

The angle of repose and coefficient of friction was determined for three surfaces wood, mild steel (MS) and

Table 3 Frictional properties of paddy seeds

| Variety | Treatment | Angle of repose (degree) | | Coefficient of static friction | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Wood | | Mild steel | | GI | |
| | | Range | Mean | Range | Mean | Range | Mean | Range | Mean |
| T1 | $V_1$ | 24.59-25.66 | 25.25 | 0.47-0.49 | 0.48 | 0.49-0.53 | 0.51 | 0.49-0.53 | 0.50 |
| | $V_2$ | 18.5-19.610 | 19.07 | 0.42-0.49 | 0.45 | 0.4-0.460 | 0.43 | 0.42-0.47 | 0.44 |
| | $V_3$ | 26.73-28.40 | 27.36 | 0.52-0.65 | 0.57 | 0.45-0.55 | 0.50 | 0.50-0.58 | 0.53 |
| | $V_4$ | 24.15-26.10 | 25.30 | 0.47-0.53 | 0.49 | 0.40-0.50 | 0.45 | 0.50-0.55 | 0.53 |
| | $V_5$ | 29.98-31.30 | 30.45 | 0.50-0.70 | 0.59 | 0.47-0.55 | 0.49 | 0.48-0.59 | 0.53 |
| T2 | $V_1$ | 26.28-28.90 | 27.49 | 0.43-0.62 | 0.51 | 0.52-0.57 | 0.55 | 0.50-0.64 | 0.55 |
| | $V_2$ | 28.50-31.57 | 29.77 | 0.51-0.61 | 0.56 | 0.48-0.59 | 0.53 | 0.47-0.55 | 0.51 |
| | $V_3$ | 28.03-30.96 | 29.52 | 0.60-0.64 | 0.62 | 0.52-0.64 | 0.55 | 0.57-0.60 | 0.59 |
| | $V_4$ | 24.59-33.56 | 29.86 | 0.65-0.69 | 0.67 | 0.58-0.62 | 0.60 | 0.61-0.65 | 0.63 |
| | $V_5$ | 31.92-33.14 | 32.70 | 0.58-0.62 | 0.60 | 0.54-0.58 | 0.56 | 0.54-0.61 | 0.58 |
| T3 | $V_1$ | 32.02-34.20 | 32.97 | 0.47-0.61 | 0.55 | 0.52-0.64 | 0.56 | 0.53-0.73 | 0.64 |
| | $V_2$ | 30.99-32.24 | 31.56 | 0.58-0.75 | 0.66 | 0.45-0.54 | 0.51 | 0.48-0.60 | 0.54 |
| | $V_3$ | 29.19-30.75 | 30.29 | 0.77-0.87 | 0.80 | 0.53-0.70 | 0.63 | 0.70-0.81 | 0.76 |
| | $V_4$ | 31.22-33.81 | 32.79 | 0.65-0.87 | 0.77 | 0.66-0.71 | 0.69 | 0.63-0.67 | 0.66 |
| | $V_5$ | 32.60-34.77 | 33.68 | 0.60-0.84 | 0.72 | 0.58-0.67 | 0.62 | 0.60-0.80 | 0.70 |
| Mean | | | 29.20 | | 0.60 | | 0.545 | | 0.579 |

Table 4 Mean physical and engineering properties of paddy seeds

| Property | Pusa 1121 | | | Pusa 44 | | | BPT 5204 | | | MTU 7029 | | | MTU 1010 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $T_1$ | $T_2$ | $T_3$ | $T_1$ | $T_2$ | $T_3$ | $T_1$ | $T_2$ | $T_3$ | $T_1$ | $T_2$ | $T_3$ | $T_1$ | $T_2$ | $T_3$ |
| Length, mm | 12.08± 1.16 | 12.12± 0.99 | 13.79± 0.93 | 8.84± 0.77 | 8.91± 0.66 | 8.93± 0.64 | 7.77± 0.6 | 7.83± 0.51 | 7.87± 0.37 | 7.32± 0.61 | 7.44± 0.55 | 7.47± 0.36 | 9.2± 0.81 | 9.28± 0.76 | 9.35± 0.57 |
| Width, mm | 2.35± 0.43 | 2.38± 0.21 | 2.4± 0.21 | 2.39± 0.27 | 2.55± 1.39 | 2.58± 0.06 | 2.16± 0.21 | 2.22± 0.23 | 2.26± 0.20 | 2.39± 0.28 | 2.49± 0.11 | 2.55± 0.24 | 2.29± 0.23 | 2.34± 0.16 | 2.37± 0.17 |
| Thickness, mm | 1.78± 0.29 | 1.79± 0.26 | 1.92± 0.12 | 1.91± 0.25 | 1.94± 0.16 | 2.01± 0.16 | 1.62± 0.23 | 1.73± 0.23 | 1.76± 0.15 | 1.77± 0.19 | 1.83± 0.18 | 1.91± 0.17 | 1.91± 0.25 | 1.99± 0.23 | 2.06± 0.14 |
| Mean Dia., mm | 3.69± 0.40 | 3.75± 0.27 | 3.82± 0.17 | 3.43± 0.25 | 3.51± 0.45 | 3.59± 0.15 | 3± 0.2 | 3.11± 0.2 | 3.15± 0.14 | 3.13± 0.23 | 3.23± 0.18 | 3.31± 0.17 | 3.43± 0.25 | 3.51± 0.21 | 3.57± 0.14 |
| Sphericity | 30.56± 3.49 | 31.01± 2.88 | 31.4± 1.93 | 38.85± 3.28 | 39.47± 5.07 | 40.19± 1.96 | 38.67± 2.67 | 39.72± 2.49 | 40.05± 1.95 | 42.83± 2.32 | 43.66± 2.45 | 43.36± 2.49 | 37.31± 2.6 | 38.16± 2.32 | 38.26± 1.97 |
| Aspect Ratio | 19.47± 3.86 | 19.66± 2.40 | 19.71± 2.15 | 27.16± 4.00 | 28.72± 15.84 | 28.91± 2.36 | 27.86± 3.54 | 28.36± 3.02 | 28.74± 2.93 | 32.63± 3.5 | 33.69± 3.45 | 34.17± 3.57 | 25± 3.12 | 25.51± 2.22 | 25.6± 2.48 |
| Surface Area, Sq.mm | 42.84± 8.72 | 44.14± 6.47 | 45.97± 3.97 | 36.96± 5.34 | 38.95± 11.67 | 40.38± 3.3 | 28.32± 3.7 | 30.37± 3.88 | 31.19± 2.88 | 30.89± 4.47 | 32.74± 3.53 | 34.52± 3.59 | 36.9±+ 5.21 | 37.85± 4.3 | 40± 3.02 |
| Bulk density, kg/Cu.m | 524.6± 3.36 | 533.16± 5.93 | 546.16± 7.82 | 626.79± 7.10 | 637.9± 5.51 | 648.74± 9.02 | 604.23± 8.35 | 646.17± 6.9 | 667.56± 12 | 633.94± 7.98 | 650.15± 9.62 | 665.29± 12.25 | 593.12± 10.95 | 627.31± 8.46 | 637.42± 4.58 |
| True density, kg/Cu. m | 1165.03± 94.84 | 1180.72± 125.43 | 1206.62± 184.95 | 1125.56± 85.95 | 1230.81± 216 | 1240.24± 148.55 | 1186.88± 199 | 1238.07± 113.13 | 1265.45± 172 | 1181.41± 133.25 | 1242.04± 168.59 | 1262.46± 134.81 | 1205.25± 185.75 | 1250.75± 183.2 | 1279.95± 150.56 |
| 1000 seed weight, g | 23.87± 0.09 | 32± 1.07 | 32.6± 0.33 | 28.13± 0.34 | 26.2± 0.23 | 27.7± 0.16 | 14.37± 0.25 | 17.07± 0.41 | 18.2± 0.49 | 18± 0.16 | 21.03± 0.25 | 21.27± 0.41 | 23.63± 0.41 | 25.93± 0.41 | 27.47± 0.25 |
| M C, % | 11.00 | 26.44 | 31.26 | 9.11 | 22.10 | 23.97 | 13.63 | 21.74 | 30.00 | 10.2 | 21.12 | 26.2 | 12.12 | 22.22 | 20.03 |
| Angle of repose, (deg) | 25.25± 0.73 | 27.49± 1.66 | 32.97± 1.41 | 19.07± 0.82 | 29.77± 2.50 | 31.56± 0.97 | 27.36± 1.04 | 29.52± 1.89 | 30.29± 1.05 | 25.54± 1.53 | 29.86± 5.67 | 32.79± 1.57 | 30.45± 0.85 | 32.7± 0.81 | 33.68± 1.3 |
| *Coefficient of friction* | | | | | | | | | | | | | | | |
| Wood | 0.48± 0.02 | 0.51± 0.12 | 0.55± 0.09 | 0.45± 0.05 | 0.56± 0.07 | 0.66± 0.13 | 0.57± 0.08 | 0.62± 0.03 | 0.8± 0.06 | 0.5± 0.05 | 0.67± 0.02 | 0.77± 0.14 | 0.59± 0.13 | 0.6± 0.03 | 0.72± 0.14 |
| Cast iron | 0.51± 0.03 | 0.55± 0.03 | 0.56± 0.08 | 0.43± 0.03 | 0.53± 0.07 | 0.51± 0.07 | 0.5± 0.07 | 0.55± 0.08 | 0.63± 0.11 | 0.54± 0.07 | 0.6± 0.03 | 0.69± 0.03 | 0.49± 0.06 | 0.56± 0.03 | 0.62± 0.07 |
| Galvanized iron | 0.50± 0.03 | 0.55± 0.09 | 0.64± 0.13 | 0.44± 0.03 | 0.51± 0.05 | 0.54± 0.08 | 0.53± 0.06 | 0.59± 0.02 | 0.76± 0.08 | 0.54± 0.05 | 0.63± 0.02 | 0.66± 0.04 | 0.53± 0.85 | 0.58± 0.04 | 0.7± 0.14 |

T1: Dry; T2: 1-day soaked; T3: 2-day soaked (95% confidence limit = mean±1.645 SD)

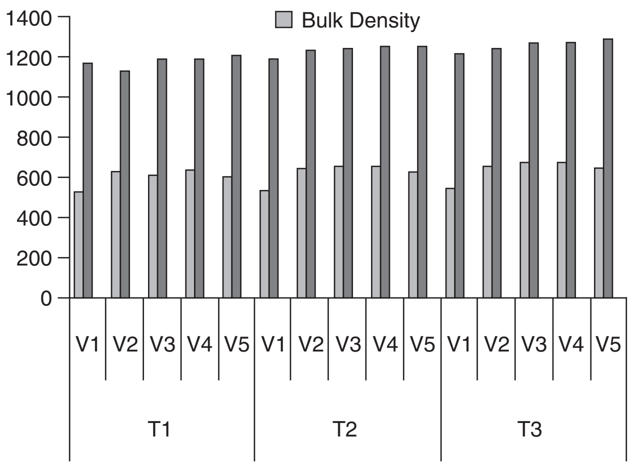


Fig 3 Variations in density parameters of paddy seeds

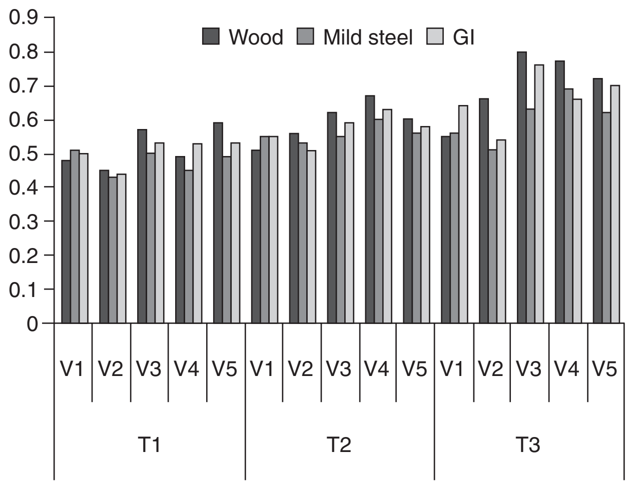


Fig 5 Variations in coefficient of friction for three surfaces

galvanized iron (GI). The average angle of repose for $V_1$, $V_2$, $V_3$, $V_4$ and $V_5$ varieties varied from 25.25 to 32.97°,19.07 to 31.56 °, 27.36 to 30.29° , 25.54 to 32.79° and 30.45 to 33.68° for dry, 1-day soaked and 2-day soaked conditions respectively. It was found that the angle of repose increased with the soaking for all varieties (Fig 4). The average coefficient of friction on MS sheet and Gl sheet for five varieties were 0.545 and 0.579 respectively (Table 5). It was observed that the coefficient of friction values increased slightly with the soaking (Fig 5). It was seen that this engineering property was also dependent upon the surface texture of the paddy grains and of that material from which grains are made to fall. Based on the results, it can be revealed that flow rate from the hopper can be affected due to angle of repose and coefficient of friction for paddy grains. Thus, to design the hopper the average values of angle of repose and coefficient of friction can be taken.

Movement of non-spherical seed is usually slower under gravity. Sphericity of varieties was found to range from 43.66± 2.45 to 30.56±3.49 respectively for MTU 7029 and Pusa 1121.The minimum sphericity observed in PUSA 1121 needs to be taken into consideration while designing the slope of seed transfer plate. Again seed weight affects the seed flow from seed metering device to the seed tube and in turn influences the seed hopper. True density of seed was highest for two day soaked MTU 1010 (1265.45±172 kg/m$^3$) and lowest for dry seed of Pusa 1121 (1165.03±94.84).The Highest mean angle of repose was found as 32.97+1.41, 31.56+0.97, 30.29+1.05, 32.79+1.57, 33.68+1.3$^0$ respectively in Pusa 1121, Pusa 44, BPT 5204, MTU 7029, MTU 1010. The highest angle of repose observed in PUSA 1121 can be used to have a seed hopper slope of 35$^0$ to ensure free flow of seed. The coefficient of friction in all the selected varieties was less with mild steel as compared to GI and wood surfaces.

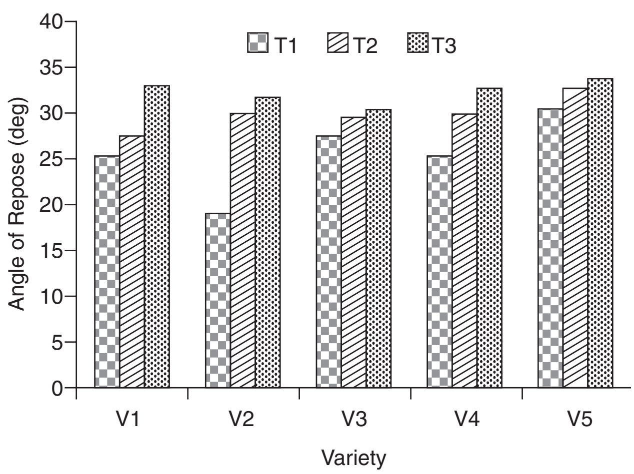


Fig 4 Variations in angle of repose of paddy seeds

(i) It was observed that the grain length varied from 7.32±0.61 to 13.79±0.93 mm, breadth 2.16±0.21 to 2.58±0.06 mm, sphericity 43.66± 2.45 to 30.56±3.49, 1000 grain weight 14.37 to 32.6 g, angle of repose 25.25 to 33.68$^0$ and bulk density 524.6 to 667.56 kg/m$^3$.
(ii) The observed values can be used to fabricate the seed metering cells for different varieties with cell diameter ranging from 10 mm to 14 mm.Thickness and cell diameters of the seed metering discs were designed in reference to the maximum breadth and length.
(iii) Based on the results, it can be revealed that flow rate from the hopper can be affected due to angle of repose and coefficient of friction for paddy grains. Thus, to design the hopper the average values of angle of repose and coefficient of friction can be taken. The highest angle of repose observed in Pusa 1121 can be used to have a seed hopper slope of 35$^0$ to ensure free flow of seed. The coefficient of friction in all the selected varieties was less with mild steel as compared to galvanized-iron and wood surfaces.
(iv) It was concluded that a minimum angle of 30$^0$ and a plate thickness of 4 mm can be used to design a hopper by selecting the low friction mild steel sheet. The measured bulk density and size values can be used to design a hopper of required capacity and seed metering plate cell size for required number of seeds/hill.

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