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Short communication

Planter design in relation to the physical properties of seeds

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Abstract

Physical properties namely, length, breadth, surface area, roundness, equivalent diameter, sphericity, seed weight, true density, angle of repose and coefficient of restitution of maize, red gram and cotton seeds were evaluated as design parameters for a planter. Thickness and cell diameters of the seed metering discs were designed in reference to the maximum breadth and length of seeds. Both roundness and sphericity affect seed flow through the various components of the planter. Roundness of maize, red gram, and cotton were 1.14 ± 0.14, 1.15 ± 0.10, and 1.26 ± 0.10 respectively, while sphericity of these seeds in the natural rest position were 0.621 ± 0.065, 0.750 ± 0.016, 0.550 ± 0.016 respectively. To ensure free flow of seeds, the slope of the seed hopper was, therefore, fixed at 30^o, which is modestly higher than the average angle of repose of seeds. In addition, the inner surfaces of the seed transfer cup was imbedded with 3 mm thick rubber sheet as its coefficient of restitution was lower than mild steel sheet of same thickness.

Key words: coefficient of restitution, cotton, maize, red gram, sphericity of seeds

Seed flow through a planter is dependent on size, shape, sphericity, true density and angle of repose of seeds. In addition, the impact of seeds on the internal components of the planter is influenced by the coefficient of restitution of seeds on various impinging surfaces. Therefore, attempts were made to find out the optimum design parameters of a planter by determining the relevant physical properties of three disparate kinds of crop seeds.

Physical properties of seeds namely, size, shape, sphericity, thousand seed weight, true density, angle of repose and coefficient of restitution for maize (*Zea mays*, cv. CoH-3), red gram (*Cajanus cajan*, cv. APK-1), and cotton (*Gossypium hirsutum*, cv. MCU-5) were determined following standard procedures. For estimating the size and shape, 10 random seeds of each species were spread at their natural rest position on the glass panel of a Leica Quantimet 500+ Digital Image Analyzer (Mahadevan et al., 1999). The image of the seed was captured using a digital camera and calibrated to scale. These images were transferred to the software Quantimet 500+ to identify the object based on the boundary of seeds, and the parameters such as length, breadth, area, roundness, and equivalent diameter were worked out. The measurement was replicated for 20 samples of each kind and their means (species-wise) were computed. For sphericity characterization, seeds were placed at its natural rest position on an overhead projector and the outline of the projected boundary was traced on the screen (Waziri and Mittal, 1983). The seed was rotated 90^o about its longitudinal axis and the projected image was traced again. From the outline of the projected image, the diameter of the largest inscribed circle (d_i) and the diameter of the smallest circumscribed circle (d_c) were drawn and sphericity was calculated as

$$\frac{d_i}{d_c} \quad \text{(Curray, 1951).}$$

The measurement was repeated for 50 random seeds of each kind and their average worked out. Thousand seed

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weight was determined for ten random samples of 1000 seeds each (per seed kind) in an electronic balance having sensitivity of 0.01 g. True density of seeds was calculated as

$$\left[\frac{Bulk\ density}{(1 - Porosity)}\right]$$

For this, porosity was determined using a standard porosity apparatus with five replicates and bulk density determined as the ratio of the weight by volume using containers of different shapes. The angle of repose of seeds was determined by the method explained by Waziri and Mittal (1983). The seeds were allowed to fall from a height of 300 mm on circular discs of 200, 150, and 100 mm diameter until maximum height was reached and the height of seed heap was noted. The experiment was replicated five times for each seed kind and the average values were computed. The following equation was used to calculate the angle of repose of the selected seeds,

$$\theta = tan^{-1}\left(\frac{h}{r}\right)$$

where θ = angle of repose, h = height of cone (mm) and r = radius of cone (mm). Coefficient of restitution of seeds was determined by the method described by Kumar (1995). In this method, a seed is dropped from a height of 50, 100, 150, 200, 250, and 300 mm on 3 mm thick mild steel and rubber sheets. A graduated scale of 500 mm was kept at the background and the maximum height of seed rebounce recorded using a high-speed digital video camera. Height of rebounce was measured in the monitor using the video editing unit. This was replicated 10 times for each seed kind and the coefficient of restitution calculated using the following equation,

$$\text{Coefficient of restitution} = \sqrt{\frac{h}{H}}$$

where h = height of rebound (mm) and H = height of drop, mm (Whitney and Porterfield, 1968).

Results show that maize, red gram and cotton seeds were 10.70±0.08, 7.35±0.06 and 9.10±0.09 mm long and 8.70±0.03, 6.35±0.07, 5.60±0.05 mm wide respectively (Table 1). Accordingly, the wheels of seed metering device were fabricated with cell diameters of 11, 8, and 10 mm for maize, redgram, and cotton respectively with a plate thickness of 10 mm. This is expected to meter 2 to 3 seeds when the cell hole overlaps with the hopper hole. The thickness of the cell wheel was selected based on the surface area of seeds (71.0±0.14, 35.8±0.05 and 37.0± 0.08 mm^2 respectively for maize, red gram and cotton) to meter 2 to 3 seeds. Roundness of maize, redgram, and cotton seeds were 1.14±0.14, 1.15±0.10, and 1.26±0.10 respectively.

Table 1. Size and shape, sphericity, thousand seed weight and true density of maize, red gram and cotton seeds at 95 % confidence limit

Parameters	kind of seeds		
	maize	red gram	cotton
Size and shape			
Length (mm)	10.70±0.08	7.35±0.06	9.10±0.09
Breadth (mm)	8.70±0.03	6.35±0.07	5.60±0.05
Area (mm^2)	71.00±0.14	35.80±0.05	37.00±0.08
Roundness	1.14±0.14	1.15±0.10	1.26±0.10
Equivalent diameter (mm)	9.50±0.10	6.74±0.06	6.90±0.07
Sphericity			
Natural rest position	0.621±0.065	0.750±0.016	0.550±0.016
Vertical position	0.551±0.015	0.721±0.032	0.455±0.032
Thousand seed weight (g)	268.30±0.092	102.12±0.060	81.42±0.018
True density (kg m^{-3})	1691.56±0.06	1301.00±0.04	1251.43±0.03

(95% confidence limit = mean±1.645 SD)

Movement of non-spherical seed is usually slower under gravity. Sphericity of maize, redgram, and cotton seeds in natural rest position were 0.621±0.065, 0.750±0.016, and 0.550±0.016, while that in the vertical position were 0.551±0.015, 0.721±0.032, and 0.455±0.032 respectively. Since the metered seeds are to be transferred to the seed placement unit (dibber) quickly, the lower sphericity value of cotton was taken into consideration for designing the slope of the seed transfer cup. Again, seed weight affects seed flow from seed metering device to the dibber, and in turn, influences the design of seed hopper. True density of the seeds was highest for maize (1691.56±0.06 kg m^{-3}), followed by red gram (1301.00±0.04 kg m^{-3})

Table 2. Coefficient of restitution of maize, red gram and cotton seeds at different dropping heights on 3 mm MS and rubber sheets

Seeds	Impact surface	Coefficient of restitution at different dropping heights					
		50 mm	100 mm	150 mm	200 mm	250 mm	300 mm
Maize	MS Sheet	0.707	0.547	0.516	0.500	0.458	0.428
	Rubber sheet	0.529	0.447	0.454	0.435	0.400	0.374
Red gram	MS Sheet	0.817	0.632	0.577	0.524	0.489	0.483
	Rubber sheet	0.678	0.500	0.483	0.458	0.428	0.424
Cotton	MS Sheet	0.501	0.447	0.417	0.403	0.374	0.365
	Rubber sheet	0.450	0.390	0.355	0.331	0.316	0.305

MS- mild steel

and cotton (1251.43±0.03 kg m^{-3}). The mean angle of repose of maize, redgram, and cotton were 22.1, 28.48, and 21.48^{o} respectively. The energy transfer during impact between the falling seed and the seed transfer cup is related to the coefficient of restitution. Hence, the slope of the seed hopper was kept at 30^{o} to ensure free flow of seed, which is modestly higher than the average angle of repose of seeds. Furthermore, seeds that fell on the rubber sheet experienced minimum coefficient of restitution compared to that on the mild steel sheet (Table 2). Therefore, a 3 mm thick rubber sheet was imbedded on the inner surface of the seed transfer cup to minimise seed bouncing.

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