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Studies on Engineering Properties of Maize for Development of Maize Dehusker cum Sheller

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ABSTRACT: The study has been conducted to investigate the physical and engineering properties of popularly grown varieties for maize seed, cob and whole cob. BIO-22027, JK-502 and Pioneer-3396 varieties were selected for the study within the moisture range of 10 to 14 % (d.b). The linear dimensions i.e. length, width, thickness and geometric mean diameter (GMD) of maize grain increased with increase in moisture content for all three varieties. However, the highest length, width and thickness were observed for the Pioneer-3396 variety as 11.73 mm, 8.99 mm 6.12 mm and 7.15 mm respectively. However, the highest sphericity, TGW and true density were observed as 0.728, 209.65g and 1.64g/cm³, respectively at moisture content of 14 % for the Pioneer-3396 Variety. Bulk density of maize grain and cob decrease with increase in moisture content.The highest angle of repose, coefficient of friction at MS sheet, rubber and glass surface, terminal velocity for grain and cob were observed 25.51˚, 0.54, 0.56, 0.43, and 15.06 m/s, 1.57 m/s respectively at 14% MC. The mean diameter of maize whole cob, cob bract, cob and stalk were found highest at bottom position as 44.67 mm, 39.94 mm, 30.17 and 12.58 respectively It was observed in all cases the diameter reduces from bottom to top linearly. The maximum length was observed to be 305.25, 293.25 and 288.25 mm for whole cob, bract and ear (cob) respectively. and the maize have 14-19 number of rows, 36-51 number of grain per row and 6-20 number of sheath per whole maize crop.

K**eywords:** physical property, maize seed, maize cob, moisture content, engineering properties.

INTRODUCTION

Maize (*Zea mays* L.) is an important cereal crop grown all over the world for human and animal consumption. It is called "Queen of cereals" because of its highest genetic yield potential (Sinha *et al.*, 2019) and "King of fodder due to its role in human and animal nutrition. It can be converted into other foods such as feed, starch, food, ethanol, gasoline, and even oil. Therefore there is increase in demand of maize (Olaniyan, 2015; Wilson and Lewis, 2015).

India ranks fourth in terms of area and seventh in terms of production among maize-growing countries. In India, the production of maize witnessed a significant increase of more than 16.6 times from a mere 1.73 million tons in 1950-51 to 28.75 million tons in 2018-19. Presently, it occupies 9.23 million hectares area with the productivity of 2.71 tons/hectare (Anonymous, 2019). The area and production under maize is just after the area of paddy in Chhattisgarh in Kharif season. It occupies 0.1196 million hectare land with the productivity of 2.57 t/ha in *Kharif* 2017-18 (Anonymous, 2020). There had been an increase of 20 percent in maize crop acreage in Chhattisgarh during the past 10 years.

The biggest threats for India during the twentieth century were the degradation of natural resources and climate change, all of which posed a danger to agricultural products. To increase agricultural production and productivity in order to ensure food security for a rapidly increasing population and prevent widespread malnutrition, agricultural production and productivity will have to rise by 85 percent and 100 percent, respectively, from current levels by the year 2025 (Sharma, 2007).

MATERIAL AND METHODS

A. Dimensions of the maize cob and grains

Twenty maize cobs from each of the three verities were taken randomly for the investigation. The length of whole cob (mm), stalk length (mm), weight of cob (g), linear dimensions of maize grains (mm), number of grain lines in a cob, number of grains in one line of a cob, minimum diameter of a cob without grains (mm), maximum diameter of a cob without grains (mm), average length of a shelled cob (mm), diameter of an whole cob (mm), and shape (Tarighi *et al.*, 2011). Fig. 1 illustrate the measurement of the dimensions of both whole cob and maize grain respectively.

Fig. 1. Measurement of the dimensions of whole (1 and 2) and dehusked maize cob (3 and 4).

B. Roundness

The sharpness of the solid's corners is measured by roundness. Several methods for estimating roundness have been proposed. On graph paper, the maize grains (10 numbers) were projected and traced (Fig. 2). The following formula was used to calculate the roundness (Jayan and Kumar, 2004)

$$\text{Roundness} = \frac{A_p}{A_c} \quad (1)$$

where, A_p = Largest projected area of maize grains in natural rest position, mm^2; A_c = Area of smallest circumscribing circle, mm^2

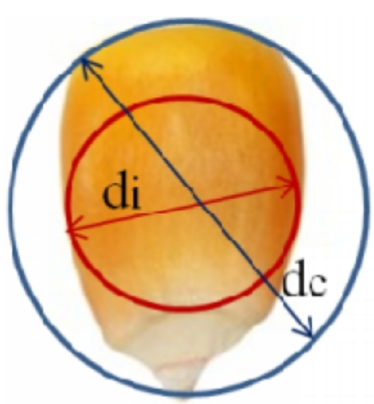


Fig. 2. Roundness of grain

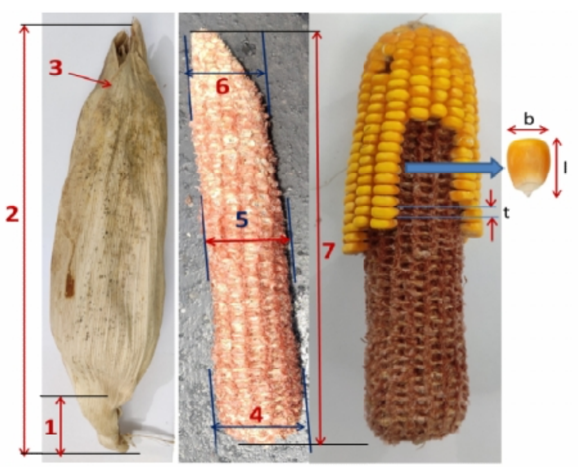
C. Arithmetic and geometric mean diameter

The length, width, thickness, and mass of maize grains were measured on 100 randomly selected maize grains for each maize variety. A digital caliper with 0.01 mm least count was used to measure the length, breadth, and thickness of grains (Fig. 3). The three axial dimensions were used to calculate the arithmetic mean and geometric mean diameters. The grains' arithmetic mean diameter (D_a) and geometric mean diameter (D_g) were estimated using the equations below (Mohsenin, 1986).

$$D_a = \frac{L + B + T}{3}, \text{ mm} \quad (2)$$

$$D_g = (LBT)^{1/3}, \text{ mm} \quad (3)$$

where, D_a = Arithmetic mean diameter, mm; D_g = Geometric mean diameter, mm; L = Length, mm; B = Width, mm; and T = Thickness, mm.



(1) Stalk cutting length, (2) Total length of whole cob (3) Sheath/husk (4) Bottom (5) Middle (6) Top end (7) length of cob.

Fig. 3. Morph physiological characteristics of whole maize, cob and seed.

D. Sphericity

Sphericity defines the ratio of the diameter of a sphere of the same volume as that of the particle and the diameter of the smallest circumscribing sphere or generally the largest diameter of the grain (Sahay and Singh, 1994). This parameter shows the shape character of maize relative to the sphere having the same volume.

$$\text{Sphericity } (\Phi) = \sqrt{\frac{\text{Volume of the particle}}{\text{volume of circumdsribed sphere}}} = \frac{(LWT)^{1/3}}{L} \quad (4)$$

Where, Φ = Sphericity; L = Largest intercept (length), mm; W= Width, mm; and T = Thickness, mm.

E. Bulk density

The average bulk density of maize was determined using a container of known volume glass jar of cylindrical shape having known height and diameter. The bulk density was calculated as the mass of seed divided by the container volume (Singh and Goswami, 1996). Likewise, for the maize cob bulk density was measured following same methodology.

$$\rho_b = \frac{M}{V} \quad (5)$$

$$\rho_b = \frac{4M}{\pi D^2 h} \quad (6)$$

where, ρ_b= Bulk density; M = Mass of the grain sample, g; V = Volume of glass jar sampler, cm^3; D = Diameter of glass jar sampler, cm; and h = Height of glass jar sampler, cm.

F. True density

The true density defined as the ratio of mass of the sample to its true volume, was determined using the toluene (C_7H_8) displacement method. Toluene was used in place of water because it is absorbed by seeds to a lesser extent 50 ml of toluene were placed in a 100ml graduated measuring cylinder and 5g seeds were immersed in the toluene (Mohsenin, 1986; Bhise *et al.*, 2014). The amount of displaced toluene was recorded from the graduated scale of the cylinder. The ratio of weight of seeds to the volume of displaced toluene gave the true density.

$$\rho_t = \frac{M}{V} \quad (7)$$

where, ρ_t = True density; g/cm^3; M = Mass of the grain sample; g and V =Volume of grains excluding void space, cm^3.

G. Moisture content

The oven dry method was used to determine the grain's moisture content on adry weight basis. A 25 g maize gr ain sample was placed in an air oven at 105°C for 48 ho urs.

An electronic balance was used to weigh the oven dried sample, and the percent moisture content was compute d using the formula below.

$$M_c = \frac{W_1 - W_2}{W_1 - W_3} \times 100, \% \quad (8)$$

Where, M_c= Moisture content, %; W_1 = Weight of the wet sample, g; W_2 = Weight of the dry sample, g; and W_3 = Weight of the tray, g.

H. Determination of the grain to dry matter ratio

Ten samples of 1000g weight each of the whole cobs at randomly was taken for determination of grain cob ratio. The grain was separated from the cob with hand maize sheller manually for each sample. The weight of grain and shelled cob separately for each sample were taken. The grain cob ratio was calculated using following formula. The average of the ten samples shall be taken as grain and shelled cob ratio.

$$\text{Grain to dry matter} = \frac{W_g}{W_t - W_g} \quad (9)$$

Where, W_g = Weight of grain from sample, g; and W_t = Weight of total maize cob sample, g.

(a) With husk (b) Without husk (a) Without grain and husk

Fig. 4. Measurement of weight of maize in different conditions.

I. Angle of Repose

A rectangular box filled with grains was kept horizontal to measure the angle of repose. After that, the grains were permitted to fall onto a horizontal circular disc that was kept below the box. After the grains were entirely heaped on the disc, the flow of grains was stopped. The height and radius of the heap's base were measured, and the angle of repose was computed using the following formula (Sahay and Singh, 1994).

$$\theta = \tan^{-1}\left[\frac{h_0}{r}\right] \quad (10)$$

where, θ = Angle of repose, degree; h_0 = Height of heap, m; and r = Radius of heap, m.

J. Terminal velocity

Terminal velocity is to decide the winnowing velocity of air blower for separation of lighter materials (Sahay and Singh, 1994). The terminal velocity was measured using an air column. For each test, a sample was dropped to the air stream from the top of the air column, and air was blown up the column to suspend the material in the air stream. The air velocity near the location of the sample suspension was measured by digital anemometer having a least count of 0.1 m/s.

K. Frictional properties

The frictional properties such as angle of repose and coefficient of friction are important in designing of hoppers, chutes, pneumatic conveying systems, screw conveyors, forage harvesters, storage bins etc. It refers to the friction that occurs between the grains and the container. In order to achieve consistent flow of materials through the chute, the coefficient of friction is utilized to define the angle at which the hopper, collecting tray, and chutes must be positioned (Sahay and Singh, 1994). A horizontal plane, a bottomless open container, and a pan make up the coefficient of friction device. In the container, known grain weights were taken. The weights were placed in the pan, and the container began to slide on the chosen surface when the pan weight exceeded the grain weight and friction. The coefficient of friction of grains was evaluated using the inclined surfaces method on four material surfaces; plywood, MS sheet, wood and grain surface.

$$\mu = \frac{F}{N} \quad (11)$$

Where, μ = Coefficient of friction; F = Frictional force (force applied); and N = Normal force (weight of the grain).

L. Determination impact strength of maize grain

The texture analyzer (TW + Di) of APFE laboratory was used. The texture analyzer consisted of two primary components: hardware (load cell with a platform to hold sample and moving head for holding probe) and software (Texture Expert) for recording and calculating the test results. Before performing the tests, the machine was calibrated for load and distance for each type of test. The load calibration was done to check whether the load cell was accurate in sensing the force imposed over the sample of grain and cob. After calibrating the texture analyzer, samples of maize grain and cob was placed on the platform. Different probes were used for different tests as per settings to generate the force-time curves.

RESULT AND DISCUSSION

A. Effect of varieties and moisture content on linear dimension and GMD

The results on linear dimensions i.*e*. length breadth and thickness of three varieties of maize seed *i.e.* BIO-22027, JK-502 and Pioneer-3396 were found out within the moisture range of 10% to 14%.The interaction between the variety and moisture content was analyzed by SPD. It was observed that there is significant difference at 1% level in between the varieties on linear dimension (length, breadth, thickness). It was found highest length (11.73 mm), breadth (8.99 mm) and thickness (6.12 mm) for Pioneer-3396 variety. The lowest linear dimensions were observed in case of BIO-22027 variety. It was also observed that with the increase in moisture content, linear dimension of maize grains also increases. It was observed length (11.45 mm), breadth (8.78 mm) and thickness (6.09 mm) in case of moisture content of 14% which were significantly highest (α = 0.01). It was observed that there is significant difference at 1% level in between the varieties on Geometric mean diameter (GMD). It was found highest (7.15 mm) for Pioneer-3396 variety and lowest in case of JK-502 variety. It was also observed that moisture content also plays a vital role on GMD. It was observed 7.09 mm in case of moisture content of 14% which was significantly highest (α = 0.01) (Bhise *et al.*, 2014; Shirsath *et al.*, 2018).

Table 1: Effect of varieties and moisture content on linear dimensions and GMD for maize.

Moisture content (%)	Length (mm)				Width (mm)				Thickness (mm)				GMD (mm)			
	V1	V2	V3	Mean	V1	V2	V3	Mean	V1	V2	V3	Mean	V1	V2	V3	Mean
M1(10.00)	9.88	9.65	11.31	10.28	8.11	8.04	8.73	8.29	5.46	5.75	5.90	5.70	6.93	6.60	7.07	6.87
M2(12.00)	10.02	10.15	11.81	10.66	8.24	8.19	8.94	8.45	5.82	5.86	6.09	5.92	7.04	6.80	7.15	7.00
M3(14.00)	11.01	11.28	12.07	11.45**	8.42	8.63	9.30	8.78**	5.99	5.91	6.37	6.09**	7.11	6.92	7.24	7.09**
Mean	10.30	10.36	11.73**		8.26	8.29	8.99**		5.75	5.84	6.12**		7.03	6.78	7.15**	
CD	0.35				NS				NS				NS			

where, V1= BIO-22027, V2= JK-502, V3= Pioneer-3396, ** = significant at 1% level of significance

B. Effect of varieties and moisture content on roundness for maize

The interaction between the variety and moisture content was observed that there is significant difference at 1% level in between the varieties on roundness and TGW (Chilur and Sushilendra, 2016). It was found highest (4.0) for Pioneer-3396 variety and lowest in case of BIO-22027 variety. It was observed 3.87 in case of moisture content of 10 % which was significantly highest (α = 0.01) The observed values of sphericity were found to be 0.65, 0.71 and 0.73 mm for BIO22027, JK-502 and Pioneer-3396 respectively and were statistically different (CD = 0.01) at α = 0.01 level of significance. The values of sphericity were found to be 0.68, 0.69 and 0.70 at 12, 14 and 16 % moisture content and were found significantly different with CD = 0.01 at 1% level of significance (Taraghi *et al.*, 2011; Bhise *et al.*, 2014). It was found highest (0.70) for variety Pioneer-3396 and lowest in case of variety BIO-22027. It was observed 0.72 in case of moisture content 14% which was significantly highest (α = 0.01). TGW was found highest (204.06g) for Pioneer-3396 variety and lowest in case of BIO-22027 variety. It was also observed that as moisture content increased, the thousand seed weight increased. Similar results were also reported by Chilur and Kumar (2018); Shirsath, *et al.*, (2018).

Table 2: Effect of varieties and moisture content on roundness, sphericity and TGW for maize.

Moisture content (%)	Roundness				Sphericity				TGW (g)			
	V1	V2	V3	Mean	V1	V2	V3	Mean	V1	V2	V3	Mean
M1(10.00)	3.25	3.69	4.67	3.873**	0.630	0.645	0.668	0.648	151.10	178.88	199.15	176.38
M2(12.00)	2.63	3.63	4.01	3.425	0.703	0.713	0.725	0.713	154.48	191.55	203.38	183.13
M3(14.00)	2.00	2.488	3.32	2.605	0.725	0.728	0.728	0.727**	171.20	199.20	209.65	193.35**
Mean	2.62	3.27	4.00**		0.686	0.695	0.707**		158.93	189.88	204.06**	
CD	NS				0.012				4.41			

where, V1= BIO-22027, V2= JK-502, V3= Pioneer-3396, ** = significant at 1% level of significance

C. Effect of varieties and moisture content on bulk density for maize grain

The results on bulk density, true density of three varieties of maize seed *i.e.* BIO-22027, JK-502 and Pioneer-3396 were found out within the moisture range of 10% to 14%.The interaction between the variety and moisture content was analyzed by SPD. It was observed that there is non- significant difference at 1% level in between the varieties on bulk density. It was found highest (0.66 kg/cm³) for Pioneer-3396 variety and lowest in case of JK-502 variety. It was also observed that moisture content also plays a vital role on bulk density. It was observed 0.62 kg/m³ in case of moisture content of 10 % which was significantly highest (α = 0.01). Bulk density decreased with increasing moisture content. Similar results found with Taraghi *et al.*, (2011); Shirsath, *et al.*, (2018); Chilur and Kumar (2018). Bulk density of maize cob was found highest (370.17 kg/cm³) for Pioneer-3396 variety and lowest in case of JK-502 variety. It was also observed that moisture content also plays a vital role on bulk density. It was observed 376.08 kg/m³ in case of moisture content of 10 %. The density values are useful for designing the hopper. Bulk density of whole maize cob decreased with increasing moisture content. Similar results found with Bhise *et al.*, (2014); Chilur and Sushilendra, (2016); Shirsath *et al.*, (2018). It was observed that there is non-significant difference at 1% level in between the varieties on true density. It was found highest (1.70g/cm³) for Pioneer-3396 variety and lowest in case of JK-502 variety.

Table 3: Effect of varieties and moisture content onbulk density and true density for maize.

Moisture content (%)	Bulk density maize grain(kg/cm³)				Bulk density maize cob (kg/cm³)				True density of maize grain(g/cm³)			
	V1	V2	V3	Mean	V1	V2	V3	Mean	V1	V2	V3	Mean
M1(10.00)	0.60	0.56	0.70	0.62**	364.75	370.25	393.25	376.08**	1.17	1.11	1.77	1.35
M2(12.00)	0.55	0.53	0.65	0.58	351.75	350.25	365.25	355.75	1.13	1.08	1.68	1.30
M3(14.00)	0.52	0.50	0.61	0.54	342.00	345.50	352.00	346.50	1.05	1.03	1.64	1.24**
Mean	0.56	0.53	0.66**		352.83	355.33	370.17**		1.12	1.07	1.70**	
CD	NS				6.08				NS			

where, V1= BIO-22027, V2= JK-502, V3= Pioneer-3396, ** = significant at 1% level of significance

D. Effect of varieties and moisture content on angle of repose for maize

The interaction between the variety and moisture content was observed that there is non-significant difference at 1% level in between the varieties on angle of repose. It was found highest (24.72°) for Pioneer-3396 variety and lowest in case of JK-502 variety. It was also observed that moisture content also plays a vital role on angle of repose. It was observed 23.07° in case of moisture content of 14% which was significantly highest (α = 0.01). It was also observed that as moisture content increases, the angle of repose increases. Similar results were found by Bhise, *et al.*, (2014); Chilur and Sushilendra (2016); Shirsath, *et al.*, (2018). It was observed that there is non-significant difference at 1% level in between the varieties on terminal velocity. It was found highest (14.78 m/s) for Pioneer variety and lowest in case of JK-502 variety. It was also observed that moisture content also plays a vital role on terminal velocity (Bhise, *et al.*, 2014, Chilur and Sushilendra, 2016). Terminal velocity of maize husk was found highest (1.29 m/s) for JK-502 variety and lowest in case of BIO-22027 variety.

Table 4: Effect of varieties and moisture content on angle of repose, and terminal velocity for maize.

Moisture content (%)	Angle of repose				Terminal velocity maize grain (m/s)				Terminal velocity maize husk(m/s)			
	V1	V2	V3	Mean	V1	V2	V3	Mean	V1	V2	V3	Mean
M1(10.00)	20.52	20.11	23.84	21.49	13.29	13.07	14.47	13.61	1.11	1.15	1.16	1.14
M2(12.00)	21.31	20.73	24.83	22.29	13.79	13.46	14.81	14.02	1.12	1.17	1.20	1.16
M3(14.00)	22.16	21.56	25.51	23.07**	14.27	13.83	15.06	14.38**	1.18	1.57	1.22	1.32**
Mean	21.33	20.80	24.72**		13.78	13.45	14.78**		1.13	1.29**	1.19	
CD	NS				NS				NS			

E. Effect of varieties and moisture content on coefficient of friction for maize

The results on coefficient of friction of three varieties of maize seed *i.e.* BIO-22027, JK-502 and Pioneer-3396 were analyzed within the moisture range of 8% to 14%. The coefficient of friction was measured on three surfaces namely MS sheet, Rubber and Glass. It was observed that there is significant difference at 1% level in between the varieties on coefficient of friction (MS-sheet, Rubber and Glass). It was found highest coefficient of friction 0.50, 0.55, 0.43 for Pioneer-3396 variety and lowest in case of BIO-22027 variety in MS sheet, Rubber and Glass surface respectively. It was also observed that moisture content affect coefficient of friction of surface (Bhise, *et al.*, 2014; Chilur and Sushilendra, 2016). It was observed 0.50, 0.47 and 0.40 in MS sheet, Rubber and Glass surface respectively in case of moisture content of 14% which were significantly highest ($\alpha = 0.01$).

Table 5: Effect of varieties and moisture content on coefficient of friction for maize

Moisture content (%)	Coefficient of friction- MS Sheet				Coefficient of friction – Rubber				Coefficient of friction –Glass			
	V1	V2	V3	Mean	V1	V2	V3	Mean	V1	V2	V3	Mean
M1(10.00)	0.44	0.39	0.47	0.43	0.52	0.52	0.54	0.52	0.34	0.35	0.35	0.35
M2(12.00)	0.47	0.42	0.50	0.47	0.53	0.54	0.56	0.54	0.36	0.37	0.39	0.37
M3(14.00)	0.50	0.46	0.54	0.50**	0.54	0.54	0.56	0.55**	0.38	0.40	0.43	0.40**
Mean	0.47	0.42	0.50**		0.53	0.53	0.55**		0.36	0.37	0.39**	
CD	NS				NS				0.01			

F. Physical characteristics of maize cob

Physical characteristics of the maize cob viz. number of sheath per maize cob, diameter of the maize whole cob, its length, number of grains per line, number of lines in the cob and the length and diameter of the cob bract were measured and analyzed for further development of the dehusker cum sheller machine. The data are presented in Table 6, 7 and 8. It was observed in all cases the diameter reduces from bottom to top linearly. The maximum diameter of whole maize cob was observed to be 45.75 whereas maximum diameter of the cob was observed to be 30.17 mm. It means the position of the glumes to the upper part of the sheath was about 7.3 mm. It was also observed that the grain is adhering to the maize ear through glumes by 3-4 mm. The immature grains were found at the top of the maize cob which reduces the size of the seed and likewise the diameter at top position in all whole cob, bract and ear (cob). It was observed that the variation in the stalk diameter in all three positions is very less and cylindrical in nature. It varies from 10.21 to 13.57 in whole.

Table 6: Diameter for whole maize cob and cob bract.

Diameter of whole cob				Diameter of cob bract			
Position of whole maize cob	**D1 (Bottom)**	**D2 (Middle)**	**D3 (Top)**	**Position of maize bract**	**D1 (Bottom)**	**D2 (Middle)**	**D3 (Top)**
Mean ($\bar{x}$)	44.67	41.08	37.48	Mean ($\bar{x}$)	39.94	37.68	35.85
Maximum, mm	45.75	41.85	39.24	Maximum, mm	40.39	38.02	36.98
Minimum, mm	43.12	40.08	35.28	Minimum, mm	39.05	36.99	34.09
CV	2.33	1.56	4.28	CV	1.31	1.12	3.05
SD (σ)	1.04	0.64	1.61	SD(σ)	0.52	0.42	1.10

Table 7: Diameter of maize cob and stalk.

Diameter of cob				Diameter of stalk			
Position of whole maize cob	**D1 (Bottom)**	**D2 (Middle)**	**D3 (Top)**	**Position of whole maize cob**	**D1 (Bottom)**	**D2 (Middle)**	**D3 (Top)**
Mean ($\bar{x}$)	30.17	28.95	27.24	Mean ($\bar{x}$)	12.58	12.35	11.41
Maximum, mm	30.56	29.04	28.05	Maximum, mm	13.57	13.25	12.51
Minimum, mm	29.79	28.79	26.12	Minimum, mm	11.02	11.23	10.21
CV	0.98	0.36	2.85	CV	7.82	6.35	9.65
SD (σ)	0.30	0.10	0.78	SD (σ)	0.98	0.78	1.10

Table 8: Length of whole cob, bract and ear (cob).

Length of whole cob, bract and ear (cob)				Number of rows/con, number of grains per row and number of sheath/whole maize (N = 10)			
Position of whole maize cob	Whole cob	Bract	Cob(ear)	Particulars	Number of rows /cob	Number of grains per row	Number of sheath /whole maize
Mean ($\bar{x}$)	234.28	222.28	217.35	Mean ($\bar{x}$)	17.30	41.80	12.60
Maximum, mm	305.25	293.25	288.25	Maximum, mm	19.00	51.00	20.00
Minimum, mm	134.89	122.89	117.89	Minimum, mm	14.00	36.00	6.00
CV	29.57	31.17	31.91	CV	9.06	10.14	34.33
SD(σ)	69.27	69.27	69.34	SD(σ)	1.57	4.24	4.33

G. Length of whole cob, bract and ear (cob)

Length of whole cob, bract and ear (cob) were measured for randomly selected 10 samples. It was observed that the ear have smallest length (217.35 mm) whereas, the whole cob have 234.28 mm length. It may be due to the length of the stalks and ear in upper positional area is covered by sheath. The maximum length was observed to be 305.25, 293.25, and 288.25 mm for whole cob, bract and ear (cob) respectively. Number of rows/cob, number of grains per row and number of sheath/whole maize were counted for randomly selected 10 samples. It was observed that the maize have 14-19 number of rows, 36-51 number of grain per row and 6-20 number of sheath per whole maize crop. The variation (34.33%) in number of sheath was observed to be highest whereas, the variation in number rows is lowest (9.06%). This indicates that the particular variety have nearly same number of rows but the increase in size and shape may very due to the climatic condition and nutrition availability to the crop.

CONCLUSIONS

1. It was concluded that the mean value of linear dimensions like length, width, thickness and geometric mean diameter (GMD), sphericity, true density of maize seed increased with increase in moisture content for all three varieties. Whereas bulk density of maize grain and cob decrease with increase in moisture content However, the highest true density and lowest value of bulk density of grain and cob were observed for the Pioneer-3396 of maize as 1700 kg/m^3, 0.70 g/cm^3 and 370.17 kg/m^3 respectively at moisture content of 14 %.

2. The highest angle of repose, coefficient of friction at GI sheet, MS sheet and plywood surface, terminal velocity were observed 25.51°, 0.54, 0.56, 0.43, 15.06 m/s and 1.57 m/s at 15 % moisture content.

3. The maximum rupture force required to deform the maize grain and cob was found to be 18747.63 g (183.85 N), and 26825.28 g (262.88 N).

4. The mean value of physical property of whole maize cob diameter and length was found at bottom, middle and top was 44.67, 41.08, 37.48 mm and 234.28, 22.28, 217.35 mm respectively. The number of rows per cob, grains in one line and number of sheath was found 17.30, 41.80 and 12.60 respectively.

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Conflict of Interest. None.

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