*Research Inventy: International Journal of Engineering And Science*
*Vol.10, Issue 7 (July 2020), PP 69-76*
*Issn (e): 2278-4721, Issn (p):2319-6483, www.researchinventy.com*

# Engineeringproperties of Tuberose bulbs and Gladiolus corms in relation to design of metering mechanism for planting

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***ABSTRACT***
*Knowledge of the engineering properties of Tuberosebulbs and Gladioluscormsplay a very important role for the design of metering mechanism in planting machines. Especially size and its uniformity is an important factor in design and development of metering mechanism of any type of planter, which helps to optimize the structural parameters for optimum performance. In this study, selected engineering properties of Tuberose bulbsandGladiolus corms relevant to develop the planting mechanism were determined.The mean size of Tuberose bulbs i.e. major, minor and intermediate diameter were found to be 54.82mm, 16.17 mm and 19.42 mm, respectively, whereas that of Gladiolus corms were found to be 43.48 mm, 25.74 mm and 34.46 mm, respectively. The mean values of geometric mean diameter, arithmetic mean diameter, sphericity, equivalent diameter, aspect ratio and surface area of Tuberose bulbs were found to be 29.6 mm, 26.74 mm, 0.435, 25.08 mm, 42.65 %, and 1764.71mm$^2$, respectively, whereas that of Gladiolus corms were found to be 33.91mm, 34.56 mm, 0.77, 34.15mm, 79.45 and 3556.33 mm$^2$, respectively. The average values of unit weight, weight of 100 corms, true density, bulk density, porosity and angle of repose of Tuberose bulbs were found to be 18.54 g, 1.65 kg, 0.875 g/cc, 0.656 g/cc, 25.02 per cent and 37 degrees, respectively, whereas that of Gladiolus corms were 25.41g, 2.54 kg, 0.879 g/cc, 0.58 g/cc, 33.92 per cent and 32 degrees, respectively. The minimum static coefficient of friction was obtained on mild steel for Gladiolus corms (0.54) and maximum value was obtained on the surface of asbestos for Gladiolus corms (0.75).*

***KEYWORDS****: Physical properties, frictional properties, gravimetric properties, bulk density.*

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Date of Submission: 10-07-2020 Date of Acceptance: 26-07-2020

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## I. INTRODUCTION

Floriculture in India has a long tradition. It has served the purpose of meeting our socio-culture requirement since time immemorial. Flowers are no more seen as commodities for specific purpose but as product or messenger to convey specific meaning on specific occasion. According to a report of the National Horticulture Board (NHB), the total area under flower crops in India during 2013-14 was reported around 2.55 m-ha. This is second largest in the world next to China. During the same year the production of flowers was estimated as 1.75 million tones of loose flowers and 0.54 million tons of cut flowers. Fresh and dried cut flowers dominate floriculture exports from India. Among states, Karnataka is the leader in floriculture with about 18,000 hectares under floriculture cultivation, accounting for 75% of India’s total flower production.Other major flower growing states are Tamil Nadu and Andhra Pradesh in the South, West Bengal in the East, Maharashtra in the West and Rajasthan, Delhi and Haryana in the North (Anon. 2015).

Tuberose (*Polianthestuberosa*) is one of the most popular ornamental flowering plants cultivated for long lasting flower spikes grown in many parts of the world. It is popularly known as Rajanigandha or Nishigandha. Tuberose is a native of Mexico from where it spread to different parts of the world during 16thCentury.It can successfully be grown in pots, borders, beds and commercially cultivated for its various uses. In India, commercial cultivation of Tuberose is popular in west Bengal, Tamil Nadu, Maharashtra, Andhra Pradesh, southern parts of Karnataka, Assam, Rajasthan, Gujarat, Uttarakhand and Uttar Pradesh.

Gladiolus is being grown in an area of 11660 ha in the country with an estimated production of 106 crore cut flowers. Amongst the cut flowers, Gladiolus occupied third position in terms of both area and production. The major Gladiolus producing states in the country are Uttar Pradesh, West Bengal, Odisha, Chhattisgarh, Haryana& Maharashtra. Gladiolus is also grown in states like Uttarakhand, Karnataka, Andhra Pradesh and Sikkim. Even though Gladiolus is mainly a winter season flower crop, in areas having moderate climatic conditions, Gladiolus can be grown throughout the year.

In design of any planting mechanism and hopper of the planter, the engineering properties play a very important role. The major physical properties influencing the design of planting mechanism are size, shape, unit mass, bulk density, true density, major, minor and intermediate diameters, sphericity, angle of repose and static co-efficient of friction against various surfaces (Ramesh, *et al*., 2015). In recent years, engineering properties have been studied for different agricultural products such asJack fruit (Shidenur, *et al.*, 2017), Ginger (Ajav&Ogunlade, 2014), JatrophaCurcas (Sharma, *et al*., 2013), Egusi Melon, (Bande, *et al*., 2012); pomegranate, seeds and arils (Riyahi, *et al*., 2011); Saffron crocus corm (Beygy*et al*., 2010), Apple cv. 'Golab (Meisami-asl*et al*., 2009) jatropha seed (Garnayak*et al*., 2008) Iranian apricot (Jannatizadeh*et al*., 2008), simarouba and kernel (Dash A. K. *et al*, 2008), Varieties of apple (Kheiralipour, *et al*., 2008); Orange (Sharifi, *et al*., 2007) fresh oil palm fruit (Owolarafe, *et al.*, 2007), squash seed (Paksoy and Aydin, 2004), almond nut and kernel (Aydin, 2003).

The physical properties of Tuberose bulbs and Gladiolus bulbs are very important in designing and fabricating particular equipment and structures for handling, transportation and storage. There is no published information on engineering properties of Tuberose bulbs and Gladiolus corms. The size (such as major, minor, intermediate, arithmetic mean diameter and geometric mean diameter) and shape are important in designing of pick up system in planting mechanism of automatic planter. The corms and bulbs shape can be determined in terms of sphericity and aspect ratio which affects the flow ability characteristics of the cormsand bulbs (Dash *et al*., 2008). The bulk density and porosity affect the loads on structures and angle of repose is important in designing of hopper (Altuntas and Yildiz, 2007).The coefficientof friction of corms on different surfaces also necessary in design and selection of material for hopper.

The aim of this study was to investigate the engineering properties of Tuberose bulbs and Gladiolus corms. The parameters studied include moisture content, size, 100 corms weight, unit mass, major, minor and intermediate diameter of corms, arithmetic mean diameter, geometric mean diameter, sphericity, aspect ratio, surface area, equivalent diameter,bulk density, true density, porosity, coefficient of friction and angle of repose for the purpose of designing metering mechanism for them .

## II. MATERIALS AND METHODS

### 2.1 Sample preparation and moisture content determination

Commercially available Tuberose bulbs and Gladiolus corms were procured from model floriculture center, GBPUA&T, Pantnagar. The sample were cleaned manually to remove all foreign materials such as dust and dirt and pooled together to get 100 corms. The moisture content of bulbs and corms was determined according to ASAE standard S358.2 (1983) by drying in an electric oven at a temperature of 105 °C and for 24 h (Ozguven and Vursavus, 2005;Obi and Offroha, 2015; DingkeandFielke, 2014).

### 2.2 Geometric properties

The size was determined by measuring the dimension of the corms and bulbs like majorminor and intermediate diameters of 100 randomly selected corms by using digital caliper having a sensitivity of 0.01 mm. The corms and bulbs weight was measured with an electronic balance of 0.001g sensitivity(Dingke and Fielke, 2014).

The geometric mean diameter ($D_g$) and arithmetic mean diameter ($A_d$)were calculated by using the following equations (Ozguven and Vursavus, 2005; Mohsenin, 1986; Gursoy and Guzel, 2010; Dash, *et al*., 2008):

$D_g = (LWB)^{0.333}$(1)

$A_d = (L+W+B)/3$ (2)

The degree of sphericity of the Tuberose bulbs and Gladiolus corms was calculated using the equation 3 described by Ajav and Ogunlade (2014)

$\phi = \frac{LWB^{0.333}}{L}$(3)

Where L is the length, W is the width and B is the breadth.

The equivalent diameter was determined by the following Equations.

Equivalent diameter = $(F_1 + F_2 + F_3) / 3$ (4)

Where, $F_1 = (a + b + c) / 3$, $F_2 = (abc)^{1/3}$and $F_3 = \{(ab + bc + ca) / 3\}^{0.5}$

a = Length of seed, mm, b = Width of seed, mm andc = Thickness of seed, mm

Specific surface area of cormswas determined by using the following equation,

Specific surface area = $6/D_e$(5)

Where, $D_e$ = Equivalent diameter, mm

Aspect ratio, $R_a$was calculated (Dash *et al*., 2008; Maduako and Faborode, 1990; Kheiralipour, 2008) as:

$$R_a = \frac{W}{L} 100 \quad (6)$$

The surface area of bulk sample of Tuberose bulbs and Gladiolus corms was determined by analogy with a sphere of the same geometric mean diameter, using the following relationship (Dash *et al*., 2008; Garnayak*et al*., 2008; Altuntas*et al*., 2005;Ajav and Ogunlade, 2014)

$$S=\pi D_g^2 \quad (7)$$

**2.3 Gravimetric Properties**

The test weight of bulbs/corms was determined in the laboratory by counting 100corms manually and weighing them with an electronic balance.

In order to determine the bulk density of bulbs/corms, the method mentioned in AOAC (1984) was used, the Tuberose bulbs and Gladiolus corms are poured into a container of predetermined volume and thereafter, the corms were taken out and weighed on an electronic balance (Dingke and Fielke, 2014;Rafiee*et al* 2007; Visvanathan*et al* 1996;Owolarafe and Shotonde, 2004; Akar and Aydin, 2005). The bulk density of the corms was determined as follows:

Bulk density (g/cc) = M/V (8)

where,M = Weight of corms in sample, g, V = Volume of corms in sample, cc

Volume of corms (V), cc = $\pi/4 \times D^2L$

where,D = Diameter of cylinder, cm, L = Height of cylinder, cm.

To determine the true density of corms, the measuring cylinderwas filled with toluene to a certain level. After that weighed corm (single) was put into the measuringcylinder, which is already filled with toluene. The difference in the level of toluene before and after putting acormin a measuring cylinder with single corm gave the true volume of corms. Then the true density of the corm was determined by the following equation (Dingke and Fielke, 2014).

$$\text{True density} = \frac{\text{Weight of single corm}}{\text{Volume of toluene rise in cylinder water}} \quad (9)$$

The porosity of the seed sample was determined from the bulk density and true density values by the equationgiven below:

Porosity, (€) = {1 − (pb/ pt)} × 100 (10)

Where,€= Porosity, %, pb = bulk density, pt = true density

**2.4 Frictional properties**

Angle of repose of corms was determined by using cylinder with a diameter of 300 mm and height of 300 mm. The cylinder rests on a smooth plate of diameter 300 mm and then is filled with corms. The cylinder was slowly lifted up until samples to form a cone. The cone height was noted and the angle of repose was measured by equation 11. The experiment was repeated for 5 times (Beygy*et al* 2010; Sharma *et al* 2013; Burubai and Amber 2014).

Angle of repose ($\varphi_r$) = $\tan^{-1}$ (2h / $D_p$) (11)

Where,h = Height of cone, cm, $D_p$= Diameter of the base plate, cm

For determination of static coefficient of friction of Tuberose bulbs and Gladiolus corms, a tilting table top setup was used. It consists of a supportingwooden plank fixed on two adjustable screws and two wooden blocks. Another wooden plank 550 × 280 × 15 mm was hinged to one end of the lower plank. The corms container used was a square wooden box 250 × 250 x 180 mm. The surface of the corms was leveled. The surface of wooden plank was raised gradually using the screw device until the box just started sliding down. The angle of tilt was measured. The tangent of angle with the horizontal was static coefficient of friction (Beygy*et al* 2010). The experiment was conducted with different surfaces (wood, mild steel, galvanized iron and asbestos sheets).

## III. RESULTS AND DISCUSSIONS

**3.1 Geometric properties**

Various physical properties of Tuberose bulbs at 47.58 per cent (d.b) and Gladiolus corms at 46.22 per cent (d.b.) of moisture content were measured experimentally and presented in the table 1. Table 1 depict that the major diameter of Tuberose bulbs (5482) was found 26per cent more than that of Gladiolus corms (43.48 mm) and it varies from 46 to 62 mm for Tuberosebulbs and 32 to 53 mm for Gladiolus corms, the minor diameter of Tuberose bulbs (16.17 mm) was found nearly about 59 per cent less than that of Gladiolus corms (25.74 mm) and it was varies from 15 to 23 mm and 20.33 to 32 mm respectively, whereas the intermediate diameter of Tuberose bulbs (19.42 mm) was found nearly about 77 per cent less than that of Gladiolus corms (34.46 mm)and it varies from 15 to 26 mm and 27 to 42 mm respectively, this shows that the Gladiolus corms are looks like oval shape and Tuberose bulbs are looks like cylindrical shape.Ajav and Ogunlade (2014) reported for ginger as 112, 72.3 and 38.3 mm respectively.Bande*et al* (2012) for Egusi Melon fruit as 9.29, 9.16 and 10.57 mm respectively.

The frequency distribution curves (Fig. 1) for the dimensions of Tuberose bulbs show a trend towards a normal distribution. This shows that 64 per cent of the Tuberose bulbs have major diameter of 52 – 56 mm, 15 % have48-52 mm and 21 % have 58 – 62 mm; 80 % of Tuberose bulbs have intermediate diameter of 18 – 22 mm, 13 % have 24 – 28 mm and 6 per cent have 20 – 24 mm whereas minor diameter of same have 77 per cent of 14 – 18 mm, 14 per cent of 10 – 12 mm and 9 per cent of 20 – 24 mm.

The frequency distribution curves (Fig. 2) for the dimensions of Gladiolus corms show a trend towards a normal distribution. This shows that 70 per cent of the Gladiolus corms have major diameter between 40 – 46 mm, 17 per cent have 48-54 mm and 13 per cent have 32 – 38 mm; 75 per cent of Gladiolus corms have intermediate diameter of 32 – 38 mm, 14 per cent have 26 – 30 mm and 11 per cent have 40 – 42 mm whereas minor diameter of same have 76 per cent of 24 – 28 mm, 11 per cent of 20 – 22 mm and 13 per cent of 30 – 32 mm. Ozguven and Vursavus (2005) reported that the lengths of 85 per cent pine nuts lies between 15.5 – 20 mm, 97 per cent had their width between 6.5 – 11 mm and 98 per cent had their thickness between 6.0 – 9.0 mm.

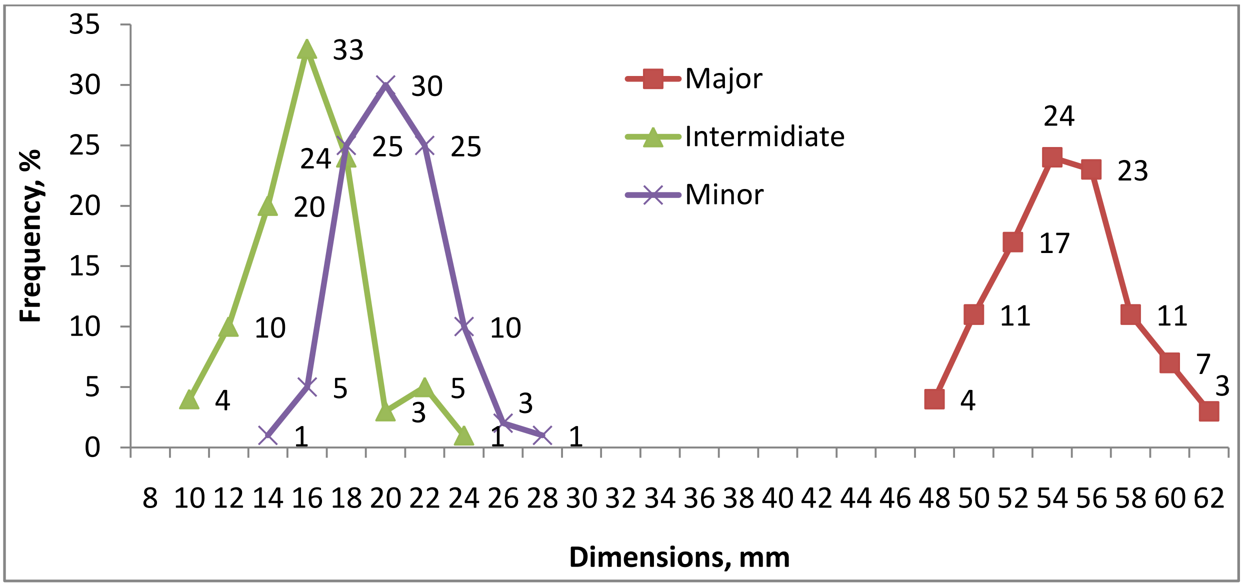


**Fig. 1 Frequency distribution of three principle axis dimensions of Tuberose bulbs**

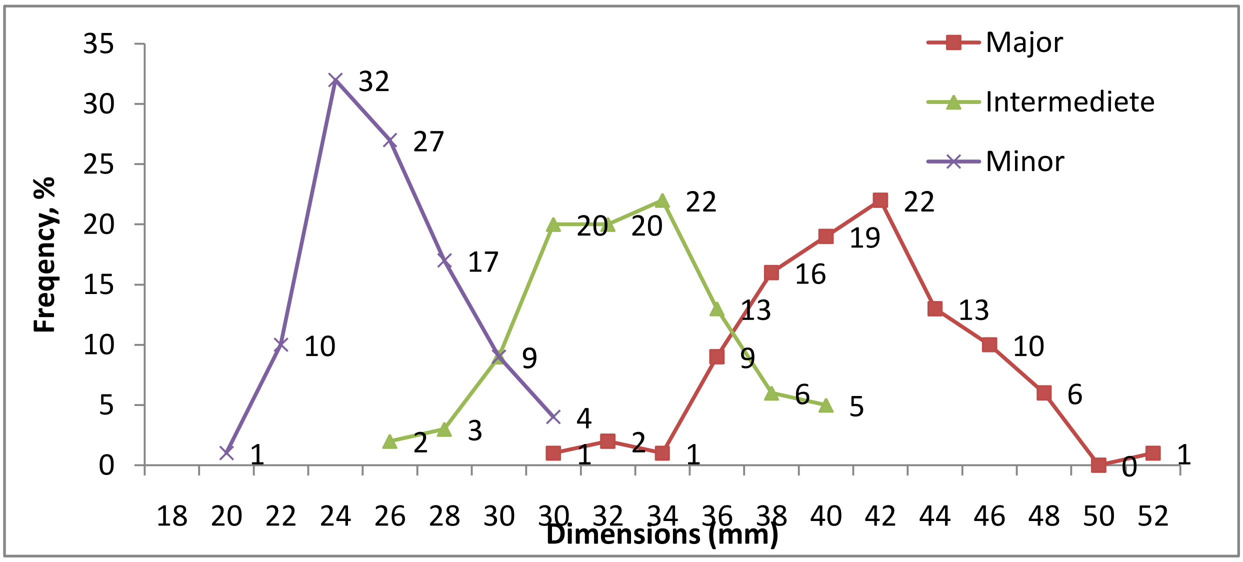


**Fig. 2 Frequency distribution of three principle axis dimensions of Gladiolus corms**

The geometric mean diameter of Tuberose bulbs and Gladiolus corms wascalculated by using the major, minor and intermediate diameters and found as 29.6±2.17 mm and 33.91±1.08 mm and it was varies from 17.52 to 31.38 and 31.30 – 36.16 mm (Table. 1), respectively, Bande*et al* (2012) reported the geometric mean values of Egusi melon fruit as 9.42 cm, Beygy*et al*(2010) reported for saffron crocus corms as 19.73 mm, whereas the arithmetic mean diameter of same was calculatedby using the major, minor and intermediate diameters of bulbs and cormsand found as 26.74±1.98 and 34.56±1.02 mm and it was varies from 22.61 – 34.66 mm and 32.11 – 36.78 mm respectively, Khoshnam*et al* (2007) reported the arithmetic mean diameter of pomegranate fruit as 17.7 mm, Lorestani and Tabatabaeefar (2006) reported as 49.44 mm for Hayward variety and 44.16 mm for abbott variety.

The mean values of sphericity was calculated for Tuberose bulbs and Gladiolus corms as 0.435±0.051 and 0.77±0.04 and it was varies from 0.35 – 0.52 and 0.71 – 0.87 (Table 1), respectively.This indicates that the Gladiolus corms look like oval shape and Tuberose bulbs look like cylindrical shape.Lorestani and Tabatabaeefar(2006) reported that the mean sphericity values of kiwi fruit (Hayward variety) as 0.81 and 0.73 for abbott variety. Owolarafe and Shotonde (2004) reported as 0.64for fresh okra fruits. Akar andAydin (2005) reported for gumbo fruits as 0.431 for sultani variety and 0.778 for Amasya variety.

For the determination of equivalent diameter of Tuberosebulbs and Gladiolus corms, major, minor and intermediate diameters was used and calculated by using the equation 4 and found as 25.08 and 34.15 mm and it varies from 19.99 – 32.94 mm and 31.81 – 36.53 mm (Table 1).Similarly Sharma *et al* (2013) studied the equivalent diameter of different varieties of JatrophaCurcas L and they reported as 12.52, 11.59, 11.60, 11.39, 12.43 and 12.28 for Shu 03001, Shu 03002, Shu 03004, Shu 03005 and Shu 04004, respectively.

The specific surface area of Tuberose bulbs and Gladiolus corms was calculated by using the equation 5. The mean values of specific surface area of Tuberose and Gladiolus corms was found as 0.239±0.019 and 0.18±0.01 $mm^2$whereas it was varies from 0.182 - 0.3 $mm^2$ and 0.16 – 0.19 $mm^2$ (Table. 1), respectively. Sharma *et al* (2003) reported that the specific surface area of different varieties of JatrophaCurcas L as 0.479, 0.517, 0.526, 0.483 and 0.489 mm for Shu 03001, Shu 03002, Shu 03004, Shu 03005 and Shu 04004, respectively.

The aspect ratiowas calculated by using the Eqn. 6. The mean values of aspect ratio of Tuberose bulbs and Gladiolus corms was obtained as 42.65±6.28 and 79.45±5.97 and it was varies from 30.23 – 59.52 and 67.39 – 94.78 (Table 1), respectively.Similarly many researchers have studied the aspect ratio of different fruits and grains such asDash *et al* (2008) studied the aspect ratio of simarouba fruit and kernel and reported as 64.95 ± 6.51 and 56.41 ± 5.54 respectively,

The surface area of bulbs/corms was calculated by using the value of geometric mean diameter (equation 7) described in the materials and methods section. The mean values of surface area of Tuberose bulbs and Gladiolus corms was determined as 1764.71±329.0 and 3556.33±228.17 $mm^2$ and it was varies from 979.0 – 3094.33 and 3077.25 - 4108.33 $mm^2$(Table 1), respectively.Corresponding values for pine nuts were 364.46 $mm^2$(Ozguven and Vursavus, 2005) whereas 22.13 $cm^2$for Soursop seeds reported by Okoroand Osunde (2013); Faleye(2013) reported for different varieties of cowpea as 103.23 (IB), 168.45 (SR), 156.19 (WH), 126.99 (IT716) and 103.96 (Oloka).

### 3.2 Gravimetric Properties

The unit weight of Tuberose bulbs and Gladiolus corms was measured in five foldsby using electronic balance in the laboratory. The mean values of the unit weights were obtained as 18.54±5.98 g for Tuberose bulbs and 25.41±41 g for Gladiolus corms and maximum unit weight of 35.20 g was obtained for Gladiolus corms and minimum value of 15.9 g was obtained for Tuberose bulbs. The mean values of weight of 100 Tuberose bulbs and Gladiolus corms were measured as 1.64±0.015 and 2.54±0.11 kg respectively.

The true density of bulbs/corms was measured in five folds. Mean values for Tuberose bulbs were obtained as 0.88 g/cc and for Gladiolus corms it was found as 0.89 g/cc. From the table 1, it shows that the bulk density of Tuberose bulbs (0.656 g/cc) is 13 per cent higher than that of Gladiolus corms (0.58 g/cc) whereas porosity of Gladiolus corms (34.83 %) was found higher than that of tuberose corms (25.6 %). Bande*et al* (2012) reported that the true density and bulk density of Egusi melon fruit as 1074.60 and 404.98 $kg/m^3$respectively.

### 3.3 Frictional properties

The angle of repose of bulbs/corms was measured by following the procedure depicted in section 2.4 and calculated by using the Eqn. 11.The maximum angle of repose obtained for Tuberose bulbs was 37 degree and minimum value of 32 degree obtained for Gladiolus corms. This indicates that the Gladiolus corms will flow easily as compared to Tuberose bulbs and this will affects the design of hopper in planting machine. Similarly Dash *et al*(2008) reported as 31.35 for simarouba fruit and 35.02 for kernel, Ajav and Ogunlade (2014) reported as 48 for ginger, Okoro and Osunde (2013) reported on different surfaces as 16.8 18.3 and 13.3 on wood, steel and glass surfaces respectively.

The static coefficient of friction of Gladiolus corms was determined on four different surfaces wood, mild steel, asbestos sheet and galvanized iron and the mean values are 0.67, 0.54, 0.75 and 0.61 respectively whereas for Tuberose bulbs it was obtained as 0.67, 0.56, 0.72 and 0.60 respectively. The table shows almost same values of coefficient of friction for both the bulbs and corms on all five surfaces and maximum value shows on asbestos surface and minimum value was on mild steel surface, hence it is desired to use the mild steel for hopper in planting machine.

**Table 1. Physical properties of Tuberose bulbs and Gladiolus corms**

| Particulars | Tuberose | | | | Gladiolus | | |
|---|---|---|---|---|---|---|---|
| | levels | Mean ±SD | Max | Min | Mean ±SD | Max | Min |
| **1. Geometric properties** | | | | | | | |
| Major, mm | 100 | 54.82±3.77 | 64 | 46 | 43.48±3.74 | 53 | 32 |
| Minor, mm | 100 | 16.17±2.71 | 23 | 15 | 25.74±2.96 | 32 | 20 |
| Intermediate, mm | 100 | 19.42±2.44 | 26 | 15 | 34.46±2.90 | 42 | 27 |
| Geometric mean diameter, mm | 100 | 29.6±2.17 | 31.382 | 17.52 | 33.91±1.08 | 36.16 | 31.30 |
| Arithmetic mean diameter, mm | 100 | 26.74±1.98 | 34.66 | 22.61 | 34.56±1.02 | 36.78 | 32.11 |
| Sphericity, % | 100 | 0.435±0.051 | 0.52 | 0.35 | 0.77±0.04 | 0.87 | 0.71 |
| Equivalent diameter, mm | 100 | 25.08±2.05 | 32.94 | 19.99 | 34.15±1.05 | 36.53 | 31.81 |
| Specific surface area, $mm^2$ | 100 | 0.239±0.019 | 0.3 | 0.182 | 0.18±0.01 | 0.19 | 0.16 |
| Aspect ratio | 100 | 42.65±6.28 | 59.52 | 30.23 | 79.45±5.97 | 94.78 | 67.39 |
| Surface area, $mm^2$ | 100 | 1764±329 | 3094 | 979 | 3556±228 | 4108 | 3077 |
| **2. Gravimetric properties** | | | | | | | |
| Unit mass, g | 100 | 18.54±5.98 | 30.7 | 15.9 | 25.41±4.14 | 35.20 | 18.40 |
| Mass of 100 corms, Kg | 5 | 1.65±0.015 | 1.67 | 1.63 | 2.54±0.11 | 2.67 | 2.41 |
| True density, g/cc | 5 | 0.882±0.019 | 0.91 | 0.86 | 0.89±0.02 | 0.92 | 0.86 |
| Bulk density, g/cc | 5 | 0.656±0.023 | 0.68 | 0.62 | 0.58±0.05 | 0.64 | 0.52 |
| Porosity, % | 5 | 25.6±2.97 | 28.73 | 22.1 | 34.83±0.04 | 0.40 | 0.29 |
| **3. Frictional Properties** | | | | | | | |
| Angle of repose, ° | 5 | 37±2.24 | 40 | 34 | 32.00±3.54 | 36.00 | 28.00 |
| Static coefficient of friction | | | | | | | |
| Wood | 5 | 0.67±0.01517 | 0.69 | 0.65 | 0.67±0.027 | 0.71 | 0.64 |
| Mild Steel | 5 | 0.56±0.01304 | 0.57 | 0.54 | 0.54±0.018 | 0.56 | 0.52 |
| Asbestos | 5 | 0.72±0.0114 | 0.73 | 0.7 | 0.75±0.012 | 0.77 | 0.74 |
| Galvanized Iron | 5 | 0.60±0.01581 | 0.62 | 0.58 | 0.61±0.021 | 0.64 | 0.59 |

## IV. CONCLUSION

The followingconclusions are drawn from the investigation on the engineering properties of Tuberose bulbs and Gladiolus corms in relation to design of metering mechanism for planting.The major, intermediate and minor diameter of both Tuberose bulbs and Gladiolus corms are significantly different. The values of geometric mean diameter, arithmetic mean diameter, sphericity, equivalent diameter, aspect ratio, surface area, unit weight, weight of 100 corms and porosity of Tuberose bulbs was found significantly less than that of Gladiolus corms. The bulk density and angle of repose of Tuberose bulbswas found significantly more than that of Gladiolus corms whereas the true density of both the bulbs/corms obtained nearly same. The minimum static coefficient of friction was obtained on mild steel for Gladiolus corms and maximum value was obtained on the surface of asbestos for Gladiolus corms.

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