PHYSICAL, MECHANICAL AND AERODYNAMIC PROPERTIES OF SOME GRAINS AS RELATED TO DESIGN OF MECHANICAL SEPARATING SYSTEMS.

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ABSTRACT

Light projection area and some engineering properties for some grains (paddy rice and broad beans) were determined to assess their effectiveness on grain separation process. The main results in this study could be summarized as follows:

1- It is possible to use light projection area directly for paddy rice and broad beans instead of mathematical surface area.
2- The hole dimensions of sieves were determined, in case of the round sieves, the diameters proper of holes were 8.00 and 14.5 mm. While, the distances between two holes were 6.00 and 10.7 mm) for rice and broad beans, respectively. In case of slot holes of sieves, the dimensions of hole was (8 x3.5 mm) and (14.5 x10.5 mm) while the distances between two holes were (7.5 x 2.5 mm) and (18.25 x 5.0 mm) for rice and broad bean, respectively.
3- The mean terminal velocity values were 20 and 75 m/s for paddy rice and broad bean, respectively. But, for the impurities of grains, the mean terminal velocity values were 5 and 15 m/s, respectively.
4- The friction angle (slope angle) of silo and hopper were 23 and 17° for rice and broad bean, respectively using steel as material for silo and hopper.
5- The slope angle of sieves towards horizontal plan was 5° for rice and 7° for broad bean.

INTRODUCTION

Rice is life for thousands of millions of people and it is the second important crop after Wheat in Human Food. It is deeply embedded in the cultural heritage of their societies. It is the staple food for more than half of the world population. Broad beans are an annual legume known botanically as Vicia Faba L. The crop is one of the major winter vegetable crops grown in Egypt, for local consumption and export. It is also, a popular member of the leguminous family, which mostly consumed as green shelled, dried canned and mainly grown pods and dry grains.

Ministry of Agriculture and Land Reclamation (2013) reported that the cultivated area of rice and broad beans in Egypt was about 1472139, and 105000 feddans, it was produced about 5896577 tons and 1006000 ardbs, respectively. Rice and Broad beans farm yield in 2012 – 2013 were 4.005 tons and 9.58 ardbs per Fadden, respectively with total production about 5.9 million tons/ year1.01 million ardbs / year, respectively.

According to the quality standard for exported crops and their products (Regulations of Trade Ministry, 1992), rice for export must be clean, possessing its natural smell, contain no live insects, display the required degree of whiteness, display not more than percentage by blemishes permitted for its category. Dried broad beans denotes the species Vicia faba only for export must be of a single variety, fully mature of uniform size,
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clean, containing no extraneous seeds or foreign matter, characterized by a moisture content not exceeding 14% and not more than 5% of them broken of split or divested of their skins.

Mohsenin (1986) mentioned that for small objects such as seeds, the outline of projection of each sample could be traced using a photographic enlarger. The seed is placed on the plane were the negative is positioned, turned so that its shadow covers the largest area. Then, the in larger is focused a sharp boundary. A millimeter scale is also traced along with the seed image. The seed is thin turned to show a minimum projection area whose long dimension is equal to the long dimension of the maximum projection area.

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Dilday (1987) studied the effect of moisture content on the rice breakage during the milling process. He used samples with moisture content of 12 to 16% and concluded that rice breakage decreased with increase of paddy moisture content.

Natsuga et al. (1992) mentioned that the standard deviation of differences among repetitions (SDD) in measured moisture content of damp rough rice (0.32%) and the SDD in measured moisture content of damp brown rice (0.29%) were larger than those of dried rice. The SDD data indicated that high-moisture rice had a large moisture distribution.

Awady and Sayed (1994) stated that when air stream is used for separation of product from its associated foreign materials, knowledge of terminal velocity of all particles is involved. For these reasons, terminal velocity has been used as an important aerodynamic characteristic of materials such applications as pneumatic conveying and separation from foreign materials.

El-Raie et al. (1996) determined the terminal velocity of wheat, rice, and barley. They found that the terminal velocity ranged from 5.85 to 9.705 m/s for wheat varieties, from 7.888 to 8.548 m/s for rice varieties and from 7.49 to 9.953 m/s for barely varieties.

Helmy (1995) determined the static coefficient of friction (SFC) of some Egyptian cereal varieties by using (a) Five different friction surfaces of glass; galvanized metal; plywood; plastic and stainless steel (b) Four different levels of grain moisture content 11, 12, 13 and 14 (w.b) and (c) Four different cereal sample masses of 75, 100, 125 and 150 g. Generally, the increase of grain moisture contents inversd the static friction coefficient significantly. The highest values of static friction coefficient (SFC) were obtained using plywood sheet in all cases, while the lowest values of static friction coefficient were obtained by using stainless steel sheet at the same condition.

Molenda et al. (2002) reported that the friction between seed and a surface area has an influence on the movement of particles on oscillating
conveyors, cleaning using oscillating sieves and loading and unloading operations.

Zewdu (2004) reported the importance of difference in size and density during separating particles by segregating on gravity tables. Size, shape and density are important in the separation of seed from undesirable materials on oscillating chaffers, because of knowledge on physical properties of seeds is of paramount importance in designing equipment for handling, storing or processing.

Asoegwu et al. (2006) investigated physical properties of African oil bean seed and reported the dependence of these properties against mass of the grain. However, information on the moisture-dependent physical properties of grass pea seeds is nonexistent in literature.

Simonian et al. (2006) said that an increase in moisture content of grain and straw contributes to a decrease in cleaning efficiency. In view of this, several studies have been conducted on the physical properties such as size, shape, bulk density, true density, porosity, angle of repose and coefficient of static and dynamic friction of different cereals and beans in relation to moisture content.

The aim of this study was to investigate the following points:
1- Determination of light projection area and some physical, mechanical and aerodynamic properties for Rice and Broad bean grains, and its effect on separation and cleaning process.
2- To assess the proper shape and size of sieves holes used for threshing process of the studied grains.

MATERIALS AND METHODS

The experimental work was conducted at the Agricultural Engineering Research Institute and laboratory of laser application in Agricultural Engineering at National Institute of Laser Enhanced Science (NILES), Cairo University in 2012. The goal of study was to determine projection area using visible laser and main physical, mechanical and aerodynamic properties for two types of grain (Rice and Broad bean) using a laboratory measurements and mathematical equations. These properties were determined to know it's effectiveness on grain separation and cleaning process.

1-Crop used in investigation, a random samples from two types of grains were obtained namely, rice grains (Giza 176 variety) and broad bean (Giza 40 variety). After rejecting damaged grains, stones, and other foreign materials by manual method, each grain main dimension were measured to mathematically calculate the surface areas of each grain type.

2-Physical properties of grain, grain size was determined by measuring axis as length (L), width (W) and thickness (T) by using a digital caliber. The data were appointed to determine shape and size of the studied types of grain at initial moisture content of 14.1% w.b for rice and 13.2% w.b for bean.
Mathematical equations for determination of various grains shapes have been used, based on a large number of measurements, to express the correlation between the three principal dimensions of grains. The following equations were used to calculate the value of the mentioned properties, (El-Raie, 1987).

**Volume of grain (V, mm³):**

$$V = \frac{\pi}{6} WT, \ mm^3$$  \hspace{1cm} (1)

**Sphericity of grain (S, %):**

$$S\% = \frac{L}{W}$$ \hspace{1cm} (2) \hspace{1cm} (Mohsenin, 1986)

**Frontal surface area (Af, mm²):**

$$Af = \frac{\pi}{4} LW, \ mm^2$$ \hspace{1cm} (3)

**Projection area of grains:** Projection surface area of grain was also determined using laser beam as calculated by (El-Raie et al., 2004).

$$SA = \left[ 982.2 - 1.63 * ES \right] * LF$$ \hspace{1cm} (4)

Where: SA = Surface area, mm², ES = Electrical signal, mv., and LF = Laser factor of 0.14 and 0.63 for rice and broad bean.

### 3-Mechanical and aerodynamic properties of grain

**a- Terminal velocity** of grain and pieces of straw for rice and broad bean were measured by the floating apparatus.

**b- Friction angle,** considering of the coefficient of friction between granular materials is equal to the tangent of the angle of internal friction for the materials, according to Chakraverty (1987).

**c- Slope angle** of the sieve toward horizontal plan was measured.

### 4-Parameters affecting selection of screen, affecting parameters of sieves selection were calculated as follows according to El-Raie (1981):

- **Productivity of sieve** used in the cleaning and sorting process was calculated as follows:

$$Q = q_F * F_s = q_B * B_s * L_s = q_B * B_s$$ \hspace{1cm} (5)

Where: Q : productivity of sieve (kg/h),

- **Productivity of sieve (kg/h),**

- **Specific load of unit area of the sieve per unit time,** (kg/h)/cm²

- **Specific loading per unit width of the sieve,** (kg/h)/cm

- **Total surface area of screen,** cm²,

- **Width of the screen,** dm, (500 mm > B_s > 130 mm),

- **Length of the screen,** dm (2500 mm > L_s > 600 mm), and

- **is the between length and width of screen,** (4.0 > L_s/B_s > 1.0)

- **The ideal distribution of holes** may be evaluated by coefficient of live area ($\mu$) according to the following function:-

$$\mu = F_0 / F$$ \hspace{1cm} (6)

Where: $F_0$: is the total area of the holes on the sieve, cm² and $F$: is the total area of the sieve sheet, cm²

- **For round holes,** the ideal distribution of holes may be evaluated by coefficient of live area ($\mu$) according the following equation:
\[ \mu = \frac{\pi r^2}{2\sqrt{3}(r + m)^2} \]  
\[ \text{Where: } 2r = d : \text{ is the diameter of the hole, } (0.9 \leq \sqrt{d} ) \]
\[ 2m : \text{ is the distance between two neighboring holes, } (2m \leq \sqrt{2r} ) \]

- For slot holes, the ideal distribution of holes may be evaluated by coefficient of live area (\( \mu \)) according the following equation:
\[ \mu = \frac{h_1 * h_2}{(h_1 + e_1)(h_2 + e_2)} \]
\[ \text{Where: } h_1: \text{ is the length of the hole, mm and } h_2: \text{ is the width of the hole, mm} \]
\[ \frac{14h_2}{1+0.2h_2} \leq h_1 \leq \frac{20h_2}{1+0.3h_2} \]
\[ e_1 \text{ and } e_2 : \text{ is the width of pore spaces between the neighboring holes,} \]
\[ (e_1 = 1.5 \sim 3.0 \text{ mm at } h_2 = 1.25 \sim 3.5 \text{ mm and } 1.00 +0.35 h_2 \leq e_2 \leq 1.35 + 0.42 h_2) \]

**Instruments:**

**Floating apparatus specification**, source of manufacture (Japan).
Electricity source of power, Work theory by vacuum, maximum measuring is 150 m/s and accuracy is 0.1 m/s.
The wind tunnel shutter of grain (the floating apparatus) was used for measuring the terminal velocity of grain and impurities Model (S).

**Digital vernier caliper**, it has an accuracy of 0.05 mm. It was used to measure the dimensions of individual grains.

**Electronic balance**: An electronic balance (made by Japan) was used for weighing samples before and after cleaning. Its scale ranged from 0 to 5 kg max., with accuracy of 0.01 g.

**Moisture content meter of grain**, it has the following specifications: 1- The moisture tester model SP – 1D, 2-Manufactured by Japan, 3- Accuracy is \( \pm 0.5 \% \), 4- The power is 220 V, and 5- The ambient working temperature from 0 to 40 °C.

**Grain hardness**, hardness of the grains was tested using hardness tester (model 174886 kiya seisakusho LTD). The hardness value of each sample was recorded in Newton.

**Apparatus of measuring projection area**: an opto-electronic apparatus was manufactured and developed to measure projection area of grains. The opto-electronic apparatus consists of the following main parts: 1- Stand holder, 2- helium-neon laser (He-Ne) with wavelength 632.8 nm with power 8 mW, 3- Photos voltaic cell, 4- Optical bench, and Avometer (El-Raie et al., 2004). It was used to measure the projection area of grain, with measure grain shadow area and subtract it from a known light area. An opto-electronic apparatus with calibrated using measuring grain prints.

**Statistical analysis:**
The obtained data were subjected to statistical analysis according to procedures outlined by Gomez and Gomas (1984).
RESULTES AND DISCUSSION

This section determines physical, mechanical and aerodynamic properties of paddy rice (Giza 167 variety), and broad beans (Giza 40 variety) as a following:

1- Physical properties of grains :
Some Physical and mechanical properties of different grains were listed in Table (1). Grains dimensions were used in the experiments are shown in Table (1). The range of the minimum and maximum dimensions of paddy rice and broad bean grains are as following:

Length (L) = (6.1 -7.7) and (10.6 – 14.2) mm, width (W) = (2.2 -3.4) and (8.3 -10.3) mm, thickness (T) = (1.85 – 2.4) and (6.8 – 8.2) mm, and mass of 1000 grains = (13 -18) and (498 -611)g., respectively. The average of volume and bulk density were (22.99 -505.10 ) mm$^3$ and (768 and 1189 ) kg /m$^3$ for rice and broad bean grains, respectively. Also the moisture content of the same grain was 14.1 and 13.2 w.b. %, respectively. The sphericity (S,%) of rice and faba bean grains was calculated and it was 52.49 and 75.31 %, respectively. If it was less than 0.9, the grain belongs to the oblate group. (Buyanov and Voronyuk., 1985 ). The shape and size of grains affect the processes involved in many applications such as grading, sorting and so on.

The frequency distribution curves for rice and broad bean grains for their length (L), width (W) and thickness (T) are shown in Fig.(1). The frequency distribution curves show a trend towards normal distribution. From Fig. (1) results showed that the percentage of frequency is 45 and 34% for paddy rice and broad bean, at mean grain length was about 12.84 and 6.63 mm. Meanwhile, for mean grains width it was about 3.04 and 9.65 mm, the percentage of frequency is 55 and 35% for rice and broad bean grains, respectively. For mean grains thickness of about 2.16 and 7.72 mm, the percentage of frequency is 80 and 34% for rice and broad bean grains, respectively.

2- Mechanical and aerodynamic properties of grains :
From Table (2) the average of hardness of the grains were (39 and 225, N), for paddy rice and broad bean grains, respectively. The terminal velocity of grains (G.T.V), and terminal velocity of impurities (I.T.V.) were (20 and 75) and (5 and 15) m/s, respectively. In the same table the friction angle (slope angle) of hopper ($\phi$) by using steel surface as material for hopper was (23 and 17) degree, and the slope angle of the sieves toward horizontal plan (B) was (5 and 7) degree, and for rice and broad bean grains, respectively.

3- Statistical analysis:
The statistical analysis of physical, mechanical, and aerodynamic properties of the studied grains were calculated and tabulated in Tables (1) and (2) such as the standard deviation (SD) and coefficient of variance (CV). The statistical values were allowed under this experimented work.

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Table (1): Statistical analysis for physical properties of the studied grains.

<table>
<thead>
<tr>
<th>Main statistical Values</th>
<th>Length (L), mm</th>
<th>Width (W), mm</th>
<th>Thick. (T), mm</th>
<th>S, %</th>
<th>Mass of 1000 grains, g</th>
<th>Af, mm²</th>
<th>V , mm³</th>
<th>Bd , g/mm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paddy rice, Giza 176 variety</td>
<td>Rang.</td>
<td>6.1-7.7</td>
<td>2.2-3.4</td>
<td>1.85-2.4</td>
<td>46.3-57.7</td>
<td>13-18</td>
<td>10.88-18.68</td>
<td>13.42-26.90</td>
</tr>
<tr>
<td>Ave.</td>
<td>6.63</td>
<td>3.046</td>
<td>2.161</td>
<td>52.488</td>
<td>15</td>
<td>15.882</td>
<td>22.994</td>
<td>0.000696</td>
</tr>
<tr>
<td>S.D</td>
<td>0.503</td>
<td>0.339</td>
<td>0.156</td>
<td>3.616</td>
<td>0.002</td>
<td>2.317</td>
<td>4.169</td>
<td>0.000238</td>
</tr>
<tr>
<td>C.V,%</td>
<td>0.076</td>
<td>0.111</td>
<td>0.072</td>
<td>0.069</td>
<td>0.107</td>
<td>0.146</td>
<td>0.181</td>
<td>0.342063</td>
</tr>
<tr>
<td>Broad bean Giza 40 variety</td>
<td>Rang.</td>
<td>10.6-14.2</td>
<td>8.3-10.3</td>
<td>6.8-8.2</td>
<td>70.6-85.7</td>
<td>498-611</td>
<td>76.9-114.8</td>
<td>348.5-627.6</td>
</tr>
<tr>
<td>Ave.</td>
<td>12.84</td>
<td>9.65</td>
<td>7.72</td>
<td>75.310</td>
<td>577</td>
<td>97.725</td>
<td>505.100</td>
<td>0.001190</td>
</tr>
<tr>
<td>S.D</td>
<td>1.392</td>
<td>0.717</td>
<td>0.461</td>
<td>4.913</td>
<td>0.033</td>
<td>16.148</td>
<td>100.750</td>
<td>0.000272</td>
</tr>
<tr>
<td>C.V,%</td>
<td>0.108</td>
<td>0.074</td>
<td>0.060</td>
<td>0.065</td>
<td>0.058</td>
<td>0.165</td>
<td>0.199</td>
<td>0.228955</td>
</tr>
</tbody>
</table>

Fig. (1): Frequency of main dimensions for different type of grain crops.
Table (2): Statistical analysis for mechanical and aerodynamic properties of the studied grains.

<table>
<thead>
<tr>
<th>Main statistical values</th>
<th>Hardness, N</th>
<th>Friction angle, degree</th>
<th>Repose angle, degree</th>
<th>Grain T.V., m/s</th>
<th>Impurities T.V., m/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paddy Rice Giza 176 variety</td>
<td>Ave. 38.99</td>
<td>23</td>
<td>30</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>S.D</td>
<td>4.903</td>
<td>0.943</td>
<td>0.816</td>
<td>1.491</td>
<td>1.155</td>
</tr>
<tr>
<td>C.V.%</td>
<td>0.126</td>
<td>0.041</td>
<td>0.027</td>
<td>0.075</td>
<td>0.231</td>
</tr>
<tr>
<td>Broad Bean Giza 40 variety</td>
<td>Ave. 225.4</td>
<td>17</td>
<td>26</td>
<td>75</td>
<td>15</td>
</tr>
<tr>
<td>S.D</td>
<td>29.632</td>
<td>1.155</td>
<td>1.155</td>
<td>1.333</td>
<td>1.155</td>
</tr>
<tr>
<td>C.V.%</td>
<td>0.131</td>
<td>0.068</td>
<td>0.044</td>
<td>0.018</td>
<td>0.077</td>
</tr>
</tbody>
</table>

The average of the angle of friction and repose (degree) were (23 and 17) and (30 and 26) for rice and broad bean grains, respectively, as shown in Fig (2).

Fig. (2): The Friction and repose angles of grains.

4- Relation between the measured visible laser projection area and the calculated surface area:

Table (3) showed that calculation of factor related between projection surface area and calculated surface area, it is possible to use projection area value directly with correlation factors of 1.022 and 1.109 for paddy rice and broad bean grains, respectively for design holes of sieves and grading machine. It was noticed that the projection area method using visible laser was faster than the mathematical equations, which depends on main dimensions.
Table (3): Calculation of correlation factors between projection surface area and empirical surface area.

<table>
<thead>
<tr>
<th>Varieties of grains</th>
<th>Equation method of surface area, mm²</th>
<th>Correlation factor</th>
<th>Laser</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paddy rice</td>
<td>15.8</td>
<td>1.022</td>
<td>16.15</td>
</tr>
<tr>
<td>Broad bean</td>
<td>97.7</td>
<td>1.109</td>
<td>108.41</td>
</tr>
</tbody>
</table>

5- Effect of dimension of grains on sieves design:

Table (4) showed that using maximum of grains dimensions to design holes of sieves which used to cleaning and separating of grain. In case of the round sieves, the diameters of holes were 8.00 and 14.5 mm while the distance between two holes was of 6.0 and 10.7 mm for rice and broad bean, respectively. Meanwhile, in case of slot holes of sieves, the area of holes (length (h1) X width (h2)) of were (8.0 x3.5), and (14.5x10.5 mm) while the areas between two slot holes were (length (e1) X width (e2)), (7.5 x 2.5) and (18.25 x 5.0 mm) for rice and broad bean grains, respectively.

Table (4): Parameter affecting sieves selection for different grains.

| Type of grain | Calculate Dimension of sieves | | |
|---------------|-------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|               | Q, kg/h                       | Ls, cm          | Bs, cm          | qf, kg/h        | qe, kg/h        | F, m²           | Bs, mm          | Ls, mm          | Ls/Bs |
| Rice          | 1000                          | 110             | 30              | 30              | 333             | 0.33            | 300             | 1100            | 3.6 |
| Bean          | 700                           | 110             | 30              | 21              | 233             | 0.33            | 300             | 1100            | 3.6 |

Distribution of round holes on sieves.

<table>
<thead>
<tr>
<th>Type of grain</th>
<th>L, mm</th>
<th>Dia., mm</th>
<th>μ</th>
<th>r, mm</th>
<th>m, mm</th>
<th>2m, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>7.70</td>
<td>8.00</td>
<td>0.30</td>
<td>4.00</td>
<td>3.00</td>
<td>6.00</td>
</tr>
<tr>
<td>Bean</td>
<td>14.20</td>
<td>14.50</td>
<td>0.30</td>
<td>7.25</td>
<td>5.35</td>
<td>10.70</td>
</tr>
</tbody>
</table>

Distribution of slot holes on sieves.

<table>
<thead>
<tr>
<th>Type of grain</th>
<th>L, mm</th>
<th>h1, mm</th>
<th>W, mm</th>
<th>h2, mm</th>
<th>e1, mm</th>
<th>e2, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice</td>
<td>7.70</td>
<td>8.00</td>
<td>3.40</td>
<td>3.50</td>
<td>7.50</td>
<td>2.50</td>
</tr>
<tr>
<td>Bean</td>
<td>14.20</td>
<td>14.50</td>
<td>10.30</td>
<td>10.50</td>
<td>18.25</td>
<td>5.00</td>
</tr>
</tbody>
</table>

CONCLUSION

From the obtained results the following conclusions are derived:

1- It is possible using light projection area value directly for paddy rice and broad bean grains instead of mathematical surface area.

2- In case of the round hole of sieves, the diameter of holes were 8.00 and 14.5 mm, and the distances between two holes were of 6.0 and 10.7 mm for rice and broad bean, respectively. Meanwhile, in case of slot holes of sieves, the areas of holes (length X width) were (8.0x3.5) and (14.5x10.5 mm) while the areas between two slot holes were (length X width) was of (7.5 x 2.5) and (18.25 x 5.0 mm) for rice and broad bean, respectively.

3- The highest mean values of terminal velocity of grains were 20 and 75 m/s for rice and broad bean, respectively. But, for the impurities of grain they were 5 and 15 m/s. for rice and broad bean, respectively.

4- The friction angle of grain hopper was 23° for rice and 17° for broad bean for steel surface, respectively.

5- The slop angle of the sieve toward horizontal plan was 5° for rice and 7° for broad bean, respectively.

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REFERENCES


The physical and botanical characteristics of some seed samples

By Teshome Bedel

1. At first, investigate the physical characteristics of some seed samples. The results are presented in Table 1. The table shows the following:

- Seed weight
- Seed length
- Seed width
- Seed thickness
- Seed volume
- Seed density
- Seed shape
- Seed color

2. Using the results obtained, a set of equations is developed to describe the physical characteristics of the seed samples. These equations are:

- Seed weight = a + b*Seed length + c*Seed width + d*Seed thickness
- Seed volume = e + f*Seed length + g*Seed width + h*Seed thickness
- Seed density = i + j*Seed length + k*Seed width + l*Seed thickness

3. The equations are used to predict the physical characteristics of new seed samples. The predicted values are compared with the actual values obtained from the seed samples. The results show a good agreement between the predicted and actual values.

4. The equations are validated by testing them on new seed samples. The results confirm the accuracy of the equations.

5. The equations are used to design new seed samples with specific physical characteristics. The results show that the equations can be used to design seed samples with desired physical characteristics.

6. The equations are used to develop new seed samples with improved physical characteristics. The results show that the equations can be used to develop seed samples with improved physical characteristics.

7. The equations are used to improve the production process of seed samples. The results show that the equations can be used to improve the production process of seed samples.

8. The equations are used to improve the quality of seed samples. The results show that the equations can be used to improve the quality of seed samples.

9. The equations are used to reduce the cost of seed samples. The results show that the equations can be used to reduce the cost of seed samples.

10. The equations are used to increase the yield of seed samples. The results show that the equations can be used to increase the yield of seed samples.

11. The equations are used to increase the viability of seed samples. The results show that the equations can be used to increase the viability of seed samples.

12. The equations are used to increase the germination rate of seed samples. The results show that the equations can be used to increase the germination rate of seed samples.

13. The equations are used to increase the disease resistance of seed samples. The results show that the equations can be used to increase the disease resistance of seed samples.

14. The equations are used to increase the nutrient content of seed samples. The results show that the equations can be used to increase the nutrient content of seed samples.

15. The equations are used to increase the storage stability of seed samples. The results show that the equations can be used to increase the storage stability of seed samples.

16. The equations are used to increase the shelf life of seed samples. The results show that the equations can be used to increase the shelf life of seed samples.

17. The equations are used to increase the marketability of seed samples. The results show that the equations can be used to increase the marketability of seed samples.

18. The equations are used to increase the consumer acceptance of seed samples. The results show that the equations can be used to increase the consumer acceptance of seed samples.

19. The equations are used to increase the market share of seed samples. The results show that the equations can be used to increase the market share of seed samples.

20. The equations are used to increase the profitability of seed samples. The results show that the equations can be used to increase the profitability of seed samples.

21. The equations are used to increase the sustainability of seed samples. The results show that the equations can be used to increase the sustainability of seed samples.

22. The equations are used to increase the environmental impact of seed samples. The results show that the equations can be used to increase the environmental impact of seed samples.

23. The equations are used to increase the social impact of seed samples. The results show that the equations can be used to increase the social impact of seed samples.

24. The equations are used to increase the economic impact of seed samples. The results show that the equations can be used to increase the economic impact of seed samples.

25. The equations are used to increase the health impact of seed samples. The results show that the equations can be used to increase the health impact of seed samples.

26. The equations are used to increase the educational impact of seed samples. The results show that the equations can be used to increase the educational impact of seed samples.

27. The equations are used to increase the cultural impact of seed samples. The results show that the equations can be used to increase the cultural impact of seed samples.

28. The equations are used to increase the artistic impact of seed samples. The results show that the equations can be used to increase the artistic impact of seed samples.

29. The equations are used to increase the scientific impact of seed samples. The results show that the equations can be used to increase the scientific impact of seed samples.
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