

## **DESIGN AND PERFORMANCE EVALUATION OF MULTI-GERM BEET-SEEDS GRADING MACHINE**

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### **ABSTRACT**

The non-uniform size of multi-germ beet seeds has made them more difficult to plant uniformly than the most grain crops. Therefore, this research was intended to design and constructed a simple grading machine for grading the sugar beet seed. The purpose of the designed grader is to sorting the beet seeds into three classes such as; (small, medium, and large seeds with high ability to germinate from medium seeds). Some physical and mechanical properties for beet seeds were measured. The obtained data helped in designing and manufacturing the proposed grading machine. The experiment was done to study the effect of seed specific load on screen, kinematic factor, screen slope, and screen to spiral speed ratio. The performance of grading machine was measured in terms of seed quality, grading capacity, grading efficiency, and energy requirements. Results showed that this machine is quite successful for grading multi-germ beet seed. The best result was obtained at 0.9 kinematic factor ( $\omega^2 r / g$ ), 0.1 kg/m<sup>2</sup> s seed specific load, and 10 degrees screen slope. At these levels the maximum grading efficiency of 92 %, 0.157 kg/s grading capacity, and 5.2 kW.h/Mg energy requirements were obtained. Before grading process, germination percentage and coefficient of variation of multi-germ beet seed were 94.5 % and 15.5 % respectively. Meanwhile, after grading process using the designed grader machine, the seed germination and coefficient of variation were significantly improved to be 98 % and 6.4 % respectively. Generally, results of the test, concluded that the fabricated grading machine was met the design objectives. It was believed that this grading machine was simple in design, easy in operation, and it greatly improved the uniform size and quality of multi-germ beet seeds.

### **INTRODUCTION**

Sugar beet becomes one of the most important crops in Egypt as a source of sugar. The Egyptian government is planning to increase the grown area of sugar beet, because the sugar beet grows under a wide variety of soil and climatic conditions, especially in newly reclaimed lands. But, the nature of sugar beet seeds is non-uniform size therefore; it constitutes one of the major obstacles that face planting mechanization. Where, the principal requirements of precision planting include that the seeds must be uniform in size. Moreover, the size of cells or grooves of the planter seed plate is selected based on seed size. Thus, grading with highly variable sizes, like multi-germ beet seed is desirable to select the proper cell plates for the planters. Also, there isn't a single good reason for planting poor quality seed, and, thank goodness, this is one thing you can control. Moreover, the general rule is the larger of the seed for any particular variety, the stronger and more vigorous the seedlings are likely to be.

Generally, the objectives of grading seed processing is to:

- 1- Remove all the foreign material.

- 2- Evenly size the seed for viability and even sowing.
- 3- Evenly treat the seed with a fungicide seed treatment with the correct application dose rate.
- 4- To separate the seed into different density groups for controlling the germination of the final production.

Therefore, a grading machine was fabricated and used for grading the multi-germ beet seed.

Hashem and Eberhard (2007) reported that, the operation of particle separation is divided into two main categories, continuous and batch operations. In continuous operation, the particles are continuously fed into the separation unit during the whole separation process. This type of particle separation is usually called 'screening'. On the other hand, batch operation is used if the particulate material is charged only once. This kind of batch separation is commonly described by the term 'sieving'. Screens can be classified into three groups according to their mode of particle movement. These groups are (a) vibrating screens in which the particulate material moves relative to the screen in a vertical plane, (b) flat screens in which the particulate material moves relative to the screen in the plane of the screen and (c) rotating screens in which the screen surface is cylindrical and the particulate material cascades over the inner surface as the screen is rotated.

Amin (1994) developed and tested a grading machine consisting of rotating cylinder and performed concave to grade potato, onion and orange crops. The machine was tested in grading potato crop. The obtained results showed that crop parameters such as (tubers dimensions and mass) and machine parameters such as (cell area and shape, drum speed, slope of drum axle and drum length) had a significant effect on grading efficiency. The capacity of machine at optimum drum speed of 25 rpm and slope of zero degree was 1.2 Mg/h with tuber damage of 0.23%.

Higher germination, seedling length and vigor index were noticed in medium sized seeds followed by bigger sized seeds as reported by Virendra Singh *et al.* (1995), and Ghosh *et al.* (1976).

Hurburgh *et al.*, (1989) tested six rotary grain cleaner models for efficiency of removal of fine material from dry corn at various flow rates. They reported, removal efficiency for all sizes of particles generally declined as flow rate increased. Removal efficiency was lower for particles sizes closer to the screen opening size.

Pierce (1985) reported that the rotary-type cleaner probably is most common for on-farm application. Rotary grain cleaners separate grain into size fractions by moving it through a trammel (revolving cylindrical screen with axis slightly inclined). As the trammel rotates, material cascades over its surface, and fine material passes through the screen. Material not passing through moves out the end of the trammel. Some cleaners employ a second trammel with larger openings for scalping (removal of material larger than the grain being cleaned). The second trammel may be concentric with or an extension of the first. Pierce reported that models are available with maximum manufacturer-rated capacities from 12.7 to 89.1t/h. He also reported that manufacturers often state that throughput may be reduced by

increasing grain moisture, by decreasing trammel slope, by increasing fines content, and by certain grain types.

Harrison and Blecha (1983) itemized parameters influencing sieving as size of the particle and sieve apertures, relative particle to sieve velocity, mean particle velocity and orientation of oblong particles. They also published that particle velocity is a function of frequency and amplitude of oscillation, sieve slope, hanger angle, friction between particle and sieve.

Feller (1980) reported that, to evaluate screen performance, both partial passage and clogging of the screen should be considered. A screen rate function, defined as the sum of the passage and clogging rate factor versus relative particle size, was developed to characterize screen performance. This function is independent of screen duration and can be used as a general expression that is not limited to a particular size distribution of the material or to one screen duration.

Klenin and Cakon (1980) reported some parameter to evaluate the efficiency of grading crop yield. These parameters are: separate the rubbish and haulm from the crop, grading crop yield, into three categories small, medium, and big with about (10 %) of weight interactions between any of two categories of them and the total damage in any group cannot be increased than 2 %.

Metwalli (1975) designed and tested a horizontal cylindrical screen for grain-straw separation by centrifugal and gravity forces. The forces affecting the separation of the particles in a rotating horizontal screen were gravity force, centrifugal force and the normal force between the screen and the particles. The centrifugal force must be equal to approximately eleven times as the gravity force in order to obtain high capacity per unit area of a horizontal cylindrical screen.

Safwat and Moustafa (1971) reported that, physical specifications of agricultural products constitute the most important parameters needed in the design of grading, transferring, processing, and packaging systems. Physical specifications, mechanical, electrical, thermal, visual, acoustic and chemical properties are among attributes of useful engineering application. Mass, volume and center of gravity are the most important physical parameters of agricultural products used in sizing systems.

Sucher and Pfof (1964) tested a trammel for removal of rodent pellets from corn. They found that, at speeds below critical speed, removal efficiency decreased as throughput increased but increased with increasing speeds. The speed effect was most pronounced at high throughput rates. The greatest removal efficiencies occurred at the highest speed tested, 87% of critical speed.

Brown *et al*, (1950) stated that the best operating speed is between 33% and 45% of critical speed. Critical speed is the minimum rotating speed at which cascading ceases and material remains in constant screen contact, held there by centrifugal force. Critical speed is a function of trammel diameter  $N = 1337 / \sqrt{D}$  where: N= critical speed, rpm; and D = trammel diameter, mm.

**The main objectives of the present study were to:**

- 1- Study the most important physical and mechanical properties of multi-germ sugar beet seeds.
- 2- Design and fabricated a cylindrical grading machine suitable for grading multi-germ sugar beet seeds.
- 3- Study the effect of most important operating parameters such as, seed specific load on screen, kinematic factor, screen slope, and screen to spiral speed ratio on the performance of fabricated grading machine.

## **MATERIALS AND METHODS**

Grading is the most important process to produce high quality production and obtain seed of similar shape and size. Screening is a common sizing or separation process that depends upon the ability of particles to pass through the apertures of a screen. A cylindrical grader was designed, fabricated, and tested at the workshop of Ag. Res. Inst. (ARC). The cylindrical grader was tested and evaluated for grading multi-germ uncoated beet seed. By means of the permanent circulation of the product and the resulting centrifugal force, each seed is forced to be in contact with the screen perforation, enabling sorting operations to be carried out with high accuracy. Based on the physical properties of multi-germ beet seed under this study, seeds are sized into three different categories as follow:

Size (1) < 4.5 mm in geometric diameter: small.

Size (2) 4.5 – 6 mm in geometric diameter: medium.

Size (3) > 6 mm in geometric diameter: large.

**Physical characteristics of multi-germ beet seeds:**

The physical dimensions of beet seeds (major, medium, and minor) diameter were measured using a digital micrometer reading to 0.01 mm. the geometric mean diameter of the seed was calculated using the following relationship (Sharma *et al.*, 1985):  $G_m = (L_1 L_2 L_3)^{1/3}$  The obtained data of sugar beet diameter was statistically analyzed to get the mean value ( $\bar{X}$ ), standard deviation ( $\sigma$ ), and coefficient of variance (CV). Table 1 shows beet seed geometric diameter was varied from 3.6 to 7.6 mm with average of 5.0 mm, standard deviation of 0.77 mm, and coefficient of variation of 15.5 %. However, smaller and undersize seeds 12.2 % of the seeds varied from 3.6 to 4.4 mm. Also, medium seeds 68 % ranged from 4.4 to 6.0 mm. But, the larger seeds are about 19.8 % ranged from 6.0 to 7.6 mm. It is obvious that, the dimensions of beet seeds are non-uniform where, the coefficient of variation (CV) of seeds was 15.5%. Therefore, it's difficult to adapt the beet planting mechanization process. Where, the principal requirements of precision planting include that the seeds coefficient of variance (CV) must be less than 10%. Thus, grading with highly variable sizes, like multi-germ beet seed is desirable to select the proper cell plates for the planters. The geometric mean diameter was considered in selecting the cylindrical screens apertures.

**Table 1. Normal frequency distribution of the estimated geometric diameter for sugar beet seeds.**

Item	No. of groups									
	1	2	3	4	5	6	7	8	9	10
Sample group, mm	3.6-4.0	4.0-4.4	4.4-4.8	4.8-5.2	5.2-5.6	5.6-6.0	6.0-6.4	6.4-6.8	6.8-7.2	7.2-7.6
Frequency, %	7.6	4.6	22.2	20.6	16.0	9.2	5.0	12.2	2.0	0.6

Mean of geometric diameter,  $X = 5.0$  mm. Stander deviation,  $\sigma = 0.77$  mm. Coefficient of variance, CV = 15.4%.

**Mechanical properties of beet seeds:**

The coefficient of friction between seed and the surface on which the material moves is essential to the design of feed hopper and grading screens. The coefficient of friction  $\mu$  was determined for used material of galvanized iron. An iron cylinder of 100 mm diameter and 50 mm height was placed on an adjustable tilting plate, faced with the galvanized iron surface, and filled with the sample. The cylinder was raised slightly so as not to touch the surface. The structural surface was the cylinder resting on it was inclined gradually with a screw device until the cylinder just started to slide down and the angle of tilt was read from a graduated scale (Friction angle,  $\phi$ ). The angle of friction ( $\phi$  was read to be 26 degree. Therefore, the coefficient of friction was calculated to be 0.49. The coefficient of friction was calculated as follows (Joshi *et al*, 1994):

$$\text{Coefficient of friction, } \mu = \tan (\phi) \tag{1}$$

Where:

- $\mu$  = coefficient of friction;
- $\phi$  = angle of tilt, degree.

**The fabricated grader machine:**

The grader machine was fabricated and evaluated at Agric. Eng. Res. Institute (ARC) workshop. The main parts of the grading machine as shown in Fig 1 & 2 consist of:

**1- Main frame:**

The main frame (2) was constructed of a steel hollow square (50x50) with 5 mm thick welded together. The frame dimensions (length, width, and height) were 140, 70, and 110 cm, respectively. It is supported on four stands distributed along the frame base. The front stand can be adjusted by a circular motion of each stand to provide different tilt angle of the grading unit. The feeding device and cylindrical grading screen are fixed on the frame.

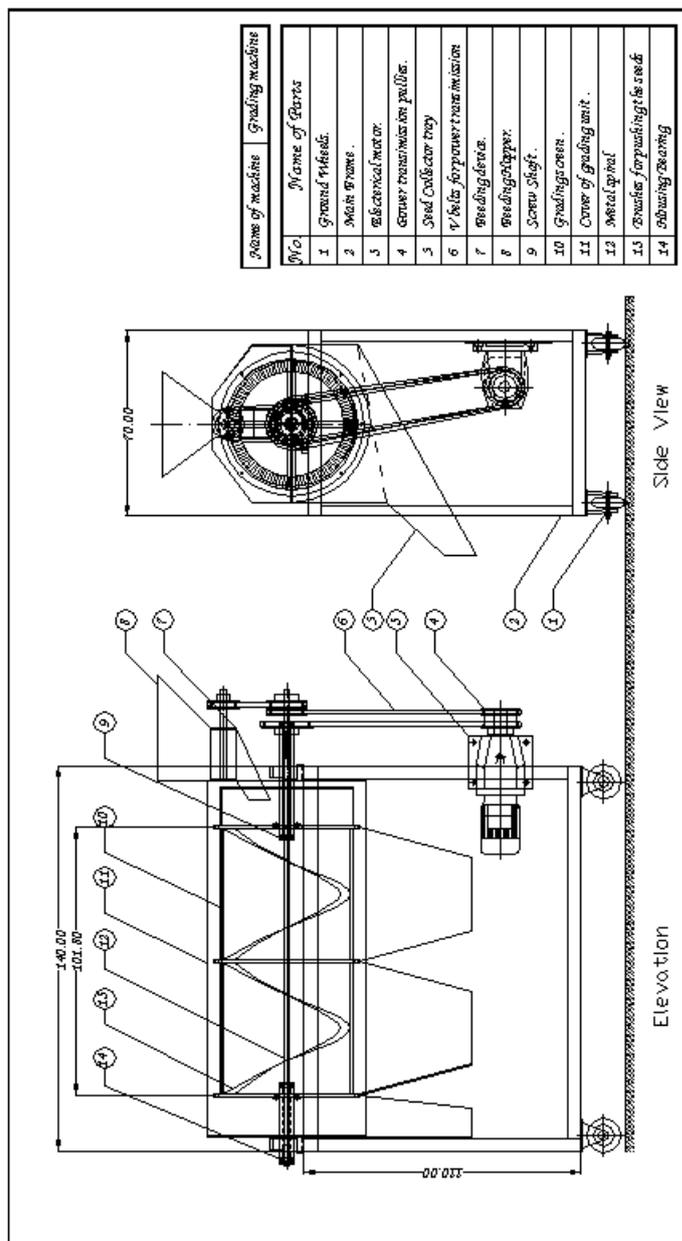


Fig. (1) : Schematic diagram of cylindrical grader of sugar beet seeds.

**2- The feeding device:**

The feeding device (7) consists of a simple hopper (8), built from iron sheet one mm thickness with a 45° sloping. This sloping of hopper is over the repose angle of the seed to keep the flow of seeds at continuous rate and to facilitate the seed feeding to the grading screen (10) unit through a fluted

wheel. The feeding rate was adjusted by changing the fluted wheel speed through a variable speed drive.



**Fig. (2): Photograph of the designed grading machine**

### **3- Grading cylindrical screen:**

A mechanism was built that consists of a cylindrical screen (10), 0.5 m in diameter and 1 m in length. The cylindrical screen consists of two sequential screens. The screens holes dimensions were selected according to seed geometric diameter show in table 1. In it, the seeds are graded into three classes. The front screen is round hole of 4.5 mm diameter to separate smaller and undersize seeds. The medium-size seeds fall out through the rear screen of 6.0 mm and the larger-size seeds transported to the end-outlet of the screen drum to fall out in to the discharge spout. A spiral was installed inside the cylindrical screen. During seed's motion in the screen some of them become clogged. For the purpose of cleaning the surface of the screen of such seeds clogged, brushes were fixed on the spiral tip. The spiral and the cylindrical screen rotate in the same direction, with the spiral rotating faster than the cylindrical screen. Rotation of the screen provides the centrifugal force that makes the separation process gravity-independent. The spiral is a positive means of supplying kinetic energy to the seeds, moves the seeds axially and would eliminate seed lodging in the screen, and also makes the operation continuous.

**4- Power source:**

An electric variable speed motor (3) of 2.21 kW (3 hp, 3 phase 380 v) with maximum rotating speed of 3000 rpm was installed to the grading machine.

**Experimental conditions:**

During the experiments, the following parameters were examined:

**1- Screen slope ( $\theta$ ):**

The designed grading machine was tested at four levels of cylindrical screen slope angle (0, 5, 10, and 15 degree).

**2- Specific load on the screen (Q):**

The specific load on the screen was measured by the mass of material which can be fed per unit time to a unit area of screen, and can be simply controlled by varying the feed rate to the equipment. Four different specific loads on the screen (0.08, 0.10, 0.12, and 0.14 kg/m<sup>2</sup> s).

**2- Screen to spiral speed ratio ( $\omega / \omega_1$ ):**

The spiral ( $\omega_1$ ) and the cylindrical screen ( $\omega$ ) rotate in the same direction, with the spiral rotating faster than the cylindrical screen. The performance of grading machine was evaluated at four different screen to spiral speed ratios (0.6, 0.7, 0.8, and 0.9).

**4- Kinematic factor (K):**

Kinematic factor (K) is the ratio of the cylindrical screen acceleration ( $\omega^2 r$ ) to gravity acceleration (g), therefore,  $K = \omega^2 r / g$ . (Kanafojski and Karwowski, 1976).

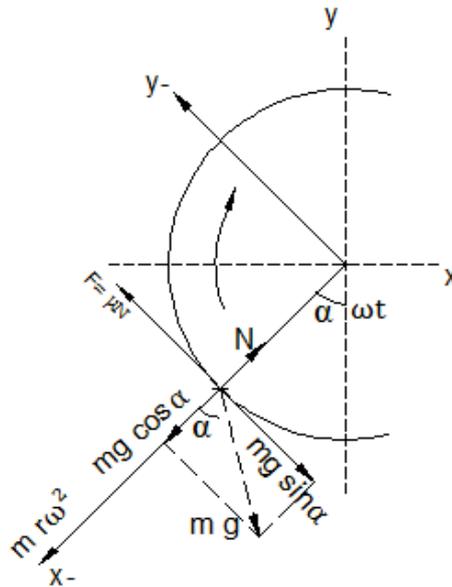


Fig. 3: Forces acting on the seed situated on the internal cylinder surface.

Consider the behavior of seeds situated within a revolving screen. On a seed, situated inside the screen (Fig. 3) acts the force of gravity  $mg$ , the centrifugal force ( $m r \omega^2$ ) and the friction force ( $T = \mu N$ ). Projecting these forces onto the axes  $x'$  and  $y'$  we obtain the following equations conditioning the seed's equilibrium in the moment of time ( $t$ ) under consideration.

$$m r \omega^2 - N + m g \cos \omega t = 0 \quad (2)$$

$$T = \mu N = m g \sin \omega t \quad (3)$$

Where:

- $K$  = kinematic factor ( $\omega^2 r / g$ );
- $\mu$  = coefficient of friction = 0.49;
- $\varphi$  = friction angle = 26 degree;
- $m$  = mass of seed, kg;
- $g$  = acceleration due to gravity,  $m/s^2$ ;
- $N$  = critical speed, rpm;
- $\omega$  = Screen angular speed,  $s^{-1}$ ; and
- $r$  = Screen radius = 0.25 m.

From equation (2)

$$N = m (r\omega^2 + g \cos \omega t) = mg (\omega^2 r/g + \cos \omega t) \quad (4)$$

$$N = mg (K + \cos \omega t) \quad (5)$$

Substituting the value of  $N$  in equation (3) and introducing  $\mu = \tan \varphi$  we obtain the expression conditioning of the seed's motion together with the rotatory motion of the cylinder (relative speed of seed = 0)

$$\tan \varphi mg (K + \cos \omega t) \geq mg \sin \omega t \quad (6)$$

$$\frac{\sin \varphi}{\cos \varphi} (K + \cos \omega t) \geq \sin \omega t \quad (7)$$

$$K \geq \frac{\sin(\omega t - \varphi)}{\sin \varphi} \quad (8)$$

$$K \sin \varphi \geq \sin(\omega t - \varphi) \quad (9)$$

The behavior of a seed depends, therefore, on the cylinder's number of revolutions at a given radius. The seed, with a certain value of  $K$ , will be situated on the cylinder surface in relative rest that is it will revolve together with the cylinder. Since  $\sin(\alpha - \varphi) \leq 1$  then also  $K \sin \varphi \leq 1$ . Hence the highest value of  $K$  is as follows:

$$K_{\max} = \frac{1}{\sin \varphi} = \sqrt{\frac{\sin^2 \varphi + \cos^2 \varphi}{\sin^2 \varphi}} = \sqrt{1 + \frac{1}{\mu^2}} \quad (10)$$

When  $K = K_{\max}$  then

$$\sin(\alpha_{\max} - \varphi) = 1 \quad (11)$$

$$\alpha = \frac{\pi}{2} + \varphi \quad (12)$$

In this research the determined coefficient of friction between the sugar beet seeds and the experimental screen  $\mu = 0.49$ , and substituting in equation (10), the maximum value of kinematic factor  $K_{\max}$  is:

$$K_{\max} = (\omega^2 r / g) = \sqrt{1 + \frac{1}{\mu^2}} = \sqrt{1 + \frac{1}{0.49^2}} = 1.96 \quad (13)$$

$$\text{Therefore, the critical rotating speed, } N = 41.89 / \sqrt{r} \quad (14)$$

Critical speed is the minimum rotating speed at which cascading ceases and material remains in constant screen contact, held there by centrifugal force. On other hand, to achieve actual sorting operation, it is necessary that the seed should slide over the cylinder surface. In such a case the value of K must be appropriately reduced which means that  $K_{\max} < 1.96$ . The performance of grading machine was evaluated at six different value of kinematic factor (0.7, 0.8, 0.9, 1.0, and 1.2).

**Measurements:**

The following measurements were carried out to investigate the effect of the previously mentioned parameters on the fabricated grading machine performance.

**1-Seed quality:**

An important consideration in sizing beet seed is seed quality. Seed quality is measured by warm germination rate (% of seed that germinates at 21°C after 10 days). The seeds germination test was carried out in laboratory by keeping 100 seeds on filter paper soaked with water in a Petri dish. After 10 days, the germinated seeds were counted to determine the percentage of germination.

Also, grading uniformity among seeds is a major indicator to seed quality. It was measured by collecting samples of the graded seeds, measuring the geometric mean diameter of each seed, and calculating the standard deviation (S) and the coefficient of variation (CV). A CV of 10 % or less meets the mechanical sowing operation as the standard requirements. The coefficient of variation was defined as the following (Herrman and Behnke, 1994):

$$CV = \frac{S}{X} \times 100 \quad (15)$$

Where:

- CV = coefficient of variation, %;
- S = standard deviation, mm; and
- x = geometric mean diameter, mm.

**2- Grading efficiency:**

Grading efficiency of screens determined by the percentage of actual graded particles mass that passed through it to theoretical particle mass. The results depend on the size distribution of the processed material. The grading efficiency of each screen was calculated according to the following equation:

$$\eta_i = \frac{M_i}{M} \times 100 \quad (16)$$

Where:

- $\eta_i$  = Grading efficiency of seeds for each screen, %;
- $M_i$  = Actual mass of the graded seeds for each screen, kg; and
- M = Theoretical mass of the graded seeds for each screen, kg.

The grading efficiency was calculated as a mean efficiency for three outlet of the machine as the following equation:

$$\eta = \frac{\eta_1 + \eta_2 + \eta_3}{3} \quad (17)$$

### 3- Grading capacity:

The grading capacity (Gs) for the developed machine was calculated using the following formula:

$$G_s = \frac{M}{T_G} \quad (18)$$

Where:

Gs = Grading capacity of the machine, kg/sec;

M = Mass of classified seeds, kg; and

T<sub>G</sub> = Grading time, sec.

### 4- Energy requirements:

The consumed power (kW) was estimated using the super clamp meter-300k (Japan made) to measure the line current strength (I) and the potential difference values (V) according to Kurt (1979) as follow:

$$\text{Consumed power (P)} = I \times V \times \xi \times \cos \theta / 1000, \text{ kW} \quad (19)$$

Where:

I = line current strength, Amperes;

V = Potential difference, Voltage;

Cos θ = power factor, equal 0.64; and

ξ = mechanical efficiency assumed (80 %).

The energy requirements in kW.h/Mg, was calculated by using the following equation:

$$\text{Energy requirements, kW.h/Mg} = P/C \quad (20)$$

Where:

P = consumed power to grading seeds, kW and

C = grading capacity of machine, Mg/h.

## RESULTS AND DISCUSSION

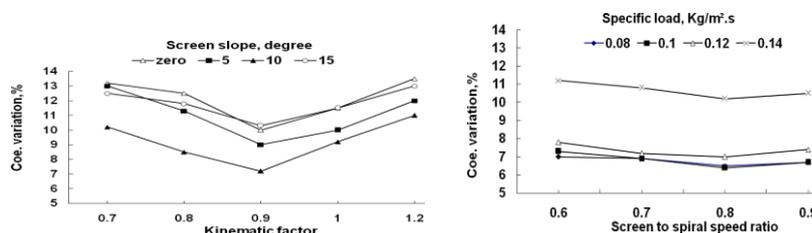
### 1- Seed quality:

Table 2 shows that, the germination percentage of multi-germ beet seeds as 94.5% before grading operation. After grading operation, the maximum germination was recorded by seeds passed through 6.0 mm screen and end-outlet (98.0%) but minimum germination by seed separated through 4.5 mm screen (87.5.0%). Interestingly, the lowest and the highest kinematic factor (0.7 and 1.2) recorded a lower germination than the mid-range of kinematic factor (0.8 to 1.0). This results may be due to average increase in seed size and weight with the increase in grading screen size. Also, this may be due to the greater amount of food reserves contained and the greater embryo size or both (Wood *et al.* 1977; Palanisamy and Ramasamy, 1985).

**Table 2: Mean germination percentage (%), of beet seeds passed through different screen at variable machine kinematic factor.**

screen aperture size (mm)	Kinematic factor				
	0.7	0.8	0.9	1.0	1.2
Bef. grading	94.5	94.5	94.5	94.5	94.5
4.5	85	87	87.5	87.5	84.5
6.0	93	98	98	97.5	92.5
End-outlet	92.5	97.5	98	96.7	92

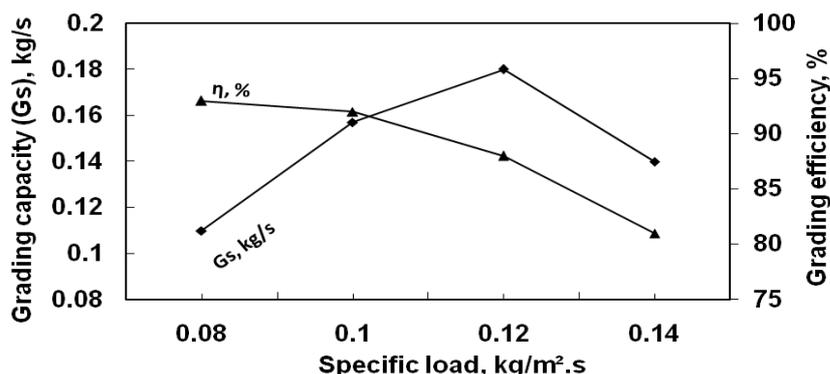
The coefficient of variation CV for grading uniformity is important index to use in evaluating the seed quality. As shown in figure 4 increasing the kinematic factor up to 0.9 can improve the seed grading uniformity which is shown as the decrease in CV from 10.2 % to 7.6%. On other hand, increasing the kinematic factor above 0.9 to 1.2 the CV increased to 11.2 %. Also increasing the screen slope angle from 0 degree to 10 degree the CV decreased by about 28%. Meanwhile, when the seed specific load increased from 0.12 to 0.14 kg/ m<sup>2</sup>.sec the CV increased by about 50 %. Generally, the best grading uniformity (CV = 6.4%) was obtained at 0.9 kinematic factor, 0.1 specific load, and screen slope of 10 degree.



**Fig. (4): Variation of coefficient of variation (CV) of beet seeds as a function of the kinematic factor, screen slope, specific load on the screen, and screen to auger speed ratio.**

**2-Grading efficiency and grading capacity:**

The grading capacity is governed by the optimal load on the screen. Figure (5) shows that, in general, with increase of the seeds load on the screen up to 0.12 kg/m<sup>2</sup>.s, the grading capacity is directly proportional, until some limiting load after which it decreases. The grading efficiency shows the extent to which grading initially occurs remain unchanged, but with further increase of the load on the screen above 0.1 kg/m<sup>2</sup>.s, the grading efficiency significantly decreases. A higher specific load on screen would mean more seed per perforation per unit time. This would impede passage of seed through the perforation of screen, which explains the decrease in grading efficiency and grading capacity. Significant decrease of grading efficiency always occurs earlier than the maximum grading capacity. Thus, the maximum grading is always greater than that which occurs at the highest factor of grading. Therefore, the optimum value of seed specific load is selected at intersect point (0.1 kg/m<sup>2</sup>.s) to obtain 0.157 kg/s grading capacity and 92 % grading efficiency.



**Fig. (5): Variation of grading capacity (Gs) of the screen and the grading efficiency (η) as a function of the specific load on the screen.**

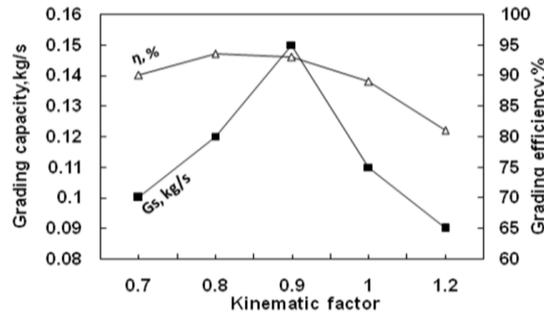
The effect of kinematic factor ( $\omega^2 r/g$ ), on the grading capacity and grading efficiency is plotted in figure 6. Results show that the maximum grading efficiency (93.5%) was obtained at kinematic factor of 0.8. But increasing kinematic factor to 0.9, the grading efficiency decreased slightly to 93 %. Above 0.9 kinematic factor, the efficiency dramatically decreased to 81% when the kinematic factor increased to 1.2. Also figure 5 shows that the grading capacity increased by about 50% when the kinematic factor increased from 0.7 to 0.9. On other hand, it decreased by about 66% with increasing the kinematic factor from 0.9 to 1.2. It was possible that at high values of kinematic factor, the centrifugal force acting on the seed was higher, and there for seed compaction impeded the grading operation. Generally, the optimum grading can be recorded at 0.9 kinematic factor to achieve 93 % and 0.15 kg/sec for grading efficiency and grading capacity respectively. According to figure 5 the optimum kinematic factor ( $\omega^2 r/g$ ) equal 0.9. Therefore, the optimum screen speed (56 rpm) is a function of cylindrical screen radius as the follow:

$$N = 28/\sqrt{r} \tag{21}$$

where:

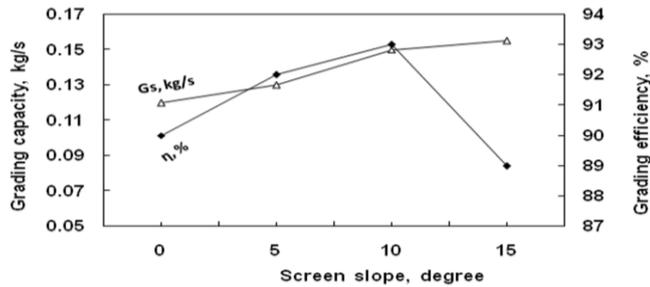
N = Optimum speed of the cylindrical screen, rpm; and  
 r = Cylindrical screen radius = 0.25 m.

According to equation (14) where, the critical rotating screen speed, N =  $41.89/\sqrt{T}$ , therefore the optimum screen speed equal 66 % of critical screen speed. Critical speed is the minimum rotating speed at which cascading ceases and material remains in constant screen contact, held there by centrifugal force. But at the optimum speed (56 rpm) only sliding motion of the seed can be achieved. As a result of friction the seed is initially lifted by the cylinder surface upward but because of the insignificant centrifugal force, the lifting is done with a lower speed than the cylinder peripheral speed.



**Fig. (6): Variation of grading capacity ( $G_s$ ) of the screen and the grading efficiency ( $\eta$ ) as a function of Kinematic factor.**

The effect of, the screen slope, on grading efficiency and grading capacity is plotted in figure 7. The results show that the grading capacity increased by about 25 % with increasing screen slope up to 10 degrees. After 10 degrees screen slope, the grading capacity slightly increased. Also the results show that the grading efficiency ranged from 90 % to 93 with screen slope from zero to 10 degrees and dramatically decreased to 89 % as screen slope increased to 15 degree. Therefore, it can be concluded that, the optimum grading capacity and grading efficiency were recorded at screen slope of 10 degree.



**Fig. (7): Variation of grading capacity ( $G_s$ ) of the screen and the grading efficiency ( $\eta$ ) as a function of screen slope.**

The grading efficiency and grading capacity were plotted against, the screen to spiral speed ratio figure 8. Data showed that the screen to spiral speed ratio ( $\omega/\omega_1$ ) did not significantly affect the grader performance.

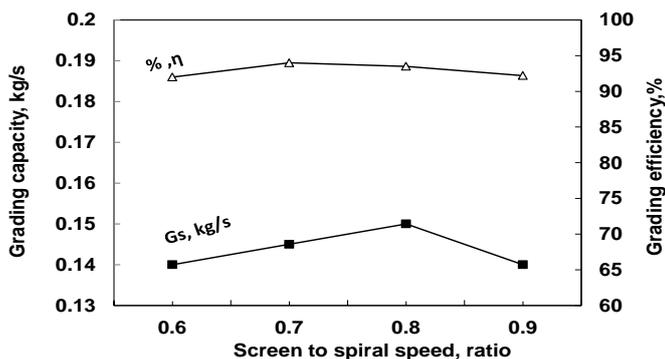


Fig. (8): Variation of grading capacity ( $G_s$ ) of the sieve and the grading efficiency ( $\eta$ ) as a function of screen to auger speed ratio ( $\omega/\omega_1$ )

**3-Energy requirements:**

Figure 9 shows the effect of screen slope and kinematic factor on energy requirements. Results show that, the energy requirements were significantly affected by the cylindrical screen slope and kinematic factor. From figure 9 it's clear that the minimum value of energy requirements is 5.2 kW.h/Mg were achieved at screen slope of 10 degrees and 0.9 kinematic factor. While, the maximum value of energy requirements (6.7 kW.h/Mg) was performed at screen slope of zero degrees and kinematic factor of 0.7. Also figure 9 shows that the energy requirements for the designed machine decreased by increasing of the screen slope up to 10 degrees and by increasing the kinematic factor to 0.9. On other hand increasing kinematic factor from 0.9 to 1.2, cause a corresponding increase in machine energy requirements.

The machine energy requirement was plotted against the screen to spiral speed ratio and screen specific load (Fig. 9). The figure shows that, the screen to spiral speed ratio ( $\omega/\omega_1$ ) did not significantly affect the energy requirement. From fig. 9 it's clear that the minimum value of energy requirement (5.23 kW.h/Mg) was achieved at cylindrical screen specific load of 0.12 kg/sec.m<sup>2</sup>. While the maximum value of energy requirement (6.9 kW.h/Mg) was performed at cylindrical screen specific load of 0.08 kg/m<sup>2</sup>s.

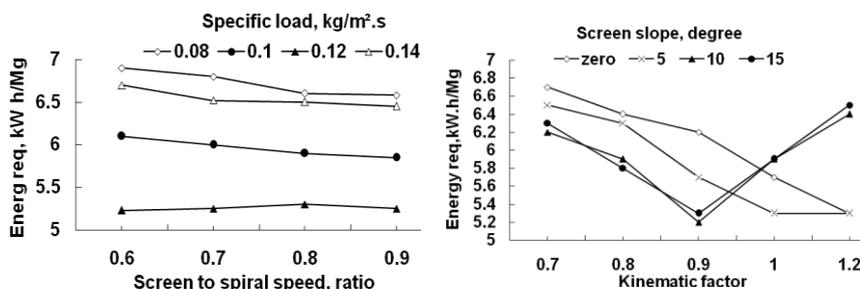


Fig. (9): Variation of energy requirements as a function of kinematic factor, screen slope, specific load, and screen to spiral speed ratio.

## CONCLUSION

The obtained results could be concluded in the following:

- 1- The germination percentage of multi-germ beet seeds was 94.5 % before grading operation. After grading operation, the maximum germination was recorded by seeds passed through 6.0 mm screen (98.0%) and minimum germination by seed separated through 4.5 mm screen (87.5 %).
- 2- The best grading uniformity (CV = 6.4%) was obtained at 0.9 kinematic factor, 0.1kg/m<sup>2</sup>sec specific load, and screen slope of 10 degree.
- 3- The results indicated that the cylindrical screen of 50 cm diameter rotating at about 56 rpm, with an inner spiral rotating at about 70 rpm, is capable of grading beet seeds.
- 4- The optimum value of seed specific load as 0.1 kg/m<sup>2</sup>.sec to obtain 0.157 kg/s grading capacity and 92 % grading efficiency.
- 5- The optimum screen speed is a function of cylindrical screen radius as the follow:  $N = 28 / \sqrt{r}$ , where: N = Optimum speed of the cylindrical screen, rpm; and r = Cylindrical screen radius, m.
- 6- The minimum value of energy requirements is (5.2 kW.h/Mg) were achieved at screen slope of 10 degrees, 0.9 kinematic factor and cylindrical screen specific load of 0.1 kg/m<sup>2</sup> s. While, the maximum value of energy requirements (6.8 kW.h/Mg) were performed at screen slope of zero degrees, kinematic factor of 0.7 and cylindrical screen specific load of 0.08 kg/m<sup>2</sup> s.
- 7- Screen to spiral speed ratio did not have a major affect the grader performance.
- 8- The proposed grading machine was found to be very promising and efficient in the beet grading process. It is simple and could be fabricated in workshops in rural areas.

## REFERENCES

- Amin, E. A., 1994, Development of grading machine for some Egyptian farm crops. *J. Agric. Sci., Mansoura Univ.*, 19(7): 2398-2411.
- Brown, G. G., Forest, D. L., and R. Schmedewind, 1950, Unit operation. New York: John Wiley & Sons, Inc.
- Chancellor, W. T., 1981, Substituting information for energy in agricultural. *Trans. Of the ASAE*, (5): 802 – 807.
- Feller, R., 1980, Screening analysis considering both passage and clogging. *Trans. ASAE*, 23(4): 1054 – 1056.
- Ghosh, R.C., Bakshish Singh and Sharma, K.K., 1976, Effect of seed grading by size on germination and growth of pine seedlings. *Indian Forester*, 102(12): 850-858.
- Hashem, A. and P. Eberhard, 2007, Particle screening phenomena in an oblique multi-level tumbling reservoir: a numerical study using discrete element simulation. *Granular Matter*, (9):415–429.
- Harrison, H. P. and A. Blecha., 1983, Screen oscillation and aperture size-sliding only. *Transactions of the ASAE* 26 (2): 343-348.

- Herrman, T., and K. Behnke, 1994, Testing mixer performance. MF 1172. Manhattan, Kansas: Kansas State University.
- Hurburgh, C. R., C. J. Bern, and T. J. Brumm, 1989, Efficiency of rotary grain cleaners in dry corn. *Trans. ASAE* 32(6): 2073 – 2077.
- Joshi, D. C., S. K. Das and R. K. Mukherjee, 1994, Physical properties of pumpkin seeds. *J. of Agric. Eng. Res.* 54(2): 219-229.
- Kanafojski, Cz. And T. Karwowski, 1976, Agricultural machines, Theory and construction. Vol. 2: Crop Harvesting Machines by the Foreign Scientific Publications Department of the National Center for Scientific, Technical and Economic Information.
- Klenin, N. I. and B. A. Cakon, 1980, Principles of farm machinery, Moscow, Caloc Public. 459 – 464.
- Kurt, G., 1979, Engineering formulas. Third Ed. Mc Graw – Hill book Company. New York St. Louis San Francisco Montreal – Toronto.
- Metwalli, M. M., 1975, Design of a horizontal cylindrical screen for separating grain during harvesting by centrifugal and gravity forces. Faculty of Agriculture, Kafr El-Sheikh, Tanta university. *Res. Bulletin* (16): 1 -12.
- Palanisamy, V. and Ramasamy.K.R., 1985, Effect of seed size and weight on seedling vigour in Bendi. *Seed Res.* 13: 82-85.
- Pierce, R. O., 1985, Grain cleaning equipment-On farm applications. ASAE Paper No. 85-3509. St. Joseph, MI: ASAE.
- Rothaug, S; P. Wacker; W. Yin and H. D. Kutzbach, 2003, Capacity increase of cleaning units by circular oscillation. *In e- Proceedings of the International Conference on Crop Harvesting and Processing.* Kentucky USA. ASAE Publication Number 701P1103e. St Joseph, Michigan. ASAE. 7 Pp.
- Safwat, M. and A. Moustafa., 1971, Theoretical prediction of volume, surface area, and center of gravity for agricultural products. *Transactions of the ASAE*, 549-553.
- Sharma, S. K., R. K. Dubey and C. K. Teckchandani, 1985, Engineering properties of bulk gram, soyabean and green gram. *Proceeding of Indian Society of Agric. Eng.*, 3: 181 – 185.
- Sucher, R. W. and H. B. Pfost, 1964, Cylinder grader performance in relation to corn cleaning problems. *Transaction of the ASAE* 17(3): 300-304, 306.
- Virendra Singh, O.P.S. Bana and Sah, V.K., 1995, Influence of seed size and GA3 treatment on the germination and growth of oak. *Ind. J. For.*, 18(1): 66-73.
- Wood, D.W., Longden P.C. and Scotte R.K, 1977, Seed size variation, its extent, source and significance in field crops. *Seed Sci. Technol.* 5: 337-352.

## تصميم وتقييم أداء آلة لتدريج بذور بنجر السكر عديدة الأجنة إبراهيم محمد عبد التواب، طاهر رشاد عويس و أسامة قدور معهد بحوث الهندسة الزراعية – مركز البحوث الزراعية

رغم الأهمية الاقتصادية لمحصول بنجر السكر إلا ان ميكنة عملية زراعة محصول بنجر السكر لم تصل الى مدى الانتشار المطلوب لهذا المحصول الحيوى والاقتصادى. حيث يعتبر عدم تجانس بذور بنجر السكر من حيث الشكل والحجم عائقا وعقبة كبيرة فى طريق تجانس زراعتها وانباتها بالوسائل الميكانيكية عن الانواع الاخرى من بذور المحاصيل المختلفة. ومن ثم أجرى هذا البحث بهدف محاولة الوصول الى حل لهذه المشكلة عن طريق تصميم وتصنيع آلة بسيطة لتدريج بذور بنجر السكر، حيث أن عملية تدريج بذور بنجر السكر إلى ثلاثة أقسام مختلفة وهى (صغيرة ، ومتوسطة ، وكبيرة ) يودى إلى تجانس وتمائل البذور بنسبة عالية فى كل فئة من الفئات التى يتم الحصول عليها من وحدة التدريج وخاصة الفئة المتوسطة والتي تمثل حوالى 68 % من إجمالى البذور. ومن ثم كان الهدف من البحث هو تدريج بذور بنجر السكر إستيفاءا للمتطلبات الأساسية للزراعة الدقيقة. وتم ذلك عن طريق:

- 1- دراسة اهم الخواص الطبيعية والميكانيكية لبذور بنجر السكر عديدة الاجنة بهدف استخدامها فى تحديد العوامل التصميمية لوحدة التدريج.
- 2- تصميم وتصنيع آلة تدريج ذات غربال اسطوانى مختلف الفتحات.
- 3- دراسة اهم العوامل الهندسية التى تؤثر على اداء الآلة مثل معدل التلقيم لوحدة مساحة الغريال، معامل الحركة ، زاوية ميل الغريال ، معامل سرعة الغريال إلى الحلزون.
- 4- دراسة نتائج عوامل تقييم الآلة والمتمثلة فى جودة البذور، انتاجية آلة التدريج، كفاءة التدريج، والطاقة اللازمة لعمليات التدريج.

وكانت اهم النتائج المتحصل عليها مايلى:

حيث تحققت أفضل النتائج عند 0.9 معامل الحركة ، 0.1 كجم/ متر<sup>2</sup> ثانية معدل التلقيم لوحدة مساحة الغريال، و 10 درجات لزاوية ميل الغريال والتي عندها كانت اقصى كفاءة للتدريج (92 %) ، و انتاجية آلة التدريج (0.157 كجم/ ث)، و الطاقة المستهلكة (5.2 كيلووات ساعة/طن).

كما اظهرت النتائج ان هناك تحسن ملحوظ فى كل من معامل الاختلاف ونسبة الانبات لبذور بنجر السكر فى الفئة المتوسطة لنواتج البذور المتدرجة لتكون 6.4 % ، 98 % على الترتيب ، عنهما قبل اجراء عملية التدريج حيث كانتا 15.5 % ، 94.5 % على الترتيب.

قام بتحكيم البحث

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