Vertical brush seed metering device for sweet sugar beet planter

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Abstract: In crop production, the mean condition for high productivity depends on singular seed holding in metering device of sugar beet planters. A general design of vertical or horizontal feeding disc is only to plant the coated sugar beet seeds due to the irregularity of surrounding shape of seeds. The paper is focused on developed and constructed vertical brush metering device to plant the ordinary types of sugar beet seeds (multi or mono germs). The physical properties of sugar beet seed species have influences on the behavior of vertical brush metering device. To evaluate the vertical brush metering device, some properties of sugar beet species were determined and some experimental results of planting were identified in this paper. The main dimensions (length, width and thickness), sphericity, geometric and arithmetic mean diameter, surface area, bulk density and true density were identified as physical parameters. Meanwhile, the terminal velocity, and hardness were measured as engineering properties. The static coefficient of friction for multi-germ seeds under different surfaces (stainless steel, sheet galvanized, plastic and rubber) were 0.48 ± 0.42; 0.51 ± 0.56; 0.57 ± 0.34 and 0.72 ± 0.53 respectively, while they were 0.26 ± 0.57; 0.28 ± 0.38; 0.30 ± 0.34 and 0.36 ± 0.74 for the mono-germ seeds respectively under the above mentioned surfaces. The regressions analysis for the relationship between the main parameters of sugar beet seed indicated that the highest positive effective factors affecting the approximation physical sugar beet seeds properties is the width of sugar beet for multi-germ while the length is more effective for mono-germ seeds. The vertical brush metering device is one key part of sweet sugar beet planter; it was evaluated by assessing the actual relationship between the three density of hair per hole (50, 75 and 100 hair/hole) and the feeding device parameters (seeding traveling and peripheral speeds of metering device). The seeds flow in brush device was controlled by seed lever control which lies in seed tank bottom. All parameters were measured at different levels of brush device with four peripheral speeds (0.16; 0.24; 0.32; and 0.4 m/s). Feeding quality, missing seeds, multiple indices and precision of seed index are the most common characteristics used to evaluate the metering device performance. The highest seed feed index was achieved on the brush device with hair density of 100 hair/hole for two different sugar beet varieties (Multi-germ of 83.07% and mono-germ of 80.56%). The lowest seed feed index was obtained from the experiments using the hair density of 50 hair/hole with peripheral brush speed of 0.4 m/s. The lower values of precision index indicate better performance of the brush device, therefore the lowest values were found at seeding speed of 2.0 m/s, 0.3 m/s peripheral speed of feeding device and 100 hair/hole densities.

Keywords: sugar beet planter, seeding device, vertical brush metering device, seed lever control, brush planter and systems analysis of seed feeding

DOI: 10.3965/j.issn.1934-6344.2010.01.026-037

Citation: Ismail Z. Ebrahem, Ayman H. Amer Eissa, Wang Yingkuan. Vertical brush seed metering device for sweet sugar beet planter. Int J Agric & Biol Eng, 2010; 3(1): 26－37.

1 Introduction

The sugar beet is considered as one of the most important crops, not only for producing sugar but also for its secondary productions; fodder, molasses and fertilizer as organic matter. The total cultivated area of sugar beet was about 190 thousand hector with an annual production of 0.5 million tons sugar[1]. Since 1970 till

Received date: 2010-01-20 **Accepted date:** 2010-03-15

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now, planting of sugar-beet has given a great deal of attention in Egypt. For the past many years sugar was produced from sugar-cane in Upper Egypt. A new strategy is considered for the future of sugar industry in Egypt. The policy depends upon establishing about five sugar factories for beet. This new policy is built on several facts; beet consumes about two-third less water than cane. It also grows under a wide variety of soil and climatic conditions[2].

Preliminary evaluation showed important improvement in the planting operation with reduction in human effort, more accurate stands and high field capacity. To attain optimum planting condition for productivity, a study to compare the performance of three different models of jab planters with the traditional method of planting was done[3]. In terms of field capacity and labor requirements, there was not much difference between the traditional planting method and the jab planters during sugar beet planting and also have high seeds damage. This showed that it is necessary for seeds to be placed at equal intervals within row with uniform spacing, so the roots can grow to a uniform size[4,5]. The years of study explained that uniformity of sugar beet plant spacing within the row affected yield, seed size, and consistency of seed size in some of the sites. Therefore, both seed population and seed spacing at planting time have effect on harvested seed yield and seed size[6].

Although there are many planters with different seed metering units, the application of pneumatic single seed planters has rapidly increased due to the fact that their sugar beet seeding performance is better than that of the others. In addition, the devices of mechanical seed metering used in conventional drills are not capable of operating at high travel speed[7]. The pneumatic planters is the best machine for sugar beet planting, but some problems face these machine such as the difficulty of the machine operation under the Egyptian fields[8]. Planted sunflower seed on a test track in the field using four seed sizes, a mechanical plate planter and an early erosion pneumatic planter was identified[9]. They also found differences in seed spacing accuracy caused by planter model, seed size, and field speed. The comparison four planter models on a grease belt test stand, each with several options, at three field speeds with three seed sizes, for a planter index was compared[10]. They found seed spacing accuracy differences among planter models, among options within models, among field speeds, and among seed sizes. During the field experiments for sugar beet planters use the gathering holes, but with different seeding mechanisms: ground driven seeding mechanism and electromotor driven seeding mechanism. It can be stated that, in the range of higher forward speed, both planters reached better results from the point of the required placement of plants in the row. This is given by the design of the seeding mechanism. In the area of the seeding quality, better results were obtained with Unicorn drive planter during more suitable velocity conditions, elimination of inaccuracies caused by losses in transmission and slippage of driving wheel of the seeding mechanism[11].

Sugar beet planting has been limited to manual planting, which is very tedious and laborious. Therefore, there is a need to develop a simple tool that will be used in planting sugar beet seeds. The conveying seeds in horizontal wheel device face many factors that affect the performance of conveying sugar beet seeds[12]. The lever control in the seeds tank bottom and the amount of feeding device parameters are considered as the main static factors influencing the seeding performance. While, the spacing uniformity, seed volumetric rate and irregular dispersion of seeds in soil for sugar beet planting are considers as the main out let factors.

Therefore, this work aimed to determine some of the physical properties of common varieties of sugar beet seeds, and to evaluate and focus on new construction of vertical brush seed metering device for planting the common varieties of sugar beet seeds (multi or mono

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germs).

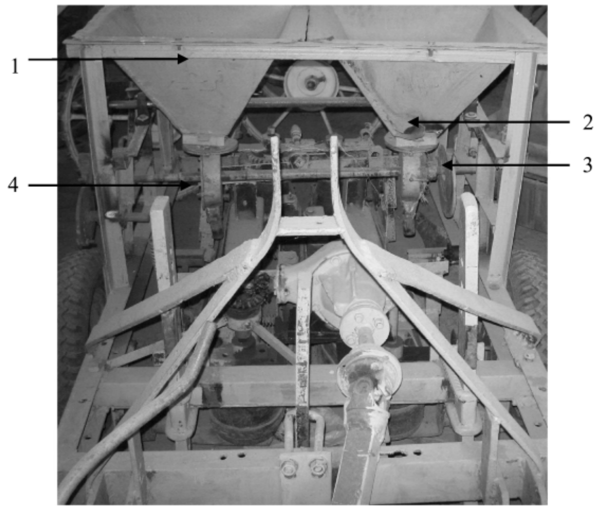
2 Materials and methods

2.1 Metering system components

The brush metering system consist of a seed hopper, seed metering device, agitator unit, transmission system and seed delivery tubes.

2.1.1 Seed hopper

The individual seed hopper which was made from iron sheet as shown in Figure 1 is connected on the planter frame. On the bottom of the hopper, the control lever is connected to regulate the seeding rate. The tank capacity is regulated to plant 4.2 hectare per certain time (100-120 kg seeds per hectare).



1- Seed hopper tank 2- Hopper bottom 3- Lever control 4- Brush feeding device

Figure 1 General view of feeding system mechanism

2.1.2 Seed metering device

The metering-wheel of brush device has the two rows of holes each having 12 holes with 5 mm diameter, that were located at the equal space on the circumference of feeding metering wheel (diameter of 15 cm) as shown in Figure 3. The seeds are picked by brush hair from the hopper and dropped into the seed tube. The revolution number of brush device can be regulated by using the power transmission of the planter land wheel. Two units of feeding brush are fixed on the main shaft (2.54 cm diameter) in span of 65 cm.

2.1.3 Agitator unit

Agitator unit is located inside of the seed hopper to agitate the sugar beet seeds. As shown in Figure 2 the agitator motion is supplied from the 4 bar mechanism. Under all experiments the peripheral speed of agitator unit is constant (25 r/min).

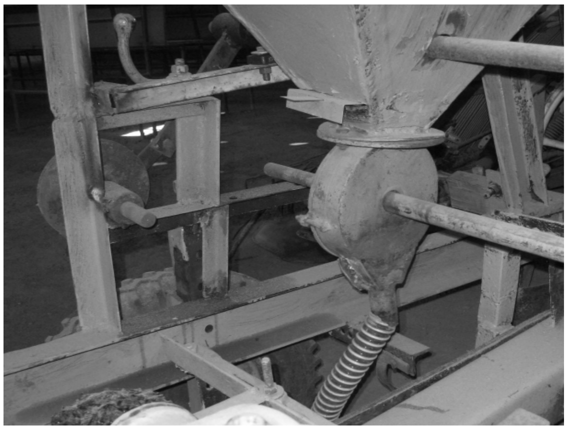


Figure 2 Brush planter

Figure 3 Brush feeding tool

2.1.4 Transmission system

Transmission system as shown in Figure 2 has two functions for driving metric device from land wheel and for changing the auger shaft rotating speed to obtain different application seed rates, kg/hectare.

2.1.5 Seed delivery tube

The seed is delivered through a plastic tube on soil surface and covered by soil that is formed by the profile maker unit.

2.2 Peration parameters of investigated device

1- Four peripheral speeds of brush plate (0.16; 0.24, 0.32 and 0.40 m/s);

2- Three levels of hair density (50; 75 and 100 hair per hole);

3- Four traveling speeds of planter (1.0, 2.0, 3.0 and

4.0 km/h), and

4- Two varieties of sugar beet seeds (mono and multi-germ).

2.3 Effects on seeding indices

Seeding indices were calculated according to[13]. These indices were quality of seed feeding index, miss index, and precision index. During the primary trials, it was observed that the peripheral speed of feeding seed disc affect seed spacing. Higher linear speed and the less peripheral speed would result in more space between seed in row.

2.3.1 Miss index

The number of seed distance is placed in the range of (1.5 x_{ref}, Em) or (0.15 - E_m) meter. It was divided by the total number of planted seeds to obtain percent miss index.

2.3.2 Multiple indices

It is the percentage of spacing that are less than or equal to half of the theoretical spacing and indicate the percentage of multiple seed drops.

2.3.3 Precision index

Precision index for each treatment was obtained by dividing the standard deviation of distances in the range of (0.5x_{ref}, 1.5x_{ref}) by x_{ref}. This index is the measure of variability in spacing between seed after accounting for variability due to both multiples and skips. Lower values for this index indicate better performance of the metering device.

2.4 Physical properties of sugar beet seed

The physical properties of seeds including seed main dimension, seed density, projected area, sphericity and one thousand seeds mass are the most important factors in determining the optimum levers dimensions for metering device.

- Seed main dimensions were determined by measuring the dimensions of three principal axes of 100 randomly selected seeds using an electrical caliper with a sensitivity of 0.01 mm.
- Sphericity "ϕ" was calculated according to[14,15] as the following equation:

$$\phi = \frac{Dg}{L} = \frac{(L \cdot W \cdot T)^{1/3}}{L}$$

Where: Dg = Geometric mean diameter, mm; L = Seed length, mm; W = Seed width, mm; T = Seed thickness, mm.

-Geometric mean diameter (Dg, mm) and the arithmetic mean diameter (Da, mm) of the sugar beet seed were calculated using the following equation.

$$Dg = (L \cdot W \cdot T)^{1/3}$$

$$Da = \frac{L + W + T}{3}$$

-Seeds surface area (A_s) was calculated by using the following equation:

$$A_s = 2\pi(L \cdot W)$$

To determine seed mass and thousand seed mass, the electric digital balance was used with an accuracy of 0.1 g. Bulk density was determined using graduated cylinder for measuring volume of seeds and weigh it. The true density was determined using water with a known mass of seeds displacement method. The 20 seeds samples were used for each sugar beet species. The terminal velocities of seeds samples were measured using the constructed instrument by[15].

For the judgment of the sugar beet exiting from the brush device, in relation to seeds density, project area, sphericity and one thousand seed mass, mathematical model were developed. The suitability of the final model was compared and evaluated using chi-square x^2, root mean square error E_{rms} and modeling efficiency E_m which were calculated as follows:

$$E_{rms} = \sqrt{\frac{\sum_{i=1}^{N}(K_{pre,i} - K_{\exp,i})^2}{N}}$$

$$X^2 = \frac{\sum_{i=1}^{N}(K_{\exp,i} - K_{pre,i})^2}{N - n}$$

$$E_m = \frac{\sum_{i=1}^{N}(K_{\exp.i} - K_{\exp,mean})^2 - \sum_{i=1}^{N}(K_{pre,i} - K_{\exp,i})^2}{\sum_{i=1}^{N}(K_{\exp,i} - K_{\exp,mean,i})^2}$$

Where: $K_{\exp}$ is the experimental seed levers dimension in mm; $K_{\exp,mean}$ is the mean value of experimental seed levers in mm; K_{pre} is the predicted seed lever control in mm; N is the number of observation; n is the number of population in the model.

Reduced chi-square is the mean square of the deviation between the experimental and calculated values for the models and, is used to determine the pest fit relation between actual and predicted data. The lower values of the reduced chi-square shows the better applicability. The root mean square error shows the deviations between the calculated and experimental values and it requires reaching zero. The modeling efficiency also shows the ability of the model and its highest values is 1.

2.5 Statistical analysis

The data were statistically analyzed to determine the effect of the traveling speed of brush device under four different the hair density and four lever control on the performance of machine indices which are mean seed spacing, miss and multiples indices, quality of feed index, precisions in spacing and the amount of seed rate. The Data analysis of this experiment was carried out by using the Statistical Analysis System GLM procedures[16]. Furthermore the simple correlation coefficients were calculated. The differences between the mean values of physical and mechanical chickpea seeds characteristics were tested for significance using Duncan test[17].

The coefficient of multiple determinations (R^2) and the mean square error (MSE) of models and the variation of predicted values with respect to measured values as well as the distribution of the residuals with respect to the estimated coefficients were used to evaluate the applicability of the models to the experimental data.

3 Results and discussion

3.1 Physical properties of sugar beet seeds

3.1.1 The main seeds dimensions

Seeds main dimension are illustrated in Table 1. The mean of the sugar beet multi-germ seeds length, width and thickness were 6.14, 5.31 and 4.18 mm respectively. While, the corresponding dimensions for sugar beet species of mono-germ were 4.33, 3.91 and 3.23 mm respectively.

Table 1 Sugar beet physical properties

Seed species	Physical properties	Mean	Maximum	Minimum	SD	CV/%
Multi-germ	Length/mm	6.143	7.71	5.10	±0.6.09	9.83
	Width/mm	5.311	6.51	4.15	±0.6.13	8.79
	Thickness/mm	4.18	5.64	3.22	±0.551	11.50
	Sphericity	7.22	10.70	3.92	±1.312	19.17
	Geometric mean diameter/mm	44.61	76.34	22.41	±10.757	21.13
	Arithmetic mean diameter/mm	5.17	6.18	4.28	±0.411	5.962
	Surface area/mm^2	204.97	296.04	134.25	±35.91	18.52
	Bulk density/g • cm^{-3}	0.28	0.29	0.27	±0.009	2.36
	True density/g • cm^{-3}	0.46	0.78	0.27	±0.153	22.11
Mono-germ	Length/mm	4.33	5.31	3.66	±0.247	6.17
	Width/mm	3.19	4.60	3.16	±0.17	4.18
	Thickness/mm	3.23	4.13	3.03	±0.15	3.19
	Sphericity	5.28	6.162	4.249	±0.35	6.74
	Geometric mean diameter/mm	22.94	29.53	17.51	±2.50	10.93
	Arithmetic mean diameter/mm	4.10	4.51	3.77	±0.15	3.63
	Surface area/mm^2	112.96	149.16	89.89	±10.22	9.05
	Bulk density/g • cm^{-3}	0.44	0.45	0.44	±0.003	0.763
	True density/g • cm^{-3}	0.75	1.08	0.59	±0.14	18.67

The normal distribution curves of the both species of sugar beet seeds length were illustrated in Figure 3. From figure the highest frequencies of the sugar beet seed length ranging from 5.1 to 7.71 mm were 63% for the multi-germ species, and from 3.66 to 5.31 mm were 73% for the mono-germ species. The highest frequencies of the sugar beet seed width were 60% and 66% respectively for multi and mono germ seed species which width ranges from 4.14 to 6.51 and 3.66 to 4.60 respectively for the sugar beet species of multi and mono-germ Figure 3. The frequencies of sugar beet seeds thickness were illustrated in Figure 4, for multi and mono-germ sugar beet species.

Referring to figure 4, the highest frequency was found

32% and 22% at seed thickness of 3.5 and 3.8 mm for multi and mono-germ respectively.

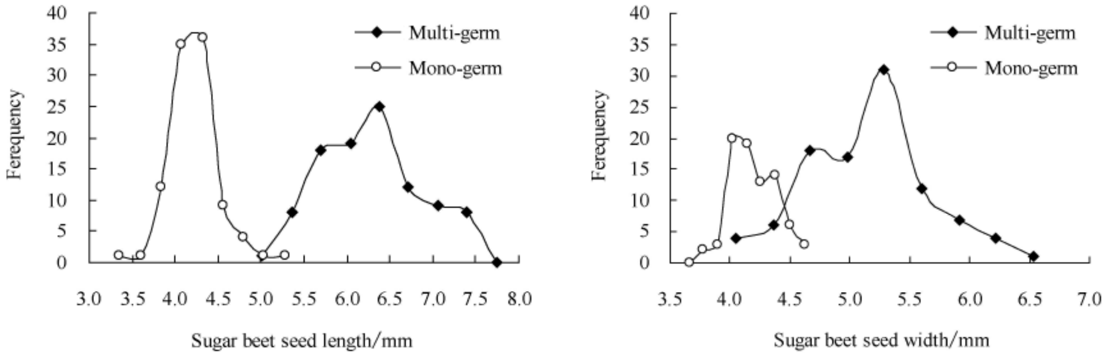


Figure 3 Sugar beet seed length and width frequency

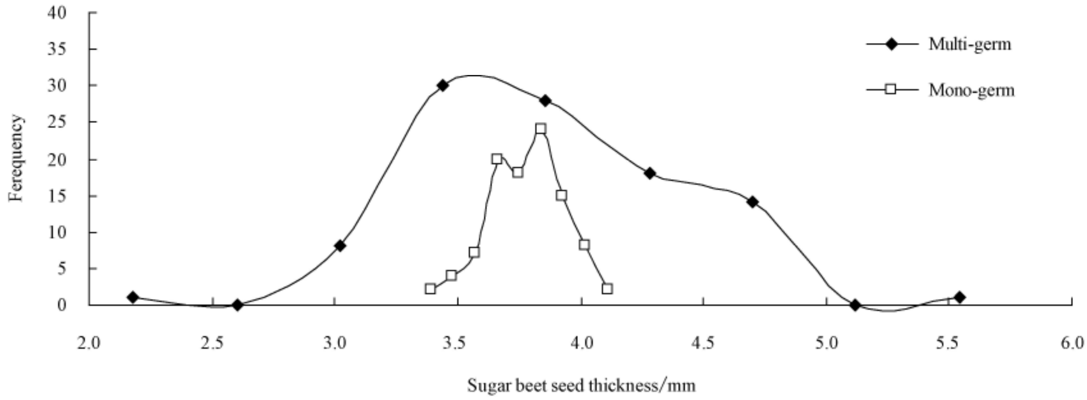


Figure 4 Sugar beet seed thickness frequency

3.1.2 Estimated physical properties

The sugar beet seeds physical properties are sphericity, geometric mean diameter, arithmetic mean diameter and surface area. Table 1 shows the mean, maximum, minimum, standard deviation and coefficient of variation of the sugar beet physical properties. The mean of the physical properties were 7.22%, 44.61 mm, 5.17 mm and 204.97 mm^2 for sphericity, geometric mean diameter, arithmetic mean diameter and surface area respectively for multi-germ species and 5.28%, 22.94 mm, 4.10 mm, 112.96 mm^2 for mono-germ species.

The analysis of variance for the main sugar beet seed dimensions (L, W and T) using the multiple regression analysis showed the highest significant linear relationship with the sugar beet seed sphericity (ϕ), geometric mean diameter (Dg), arithmetic mean diameter (Da), seed surface area (As) and seed terminal velocity (Tv) for the two sugar beet seed species.

The best appropriate equation to explain the correlation between the sugar beet seed sphericity (ϕ), geometric mean diameter (Dg), arithmetic mean diameter (Da), surface area (As) and terminal velocity (Tv) and each of the main sugar beet seed dimensions (L, W and T) could be indicated as follows:

The sphericity (ϕ) of sugar beet function is:

$$\phi = -0.44L + 0.83W + 1.36T$$

$R^2 = 0.99$ for multi-germ

$$\phi = -0.12L + 0.76W + 0.70T$$

$R^2 = 0.99$ for mono-germ

The above model applicable for seed length ranged from 5.10 to 7.71 mm and from 3.66 to 5.31 mm for multi and mono germ respectively and at seed width and thickness ranged from 5.51 to 6.41 and 3.16 to 4.6 mm respectively for multi-germ and 3.22 to 5.64 mm and 3.03 to 4.13 mm respectively for mono-germ. The above regression equation showed that every increase of 1 mm seed length decreases the sphericity (ϕ) about 0.44% at constant all other dimensions. While at increasing the seed width and thickness, the sphericity (ϕ) increased about 0.83 and 1.36% respectively for the multi-germ. The same trend was found for mono-germ.

The equations of geometric mean diameters (Dg) of sugar beet function are found as:

$Dg = 1.74L + 2.21W + 5.56T$

$R^2 = 0.97$ for multi -germ

$Dg = 4.31L + 1.04W + 0.02T$

$R^2 = 0.99$ for mono-germ

From above equations the "Dg" values are directly proportional with main dimensions of sugar beet seeds.

The equations of arithmetic mean diameters (Da) of sugar beet function are found as:

$Da = 0.31L + 0.23W + 0.36T$

$R^2 = 0.90$ for multi -germ

$Da = 0.23L + 0.38W + 0.22T$

$R^2 = 0.92$ for mono-germ

Also the "As" and "Tv" prameters are found as:

$As = 20.43L + 25.14W - 12.77T$

$R^2 = 0.99$ for multi -germ

$As = 24.14L + 15.91W - 15.15T$

$R^2 = 0.99$ for mono-germ

and

$Tv = 0.11L + 0.112W + 0.09T$

$R^2 = 0.98$ for multi -germ

$Tv = 0.136L + 0.341W + 0.27T$

$R^2 = 0.99$ for mono-germ

From the above regressions analysis, the highest positive effective factors affecting the approximation physical sugar beet seeds properties is the width of sugar beet for multi-germ while the length is more effective for mono-germ seeds.

3.1.3 Sugar beet bulk density

The bulk and true densities of sugar beet seed were presented in Table 1. The denote of seed bulk densities were about 0.28±0.009 and 0.44±0.003 g/cm^3 at seed species of multi and mono-germ respectively. But, the average true densities were 0.46±0.153 and 0.75±0.14 g/cm^3 respectively, for multi and mono-germ.

3.2 Sugar beet engineering properties

Some engineering properties of sugar beet seed such as static coefficient of friction, seed terminal velocity and seed hardness were determined. Figure 5 shows the mean and standard deviation values of the coefficient of friction for sugar beet seeds at the two sugar beet seed species.

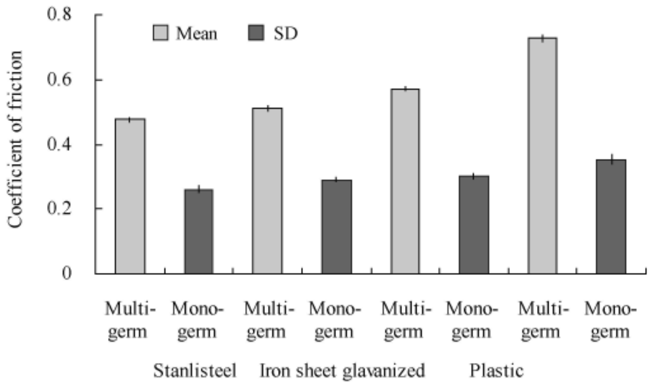


Figure 5 Coefficients of sugar beet seed friction (Ismail *et al*., 2009)

The static coefficient of friction for sugar beet seed multi-germ under different coefficient surfaces (stainless steel, iron sheet galvanized, plastic and rubber) were 0.48±0.42; 0.51±0.56, 0.57±0.34 and 0.72±0.53 respectively whereas, the data for the sugar beet mono-germ were 0.26±0.57; 0.28±0.38; 0.30±0.34 and 0.36±0.74 respectively.

Table 2 shows the mean, maximum, minimum, SD and CV% for the terminal velocity (Tv) and seed hardness values. The data cleared that the mean of terminal velocity and seed hardness for multi-germ species were 1.65±0.16 m/s and 17.64±1.67 N respectively. But for the mono-germ data were 3.04±0.26 m/s and 23.29± 2.42 N respectively.

Table 2 Terminal velocity and hardness of sugar beet seeds

Seed species	Engineering properties	Mean	Max.	Min.	SD	CV/%
Multi-germ	Terminal velocity /m • s^{-1}	01.65	02.27	01.48	±0.16	9.86
	Hardness/N	17.64	20.40	15.10	±1.67	9.46
Mono-germ	Terminal velocity /m • s^{-1}	03.05	03.83	02.35	±0.26	8.63
	Hardness/N	23.29	27.70	20.10	±2.42	10.37

3.3 Evaluation of the brush device

3.3.1 Quality of feed index

3.3.1.1 Effect of hair density of brush device on the feed index

The seed feed index was evaluated as ratio. According to the results of the variance analysis for all hair density of brush device affect the seed feed index at 1% ($P < 0.01$) significance. In addition, as a result of Duncan's test (χ^{-1}), the differences between the seed feed index of sugar beet varieties were statistically significant for the 3 types of hair density Table (3). The highest seed feed index was achieved on the hair density with 100 hair per hole (Hd_3) of brush device seed meter for all sugar beet varieties (multi-germ and mono-germ). The lowest seed feed index was obtained from the experiments using the brush device with hair density of 50 hair per hole (Hd_1).

Table 3 Effect of hair density per hole on seed feed index

Sugar beet variety	Seed feed index, %			
	Hd_1	Hd_2	Hd_3	χ^{-1}
Multi-germ	69.09	76.85	83.07	76.33
Mono-germ	66.78	74.87	80.56	74.07

3.3.1.2 Effect of brush device peripheral speed on seed feed index

For each sugar beet varieties, it was determined that the peripheral speed of the brush device was affected by the seed feed index at 1% ($P<0.01$) significance and there were statistical differences between the seed feed index and the hair density Table 4. An increase in the peripheral speed of the brush device caused the seed feed index to drop. In other words, when the peripheral speed of the brush device increased, the empty feed number on the brush device also increased. The highest seed feed index was achieved in Hd_3 (71.85%) at the plate speed of 0.16 m/s, whereas the lowest seed feed index was obtained in Hd_1 hair density (29.75%) at the speed of 0.40 m/s. As can be seen from Table 4, the seed feeding index decreased with an increase in the brush device speed for different sugar beet varieties. Based on seed varieties, there were important differences between the seed feed index means of seed varieties (at χ^{-1} column). When the feeding speed was increased from 0.16 m/s to 0.40 m/s, the seed feed index of Hd_1, Hd_2 and Hd_3 hair density dropped 49.17%; 35.86%; and 38.52% respectively for sugar beet multi-germ, according to the seed feed index in the velocity of 0.16 m/s. The worst seed feed index was obtained with Hd_3 when the speed was increased because of its extra hair density per hole of feeding device. The changing of the brush device speed affected the seed feed index of Hd_3 multi-germ more than the mono-germ seeds.

Table 4 Effect of brush device peripheral speed on seed feed index

Seed brush peripheral Speed/m • s^{-1}	Seed feed index/%							
	Hd_1		Hd_2		Hd_3		Duncan test χ^{-1}	
	Multi-germ	Mono-germ	Multi-germ	Mono-germ	Multi-germ	Mono-germ	Multi-germ	Mono-germ
0.16	58.52	53.32	63.05	59.34	71.85	68.98	64.47_d	60.55_d
0.24	49.30	43.95	56.04	49.98	63.71	62.12	56.35_c	52.02_c
0.32	39.20	31.97	48.03	37.39	55.26	49.98	47.50_b	39.78_b
0.40	29.75	31.89	40.45	33.32	44.17	41.56	38.12_a	34.44_a
Average (X$^-$)	44.19	40.28	51.90	45.01	58.75	55.66	51.61	

Note: Differences at 1% level, Hd is the hair density per hole in the brush device.

3.3.1.3 Effect of planting speed on the seed feed index

This relation was carried out only for multi-germ of sugar beet seed. It was found that the planting speed (1.0, 2.0, 3.0 and 4.0 km/h) affected the seed feed index at 1% ($P<0.01$) significance. The mean differences between the seed feed index of the planting speed levels (χ^{-1}) were significant according to the results of Duncan's test (Table 5). The planting speed affect the seed feed index. It is inversely proportional and while the planting speed was increased the value of the seed index decreased. As shown in Table 5, the highest seed feed index was with Hd_3 (86.73%) at 1.0 km/h, whereas the lowest seed feed index was with Hd_1 (35.98%) at 3.0 km/h. These results synchronize with the result of[8]. The seed feed index was 86.73%, 79.77% and 74.56% for Hd_3, Hd_2 and Hd_1 hair density of feeding device at 1.0 km/h planting speed, while at 4.0 km/h the seed feed index was 71.04%, 61.07% and 46.21%, respectively. In general, the altering in planting speed is effected on seed feed index, but it is more effect at hair density of Hd_3 than the other

2 hair density (Hd_1 and Hd_2).

Table 5 Effect of planting speed on the seed feed index (Multi-germ)

Planting speed /km • h^{-1}	Seed feed index/%			
	Hd_1	Hd_2	Hd_3	χ^{-1}
1.0	74.56	79.77	86.73	80.35
2.0	60.34	60.36	76.52	65.74
3.0	35.98	46.87	56.28	46.38
4.0	46.21	61.07	71.04	59.44
X^{-}	54.27	62.08	72.65	62.98

Note: Differences at 1% level.

3.3.2 Quality of miss index

3.3.2.1 Effect of hair density of brush device on the miss index

The relationship between the hair densities of brush device on the seed miss index at different seed variety are illustrated in Figure 6. The general trend of above treatment is that as the hair density of brush feeding device increases the seed miss index decreases. The rate of decreasing was 0.87 times.

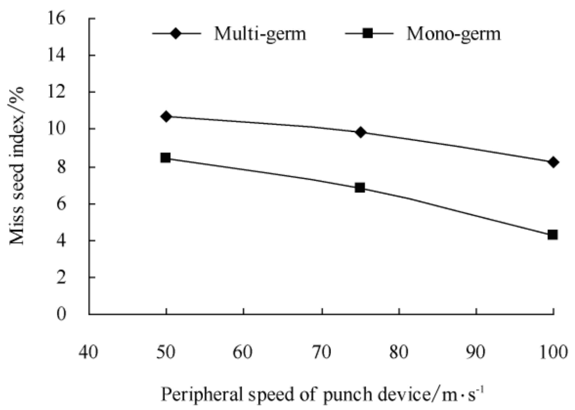


Figure 6 Effect of hair density of brush device on the miss index

3.3.2.2 Effect of the peripheral speed of the seed plate on the misses index

Figure 7 illustrates the relationship between the values of seed miss index (y) and the brush device peripheral speed (x). An increase in the peripheral speed of the brush device cause the seed miss index to improve. In other words, when the peripheral speed of the seed plate increased, the empty feed number on the seed plate also increased. The highest seed miss index was achieved for multi-germ seed (12.4%) at the plate speed of 0.4 m/s, whereas the lowest seed miss index was obtained for mono-germ seed at the speed of 0.40 m/s. The power regression for above relation was found as follows:

$y = 26.73x^{0.9545}$ $R^2 = 0.95$ for multi-germ

$y = 34.16x^{1.3815}$ $R^2 = 0.95$ for mono-germ

Where: y is the seed miss index and x is the brush device peripheral speed.

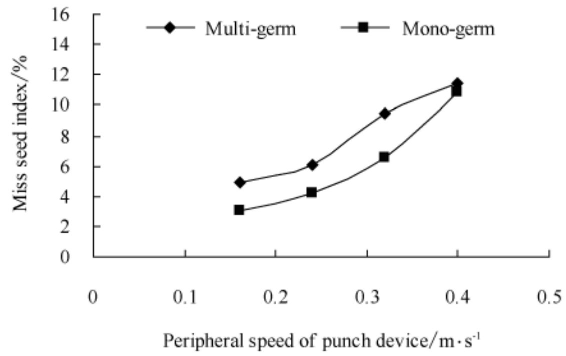


Figure 7 Effect of feeding disc peripheral speed on the seed miss index

3.3.2.3 Effect of planting speed on the seed miss index

Graph in Figure 8 demonstrate the effect of planting speed on the amount of seed miss in percentages. Increasing the planting speed with constant peripheral disc speed increases the seed miss index. The data analyses indicated no significant effect between the types of seed differences.

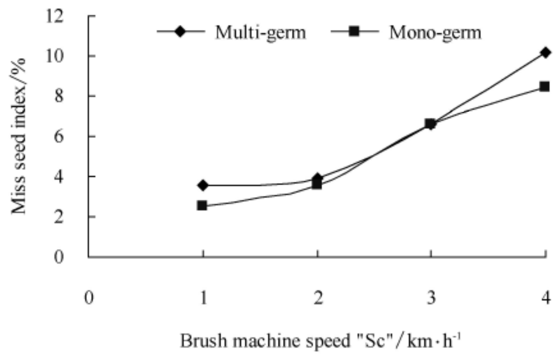


Figure 8 Effect of seeding speed on the seed miss index

Using regression analysis, the relationship between seeding speed and seed miss index was computed for the average data of sugar beet varieties as follows:

$Mi = 2.226\, e^{0.365\, Ss}$ $R^2 = 0.93$ for Multi-germ

$Mi = 1.732\, e^{0.432\, Ss}$ $R^2 = 0.96$ for Multi-germ

Where: M_i is the seed miss index; S_s is the brush machine speed at experimental data ranged.

3.3.3 Quality of multiple index

The effect of hair density of brush device, brush device peripheral speed and planting speed on the seed multiple indices are illustrated in Figure 9 and the domino effect of analysis are given in Tables 6 and 8. All measurement of operation parameters were affected by two sugar beet varieties.

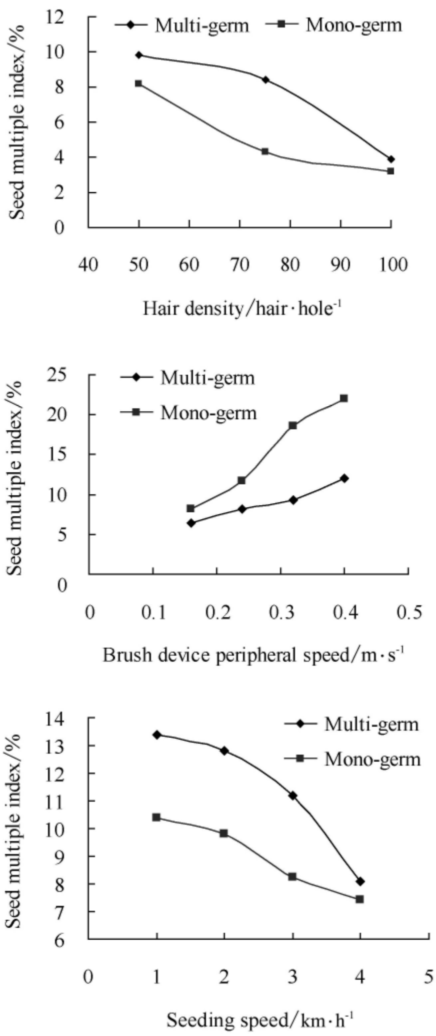


Figure 9 Effect of hair density, peripheral speed and seeding speed on the multiple indices

The data analysis in tables show that hair density, brush device peripheral speed, m/s and planting speed (1.0, 2.0, 3.0 and 4.0 km/h) affected the multiple index at 1% ($P<0.01$) significance. The differences between the seed multiple index means of hair density, brush device peripheral speed and planting speed levels (χ^{-1}) were significant according to the results of Duncan's test (Tables 6, 7 and 8). The relation in Figure 10 indicated that the seed multiple index decreased by increasing each of hair density per hole and seeding speed but the decreasing rate affecting seeding speed is more than the hair density effect and the vice versa at increasing the peripheral speed of feeding disc.

Table 6 Multiple indexes as affected by hair density of brush device

Sugar beet variety	Multiple index/%			
	Hd_1	Hd_2	Hd_3	χ^{-1}
Multi-germ	10.7	9.8	7.3	9.57
Mono-germ	6.8	8.4	3.9	6.50

Table 7 Seed multiple indices via peripheral speed for multi-germ

Brush device peripheral speed/m • s^{-1}	Seed multiple index/%			
	Hd_1	Hd_2	Hd_3	χ^{-1}
0.16	11.2	8.1	6.4	8.90^{d}
0.24	12.2	11.7	8.2	11.03^{b}
0.32	11.4	18.6	9.3	14.43^{c}
0.40	18.2	22.0	12.0	18.73^{a}
X^{-}	13.25	15.10	8.67	13.28

Table 8 Effect of planting speed on the multiple indices

Planting speed /km • h^{-1}	The multiple index; % for multi-germ seed			
	Hd_1	Hd_2	Hd_3	χ^{-1}
1.0	17.9	10.4	13.4	13.90
2.0	16.7	9.8	12.8	13.10
3.0	15.1	8.23	11.2	11.51
4.0	13	7.42	8.1	9.51
X^{-}	15.68	8.96	11.38	12.00

3.3.4 Quality of precision index

Data in Figure 10 demonstrate the effect of hair density of brush device, its peripheral speed and planting speed on the amount of seed precision in percentages. Increasing the planting speed with constant peripheral disc speed decreases the seed space distance. Consequently, the percentage of seed precision is decreased until average seeding speed of 2.1 km/h after that the precision index increased. The same trend is found at affecting the peripheral speed.

The data analysis in Tables 9, 10 and 11 show that hair density, seed plate peripheral speed, m/s and planting speed (1.0, 2.0, 3.0 and 4.0 km/h) affected the precision index at 1% ($P<0.01$) significance as shown in Figure 10. The differences between the seed multiple index means of hair density, peripheral speed and planting speed levels (χ^{-1}) were significant according to the results of Duncan's test (Tables 9, 10 and 11). The lower values of precision index indicate better performance of the brush device, therefore the lowest values of it was found at seeding speed of 2.0 m/s, 0.3 m/s peripheral speed of feeding device and 100 hair/hole density.

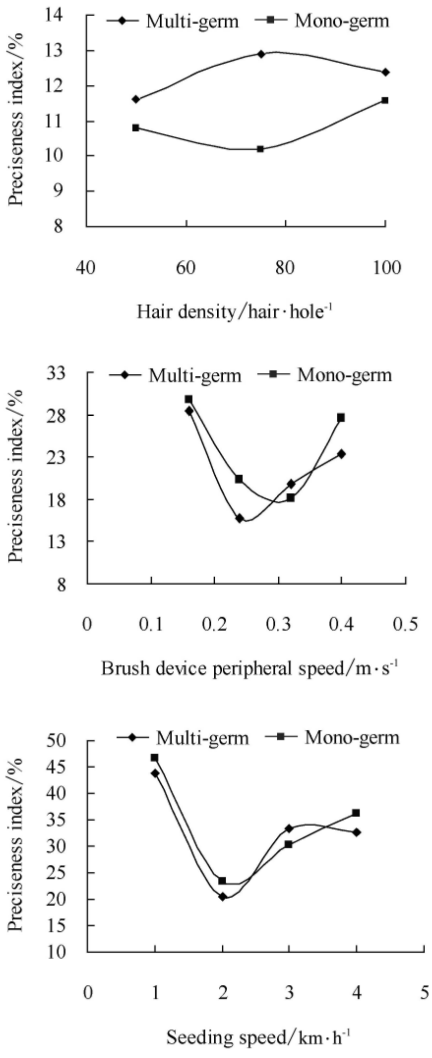


Figure 10 Effects of hair density, peripheral speed and seeding speed on the precision indices

Table 9 Sugar beet type in relation to precision index

Sugar beet type	Precision index/%			
	Hd_1	Hd_2	Hd_3	χ^{-1}
Multi-germ	15.3	11.6	10.8	12.57
Mono-germ	16.5	12.9	10.2	13.20

Table 10 Effect of seed plate peripheral speed on precision index

Seed plate peripheral Speed/m • s-1	Precision index/%			
	Hd_1	Hd_2	Hd_3	χ^{-1}
0.16	28.4	29.8	35.4	31.2
0.24	15.7	20.3	32.7	22.9
0.32	19.9	18.2	18.7	18.93
0.40	23.4	27.6	31.6	27.53
X^-	21.85	23.98	29.60	25.14

Table 11 Effect of planting speed on precision index

Planting speed /km • h-1	Precision index/%			
	Hd_1	Hd_2	Hd_3	χ^{-1}
1.0	43.8	46.7	48.6	46.37
2.0	20.4	23.3	28.2	23.97
3.0	30.3	33.4	36.9	33.53
4.0	32.7	36.1	38.9	35.90
X^-	31.75	34.88	38.15	34.94

Note: Differences at 1% level.

4 Conclusions

The conclusions of this paper can be summarized as follows:

- The mean of the sugar beet multi-germ seeds length, width and thickness were 6.14, 5.31 and 4.18 mm respectively. While, the corresponding dimensions for sugar beet species of mono-germ were 4.33, 3.91 and 3.23 mm respectively.
- The regression equation between the sphericity (ϕ) and the dimensions of seed show that the increase of 1mm seed length decreases the sphericity (ϕ) about 0.44% while the other seed dimensions is constant. whilst at increasing the seed width and thickness, the sphericity (ϕ) increased about 0.83% and 1.36% respectively for the multi-germ. The same trend was found for mono-germ.
- The static coefficient of friction for sugar beet seed multi-germ under different coefficient surfaces (stainless steel, iron sheet galvanized, plastic and rubber) were 0.48±0.42; 0.51±0.56, 0.57±0.34 and 0.72±0.53 respectively, whereas, the data for the sugar beet mono-germ were 0.26±0.57; 0.28±0.38;

0.30±0.34 and 0.36±0.74 respectively.

- The obtained results add more power to the necessity of utilize the vertical brush metering device to plant the ordinary types of sugar beet seeds (multi or mono germs) because:-

1) The highest seed feed index was achieved on the hair density with 100 hair per hole (Hd_3) of brush device seed meter for all sugar beet varieties (multi-germ and mono-germ).

2) As the brush device peripheral speed is increased from 0.16 m/s to 0.40 m/s, the seed feed index of Hd_1, Hd_2 and Hd_3 hair density dropped 49.17%; 35.86%; and 38.52% respectively for sugar beet multi-germ, according to the seed feed index in the velocity of 0.16 m/s.

3) The seed feed index was 86.73%, 79.77% and 74.56% for Hd_3, Hd_2 and Hd_1 hair density of feeding device at 1.0 km/h planting speed, while at 4.0 km/h the seed feed index was 71.04%, 61.07% and 46.21%, respectively.

4) The optimum operation of brush metering device is found at seeding speed of 2.0 m/s, 0.3 m/s peripheral speed of feeding device and 100 hair/hole densities.

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