Measuring some physical properties of sunflower (helianthus annus l.) head and modeling dimensions

Amir Hossein Mirzabe*, JavadKhazaei, Gholam Reza Chegini

(Department of Mechanical Engineering of Biosystems, Aboureihan College, University of Tehran, Tehran, Iran)

Abstract: For 100 sunflower head, maximum and minimum diameters, thickness, height of the ground, and mass of all seeds on sunflower head (SH) for five conventional varieties were measured. To examine the correlation between maximum SH diameter and minimum SH diameter, SH thickness, SH height from the ground and SH seeds mass, linear regression method was used. Also SH diameter and SH thickness of four sunflower hybrids varieties were measured. Log-normal, Weibull and Generalized extreme value (G.E.V) distribution were used in order to model SH diameter and SH thickness distributions of all varieties and hybrids; also, Kolmogorov-Smirnov methods were used for comparison of all probability density. Results indicated that value of average of dimensions, geometric and arithmetic mean diameter, head height from the ground, and mass of the seeds on each head of Dorsefid and Sirena varieties were more and less than the other varieties, respectively. For all varieties, there was linear correlation between maximum SH diameter and minimum SH diameters, SH thickness and mass of seeds; while there wasn't any correlation between SH height and maximum SH diameter. Results showed that whenever skewness and kurtosis had positive values, Log-normal and G.E.V distribution had good performance and whenever skewness and kurtosis had negative values, Weibull and G.E.V distribution had good performance based on Kolomogrov-Smirnov methods.

Keywords: thresher machine, image processing technique, modeling, generalized extreme value, Log-normal, Wiebull

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1 Introduction

Sunflower is a plant of Composita family, Helianthus genus and Annus species. Sunflower is one of the most important oil crops due to its high amount of unsaturated fatty acids and also absence of cholesterol (Razi and Assad 1998; Darvishzadeh et al. 2010). Along with soybean, canola, and cotton, sunflower contributes considerably to the edible vegetable oil market. Sunflower oil has a light color, a bland flavor, a high smoke point, and contains a relatively high concentration of the polyunsaturated fatty acid, linoleic acid. This fact makes sunflower oil a premium cooking oil and one of the major vegetable oils used in the food manufacturing industry (Chandrasekaran, 2012).

Iran and many developing countries rely heavily on imports of edible oil to offset the low production levels of oil crops for they cannot meet the growing demands of oil factories. In Iran, sunflower is usually cultivated in small farmers. The area under sunflower production in Iran has been on the increase; but in Iran and many developing countries there are many problems for sunflower planting such as: pest's damage, poor soil fertility, diseases damage, water stress (Nderitu et al. 2008) and non-availability of suitable machinery for sunflower's sowing, harvest, post-harvest and oil extraction operations(Goel et al., 2009; Mirzabe et al., 2012; Mirzabe et al., 2014).

Due to non-availability of suitable machinery for sunflower harvest and post-harvest operations, farmers follow manual methods. During harvesting and threshing of sunflowers using manual methods, the most time and labor-consuming operation is the threshing of sunflower by beating the sunflower heads with a stick, by rubbing wear heads against a rough metal surface, or by

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***Corresponding author: Amir Hossein Mirzabe,** Department of Mechanical Engineering of Biosystems, Aboureihan College, University of Tehran, Tehran, Iran, Tel: +98-9399442161; Fax: +98-21-36040614; Email: a_h_mirzabe@alumni.ut.ac.ir.

power tiller treading (Mirzabe et al., 2012; Goel et al., 2009). The capacity and efficiency for these threshing methods are very low, and impurities are very high. Farmers in some areas thresh sunflowers with rice or soybean threshers. The results indicated that these types of threshers are not efficient for threshing sunflowers (Sudajan et al., 2002).

However, decreasing the power consumption, the complexity of sunflower thresher machines and reducing the number of the damaged seeds, as well as increasing its efficiency, are the main problems in many developing countries; so, in such countries, these machines should be redesigned or optimized or new methods should be used to remove the sunflower seeds from their heads. Today, air-jet impingement and water-jet impingement have many applications in industry, food science and agriculture. Jet impingement is one of the efficient methods to remove the arils of pomegranate fruits and extract the citrus juice and juice sacs (Hayashi et al., 1981; Nahir and Ronen, 1992; Sarig et al., 1985; Schmilovitch et al., 2014). This method can be used to remove sunflower seeds from their head. Therefore, design and construction of sunflower remover machine based on air-jet impingement were considered.

For the designing, construction and regulation of any machine suitable for removing sunflower seeds, physical and mechanical properties of different parts of sunflower such as stem, head, seeds and kernels must be known. There are many researches published on the physical, mechanical and morphological properties of sunflower seeds. Fracture resistance of sunflower seeds and kernels to compressive loading was calculated by Gupta and Das (2000). Aerodynamic properties and terminal velocity of sunflower seeds were measured by Gupta et al. (2007). Some Physical and morphological properties of wild sunflower seeds were investigated by Perez et al. (2007). Some physical properties of sunflower seeds and kernels related to harvesting and hulling systems were studied by Khazaei et al. (2006). Diversity of sunflower pollinators and their effect on seed yield in Makueni district, eastern Kenya was examined by Nderitu et al. (2008).

Head of sunflower is an important part of the plant of which information is needed for harvesting operations and designing thresher machines. Thickness, diameter and height of head are three practical parameters for designing and regulating combined harvester and thresher machines. Santalla et al. (2002) investigated the effects of intercepted solar radiation on sunflower seed composition from different head positions. Munshi et al. (2003) investigated the compositional changes in seeds influenced by their positions in different whorls of mature sunflower head. Yeatts (2004) exhibited a growth-controlled model of the shape of a sunflower head.

Literature review showed that there is no published work on dimensional parameters on sunflower head. For a single head, diameter and thickness can be determined; but they vary for each individual head. For designing and regulating harvesting, threshing and separating machines, the frequency distributions of diameter and thickness of a set of sunflower heads need to be described. For the description of the diameter, thickness, height, weight and some other cases, lots of continuous distributions have been used. The most common functions that have been used to describe diameter, thickness, weight and height, distributions are the normal distribution, two-parameter and three-parameter Weibull distribution, two-parameter and three-parameter Log-normal distribution, gamma distribution, extreme value distribution and generalized extreme value distribution.

There are many published literature in different science on modelling parameters by continuous distributions. The effect of impact angle and velocity on the fragment size distribution of glass spheres were investigated by Cheong et al. (2003). Modelling fragment size distribution using two-parameter Weibull equation was investigated. Log-normal, Normal and Weibull distributions for modeling the mass and size distributions of sunflower seeds and kernels were investigated by Khazaei et al. (2008). In order to find the statistical model that best describes the pattern of fruit growth of sweet orange, Logistic, Gompertz, Weibull, Morgan Mercer Flodin, Richards, and re-parameterizations of the Logistic and Gompertz models were evaluated and compared by Avanza et al. (2008). Sample size dependence of flaw distributions for the prediction of brittle solids strength using additive Weibull bimodal distributions was studied by Zinck (2011).

The aim of the present work was determining the SH diameter and SH thickness for designing feeding mechanism of a new thresher machine for sunflower head; therefore, maximum SH diameter, minimum SH diameter and SH thickness for 100 SHs of five conventional varieties and 80 SHs of four hybrid varieties were measured. Height of each SH from the ground for 100 SHs of five conventional varieties was measured. The linear regression method was used to examine the correlation between maximum SH diameter and minimum SH diameter, SH thickness, SH height from the ground, and SH seeds mass. In order to model the maximum SHs diameter and SHs thickness, three-parameter Log-normal distribution, three-parameter Weibull distribution, and Generalized Extreme Value distribution were used.

D_a	Arithmetic mean diameter, mm	T	Thickness of sunflower head, mm
D_g	Geometric mean diameter, mm	W	Width, mm
D_1	Maximum mean diameter, mm	φ	Sphericity, %
D_2	Minimum mean diameter, mm	α	Location parameter in Weibull distribution
$f(x)$	Probability density function	$\boldsymbol{\beta}$	Scale parameter in Weibull distribution
$F(x)$	Cumulative density function	$\boldsymbol{\gamma}$	Shape parameter in Weibull distribution
H	Height of sunflower head, mm	$\boldsymbol{\theta}$	Location parameter in lognormal distribution
Ks	Kolmogorov-Smirnov index	λ	Scale parameter in lognormal distribution
L	Length, mm	μ	Location parameter in G. E. V distribution
M	Mass of sunflower head, g	ξ	Shape parameter in G. E. V distribution
SH	Sunflower head	τ	Shape parameter in lognormal distribution
SHs	Sunflower heads	ψ	Scale parameter in G. E. V distribution
STD	Standard deviation		

2 Materials and method

2.1 Sampling preparation

Five conventional varieties of sunflowers, widely cultivated in Iran namely Mikhi, Songhori, Dorsefid, Shamshiri, and Sirena, were used in the present work. Mikhi, Songhori, Dorsefid and Shamshiri varieties are native of Iran. Mikhi and Songhori varieties were planted on June 17th, 2011 in local farms of Foodan located on Shahreza, Isfahan province, Iran (longitude of 31.59 ° N, latitude of 51.50 ° E, average annual Precipitation 135 mm from 2000 to 2010, height above the sea level of 1845 m, average annual temperature of 14.7 ℃ from 1993 to 2010). Dorsefid, Shamshiri, and Sirena varieties were planted on April 27th, 2012 in the research farms of the University of Tehran, located on Pakdasht, Tehran province, Iran (longitude of 35.47 °N, latitude of 51.67 °E, average annual precipitation 110 mm from 2000 to 2010, height above the sea level of 1025 m, average annual temperature of 18.0 ℃ from 1993 to 2010). Getting data for Dorsefid, Shamshiri and Sirena varieties was carried out in late September, when sunflowers matured completely. For Mikhi and Songhori varieties, getting data was carried out in late October. According to the time of plantation and harvesting of different varieties, it is because of different genetic characteristics of these varieties and also the climatological conditions of the plantation area that some varieties have reached maturation about 15 days before others (varieties planted in Pakdasht, i.e. Dorsefid, Shamshiri, and Sirena, reached maturation 15 days after those planted in Foodan, i.e. Mikhi and Songhori).

In the present work, also, four hybrids of sunflowers, namely Aline 1221/1*R-14, Farokh, Aline 19*R-1031, and Euroflor, which are not widely cultivated in Iran, were used. All the hybrids used in the present research were planted in late June, 2011 in local farms of Karaj, Alborz, Iran (longitude of 35.55 °N, latitude of 50.99 °E, average annual Precipitation 248 mm from 2000 to 2010, height above the sea level of 1312 m, average annual temperature of 15.1 ℃ from 1993 to 2010). Getting data for all hybrids was carried out in late October, when sunflowers matured completely.

2.2 Getting data

From each conventional variety (Dorsefid, Mikhi, Shamshiri, Sirena and Songhori), 100 sunflower heads with different sizes were selected randomly; while from each hybrids variety (Aline 1221/1*R-14, Farokh, Aline 19*R-1031, and Euroflor), 80 sunflower heads with different sizes were selected randomly. Statistically, when the number of repetition of data was more than 30, the obtained results are considered as accurate, and with increasing number of repetitions, the accuracy also increases. As the area of the planted zone for conventional varieties is far more than that for hybrid varieties; also, as our concentration was on conventional varieties, more heads were chosen from conventional varieties, because when the machine is built, it would be usually used for the conventional varieties, not the hybrid ones. Before the harvesting sunflower heads, heights of the sunflower heads were measured. Then the selected sunflower heads were harvested manually after SHs were matured completely. For harvesting, the SHs were grabbed by one hand and the other hand cut the head using a sickle.

2.2.1 Height of the sunflower head

Height of the SHs is one of the most important parameters in regulate of harvester machines. For regulation of harvester head height in harvesting sunflowers using a combined machine, the maximum, minimum, and average head height of sunflowers must be known. Heights of the sunflower heads of Dorsefid, Shamshiri, Mikhi, Songhori, and Sirena varieties were measured (in other words height of the sunflower head of conventional varieties was measured; while, height of the sunflower head of hybrids wasn't measured). As the area of the planted zone for conventional varieties is far more than that for hybrid varieties; also, because hybrid varieties have undergone genetic corrections, their height is lower than conventional ones, and also their range of height is very limited, and our concentration was on conventional varieties, so the height of the hybrid varieties was not measured. Height of the sunflower head is considered as the distance between the center of sunflower head and the earth surface (Figure 1). Height of the each sunflower head was measured using flexible meter with 500 cm length and an accuracy of 1 mm.

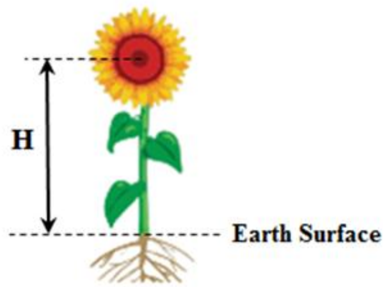

Figure 1 Height of the sunflower head

Source: retrieved from https://en.wikipedia.org/wiki/Function-spacer-lipid_construct on May 20, 2015

2.2.2 Mass of seeds

In order to measure the efficiency of the thresher machine, the total mass of all the seeds on a single SH must be known; therefore, the total mass of the all the seeds on each sunflower head were measured. Mass of seeds of Dorsefid, Shamshiri, Mikhi, Songhori, and Sirena varieties was measured (in other words mass of seeds of conventional varieties was measured; while, mass of seeds of hybrids wasn't measured). Seeds of each SH were removed manually. In order to manually remove the seeds, the sunflower heads rubbed over a piece of metal and rubbed the sunflower heads on the earth. Total seeds of each sunflower head collected and unwanted debrises and materials were removed from the seeds. Mass of the total seeds of each SH was measured using digital balance with an accuracy of 0.1 g (KERN, Japan, PLS 360-3).

Seeds moisture content was measured after measurement of the seeds mass. The seeds were cleaned manually to remove all foreign materials. The moisture content of each sample was determined using the standard hot air oven method at 105±1°C for 24 hours (Gupta and Das, 1997; Altuntaş et al., 2005). Average value of moisture content of seeds of five samples of Dorsefid, Shamshiri, Mikhi, Songhori, and Sirena varieties were 24.55%, 25.22%, 25.36%, 24.09% and 26.05% wet basis (w.b), respectively. In other words, dry basis moisture content of the seeds of Dorsefid, Shamshiri, Mikhi, Songhori, and Sirena varieties equals to 32.54%, 33.74%, 33.97%, 31.74% and 35.23% (d.b), respectively.

2.2.3 Head thickness

Sunflower head thickness is one of the most important parameters to design thresher machines; the parameter had great effect on dimensions of the different parts of the thresher machines such as feeding systems. Head thickness of five conventional varieties and four hybrids were measured. For measuring the head thickness image processing technique was used.

2.2.4 Head diameter

Sunflower head diameter had great effect on the picking force of sunflower seeds from their head and the picking force of sunflower seeds from their head is one of the most important parameters to design sunflower thresher machine(Mirzabe and Chegini, 2015). Also sunflower head diameter had great effect on dimensions of the different parts of the thresher machine such as feeding systems(Mirzabe and Chegini, 2015; Mirzabe et al., 2014). Head diameter of five conventional varieties and four hybrids were measured. For each SH, several diameters were measured in different directions, and the maximum and minimum values were accepted (D1and D2, respectively). Diameter of each head was measured using image processing technique.

2.2.5 Image processing setup

The image processing system consisted of a camera (Canon, IXY 600F, Japan) with 3X IS lens capable of filming up to 120 frames per second (fps) and 12.1 megapixels, USB connection, four white-colored fluorescent lamps (32 W) and a laptop computer (DELL, INSPIRON 1558, China) equipped with Matlab R2012a software package. The camera was mounted on an image processing box (Mansouri et al., 2015b; Mansouri et al., 2015a). Each sunflower head was placed at the center of the camera’s field of view and three metal spheres with the same and identified diameters were placed at the side (three different positions) of the sunflower head; then two RGB color images were captured from up view and front view of sunflower head. The original color image of each sunflower head and each metal sphere was converted to an eight-bit grayscale image by Photoshop software package. Eight-bit grayscale intensity represents 256 different shades of gray from black (0) to white (255). The eight-bit grayscale images were digitized to binary image by using binary transformation on the basis of all the pixels with a brightness level which was the average of the brightness levels of the three channels (Uozumi et al., 1993; Mansouri et al., 2015b). The threshold value of sunflower heads was determined experimentally by Photoshop software package(Koc, 2007; Mansouri et al., 2015b). The holes and noise of binary images are filled by morphological closing and opening (Li et al., 2012; Mansouri et al., 2015b). The pixels showing the melon seed and kernel boundary had the value of 0 and the remainder of the pixels in the image had the value of 255. The number of pixels representing the diameter and thickness of the sunflower head was also measured on the captured images using Matlab R2012.

2.3 Dimensional properties

Maximum diameter, minimum diameter and thickness of SHs were measured using caliper with an accuracy of 0.1 mm. According to the SH diameter in two directions and SH thickness, geometric mean diameter, arithmetic mean diameter and sphericity of SHs were calculated using the Equation 1, Equation 2 and Equation

3 (Mirzaee et al., 2009; Kibar et al., 2010; Shahbazi et al., 2011; Taghi Gharibzahedi et al., 2011):

$$\mathbf{D_g = \sqrt[3]{LWT} = \sqrt[3]{D_1 D_2 T}} \qquad (1)$$

$$\mathbf{D_a = \frac{L+W+T}{3} = \frac{D_1+D_2+T}{3}} \qquad (2)$$

$$\boldsymbol{\varphi} = \left(\frac{\sqrt[3]{\mathbf{LWT}}}{\mathbf{L}}\right)\times \mathbf{100} = \left(\frac{\sqrt[3]{\mathbf{D_1 D_2 T}}}{\mathbf{D_1}}\right)\times \mathbf{100} \qquad (3)$$

2.4 Statistical analysis

For each set of the diameter, thickness, height and mass of the seeds data, the skewness and kurtosis values were calculated to determine whether the data were normally distributed. The skewness and kurtosis were calculated using the Equation 4 and Equation 5 (Mirzabe et al., 2012; Khazaei et al., 2008; Lucian, 2006):

$$\mathbf{skewness} = \left(\frac{\mathbf{n}}{(\mathbf{n}-\mathbf{1})(\mathbf{n}-\mathbf{2})}\right)\left\{\sum_{\mathbf{i=1}}^{\mathbf{n}}\left(\frac{\mathbf{x_i - x_{avr}}}{\mathbf{s}}\right)\right\} \qquad (4)$$

$$\mathbf{kurtosis} = \left\{\left[\frac{\mathbf{n(n+1)}}{\mathbf{(n-1)(n-2)(n-3)}}\right]\sum_{\mathbf{i=1}}^{\mathbf{n}}\left(\frac{\mathbf{x_i - x_{avr}}}{\mathbf{s}}\right)^{\mathbf{4}}\right\} - \frac{\mathbf{3(n-1)^2}}{\mathbf{(n-2)(n-3)}} \qquad (5)$$

Where: n is number of occurrence; x_i is midpoint of each class interval in metric; x_{avr} is mean head parameter (diameter, thickness, height); s is standard deviation.

2.5 Modeling methods

For five conventional varieties and four hybrids, SH diameter and SH thickness distributions were modeled with three probability density functions. These functions were: (1) log-normal, (2) Generalized Extreme Value (G.E.V) and (3) Weibull. The probability density function and cumulative frequency for the models are described in Table 1.

Table 1 The probability density function and cumulative frequency for lognormal, Generalized Extreme Value and Weibull distribution

Distribution name	Probability density and Cumulative frequency Functions		Reference
Log-normal	Probability density	$\mathbf{f(x)} = \left(\frac{\mathbf{1}}{(\mathbf{x}-\boldsymbol{\theta})\,\boldsymbol{\tau}\sqrt{\mathbf{2\pi}}}\right)\mathbf{exp}\left(-\frac{\mathbf{1}}{\mathbf{2}}\left(\frac{\mathbf{ln(x-\boldsymbol{\theta})-\boldsymbol{\lambda}}}{\boldsymbol{\tau}}\right)^2\right)$	(Aristizabal 2012; Nanang, 1998)
	Cumulative frequency	$\mathbf{F(x)} = \phi\left(\frac{\mathbf{ln(x-\boldsymbol{\theta})-\boldsymbol{\lambda}}}{\boldsymbol{\tau}}\right)$, $\phi(\mathbf{x}) = \left(\frac{\mathbf{1}}{\sqrt{\mathbf{2\pi}}}\right)\int_{\mathbf{0}}^{\mathbf{x}} \mathbf{e}^{-\mathbf{t}^2/2}\,\mathbf{dt}$	
Generalized extreme value	Probability density	$\mathbf{f(x)} = \frac{\mathbf{1}}{\boldsymbol{\psi}}\left[\mathbf{1}+\boldsymbol{\xi}\left(\frac{\mathbf{x}-\boldsymbol{\lambda}}{\boldsymbol{\psi}}\right)\right]^{(-1/\xi)-1}\mathbf{exp}\left\{-\left[\mathbf{1}+\boldsymbol{\xi}\left(\frac{\mathbf{x}-\boldsymbol{\lambda}}{\boldsymbol{\psi}}\right)\right]^{-1/\xi}\right\}$	(Mirzabe et al., 2012)
	Cumulative frequency	$\mathbf{F(x)} = \mathbf{exp}\left\{-\left[\mathbf{1}+\boldsymbol{\xi}\left(\frac{\mathbf{x}-\boldsymbol{\lambda}}{\boldsymbol{\psi}}\right)\right]^{-1/\xi}\right\}$	
Weibull	Probability density	$\mathbf{f(x)} = \frac{\boldsymbol{\gamma}}{\boldsymbol{\beta}}\left(\frac{\mathbf{x}-\boldsymbol{\alpha}}{\boldsymbol{\beta}}\right)^{\alpha-1}\mathbf{exp}\left(-\left(\frac{\mathbf{x}-\boldsymbol{\alpha}}{\boldsymbol{\beta}}\right)^{\gamma}\right)$	(Bhunya et al., 2007; Gorgoso et al., 2007)
	Cumulative frequency	$\mathbf{F(x)} = \mathbf{1} - \mathbf{exp}\left(-\left(\frac{\mathbf{x}-\boldsymbol{\alpha}}{\boldsymbol{\beta}}\right)^{\gamma}\right)$	

Note: In Weibull and Log-normal distributions, if Location parameter ($\boldsymbol{\alpha}$and $\boldsymbol{\theta}$) equals to zero, was called two-parameter Weibull or Log-normal distribution. Otherwise it was called three-parameter Weibull or Log-normal distribution. In the present work, for modeling the data, three-parameter Weibull and Log-normal distributions were used.

The adjustable parameters for each probability density function were estimated using the commercial spreadsheet package of Easy Fit 5.5. Kolmogorov-Smirnov methods were used for comparison of all probability density. Kolmogorov-Smirnov goodness of fit test was used to test how well different prediction techniques work for the prediction of diameter, thickness and height distributions (Gorgoso et al., 2007). The test is based on the vertical deviation between the observed cumulative density function and estimated cumulative density function based on Equation 6. In this equation, small values of the test statistics Ks (Kolmogorov-Smirnov index) indicated a better fit.

$$\mathbf{Ks} = \mathbf{max}[\mathbf{S}(\mathbf{x}) - \mathbf{F}(\mathbf{x})] \qquad (6)$$

Where: *S(x)* is the cumulative frequency distribution observed and *F(x)* is the probability of the theoretical cumulative frequency distribution.

3. Results

3.1 Conventional varieties

3.1.1 Height of the sunflower head

Results of height of the sunflower head (SH) from the ground of five conventional varieties are shown in Table 2. Height of the SH from the ground of Dorsefid, Mikhi, Shamshiri, Sirena and Songhori varieties ranged from 701 to 1750 mm, 679 to 2650 mm, 680 to 2870 mm, 430 to 1395 mm and 455 to 2660 mm, respectively. The average values of height of the SH from the ground of the Dorsefid, Mikhi, Shamshiri, Sirena and Songhori varieties equal to 1771.87 mm, 1400.51 mm, 1505.67 mm, 722.75 mm and 1230.25 mm, respectively.

Table 2 Height of the sunflower head from the ground, total mass of the seeds of the sunflower head, head thickness, maximum and minimum head diameter of Dorsefid, Mikhi, Shamshiri, Sirena and Songhori varieties

Parameter	Variety	Maximum	Minimum	Mean	STD	Skewness	Kurtosis
	Dorsefid	1750	701	1771.87	1651.77	8.89	85.16
	Mikhi	2650	679	1400.51	451.85	1.02	0.64
H , mm	Shamshiri	2870	670	1505.67	477.60	0.58	0.04
	Sirena	1395	430	722.75	158.08	1.03	3.66
	Songhori	2660	455	1230.25	379.64	0.69	1.92
	Dorsefid	433	50	226.95	93.38	0.13	-0.82
	Mikhi	311	33	130.37	55.88	1.02	1.49
M , g	Shamshiri	387	33	166.60	88.69	0.76	-0.36
	Sirena	273	33	108.01	49.70	1.23	1.82
	Songhori	344	110	192.83	44.61	1.27	2.61
	Dorsefid	112	29	60.86	18.75	0.39	-0.47
	Mikhi	90	27	50.24	13.25	0.98	1.15
T , mm	Shamshiri	90	27	52.93	14.79	0.53	-0.25
	Sirena	65	24	38.78	9.22	0.65	0.19
	Songhori	83	42	57.84	8.12	0.82	0.95
	Dorsefid	387	100	228.70	66.81	0.21	-0.71
	Mikhi	313	91	167.90	43.95	1.10	1.65
D1, mm	Shamshiri	345	91	188.38	61.67	0.79	-0.13
	Sirena	266	88	142.04	37.05	1.27	1.89
	Songhori	345	170	223.73	33.52	1.44	3.02
	Dorsefid	370	95	220.29	64.72	0.22	-0.71
	Mikhi	303	90	163.00	42.64	1.07	1.55
D2, mm	Shamshiri	327	90	182.42	57.84	0.72	-0.18
	Sirena	252	83	137.95	36.05	1.22	1.69
	Songhori	335	156	215.25	33.91	1.32	2.59

Note：H is height of the sunflower head from the ground; M is total mass of the seeds of the sunflower head; T is head thickness; D1 is maximum head diameter; D2 is minimum head diameter, STD is standard deviation.

3.1.2 Total mass of seeds

Results of the total mass of the seeds of SH of five conventional varieties are shown in Table 2. Results showed that values of total mass of the seeds of SH of the Dorsefid, Mikhi, Shamshiri, Sirena and Songhori varieties ranged from 50 to 433 g, 33 to 311 g, 33 to 387 g, 33 to 273 g and 110 to 344 g, respectively. The average values of total mass of the seeds of SH of the Dorsefid, Mikhi, Shamshiri, Sirena and Songhori varieties equal to 226.95 g, 130.37 g, 166.60 g, 108.01 g and 192.83 mm, respectively.

3.1.3 Head thickness

Results showed that values of the SH thickness the Dorsefid, Mikhi, Shamshiri, Sirena and Songhori varieties ranged from 29 to 112 mm, 27 to 90 mm, 27 to 90 mm, 24 to 65 mm and 42 to 83 mm, respectively (Table 2). The average values of the SH thickness of the Dorsefid, Mikhi, Shamshiri, Sirena and Songhori varieties equal to 60.86 mm, 50.24 mm, 52.93 mm, 38.78 mm and 57.84 mm, respectively (Table 2).

3.1.4 Head diameter

Results showed that values of the maximum SH diameter the Dorsefid, Mikhi, Shamshiri, Sirena and Songhori varieties ranged from 100 to 387 mm, 91 to 313 mm, 91 to 345 mm, 88 to 266 mm, and 170 to 345 mm, respectively (Table 2). Also results showed that values of the minimum SH diameter the Dorsefid, Mikhi, Shamshiri, Sirena and Songhori varieties ranged from 95 to 370 mm, 90 to 303 mm, 90 to 327 mm, 83 to 252 mm, and 156 to 335 mm, respectively (Table 2). The average values of minimum and maximum SH diameter of the Dorsefid, Mikhi, Shamshiri, Sirena and Songhori varieties equal to 220.29 and 228.70 mm, 163.00 and 167.90 mm, 182.42 and 188.38 mm, 137.95 and 142.04 mm, and 215.25 and 223.73 mm, respectively (Table 2).

3.1.5 Dimensional properties

Results of dimensional properties of the sunflower head (SH) of the five conventional varieties are shown in Table 3. Results indicated that values of the arithmetic mean diameter, geometric mean diameter and sphericity of the SH of Dorsefid variety ranged from 85.33 to 285.33 mm, 72.62 to 249.32 mm and 47.69% to 87.18%, respectively. Values of the arithmetic mean diameter, geometric mean diameter and sphericity of the sunflower head of Mikhi variety were 69.33 to 232.00 mm, 60.47 to 196.97 mm and 53.96% to 74.93%, respectively. The corresponding values for Shamshiri variety were 74.67 to 207.33 mm, 65.07 to 174.61 mm and 41.81% to 96.07%, respectively. The corresponding values for Sirena variety were 65.00 to 194.33 mm, 55.97 to 163.33 mm and 57.27% to 77.00%, respectively. The corresponding values for Songhori variety were 125.67 to 253.33 mm, 106.83 to 209.89 mm and 58.17% to 67.87%, respectively.

Table 3 Arithmetic mean diameter, geometric mean diameter and sphericity of the sunflower head of Dorsefid, Mikhi, Shamshiri, Sirena and Songhori varieties

Parameter	Variety	Maximum	Minimum	Mean	STD	Skewness	Kurtosis
Da , mm	Dorsefid	285.33	85.33	169.95	41.12	0.40	-0.01
	Mikhi	232.00	69.33	127.05	33.00	1.06	1.51
	Shamshiri	207.33	74.67	141.24	30.33	0.10	-0.73
	Sirena	194.33	65.00	106.26	27.23	1.21	1.63
	Songhori	253.33	125.67	165.61	24.94	1.36	2.66
Dg , g	Dorsefid	249.32	72.62	143.39	37.00	0.50	-0.11
	Mikhi	196.97	60.47	111.09	28.64	1.03	1.44
	Shamshiri	174.61	65.07	119.34	25.32	0.15	-0.57
	Sirena	163.33	55.97	91.16	22.77	1.11	1.29
	Songhori	209.89	106.83	140.65	20.64	1.24	2.24
φ , %	Dorsefid	87.18	47.69	64.01	8.74	0.65	0.65
	Mikhi	74.93	53.96	66.25	1.98	-1.50	17.32
	Shamshiri	96.07	41.81	66.09	11.34	0.17	0.10
	Sirena	77.00	57.27	64.34	2.34	2.83	14.11
	Songhori	67.87	58.17	62.90	1.71	-0.08	0.65

Note: Da is arithmetic mean diameter of the sunflower head; Dg is geometric mean diameter of the sunflower head; φ is sphericity of the sunflower head.

3.2 Correlation between parameters

Correlation between maximum sunflower head diameter and some other parameters including minimum SH diameter, SH thickness, SH height from the ground and SH seeds mass, for Dorsefid, Mikhi, Shamshirri, Sirena and Songhori varieties were examined. Using Microsoft Excel 2010 package and linear regression method, the examinations were done. Correlation between maximum sunflower head diameter and some other parameters for Dorsefid, Mikhi, Shamshirri, Sirena and Songhori varieties are shown in Figure 2, Figure 3, Figure 4, Figure 5 and Figure 6, respectively. Results indicated that, there are linear correlations with high (value of R-square more than 0.9500) values of R-square index between maximum SH diameter and minimum SH diameter.

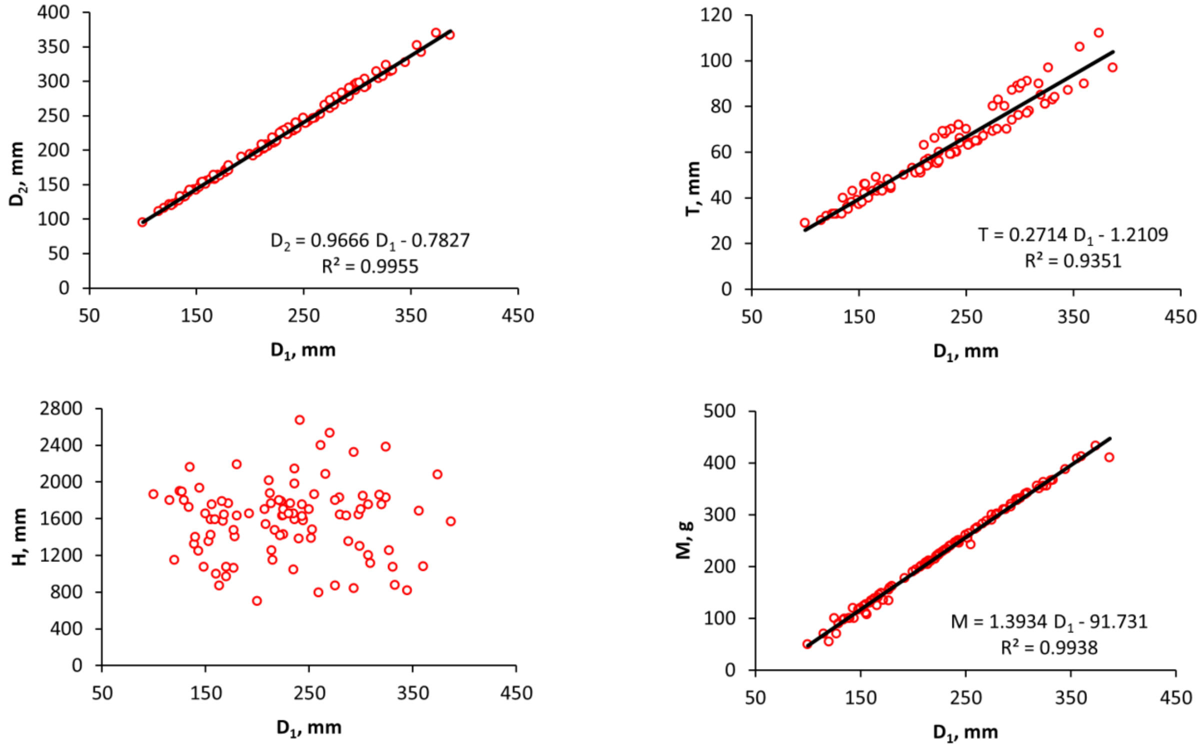

Figure 2 Correlation between maximum SH diameter and minimum SH diameter, SH thickness, SH height from the ground and mass of SH seeds for Dorsefid variety

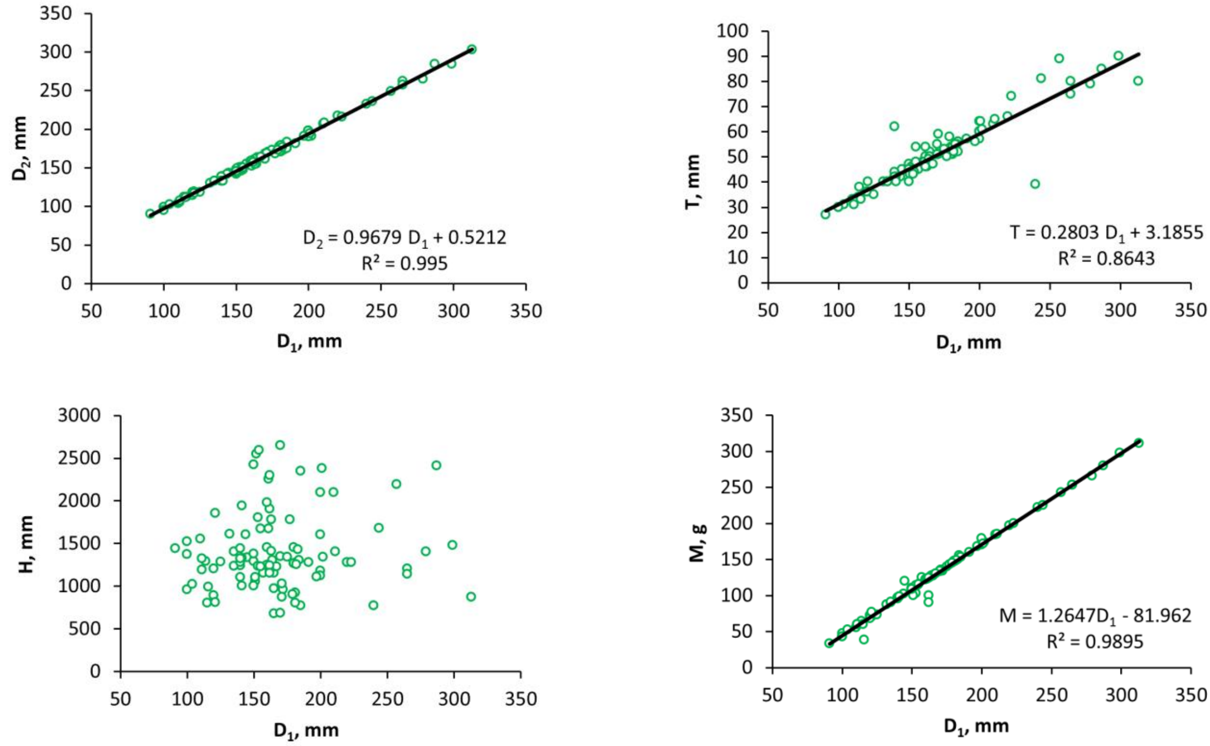

Figure 3 Correlation between maximum SH diameter and minimum SH diameter, SH thickness, SH height from the ground and mass of SH seeds for Mikhi variety

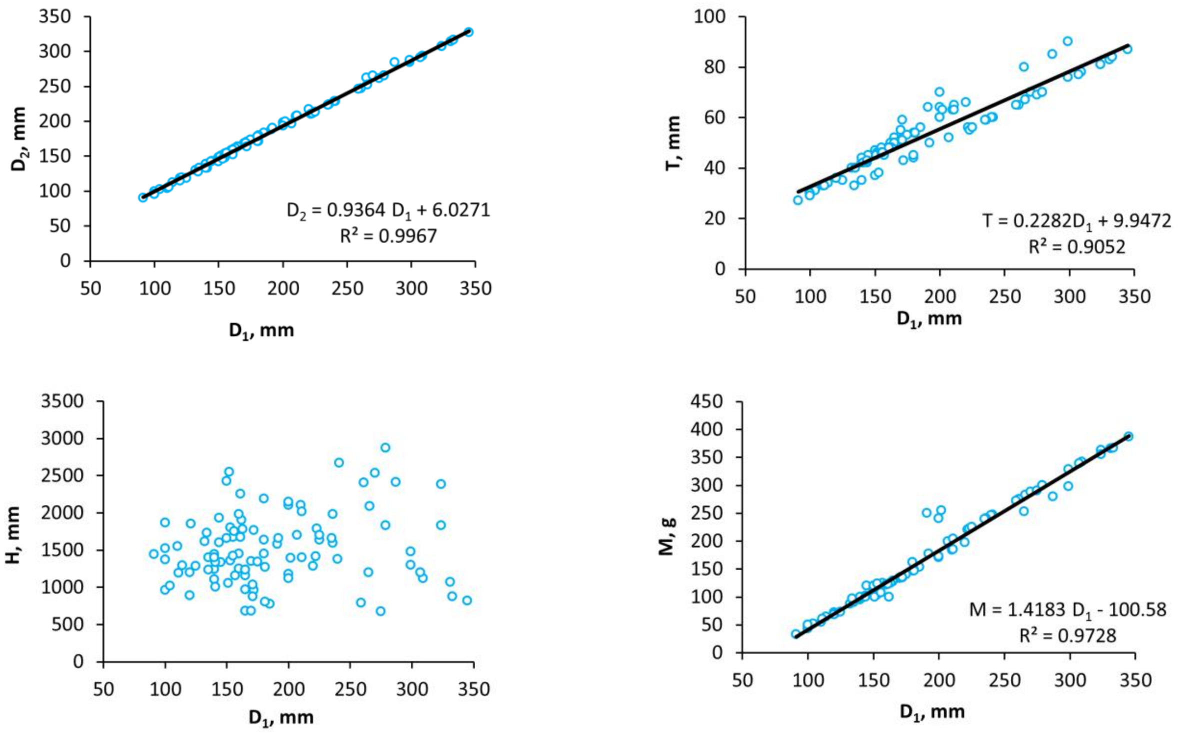

Figure 4 Correlation between maximum SH diameter and minimum SH diameter, SH thickness, SH height from the ground and mass of SH seeds for Shamshiri variety

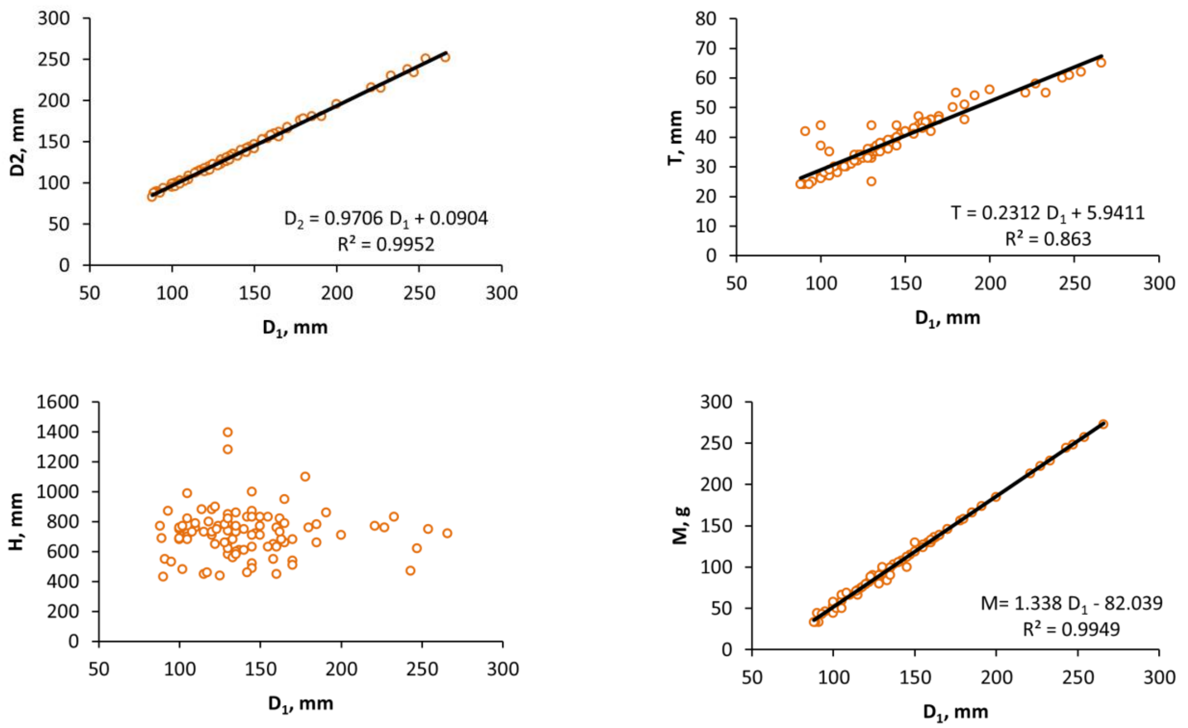

Figure 5 Correlation between maximum SH diameter and minimum SH diameter, SH thickness, SH height from the ground and mass of SH seeds for Sirena variety

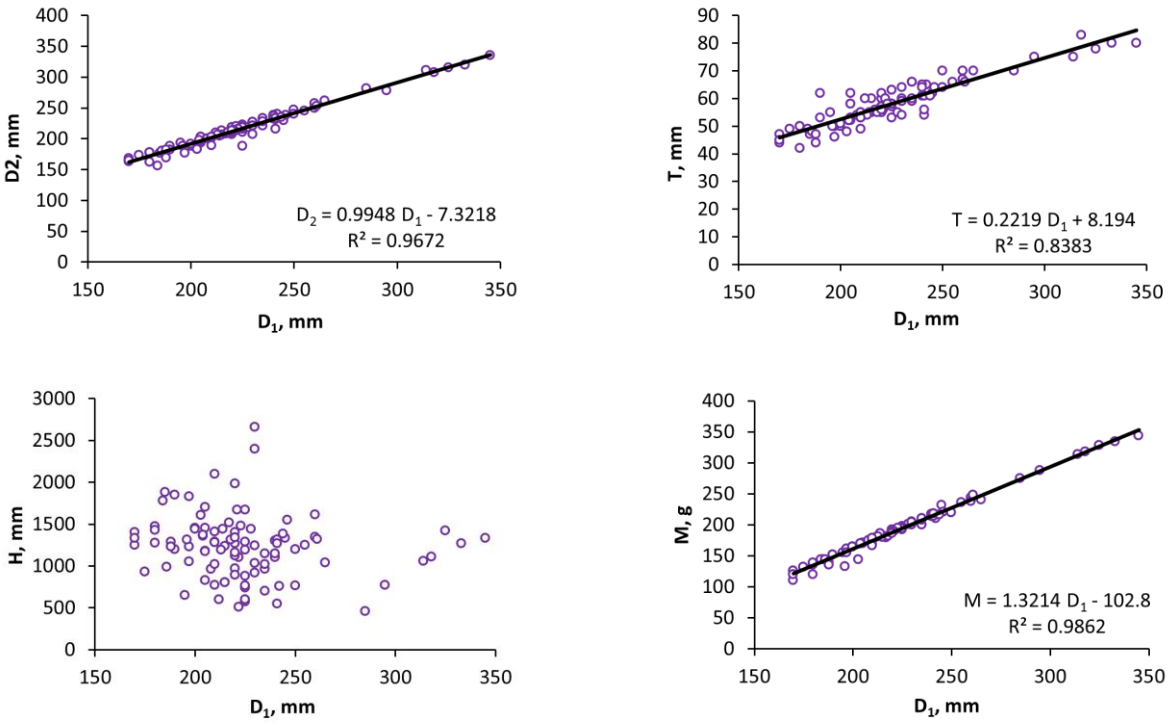

Figure 6 Correlation between maximum SH diameter and minimum SH diameter, SH thickness, SH height from the ground and mass of SH seeds for Songhori variety

Results of correlation between maximum sunflower head diameter and SH thickness showed that for Dorsefid and Shamshiri varieties, there are linear correlations with good (value of R-square more than 0.9052) values of R-square index between maximum SH diameter and SH thickness (Figure 2 and Figure 4). Results of correlation between maximum sunflower head diameter and SH thickness of Mikhi, Sirena and Songhori varieties showed that values of R-square index were equal to 0.8643, 0.8630 and 0.8383, respectively.

Results of correlation between maximum sunflower head diameter and total mass of the sunflower head showed that for all (five) varieties there are linear correlations with high values of R-square index (from Figure 2 to Figure 6). Values of R-square of linear correlations between maximum SH diameter and total mass of the SH for Dorsefid, Mikhi, Shamshiri, Sirena and Songhori varieties were equal to 0.9938, 0.9895, 0.9728, 0.9949 and 0.9862, respectively. Results showed that there is no linear correlation between maximum sunflower head diameter and SH height of the ground for any variety.

3.3 Hybrids

Statistical indices including maximum, minimum, average, standard deviation, skewness and kurtosis of SH diameters of all hybrids are shown in Table 4.Maximum diameter of Aline 1221/1*R-14, Farokh, Aline 19*R-1031, and Euroflor hybrids ranged from 111 to 285 mm, 92 to 305 mm, 76 to 254 mm, and 91 to 225 mm, respectively. Skewness and kurtosis of diameter of Aline 1221/1*R-14 and Farokh hybrid had positive values; while skewness and kurtosis of diameter of Aline 19*R-1031 and Euroflor hybrids had negative values.

Table 4 Statistical indices of sunflower head diameter of four hybrids

Statistical indices	Sunflower hybrids			
	Aline 1221/1*R-14	Farokh	Aline 19*R-1031	Euroflor
Max, mm	285	305	254	225
Min, mm	111	92	76	91
Mean, mm	185.308	182.963	170.988	158.900
STD	32.801	38.925	44.575	28.934
skewness	0.511	0.259	-0.435	-0.388
kurtosis	0.590	0.857	-0.529	-0.046

Statistical indices of SH thickness of all hybrids are shown in Table 5. Thickness of Aline 1221/1*R-14, Farokh, Aline 19*R-1031, and Euroflor hybrids ranged from 111 to 285 mm, 92 to 305 mm, 76 to 254 mm, and 91 to 225 mm, respectively. Skewness of thickness of Aline 1221/1*R-14 and Farokh hybrids had positive values, while skewness of thickness of Aline 19*R-1031 and Euroflor hybrids had negative values. Kurtosis of thickness of Aline 1221/1*R-14, Farokh, and Euroflor hybrids had positive values, while skewness of thickness of Aline 19*R-1031 hybrid had negative values.

Table 5 Statistical indices of sunflower head thickness of four hybrids

Statistical indices	Sunflower hybrids			
	Aline1221/1*R-14	Farokh	Aline 19*R-1031	Euroflor
Max, mm	80	91.9	65.8	60.5
Min, mm	35.5	31.2	30.2	33.8
Mean, mm	56.229	57.109	49.198	48.498
STD	8.339	11.074	8.915	5.318
skewness	0.973	0.267	-0.435	-0.482
kurtosis	0.731	0.878	-0.529	0.234

3.4 Modeling results

Maximum SH diameter and SH thickness of all varieties and all hybrids were modeled using Log-normal, Weibull and G.E.V distributions. Results for modeling of maximum SH diameter of five conventional varieties of sunflower are shown in Table 6. These results indicated that in order to model maximum SH diameter of Shamshiri, Mikhi and Songhori varieties, Log-normal distribution had the best performance. For Sirena and Dorsefid varieties G.E.V and Weibull distributions had the best performance, respectively. For Shamshiri, Mikhi, Songhori and Sirena varieties, Weibull distributions had poor performance to other distributions (see to the values of the Ks in the Table 6).

Table 6 The calculated parameter values of the different distributions for maximum SH diameter of five conventional varieties

Variety	Distribution	Location parameter	Scale parameter	Shape parameter	Ks	Rank of distribution
	Log-normal	−263.04	6.189	0.135	0.0787	3
Dorsefid	Weibull	84.854	162.46	2.315	0.0684	1
	G.E.V	202.44	64.819	−0.206	0.0727	2
	Log normal	40.581	4.911	0.414	0.0717	1
Shamshiri	Weibull	88.041	112.32	1.677	0.0828	3
	G.E.V	159.08	47.669	0.037	0.0740	2
	Log-normal	32.461	4.86	0.310	0.0919	1
Mikhi	Weibull	87.7	90.297	1.915	0.1063	3
	G.E.V	148.43	33.551	0.002	0.0950	2
	Log-normal	131.6	4.464	0.341	0.0818	1
Songhori	Weibull	166.71	63.996	1.773	0.0988	3
	G.E.V	208.87	24.143	0.037	0.0850	2
	Log-normal	59.696	4.318	0.430	0.0894	2
Sirena	Weibull	86.483	61.650	1.540	0.0928	3
	G.E.V	124.93	26.791	0.059	0.0867	1

Results for modeling of SH thickness of five conventional varieties of sunflower are shown in Table 7. These results indicated that in order to model SH thickness of Shamshiri, Mikhi, Songhori and Sirena varieties Log-normal distribution had best performance. For Dorsefid variety Weibull distributions had the best performance. For Shamshiri, Mikhi, Songhori and Sirena varieties, Weibull distributions had the poorest performance to other distributions (see to the values of the Ks in the Table 7).

Table 7 The calculated parameter values of the different distributions for SH thickness of five conventional varieties

Variety	Distribution	Location parameter	Scale parameter	Shape parameter	Ks	Rank of distribution
	Log-normal	−15.989	4.312	0.244	0.0658	3
Dorsefid	Weibull	26.417	38.775	1.907	0.0519	1
	G.E.V	53.006	17.343	−0.142	0.0626	2
	Log-normal	−2.313	3.976	0.266	0.0434	1
Shamshiri	Weibull	25.232	31.214	1.955	0.0568	3
	G.E.V	46.467	12.981	−0.086	0.0457	2
	Log-normal	8.901	3.674	0.309	0.0680	1
Mikhi	Weibull	25.966	27.347	1.924	0.0856	3
	G.E.V	44.356	10.361	−0.009	0.0707	2
	Log-normal	26.368	3.417	0.252	0.0682	1
Songhori	Weibull	41.003	18.995	2.180	0.0774	3
	G.E.V	54.285	6.734	−0.052	0.0723	2
	Log-normal	6.798	3.425	0.285	0.0535	1
Sirena	Weibull	22.467	18.318	1.822	0.0698	3
	G.E.V	34.765	7.954	−0.078	0.0565	2

Results for modeling of SH diameter of four hybrids of sunflower are shown in Table 8. These results indicated that in order to model SH diameter of Aline 1221/1*R-14 hybrid, Log-normal distribution had the best performance, while, for Farokh, Aline 19*R-1031and Euroflor hybrids, G.E.V distribution had the best performance. Also results showed that to model SH diameter of Aline 1221/1*R-14 and Farokh hybrids, Weibull distribution had the worst performance; while, to model SH diameter of Aline 19*R-1031and Euroflor hybrids, Log-normal distribution had the worst performance (see to the values of the Ks in the Table 8).

Table 8 The calculated parameter values of the different distributions for SH diameter of four hybrids.

Hybrid	Distribution	Location parameter	Scale parameter	Shape parameter	Ks	Rank of distribution
	Log-normal	−42.167	5.417	0.142	0.0757	1
Aline 1221/1*R-14	Weibull	100.540	95.064	2.752	0.0891	3
	G.E.V	171.450	28.575	−0.102	0.0870	2
	Log-normal	−420.46	6.401	0.064	0.1293	2
Farokh	Weibull	74.643	121.02	3.002	0.1368	3
	G.E.V	169.230	37.317	−0.260	0.1255	1
	Log-normal	−1245.7	7.256	0.0314	0.1276	3
Aline 19*R-1031	Weibull	−94.797	284.08	7.202	0.0886	2
	G.E.V	159.960	48.571	−0.501	0.0874	1
	Log-normal	−788.01	6.853	0.030	0.1123	3
Euroflor	Weibull	25.394	144.79	5.415	0.0933	2
	G.E.V	151.35	30.94	−0.4687	0.0820	1

Results for modeling of SH thickness of four hybrids of sunflower are shown in Table 9. These results indicated that in order to model SH thickness of Aline 1221/1*R-14, Farokh and Aline 19*R-1031 hybrids G. E. V distribution had the best performance; while, to model SH thickness of Euroflor hybrid, Weibull distribution had the best performance. Also results showed that to model SH thickness of Aline 1221/1*R-14 and Farokh hybrids, Weibull distribution had the worst performance; while, to model SH thickness of Aline 19*R-1031and Euroflor hybrids, Log-normal distribution had the worst performance (see to the values of the Ks in the Table 9).

Table 9 The calculated parameter values of the different distributions for SH thickness of four hybrids

Hybrid	Distribution	Location parameter	Scale parameter	Shape parameter	Ks	Rank of distribution
Aline 1221/1*R-14	Log-normal	−19.622	4.323	0.109	0.0762	2
	Weibull	32.280	26.733	3.084	0.0858	3
	G.E.V	52.791	7.480	−0.1332	0.0710	1
Farokh	Log-normal	−110.65	5.120	0.065	0.1287	2
	Weibull	26.329	34.390	2.996	0.1363	3
	G.E.V	53.205	10.617	−0.260	0.1247	1
Aline 19*R-1031	Log-normal	−215.57	5.578	0.034	0.1330	3
	Weibull	−3.959	56.817	7.202	0.0886	2
	G.E.V	46.992	9.714	−0.501	0.0874	1
Euroflor	Log-normal	−119.22	5.122	0.031	0.0946	3
	Weibull	20.027	30.596	6.326	0.0634	1
	G.E.V	47.163	5.688	−0.486	0.0 78	2

4 Discussions

Comparison between different varieties indicated that values of the average of dimensions, geometric and arithmetic mean diameter, head height of the ground and mass of the seeds on each head of Dorsefid variety were more than the other varieties; while for Sirena variety, values of average of mentioned parameters were less than the other varieties (Table 2).

Comparison between different hybrids indicated that values of average of diameter of Aline 1221/1*R-14 hybrid were more than the other hybrids; while, the average of diameter of Euroflor hybrid were less than the other hybrids. Values of the average of thickness of the Farokh hybrid were more than the other hybrids and the average of thickness of Euroflor hybrid were less than the other hybrids (Table 4 and Table 5).

Result indicated that for the Mikhi variety, value of sphericity was more than the other cases, while the value of sphericity for the Songhori variety was less than the other cases. So it cannot be said that the size of the sunflower head and its sphericity are correlated. For example, values of the maximum and minimum SH diameters of Dorsefid variety were more than the other varieties, but values of sphericity of the Mikhi and Shamshiri varieties were more than the Dorsefid variety (Table 3).

The result of linear correlations between maximum SH diameter and minimum SH diameter, SH thickness and mass of the SH seeds, for all varieties showed that the value of r-square index for correlation between maximum and minimum SH diameter was more than the other cases.Also the value of r-square index for correlation between maximum SH diameter and SH thickness was less than the other cases. Results indicated that for all varieties there is no correlation between maximum SH diameter and SH height from the ground. The highest value of R-square for the relationship between the maximum and the minimum diameters of the head was found to be for Shamshiri variety, which was equal to 0.9967 and the lowest value was found to be for Songhori variety, which was equal to 0.9672. The highest value of R-square for the relationship between the maximum diameter and thickness of heads was found to be for Dorsefid variety, equal to 0.9351, and the lowest value was found for Songhori variety, equal to 0.8338. The highest R-square value for the relationship between the maximum diameter and mass of the seeds was found for Sirena variety, equal to 0.9967, and the lowest value was found for Shamshiri variety, equal to 0.9728.

A comparison between the height of the ground of different varieties indicated that, harvesting of Sirena variety using combined harvester is possible, but it is impossible for the other varieties, because the distance between maximum height and minimum height is high in Dorsefid, Shamshiri, Mikhi and Songhori varieties; in other words, the range of height variance is high in these four varieties. In practice, combined harvesters are not used for harvesting these four varieties in Iran.

For an easy comparison between maximum sunflower head diameter of five conventional varieties together, probability density functions are shown in Figure 7. For all modeling in Figure 7, Generalized Extreme Value was used, because it had good prediction of probability density functions of maximum sunflower head diameter of five conventional varieties. In Figure 7, skewness of diameter data of five varieties had the positive value and kurtosis of diameter data of Mikhi, Sirena and Songhori varieties had positive value; while, kurtosis of Dorsefid and Shamshiri had negative value.

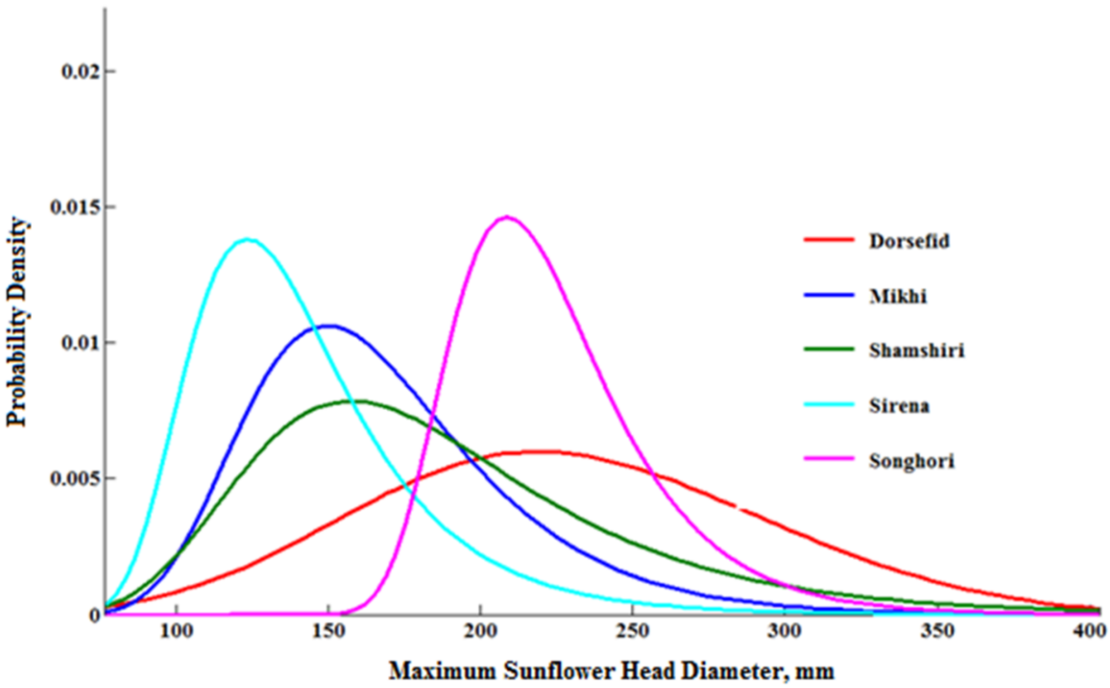

Figure 7 probability density function of maximum sunflower head diameter for Dorsefid, Mikhi, Shamshiri, Sirena and Songhori varieties

Skewness and kurtosis are two statistical indices calculated so that the reader would better understand the probability density distribution data. The first usually noticed about a distribution's shape is whether it has one mode (peak) or more than one. If it's unimodal(has just one peak), like most data sets, the next thing noticed is whether it is symmetric or skewed to one side. If the bulk of the data is at the left and the right tail is longer, the distribution is skewed right or positively skewed; if the peak is toward the right and the left tail is longer, the distribution is skewed left or negatively skewed (see Table 2 and Figure 7, value of skewness of Dorsefid variety is less while, value of skewness of Songhori variety is more than the other varieties).

Kurtosis is measured to see if the data have reached their highest point and have a peak, or they are flat. The data sets with high kurtosis tend to have separate peak near the mean. Data sets with low kurtosis tended to have a flat top near the mean rather than a sharp peak (see Table 3 and Figure 7, value of kurtosis of Dorsefid variety is less while, value of kurtosis of Songhori variety is more than the other varieties).

Results of SH diameter and SH thickness modeling showed that whenever skewness and kurtosis had the positive values, Log-normal distribution and Generalized Extreme Value distribution had good performance, while Weibull distribution had poor performance to model diameter or thickness. Whenever skewness and kurtosis had negative values, Weibull distribution and Generalized Extreme Value had good performance, while Log-normal distribution had poor performance to model diameter or thickness. Also whenever skewness had positive value and kurtosis had a great negative value, Weibull distribution and G.E.V had good performance; while

Log-normal distribution had poor performance to model diameter or thickness. Khazaei et al. (2008) modeled mass and size distributions of Daneriz and Dorsefid varieties of sunflower seeds and kernels using Log-normal, Normal and Weibull distributions. They cited that when skewness had a positive value, Log-normal distribution was the best and normal distribution was the worst model for predicting data. Mirzabe et al. (2012) modeled distance between adjacent seeds of Mikhi, Sirena and Songhori varieties using Log-normal, normal and Weibull distributions. They cited that whenever skewness and kurtosis had negative value, Weibull distribution was the best fit.

For future designs, we decided to transform the sunflower heads to the machine using a conveyor. In design of the mechanism of sunflower head feed, one of the important parameters is the width of the conveyor which is directly related to the maximum diameter of the sunflower head. Results from the diagram of probability density function of the maximum diameter of the sunflower heads (Figure 7) showed that 31%, 29%, 50%, 49%, and 48% of the diameters of the sunflower heads of Dorsefid, Shamshiri, Mikhi, Sirena, and Songhori varieties ranged between 200 to 250 mm, 150 to 180 mm, 150 to 180 mm, 120 to 160 mm, and 200 to 230 mm, respectively. The analysis of the results also showed that for transformation of all of the sunflower heads, the width of the conveyor has to be 400 mm. If in design and production of the machine, there are restrictions for the space or cost of the conveyor, this number can be 350 mm; in this case, only the diameter of 0.8% of the sunflower heads would be more than the width of the conveyor.

In design of the mechanism of sunflower head feed, one of the important parameters is the height of the feed channel which is directly related to the thickness of the sunflower head. Results obtained from the data of probability density function of the thickness of the sunflower heads showed that 55%, 48%, 57%, 59%, and 49% of the thickness of the sunflower heads of Dorsefid, Shamshiri, Mikhi, Sirena, and Songhori varieties ranged between 40 to 70 mm, 40 to 60 mm, 40 to 55 mm, 30 to 45 mm, and 54 to 63 mm, respectively. The analysis of the results also showed that for transformation of all of the sunflower heads, the height of the feed channel has to be 110 mm. If in design and production of the machine, there are restrictions for the space or cost of the channel, this number can be 100 mm; in this case, only the thickness of 0.4% of the sunflower heads would be more than the height of the feed channel. Also, the height of the channel can be 90 mm; in this case, only thickness of 1.4% of sunflower heads would be more than the height of the feed channel.

5 Conclusions

Maximum and minimum SH diameter, SH thickness, SH height of the ground, and mass of all seeds on SH for five varieties of sunflower were measured. Geometric mean diameter, arithmetic mean diameter and sphericity of SHs were calculated. Log-normal, Weibull and Generalized Extreme Value distribution were used in order to model SH diameter and SH thickness distribution. Parameters of each distribution were calculated. Results indicated that:

(1) Average of maximum SH diameter, minimum SH diameter, SH thickness, mass of the SH seeds, and SH height from the ground of Dorsefid variety were more than the other cases.

(2)Average of maximum SH diameter, minimum SH diameter, SH thickness, mass of the SH seeds, and SH height from the ground of Sirena variety were less than the other cases.

(3) Values of average of diameter and thickness of Euroflor hybrid were less than the other hybrids. The average of diameter and thickness of Aline 1221/1*R-14 and Farokh hybrids were less than the other hybrids, respectively.

(4) There are linear correlations between maximum SH diameter and minimum SH diameter, SH thickness and mass of the SH seeds, for all varieties. Value of

R-square index for correlation between maximum and minimum SH diameter was more than the other cases.

(5) There is no correlation between maximum SH diameter and SH height from the ground for any variety.

(6) For modeling of SH maximum diameter and SH thickness, Log-normal and Weibull distributions were the best and worst distributions, respectively.

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