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Mass Prediction of Cherry Laurel Genotypes Based on Physical Attributes Using Linear Regression Models

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Abstract: This investigation was inducted to predict the mass models of cherry laurel genotypes (55 K 07, 61 K 04 and mixed) based on some physical characteristics such as dimension, geometric mean diameter (D_g), the first, second, third projection areas (PA_1, PA_2, PA_3), the criteria area (*CAE*) and oblate and ellipsoid shaped volumes (V_{ob}, V_{ell}). The analysis was executed using 57 linear regression models for the selected genotypes. The statistical results substantiated that three variables mass model based on major, intermediate and minor diameter (a, *b*, *c*) as R^2 = 0.876, and R^2 = 0.798 can be recommended for mass estimation according to fruit sizes for 55 K 07 and 61 K 04 genotypes, respectively. According to the projection areas, mass models based on the projection areas $PA_1 + PA_2 + PA_3$ (R^2 = 0.881) and $PA_1 + PA_2$ (R^2 = 0.803) for the 55 K 07 and 61 K 04 genotypes were proposed to estimate the masses. In addition, the mass models based on the V_{ell} (R^2 = 0.877) and $V_{ob} + V_{ell}$ (R^2 = 0.791) for the 55 K 07 and 61 K 04 genotypes can be used to estimate the masses, respectively. For mixed genotypes, three variables mass model based on a + b + c (R^2= 0.964), single variable mass model based on *CAE* (R^2 =0.964), and single variable mass model based on V_{ell} (R^2= 0.959) can be recommended, respectively. These models can be used in the design and development of sizing machines for cherry laurel fruits.

Keywords: Cherry laurel, criteria area, mass models, physical characteristics,

Doğrusal Regresyon Modelleri Kullanılarak Fiziksel Özelliklere Göre Karayemiş Genotiplerinin Kütle Tahmini

Öz: Bu araştırma, 55 K 07 ve 61 K 04 karayemiş genotiplerin boyut, geometrik ortalama çap (D_g), birinci, ikinci, üçüncü izdüşüm alanları (PA_1, PA_2, PA_3), kriter alan (CAE) ve oblate ve elipsoid şekilli hacimlere (V_{ob}, V_{ell}) kütle tahminini belirlemek için yürütüldü. Analiz, seçilen bu genotipler için 57 doğrusal regresyon modeli kullanılarak gerçekleştirildi. İstatistiksel sonuçlar, için meyve boyutlarına göre kütle tahmini için büyük, orta ve küçük çapa (*a*, *b*, *c*) dayalı olarak üç değişkenli kütle modeli için sırasıyla k R^2 = 0.876, and R^2 = 0.798 önerilebilir. Projeksiyon alanlarına göre, kütleleri tahmin etmek için 55 K 07 ve 61 K 04 genotipleri için $PA_1+ PA_2+ PA_3$ (R^2 = 0.881) ve $PA_1+ PA_2$ (R^2 = 0.803) projeksiyon alanlarına dayalı kütle modelleri önerilmiştir. Ek olarak, 55 K 07 ve 61 K 04 genotipleri için kütleleri tahmin etmek için sırasıyla V_{ell} (R^2 = 0.877) ve $V_{ob}+ V_{ell}$ (R^2 = 0.791) kütle modelleri kullanılabilir. Karma genotipler için, sırasıyla *a* + *b* + *c*'ye (R^2 = 0.964) dayalı üç değişkenli kütle modeli, CAE'ye dayalı tek değişkenli kütle modeli (R^2 = 0.964) ve V*ell*'e dayalı tek değişkenli kütle modeli (R^2 = 0.959) önerilebilir. Bu modeller, karayemiş meyveleri için boyutlandırma makinelerinin tasarımında ve geliştirilmesinde kullanılabilir.

Anahtar Kelimeler: Karayemiş, kütle modelleri, fiziksel özellikler, kriter alanı

1. Introduction

Cherry laurel (*Laurocerasus officinalis* Roem.) was reported to be originated in Anatolia, West, Central Asia, and Southeast Europe. The fruit has the potential to be used as alternative food and a natural source as a compound (Ansin and Özkan 1993). The Black Sea region of Turkey has rich cherry laurel genotypes with different local conditions, and it is a valuable fruit for industrial applications (Bostan and Islam 2003). Apart from consumption in fresh and dried form, Cherry laurel fruits are processed for jam, puree, marmalade and beverage (Ayaz et al. 1997). The production of cherry laurel fruits has increased over time and its evaluation possibilities are varied (Sulusoglu et al. 2015).

Consumers generally prefer fruits of equal shape and size and therefore are considered as most important quality parameters for consumer demands. Fruit firmness, colour, and chemical properties must also be considered from the consumer perspective for cherry laurel fruit marketing. Sorting increases uniformity in terms of size and shape and can reduce the packaging and shipping expenses and also ensure optimum packaging (Sadrnia et al. 2007; Rashidi and Seyfi 2007). In addition, sorting is important in meeting quality standards, increasing marketing operations and market value (Wilhelm et al. 2005; Rashidi and Seyfi 2008a). Determination of physical attributes viz. mass, size, volume, shape, projection area is of prime importance to determine the appropriate design standards related to sizing, transportation, classification, packaging and processing systems (Tabatabaeefar and Rajabipour, 2005). The size of agricultural materials can generally be determined by their mass because they are relatively simple to measure. Classification based on some geometric properties is a more efficient method than collective classification.

However, if the mass model of the agricultural materials is known, the mass of the product can be easily estimated from the geometric properties (Rashidi and Seyfi, 2007; Rashidi and Seyfi, 2008b). Many researchers have predicted mass modeling based on some physical properties of different agricultural products like Lorestani and Tabatabaeefar (2006) for kiwifruit; Shahi-Gharahlar et al. (2005) for loquat fruit (Eriobotrya japonica Lindl.); for Keramat Jahromi et al. (2008); Khodabakhshian and Emadi (2016) for date fruit; Mirzabe et al. (2013) for almonds; Jaliliantabar and Lorestani (2014) for kumquat fruit; Berberoglu et al. (2014) for potato varieties; Mahawar et al. (2019) for kinnow mandarin, Sasikumar et al. (2020) for blood fruit (Haematocarpus validus); Zainal A'Bidin et al. (2020) for banana fruit.

Mathematical relationships established using mass modeling will assist in grading fruits at a commercial scale making the process more accurate and less labor-intensive. This in turn will enhance the market value and commercialization potential of the cherry laurel fruits.

It has not been reported in the literature about modeling the mass of cherries genotypes based on some physical characteristics which might be useful to establish the relevant design standards of machinery related to post-harvest management, handling, and packaging. n this study, predicted masses models based on major, intermediate and minor diameter (*a*, *b*, *c*), geometric mean diameter (*Dg*), the area first, second, third projection areas (PA_1, PA_2, PA_3), the criteria area (CAE) and oblate and ellipsoid shaped volumes were determined for 55 K 07, 61 K 01 cherry laurel genotypes, and mixed genotypes. Therefore, the main purpose of this research was to determine the optimum mass models by the establishment of a valid correlation between size, projection area, and volume, and fruit mass of the cherry laurel genotypes.

2. Material and Methods

The fruits of cherry laurel genotypes (55 K 07 and 61 K 04) grown at Samsun Black Sea Agricultural Research Institute (40° 05' and 41° 45' N latitude, 37° 08' and 34° 30' D longitude and 4 m altitude) of Turkey were obtained for the study. The fruits were commercially harvested in accordance with the harvest criteria (skin color) for each genotype on August 15, 2016, and to reduce water loss they were stored in polyethylene bags and transferred to the laboratory. Fruits of various sizes were randomly selected for each genotype and were kept at 90 ± 5% relative humidity and 4 ± 1°C temperature for experiments. The fruits dimensions for each genotype such as length (major diameter, *a*), width (intermediate diameter, *b*), and thickness (minor diameter, *c*) was measured by a digital vernier caliper (Mitutoyo, Japan, ±0.01 mm) as shown in Figure 1. The mass of selected fruits was measured with a digital weighing scale, sensibility ±0.001 g.

The geometric mean diameter (D_g) of cherry laurel fruit for each genotype was calculated by the following equation:

$$D_g = (abc)^{1/3} \quad (1)$$

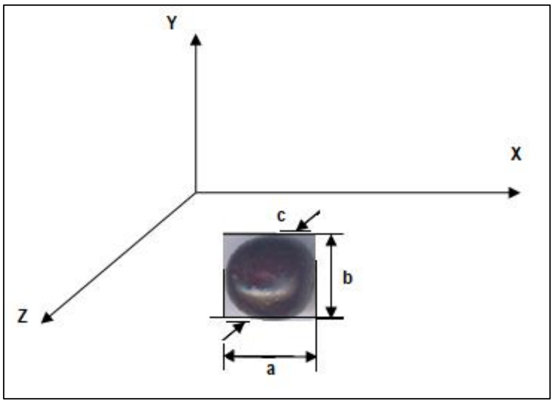

Figure 1. Size measurements of 55 K 07 cherry laurel fruit.
Şekil 1. *55 K 07 karayemiş meyvesinin boyut ölçümleri*

For the predicted modeling, 3 different classifications were made i.e. dimensions as first classification, projection areas as the second classification, and volumes as the third classification.

For dimensional model classification, mass modeling was accomplished according to the independent variables (a, b, c) with respect to one, two or three diameters. And also, the D_g of cherry laurel fruit was taken into account for dimensional models.

For the second projected area model classification, three projected areas of each cherry laurel variety, the first projected area (PA_1), second projected area (PA_2), and third projected area (PA_3) were also calculated using the following equations. And also, the Criteria area (CAE), known as the average projected area for each cherry laurel genotype was determined from Equation 5.

$$PA_1 = {(\pi ab)}/{4} \quad (2)$$

$$PA_2 = {(\pi ac)}/{4} \quad (3)$$

$$PA_3 = {(\pi bc)}/{4} \quad (4)$$

$$CAE = {(PA_1 + PA_2 + PA_3)}/{3} \quad (5)$$

Mass modeling was estimated as a function of one, two, or three mutually perpendicular projected areas three diameters, and criteria area (Khezri et al. 2012).

For the third category, mass related to volume was estimated as a function of the oblate and ellipsoid volumes. The cherry laurel shape was assumed as a regularly geometrical shape, oblate spheroid (V_{ob}) and V_{ell} ellipsoid (V_{actual}) shapes and was calculated as following by Keramat Jahromi et al. (2008):

$$V_{ob} = \frac{4\pi}{3}\left(\frac{a}{2}\right)\left(\frac{b}{2}\right)^2 \quad (6)$$

$$V_{ell} = \frac{4\pi}{3}\left(\frac{a}{2}\right)\left(\frac{b}{2}\right)\left(\frac{c}{2}\right) \quad (7)$$

A typical linear multiple regression model for predicted mass for cherry laurel fruits in this research is shown below:

$$Y = k_0 + k_1X_1 + k_2X_2 + k_3X_3 + \cdots + k_nX_n \quad (8)$$

where:
Y = Dependent variable (mass of cherry laurel fruit)
X₁; X₂,…Xₙ = Independent variables (physical attributes of cherry laurel fruit)
k₀, k₁, k₂,…, kₙ = Regression coefficients

Root mean squared error (RMSE) and Coefficient of variation [C.V(%)] was calculated as following below equation (Rashidi, M, Gholami M (2011).

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(M_i - M*_i)^2}{n}} \quad (9)$$

$$CV = (Standard\ deviation/Mean)100 \quad (10)$$

where:
Mi = cherry laurel measured by digital balance, g
M*i = cherry laurel estimated by mass model, g
n= number of samples

For the mass prediction, total of 57 linear regression mass models were adopted and the data were subjected to linear regression analysis using SPSS (Version 13.0). Coefficient of determination (R^2) and regression standard error (RSE) were considered and the models having maximum R^2 , minimum *RSE and RMSE* values represented the best fit (Mahawar et al. 2019, Sasikumar et al. 2020).

3. Results and Dıscussıon

Table 1 shows some physical attributes of the cherry laurel fruits which were used to determine the mass models. The physical properties i.e. dimensions (a, b, c) for 55 K 07 were lower than 61 K 04 cherry laurel genotype and mixed genotypes. While the geometric mean diameter (D_g) was found 30.83% higher for 61 K 07 genotype compared to 55 K 07, the PA_2 projection area was 84.96% higher for 61 K 07 genotype compared to 55 K 07.

Table 1. Some physical attributes of cherry laurel genotypes to determine mass models.
Çizelge 1. *Kütle modellerini belirlemek için karayemiş genotiplerinin bazı fiziksel özellikleri.*

Cherry laurel genotypes	Parameter	Minimum	Maximum	Mean (*)	S.D.	C.V. (%)
55 K 07	Mass (*M*), g	1.05	3.15	1,63	0.446	27.35
	Major diameter (*a*), cm	1.11	1.64	1,31	0.119	9.04
	Intermediate diameter (*b*), cm	1.21	1.68	1,39	0.106	7.59
	Minor diameter (*c*), cm	1.14	1.66	1,29	0.094	7.33
	Geometrical mean diameter (D_g), cm	1.17	1.62	1,33	0.100	7.54
	First projected area (PA_1), cm^2	1.10	2.15	1,44	0.238	16.49
	Second projected area (PA_2), cm^2	1.03	2.02	1,33	0.213	15.99
	Third projected area (PA_3), cm^2	1.09	2.13	1,42	0.209	14.71
	Criteria area (*CAE*), cm^2	1.08	2.07	1,40	0.217	15.50
	Oblate volume (V_{ob}), cm^3	0.889	2.40	1,36	0.333	24.54
	Ellipsoid volume (V_{ell}), cm^3	0.840	2.25	1,25	0.299	23.87
61 K 04	Mass (*M*), g	2.48	4.37	3,38	0.437	12.95
	Major diameter (*a*), cm	1.67	2.26	1,96	0.129	6.56
	Intermediate diameter (*b*), cm	1.45	1.89	1,70	0.089	5.22
	Minor diameter (*c*), cm	1.33	1.76	1,59	0.089	5.55
	Geometrical mean diameter (D_g), cm	1.49	1.93	1,74	0.089	5.09
	First projected area (PA_1), cm^2	1.96	3.20	2,63	0.274	10.46
	Second projected area (PA_2), cm^2	1.80	3.05	2,46	0.274	11.14
	Third projected area (PA_3), cm^2	1.52	2.56	2,13	0.209	9.80
	Criteria area (*CAE*), cm^2	1.76	2.93	2,41	0.244	10.13
	Oblate volume (V_{ob}), cm^3	1.89	3.97	2,99	0.449	15.00
	Ellipsoid volume (V_{ell}), cm^3	1.74	3.74	2,80	0.421	15.05
Mixed genotypes	Mass (*M*), g	1.05	4.37	2.50	0.979	39.10
	Major diameter (*a*), cm	1.11	2.26	1,64	0.349	21.34
	Intermediate diameter (*b*), cm	1.21	1.89	1,55	0.182	11.74
	Minor diameter (*c*), cm	1.14	1.76	1,44	0.178	12.36
	Geometrical mean diameter (D_g), cm	1.17	1.93	1,54	0.228	14.84
	First projected area (PA_1), cm^2	1.10	3.20	2,04	0.646	31.73
	Second projected area (PA_2), cm^2	1.03	3.05	1,90	0.617	32.49
	Third projected area (PA_3), cm^2	1.09	2.56	1.78	0.415	23.35
	Criteria area (*CAE*), cm^2	1.08	2.93	1,90	0.556	29.20
	Oblate volume (V_{ob}), cm^3	0.889	3.97	2.18	0.909	41.77
	Ellipsoid volume (V_{ell}), cm^3	0.840	3.74	2,03	0.859	42.31

SD: Standard deviation; CV: coefficent of variation; (*): 100 cherry laurel fruits

3.1. First Classification Models

The linear regression mass models for 55 K 07 and 61 K 04 cherry laurel genotypes, and mixed genotypes were predicted using single variable linear regressions of major diameter (*a*), intermediate diameter (*b*), minor diameter (*c*), and geometrical mean diameter (D_g) of cherry laurel or multiple (two and three) variables linear regressions of cherry laurel diameters. The results of mass modeling were given by the coefficient of determination predicted R^2 , R.S.E and RMSE coefficients for the single, two, and three variable classifications (Table 2). A graph of the estimated and measured values of a 55 K 07 cherry laurel genotype shown in Figure 2.

As seen in Table 2, among the models in the estimation of the mass model according to imensions, model 8, based on a + b + c, has the

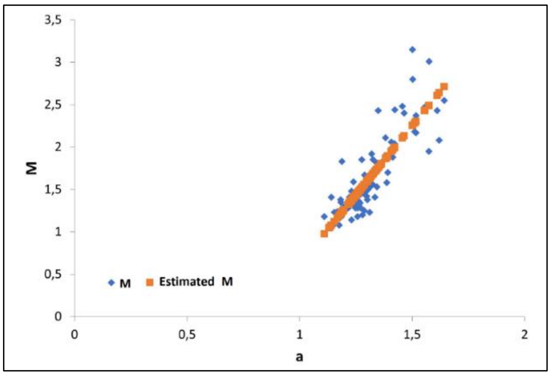

Figure 2. A graph of the estimated and measured values of a 55 K 07 cherry laurel genotype.
Şekil 2. *55 K 07 karayemiş genotipinin tahmini ve ölçülen değerlerinin grafiği.*

highest R^2 value (0.876) and the lowest RMSE value (0.1564) for the 55 K 07 genotype. Similarly, model No. 8, has the highest R^2 value (0.798) and the lowest RMSE value (0.1957) for61 K 04 genotype as well and hence can be recommended for mass estimation. And also, model No. 8, the three variables mass model based on a + b + c, has the highest R^2 value (0.965) and the lowest RMSE value (0.1819) for mixed genotypes. According to the statistical results, model number 8 was chosen as the best model of the first classification for 55 K 07 and 61 K 04 cherry laurel, and these model equations are given below.

Table 2. Coefficient of determination (R^2), regression standard error (R.S.E.), and root mean squared error (RMSE) for linear regression models based on dimensions classification.
Çizelge 2. *Boyut sınıflandırmasına dayalı doğrusal regresyon modelleri için belirtme katsayısı (R^2), regresyon standart hatası (R.S.E.) ve kök ortalama kare hata (RMSE) değerleri.*

Cherry laurel genotypes	Model No	Model	Model	R^2	R.S.E.	RMSE	Sig. M	Sig. RC
55 K 07	1	$M= k_0 + k_1 a$	$M= - 2.634 + 3.254 a$	0.744	0.226	0.2237	*	* *
	2	$M= k_0 + k_1 b$	$M= - 3.652 + 3.789 b$	0.806	0.198	0.1955	*	* *
	3	$M= k_0 + k_1 c$	$M= - 3.781 + 4.201 c$	0.791	0.205	0.2031	*	* *
	4	$M= k_0 + k_1 D_g$	$M= - 3.890 + 4.153 Dg$	0.870	0.162	0.1603	*	* *
	5	$M= k_0 + k_1 a + k2 b$	$M= - 3.586 + 1.271 a + 2.547 b$	0.834	0.184	0.1812	*	* * *
	6	$M= k_0 + k_1 a + k2 c$	$M= - 3.791 + 1.579 a + 2.602 c$	0.852	0.173	0.1708	*	* * *
	7	$M= k_0 + k_1 b + k2 c$	$M= - 4.156 + 2.161 b + 2.152 c$	0.865	0.166	0.1631	*	* * *
	8	$M= k_0 + k_1 a + k2 b + k3 c$	$M= - 4.053 + 0.836 a + 1.537 b + 1.898 c$	**0.876**	0.160	0.1564	*	* * * *
61 K 04	1	$M= k_0 + k_1 a$	$M= - 2.298 + 2.891 a$	0.724	0.231	0.2286	*	* *
	2	$M= k_0 + k_1 b$	$M= - 2.297 + 3.336 b$	0.459	0.323	0.3200	*	* *
	3	$M= k_0 + k_1 c$	$M= - 2.713 + 3.821 c$	0.598	0.279	0.2758	*	* *
	4	$M= k_0 + k_1 D_g$	$M= - 4.178 + 4.332 D_g$	0.772	0.210	0.2078	*	* *
	5	$M= k_0 + k_1 a + k2 b$	$M= - 3.505 + 2.350 a + 1.334 b$	0.772	0.211	0.2077	*	* * *
	6	$M= k_0 + k_1 a + k2 c$	$M= - 3.407 + 2.063 a + 1.715 c$	0.785	0.205	0.2017	*	* * *
	7	$M= k_0 + k_1 b + k2 c$	$M= - 3.500 + 1.334 b + 2.891 c$	0.636	0.267	0.2625	*	* * *
	8	$M= k_0 + k_1 a + k2 b + k3 c$	$M= - 3.834 + 1.956 a + 0.786 b + 1.277 c$	**0.798**	0.200	0.1957	*	* * * *
Mixed variety	1	$M= k_0 + k_1 a$	$M= - 1.955 + 2.724 a$	0.944	0.232	0.2314	*	* *
	2	$M= k_0 + k_1 b$	$M= - 5.384 + 5.096 b$	0.894	0.318	0.3169	*	* *
	3	$M= k_0 + k_1 c$	$M= - 5.093 + 5.271 c$	0.919	0.277	0.2766	*	* *
	4	$M= k_0 + k_1 D_g$	$M= - 4.178 + 4.332 D_g$	0.772	0.210	0.1857	*	* *
	5	$M= k_0 + k_1 a + k2 b$	$M= - 3.257 + 1.894 a + 1.720 b$	0.958	0.201	0.2002	*	* * *
	6	$M= k_0 + k_1 a + k2 c$	$M= - 3.380 + 1.684 a + 2.170 c$	0.962	0.191	0.1861	*	* * *
	7	$M= k_0 + k_1 b + k2 c$	$M= - 5.439 + 2.068 b + 3.290 c$	0.937	0.246	0.2446	*	* * *
	8	$M= k_0 + k_1 a + k2 b + k3 c$	$M= - 3.739 + 1.489 a + 0.956 b + 1.614 c$	**0.965**	0.183	0.1819	*	* * * *

M: the mass of cherry laurel; a: the the major diameter, b: intermediate diameter; c: minor diameter; k_i is regression coefficient.
R.S.E: Regression Standard Error; RMSE: Root Mean Squared Error; Sig. M: Significant of model; Sig. RC: Significant of regression coefficient

For 55 K 07 genotype:

$$M= - 4.053 + 0.836 a + 1.537 b + 1.898 c \quad (11)$$

For 61 K 04 genotype:

$$M= - 3.834 + 1.956 a + 0.786 b + 1.277 c \quad (12)$$

For mixed genotypes:

$$M=- 3.739 + 1.489 a + 0.956 b + 1.614 c \quad (13)$$

Sasikumar et al. (2020) has recommended quadratic model based on width of blood fruit

(M= $0.019W^2$-0.463W+ 26.88; R^2= 0.97) for mass prediction. Similarly, Shahbazi and Rahmati (2013) have also found the quadratic model based on fig fruit width (M = 58.443–3.318W+$0.064W^2$; R^2 =0.969) best for mass prediction. A linear model based on length (M =0.3783L-5.876, R^2=0.70) of date fruit (*cv.* Zahedi) was suggested by Keramat Jahromi et al. (2008) for mass prediction.

3.2. Second Classification Models

In this second classification linear regression mass models for 55 K 07 and 61 K 04 cherry laurel genotypes, and mixed genoypes were predicted using single variable linear regressions of PA_1, PA_2, PA_3 and *CAE* of cherry laurel or multiple (two and three) variables linear regressions. The results of mass modeling were given by R^2, R.S.E and RMSE coefficients for the single, two and three variable classifications as presented in Table 3.

Table 3. Coefficient of determination (R^2), regression standard error (R.S.E.), and root mean squared error (RMSE) for linear regression models based on projected areas classification.
***Çizelge 3**. Projeksiyon alan sınıflandırmasına dayalı doğrusal regresyon modelleri için belirtme katsayısı (R^2), regresyon standart hatası (R.S.E.) ve kök ortalama karesel hata (RMSE) değerleri.*

Cherry laurel genotypes	Models No.	Model	Model	R^2	R.S.E.	RMSE	Sig. M	Sig. RC
55 K 07	1	$M= k_0 + k_1 PA_1$	$M= - 0.837 + 1.709 PA_1$	0.832	0.184	0.1820	*	* *
	2	$M= k_0 + k_1 PA_2$	$M= - 0.943 + 1.930 PA_2$	0.851	0.173	0.1715	*	* *
	3	$M= k_0 + k_1 PA_3$	$M= - 1.200 + 1.997 PA_3$	0.871	0.161	0.1598	*	* *
	4	$M= k_0 + k_1 CAE$	$M= - 1.061 + 1.925 CAE$	0.875	0.159	0.1570	*	* *
	5	$M= k_0 + k_1 PA_1 + k_2 PA_2$	$M= - 0.945 + 0.576 PA_1 + 1.308 PA_2$	0.857	0.171	0.1680	*	* * *
	6	$M= k_0 + k_1 PA_1 + k_2 PA_3$	$M= - 1.155 + 0.543 PA_1 + 1.412 PA_3$	0.880	0.156	0.4871	*	* * *
	7	$M= k_0 + k_1 PA_2 + k_2 PA_3$	$M= - 1.158 + 0.704 PA_2 + 1.305 PA_3$	0.879	0.157	0.1544	*	* * *
	8	$M= k_0 + k_1 PA_1 + k_2 PA_2 + k_3 PA_3$	$\mathbf{M= - 1.147 + 0.348 PA_1 + 0.394 PA_2 + 1.235 PA_3}$	**0.881**	0.156	0.1531	*	* * * *
61 K 04	1	$M= k_0 + k_1 PA_1$	$M= - 0.259 + 1.384 PA_1$	0.756	0.217	0.2150	*	* *
	2	$M= k_0 + k_1 PA_2$	$M= - 0.104 + 1.413 PA_2$	0.786	0.203	0.2010	*	* *
	3	$M= k_0 + k_1 PA_3$	$M= - 0.170 + 1.662 PA_3$	0.632	0.267	0.2639	*	* *
	4	$M= k_0 + k_1 CAE$	$M= - 0.446 + 1.587 CAE$	0.785	0.204	0.2019	*	* *
	5	$M= k_0 + k_1 PA_1 + k_2 PA_2$	$\mathbf{M= - 0.291 + 0.540 PA_1 + 0.913 PA_2}$	**0.803**	0.196	0.1931	*	* * *
	6	$M= k_0 + k_1 PA_1 + k_2 PA_3$	$M= - 0.335 + 1.239 PA_1 + 0.214 PA_3$	0.758	0.217	0.2141	*	* * *
	7	$M= k_0 + k_1 PA_2 + k_2 PA_3$	$M= - 0.210 + 1.273 PA_2 + 0.212 PA_3$	0.789	0.203	0.1999	*	* * *
	8	$M= k_0 + k_1 PA_1 + k_2 PA_2 + k_3 PA_3$	$M= - 0.274 + 0.563 PA_1 + 0.924 PA_2 – 0.049 PA_3$	0.803	0.197	0.1930	*	* * * *
Mixed genotypes	1	$M= k_0 + k_1 PA_1$	$M= - 0.515 + 1.483 PA_1$	0.956	0.204	0.2037	*	* *
	2	$M= k_0 + k_1 PA_2$	$M= - 0.447 + 1.555 PA_2$	0.959	0.198	0.1972	*	* *
	3	$M= k_0 + k_1 PA_3$	$M= - 1.554 + 2.285 PA_3$	0.936	0.247	0.2466	*	* *
	4	$M= k_0 + k_1 CAE$	$\mathbf{M= - 0.789 + 1.730 CAE}$	**0.964**	0.185	0.1849	*	* *
	5	$M= k_0 + k_1 PA_1 + k_2 PA_2$	$M= - 0.490 + 0.631 PA_1 + 0.901 PA_2$	0.962	0.190	0.1892	*	* * *
	6	$M= k_0 + k_1 PA_1 + k_2 PA_3$	$M= - 0.845 + 1.070 PA_1 + 0.660 PA_3$	0.960	0.196	0.1907	*	* * *
	7	$M= k_0 + k_1 PA_2 + k_2 PA_3$	$M= - 0.788 + 1.137 PA_2 + 0.638 PA_3$	0.963	1.889	0.1877	*	* * *
	8	$M= k_0 + k_1 PA_1 + k_2 PA_2 + k_3 PA_3$	$M= - 0.739 + 0.441 PA_1 + 0.776 PA_2 + 0.491 PA_3$	0.964	0.186	0.1842	*	* * * *

M: the mass of cherry laurel; a: the the major diameter, b: intermediate diameter; c: minor diameter; k_i is regression coefficient.
R.S.E: Regression Standard Error; RMSE: Root Mean Squared Error; Sig. M: Significant of model; Sig. RC: Significant of regression coefficient

As seen in Table 3, among the models in the estimation of the mass model according to projected areas, model No. 8, three variables mass model based on the PA_1+ PA_2 + PA_3, has the highest R^2 value (0.881) and the lowest RMSE value (0.1531) for 55 K 07 genotype, while, the second classification category, model No. 5, two variables mass model, based on PA_1 + PA_2, has the highest R^2 value (0.803) and the lowest RMSE value (0.1931) for 61 K 04 genotype and hence can be recommended for mass estimation. And also, model No. 4, a single variable mass model based on *CAE*, has the highest R^2 value (0.964) and the lowest RMSE value (0.1849) for mixed genotypes.

3.3. Third Classification Models

In this third classification linear regression mass models for 55 K 07 and 61 K 04 cherry laurel genotypes and mixed genotypes can be predicted using single or two variables linear regressions of the oblate assumed shape (V_{ob}) or ellipsoid volume (V_{ell}) of cherry laurel fruits (Table 4).

Table 4. Coefficient of determination (R^2), regression standard error (R.S.E.), and root mean squared error (RMSE) for linear regression models based on volume classification.
Çizelge 4. *Hacim sınıflandırmasına dayalı doğrusal regresyon modelleri için belirtme katsayısı (R^2), regresyon standart hatası (R.S.E.) ve kök ortalama kare hatası (RMSE) değerleri.*

Cherry laurel genotype	Model No.	Model	Model	R^2	R.S.E.	RMSE	Sig. M	Sig. RC
55 K 07	1	$M= k_0 + k_1 V_{ob}$	$M= - 0.042 + 1.232 V_{ob}$	0.847	0.175	0.1737	*	* *
	2	$M= k_0 + k_1 V_{ell}$	$\mathbf{M= - 0.119 + 1.396 V_{ell}}$	**0.877**	0.158	0.1560	*	* *
	3	$M= k_0 + k_1 V_{ob} + k_2 V_{ell}$	$M= - 0.120 – 0.088 V_{ob} + 1.493 V_{ell}$	0.877	0.158	0.1560	*	* * *
61 K 04	1	$M= k_0 + k_1 V_{ob}$	$M= 0.798 + 0.920 V_{ob}$	0.787	0.203	0.2394	*	* *
	2	$M= k_0 + k_1 V_{ell}$	$M= 0.943 + 0.813 V_{ell}$	0.697	0.242	0.2007	*	* *
	3	$M= k_0 + k_1 V_{ob} + k_2 V_{ell}$	$\mathbf{M= 0.826 + 1.147 V_{ob} – 0.222 V_{ell}}$	**0.791**	0.202	0.1989	*	* * *
Mixed genotypes	1	$M= k_0 + k_1 V_{ob}$	$M= 0.224 + 1.048 V_{ob}$	0.946	0.227	0.2266	*	* *
	2	$M= k_0 + k_1 V_{ell}$	$\mathbf{M= 0.238 + 1.117 V_{ell}}$	**0.959**	0.199	0.1797	*	* *
	3	$M= k_0 + k_1 V_{ob} + k_2 V_{ell}$	$M= 0.241 - 0.080 V_{ob} + 1.201 V_{ell}$	0.959	0.199	0.1980	*	* * *

M: The mass of cherry laurel; V_{ob}: The oblate volume, Vell: The ellipsoid volume; k_i is regression coefficient.
R.S.E: Regression Standard Error; RMSE: Root Mean Squared Error; Sig. M: Significant of model; Sig. RC: Significant of regression coefficient

As seen in Table 4, among the models in the estimation of the mass model according to volumes, model No. 2, single variable mass model based on *Vob*, has the highest R^2 value (0.877) and the lowest RMSE value (0.1560) for 55 K 07 genotype, while, the third classification category, model No. 3, two variable mass model, based on *Vob* + *Vell*, has the highest R^2 value (0.791) and the lowest RMSE value (0.1989) for 61 K 04 genotype and hence can be recommended for mass estimation. And also, model No. 2, a single variable mass model based on *Vell*, has the highest R^2 value (0.959) and the lowest RMSE value (0.1797) for mixed genotypes. According to the statistical results, models' number 3 was chosen as the best model of the third classification for 55 K 07 and 61 K 04 cherry laurel, and mixed genotypes, respectively, and these model equations are given below:

For 55 K 07 genotype:

$$M= - 0.119 + 1.396 V_{ell} \tag{17}$$

For 61 K 04 genotype:

$$M= 0.826 + 1.147 V_{ob} – 0.222 V_{ell} \tag{18}$$

For mixed genotypes:

$$\mathrm{M}= 0.238 + 1.117 \mathrm{V}_{\mathrm{ell}} \tag{19}$$

Pathak et al. (2019) has suggested the best regression model (linear and quadratic) based on the ellipsoid volume and true volume with R^2 of 0.97 for *Terminalia chebula* fruit. Keramat Jahromi et al. (2008) reported the mass model based on actual volume and prolate spheroid as best for sizing of date *cv*. Zahedi.

4. Conclusions

The present study encompassed evaluation of physical characteristics of cherry laurel fruits and then correlating the measured properties with fruit mass. To predict the mass of cherry laurel fruits based on the dimension, a mass model based on 8as e diameter + intermediate diameter + 8as e diameters for both the genotypes was found best fitted. To estimate the mass of the cherry laurel fruits according to the projection area, based on the first projection area (PA_1) + the second projection area (PA_2) + the third projection areas (PA_3) for both the genotypes can be suggested. In addition, to estimate the mass of cherry laurel fruits based on the volüme the model based on ellipsoid volumes for both the genotypes can be recommended. These mass models can be used in the design and development of machines to be used for sizing cherry laurel fruits. The presented findings shall definitely act as a database 8as efo researchers and simultaneously enhance the knowledge 8as efor the fabrication of post-harvest machinery.

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