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Development of Leaf Area Model in Chokeberry Plant Grown in Different Irrigation Water Quality

Farklı Sulama Suyu Kalitesinde Yetişen Aronya Bitkisinde Yaprak Alan Modelinin Geliştirilmesi

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DEVELOPMENT OF LEAF AREA MODEL IN CHOKEBERRY PLANT GROWN IN DIFFERENT IRRIGATION WATER QUALITY

ABSTRACT

Chokeberry is a berry fruit species that has grown in the world in a few decades, and it is used in many fields, especially in the pharmaceutical industry. There needs to be a study examining the relationship between leaf area and irrigation water quality in this species, whose cultivation has started to increase. In this study, which was carried out between 2021 and 2022, the effects of irrigation water quality on leaf area in 1-year-old chokeberry plants of the 'Viking' variety grown in peat and soil media were determined. Irrigation water with 0.65 dS m^{-1} (Control), 2dS m^{-1}, 4dS m^{-1}, 8dS m^{-1}, and 10dS m^{-1} electrical conductivity were used in the study. A model was developed in this study to estimate leaf area (LA) using leaf width (W) and leaf length (L) values to determine leaf area. The proposed prediction model was determined as (R^2= 0.99). Three-dimensional graphs of the developed models were drawn, and the changes in leaf width, length, and leaf area values against irrigation water salinity were determined. As a result, it was determined that there was a negative relationship between the electrical conductivity of irrigation water and leaf width, length, and area values.

Keywords: *Aronia Melanocarpa*, Leaf Area, Modeling.

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FARKLI SULAMA SUYU KALİTESİNDE YETİŞEN ARONYA BİTKİSİNDE YAPRAK ALAN MODELİNİN GELİŞTİRİLMESİ

ÖZ

Aronya, başta ilaç sanayi olmak üzeri birçok alan da kullanılmasıyla birlikte dünyada son yüzyılda yetiştirilmeye başlanmış üzümsü bir meyve türüdür. Yetiştiriciliği artmaya başlayan bu türde yaprak alanı ile sulama suyu kalitesi arasındaki ilişkiyi inceleyen bir çalışmaya ihtiyaç bulunmaktadır. 2021-2022 yılları arasında yürütülen bu çalışmada, torf ve toprak ortamlarında yetiştirilen 1 yaşlı 'Viking' çeşidine ait aronya bitkilerinde sulama suyu kalitesinin yaprak alanı üzerine etkileri belirlenmiştir. Çalışmada kontrol (0.65 dS m^{-1}), 2dS m^{-1}, 4dS m^{-1}, 8dS m^{-1} ve 10dS m^{-1} elektriksel iletkenliğe sahip sulama suları kullanılmıştır. Kalite parametrelerinden biri olan yaprak alanını belirlemek amacıyla bu çalışmada yaprak en (W) ve yaprak boy (L) değerlerini kullanarak yaprak alanını (LA) tahmin etmek için bir model geliştirilmiştir. Önerilen tahmin modeli (R^2= 0.99) olarak belirlenmiştir. Geliştirilen modellerin üç boyutlu grafikleri çizilerek yaprak en, boy, yaprak alan değerlerinin sulama suyu tuzluluğu karşısındaki değişimleri belirlenmiştir. Sonuç olarak sulama suyunun elektriksel iletkenliği ile yaprak en, boy ve alan değerleri arasında negatif ilişki olduğu tespit edilmiştir.

Anahtar Kelimeler: *Aronia Melanocarpa*, Modelleme, Yaprak Alanı.

1. INTRODUCTION

Chokeberry is an essential fruit with its rich nutrient content. It is a newly introduced species in Türkiye, and its popularity is increasing. Its high vitamin, mineral, antioxidant, anthocyanin, and phenolic compounds allow chokeberry to treat some metabolic diseases (Engin et al., 2018). Thanks to its bioactive compounds, chokeberry is used in the pharmaceutical industry as fresh or processed.

Leaf area is an important physiological input that plays a role in the plant's physiological events, such as photosynthesis, transpiration, and evapotranspiration, and affects the yield and quality parameters of the plant (Smith and Kliewer, 1984; Cemek et al., 2011). Leaf area can be measured directly in the field or determined more effortlessly using estimation models (Robbins and Pharr, 1987). Building a multiple linear regression model (MLR) using easy-to-measure leaf width and length parameters is the most valuable and common approach to determining leaf area (Rouphael et al., 2010). This approach allows us to obtain results effortlessly and without destroying the plant, using fewer inputs and saving time. Accordingly, different leaf area estimation models have been developed for various crops, including pickling cucumber (Robbins and Pharr, 1987), blueberry (NeSmith, 2006; Odabas et al., 2022), banana (Potdar and Pawar, 1991), white mulberry (Satpathy et al., 1992), pecan (Sparks, 1996), avocado, lotus plum, persimmon, kiwi, eggplant, pepper, grape, blackcurrant, pumpkin, raspberry and blackberry (Uzun and Çelik, 1999), sweet cherry (Demirsoy and Demirsoy, 2003), peach (Demirsoy et al., 2004), strawberry (Demirsoy et al., 2005), chestnut (Serdar and Demirsoy, 2006), faba bean (Odabas and Gülümser, 2005; Peksen, 2007), kiwifruit (Mendoza-de Gyves et al., 2007), hazelnut (Cristofori et al., 2007), medlar (Mendoza-de-Gyves et al., 2008), persimmon (Cristofori et al., 2008), coffee (Antunes et al., 2008), corn (Sezer et al., 2009; Öner at al., 2011), grapevine (Miguel et al., 2011; Tsialtas et al., 2008), citrus (Mazzini et al., 2010), apple (Sala et al., 2015), walnut (Keramatlou et al., 2015), apricot (Cirillo et al., 2017), cacao (Salazar et al., 2018), loquat (Teobaldelli et al., 2019), pear (Öztürk et al., 2019), bell pepper (Cemek et al., 2020), paddy (Öner and Odabaş, 2023) and echinacea (Öner et al., 2023).

Plant-based modeling and coefficients are essential for the accuracy of the equation (Öztürk et al., 2019). The physiological responses of plants grown under different conditions differ from each other. Chokeberry plants grown under different irrigation water quality conditions have different leaf area values. Although leaf area estimation has been done in many plants, no model has been developed for the chokeberry plant. Therefore, the prediction model developed for the chokeberry plant is crucial to close this gap.

This study aims to close this gap by developing the leaf area model of the chokeberry plant, which develops in different irrigation water quality and growing medium.

2. MATERIAL AND METHOD

The study was conducted in a greenhouse of Samsun Ondokuz Mayıs University, Faculty of Agriculture, between 2021 and 2022. Viking variety chokeberry plants were grown in 15 L capacity pots in two growing mediums (soil and peat) with five irrigation water qualities. The soil was analyzed at Ondokuz Mayıs University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition (Table 1). The peat used is standard seedling peat with a pH of 6 and 1.5 g fertilizer per liter (Klasmann TS1®).

Table 1. Characteristics of the soil used in the experiment.

Saturation*	Structure	pH	EC**	$CaCO_3$*	OM*	N*	P***	Ca****	Mg****	K****	N****
51	Loamy	7.77	0.32	2.05	2.65	0.08	20.5	32.37	14.48	0.41	0.95

*: %; **: (dS m^{-1}); ***: ppm; ****: Mek/100g

The effects of 5 different irrigation water qualities such as T-K (control subject, 0.65dS m^{-1}), T-2 (2dS m^{-1}), T-4 (4dS m^{-1}), T-8 (8dS m^{-1}) and T-10 (10dS m^{-1}) on chokeberry plants were investigated.

Irrigation water was prepared using three different salt mixtures. For this purpose, 99% pure $MgSO_4$, 99% pure $CaCl_2$, and 99.5% pure NaCl salts with high water solubility were used. The required electrical conductivity (EC) value for each treatment subject was determined in the QBASIC computer program with a Sodium Adsorption Ratio (SAR) <5 and Ca/Mg ratio 1/1. The amounts of salt used per 1L of water according to the application subjects are given in Table 2.

Table 2. Amounts of salts to prepare 1L of water solution.

EC	NaCl	$MgSO_4$	$CaCl_2$
2dS m^{-1}	0.56	0.45	0.31
4dS m^{-1}	0.87	1.75	0.75
8dS m^{-1}	1.50	5.00	1.75
10dS m^{-1}	2.00	6.12	2.50

After harvest, leaf samples were taken for each subject (3 replicates) to determine the effect of different irrigation water qualities. Leaves were fixed on A4 paper and scanned into a computer. The areas of the scanned leaves were determined according to Tunca et al. (2018). The widest part of the leaf base (W) and the part along the midrib from the tip to the petiole (L) were measured to create a model. For all treatments, 70% of the data were used for model analysis and 30% for model validation.

A model for multiple linear regressions (MLR) was constructed to estimate the leaf area of chokeberry for all irrigation water treatments. Microsoft Office 2015 Excel Package Program was used to create the MLR model. MLR analysis was performed using irrigation water salinity, leaf width, length, and leaf area values. Three-dimensional graphs of the estimated models were drawn with the Slide Write Version 2.0 package program, and the variables' interactions were determined.

3. RESULTS AND DISCUSSION

Descriptive statistics values of leaf width, length, and area values obtained for the leaf area estimation model of chokeberry plants grown in the soil medium are given in Table 3. Leaf width values varied between 1.2 (T-10) and 6.30 cm (T-2) in training data and between 1.60 (T-8) and 6.7 cm (T-K) in test data. Leaf length ranged from 2.40 to 9.40 cm in training data and 2.70 to 9.20 cm in test data. The highest leaf area value was obtained from the control plants, with 46.80 cm^2 in training data and 39.25 cm^2 in test data.

Table 3. Descriptive statistics of leaf width, length, and area data of chokeberry plants grown in soil.

	Training								
	Leaf width (W)(cm)			Leaf length (L)(cm)			Leaf area (LA)(cm²)		
Treatment	Mean±SD	max	min	Mean±SD	max	min	Mean±SD	max	min
T-K	5.54±1.25	6.27	2.91	8.65±0.71	9.20	7.20	35.14±5.78	46.80	23.63
T-2	4.69±0.87	6.30	3.49	7.31±1.50	9.40	5.40	27.54±9.03	41.30	17.02
T-4	4.40±1.17	6.27	2.84	7.19±1.30	8.88	4.85	25.20±9.42	38.46	12.06
T-8	2.61±0.65	3.81	1.87	4.19±0.96	5.88	3.14	9.12±4.35	17.82	5.20
T-10	2.31±1.02	4.72	1.20	3.85±1.49	7.31	2.40	8.12±7.25	27.73	3.08
	Testing								
	Leaf width (W)(cm)			Leaf length (L)(cm)			Leaf area (LA)(cm²)		
Treatments	Mean±SD	max	min	Mean±SD	max	min	Mean±SD	max	min
T-K	5.41±0.69	6.70	4.78	8.11±0.58	9.07	7.31	30.83±5.58	39.25	22.89
T-2	4.50±1.09	5.80	3.24	7.58±1.29	9.20	5.79	26.64±8.67	37.40	15.85
T-4	4.17±0.84	5.42	3.43	6.90±1.34	8.58	5.50	23.11±7.81	34.94	15.96
T-8	2.61±0.71	3.66	1.60	4.64±0.89	5.90	3.20	10.15±4.02	16.42	3.70
T-10	2.24±0.55	3.13	1.70	3.54±0.99	5.16	2.70	6.54±3.48	12.16	3.50

For the plants grown in the peat medium, the lowest leaf width value was obtained in T-10 treatment with 0.96 cm, and the highest leaf width value was obtained in T-K with 8.19 cm in the training data (Table 4). The leaf length value varied between 3.2 (T-10) and 12.46 cm (T-K). Leaf area ranged from 2.64 (T-10) to 73.06 cm (T-K).

Table 4. Descriptive statistics values of leaf width, length, and leaf area data of chokeberry plants grown in peat.

Treatments	Training								
	Leaf width (W)(cm)			Leaf length (L)(cm)			Leaf area (LA)(cm^2)		
	Mean±SD	max	min	Mean±SD	max	min	Mean±SD	max	min
T-K	6.51±1.02	8.19	4.83	9.56±1.41	12.46	6.91	48.11±12.76	73.06	30.04
T-2	6.06±0.49	7.02	5.23	8.73±0.70	10.42	8.10	40.35±5.97	53.33	33.59
T-4	5.85±0.90	7.52	4.46	8.28±0.81	9.43	6.87	37.65±8.21	52.65	24.56
T-8	3.13±0.78	4.55	1.88	5.36±1.02	7.66	3.49	13.04±4.54	22.90	7.31
T-10	2.40±0.63	3.70	0.96	4.21±0.48	4.95	3.20	7.92±1.97	10.86	2.64
	Testing								
Treatments	Leaf width (W)(cm)			Leaf length (L)(cm)			Leaf area (LA)(cm^2)		
	Mean±SD	max	min	Mean±SD	max	min	Mean±SD	max	min
T-K	6.55±0.47	7.12	5.80	8.95±0.80	9.88	7.78	45.73±7.68	51.65	35.94
T-2	5.60±0.75	6.44	4.30	7.53±0.97	8.59	5.97	34.81±6.81	42.73	24.08
T-4	5.30±0.48	5.70	4.40	7.62±0.89	8.90	6.34	31.97±7.27	42.25	20.21
T-8	2.86±0.53	3.56	2.33	4.73±1.17	6.04	3.18	10.12±3.26	13.83	7.02
T-10	1.87±0.66	2.68	0.95	3.19±0.59	3.85	2.20	5.24±2.29	7.86	1.91

The relationships between leaf width, length, and area parameters were analyzed with three-dimensional graphs for plants grown in the soil (Figure 1) and peat mediums (Figure 2).

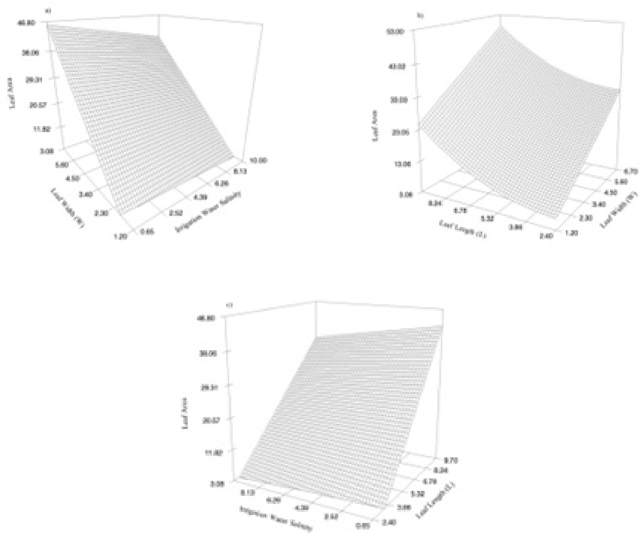

Figure 1. Relationships between leaf area and leaf width-irrigation water salinity (a), leaf area and leaf length-width (b), leaf area and irrigation water salinity- leaf length (c) in aronia plants grown in soil medium.

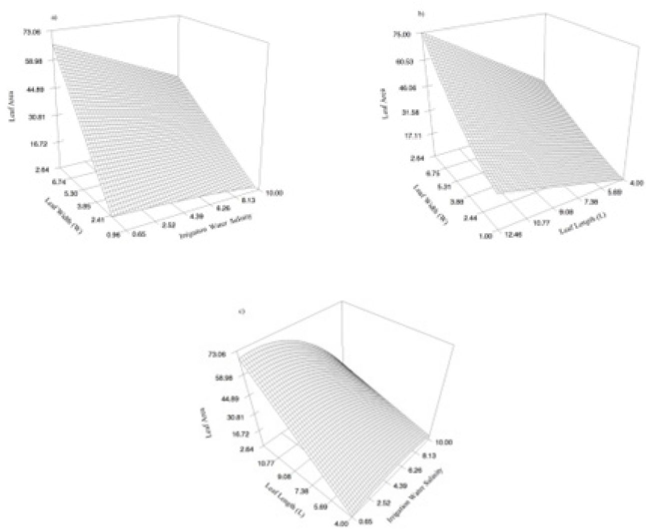

Figure 2. Relationships between leaf area and leaf width-irrigation water salinity (a), leaf area and leaf length-width (b), leaf area and irrigation water salinity- leaf length (c) in aronia plants grown in peat medium.

Effect of irrigation water salinity and leaf width on leaf area (Model 1 (Figure 1a, Figure 2a)): In this model, the effect of increasing irrigation water salinity and plant width on leaf area was determined. Increasing leaf width caused an increase in leaf area at all irrigation water salinity values in both soil (Figure 1a) and peat (Figure 2a). The highest leaf area value was obtained at low salinity and high leaf width values.

Effect of leaf width and leaf length on leaf area (Model 2 (Figure 1b, Figure 2b)): In this model, the effect of change in leaf width and leaf length on leaf area was examined. In Figure 1b, leaf area increased with increasing leaf width and leaf length values in the soil medium. In parallel, the highest leaf area value was obtained at higher leaf width and length values in peat medium (Figure 2b).

Effect of leaf length and irrigation water salinity on leaf area (Model 3 (Figure 1c, Figure 2c)): In this model, the effect of change in leaf em and irrigation water salinity on leaf area was determined. An increase in leaf length leads to an increase in leaf area at all irrigation water salinity values in both soil (Figure 1c) and peat (Figure 2c). The highest leaf area value was obtained at low salinity and high leaf length values.

The leaf area values modeled with MLR were compared with the calculated values. The prediction graph of the models for chokeberry plants grown in soil is given in Figure 3, and the predictions for chokeberry plants grown in peat are given in Figure 4.

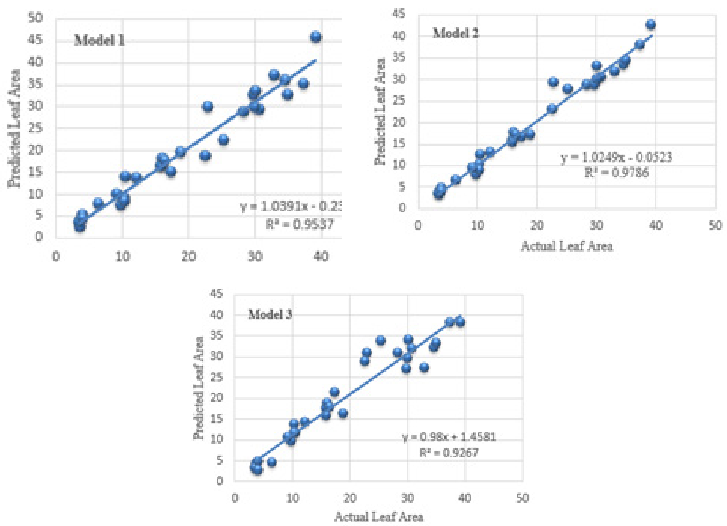

Figure 3. Comparison of leaf area of aronia plants grown in different irrigation water quality and soil with the values estimated from multiple linear regression analysis.

When the models created for leaf area estimation were examined, R^2 values ranged between 92 and 97% in the soil medium (Figure 3). In the peat medium (Figure 4), R^2 values ranging between 95 and 96% were obtained.

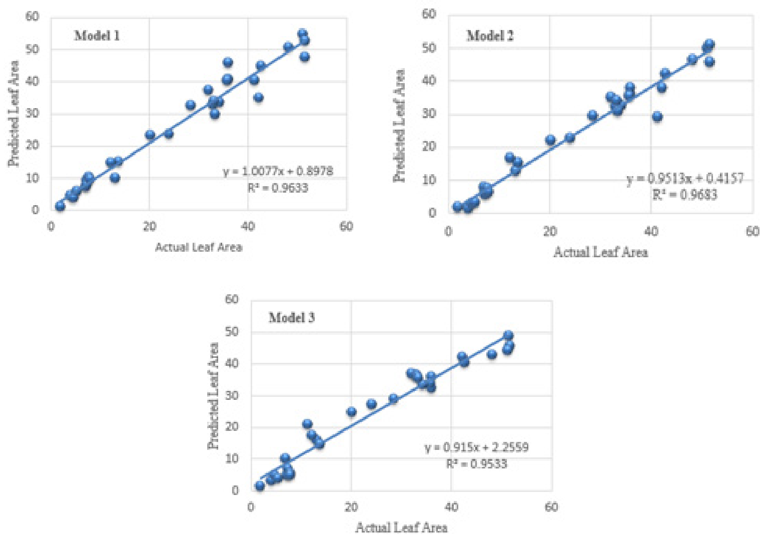

Figure 4. Comparison of leaf area of aronia plants grown in different irrigation water quality and peat with the values estimated from multiple linear regression analysis.

The relationships between irrigation water availability and leaf width, length, and area determined by MLR for chokeberry plants grown in soil and peat media are given in Table 5.

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Table 5. Relationships between leaf width, length, irrigation water salinity, and leaf area determined by MLR of chokeberry plant grown in peat and soil medium.

Soil	Model 1	Relationship between irrigation water salinity and leaf width with leaf area	LA=-14.201+0.596×EC-0.207×EC×W+9.039×W SE= (2.68) (0.31) (0.07) (0.51) R^2=0.96
	Model 2	Relationship between leaf width and leaf length with leaf area	LA=2.86+4.448×W+0.33×L^2-1.496×L SE= (1.26) (0.30) (0.03) (0.50) R^2=0.99
	Model 3	Relationship between leaf length and irrigation water salinity with leaf area	LA=-19.225+6.376×L-0.168×L×EC+0.919×EC SE= (3.22) (0.39) (0.05) (0.37) R^2=0.95
Peat	Model 1	Relationship between irrigation water salinity and leaf width with leaf area	LA=-23.155+1.901×EC-0.581×EC×W+11.166×W SE= (4.25) (0.46) (0.09) (0.66) R^2=0.96
	Model 2	Relationship between leaf width and leaf length with leaf area	LA=-9.635+2.73×W+0.04×W^2×L+2.326×L SE= (1.46) (0.45) (0.004) (0.31) R^2=0.98
	Model 3	Relationship between leaf length and irrigation water salinity with leaf area	LA=-28.945+2.488×EC-0.052×EC^2×L+7.727×L SE= (6.77) (0.98) (0.01) (0.62) R^2=0.94

The performance of the models developed for LA estimation in chokeberry with L and W inputs is relatively high (Table 5). It is seen that there is no significant difference between the calculated and estimated LA values in all models. It is seen that the values obtained are also consistent with previous studies. In some horticultural crops, R^2 values were calculated as 0.9975 in peach (Demirsoy et al., 2004), 0.993 in strawberry (Demirsoy et al., 2005), 0.988 in chestnut (Serdar and Demirsoy, 2006), 0.987 in pear (Öztürk et al., 2019), 0.982 in hazelnut (Cristofori et al., 2007). Cemek et al. (2020) estimated the leaf area with an accuracy of 0.99-0.96 (R^2) in bell pepper under different irrigation regimes and stress conditions. Also, they reported that irrigation water salinity caused a decrease in leaf area (Cemek et al., 2020). In another study, Bozkurt and Mansuroğlu (2019) stated that water restriction applications reduced leaf area in their study. Our results from coincide with the previous studies that increase in irrigation water salinity caused a decrease in leaf area.

4. CONCLUSION

According to the results, the increase in the applied irrigation water salinity causes a decrease in leaf area. Leaf width, length, and area values of chokeberry showed changes concerning each other with the applied salt concentrations. Models with high accuracy levels were developed to estimate the chokeberry plant's leaf area by measuring leaf width and length values without damaging the plant. The relationship between leaf area, leaf width, and length values for peat and soil media (model 2) can be used reliably for chokeberry leaf estimation. In this model, leaf area can be estimated using the equation. This model allows leaf area determination without the need to measure leaf area in the field with expensive methods that require more time and effort.

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Conflict of Interest

The authors declare that there is no conflict of interest.

Ethics

This study does not require ethics committee approval.

Author Contribution Rates

Design of Study: AA(%50), BC(%50)

Data Acquisition: AA(%80), BC(%20)

Data Analysis: AA(%50), BC(%50)

Writing Up: AA(%50), BC(%50)

Submission and Revision: AA(%80), BC(%20)

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