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Leaf Area Prediction Models (*Uzçelik-I*) For Different Horticultural Plants

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Abstract: A total of 343 leaves were selected randomly from fifteen different horticultural plants, that are widely grown under Samsun ecological conditions. Lamina width, length and leaf area were measured. The plants were divided into three groups according to lamina shape, plants with similar shapes being put into the same group for developing an equation to predict their leaf areas. The first group of plants included avocado species [1], lotus plum used as persimmon rootstock [2], 52 ÜN 13 selected persimmon type [3], Hayward kiwifruit cultivar [4], Bonica F1 aubergine [5] and Yalova F1 pepper [6]. The second group included GAP F1 cucumber [7], Kara üzüm (Isabella) (*Vitis labrusca* L.) [8], Narince grape cultivar (*Vitis vinifera* L.) [9], red-currant species [10], local summer squash type [11] and local Urfa squash type [12]. The third group were selected runner bean type [13], Rubin red raspberry cultivar [14] and blackberry species [15]. The numbers in square brackets represent the plant species (PS) for the equations. The actual leaf area of the plants were measured by PLACOM Digital Planimeter, and multiple regression analysis with EXCEL 7.0 was performed on the groups separately. The leaf area models developed for the first, second and third groups, were

$LA = -50.63 - 1.353*L/W*PS + 5.347*W + 0.06*W^2*PS + 5.489*L$

$LA = -114.43 - 7.31*L/W*PS + 0.651*W^2 + 210.86*L/W$

$LA = -148.65 - 2.39*LLL*PS + 2.126*ULL*PS + 29.72*LLL$

respectively, where LA is leaf area, L is leaf length, W is leaf width, ULL is upper leaf lobe length and LLL is lower leaflet length. All R^2 values (0.983, 0.986 and 0.988 for the first, second and third group, respectively) and standard errors for all subsets of the independent variables were found to be significant at the $p<0.001$ level.

Bazı Bahçe Bitkilerinde Yaprak Alanı Tahmin Modelleri (*Uzçilek-1*)

Özet: Yaz gelişme periyodu boyunca ısıtılmayan serada, bağda veya meyve bahçesinde yetişen 15 farklı bahçe bitkisinden tesadüfi olarak seçilen toplam 343 yaprağın uzunluk, genişlik ve alanları ölçülmüştür. Çalışmada kullanılan ve bulunduğumuz bölgede araştırıcılar tarafından yoğun olarak çalışmalarda kullanılan bitkiler yaprak ayalarının formuna göre üç ana gruba ayrılmış ve her bir grup için sadece bir yaprak alanı tahmin modeli geliştirilmiştir. Çalışmada Avokado [1], Trabzonhurması için anaç olarak kullanılan *Lotus* eriği [2], 52 ÜN 13 tip nolu Trabzonhurması [3], Hayward kivi çeşidi [4], Bonica F1 patlıcan çeşidi [5] ve Yalova F1 sivri biber çeşidi [6] birinci grupta, GAP F1 hıyar çeşidi [7], Siyah üzüm (Isabella) (*Vitris labrusca* L.) [8], Narince üzüm çeşidi (*Vitis vinifera* L.) [9], kırmızı frenk üzümü [10], yöresel yaz kabağı tipi [11] ve yöresel Urfa kabağı tipi [12] ikinci grupta, seçilmiş fasulye tipi [13], Rubin kırmızı ahududu çeşidi [14] ve böğürtlen [15] ise üçüncü grupta toplanmıştır. Parantez içinde verilen rakamlar eşitliklerdeki bitki türünü (PS) belirtmektedir. Yaprakların gerçek alanı PLACOM Dijital Planimetre ile ölçülmüş ve her bir gruba ayrı yarı olmak üzere EXCELL 7.0 paket programı ile değişkenlere ait verilere çoklu regresyon analizi uygulanmıştır. Gruplar için geliştirilen yaprak alanı tahmin modelleri sırasıyla aşağıdaki gibi saptanmıştır.

$LA = -50.63 - 1.353*L/W*PS + 5.347*W + 0.06*W^2*PS + 5.489*L$

$LA = -114.43 - 7.31*L/W*PS + 0.651*W^2 + 210.86*L/W$

$LA = -148.65 - 2.39*LLL*PS + 2.126*ULL*PS + 29.72*LLL$

Eşitliklerde LA tahmini yaprak alanını, L yaprak ayası uzunluğunu, W yaprak ayasanını en geniş iki noktası arasındaki mesafeyi, ULL fasulye, ahududu ve böğürtlen için ayadaki üst dilimin uzunluğunu, LLL ise aynı bitki türleri için ayadaki alt iki dilimin uçtan uca uzunluklarını ifade etmektedir. Gruplar için hesaplanan R^2 değerleri (sırasıyla 0.983, 0.986 ve 0.988) ve model eşitliklerinin hesaplanmasında kullanılan tüm bağımsız değişkenlerin standard hataları $p<0.001$ düzeyinde önemli olmuştur.

Introduction

Non-destructive estimation of plant leaf areas offers reseachers reliable and inexpensive alternatives in horticultural experiments. Non-destructive leaf-area or plant-growth measurements are often desirable because continued use of the same plants over time can reduce variability in experiments as compared with destructive sampling (1, 2, 3). Additionally, the use of simple linear measurement for predicting the leaf area of horticultural plants eliminates the need for expensive leaf area meters (4). For these reasons, the development of mathematical models and equations from linear leaf measurements for predicting total or individual leaf-area has been shown to be very useful in studying plant growth and development (5, 6, 7, 8, 9, 10, 11, 12, 13, 14). Non-destructive leaf-area estimation also saves time as compared with geometric reconstruction. Determination of the intersection of several leaves is also difficult when leaves remain attached to plants, and repeated measurements are required. Common measurements for prediction equations in some models carried out previously have included leaf length, leaf width, petiole length, main and/or lateral vein length, and different combination of these variables. Recent authors have tried using new equipment and tools such as hand scanner or laser optic apparatuses for predicting plant growth non-destructively, but these are very expensive investments for basic and simple research (15, 16).

For prediction of leaf area of some horticultural plants such as avocado, persimmons, aubergine, grape cultivars, currants, squashes and brambles having similar leaf shapes were grouped for the same equation, since many researchers have reported that there is a marked relationship between leaf area and leaf shape (17). It was our intention to produce equations that researchers will be able to utilise to predict leaf areas for the plants studied.

Materials and Methods

Leaf samples used in this research were selected randomly from fifteen different horticultural plants during the summer of 1997. Tropical, subtropical, currant, grape and small fruit plants were selected from the horticultural research area and vegetables were selected from plants grown in an unheated greenhouse at the Agricultural Faculty. Selected plants that are widely grown under Samsun ecological conditions were divided into three groups according to lamina shape. Plants having similar leaf shape were put into the same group for the development of an equation. For plants having that shape. The first group included avocado species [1], Lotus plum used as persimmon rootstock [2], 52 ÜN 13 selected persimmon type [3], Hayward kiwifruit cultivar [4], Bonica F1 aubergine [5] and Yalova F1 pepper [6]; the second group included GAP F1 cucumber [7], Kara üzüm (Isabella) (*Vitis labrusca* L.) [8], Narince grape cultivar (*Vitis vinifera* L.) [9], red-currant species [10], local summer squash type [11] and local Urfa squash type [12] and the third group were selected runner bean type [13], Rubin red raspberry cultivar [14] and blackberry species [15] (Fig. 1.). The numbers in square brackets represent the plant species (PS) for the equations.

A total of 343 leaves were measured in the experiment. The first, second and third groups were comprised of 168, 112 and 63 leaves respectively. Each leaf was processed in the following manner. First, they were placed on the photocopier desktop by holding flat and secure and copied on A3 sheet (1:1) one by one. Second, a Placom Digital Planimeter (SOKKISHA Planimeter Inc., Model KP-90) was used for estimation of leaf area. In addition to the leaf area measurements, a series of linear measurements was also performed. The linear dimensions are illustrated in Fig. 1 for the groups and plant species. The measurements were leaf width (W) measured from tip to tip at the widest part of the lamina, and leaf length (L) measured from lamina tip to the point of petiole intersection along the lamina midrib, for plants 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12. Leaf width for plants 12, 13 and 14 was measured from the uppermost large lobe tip to the point of inner petiole intersection of the uppermost lobe lamina along the midrib, and leaf length was measured from tip to tip between the lowermost two leaflets. The leaf positions were selected with regard to points that can be easily identified and used to facilitate non-destructive measurement of leaf length and width. All values were recorded to the nearest 0.1 cm.

Multiple regression analysis was performed on the groups separately. A search for the best model for predicting leaf area (LA) was conducted with various subsets of the independent variables, namely, length (L), length square (L^2), width (W), width square (W^2), length/width (L/W), length/width*plant species (L/W*PS), width square*plant species (W^2*PS), upper leaf lobe length (ULL), lower leaflets length (LLL), upper leaf lobe length*plant species (ULL*PS) and lower leaflets length * plant species (LLL*PS).

The best estimating equations for the leaf area (LA) of the plants were determined with The EXCEL 7.0. Multiple regression analysis was carried out until the least sum of squares was obtained.

Results and Discussion

Multiple regression analysis was used for determination of the best fitting equations for estimation of leaf area in the species studied showed that most of the variation in leaf area values was explained by the selected parameters (length, width, upper leaf lobe length and lower leaflet length). The variations explained by the parameters were 98.3% for group I (Avocado, Lotus plum, 52 ÜN 13 persimmon type, Hayward kiwifruit, Bonica F1 aubergine and Yalova F1 pepper), 98.6% for the group II (GAP F1 cucumber, Isabella, Narince grape cultivar, red currant species, local summer squash type and local Urfa squash type) and 98.8% for group III (selected local runner bean type, Rubin red-raspberry and blackberry species) (Table 1).

Many researchers have also reported that leaf area can be estimated by linear measurements such as leaf width and leaf length in the following plants: squash (7, 11), cucumbers (4), onions (3), pecans (18), rabbiteye blueberries (1), grapes (7, 17, 19), watermelons (10), oranges (11, 20), French beans (24), coconuts (8), bananas (9), goose berries (21), tomato (22), muskmelon (13) and Feijoa (23). The same authors found that there were close relationships between leaf area value, leaf length and leaf width for these plants (R^2= 0.976 to 0.983 for summer squash, R^2= 0.76 to 0.99 for cucumber, R^2=0.95 for Rabbiteye blueberries, R^2= 0.9841 to 0.9884 for grapes, R^2= 0.89 to 0.93 for oranges, R^2= 0.99 for French bean and R^2= 0.95 to 0.98 for coconut). We found that there was very close

Table 1. Correlation of actual leaf area with area estimated using predicition models.

The Plant Groups and The Number of The Plant Species (PS)		Models^y	R^{2z}
I	[1] Avocado [2] *Lotus* plum (*Diospyros lotus*) [3] 52 ÜN 13 persimmon type (*Diospyros kaki*) [4] Hayward kiwifruit [5] Bonica F1 aubergine [6] Yalova F1 pepper	LA=-50.63 -1.353*L/W*PS+5.347*W+0.06*W^2*PS+5.489*L SE^z (5.37)** (0.298)** (0.713)** (0.007)** (0.138)**	0.983
II	[7] GAP F1 cucumber [8] Kara grape (Isabella) (*Vitis labrusca* L.) [9] Narince grape (*Vitis vinifera* L.) [10] Red-currant [11] Local summer squash type [12] Local Urfa squash type	LA=-114.43-7.31*L/W*PS+0.651*W^2+210.86*L/W SE^z (13.539)** (1.479)** (0.009)** (25.166)**	0.986
III	[13] Local runner bean type [14] Rubin red raspberry [15] Blackberry	LA=-148.65-2.39*LLL*PS+2.126*ULL*PS+29.72*LLL SE^z (3.864)** (0.112)** (0.088)** (0.856)**	0.988

^{y}LA: leaf area, L: leaf length, L^2: leaf length square, W: leaf width, W^2: leaf width square, L/W: leaf length/width, PS: plant species, ULL: upper leaf lobe length, LLL: lower leaflets length.

SE : Standard Errors

^{z} All R^2 and SE values are significant at $p<0.001$

relationship between actual and predicted leaf areas for all the plant groups (Fig. 2).

In the present study, the equations produced for each group can be used for more than one plant species. To date, no simple equations have been produced for prediction of leaf areas of more than one plant. Thus, the models from the present study will enable researchers of plant growth modelling both fruit trees and vegetables to study the leaf growth in several species with just one equation. However, the equations produced should be validated with leaf samples taken from different environments and cultivars. The present models can be evaluated with leaf samples gathered from different growing periods and environments.

As the understanding of plant growth and development has been increasing, such mathematical models as those shown in Table 1 will be very useful tools for the prediction of leaf area for many plants without the use of expensive devices. Model developing processes of this sort may be used for other field crops, plantation crops, vegetable crops and ornamentals.

In order to utilise the equations from the present study, one may insert the formula shown in the Table 1 in to a cell in EXCELL 5.0, 6.0, 7.0 or LOTUS 3.0, 4.0, 5.0 to calculate the predicted leaf areas of any given plant species included in the models from the present study. In addition, care should be taken when using the produced models to predict the leaf areas of the plants in question to make certain that the leaf shapes are similar in form to those shown in Figure 1.

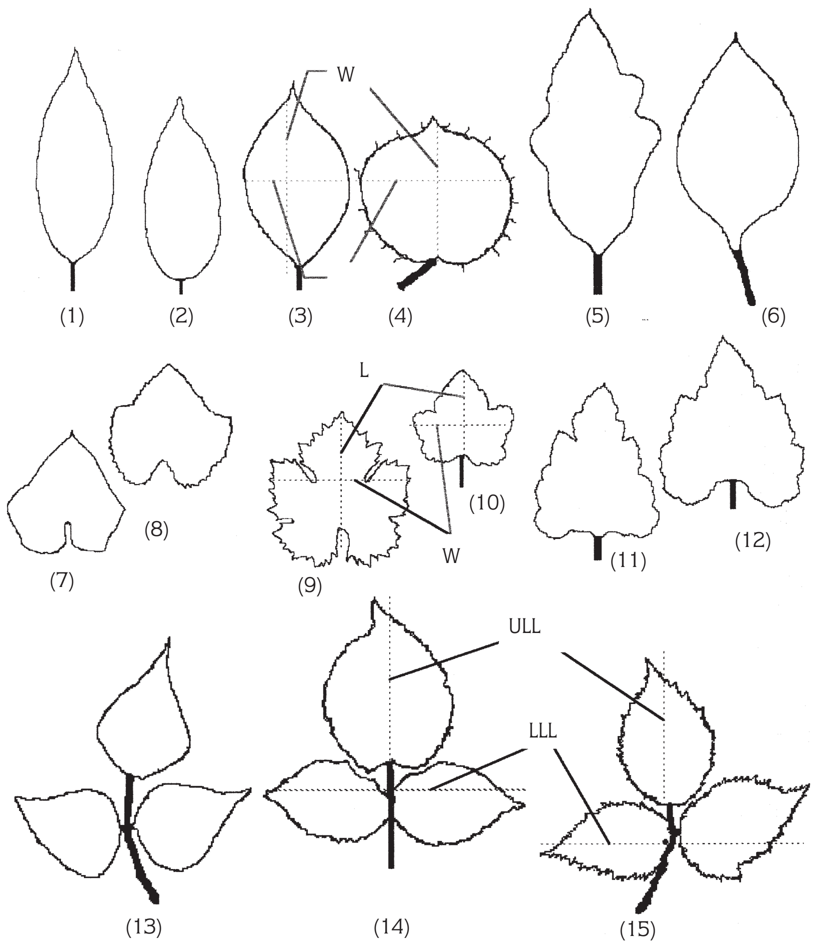

Figure 1. Diagram of some horticultural plant leaves showing the positions of leaf length (L), leaf width (W), upper leaf lobe length (ULL) and lower leaflet length (LLL) (the numbers in parentheses represents the plant species, PS).

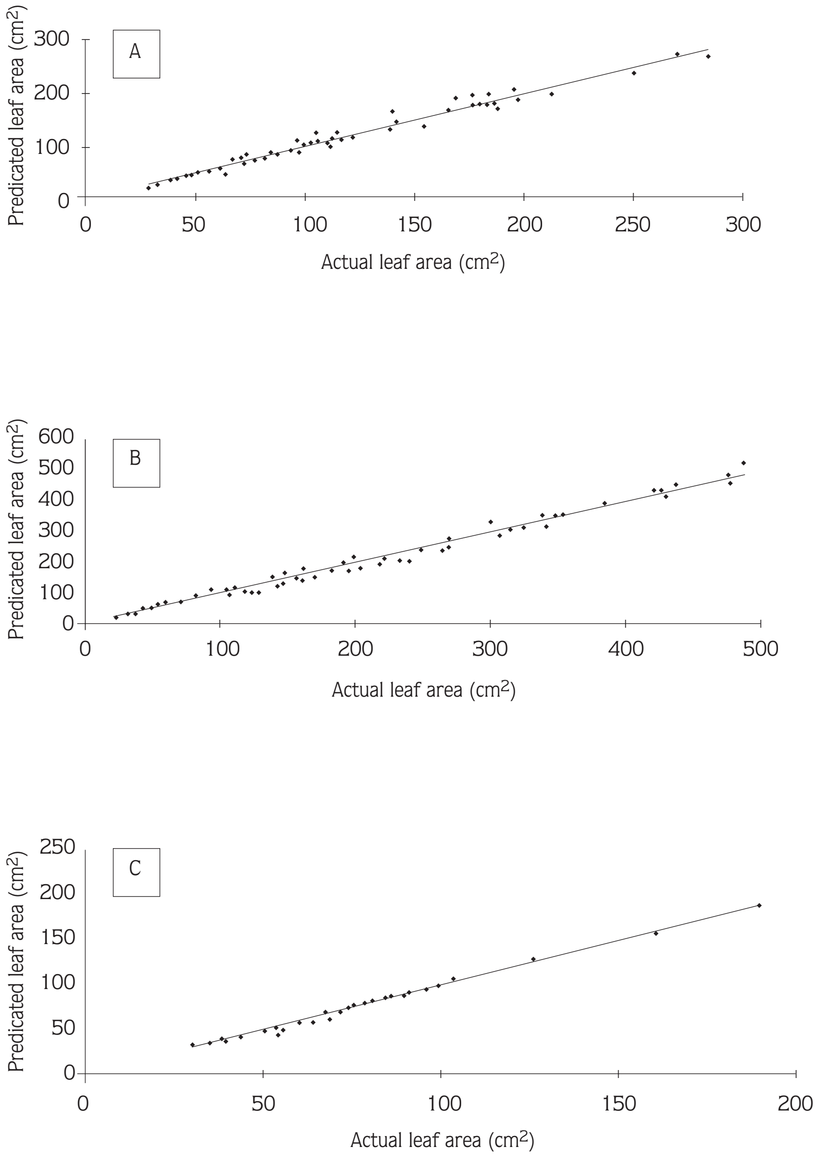

Figure 2. Relationships between actual leaf area (cm^2) and predicted leaf area (cm^2) for the plants of Group I (A), Group II (B) and Group III (C).

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