Original Research

A MODEL FOR PREDICTING LEAF AREA IN YOUNG AND OLD LEAVES OF GREENHOUSE TYPE TOMATO (*Lycopersicon esculentum,* Mill.) BY LINEAR MEASUREMENTS

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ABSTRACT: The aim of this study was to produce a simple leaf area estimation model by linear measurements for young and old leaves of greenhouse type tomato. Starting from early plant growth period to mature plant stage, a total of 150 leaves were collected to carry out linear measurements and produce a leaf area estimation model for tomato. Therefore, firstly a relationship between mean leaflet length (MLL) of a main compound tomato leaf and the length of the longest leaflet (LLL) of the top three leaflets of the main compound leaf (MLL(cm)=-0.36+1,02*LLL–0,02*LLL^2, r^2=0.98, Equation 1). Secondly, an equation was obtained by plotting actual leaf area measured by PLACOM Digital Planimeter against mean leaflet length (MLL), longest leaflet length of the top three leaflets of the main leaf (LLL) and longest leaflet width (LLW) of the top three leaflets by using multi-regression analysis. The leaf area estimation model was found as LA (cm^2) =31,6–18.41*MLL+2.40*MLL^2+0.45*LLL^2*LLW, r^2=0.99 (Equation 2). Standard errors of all subsets of the independent variables were found to be significant at $p<0.001$). Lastly, Equation 1 was combined with Equation 2 and final equation for leaf area estimation was obtained to be LA=31.6–18.41*(-0.36+1.02*LLL–0.02*LLL^2)+2.40*(-0.36+1.02*LLL–0.02*LLL^2)^2 +0.45*LLL^2*LLW (Equation 3)

Key words: Leaf shape, Leaflet length, Leaflet width, Modeling, Leaf area, Tomato

GENÇ VE YAŞLI SERA TİPİ DOMATES (*Lycopersicon esculentum*, Mill.) YAPRAKLARINDA DOĞRUSAL ÖLÇÜMLERLE YAPRAK ALANI TAHMİN MODELİ

Özet: Bu araştırmanın amacı sera tipi domatesin genç ve yaşlı yapraklarında doğrusal ölçümlerle basit bir yaprak alanı tahmin modeli oluşturmaktır. Bitki gelişiminin başlangıç aşamasından başlayarak olgun safhaya kadar yaprak alanı tahmin modeli oluşturmak ve doğrusal ölçümler yapmak amacıyla toplam 150 yaprak toplandı. Bu amaçla, ilk olarak domates yaprağı ana bileşenlerinin ortalama yaprakçık uzunluğu (OYU) ve yaprak ana bileşenlerinin ucundaki en uzun üç yaprakçığın yaprakçık uzunluğu (YYU) arasındaki ilişki (OYU(cm)= -0.36+1,02*YYU -0,02*YYU^2, r^2=0.98, Eşitlik 1) belirlendi. İkinci olarak, çoklu regresyon analizi kullanılarak ortalama yaprakçık uzunluğu (OYU), ana yaprağın uç kısmındaki en uzun üç yaprakçığın uzunluğu (YYU), uç kısımdaki en uzun üç yaprakçığın genişliğine (YYG) karşılık gelen gerçek yaprak alanı dijital planimetre PLACOM ile belirlenerek bir eşitlik elde edildi. Yaprak alanı tahmin modeli, LA(cm^2)=31,6-18.41*OYU +2.40* OYU^2+0.45*YYU^2* YYG, r^2=0.99 (Eşitlik 2) olarak bulunmuştur. Bağımsız değişkenlerin tüm alt verilerinin standart hataları $p<0.001$ düzeyinde önemli bulunmuştur. Son olarak, eşitlik 1 ile eşitlik 2 birleştirildiğinde nihai yaprak alanı tahmini için LA=31.6-18.41*(-0.36+1.02*YYU-0.02*YYU^2)+2.40*(-0.36+1.02*YYU-0.02YYU^2)^2+0.45*YYU^2*YYG (Eşitlik 3) eşitliği elde edilmiştir.

Anahtar kelime: Yaprak şekli, Yaprakçık uzunluğu, Yaprakçık genişliği, Modelleme, Yaprak alanı, Domates

INTRODUCTION

Plant growth is dynamic, and a vegetative plant produces a succession of new leaves with the elapse of he time to contribute to total plant dry weight. Therefore, leaf area measurements for physiological studies is one of the most essential processes, such as one of the physiological determinants of plant growth is the efficiency of the leaves with which the intercepted light energy is used in the production of new dry matter (Evans, 1972; Uzun, 1996). Moreover, leaf area is an indicator of photosynthetic capacity and growth rate of a plant and its measurement is of value in studies of plant competition for light and nutrients, plant-soil-water relations and in crop like tobacco, where leaf area is the major commercial product, leaf area is good indicator of yield potential (Mohsenin, 1980). On the other hand, leaf area measurements at is accordingly not surprising that many attempts have been made to produce some quick, simple and reliable means of determining leaf area during destructive or non-destructive plant harvests (Evans, 1972; Charles-Edwards et al., 1986).

The use of simple linear measurement for predicting the leaf area of horticultural plants eliminates the need for expensive leaf area meters (Robins and Pharr, 1987). The size of compound leaf of tomato is variable. The lowest two or three may be small with few leaflets. Thereafter, leaves of popular greenhouse types are typically 0.5 meters long, a little less in breadth, with a large terminal leaflet and up to eight large lateral leaflets, which may themselves be compounded (Figure 1a).

Many smaller leaflets or folioles may be interspersed with the larger leaflets. The leaflets are initiated in basipetal progression from the terminal leaflets towards the stem. The terminal leaflet is formed by the action of a marginal meristem along the flanks of the primordium at the distal end. Later other leaflets develop similarly from groups of cells which form small bulges on the flanks of the primordium (Atherton & Rudich, 1986). The leaves of seed plants can be classified as being either simple or compound according to their shape. Two hypotheses address the homology between simple and compound leaves, which equate either individual leaflets of compound leaves with simple leaves or the entire compound leaf the same time may be one of the most tedious work. It with a simple leaf (Champagne & Sinha, 2004).

Common measurements for production of leaf area estimation models have included leaf length, leaf width, petiole length, main and/or lateral vein length, and different combination of these variables (Uzun & Çelik, 1999). Many researcher have produced leaf area estimation models by linear measurements of the leaves of some horticultural crops such as summer squash (Elsner & Jubb, 1988; Ramkhelawan & Brathwaite, 1992; Uzun & Çelik,1999), runner bean (Rai et al., 1990; Uzun & Çelik,1999), aubergine (Uzun & Çelik,1999), pepper (Uzun & Çelik,1999), cucumber (Robbins & Pharr, 1987; Uzun & Çelik,1999), watermelon (Rajendran & Thamburaj, 1987), avocado (Uzun & Çelik,1999), muskmelon (Sirinivas & Hedge, 1993), red current (Uzun & Çelik,1999), tomato (Dumas, 1990), kiwifruit (Uzun & Çelik, 1999), grapes (Elsner & Jub, 1988; Yin, 1990; Pedro et. al., 1989; Uzun & Çelik, 1999), cherry (Demirsoy & Demirsoy, 2003) and peach (Demirsoy et.al.,2004).

However, there have been a few attempts to produce a leaf area estimation model predicting leaf area of young and old tomato leaves by means of using simple linear leaf measurements. Therefore, the present study aims to produce a simple model estimating the leaf area of young and old tomato leaves with high predicting capacity by linear leaf measurements.

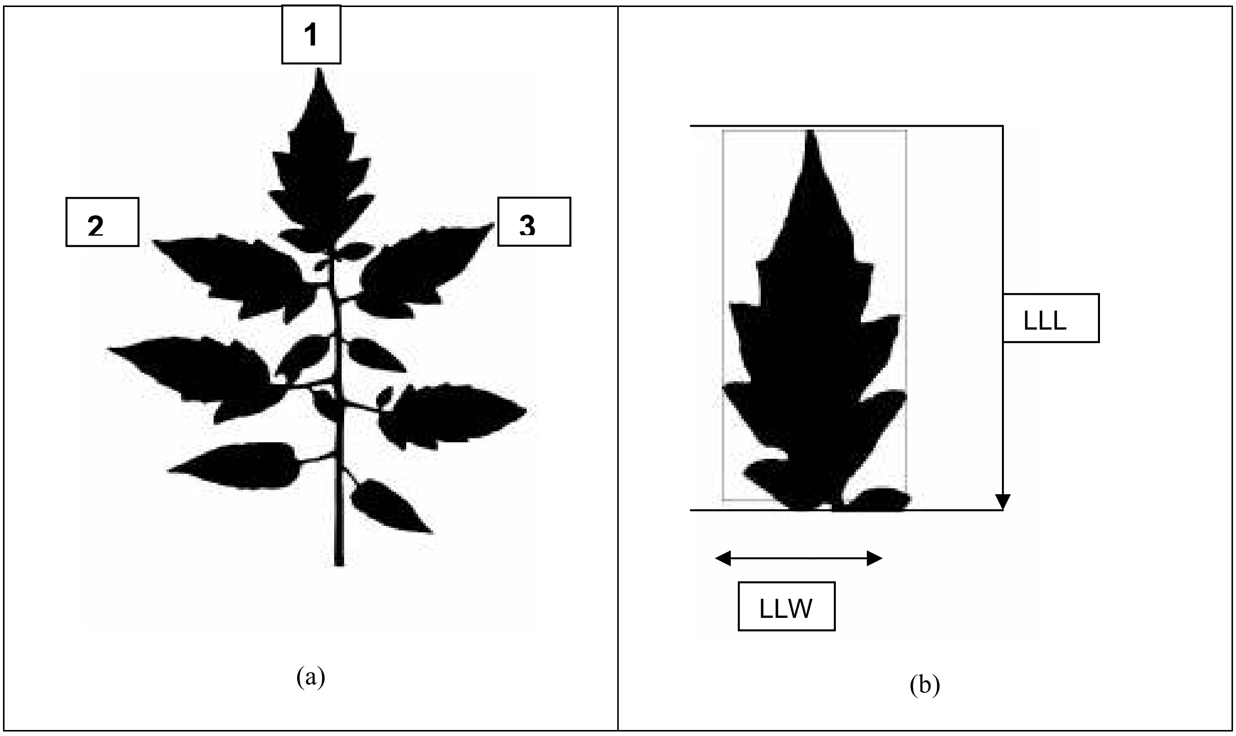

Figure 1. (a) A typical compound tomato leaf showing top three leaflets (1,2,3) and (b) a single longest leaflet (generally terminal leaflet) of the top three leaflets of the main leaf showing the measurement positions of the leaflet length (LLL) and width (LLW).

MATERIAL AND METHODS

The tomato type (cv. Tore F1) used in the present study was indeterminate standard greenhouse type. Leaf samples were selected from the top, middle and bottom of the plants starting from planting at the stage of seedling to mature growth stage. The aim of selecting leaf samples from different parts and growing stages of the plants was to obtain wide variations in leaf sizes. A total of 220 leaves were selected for using in modeling procedure. As a first step of the model producing procedure, all the leaves used in the present study were fixed on A3 sheet and photocopied then the length, width and actual leaf areas (using a Placom Digital Planimeter, SOKKISHA Planimeter Inc., Model KP-90) of the leaflets of the main leaf were measured.

Leaflet widths (cm) were measured from tip to tip at the widest level of the leaf lamina. Leaflet lengths (cm) were measured from leaflet lamina tip to the point of petiole intersection along the lamina midrib. The linear dimensions used for linear measurements on the leaf lamina were shown in Figure 1b.

Secondly, using multiple regression analysis, a relationship was found between mean leaflet length and leaf by plotting mean leaflet length against the length of the longest leaflet of the top three leaflets of the main. This relationship was used as an independent parameter in producing leaf area estimation model.

Thirdly, multiple regression analysis was carried out by plotting actual leaf area (LA) against different subsets of the independent variables such as mean leaflet length (MLL), the longest leaflet length of the top three leaflets of the main leaf (LLL) and the width of the longest leaflet of the top three leaflets of main leaf (LLW). The equation produced between actual leaf area and the independent variables was determined when the least sum of squares were obtained. The Excel 7.0 package program was used in all the analysis performed for model producing procedure.

RESULTS AND DISCUSSION

In the present study, multiple regression analysis were carried out in order to produce a leaf area estimation model by linear measurements for tomato leaves. As a first step, a relationship between mean leaflet length (MLL) per main leaf and the length of the longest leaflet (LLL) of the top three leaflets (generally the terminal leaflet) of the main leaf were obtained by plotting the length of the mean leaflet per main leaf against the length of the longest leaflet of the top three leaflets using multiple regression analysis. The aim of producing such a sub-model was find a relationship between mean leaflet length (MLL) and longest leaflet length of top three leaflets (LLL) and enable researchers to estimate leaf area of tomato by means of measuring only length and width of a single leaflet (mostly terminal leaflet) of the compound leaf accordingly.

$$MLL\ (cm) = -0.36 + 1{,}02 \cdot LLL - 0{,}02 \cdot LLL^2 \ldots\ldots (1)$$

SE (0,082)*** (0,029)*** (0,002)***

$r^2 = 0{,}98$ ***

The second step was the determination of an equation between dependent and independent variables. For implementation a relationship between leaf area (LA), mean leaflet length predicted by equation 1 (MLL), the length of the longest leaflet length of the top three leaflets of the main leaf (LLL) and the width of the longest leaflet of the top three leaflets of the main leaf (LLW), multiple regression analysis were carried out and the following equation was obtained

$$LA\ (cm^2) = 31{,}60 - 18.41 \cdot MLL + 2.40 \cdot MLL^2 + 0.45 \cdot LLL^2 \cdot LLW \ldots\ldots (2)$$

SE (6.50)*** (3.90)*** (0.59)*** (0.03)***

$r^2 = 0{,}99$ ***

Here, LA represents leaf area of a single main leaf and LLW represents the width of the longest leaflet of top three leaflets of the main leaf. SE represents standard error of means. When we rewrite the above equation using Equation 1, the final equation becomes as the following;

$$LA = 31.6 - 18.41 \cdot (-0.36 + 1.02 \cdot LLL - 0.02 \cdot LLL^2) + 2.40 \cdot (-0.36 + 1.02 \cdot LLL - 0.02 \cdot LLL^2)^2 + 0.45 \cdot LLL^2 \cdot LLW \ldots\ldots (3)$$

This equation predicts leaf area of tomato by only measuring the length (LLL) and the width (LLW) of the longest leaflet of the top three leaflets of a main compound tomato leaf. The selected independent variables in Equation 1 explained 99 % of the variation in leaf area.

The present model of leaf area estimation by linear leaflet measurements in tomato can be used for physiological and quantitative studies of greenhouse tomato cultivars.

As seen in Figure 2, there was a very close relationship between actual and predicted leaf areas of tomato. As mentioned previously, the model predicts leaf area highly reliably and is open to being evaluated. Many researchers have reported close relationships between leaf area and linear measurements such as leaf length and leaf width for many crops (Pharr, 1987; Rajendran & Thamburaj, 1987; Elsner & Jubb, 1988; Pedro et. al., 1989; Dumas, 1990; Rai et al., 1990; Yin, 1990; Ramkhelawan & Brathwaite, 1992; Sirinivas & Hedge, 1993; Uzun & Çelik, 1999; Çelik & Uzun, 2002; Demirsoy & Demirsoy, 2003; Demirsoy et.al., 2004). The most important advantages of the model produced in the present study is that (a) the model

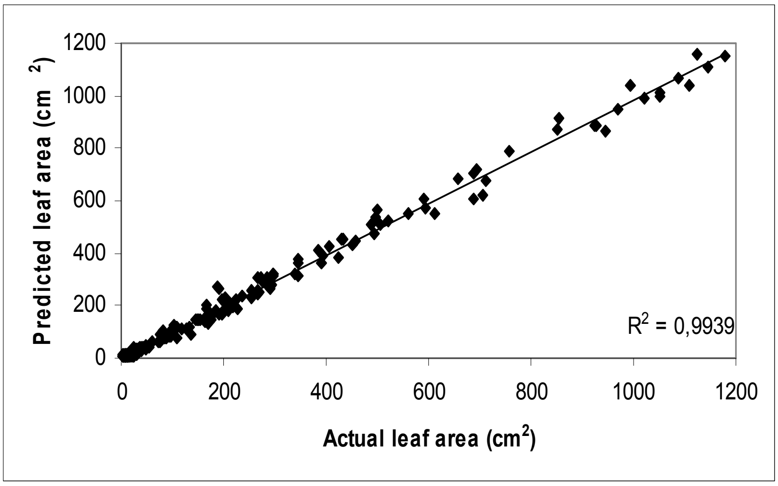

Figure 2. The relationship between actual leaf area (cm^2) and predicted leaf area (cm^2) for tomato leaves.

enables researchers to calculate the area of a compound tomato leaf by determining the longest leaflet of the top three leaflets of the main leaf, measuring its length and width and using these values in Equation 1 and 3 and (b) the model can be used in the studies that need non-destructive leaf area measurements. However, the present model is open to being evaluated for the future studies concerning leaf area estimation by linear leaf measurements.

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