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A Leaf Area Estimation Model for Faba Bean (*Vicia faba* L.) Grown in the Mediterranean Type of Climate

Cahit ERDOĞAN*

Mustafa Kemal Üniversitesi Ziraat Fakültesi Tarla Bitkileri Bölümü Antakya/Hatay
*Yazışma yazarı: cerdogan@mku.edu.tr

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Abstract: Determination of leaf area index is an important parameter for assessing carbon exchange and light interception and transmission from the leaf. A simple and quick leaf area estimation model for faba bean (*Vicia faba* L.) was developed by using the leaflet length (L) and width (W). The proposed leaf area (LA) estimation model is LA= -1,6923 + (L*0,0161) + (W*0,0929) + (0,0062*L*W), where LA is leaf area (cm^2), L is leaflet length (cm), W is the leaflet width (cm). A standard method (Model MK2, Eijkelkamp Inc., Giesbeek, The Netherlands) 3050C) was used to compare the estimated leaf area with the actual measured leaf area**.** As a result of regression analysis, performed with 26 faba bean genotypes, parameters responsible for the variation in leaf area values produced the determination coefficient (R^2) of 97,59%. None significant differences between observed and predicted LA showed that the suggested model can be used for faba bean regardless of the expensive instruments.

Key words: Faba bean, v*icia faba,* leaf area, model estimation

Akdeniz Bölgesinde Yetiştirilen Bakla (*Vicia faba* L.) Bitkisi İçin Bir Yaprak Alanı Tahmin Modeli

Özet: Yaprak alanı indeksinin belirlenmesi yaprakların karbon alışverişi, tutulan ve geçirilen ışık miktarının belirlenmesi için önemli bir parametredir. Bakla (*Vicia faba* L.) için basit ve hızlı bir yaprak alanı tahmin modeli, yaprakçık uzunluğu (L) ve yaprakçık eni (W) kullanılarak geliştirildi. Geliştirilen yaprak alanı tahmin modeli LA= =-1,6923 + (L* 0,0161) + (W*0,0929) + (0,0062*L*W) şeklindedir. Bu modelde LA yaprak alanını (cm^2), L yaprakçık uzunluğunu (cm) ve W yaprakçık enini (cm) göstermektedir. Tahmin edilen yaprak alanı ile ölçülen yaprak alanını karşılaştırmak amacıyla standart bir yöntem (Model MK2, Eijkelkamp Inc., Giesbeek, The Netherlands) 3050C) kullanıldı. 26 bakla genotipine ait veriler kullanılarak elde edilen regresyon analizi sonucunda, yaprak alanındaki varyasyondan sorumlu parametreler %97,59 olan belirleme katsayısını (R^2) ortaya çıkarmıştır. Ölçülen ve tahmin edilen yaprak alanları arasındaki önemli olmayan farklılıklar, bu modelin pahalı yaprak alanı cihazlarına gereksinim duymadan kullanılabileceğini göstermiştir.

Anahtar kelimeler: Bakla**, v**icia faba, yaprak alanı, tahmin modeli

Introduction

Faba bean, one of the oldest domesticated plants, is used for human and animal nutrition because of their seeds with high protein (about 25%) content. This makes it a valuable crop especially in animal nutrition (Musallam *et al*, 2004). Major faba bean producer countries are China, Ethiopia, France and Egypt. Faba bean ranks fourth in the grain legume production of Turkey (FAO, 2009).

Leaf area is an important factor affecting radiation interception, transpiration and photosynthesis (Thomson and Siddique, 1997; Rao *et al*., 2002). In agronomy studies, determination of leaf area index (LAI) is an important parameter for the studies of crop growth and development. Especially, in the studies of plant densities, knowing leaf area (LA) of grain legume crops helps agronomist to determine optimum number of plants per unit area. The radiation energy incident from the sun is intercepted by the leaf and used in photosynthesis. The photosynthesis is increased at the extent to the ratio of green covering (Leach and Beech, 1988; Lopez-Bellido *et al*., 2005; Karamanos and Gimenes, 1991). In addition to radiation interception, transpiration and photosynthesis, rapid development of LA is one of the effective ways for weed suppression.

A lot of methods such as photographing, scanning or using an area meter device have been employed to measure LA (Gamper, 2005; Serdar and Demirsoy, 2007; Peksen, E., 2007; Rico-García *et al*, 2009). However, it is impossible, by these methods, for repetitive measurement of the same leaf because of requiring excised leaves. Furthermore, these methods are expensive, time and labor-consuming.. Therefore, a cheaper, rapid, accurate, and non-destructive method is desired to measure LA of faba bean and other crops.

Various LA estimation models were developed for agricultural crops, using linear measurement of leaf length and width (Uzun and Celik, 1999; Kurt *et al*., 2005; Beyhan *et al*., 2008). Although there are a few LA estimation models developed for faba bean, none of them is perfectly suitable for Mediterranean type of climate and should be updated under different environmental conditions (Odabas and Gulumser, 2005; Peksen, 2007), because leaf geometry may change under different light and soil nutrient (Gamper, 2005).

The objective of this study was to develop a simple, non-destructive, accurate and time saving LA estimation model for faba bean grown in the Mediterranean type of climates.

Material and Methods

Leaflet samples were taken from faba bean plants, grown at the experimental area of Agricultural Faculty, Mustafa Kemal University, Hatay during 2010-2011growing season. The experimental area is located at the South of Turkey, with a geographical coordinates of 36°15'N 36°30'E. Three cultivars and twenty three lines of faba bean were used for LA estimation model. The genotypes and their origins are presented in the Table 1. The leaflets were sampled at the flowering stages, paying attention to taking randomly at the different part of faba bean genotypes. Fifty leaflets per genotype were excised for measurement. Leaflet length (maximum length from petiole-lamina intersection to lamina tip along the midrib) and width (the widest line between two leaflet edges perpendicular to midrib) were measured in mm. A typical faba bean leaflet is shown in Figure 1. Actual leaflet areas were measured by a leaf area meter (Model MK2, Eijkelkamp Inc., Giesbeek, The Netherlands).

Multiple regression analysis of the data was performed using SAS statistic software (1998). Various subsets of the independent variables, viz., leaf length, leaf width and leaf length*leaf width, were used to develop the best model for predicting the LA. Scatter plot of values for the predicted leaf area (PLA) versus the observed leaf area (OLA) was performed using MS Excel 2010 spreadsheet software.

Results and Discussion

Since regression model with the highest R^2 value was considered as the best prediction equation (Abraham and Ledolter, 1983), various parameters were tried to obtain the highest R^2 value.

As a result of regression analysis, performed with all varieties and lines, parameters responsible for the variation in LA values produced the determination coefficient (R^2) of 97.59% (Fig. 2).

The proposed LA estimation model is
$LA = -1.6923 + (L*0,0161) + (W*0,0929) + (0,0062*L*W)$,
where LA is leaf area (cm^2), L is leaflet length (cm), W is the leaflet width (cm).

Table 1. Faba bean genotypes used for leaf area estimation model and their origins

No	Genotypes	Cultivar/Line	Origin
1	Kıtık	Cultivar	AARI*
2	Eresen	Cultivar	AARI
3	Filiz	Cultivar	AARI
4	FLIP06-001FB	Line	ICARDA‡
5	FLIP06-003FB	Line	ICARDA
6	FLIP06-012FB	Line	ICARDA
7	FLIP06-013FB	Line	ICARDA
8	FLIP06-015FB	Line	ICARDA
9	FLIP08-051FB	Line	ICARDA
10	FLIP08-052FB	Line	ICARDA
11	FLIP08-053FB	Line	ICARDA
12	FLIP08-054FB	Line	ICARDA
13	FLIP08-055FB	Line	ICARDA
14	FLIP08-056FB	Line	ICARDA
15	FLIP08-057FB	Line	ICARDA
16	FLIP08-058FB	Line	ICARDA
17	FLIP08-059FB	Line	ICARDA
18	FLIP08-060FB	Line	ICARDA
19	FLIP08-061FB	Line	ICARDA
20	FLIP08-062FB	Line	ICARDA
21	FLIP08-063FB	Line	ICARDA
22	FLIP08-064FB	Line	ICARDA
23	FLIP08-065FB	Line	ICARDA
24	Ascot	Line	ICARDA
25	Reina blanca	Line	ICARDA
26	Syrian local large	Line	ICARDA

*Aegean Agricultural Research Institute, Menemen/Izmir
‡International Center for Agricultural Research in the Dry Areas

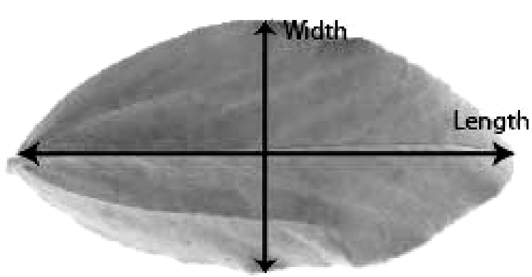

Figure 1. Measured parts of faba bean leaflet for leaf area determination

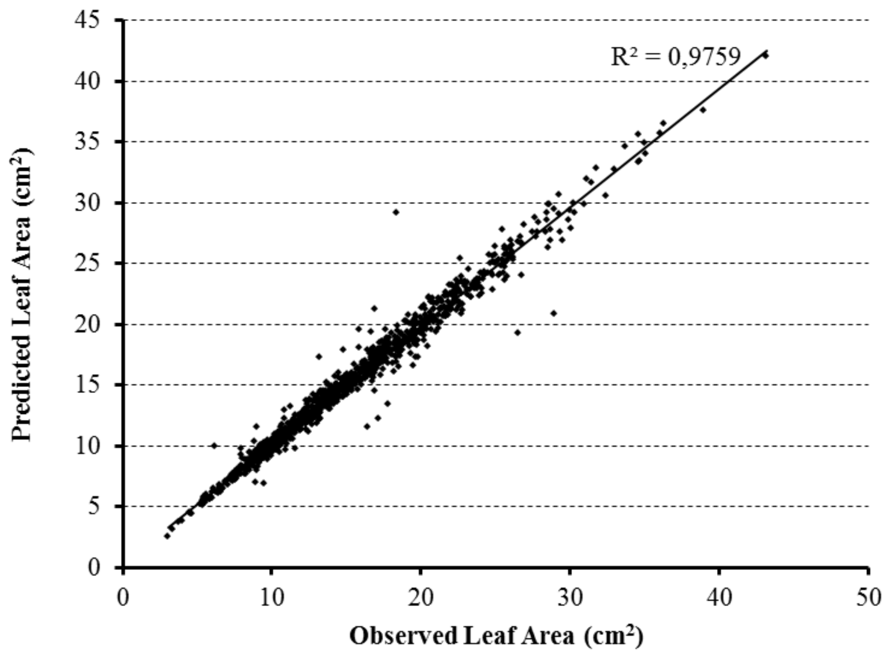

Figure 2. The relationship between predicted and observed leaf area for faba bean genotypes.

The R^2 seems to be enough to predict LA of faba bean plants, due to combination of 26 varieties and lines. Predicted leaf areas, obtained using this general R^2, are presented in Table 2. However, estimation models for each variety and line can be proposed if needed for more accurate results. As seen in the Table 2, it was found that the relationship (R^2 values) between observed and predicted leaf areas varied from 0.8856 in FLIP08-062FB to 0.9926 in FLIP08-061FB.

The present study is in agreement with the reports of Odabas and Gulumser (2005) in the sense of high determination coefficient and differs from the fact that they used only one faba bean variety.

Peksen (2007) reported similar results in his study, using fourteen faba bean genotypes. Some studies on the other economically important crop plants have also similar results (Bhatt and Chanda, 2003; Kurt *et al*., 2005; Gamper, 2005).

In this study, a LA estimation model, simple and quick, was developed to predict the LA of faba bean grown in the Mediterranean type of climates.

Differences between observed and predicted LA are statistically small enough to use the model in the crop growth and development studies regardless of the expensive instruments.

The LA can be predicted easily by measuring only leaflet length and width of faba bean. Spreadsheet softwares such as MS Excel or Libreoffice Calc may be useful for calculation of the LA using this model taking into account mass data.

The suggested new LA estimation model, developed by using twenty six genotypes, can be reliably used in the Mediterranean type of climates.

Table 2. Observed and Predicted Leaf Area (cm^2) of genotypes used for leaf area estimation model

Genotype	Observed Leaf Area (cm^2)	Predicted Leaf Area (cm^2)	R^2	Standard Error
Kıtık	13,82	13,84	0,9561	0,7765
Eresen	12,33	12,61	0,9780	0,6463
Filiz	12,09	12,16	0,9713	0,5295
FLIP06-001FB	12,68	12,67	0,9495	0,9518
FLIP06-003FB	13,95	13,86	0,9897	0,4898
FLIP06-012FB	18,69	17,81	0,9883	0,9952
FLIP06-013FB	13,75	14,23	0,9896	0,5524
FLIP06-015FB	16,74	16,38	0,9900	0,6303
FLIP08-051FB	15,43	15,24	0,9782	0,6166
FLIP08-052FB	18,27	18,03	0,9714	1,3003
FLIP08-053FB	16,9	16,75	0,9913	0,6163
FLIP08-054FB	17,02	16,98	0,9778	0,7236
FLIP08-055FB	14,85	14,95	0,9911	0,4855
FLIP08-056FB	14,21	14,29	0,9919	0,6033
FLIP08-057FB	24,53	24,18	0,9830	0,9217
FLIP08-058FB	16,9	16,83	0,9790	0,7311
FLIP08-059FB	16,91	16,85	0,9903	0,5197
FLIP08-060FB	15,65	16,03	0,9882	0,7613
FLIP08-061FB	11,42	11,7	0,9926	0,4107
FLIP08-062FB	17,65	17,56	0,8856	1,9949
FLIP08-063FB	15,63	16,19	0,9905	0,5085
FLIP08-064FB	14,34	14,57	0,9787	0,5769
FLIP08-065FB	14,94	14,81	0,9849	0,977
Ascot	15,37	15,47	0,9712	0,8921
Reina blanca	18,06	18,04	0,9862	0,491
Syrian local large	13,5	13,66	0,9803	0,6005

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