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Leaf Area Prediction Model for Safflower (*Carthamus tinctorius* L.)

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Abstract: In the present study, it was aimed to develop a leaf area prediction model for safflower (*Carthamus tinctorius* L.). The experimental design was a Randomized Complete Block Design with three replications in the 2004 growing season in the Middle Black Sea Region conditions of Turkey. Three safflower cultivars (5-154, Dinçer and Yenice) were grown at five locations (Bafra, Ladik, Suluova, Gümüşhaciköy and Osmancik). Totally, 9604 leaves for five different times were measured in the experiment. Leaf width, length and leaf area were measured. The actual leaf area of the plant was measured by PLACOM Digital Planimeter and Multiple regression analysis with Excel 7.0 was performed. The leaf area model developed was $LA= (3.88) – (3.14\times W) + (0.76\times W^2) + (0.73\times W\times L) + [0.009 (W\times L^2)] - [0.004 (W^2\times L^2)]$. LA is leaf area, L is leaf length, W is leaf width. R^2 value (0.95) and standard errors were found to be significant at the $p<0.001$ level.

Key words: Safflower, leaf area, modelling

INTRODUCTION

Safflower (*Carthamus tinctorius* L.) is a member of the family Compositae or Asteraceae, cultivated mainly for its seed, which is used as edible oil and for dye production since ancient times. Traditionally, the crop was grown for its flowers, used for colouring and flavoring foods and making dyes, especially before cheaper aniline dyes became available and in medicine[1]. It is an important oilseed crop with 35-40% oil content[2]. Safflower has been cultivated in 800.000 ha in the world and 650.000 tons seed yield has been obtained from this area. Although India has half of the world seeding area, it has 25 of world's production because of the low yield. USA, Kazakhstan, Mexico and Ethiopia have important acreages; however USA, Mexico and China have high yields. Safflower is cultivated about 300 ha in Turkey[3]. Even though safflower has no important production area in Turkey, many researchers have studied on this crop and important data have been obtained from these researches. Middle Blacksea Region is one of the important agricultural regions and it has suitable conditions for different kinds of plants.

The development of mathematical models from linear leaf measurements for predicting total leaf area has been shown to be a useful tool in studying plant growth and development[4-9].

Non-destructive estimation of plant leaf areas offers researchers reliable and inexpensive alternatives in field 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. Additionally, the use of simple linear measurement for predicting the leaf area of field crops eliminates the need for expensive leaf area meters. For these reasons, the development of mathematical model and equation from linear leaf measurement for predicting total or individual leaf area has been shown to be very useful in studying plant growth and development[10].

Common measurements for prediction equations in some models carried out previously have included leaf width, leaf length, petiole length, main and/or lateral vein length and different combination of these variables. Some researchers 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[11,12].

The objective of this study was to develop and evaluate linear regression models that can accurately predict safflower leaf area using simple linear leaf measurements.

MATERIALS AND METHODS

Safflower (*Carthamus tinctorius* L.) cultivars (5-154, Dinçer and Yenice) were used as experimental material. Field experiments were established in Bafra (41° 35′ N Lat., 35° 56′ E Long. and 15 m elevation), Ladik (40° 56′ N Lat.,

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35° 54´ E Long. and 920 m elevation), Suluova (40° 47´ N Lat., 35° 41´ E Long. and 484 m elevation), Gümüşhaciköy (40° 52´ N Lat., 35° 14´ E Long. and 785 m elevation) and Osmancik (40° 58´ N Lat., 34° 51´ E Long. and 449 m elevation), in Middle Black Sea Region, Turkey, on 8-11 April 2004 and were carried out throughout the vegetation periods of the selected locations. Normal growing season precipitation (April through September) is 445 mm at Bafra, 298 mm at Osmancik, 282.3 mm at Suluova, 281.8 mm at Gumushacikoy and 145 mm at Ladik. Normal mean temperatures during this period are 18.28, 19.58, 18.26, 17.61 and 14.1°C at Bafra, Osmancik, Suluova, Gumushacikoy and Ladik, respectively. Soil types of Bafra, Suluva and Gümüşhaciköy are clay loam, of Osmancik and Ladik are silty clay loam.

The experimental design was a Randomized Complete Block Design with three replications. Seeding rates were 10 kg ha^{-1}. Individual plot size was 2×5 m = 10 m^2. Four plants in each safflower plots were harvested in five different location and five different periods. Pulling dates: 1. pulling: 3-5 June, 2. pulling: 21-23 June, 3. pulling: 11-13 July, 4. pulling: 5-7 August and 5. pulling: 27-29 August 2004. A total of 9604 leaves were measured in the experiment. Each leaf was processed in the following manner. First, they were placed on the photocopier desktop by holding flat and secure and copied on A4 sheet (1:1) one by one. Second, 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 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.

Multiple regression analysis was performed on the cultivars together. A search for the best model for predicting Leaf Area (LA) was conducted with various subsets of the independent variables, namely, length (L), width (W), length width (W×L), length square width (L^2×W) and length width square (L×W^2). The best estimating equation for the leaf area (LA) of safflower was determined with the Excel 7.0. Multiple Regression Analysis was carried out until the least sum of square was obtained.

RESULTS AND DISCUSSION

Multiple regression analysis used for determination of the best fitting equation for estimation of leaf area in safflower showed that most of the variation in leaf area values was explained by the selected parameters (length and width) (Table 1). The variation explained by the parameters was 95%.

Table 1: The equation of leaf area for safflower

LA^a =	(3.88) - (3.14×^bW) + (0.76×$^cW^2$) + (0.73×^dW×L) + [0.009 (^eW×L^2)] - [0.004 ($^fW^2$×L^2)]				
SE^g =	1.38***	0.31***	0.07**	0.04***	0.003***
	0.04***				
	R^2= 0.95***				

^{a}LA: leaf area, ^{b}L: leaf width, ^{c}W^2: leaf width square, ^{d}W×L : leaf width leaf length, ^{e}W×L^2 : leaf width leaf length square, ^{f}W^2×L^2 : leaf width square leaf length square, ^{g}SE: Standard Error '''R^2 and all SE values are significant at p<0.001

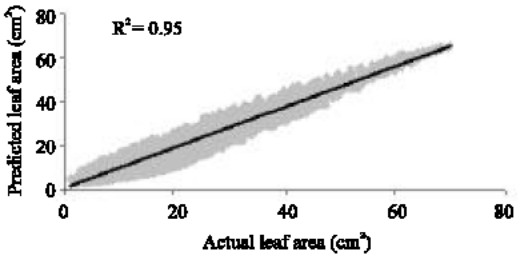

Fig. 1: The relationship between actual leaf area (cm^2) and predicted leaf area (cm^2) for safflower

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: cucumbers (*Cucumis sativus* L.)[4], orange (*Citrus aurantium* L.)[13,14], French bean (*Phaseolus vulgaris* L.)[15], coconut (*Cocos nucifera* L.)[16], Grape (*Vitis vinifera* L.)[10] and broad bean (*Vicia faba* L.)[17] and also found that there were close relationship between leaf area value, leaf length and leaf width for these plants (R^2= 0.76 to 0.99 for cucumber, R^2= 0.89 to 0.93 for orange, R^2= 0.99 for French bean, R^2= 0.95 to 0.98 for coconut, R^2= 0.98 for grapes and R^2= 0.99 for broad bean). The present model of leaf area estimation by linear leaflet measurements in safflower can be used for physiological and quantitative studies. There was a very close relationship between actual leaf area and predicted leaf area highly reliably and is open to being evaluated (Fig. 1).

Consequently, the present model can be evaluated with leaf samples gathered from different growing periods. As the understanding of plant growth and development has been increasing, such mathematical models will be very useful tools for prediction of leaf area for many plants without using of expensive devices (Table 1). Model developing processes of this sort may be used for other field crops, plantation crops, vegetables and ornamentals.

These results demonstrate that safflower leaf area can be predicted using simple linear measurements. However, environment has been shown to influence model development for cucumbers[4]. Prediction equations, therefore, may need to be adjusted for safflower grown under various environmental conditions.

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