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RAPID ESTIMATION OF SUNFLOWER LEAF AREA FROM LINEAR MEASUREMENTS[1]

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ABSTRACT

A rapid, simple and nondestructive method is described for estimating the area of sunflower leaves based on leaf length or leaf length and width. Prediction equations were derived from these variables separately for each of three cultivars used and also for all the cultivars combined.

Measurements of 180 leaves of a range of sizes from three cultivars of sunflower grown under controlled temperature and humidity indicated a very close correlation between leaf area and the product of leaf length and width. The correlation coefficient was found to be 0.99. The correlation coefficient was slightly higher when the cultivars were considered separately.

Linear relationships were also found between $\log_{10}$ leaf area and $\log_{10}$ leaf length for all the cultivars with a correlation coefficient of 0.97. Similarly, when the three cultivars were considered separately, the correlation coefficients were slightly higher.

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INTRODUCTION

In the study of plant processes, such as photosynthesis, transpiration and growth rate, it is often necessary to obtain information on leaf area. Different methods have been used to estimate the leaf area of plants depending on the purpose of the experiment. Quantitative studies of plants often require a nondestructive method of determining leaf area. Hopkins (4) summarized different categories of methods for estimating the area of leaves and introduced a method which allowed measurement of leaf area nondestructively. The usual procedure involves measuring maximum length, width, and area of different samples of leaves and developing simple linear or logarithmic regression equations relating leaf area to leaf length or leaf length x width. The accuracy and advantages of this method was later discussed by Kemp (5).

Several mathematical formulas have been derived to relate leaf dimensions to leaf area for different species. Epstein and Robinson (2) obtained a linear relationship between potato (*Solanum tuberosum* L.) leaflet area and the product of leaflet length and leaflet width and a logarithmic relationship between length and area. Hoffman (3) found a logarithmic relationship between the length and area of leaves of onion (*Allium cepa* L.) grown under controlled temperature and humidity. Wendt (9) reported that a relationship between log of leaf area and log of leaf length existed for castor bean (*Ricinus communis* L.) cotton (*Gossypium hirsutum* L.), and sorghum (*Sorghum vulgare* L.) with correlation coefficient of 0.99, 0.95 and 0.94, respectively.

Wiersma and Bailey (10) made a thorough study on different cultivars of soybean plants (*Glycine max L.)* and suggested different equations derived from independent variables involving measurements of length and width and measurements of only length or width. They concluded that although regression equations developed from measurements of only length or width, the latter were simpler and involved considerable savings of time. Several other mathematical formulas have been derived for different crops (1, 7, 8).

There is little information available on methods of measuring leaf area of sunflower plants nondestructively. The purpose of this report is to introduce a nondestructive, fairly rapid technique which does not require elaborate equipment for determining sunflower leaf area.

MATERIALS AND METHODS

The leaves used in this investigation were obtained from three cultivars of sunflower (*Helianthus annuus L.)*, Record, Krasnodarets, and Hybrid 896. The plants were grown from seed in a 1:1 mixture of vermiculite and gravel in 25 cm plastic pots in the Duke University Phytotron with the specifications described by Kramer *et al.* (6). The temperature was 26 C during the 9-hour day time and 20 C during the 15-hour night time. The relative humidity was 70%. The plants were watered every day to the drip point with half strength Hoagland's solution in the morning and demineralized water in the afternoon.

Different leaves were selected within a population of each cultivar during different stages of growth to include a wide range of sizes. Each leaf was mounted between two sheets of plexiglass and the outline of the leaf was traced on graph paper while the plexiglass sheets were illuminated from below. The area of the tracing was determined by counting the squares on the graph paper (one square = 0.40 cm^2). The length and the maximum width of each leaf were determined to the nearest mm.

Linear regression equations of the form Y = a + bx relating leaf area to the product of leaf length and leaf width or $\log_{10}$ leaf area to $\log_{10}$ leaf length were calculated using the method of least squares. The two regression equations were obtained for each of the three cultivars and for all three cultivars combined.

RESULTS AND DISCUSSION

There was generally a slightly higher correlation coefficient between leaf area and the product of leaf length and width than between $\log_{10}$ leaf area and $\log_{10}$ leaf length. With the three cultivars either considered separately or grouped together, the correlation coefficient for leaf area and the product of leaf length and leaf width was always 0.99 or greater (Table 1). This relationship held for a wide range of leaf sizes (0.52 to 4.80 dm^2). The close correlation between leaf area and the product of leaf length and width is further shown in Fig. 1 where the value for all 180 leaves are plotted.

For the relationship between $\log_{10}$ leaf area and $\log_{10}$ leaf length, the correlation coefficients ranged from 0.96 to 0.98 for the individual cultivars treated separately (Table 1). When all three cultivars were grouped, the correlation coefficient was 0.96. There was a greater scatter about the regression line when $\log_{10}$ area and $\log_{10}$ length were plotted for all 180 leaves from the three cultivars (Fig. 2).

Our results indicate that measurements of either leaf length or leaf length and width can be used to estimate leaf area in sunflower. It appears that a single regression equation can be used for estimating leaf area from linear measurements for the three cultivars we examined. This equation has the R^2 value of 0.93 which is fairly high. More accurate estimation of leaf area can be obtained by using both the length and width of the leaf. However, when a more rapid method is desirable, estimation may based just on the leaf length.

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Table 1. Regression equations for leaf area as a function of leaf length or the product of leaf length and width for three cultivars of sunflower. A= leaf area (dm^2); L = leaf length (dm); and W = leaf width (dm).

Cultivar	No. of leaves measured	Leaf size range dm^2	Regression equation	r
Record	20	(0.69 – 2.91)	$A = 0.663 (L \times W) + 0.091$	0.990
			$Log_{10} A = 2.291 (Log_{10} L) - 0.273$	0.966
Hybrid 896	82	(0.58 – 4.20)	$A = 0.708 (L \times W) + 0.017$	0.994
			$Log_{10} A = 2.350 (Log_{10} L) - 0.307$	0.980
Krasnodarets	78	(0.52 – 4.80)	$A = 0.684 (L \times W) + 0.026$	0.991
			$Log_{10} A = 2.140 (Log_{10} L) - 0.284$	0.962
All three cultivars	180	(0.52 – 4.80)	$A = 0.696 (L \times W) + 0.021$	0.992
			$Log_{10} A = 2.242 (Log_{10} L) - 0.291$	0.969

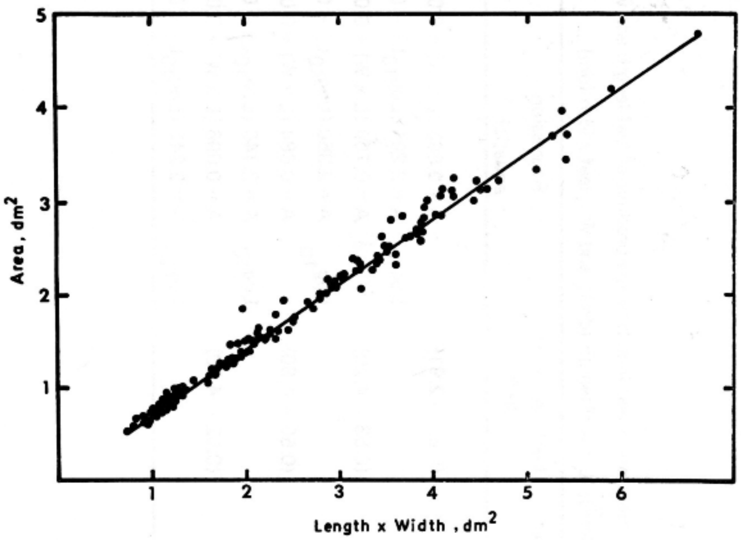

Fig. 1. Leaf area as a function of the product of leaf length and leaf width. The points represent data of all three cultivars.

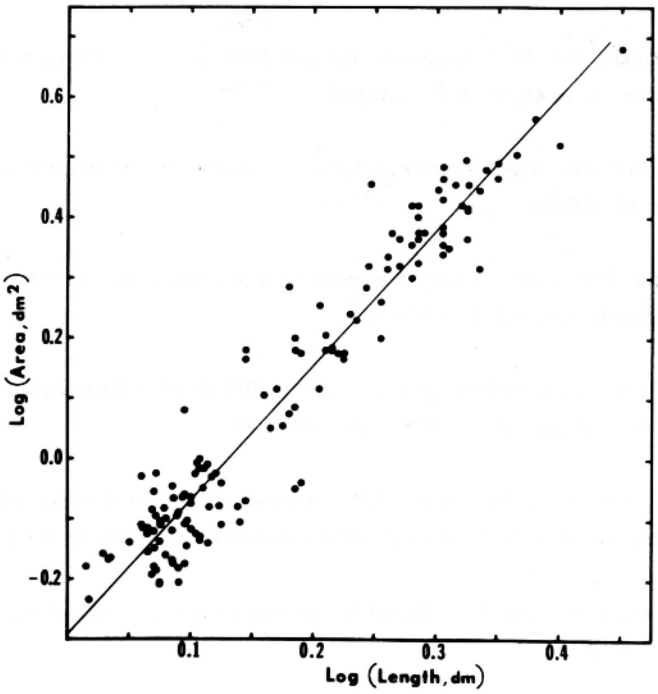

Fig. 2. Logarithm of leaf area as a function of logarithm of leaf length. The points represent data of all three cultivars.

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