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Short Communication

Leaf area estimation by a simple and non-destructive method

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ABSTRACT-In this study, the relation between leaf area and its dimensions was estimated using a non-destructive method. This method is based on this fact that the leaf shape does not change during the growing season. In this method, leaf area during the growing season is estimated based on the dimensions of the smallest leaf in the initial stage of plant growth or at any growth stage by measuring the leaf area and dimensions of this leaf ($K=\frac{LA_s}{L_s \times W_s}$), where the K value was obtained by dividing the measured area of smallest leaf (LA_s) by its dimensions; length (L_s) and width (W_s).This method was used for 16 plant species. The values of the index of agreement and normalized root mean square error for all plants showed a good agreement between the measured and estimated leaf area by this method.

INTRODUCTION

Leaf area is one of the most important traits of plants. There are many methods of measuring the leaf area to assess the leaf growth: destructive and non-destructive methods. In destructive methods, leaves should be detached from the plant and leaf area is measured by leaf area meter or plain meter (tools. In non-destructive methods, leaf area is estimated based on other parameters such as length and width of leaf (without cost) or by portable leaf area meter tools, i.e. LI-3000C instrument (with cost). For estimating leaf area by using its length and width, the length and width of leaf is directly measured by a ruler in the field; then, leaf area is estimated by relation between leaf area and the leaf length and width and/or length×width (Sepaskhah, 1977; Montero et al., 2000; Mousavi Bazaz et al., 2011; Shabani et al., 2013). However, it is difficult and even impossible to measure these relations in some experiments; namely, pot experiments, in which the number of leaves is small.

There are two types of plant leaf growth patterns. First, leaf growth occurs along with changes in leaf shape [i.e., rapeseed (Shabani et al., 2013), radish etc.]. Second, leaf growth occurs along with changes in leaf size. Therefore, more than one relation between leaf area and leaf dimensions is needed for the first leaf group. However, for the second group, one relation is sufficient (McKee, 1964; Stewart and Wiersma and Bailey, 1975; Dwyer, 1999; Peksen, 2007).

In the case of limited number of leaves and in without-cost conditions, non-destructive methods should be used to establish a relation between leaf area and its dimensions. A simple and non-destructive method was used to determine the relation between leaf area and its dimensions for leaves whose shape did not change during the growing season in a pot experiment with a small number of leaves.

MATERIALS AND METHODS

If the length (L) and width (W) of a large rectangular surface area and b times of those values in a small rectangular surface, respectively, the ratio of the two rectangles areas is as follows:

$$A_2/A_1=a\times b \qquad (1)$$

where A_1 and A_2 are the areas of small and large rectangular surfaces, respectively. Therefore, if the ratio of length and width of two rectangles is known, the area of one rectangular surface can be determined based on the area of another rectangular surface. Comparison between many leaves of different plants showed that this method can probably be used to estimate the leaf area in plants whose leaf grows along with changes in leaf size and not in leaf shape. In these plants, leaf area increases with an increase in width and length of the leaf. Therefore, similar to the area of rectangles, the area of a large leaf can be estimated by using the area of a smaller leaf if the K coefficient is determined by using the area, width and length of the smallest leaf of the plant as follows:

$$K = \frac{LA_S}{L_S \times W_S} \quad (2)$$

where LA_s, L_s and W_s are the area, length and width of the smallest leaf at the beginning of leaf growth or at any growth stage, respectively. The K is a specific coefficient for any plant. Therefore, the area of larger leaf can be estimated by the following equation:

$$LA_l = K \times L_l \times W_l \quad (3)$$

where LA_l, L_l and W_l are the area, length and width of the larger leaf during the growing season, respectively. This method, in which the assessment of leaf area change is obtained without cutting the plant leaves during the growing season, can be used to estimate the leaf area in pot experiments with limited number of leaves. To assess this principle, 16 plant species with different leaf shapes were selected (Table 1). Twelve to twenty leaves of each plant were cut from plants and transferred to laboratory. Leaves were prepared from orchards, greenhouses, landscape and other locations at Fasa, Fars province, I. R. of Iran. The area of each leaf was measured by plan meter and their length and width were measured by a ruler and the smallest leaf was selected. The average of width, length and area of leaves for each plant are shown in Table 1. To compare the estimated area with those measured values, the index of agreement (d) and normalized root mean square error (NRMSE) were used (Willmott et al., 1985). As the value of d is closer to 1.0 and NRMSE is closer to 0.0, the accuracy of results is higher. The estimation is considered excellent if the NRMSE is less than 10%, good if the NRMSE is greater than 10% and less than 20%, fair if the NRMSE is greater than 20 and less than 30%, and poor if the NRMSE is greater than 30% (Jamieson et al., 1991).

RESULTS AND DISCUSSIONS

Constant value of K was calculated by Eq. (2) for the smallest leaf of each plant. Results are shown in Table 1. According to the results, K varied in different plants from 0.5 to 0.8. These values are similar to the slope of the line between leaf area and leaf dimensions as reported by others for corn (McKee, 1964; Stewart and Dwyer, 1999), Soybean (Wiersma and Bailey, 1975), hazelnut (Cristofori et al., 2007), and faba bean (Peksen, 2007). Therefore, the two methods lead to similar results but in the present method, instead of several leaves, justone leaf is damaged. The areas of larger leaves of each plant were estimated based on their length and width and by using Eq. (3) and then, the estimated leaf area was compared with the measured values. Results of some plants are shown in Fig. 1.

The NRMSE values for climbing begonia, rose, alstroemeria, oleander, acacia, eucalyptus, knotgrass and sudangrass varied between 0 and 10%, which indicated that the accuracy of estimated leaf area by Eq. (3) was excellent (Jamieson et al., 1991). For persimmon, almonds, fig, bergamot, pomegranate, mulberry and olive, the NRMSE values were between 10 and 20% (Table 1), which indicated that the accuracy of the leaf area estimation was good. The NRMSE for ziziphus was higher than 20% (between 20 and 30%) and showed that the leaf area prediction is fair by this method. The values of the index of agreement (d) for all plants are more than 0.9 showing a good agreement between the estimated and measured leaf areas.

Table 1. Mean values of leaves properties for plant species used in this study

Plant	Number	Width (cm)	Length (cm)	Area (cm^2)	K	d	NRMSE
Persimmon	15	6.18 (1.60)	10.19 (2.54)	43.15 (22.05)	0.71	0.977	0.14
Almonds	14	2.29 (0.39)	8.29 (1.40)	14.12 (4.08)	0.67	0.931	0.12
Ziziphus	15	2.83 (0.58)	3.50 (0.58)	7.97 (2.74)	0.67	0.865	0.22
Fig	13	8.41 (3.89)	8.74 (4.13)	49.2 (45.59)	0.53	0.995	0.114
Bergamot	15	5.34 (1.51)	10.70 (2.82)	47.05 (24.57)	0.68	0.963	0.17
Pomegranate	13	1.83 (0.40)	4.92 (1.79)	6.15 (3.08)	0.55	0.959	0.176
Mulberry	14	6.34 (2.15)	8.56 (3.45)	44.13 (31.40)	0.77	0.988	0.15
Climbing begonia	15	5.55 (1.91)	6.50 (2.08)	25.83(14.99)	0.63	0.997	0.05
Rose	20	3.13 (0.84)	4.11 (1.13)	11.06 (5.38)	0.75	0.991	0.08
Alstroemeria	15	2.61 (0.51)	9.09 (0.98)	16.34 (4.21)	0.63	0.948	0.09
Oleander	15	2.10 (0.29)	11.75 (1.37)	17.86 (4.39)	0.71	0.994	0.029
Olive	15	0.96 (0.21)	6.48 (0.78)	4.03 (1.09)	0.68	0.945	0.112
Acacia	12	1.32 (0.29)	9.54 (0.89)	7.40 (1.45)	0.58	0.965	0.064
Eucalyptus	15	2.49 (0.60)	12.29 (2.36)	18.87 (6.05)	0.56	0.962	0.099
Knotgrass	19	0.33 (0.03)	8.66 (1.03)	1.48 (0.21)	0.53	0.933	0.069
Sudangrass	13	1.44 (0.22)	28.18 (7.93)	28.65 (11.12)	0.67	0.986	0.074

Notes: NRMSE is the normalized root mean square error, d is the index of agreement, K is a specific coefficient for any plant and numbers in parenthesis are standard deviation.

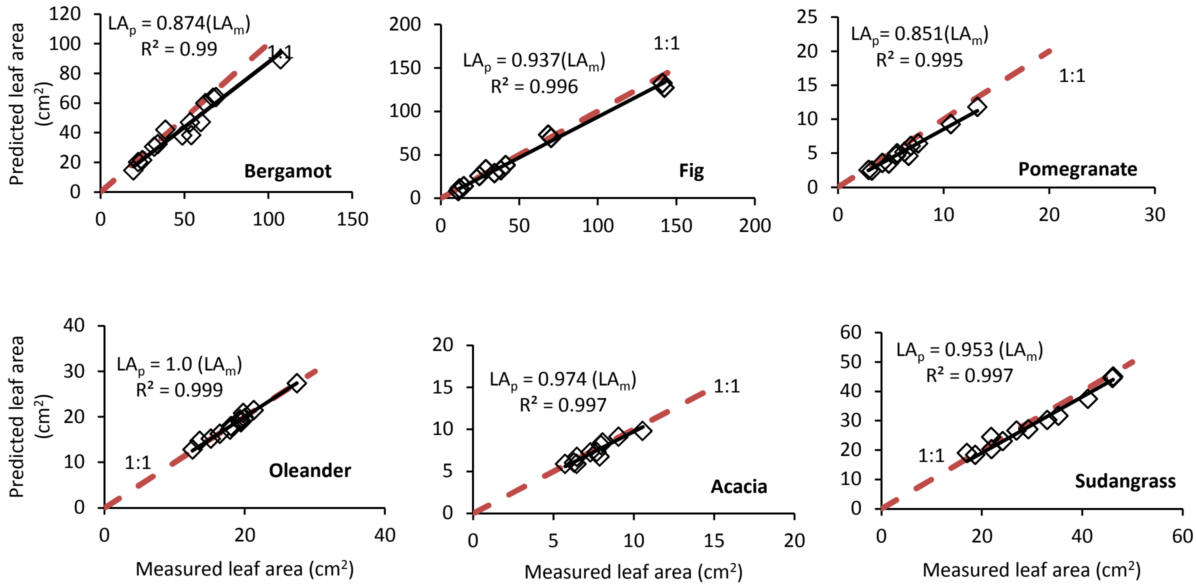

Fig. 1. Relation between the measured LA_m and predicted LA_p leaf area for some plant species

CONCLUSIONS

There are many methods of estimating the leaf area. In some methods, several leaves must be cut from the plant to determine the relation between leaf area and leaf dimensions. This destructive method is not appropriate in some experiments, i.e., pot experiments, in which the number of leaves is limited. In this study, a non-destructive method was presented to obtain the relation between leaf area and its dimensions for leaves with invariant shape during the growing season. The values of the index of agreement and normalized mean square error for all of the plants used in this study showed a good agreement between the measured and estimated leaf area by this method. The advantage of this method is its non-destructiveness which makes it a useful tool for assessing the leaf area and leaf area index in pot experiments with limited number of leaves. This method is applicable in field conditions to obtain the relation between leaf area and its dimensions for leaves in a very short time period. This method can be used for cereals, oilseeds, and other plants whose leaves shape change during the growing season when leaves shape is invariant.

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مقاله کوتاه

تخمین سطح برگ به روش ساده و غیر تخریبی

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واژه های کلیدی:
مساحت برگ
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چکیده- در این مطالعه رابطه بین سطح برگ و ابعاد آن بر اساس اصل تشابه وبا استفاده از یک روش غیر مخرب تخمین زده شد. این مفهوم بر این حقیقت استوار است که شکل برگ ها در طول دوره رشد تغییر نمی کند. در این روش سطح هر برگی در طول دوره رشد بر اساس ابعاد کوچکترین برگ در مرحله ابتدایی رشد یا در هر مرحله ای از رشد با اندازه گیری سطح و ابعاد این برگ با استفاده از رابطه ($K=\frac{LA_S}{L_S \times W_S}$) تخمین زده می شود، بطوری که مقدار K از تقسیم مساحت اندازه گیری شده کوچکترین برگ بر ابعاد آن بدست می آید.این روش برای ۱۶ گونه گیاهی استفاده شد. مقدار شاخص توافق و میانگین مربعات خطای استاندارد شده برای همه گیاهان نشان داد که با این روش مساحت برگ ها با دقت خوبی تخمین زده می شود.