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Determination of *Merremia cissoides* leaf area using the linear measures of the leaflets

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ABSTRACT. Knowledge of the weed leaf area may give support to study the interference relationships between weeds and crops. The objective of this research was to determine a mathematical equation for *M. cissoides* leaf area estimation based on the relationship between the leaf blade linear measures. Leaves of the species were collected from a variety of agroecosystems at São Paulo State University, Jaboticabal, São Paulo State, Brazil, measuring the length (L), maximum width (W) and real leaf blade area of the three kinds of leaflets. Linear equations Y = *a* x (X) were estimated for each kind of leaflet. The confidence intervals of the primary leaflet equation overlapped those ones from the secondary leaflet equation, and then only one equation was considered for these leaflets. So, an equation of principal leaflet plus that one of primary + secondary leaflets were used to determine the *M. cissoides* leaf area. Thus, the leaf area of the species might be determined by the sum of the leaf areas of the principal leaflet with the primary + secondary leaflets, according to the equation LA_{est} = 0.501 x (X) + 2.181 x (Z), where X indicates L x W of the principal leaflet and Z indicates medium L x W of the primary + secondary leaflets, respectively.

Keywords: weed, growth, roadside woodrose, linear fit.

RESUMO. Determinação da área foliar de *Merremia cissoides* utilizando dimensões lineares dos folíolos. O conhecimento da área foliar de plantas daninhas pode auxiliar o estudo das relações de interferência entre elas e as culturas agrícolas. O objetivo desta pesquisa foi determinar uma equação matemática que estime a área foliar de *Merremia cissoides*, a partir da relação entre as dimensões lineares dos limbos foliares. Folhas da espécie foram coletadas de diferentes locais na Universidade Estadual Paulista, Jaboticabal, Estado de São Paulo, Brasil, medindo-se o comprimento (C), a largura máxima (L) e a área foliar de três tipos de folíolos. Foram estimadas equações lineares Y = *a* x (X) para cada tipo de folíolo. Houve sobreposição dos intervalos de confiança das equações dos folíolos primário e secundário, por isso considerou-se uma única equação da média desses folíolos, além da equação do folíolo principal, para caracterização da área foliar de *M. cissoides*. Assim, a área foliar dessa espécie pode ser estimada pelo somatório das áreas dos limbos foliares dos folíolos principal e primário + secundário, por meio da equação AF_{est} = 0,501 x (X) + 2,181 x (Z), em que X indica C x L do folíolo principal e Z indica C x L médios dos folíolos primário + secundário, respectivamente.

Palavras-chave: planta daninha, crescimento, jitirana, ajuste linear.

Introduction

Merremia cissoides, Convolvulaceae, is an indigenous plant to Tropical America (LEJOLY; LISOWSKI, 2001; VITAL et al., 2008). This species is important as ornamental due to its showy flowers; however it may cause serious problems to mechanical harvest due to its climbing growth habit (KISSMANN; GROTH, 1999). The negative effects of Convolvulaceae weed species on crop harvest were recently affirmed by Hager and Nordby (2007) and Davis (2008). Moreover, *M. cissoides* have been described as a leading weed on sugar cane, a very important crop in Brazil (KUVA et al., 2007, 2008). So, the *M. cissoides* biology must be studied better for giving support to research on crop protection.

Basic studies are necessary for better comprehension on weed biology, regarding aspects as growth, development, nutritional requirement, reproduction and others. They may also help to know the weed response to control methods. In most of these studies, the leaf area determination is essential because it is one of the most important characteristics for vegetal growth evaluation and may help to understand the interference relationships among crop and weeds (BIANCO et al., 2008a and b).

Mathematical equations have been used for leaf area determination with high precision. This non-destructive, easy and quick method for leaf area estimation is important for plant growth evaluation in field conditions (BIANCO et al., 2007). The relationship between the real leaf area and the linear measures of leaves had been studied successfully for weed leaf area determination based on regression analysis by Carvalho and Christoffoleti (2007), Bianco et al. (2007), Bianco et al. (2008a and b) and others.

The objective of this research was to determine a mathematical equation to estimate *M. cissoides* leaf area based on the relationship between the leaf blade linear measures.

Material and methods

This research was conducted at College of Agrarian and Veterinarian Sciences of São Paulo State University (FCAV/UNESP), Jaboticabal, São Paulo State, Brazil. The leaves used in this study were collected in a variety of agroecosystems at FCAV/UNESP, in December 2008, regarding many ecological conditions where the species grows in the agricultural fields. One hundred leaves with no injury caused by insects, fungi or weather conditions were randomly gathered from *M. cissoides* plants in flowering stage, and then the leaf blades of the three kinds of leaflets (Figure 1) were separated.

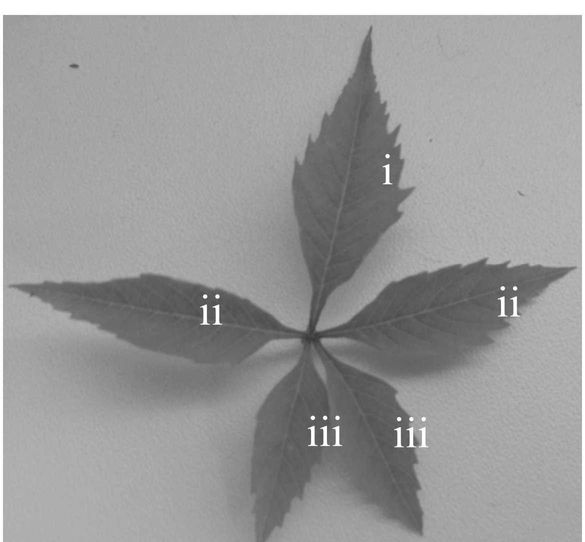

Figure 1. Representation of *Merremia cissoides* leaves compounded by three kinds of leaflets (i - principal; ii - primary; iii - secondary).

Around fifteen leaves of a variety of *M. cissoides* plants were collected at each sampling place. We measured the leaf blade length through principal nervure (L), the leaf blade maximum width perpendicular to principal nervure (W) and the real leaf blade area (LA) for each kind of leaflet, using the Portable Area Meter Licor Mod. L1-3000. The L, W and LA data of the three kinds of leaflets were submitted to analysis of variance with application of the F and Tukey tests at 5% of significance, considering the average values of the two leaf blades for primary and secondary leaflets. The total leaf area of the species was determined by the sum of the leaf areas of the principal leaflet with the primary + secondary leaflets.

A linear regression analysis was performed to examine the relationship between the leaf blade area and the leaflet linear measures of the three kinds of leaflets, according to the equation $Y = a \times (X) + e$, where Y indicates the estimated leaf blade area value while X indicates L x W value, so that *a* expresses the equivalent percentage of L x W corresponding to the real leaf blade area, and *e* is the standard error associated with observation Y. This equation was chosen why Bianco et al. (2007, 2008a and b) and others concluded that it may be used satisfactorily for leaf area determination, showing better practical application.

The regression equations of each leaflet were compared by the confidence intervals based on *a* parameter to 5% of significance. The equations are considered equivalents when the confidence intervals are overlapped (CARVALHO; CHRISTOFFOLETI, 2007), so that the regression analyses must be processed separately if the overlapping do not occurred.

Spearman-Rank test was processed to verify the correlation between the real and estimated values for leaf blade area. Shapiro-Wilk test was employed on the residual values of the statistical model used to verify the normality of residual distribution.

Results and discussion

Just little information on weed biology is available in literature, so that any work on *M. cissoides* leaf area determination was not found. However, comparing this species with other Convolvulaceae weeds, *M. cissoides* showed smaller leaf area (20.095 cm^2) than *Ipomoea hederofolia* (29.760 cm^2) and *Ipomoea nil* (21.280 cm^2) studied by Bianco et al. (2007). The plants may intercept less sunlight than ones competing with them when their leaf area is smaller, although Taiz and Zeiger (2006) and Zhao and Liu (2009) stated that the photosynthesis efficiency depends on the species photosynthetic potential.

Sixty six percent of the principal leaflets were distributed in the 2.01-6.00 cm^2 leaf blade size range, while 82 and 83% of the primary and secondary leaflets, respectively, were distributed in this one (Table 1). Forty four percent of the principal leaflets showed leaf blade area larger than 6.00 cm^2 while 16 and 2% of the primary and secondary leaflets, respectively, were in this size range. Thus, the principal leaflets were distributed in larger size ranges than primary and secondary leaflets, respectively.

Table 1. Distribution of the percentage of leaflets of one hundred leaf blades of the three kinds of *Merremia cissoides* leaflets in relation to size ranges.

Size (cm^2)	Kind of leaflets		
	Principal	Primary	Secondary
[00.01 – 02.00]	-	2	15
[02.01 – 04.00]	17	50	69
[04.01 – 06.00]	49	32	14
[06.01 – 08.00]	22	14	2
[08.01 – 10.00]	7	2	-
[> 10.00]	5	-	-

The principal leaflet showed higher L, W and LA values than the primary and secondary leaflets, respectively (Table 2). The principal leaflet showed higher L value than the primary and secondary leaflets in the order to 17 and 34%, respectively. Furthermore, the principal leaflet showed higher W value than the primary and secondary leaflets in the order to 13 and 28%, respectively. Thereby, the principal leaflet showed higher LA value than the primary and secondary leaflets in the order to 23 and 47%, respectively.

However, the confidence intervals of the primary and secondary leaflet regressions were overlapped (Table 3), so that the primary and secondary leaflet equations were equivalents. Thus, a new regression considering the average data between the primary and secondary leaflets was processed to obtain only one equation for these leaflets.

Table 2. Average values of length (cm), maximum width (cm) and leaf blade area (cm^2) of the three kinds of leaflets from *Merremia cissoides*, and coefficient of variation (CV) and least significant differences (LSD) at Tukey test.

Leaflet	Variables[1]		
	Length	Maximum width	Leaf area
Principal	4.902 a	2.212 a	5.580 a
Primary	4.086 b	1.944 b	4.303 b
Secondary	3.261 c	1.609 c	2.955 c
CV (%)	17.810	18.710	36.560
LSD (cm)	0.242	0.120	0.521

[1]Average values followed by the same letters are not different to Tukey Test ($p < 0.05$).

Table 3. Estimates for parameter *a* of regression equation, standard error, coefficient of determination (R^2) and confidence interval (CI) to 5% of significance for leaf area determination of *Merremia cissoides* leaflets based on linear measures of the leaf blades.

Leaflet	*a*	Error	R^2	CI (5%)	
				Minimum	Maximum
Principal	0.501**	0.004	0.946	0.493	0.509
Primary	0.531**	0.005	0.934	0.522	0.540
Secondary	0.546**	0.006	0.901	0.534	0.557
Primary + Secondary	0.545**	0.004	0.949	0.537	0.553

**T test significant to 1% of probability.

The regressions of the principal leaflet and primary + secondary leaflets showed the highest coefficient of determination and the least error (Table 3), indicating high precision for leaf blade area estimation. The data variation might be explained by these regressions in the order of 94.6 and 94.9%, respectively, to the principal and primary + secondary leaflets. Furthermore, the leaf blade area was represented by 50.1 and 54.5% of L x W to the principal and primary + secondary leaflets, respectively. In accordance to these results, the leaf blade area of the principal leaflet might be determined by $LA_{pc} = 0.501 \times (L_{pc} \times W_{pc})$ while that one of the primary + secondary leaflets might be determined by $LA_{pmsc} = 0.545 \times (L_{pmsc} \times W_{pmsc})$ represented graphically in Figure 2.

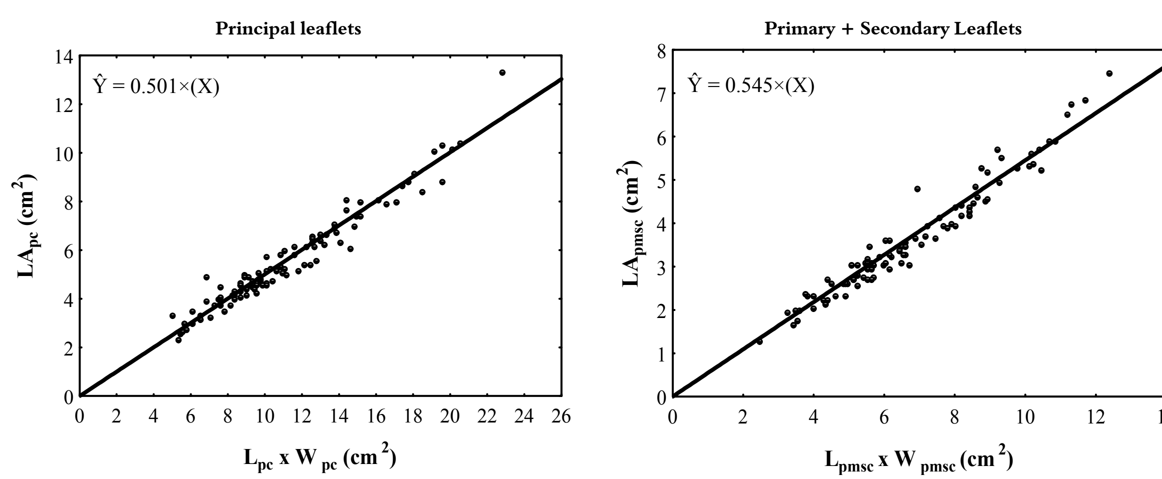

Figure 2. Relationship of leaf blade area of the *Merremia cissoides* principal leaflet (LA_{pc}) and primary + secondary leaflets (LA_{pmsc}) to the length (L_{pc}) and maximum width (W_{pc}) of the principal leaflet and length (L_{pmsc}) and maximum width (W_{pmsc}) of the primary + secondary leaflets.

The Spearman-Rank test with real and equation estimated leaf blade area values was significant ($p < 0.05$) to the principal and primary + secondary leaflets, with coefficient of correlation 0.967 and 0.968, respectively, indicating high correlation between them. Furthermore, the Shapiro-Wilk test on the residuals values was not significant ($p > 0.05$) to the principal ($p = 0.113$) and primary + secondary leaflets ($p = 0.129$), evidencing the residual normality. Therefore, the equations of the principal and primary + secondary leaflets might determine satisfactorily the leaf blade area of these *M. cissoides* leaflets.

Therefore, a general equation was proposed for *M. cissoides* leaf area determination, using the sum of the leaf blade area of the principal with primary + secondary leaflets. Thus, the general equation estimating the *M. cissoides* leaf area (LA_{est}) was described by $LA_{est} = 1 \times [0.501 \times (L_{pc} \times W_{pc})] + 4 \times [0.545 \times (L_{pmsc} \times W_{pmsc})]$, where L_{pc} and L_{pmsc} indicate the leaf blade length through principal nervure and W_{pc} and W_{pmsc} indicate the leaf blade maximum width perpendicular to principal nervure of the principal and primary + secondary leaflets, respectively. As the *M. cissoides* leaves are compounded by five leaflets, one principal and two primaries and two secondaries (Figure 1), the L and W average values of the primary + secondary leaflets must be used in the general equation for *M. cissoides* leaf area determination. Bianco et al. (2007) obtained that the *I. hederifolia* leaf area was represented to 75.8% of its L x W while the *I. nil* leaf area was represented to 61.2% of its L x W. The genus *Ipomoea* does not have the leaves compounded by leaflets as observed in the genus *Merremia*, so that this morphological characteristic is a basis of the differentiation between the genera (KISSMANN; GROTH, 1999).

The Spearman-Rank test on real and general equation estimated leaf area values was significant ($p < 0.05$) with coefficient of correlation 0.976, indicating high correlation between them. Furthermore, the Shapiro-Wilk test on the correlation residual values was not significant ($p > 0.05$) to the general equation ($p = 0.129$), evidencing the residual normality.

Conclusion

The equation $LA_{est} = 0.501 \times (X) + 2.181 \times (Z)$ may determinate satisfactorily the *M. cissoides* leaf area, where X indicates L x W of the principal leaflet and Z indicates medium L x W of the primary + secondary leaflets, respectively.

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