REVISTA CAATINGA — ISSN 0100-316X
UNIVERSIDADE FEDERAL RURAL DO SEMI-ÁRIDO (UFERSA)
Pró-Reitoria de Pesquisa e Pós-Graduação

EQUATIONS FOR LEAF AREA ESTIMATION IN SOME SPECIES ADAPTED TO THE BRAZILIAN SEMI-ARID

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ABSTRACT - The objective of this study was to determine equations of the type $y = a + bx$, where y = leaf area (A) and x = leaf length (L) × width (W), allowing the leaf area to be estimated from L and W in nine species adapted to the Brazilian Semi-Arid Region. One hundred leaves were collected from the middle third portion of the canopy of several plants of species with simple leaves (*Auxemma oncocalyx*, Ao; *Bauhinia forticata*, Bf; *Combretum leprosum*, Cl) and of species with compound leaves: *Azadirachta indica* (Ai), *Caesalpinia bracteosa* (Cb), *Leucaena leucocephala* (Ll), *Mimosa caesalpiniifolia* (Mc), *Schinus terebenthifolius* (St), and *Tamarindus indica* (Ti). In species with compound leaves, leaf length, width, and area were measured on the intact leaf (without detached leaflets) and on detached leaflets. The intercept coefficient was significant in Ao and Bf, and non-significant, with intact leaves, in Ai, Cb, St, and Ti. All slope coefficients were different from zero, but only in Mc those coefficients were not different from one another, when the equations were fitted from intact leaves or detached leaflets. The coefficient of determination in simple-leaf species varied from 0.85 to 0.97, while in compound-leaf species, the corresponding variation was between 0.28 and 0.93, indicating that the leaf area variation explained by the regression is greater in simple-leaf species. In most compound-leaf species, the coefficient of determination value was higher when estimation was done from intact leaves, except in St.

Key words: leaf length, leaf width, regression

EQUAÇÕES PARA ESTIMAÇÃO DA ÁREA FOLIAR DE ALGUMAS ESPÉCIES ADAPTADAS AO SEMI-ÁRIDO BRASILEIRO

RESUMO – O objetivo deste estudo foi determinar equações do tipo $y = a + bx$, onde y = área foliar e x = comprimento da folha (C) x largura da folha (L), que permitam a estimação da area foliar, a partir de C e L, em nove espécies adaptadas à região Semi-Árida brasileira. Cem folhas foram coletadas do terço mediano da copa de diversas árvores de espécies de folhas simples (*Auxemma oncocalyx*, Ao; *Bauhinia forticata*, Bf; *Combretum leprosum*, Cl) e de espécies com folhas compostas: *Azadirachta indica* (Ai), *Caesalpinia bracteosa* (Cb), *Leucaena leucocephala* (Ll), *Mimosa caesalpiniifolia* (Mc), *Schinus terebenthifolius* (St), and *Tamarindus indica* (Ti). Nas espécies com folhas compostas, C, L e A foram medidos em folhas intactas (sem folíolos destacados) e nos folíolos destacados. O coeficiente linear foi significativo em Ao e Bf, e não significativo, com folhas intactas em Ai, Cb, St, e Ti. Todos os coeficientes angulares foram diferentes de zero, mas somente em Mc esses coeficientes não diferiram entre si, quando as equações foram ajustadas a partir de folhas intactas e a partir de folíolos destacados. O coeficiente de determinação nas espécies de folhas simples variou de 0,85 to 0,97, enquanto em folhas compostas a variação correspondente foi de 0,28 a 0,93, indicando que a variação na área foliar explicada pela regressão é maior em espécies de folhas simples. Na maioria das espécies de folhas compostas o coeficiente de determinação foi maior quando a estimação foi feita a partir de folhas intactas, exceto em ST.

Palavras-chave: comprimento da folha, largura da folha, regressão.

INTRODUCTION

The semi-arid region of Northeastern Brazil covers an estimated area of 6 to 9 x 10^5 km^2, which represents nearly 10 % of the Brazilian territory. The main vegetation type is decidous thorn forest or thor bush savanna know as Caatinga (SAMPAIO et al., 1995). Despite its importance for mankind, the Caatinga region of Brazil is seriously threatened by desertification, at the same time that an increase in productivity is required to provide support to a growing population in search of development. The reasons for the desertification of the Caatinga are not different from those normally found in other areas of the world (CERVANTES et al., 1998). Almost always they are the result of inadequate utilization of resources, inappropriate practices in the use of resources, and, particularly, shortsighted models for regional development (BRASIL, 2001). Forest resources are usually the first to be exploited, because their products provide important income supplementation, and are also a source of primary energy. Consequently, there is interest in evaluating the behavior of native species aiming at reforestation projects, the adoption of agroforestry systems, and even the cultivation of these species to preserve the Caatinga. It is interesting to include exotic species adapted to the Caatinga in this evaluation, since some of these species offer products that are not found in native species, such as neem, which is generating great interest among growers, researchers, and landscapers in the Brazilian northeast.

Several papers have been conducted in order to estimate characteristics that are hard to evaluate, based on characters that are easier to be measured. Among these studies, the most frequent are probably those intended to estimate leaf area. This certainly stems from the fact that leaf area estimation is so important in agronomic and physiological studies. Leaf area determination is an essential part of classical growth analyses and is necessary in many physiological studies (FONTES et al., 2005). Leaf area is an indicator of the photosynthetic capacity of plants, and its determination is important in nutrition, intraspecific and interspecific competition (RAJCAN; SWANTON, 2001) and soil-water-plant relations studies (BENICASA et al., 1976).

A large number of methods, either destructive or not, have been developed to measure leaf area. Non-destructive methods, i.e., methods that do not require the leaves to be detached, are interesting in that they allow measurements to be repeated during the plant's growth period, and reduce the variability associated with destructive sampling procedures. Automatic non-destructive leaf area measuring devices do exist, but their price is even higher than the automatic destructive measuring machines. For this reason, many researchers have developed other non-destructive methods for leaf area estimation (see references in SILVA et al., 2000) in major crops, vegetables, fruit trees, ornamental plants, and even weeds. The most frequently used indirect method is one which tries to establish regression equations between the leaf area and linear leaf measurements, usually the maximum length and width. In other words, in a leaf sample, leaf area is determined by some precise mechanism. Length and width are measured on the same leaves. Equations of the type $y = a + bx$ are then established, where y is the estimated leaf area and x is the product of length by width. The equations are then used in subsequent samples. This method is adopted by many researchers (see references in KOBAYASHI, 1988) and still shows recent interest for many groups of crops (CHO et al., 2007; MONTEIRO et al., 2005; PINTO et al., 2004).

The objective of this study was to determine equations of the type $y = a + bx$ that will allow leaf area to be estimated based on leaf length and width in nine species adapted to the Brazilian Semi-Arid Region.

MATERIAL AND METHODS

One hundred leaves were collected from the middle third of the canopy of several plants of the following species: pau-branco (*Auxemma oncocalyx* (Allemao) Taub.), neem (*Azadirachta indica* A. Juss.), mororó (*Bauhinia forticata* Link.), catingueira (*Caesalpinia bracteosa* Tul.), mofumbo (*Combretum leprosum* Mart.), white popinac (*Leucaena leucocephala* Lam. de Wit), sabiá (*Mimosa caesalpiniifolia* Benth.), pink pepper (*Schinus terebenthifolius* Raddi), and tamarind (*Tamarindus indica* L.). Mororó, mofumbo, and pau-branco have simple leaves, while the other species have compound leaves. The leaves were obtained from plants at the Experimental Farm (latitude 5° 11'S, longitude 37° 20'W, elevation 18 m). The plants selected for leaf collection seemed to be free from diseases or the attack of pests. The leaves were harvested haphazardly, that is, collections were made at random, however without the use of drawing mechanisms.

Leaf length and width were determined with a ruler. The distance between the insertion point of the petiole into the leaf blade and the opposite end of the leaf was taken as leaf length. The largest dimension perpendicular to the length axis was measured as leaf width. Leaf area was determined with a LI-COR model 3100 measuring device (LI-COR, Inc. Lincoln, Nebraska, USA). In species with compound leaves, leaf length, width, and area were measured on the leaf without detached leaflets and on detached leaflets. In other words, in these species, leaf area was determined in two different manners, using the device to measure the intact leaf, that is, with the leaflets attached, and the leaflets detached from the same leaf.

The analyses of variance and regression analyses were performed according to Zar (1999) using the Table Curve software (JANDEL SCIENTIFIC, 1991).

RESULTS AND DISCUSSION

In some cases, the intercept coefficient was not significant (Table 1). This occurred in simple-leaf species (one out of three cases), but was more frequent in compound-leaf species (four out of six cases). In compound leaves, the intercept coefficient was equal to zero, in general, in equations fitted based on intact leaves. In those cases, the *a* value was discarded and a new equation was fitted containing only the slope coefficient value (*b*). Similar procedures have been adopted by other authors (Silva et al., 2000). The adoption of equations of the type y = bx, where x is the product of leaf blade length by leaf width, is obviously more practical than using equations of the type y = a + bx.

All slope coefficients were different from zero, but only in *Mimosa caesalpiniifolia* those coefficients were not different from one another, when the equations were fitted from intact leaves or detached leaflets. That is, in most cases, the equations obtained from intact leaves and from detached leaflets of a given species were different. It is likely that some of these differences were caused by leaflet overlapping when the area of compound leaves was measured, or that the device "reads" the area of a compound leaf as if it were a simple leaf. This probably occurs mainly in species with a large number of small leaflets, although the equations were different in *Caesalpinia bracteosa* but not in *M. caesalpiniifolia*, both with four leaflets, albeit the leaflets in the second species are larger. Therefore, the leaf area estimation method, as verified in the present study and by other authors (Silva et al., 2000), and other factors, such as the crop's developmental stage and the environment where cultivars are evaluated (ROBINS; PHARR, 1987) may influence the equation obtained. Similar differences were verified between saffron cultivars (*Carthamus tinctorius* L.) (Sepaskhah, 1977) and between *Zinnia* species (Pinto et al., 2004). In those cases, it has been suggested that the same equation should not be used for leaf area estimation in the genotypes studied, because of differences between the regression coefficients obtained (SEPASKHAH, 1977; PINTO et al., 2004).

Table 1 – Mean number of leaflets, length, width, and leaf blade area of intact leaves and detached leaflets (in the case of compound leaves), estimates of the *a* and *b* parameters of the equation y = *a* + *b*x, where x = L.W and y = A, and coefficients of determination of some species adapted to the Semi-Arid Region of Brazil[1]

Species	Material measured	Mean number of leaflets	Means			a	b	R^2
			Length (L, cm)	Width (W, cm)	Area (A, cm^2)			
Auxemma oncocalyx	Leaf	-	19.3	5.8	71.4	4.06	0.58	0.97
Bauhinia forticata	Leaf	-	3.7	10.4	70.0	6.78	1.64	0.85
Combretum leprosum	Leaf	-	9.4	6.9	66.1	0.00	0.74	0.94
Azadirachta indica	Leaf	18	35.5	14.6	153.6	0.00	0.29 a	0.81
	Leaflets	-	6.9	2.0	8.6	21.11	0.26 b	0.75
Caesalpinia bracteosa	Leaf	4	16.8	15.1	97.2	0.00	0.37 a	0.81
	Leaflets	-	8.9	4.9	26.0	0.00	0.39 b	0.79
Leucaena leucocephala	Leaf	13	26.6	16.5	102.0	34.88	0.15 a	0.47
	Leaflets	-	9.3	1.8	6.7	47.54	0.09 b	0.28
Mimosa caesalpiniifolia	Leaf	4	20.2	15.2	164.9	34.81	0.42 a	0.70
	Leaflets	-	10.0	7.4	44.6	42.87	0.43 a	0.69
Schinus terebenthifolius	Leaf	11	19.0	11.2	123.1	0.00	0.57 a	0.49
	Leaflets	-	5.3	2.7	11.7	24.85	0.49 b	0.56
Tamarindus indica	Leaf	23	10.8	3.9	27.6	0.00	0.63 a	0.93
	Leaflets	-	1.6	0.6	0.8	-2.45	0.66 b	0.85

[1] All non-null coefficients were significant at 5% probability by the t test

[2] In the same species, values followed by the same letter do not differ at 5% probability by the t test

The coefficient of determination in simple-leaf species varied from 0.85 to 0.97, while in compound-leaf species, the corresponding variation was between 0.28 and 0.93, indicating that the leaf area variation explained by the regression is greater in simple-leaf species. In most compound-leaf species, the R^2 value was higher when estimation was done from intact leaves. Therefore, it is more comfortable and convenient to use intact leaves to estimate leaf area in these species. Values with similar magnitude have been obtained by other authors (SILVA et al., 2000; PINTO et al., 2004), but values ranging between 0.20 and 0.48 have been obtained in lychee (*Nephelium litchi* Lamk.) (RAY et al., 1992). The magnitude of the R^2 values seems to be dependent upon several factors, among which are the species and method used for leaf area estimation (MIELKE et al., 1995), the characteristic included in the model (RAY et al., 1992) and obviously, the model itself.

CONCLUSIONS

The intercept coefficient was significant in *Auxemma oncocalyx* and *Bauhinia forticata*, and non-significant, with intact leaves, in *Azadirachta indica*, *Caesalpinia bracteosa*, *Schinus terebenthifolius*, and *Tamarindus indica*. All slope coefficients were different from zero, but only in *Mimosa caesalpiniifolia* those coefficients were not different from one another, when the equations were fitted from intact leaves or detached leaflets. The coefficient of determination in simple-leaf species varied from 0.85 to 0.97, while in compound-leaf species, the corresponding variation was between 0.28 and 0.93, indicating that the leaf area variation explained by the regression is greater in simple-leaf species. In most compound-leaf species, the coefficient of determination value was higher when estimation was done from intact leaves, except in *Schinus terebenthifolius*.

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