

LEAF AREA, LEAF AREA INDEX AND LIGHT EXTINCTION COEFFICIENT FOR TARO CULTURE

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ABSTRACT

Taro, *Colocasia esculenta* (L.) Schott, is the most important species from the Araceae family. The leaf area (LA) is important for the interception of solar radiation and for the biomass production. The light extinction coefficient (k) is related to the leaf inclination angle, leaf arrangement, regarding the Leaf Area Index (LAI), providing an indication of the plants efficiency on intercepting the solar radiation. Studies with this emphasis provide important answers about the use of solar radiation by the plants. However, for taro culture there are a few available studies concerning this subject and for this reason this work had the objective of estimating the LA, by linear measures of the leaf blade, add to that determine the taro K and the LAI. For this the photosynthetically active radiation was measured upon and under the culture canopy, in 15 random points, on these same points LAI was measured. With the data from LAI and the light interception K was obtained. The obtained equations by linear measurements of the leaf blade can be used to estimate the leaf area of *Colocasia esculenta* precisely. The equation $Sf = 7,9012 + 0,8437*(C_2 \times L)$ was the one which best represented the real leaf area and the light extinction coefficient was considered low.

KEYWORDS: *Colocasia esculenta*, leaf blade, solar radiation.

ÁREA FOLIAR, ÍNDICE DE ÁREA FOLIAR E COEFICIENTE DE EXTINÇÃO LUMINOSA PARA A CULTURA DO TARO

RESUMO

O taro, *Colocasia esculenta* (L.) Schott, é a principal espécie da família Araceae. A área foliar (AF) é importante para interceptação da radiação solar e produção de biomassa. O coeficiente de extinção luminosa (k) está ligado ao ângulo de inclinação das folhas, disposição das folhas, juntamente com o

Índice de Área Foliar (IAF), fornecendo uma indicação da eficiência das plantas em interceptar a radiação solar. Estudos com esse enfoque fornecem importantes respostas sobre a utilização da radiação solar pelas plantas. Entretanto, para a cultura do taro poucos são os estudos disponíveis nesse contexto e por essa razão este trabalho teve o objetivo de estimar a AF, por meio de medidas lineares do limbo foliar, além de determinar o k e o IAF do taro. Para tanto a radiação fotossinteticamente ativa foi medida sobre e sob o dossel da cultura, em 15 pontos aleatórios, nesses mesmos pontos IAF foi medido. Com os dados de IAF e a interceptação luminosa obteve-se o k. As equações obtidas por meio de medidas lineares do limbo foliar podem ser utilizadas para estimar a área foliar de *Colocasia esculenta* com precisão. A equação

$S_f = 7,9012 + 0,8437 \cdot (C_2 \times L)$ foi a que melhor representou a área foliar real e o valor do coeficiente de extinção luminosa obtido **foi considerado baixo**.

PALAVRAS-CHAVE: *Colocasia esculenta*, limbo foliar, radiação solar.

INTRODUCTION

The species *Colocasia esculenta* (L.) Schott, popularly known in Brazil as “inhame” is the most important species from the family Araceae, and recently to avoid confusions with “cará” (*Dioscorea alata*) it started to be called “taro”. Nowadays this species is adapted to the tropical climate, with low susceptibility to the attack of pests and diseases. Its rhizomes present high proportions of carbohydrates and mineral salts (FILGUEIRA, 2008). These nutritional characteristics turn taro sufficiently scattered among the familiar agriculturists, due to the necessity of reducing the quantity of supplies on their production sites.

Despite this rusticity, taro productivity can be reduced or limited by some environmental factors as, for instance, the excessive or insufficient exposition to the radiation to reach the optimum levels of the culture.

Radiation is one of the important basic meteorological parameters for the culture. Under favorable conditions, the radiation develops a decisive role for the vegetal growth and development. This way, the radiant energy variation inside the culture field can provide a way to create conditions of canopy saturation, with the purpose of efficient use of the solar energy for the agricultural production (LUNAGARIA & SHEKH, 2006).

The leaf area of taro plants has important role on the interception of solar radiation and on biomass production. Morphological characteristics as the size of the leaf and physiological characteristics such as the efficiency of transforming light energy into chemical energy depends on the availability of nutrients asserted by the absorption processes (roots) and nutrients recycling on the system (TAIZ & ZEIGER, 2008).

According to WATSON (1947) mentioned by ALMEIDA et al. (2007), the leaf area index (LAI), is the ratio between the canopy leaf area of the culture and the unit of surface projected on the soil, and it is directly related to the transpiration and forestry productivity, and indirectly related with the efficiency of water use. It is, this way, the leaf area per unit of terrain (m² of leaves by m² of terrain).

The plants efficiency on the conversion of solar energy into dry matter is

presently dependent on the photosynthetic activity of the individual leaves and the leaf set of the culture, and this photosynthetic activity is intimately related to the local environmental conditions where the culture is being developed. However, lots of morphological and physiological aspects of the plant are involved on the light interception by the cultures.

Factors as the leaf area index and the light extinction coefficient (k) are the parameters that most influence the interception and the level of attenuation of solar radiation (SHIBLES & WEBER, 1965).

The study of the light extinction coefficient (k) is related to the leaf inclination angle, leaf arrangement, the Leaf Area Index (LAI), providing an indication of the plants efficiency on intercepting radiation. YUNUSA et al. (1993) related that a higher value of k might be assigned to a more uniform distribution of the leaf area and to the plainer architecture of the canopy.

Coming from the principle that 90% of dry matter weight of the plants is originated from the photosynthetic activity (BENINCASA, 2003; LARCHER, 2006; TAIZ & ZEIGER, 2008) the leaf area, solar radiation and light interception by the plants are really important factors for the plants growth and development.

The importance of these informations to the management of agronomic cultures has been detached by different authors. However, lots of the data related to the growth and ecophysiology were generated in plants from tempered regions, with little available information for the most part of the tropical species. This way, the present work had the objective of estimating the leaf area by linear measures of the leaf blade, and to determine the leaf area index and the light extinction coefficient for taro culture.

METHODOLOGY

This work was carried out in a taro planting, Chinese variety, with approximately four months old and spacing 0.90 x 0.30 m, planted in an area of 230 m², irrigated by conventional aspersion daily, in the experimental area of the Center of Agrarian Sciences of Espírito Santo Federal University (CCA/UFES), located on ES highway 482 - Km 7, Rive District, pertaining to the municipality of Alegre-ES. Situated by definition on the geographical coordinates 20° 45' and 20° 50' of South Latitude and 41° 35' and 41° 30' of West Longitude of Greenwich.

The soil of the experimental area has an average texture and the climate in the region was classified as Cwa, according to the Köppen system, presenting rain in the summer and drying in the winter, with average annual amount of rainfall of 1405.77mm and average annual temperature among 25 to 28°C.

To determinate a suitable equation to estimate the leaf area of *Colocasia esculenta*, by linear measurements of its leaf blades, collects were carried out in the field, harvesting 20 leaf blades from different taro plants which did not present deformations derived from extern factors, as pests and diseases, for the determination of the smallest length of the leaf blade along the main nervure (L1), of the higher length of the leaf blade (L2) and of the maximum width of the leaf blade (W) perpendicular to the main nervure.

Subsequently a model, which consisted of four wooden sticks, was used to determine an area of 1 m², space where the plant leaves in study were collected and the collected material was conducted to the laboratory and the determination of the

real leaves areas (Sf) by a leaf measurer was carried out.

The obtainment of the equation which best relates the leaf area in function of the leaves dimensions (L and W) was carried out by regression analysis, using the linear equation $Y = a + bx$. The value Y estimates the leaf area of the leaf blade in function of X, whose values may be the length (L), the width (W) or the product (L x W). To develop the model, the square sum of the differences among the values observed and estimated by the model was obtained, denominating this the sum of the square residue.

The adopted methodology allows the obtainment of an equation for the estimative of leaf area by a non destructive method, which makes possible to follow the growing and the leaf expansion of the same plant until the end of the cycle or assay, besides being fast and precise, as proposed by BIANCO et al. (2003). Add to the usage facility due to the model simplicity (PINTO et al., 2008).

To carry out the comparisons between the equations considering each of the linear measurements, the sums of square of the differences among the observed and predetermined values (predetermined by the model) were obtained. The determination coefficients are those obtained with the work variables X and Y, in this case linear.

Simultaneously, the measurement of the Leaf Area Index (LAI) of taro plants was carried out in five points, by the difference among the measured radiation upon and under the canopy with a sensor connected to an automatic registrant. Characterizing the LAI, this is, m² of leaves by m² of terrain.

For the obtainment of the transmissibility coefficient the photosynthetic active radiation was measured, upon and under the canopy of taro culture, using a linear sensor that collected the radiation data in 15 random points.

The readings were carried out at about 12:00 noon under cloudy sky, measuring the luminosity intensity above the canopy (I_0) and on the soil level (I). The luminosity interception was calculated as: $(I_0 - I) / I_0$. And with the LAI data and the luminosity interception, the light extinction coefficient (k), according to what was described by SHEEHY & COOPER (1973) as $k = [\log_e (I/I_0)] / LAI$, where I and I_0 are the irradiance values upon and under the canopy, respectively.

RESULTS AND DISCUSSION

The results of the regression effectuated, related to the real leaf area (Sf), the linear measures of length (L) and the width (W) and the product of the length by the width of the leaf (L x W), are presented on Table 1. All the equations presented allowed the obtainment of satisfactory estimations of *C. esculenta* leaf area. On the linear equation involving the component leaf width only, a determination coefficient inferior than 0.99 was obtained, what indicates little precision on the leaf area estimation.

TABLE 1. Equations of linear regression estimated, determination coefficient (r^2), degrees of freedom and sums of squares of the deviation of the leaf area regression in function of the leaf blade linear measurements of *Colocasia esculenta*.

X*	Estimated Equation	Determination Coefficient	D.F.	S.S. Residue
L ₁	- 327.4323+ 1.8795*(L ₁)	0.9833	18	6.627.2701
L ₂	- 334.2031+26.1046*(L ₂)	0.9908	18	3.660.0731
W	- 265.5379+32.9493*(W)	0.9893	18	4.266.8978
L ₁ x W	7.3321+ 0.6827*(L ₁ x W)	0.9909	18	3.640.6015
L ₂ x W	7.9013+ 0.8437*(L ₂ x W)	0.9924	18	3.030.8852

*Linear Measurements: Lengths (L₁ and L₂) and Width (W)

On the other equations involving the leaf length and the product of the length by the width, determination coefficients higher than 0.99 were obtained. This indicates that 99% of the variations observed on the leaf area were explained by the obtained equations. The equations which represent the product between the length (L) and the width (W), not passing by the origin, did not show significant differences when compared with each other.

The presented equations allowed the obtainment of satisfactory estimative of *C. esculenta* leaf area. On the linear equation, concerning the parameter leaf width a determination coefficient of 0.9893 was obtained, equivalent to 99%, what indicates good precision on the leaf area estimative. On the other equations concerning the smallest length of the leaf, the obtained value was of 0.9833 (98%) and for the higher length of the leaf the value 0.9908 was obtained, which corresponds to 99%.

On the equation involving the product of the lower length by the width determination coefficient of 0.9909 was obtained and on the equation that involved the product of higher length by the width the coefficient was of 0.9924 both indicate that more than 99% of the observed variations on the leaf area were explained by the obtained equations.

By the results presented on Table 1, it is verified that the higher value of the determination coefficient and the lower value of the sums of square of the residue were observed for the simple linear regression among the real leaf area and the product of the higher length by the leaf width, showing to be the equation that allows to obtain the most accurate estimative of taro leaf area.

It is observed that this equation presented estimation of the determination coefficient of 0.9924, indicating that, of the total variability existent on the leaf area, 99.24% can be explained by linear regression. The simple linear equation with the line not passing by the origin is the most recommended, because it does not alter expressively the sums of square of the residue and it is easier to use regarding the practical point of view. This way, taro leaf area estimation considering L x W, can be done by the equation $S_f = 7,9012 + 0,8437*(L_2 \times W)$, where it is observed the little dispersion of the data concerning the obtained line. This indicates that this equation can represent the real leaf area satisfactorily (Figure 1).

Inferior results were obtained by PINTO et al. (2008) when they evaluated *Curcuma alismatifolia* leaves, by CARVALHO et al. (2011) for *Pistia stratiotes* leaves and by CARVALHO & CHRISTOFFOLETI (2007) in *Amaranthus deflexus* leaves.

Similar results were obtained by BIANCO et al., (2007) studying *Leonotis nepetifolia* and by BIANCO et al., (2008) for *Sida cordifolia* and for *Sida rhombifolia*.

The values of lower length (L1) and of the higher length (L2) of the leaves varied from 15.30 to 26.90 cm and from 18.70 to 33.20 cm, with average values of 20.76 cm and of 25.61cm, respectively. While the maximum width (W) of the leaves varied from 13.00 to 23.20 cm, with average values of 18.20 cm. For the real leaf area, the values varied among 168.33 and 525.01 cm² and the average was of 334.48 cm², according to data from Table 2.

TABLE 2. Maximum, minimum and average values of the Lower length of the leaf blade along the main nervure (L₁), of the higher length of the leaf blade (L₂), of the maximum width of the leaf blade (W) perpendicular to the main nervure and the leaf area of the 20 leaf blades.

Characteristic	Higher value	Lower value	Average
Lower length (cm)	26.90	15.30	20.76
Higher length (cm)	33.20	18.70	25.61
Maximum width (cm)	23.20	13.00	18.20
Leaf Area (cm ²)	525.01	168.33	334.48

On Figure 1 it is graphically represented the value obtained by the product of the higher length by the maximum width of the leaf blade and the correspondent value of the real leaf area (Sf) and also the graphic representation of the indicated equation for *Colocasia esculenta* leaf area estimation.

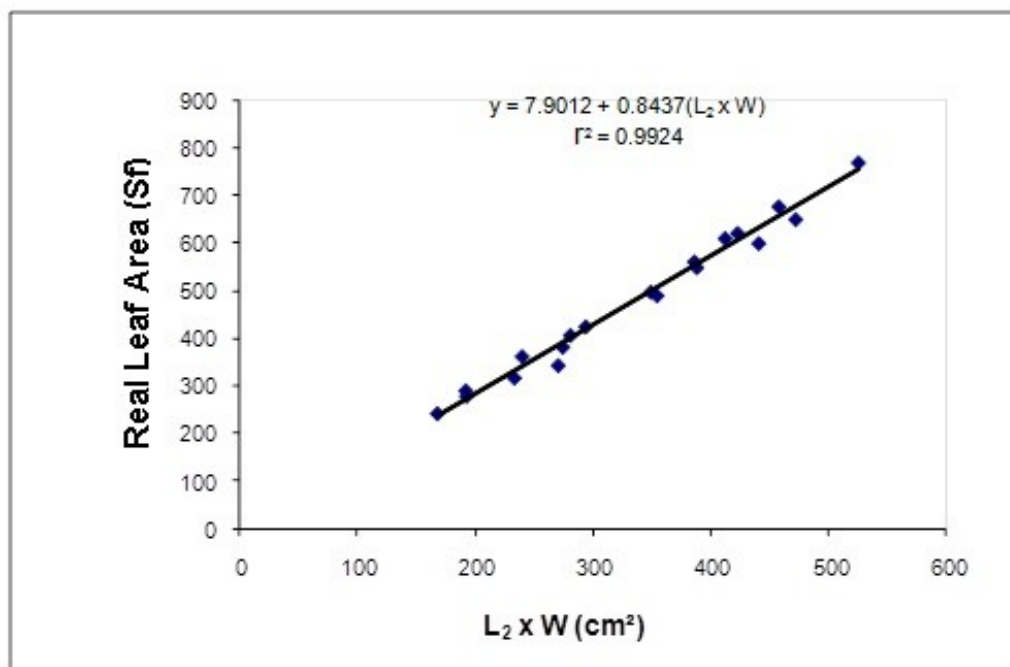


FIGURE 1. Graphic presentation of *Colocasia esculenta* leaf area and of the regression equation indicated for the plant leaf area estimative, in function of the product of the higher length (L2) by the maximum width (W) of the leaf blade.

On Table 3 the average values of Leaf Area Index of Taro (*Colocasia esculenta*) are presented.

The method of direct measurement by the device “scanner” presents good accuracy and precision, by measuring the real leaf area of the plant. However, a limiting point for such method is that the obtainment of the real leaf area is a destructive method.

TABLE 3. Measured values of the LAI of Taro culture

Points	1	2	3	4	5
Measured	1.2	1.3	1.3	1.4	1.5

The obtained values for the LAI were presented between 1.2 to 1.5 and the solar radiation values varied from 469 to 575 and from 202 to 473 $\mu\text{mol}/\text{m}^2.\text{s}^{-1}$, respectively for the intercepted radiation by the canopy and to the soil level. The plants growth is highly dependent on the solar radiation. However, the variation of the solar radiation under the culture canopy probably influenced the plants photosynthetic activity and as this influence has direct effect on the leaves production and consequently on the LAI, this index was presented with dispersed values as well as the one found for solar radiation.

Superior results were obtained by BRANTLEY & YOUNG (2007) when they determined the leaf area index of *Morella cerifera*.

The results of extension coefficient found for *Colocasia esculenta* are presented on Table 4.

TABLE 4. Light extinction coefficient (k) estimated from taro on the 15 collect points

Collect Points	Light extinction coefficient (k)
1	0.44
2	0.49
3	0.54
4	0.58
5	0.72
6	0.64
7	0.88
8	0.63
9	0.58
10	0.69
11	0.68
12	0.78
13	0.79
14	0.85
15	0.91

By Table 4, it is verified that the values of k are distributed among 0.44 and 0.91, with an average of 0.68. That indicates that the k of *C. esculenta* is low, due to the leaf architecture of the species that directly influences on the good use of the radiation by the culture. Similar results were obtained by CARVALHO et al. (2007) working with capim-elefante (*Pennisetum purpureum* Schum.). The k value obtained

on this study is superior to the result obtained by DETOMINI et al. (2008) in a study carried out with *Zea mays* L. (maize), genotype DKB 390 fertilized and irrigated.

According to CARVALHO et al. (2007), the different k values observed on the literature, for different kinds of vegetable species, occur due to the morphological differences of the studied species and of their responses to the variations on the availability and quality of light inside the canopy.

Due to the scarceness of the data related to the leaf area, the leaf area index and the light extinction coefficient for the other vegetable crops. It becomes necessary the realization of other studies to amplify the knowledge of the morphophysiological characteristics of the vegetable crops of social and economic importance in Brazil.

CONCLUSIONS

The equations obtained by the linear measures of the leaf blade can be used to estimate the leaf area of *Colocasia esculenta* precisely. The equation $Sf = 7.9012 + 0.8437*(L_2 \times W)$ was the one that best represented the real leaf area and the light extinction coefficient was considered low.

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