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Estimation of leaf area in two abaca (*Musa textiles* Nee) varieties by regression methods

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ABSTRACT

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A rapid, non-destructive and precise method for leaf area (LA) determination in two varieties (Inosa and Laylay) of abaca (*Musa textiles* Nee) was developed from linear measurements. Combining both length (L) and width (W) in the model could predict accurately the actual leaf area of abaca. The regression equations that gave the modest estimate for leaf area were LA = 1733.01 + 0.58 (L x W) (r = 0.87) for Inosa and, LA = -106.74 + 0.81 (L x W) (r = 0.99) for Laylay variety. Total leaf area can be estimated using leaf number 3 (third leaf below the newly expanded leaf) and leaf number 1 (newly expanded leaf) for Inosa and Laylay varieties, respectively.

Keywords: leaf area. linear measurements. *Musa textiles*.

INTRODUCTION

Abaca (*Musa textiles* Nee) belongs to the family Musaceae and is similar to banana in general appearance except that abaca leaves are upright, pointed, narrower and more tapering than banana leaves. In addition, abaca leaves and stalk are more dark green compared with those of banana. The stalk of

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abaca grows more slowly than that of banana reaching a height of 3.5 to 7.5 meters in 18 to 30 months (Demsey, 1963).

Determining the leaf area of plants is necessary to be able to measure the ability of the plant to capture light energy during the conversion of CO_2 and H_2O into a useful product, the carbohydrates (CH_2O) (Weier *et al.*, 1974). Leaf area is one of the most important parameters in the assessment of plant growth. For instance, it is necessary in establishing growth indices like leaf area index, leaf area duration, net assimilation rate and crop growth rate. However, leaf area determination is normally very laborious and time consuming even with the help of an electronic area meter (Pardales, 1980). This electronic device, although accurate, requires special care as well as large initial investment (Sharratt and Baker, 1986). Rapid and precise methods for measuring leaf area are therefore required (Rhoden and Croy, 1988).

There are several destructive and non-destructive methods to determine the areas of leaves and surface of other assimilating plant organs (Kvet and Marshall, 1971). The most common among which is the development of mathematical regression formula using easily measured parameters as was successfully done in a number of plants such as grass (Kemp, 1960), grain sorghum (Stickler *et al.*, 1961), sunflower (Schneiter, 1978), green gram (Potdar *et al.*, 1980), cucumber (Robbins and Pharr, 1987), southern peas (Rhoden and Croy, 1988), taro (Pardales, 1980), banana (Potdar and Pawar, 1991), and rice (Paliniswamy and Gomez, 1974). The usual procedure involves linear measurement of leaf length (L), width (W) and areas (A) of some samples of leaves and then calculating possible correlation coefficient, regression coefficient or a leaf factor ($K = LW/A$ or $K = A/LW$) for predicting areas of subsequent samples. This paper reports a rapid, non-destructive and precise method for the determination of leaf area of two abaca cultivars through regression methods.

MATERIALS AND METHODS

The sampling area

Two abaca varieties (Inosa and Laylay) from the nursery of the National Abaca Research Center (NARC) in Baybay, Leyte were selected for leaf area determination. These varieties are widely grown throughout the islands of Leye and Samar. Inosa is a good source of fiber for pulp and paper production while Laylay is best suited for fibercraft industry. The plants were grown for one year spaced at one meter between rows and one meter between hills. They were fertilized with complete fertilizer(14-14-14) at the rate of 30-30-30 kg N, P_2O_5, K_2O ha^{-1} at planting.

Leaf sampling, data collection and leaf area determination

Nine sample plants from each variety were selected at random in the field. All the leaves of each plant were removed and numbered serially starting from the youngest open leaf to the oldest green leaf. Each leaf was measured for length (L) as a straight line from the apex to the base of the leaf lamina, and width (W) which was measured across the widest portion of the leaf lamina at a right angle to L. The measured leaf was traced in a wide paper for actual area determination. Since abaca leaves are large, the traced leaf was cut into smaller pieces or strips (i.e. 3-4 in. width). For the actual leaf area (ALA) measurement was done using a leaf area meter (Model CI-203 CID, Incorporated, USA).

Determination of index leaf

In this study an index leaf was determined to estimate the total leaf area. This was done by correlating each individual leaf area with the total leaf area of one plant. The leaf with an area that was most significantly correlated with the total leaf area of the plant was considered as the index leaf.

Data analysis

Data gathered based on leaf area meter readings were analyzed statistically by simple linear regression and correlation analysis. Regression model was developed between LA as a dependent variable and various combinations of L and W as independent variables. In each variety, five regression models of the following form were developed and tested for their LA predictability:

(1) $LA = a + bL$
(2) $LA = a + bW$
(3) $LA = a + b(L \times W)$
(4) $LA = a + b(L^2)$
(5) $LA = a + b(W^2)$

where:

LA = leaf area
L = leaf length
W = leaf width
a = is the intercept for LA
b = regression coefficient of L, W or LxW

Validity of the regression model used

The validity of the selected regression equation was verified by taking three more sample plants at random from each of the two abaca varieties. The leaf area was obtained by using the most appropriate and best fit for the regression models used. The means of the leaf areas were compared using t-test.

RESULTS AND DISCUSSION

Leaf characteristics of Inosa and Laylay varieties

In some crops the leaf area varies with genotypes especially in those possessing contrasting leaf types. For abaca, the distinguishing varietal characteristics include leaf size, shape, color and orientation. However, among the different abaca cultivars such as Inosa and Laylay varieties, these features have to be properly evaluated.

In terms of appearance, Inosa possesses slightly erect, slender and light green leaves which in some cases bend or curl in their uppermost part. Curling of the topmost portion of the leaf lamina is one of the distinguishing characteristics of Inosa which is used by abaca growers. On the other hand, Laylay leaves which appear droopy are big and much lighter in color than those of Inosa. The name Laylay was based on its leaf orientation (i.e droopy means locally as *laylay*).

Table 1 shows the differences between the two varieties in terms of length (L), width (W) and actual leaf area (ALA). It shows that Laylay has longer leaf length which ranges from 178.61 cm to 202.88 cm compared to that of Inosa which ranges only from 183.86 cm.to 189.86 cm. In terms of width, Laylay shows a range from 52.50 cm to 44.52 cm while Inosa has 51.20 cm to 49.78 cm with an average width of 48.25 and 49.92 cm, respectively, indicating that Laylay has narrower leaves than Inosa. On the average, however, variability of the actual leaf area of Inosa variety ranges only from 6933 to 7305 cm^2 while that of Laylay ranges from 6371.85 to 8590 cm^2. This high variability in leaf area can be attributed to the wide variability of both leaf width and length. It appears that this parameter is an inherent characteristic of a particular variety.

In order to reconcile the contradicting attributes in terms of length and width of the two varieties used, chi-square test of independence was done. Results of the test for all the parameters evaluated on the various leaf numbers of both varieties are presented in Table 2. Leaf length and width were not significantly affected by the leaf numbers of the two varieties used. On the other hand, actual leaf area was significantly affected by the leaf number of the

Table 1. Average leaf length, width and actual leaf area of two abaca varieties

	Leaf No.	Leaf length (L) (cm)	Leaf width (W) (cm)	Actual Leaf Area (ALA)
Inosa	1	189.86±10.98	51.20±4.36	7305.38±811.75
	2	189.68±10.13	49.61±3.62	7159.51±582.78
	3	186.86±11.47	49.20±3.68	7101.69±546.89
	4	185.53±11.66	49.81±2.57	7111.39±573.26
	5	183.62±13.21	49.78±2.89	6933.30±563.90
Laylay	1	202.88±34.43	52.50±2.80	8590.91±1848.20
	2	201.78±31.30	50.41±3.17	8149.03±1824.34
	3	192.06±31.30	47.72±4.05	7378.29±1749.62
	4	183.94±36.32	46.09±4.51	6855.11±2010.74
	5	178.61±34.94	44.52±5.97	6371.85±2096.00

Table 2. Chi-square test of independence on the various leaf numbers for the two abaca varieties

Paramater	Chi-square value	Test of significance
Leaf length	0.6561	Not significant
Leaf width	0.3347	Not significant
Actual leaf area	160.48	Highly significant

Critical value with the degress of freedom (r-1)(c-1) = 4 at 5% and 1% levels were 9.49 and 13.28, respectively.

two abaca varieties used. This result reveals that actual leaf area is dependent on the leaf length and width of Laylay and Inosa varieties but independent of leaf number. This dependency of the leaf area with the leaf size and length could be attributed to the varying leaf sizes of mature and newly expanded leaves of the plant.

Leaf area determination through regression model

Proper selection of independent variable(s) is important in modeling through regression and correlation analysis. Five mathematical models involving leaf length (L), width (W), length squared (L^2), width squared (W^2) and the product of length and width (LW) were identified as a function of leaf area namely: $LA = a + bL$; $LA = a + bW$; $LA = a + b(L \times W)$; $LA = a + b(L^2)$; and $LA = a + b(W^2)$. In all the identified independent variables, leaf area was estimated by the use of simple linear regression $Y = a + bX$. In this equation Y and X are dependent and independent variable(s), respectively, while a and b are regression coefficients. The regression models which give the highest correlation or r value will be the best predictor of the leaf area.

Table 3 shows the correlation coefficients among the five regression models used to estimate leaf area. All regression models were found significant which obtained high r^2 values based on leaf area meter readings in Laylay and Inosa. These data indicated that the formula incorporating both length (L) and width (W) with a formula of $LA = a + b(LW)$ predicted accurately and could

Table 3. Regression model parameters and statistics in establishing leaf area (LA) as a function of length (L) and width (W):

	Regression Model	a	b	r
Inosa				
	LA = a + b (L)	-247.78	39.48	0.76
	LA = a + b (W)	2126.90	99.49	0.57
	LA = a + b (LW)	1733.01	0.58	0.87
	LA = a + b (L^2)	3417.02	0.11	0.75
	LA = a + b (W^2)	4552.24	1.02	0.58
Laylay				
	LA = a + b (L)	-3676.14	58.04	0.98
	LA = a + b (W)	-10032.70	362.94	0.91
	LA = a + b (LW)	-106.74	0.81	0.99
	LA = a + b (L^2)	1877.17	0.15	0.97
	LA = a + b (W^2)	-1679.86	3.89	0.91

be applicable for estimation of abaca leaf area. This can be done by substituting the mean value of the intercept (a) and regression coefficient (b). In this way, actual leaf area can be obtained very conveniently by using the established regression equation. However, poor relationship was noted between leaf area and leaf width, and between leaf area and square of leaf width. This suggests that the leaf width function is not a good predictor for LA measurement. Thus, the general regression equation as the modest estimate for leaf area of abaca is: LA = 1733.01 + 0.58 (LxW) for Inosa and LA = -106.74 + 0.81 (LxW) for Laylay variety.

Determination of the index leaf

The determination of an index leaf in abaca that will represent its total leaf area is important to speed up computation of total leaf area. Leaf area of the index leaf was found to be correlated with the total leaf area (TLA) from readings obtained using a leaf area meter. Results showed that the area of leaf # 3 (third newly expanded leaf) of Inosa gave the highest correlation ($r=0.90$) with the total leaf area reading using leaf area meter (Table 4). On the other hand, it was leaf #1 which gave the highest correlation ($r=0.96$) with the total leaf area of Laylay. This first newly expanded leaf can possibly be used as the index leaf. Although the newly expanded leaf gave the highest correlation value but it might not apply to all plants in this particular variety since a wide variability of leaf size in each plant was also observed (Table 1). It was noted that with smaller leaf area reading, there was a corresponding increase in variability resulting significant *r* values among all the leaf samples evaluated (Table 4). Hence, further asssessment is necessary to validate the wide variability and to

Table 4. Regression and correlation coefficients for the determination of index leaf in two abaca varieties

	Leaf Number	Coefficients *a*	*b*	*r*
Inosa	1	-757.48	0.23	0.73
	2	449.26	0.19	0.84
	3	321.83	0.19	0.90
	4	352.64	0.19	0.83
	5	-366.18	0.20	0.76
Laylay	1	1693.87	0.19	0.96
	2	1216.07	0.19	0.92
	3	711.80	0.18	0.92
	4	-800.32	0.21	0.92
	5	-1404.52	0.21	0.90

be able to have a realistic index leaf of Laylay variety.

Validation of the model used for estimating leaf area of abaca

The validity of the model used was tested by randomly selecting three leaf samples in the field. The estimated leaf area was determined with the use of a regression model based on the leaf area meter readings. The average of the leaf areas obtained with the regression model and the actual leaf area were compared using t-test.

Table 5. T-test for the validation of regression models for leaf area determination in two abaca varieties

Variety	Actual leaf area (cm^2)	Average of leaf area (cm^2)	Standard deviation	T value
Inosa	7646.53	7337.36	263.60	1.17 ns
Laylay	8816.71	9545.43	492.95	-1.48 ns

ns = not significant

Results showed that the two leaf areas were not significantly different from each other (Table 5).

CONCLUSION

We conclude that the leaf area of abaca can be estimated by the formula LA = 1733.01 + 0.58 (LxW) and LA = -106.79 + 0.81 (LxW) for Inosa and Laylay varieties, respectively. Based on the results of the study it can also be deduced that leaf no. 3 (third leaf below the newly expanded leaf) can be used as the index leaf for total leaf area determination in Inosa while leaf no. 1 (newly expanded leaf) for Laylay variety. Our data support the view that leaf area of *Musa* (e.g. abaca) can be estimated through linear measurements, a simple and non-destructive method.

This study likewise indicates that the regression models based on linear measurements can be used precisely for non-destructive leaf area determination in abaca. The approach used here is rapid, inexpensive, simple and precise for leaf area determination in plants with non-lobed leaves and greater leaf area per plant.

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