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# LEAF AREA DETERMINATION IN ROSELLE (*Hibiscus sabdariffa* L.) USING LINEAR MEASUREMENTS

**Nnebue, O.M., Ogoke, I.J. and Obilo, O.P.**
[1]Department of Crop Science and Technology, Federal University of Technology, Owerri, Imo State, Nigeria
E-mail: gen2_o@yahoo.com (**Corresponding Author*)

**Abstract:** This study was carried out to develop a reliable model for the non-destructive determination of leaf area in roselle. A total of 128 leaves from two roselle accessions were sampled. The longest lengths and widest widths of the leaves were measured, and their margins traced on standard graph sheets. The traced areas were regressed on the corresponding lengths (L) and widths (W), $L^2$, $W^2$, LW, $L^2W$, $LW^2$, $L^2W^2$, $^1/_L$, $^1/_{L^2}$, $^1/_W$, $^1/_{W^2}$, and $^1/_{L^2W^2}$. Coefficient of determination ($r^2$) values were high (0.805-0.932) for models that involved L, W and their various products and low (0.041-0.579) for models that had inverse L and W values. Although models involving LW had slightly higher $r^2$ values (91-93% of variability) compared to those involving $L^2$ (90-92% variability), tests of equality of means using two-sample t-test showed that the probability that the mean value of leaf area determined using the model with $L^2$ was not different from that with LW was 99.8% when the values were pooled for both accessions, 97.8% for purple calyx accession, and 94.3% for green calyx accession. Consequently, leaf area in roselle may be estimated using a single leaf length measurement fitted into the following models: Leaf Area = 0.05 + 0.5918 $L^2$ for purple roselle; Leaf Area = 1.60 + 0.5968 $L^2$ for green roselle; and Leaf Area = 0.66 + 0.5968 $L^2$ for either of purple or green accessions.
**Keywords:** Leaf Area, Roselle.

## INTRODUCTION

Leaf area is an indispensable parameter in crop growth analysis. The size of the leaf surface determines the amount of light interception, gaseous exchange and transpiration rate in plants (Anyia and Herzog, 2004; Wünsche and Lakso, 2000; Yan *et al.*, 2012). Consequently leaf area is a measure of a plant's photosynthetic capacity. Leaf area is used to estimate thickness and has been applied in the screening of cultivars (Vile *et al.*, 2005; Mediavilla *et al.*, 2001). Leaf area is also used in the estimation of Leaf area index which is a major yield determining factor for field grown crops (Blanco and Folegatti, 2003; Fageria *et al.*, 2007), specific leaf area, leaf area index and leaf area ratio.

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Several destructive and non-destructive methods of leaf area estimation have been developed by researchers. These methods may be costly and time-consuming. Weight measurements have been used in leaf area determination (Bhatt. and Chanda, 2003; Pandey and Singh, 2011; Junior and Kawakam, 2013). Leaf area has been assumed to be closely related to leaf dry weight and total plant dry weight hence it can be estimated from these parameters (Chanda and Singh, 2002; Karimi *et al*., 2009). Leaf area meters and digital image analysis have also been employed (O'Neal *et al*., 2002; Sadik *et al*., 2011; Chaudhary *et al*., 2012; Campillo *et al*., 2010).

The use of models in leaf area estimation has also gained extensive acceptance beginning from when Montgomery (1911) first suggested that leaf area of a plant can be calculated from linear measurements of leaves using a general relationship $A=b\times L\times W$ where b is a coefficient, L is length measurement, and W is width measurement. The use of mathematical models for estimating leaf area reduces sampling effort and cost, may increase precision where sample of leaf size are difficult to handle (Bhatt and Chanda, 2003). Mathematical models have the advantage of being non-destructive as measurements are taken on live plants. Models are also invaluable considering the high cost and maintenance of leaf area meters and other methods involving image analysis. Leaf area model is specific to each particular crop variety and in each case either a single length or width measurement or both are involved. While Ogoke *et al*. (2003) have undertaken a review of some available leaf area models for different crops, there is none available in literature for roselle (*Hibiscus sabdariffa* L.). This study was therefore carried out to develop an appropriate mathematical model in order to facilitate leaf area estimation in roselle.

## MATERIALS AND METHODS

This study was carried out at the Teaching and Research Farm of the Department of Crop Science and Technology, Federal University of Technology, Owerri. Seeds of two roselle accessions (purple petiole and green petiole) were planted out in the field. Longest length (L) and widest width (W) measurements were made (at different stages of growth) on 128 leaves of the two roselle accessions. The leaves were of varying sizes. The leaf margin of each leaf was traced on standard graph sheet with 1 $cm^2$ square cells. Leaf area of a single leaf was determined by counting the number of squares enclosed in each tracing (Ogoke *et al*., 2009). The leaf area determined by tracing was subsequently regressed on the corresponding L, W, $L^2$, $W^2$, LW, $L^2W$, $LW^2$, $L^2W^2$, $^1/_L$, $^1/_{L^2}$, $^1/_W$, $^1/_{W^2}$, and $^1/_{L^2W^2}$ for each accession. The coefficients of determination ($r^2$) and leaf area models were determined from the results of regression analysis.

**RESULTS AND DISCUSSION**

Results of regression analysis showed that the relationship between roselle leaf area determined using graph tracing, and any of roselle leaf length (L), roselle leaf width (W), $L^2$, $W^2$, LW, $L^2W$, $LW^2$, $L^2W^2$, $^1/_L$, $^1/_{L^2}$, $^1/_W$, $^1/_{W^2}$, and $^1/_{L^2W^2}$ was significantly linear. Several other workers have reported linear relationships between leaf length and width (Ogoke *et al*., 2003; Blanco and Folegatti, 2005; Rouphael *et al*., 2007; Cristofori *et al*., 2007; Ogoke *et al*., 2009 Jayeoba *et al*., 2007). In this study, coefficient of determination ($r^2$) values were high (0.805-0.932) for models that involved L, W and their various products (Table 1), and low (0.041-0.579) for models that had inverse L and W values. In purple calyx roselle accession the 93% of variability in leaf area was accounted for with model involving length and width measurements (LW) compared to 92% when only the square of length measurement ($L^2$) was used in the model. Similarly, in the green roselle calyx accession, 90.6% of variability was explained by model with LW compared to 89.8% when $L^2$ was used. When both accessions were pooled, 91.6% of variability in roselle leaf area was explained by model with LW compared to 90.8% with $L^2$.

For easy, accurate and non-destructive leaf area determination for roselle, appropriate model may be chosen between the use of length measurement alone or measurement of both length and width. For double measurements of length (L) and width (W), leaf area may be determined using: Leaf Area = 4.29 + 0.5142 LW ($r^2$ = 0.932); Leaf Area = 6.43 + 0.5173 LW ($r^2$ = 0.906); and Leaf Area = 5.20 + 0.5179 LW ($r^2$ = 0.916) respectively for purple roselle, green roselle and either of the accessions. For single measurement of length (L), leaf area may be determined using Leaf Area = 0.05 + 0.5918 $L^2$ ($r^2$ = 0.921); Leaf Area = 1.60 + 0.5968 $L^2$ ($r^2$ = 0.898); and Leaf Area = 0.66 + 0.5968 $L^2$ ($r^2$ = 0.908) respectively for the purple roselle, green roselle and either of accessions.

While models involving LW had slightly higher $r^2$ values compared to those involving $L^2$, they however, involve the measurement of both length (L) and width (W). Rouphael, *et al.,* (2007) have proposed the use of single width measurement in determining leaf area in sunflower. Models requiring single measurement of L or W reduce the labour and amount of time for making measurements. Also, tests of equality of means using two-sample t-test showed that the probability that the mean value of leaf area determined using the model with

$L^2$ was not different from that with LW was 99.8% when the values were pooled for both accessions, 97.8% for purple calyx accession, and 94.3% for green calyx accession.

These considerations are important in determining models that are convenient and appropriate for the non-destructive determination of leaf area. With a single length measurement convenient and less laborious, leaf area in roselle can be determined using the following models:

Leaf Area = $0.05 + 0.5918\ L^2$ for purple roselle;

Leaf Area = $1.60 + 0.5968\ L^2$ for green roselle; and

Leaf Area = $0.66 + 0.5968\ L^2$ for either of purple or green accessions

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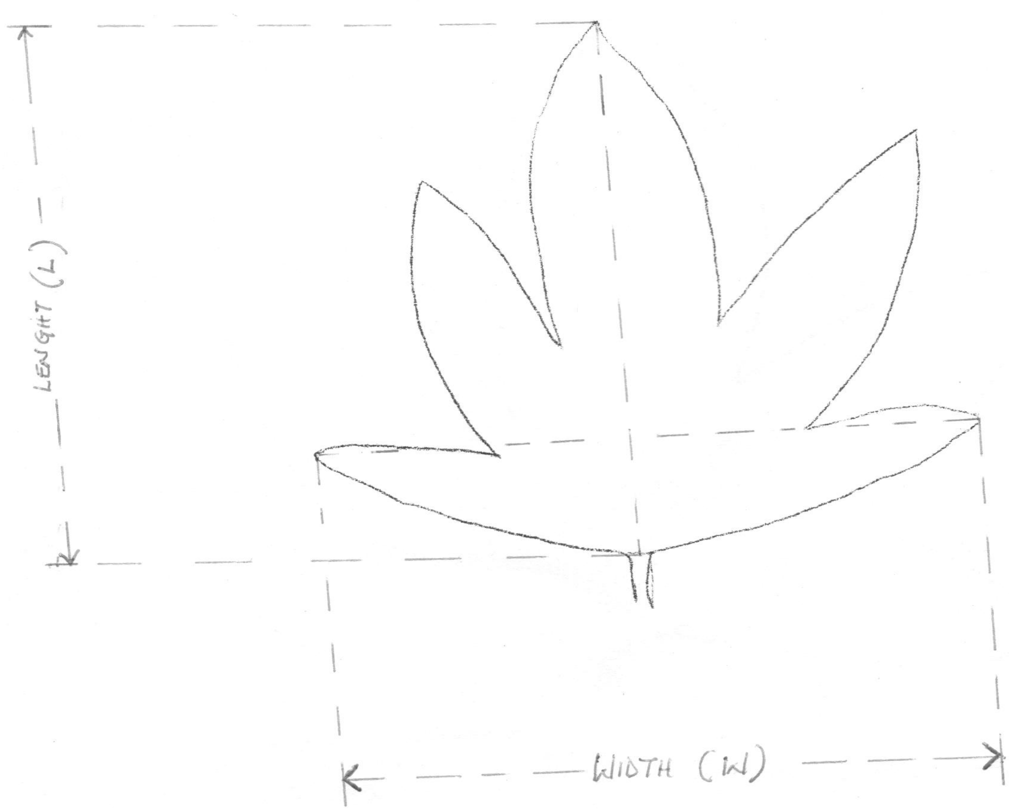

**Table 1.** Leaf area models for roselle

| Variable | -------Purple calyx------- | | -------Green calyx------- | | -------Both accessions combined------- | |
|---|---|---|---|---|---|---|
| | $r^2$ | Leaf area Model | $r^2$ | Leaf area Model | $r^2$ | Leaf area Model |
| L | 0.860 | -37.26+10.196L | 0.882 | -54.67+12.490L | 0.868 | -47.11+11.534L |
| W | 0.864 | -21.09+8.061W | 0.850 | -27.82+9.337W | 0.852 | -25.48+8.852W |
| LW | 0.932 | 4.29+0.5142LW | 0.906 | 6.43+0.5173LW | 0.916 | 5.20+0.5179LW |
| $L^2$ | 0.921 | $0.05+0.5918L^2$ | 0.898 | $1.60+0.5968L^2$ | 0.908 | $0.66+0.5968L^2$ |
| $W^2$ | 0.892 | $9.16+0.4251W^2$ | 0.878 | $11.42+0.4343W^2$ | 0.885 | $10.07+0.4328W^2$ |
| $L^2W$ | 0.918 | $16.45+0.0339L^2W$ | 0.868 | $22.68+0.0293L^2W$ | 0.884 | $20.14+0.0307L^2W$ |
| $LW^2$ | 0.908 | $18.03+0.02958LW^2$ | 0.869 | $23.69+0.026LW^2$ | 0.882 | $21.31+0.027135LW^2$ |
| $L^2W^2$ | 0.873 | $24.23+0.00198L^2W^2$ | 0.805 | $32.05+0.001482L^2W^2$ | 0.819 | $29.19+0.0016L^2W^2$ |
| 1/L | 0.372 | $81.28-221.2(1/L)$ | 0.583 | $146.36-671.5(1/L)$ | 0.391 | $100.69-333.7(1/L)$ |
| $1/L^2$ | 0.190 | $56.67-272.4(1/L^2)$ | 0.379 | $91.75-1622(1/L^2)$ | 0.169 | $64.64-409.3(1/L^2)$ |
| 1/W | 0.449 | $83.62-225.2(1/W)$ | 0.579 | $128.84-488.5(1/W)$ | 0.469 | $101.73-318.2(1/W)$ |
| $1/W^2$ | 0.211 | $57.3-260(1/W^2)$ | 0.392 | $88.37-1108(1/W^2)$ | 0.212 | $66.52-402.5(1/W^2)$ |
| $1/L^2W^2$ | 0.067 | $50.04-499(1/L^2W^2)$ | 0.145 | $68.12-828.2(L^2W^2)$ | 0.041 | $55.72-646(L^2W^2)$ |

$r^2$ = Coefficient of determination; L = length; W = widt