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NON–DESTRUCTIVE LEAF AREA DETERMINATION IN AFRICAN EGGPLANT (*Solanum macrocarpon*)

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ABSTRACT

Leaf area models are simple, accurate and non-destructive. They are important in many experimental comparisons where leaf area meters are not available. No such model exists for African eggplant (Solanum macrocarpon). This study was, therefore, conducted to develop a leaf area model for S. macrocarpon using linear measurements. A total of 80 fully opened leaves of different sizes were randomly selected. The maximum Lamina length (L) and width (W) of leaf samples were measured. Each leaf margin was traced on standard graph paper. Leaf area was subsequently estimated from the number of squares within each tracing. While the linear functions of length or width measurements, and their squares or products explained 79-92% of variations in leaf area, the linear functions of the inverse of length or width measurements, and their squares or products explained about 40-68% of the variations. Regression analysis of leaf area obtained from graph tracing as dependent variable, L and W as independent variables revealed several models that can be used for estimating the area of individual leaf. While models involving L, W, L^2, W^2, $L \times W$, *and* $L^2 \times W^2$ *explained 78-91% of the variations in leaf area, models with inverse parameters (*$^1/L$, $^1/W$, $^1/L^2$, $^1/W^2$,*and* $^1/LW$*), explained 39-67% of the variations. Relative to all parameters evaluated, the model involving* L^2 *had the highest* r^2*, and explained 91% of the variation in leaf area. Since only a single linear measurement is required, the model: Leaf area =* $1.06+0.4731L^2$*, is recommended for predicting leaf area in S. macrocarpon.*

Keywords: Eggplant, *Solanum macrocarpon*, Leaf area, Leaf area meter, Leaf area model

INTRODUCTION

Solanum macrocapon L. otherwise known as African eggplant belongs to the *Solanaceae* family. It is native to West Africa and is cultivated for its use as food, medicinal or ornamental purposes. Eggplant fruits are known for being low in calories with considerable amounts of low soluble carbohydrates, fibre, proteins and some minerals beneficial to human health. *S. macrocapon* is also a rich source of potassium, calcium, magnesium and iron (Zenia *et al.*, 2008).

The leaves are also consumed either fresh or cooked (Oboh *et al*., 2005).

Despite the food and medicinal benefits of *S. macrocapon*, research in the genetic improvement and agronomy of the crop has been limited. Any meaningful research aimed at improving the productivity and cultivation of *S*. *macrocarpon* involves crop growth analyses and one major parameter in crop growth analysis is leaf area. Leaf area is an important variable for most eco-physical studies in terrestrial ecosystem concerning light interception, evapo-transpiration, photosynthetic efficiency, fertilization and irrigation and plant growth (Blanco and Folegatti, 2005). Leaf area estimate is also valuable in studies of plant nutrition, plant-soil-water relations, light reflectants and heat transfer in plants (Mohsenin, 1986) and is consequently important in understanding photosynthesis, water and nutrient use, crop and yield potential (Williams, 1987; Takim *et al*., 2013). Studies have shown the important roles leaf area plays in explaining variation in potential relative growth rate and ecological behavior in plants (Poorter and Van de Werf, 1998; Garnier *et al*., 2001). Genotypic differences in yield of many crops are mainly associated with variations in leaf area, since genotypic differences in photosynthetic activity per unit leaf area are inconsistent and generally not significant (Wallace *et al.*, 1972). A higher specific leaf area can compensate for the resultant lower photosynthesis through greater light interception early in crop development (Richards, 2000). Leaf area is, therefore, an important parameter that needs to be estimated for holistic analysis of crop growth.

Although leaf area measurements can be carried out using linear measurements, leaf area meters, and digital image analysis, the use of linear measurements have remained easy, cheap, and non-destructive. Linear measurements for leaf area determination are premised on the relationship of area with length and width measurements. These measurements are used to develop models that may be conveniently used for leaf area estimation in crop varieties. Ogoke *et al.* (2003) have undertaken a review of several models available for leaf area determination. Many of these models have been adapted for use in crop research (Ray and Singh, 1989; Imonide and Obi, 1991; Arunah and Ibrahim, 2004). There is however no report of a model that can be used to non-destructively determine leaf area in *S. macrocapon.* Considering that leaf area meters are not common and readily available, this study was carried out in order to develop a reliable model for the determination of leaf area in the crop.

MATERIALS AND METHODS

This study was carried out at the Teaching and Research Farm of Federal University of Technology Owerri. Owerri is located at latitude 05° and 27'N, and longitude 07° and 2'E. The area is characterized by two distinct seasons; Rain season and Dry season. The seeds of *Solanum macrocapon were* sourced from germplasm collections of Department of Crop Science and Technology, Federal University of Technology Owerri. The seeds were raised in seed trays in the nursery, and subsequently transplanted into 15 cm diameter polyethylene bags.

Beginning at 2 Weeks After Transplanting (WAT), 20 fully opened leaves were randomly selected form different plants up to 8 WAT giving a total of 80 leaves. *S. macrocarpon* has an alternate leaf pattern with a blade width of 4-15 cm and a length of 10-30 cm. The leaves are oval and lobed with wavy margins. The leaf margins of the 80 fully opened leaves were traced on graph sheets. The total number of cells in each tracing was determined by counting. Each cell measured 1 cm^2 and contained 25 smaller cells measuring 0.04 cm^2. Leaf area of a single leaf was subsequently determined by multiplying total number of 0.04 cm^2 cells within the graph tracing, by 0.04 cm^2. The maximum length and width of the same leaves were also measured in centimetres. The leaf length was measured from the lamina tip to the point of interception of the lamina to the petiole along the midrib of the leaf lamina. The leaf width was determined by measuring the widest width across the lamina (Figure 1).

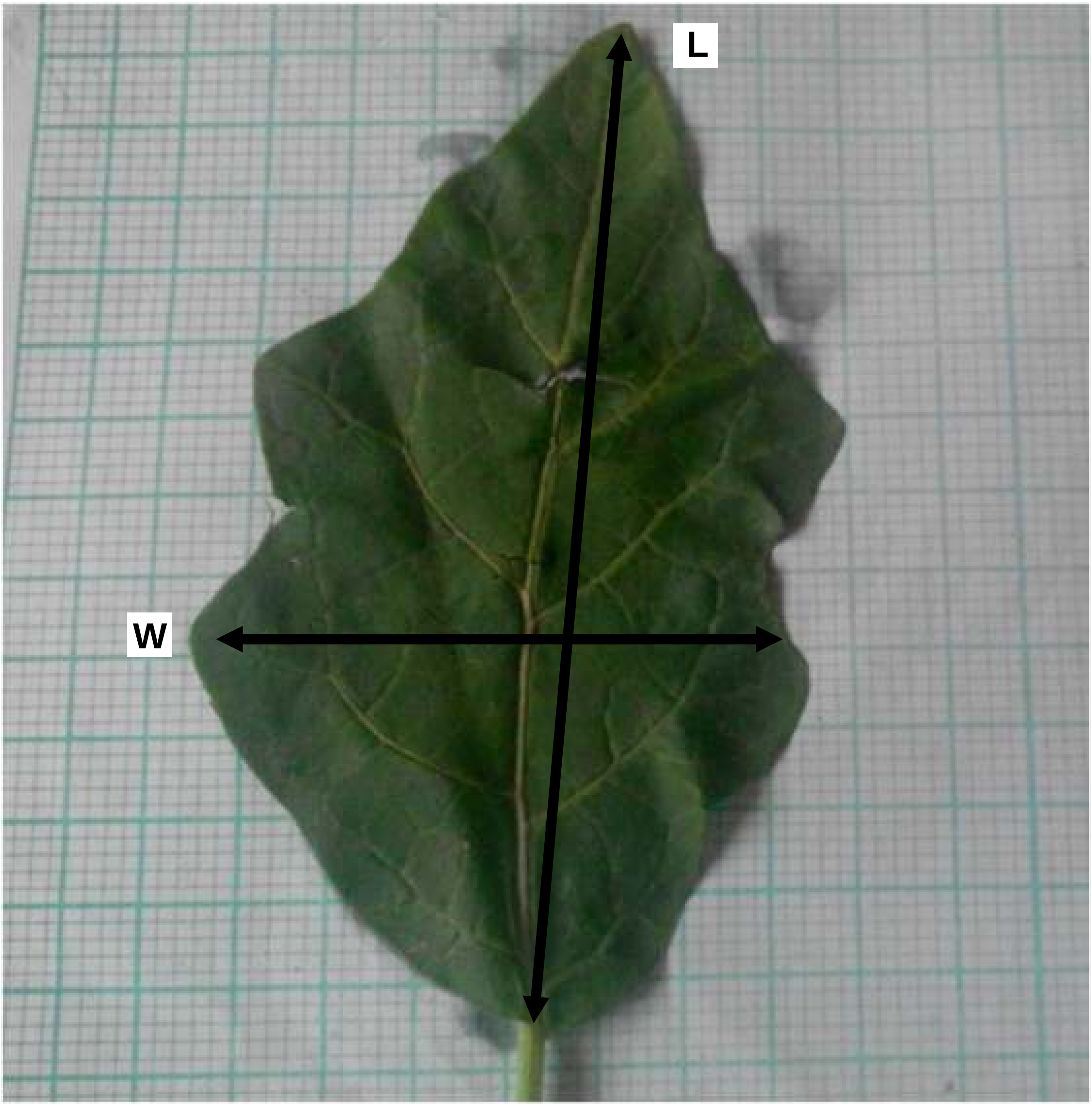

Figure 1.Length (L) and Width (W) measurements on the leaf of *S. macrocarpon.*

Using the leaf areas determined from tracing leaf margins as dependent variable, regression analysis was carried out with leaf length measurement (L), leaf width measurement (W), L^2, W^2, L×W, $L^2 \times W^2$, $^1/L$, $^1/W$, $^1/L^2$, $^1/W^2$, and $^1/LW$ as independent variables. The selection of appropriate parameter, and leaf area model was based on highest r^2 value and the least number of measurements needed.

RESULTS AND DISCUSSION

While the leaf area was determined using graph tracing correlated positively with length or width measurements, and their squares or products, the correlation was negative for the inverse of length and width measurements (Table 1). Results show that 79-92% of variations in leaf area were explained by the linear functions of length or width measurements, and their squares or products. Several other workers have reported linear relationships between actual leaf area values, and leaf dimension of different vegetable crops (Robbins and Pharr, 1987; Elsner and Jubb 1988; Braithwaite, 1992; Schwarz and Klaring, 2001; Blanco and Folegatti, 2003; De Swart *et al*., 2004; Ramkhelawan and Ogoke *et al*., 2009). Arias *et al*. (1989) have also reported similar relationships for oranges. On the other hand, linear functions of the inverse of length or width measurements, and their squares or products explained about 40-68% of the variations in leaf area. Comparatively, the square of length measurement (L^2) correlated more highly (r = 0.957) with leaf area than other parameters.

Table 1: Correlation matrix of traced area (graph) and linear leaf measurements

	L	L^2	L^2W^2	LW	W	W^2	$^1/L$	$^1/L^2$	$^1/LW$	$^1/W$	$^1/W^2$
Graph	0.940	0.957	0.913	0.944	0.888	0.893	-0.825	-0.722	-0.692	-0.763	-0.635

Results of the linear regression analysis show significant (p<0.001) linear relationships between actual leaf area determined using graph tracing with any of L, W, L^2, W^2, L×W, $L^2 \times W^2$, $^1/L$, $^1/W$, $^1/L^2$, $^1/W^2$,and $^1/LW$. While leaf area models involving L, W, L^2, W^2, L×W, and $L^2 \times W^2$ explained 78-91% of the variation in *S. macrocarpon*. With a coefficient of determination (r^2) of 0.88, the model involving L (Leaf area = -42.87 + 9.765*L*) was superior to the model, Leaf area = -30.62 + 12.228*W*, which involves W (r^2=0.78). The contribution of W to variation in *S. macrocarpon* leaf area improved when this parameter was squared or multiplied with L. By squaring the length measurement (L^2) the coefficient of determination (r^2) was greatly improved and the model consequently explained 91% of the variation in *S. macrocarpon* leaf area. The model, Leaf area = 1.06+0.4731L^2, is therefore recommended for the prediction of leaf area in *S. macrocarpon*. With this model, *S. macrocarpon* leaf area can be estimated accurately and non-destructively using a single linear measurement. Flavio and Marcos (2003) have similarly shown that single measurement of length or width can be conveniently used to estimate leaf area in cucumber and tomato. Models involving the inverse parameters $^1/L$, $^1/W$, $^1/L^2$, $^1/W^2$,and $^1/LW$, however, explained 39-67% of the variation (Table 2) and consequently did not explain much of the variation in leaf area as did L, W, L^2, W^2, L×W, and L^2×W^2.

Table 2. Regression models of relationships between traced leaf area (graph) and linear leaf

S/N	Parameters	Model	r^2
1.	L	Leaf area = -42.87 + 9.765L	0.88
2.	L^2	Leaf area = 1.06 + 0.4731 L^2	0.91
3.	L^2W^2	Leaf area = 24.35 + 0.0031 L^2W^2	0.83
4.	LW	Leaf area = 3.14 + 0.6537 LW	0.89
5.	W	Leaf area = -30.62 + 12.228 W	0.78
6.	W^2	Leaf area = 8.10 + 0.8212 W^2	0.79
7.	$^1/L$	Leaf area =131.52 + (-678.1) $^1/L$	0.67
8.	$^1/L^2$	Leaf area = 84.95 + (-2167) $^1/L^2$	0.51
9.	$^1/LW$	Leaf area = 81.35 + (-1313) $^1/LW$	0.47
10	$^1/W$	Leaf area = 116.89 + (-376.2) $^1/W$	0.57
11	$^1/W^2$	Leaf area = 75.52 + (-713.0) $^1/W^2$	0.39

CONCLUSION

Leaf area determined using graph tracing correlated positively with leaf length and width measurements, and their squares or products. The correlation was, however, negative for the inverse of length and width measurements. The square of length measurement (L^2) correlated more highly (r = 0.957) with leaf area determined using graph tracing compared to other parameters. By squaring the length measurement, r^2 was greatly improved and the model consequently explained 91% of the variation in *S. macrocarpon* leaf area. The contribution of W to variation in *S. macrocarpon* leaf area also improved when this parameter was squared or multiplied with L. Consequently, with a high r^2 and requiring a single length measurement, the model: Leaf area = $1.06+0.4731L^2$, is recommended for the prediction of leaf area in *S. macrocarpon*.

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