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Leaf area determination of shea butter tree (*Vitellaria paradoxa* C.F. Gaertn.)

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A b s t r a c t. Linear dimensions (length and width) and adaxial area of shea butter leaves obtained from 13 month old seedlings were measured. Correlation analysis revealed highly significant ($P < 0.01$) positive relationship between leaf area (*LA*), leaf length (*L*), leaf width (*W*) and the product of the leaf length and width (*LW*). By means of regression analysis, the following model was developed to estimate the adaxial leaf area: $LA = 4.41+1.14LW$ ($P < 0.001$; $r^2 = 95.2\%$), where *LA* is adaxial leaf area (cm^2) and *LW* is the product of the linear measurement of the leaf length and width. This method of leaf area estimation is simple, cheap and could enable repeated *in-situ* measurements of leaf area of the plant since it is non-destructive.

K e y w o r d s: shea butter tree, leaf area, linear models

INTRODUCTION

Leaf area is important in the study of physiological processes of plants as well as in assessment of plant growth and development. Some methods of leaf area estimation involving defoliation suffer the disadvantage of being either destructive, laborious or time consuming. Destructive sampling is undesirable, especially in studies involving small plots or small numbers of plants as is frequently encountered in the study of tree crops. Besides, some of the methods require the use of expensive equipment and high level of technical competence for operation and maintenance of the equipment. Both of these may not be readily available in some developing countries. It was considered helpful to evolve a simple, cheap and non-destructive method for leaf area estimation in shea butter plant.

The shea tree is traditionally an African tree that is widely distributed across the vast African savanna (Umali and Nikiema, 2002). Boffa *et al*. (1996) have reported on the increasing realization and appreciation of the usefulness of the shea butter tree and its products. Available evidence indicates a higher demand for shea butter nuts in the international market (Umobong, 2006). This is expected to boost the volume of agronomic research activity on the species as has been suggested by Popoola and Tee (2001). Already the Vitellaria species has been identified alongside 16 other species for domestication (Leakey, 1999). To facilitate research effort in this direction, we embarked on this study to evolve a reliable but cheap and less technical method for leaf area determination in the shea butter tree.

MATERIALS AND METHODS

Shea butter seeds were collected from nine locations across Nigeria in July, 2006. The nine locations span the three agro-ecologies, namely, the Southern Guinea Savanna, Northern Guinea Savanna and the Sudan Savanna, identified as the major shea butter zones in Nigeria (Keay, 1989). Seeds were sown on July 19th, 2006, at the Teaching and Research Farm of the University of Agriculture, Makurdi (7.41'N, 8.37'E, 97m above mean sea level) at 50 cm inter-row and 20 cm intra-row spacing. Seeds were sown according to the various accessions on a sandy loam soil. Thirteen months after sowing, twenty five undamaged leaves from four of the nine accessions were sampled. The original intention was to sample two accessions from each of the three agro-ecological zones. Unfortunately, the only two accessions from the Northern Guinea Savanna did not have sufficient number of the required leaves to guarantee random sampling. Consequently, plots sampled were those of Makurdi and Akwanga (Southern Guinea Savanna) as well as Yola and Kano (Sudan Savanna). The sampled leaves included both young and mature leaves of variable sizes (Fig. 1).

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Fig. 1. Shea butter tree leaves at three physiological growth stages.

T a b l e 1. Correlations among shea butter tree leaf area, linear dimensions and their product

Parameters	*L* (cm)	*W* (cm)	*LW* (cm^2)	*LA* (cm^2)
LA	0.925**	0.928**	0.976**	–
LW	0.956**	0.946**	–	
W	0.896**	–		
L	–			

**Correlation is significant at the 0.01 level of probability.

T a b l e 2. Coefficient of determination (R^2) values associated with the regression of leaf area (*LA*) against linear dimensions of length (*L*), width (*W*) and their product (*LW*) in the shea species

Functions	Regression		
	LA versus *L*	*LA* versus *W*	*LA* versus *LW*
Linear	85.6 (14.4)*	86.2 (13.8)	95.2 (4.8)
Quadratic	89.5 (10.5)	90.4 (9.6)	95.2 (4.8)

*Values in parentheses denote percentage of variation that is unexplained.

Detached leaves of shea butter tree were stored under low temperature at harvest to guard against loss of turgidity before determination of leaf area (Osei-Yeboah *et al*., 1981). The leaves were later taken during cool weather to the Crop Physiology Laboratory of the Department of Crop Science, University of Nigeria Nsukka, for area determination. The linear dimensions of length (*L*) and width (*W*) at the broadest part of the lamina of each leaf were measured with a ruler. The adaxial leaf area (*LA*) was determined using a leaf area meter (Burle, Delta T. Devices Ltd. No. 9884). Data from the leaves of each agro-ecology were merged together since a plot of the individual accession data revealed a similar pattern. As such, data from all the accessions were pooled together. The pooled data were subjected to correlation analysis so as to explore the nature, and quantify the degree of association between the variables. Both linear and quadratic equations were fitted to the data in order to determine the best function to describe the nature of the relationship between leaf area and leaf linear dimensions and their product (Gomez and Gomez, 1984).

RESULTS

Correlation analysis revealed highly significant positive relationship among all the variables considered, namely, leaf area, leaf length, leaf width and the product of leaf length and width (Table 1). The R^2-values obtained from residual analysis after fitting both linear and quadratic equations to the data are presented in Table 2. Coefficient of determination value was highest (95.2%) when *LA* was regressed against *LW*. The quadratic equation (relative to the linear equation) only served to improve R^2-values slightly when leaf area was regressed against leaf length and width. Therefore, the model arrived at to estimate leaf area of shea leaves was the linear relationship between *LA* and *LW*. Thus, the following function was established:

$$LA = 4.41 + 1.14LW \; (P < 0.001;\ R^2 = 95.2\%),$$

where: *LA* stands for leaf area (cm^2) and *LW* is the product of the linear dimensions of leaf length (cm) and width (cm) at the widest point. The coefficient of determination was 95.2%, with an unexplained variation of 4.8%. The above model was chosen since the second degree polynomial did not improve the R^2-value, indicating that the functional relationship was linear. Graphical representations of the linear models tested are shown in Figs 2-4. The linear relationship between *LA* and *LW* gave the best fit (Fig. 4).

DISCUSSION

Significant correlations between leaf area and leaf linear dimensions as found in this study were similar to earlier reports on guava (Kobayashi, 1988) and grape (Manivel and Weaver, 1974). Because of this co-linearity, no attempt was made to develop a multiple regression model that would include both variables.

Koteswara Rao *et al*. (1978) and Kobayashi (1988) had developed equations to estimate leaf area of guava cultivars from leaf length. This has the advantage of hastening leaf

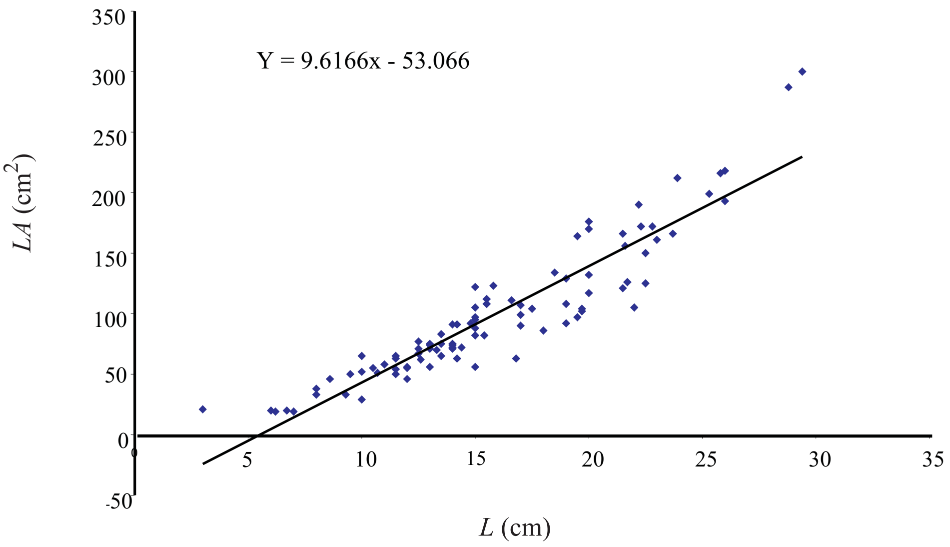

Fig. 2. Relationship between leaf area (*LA*) and length (*L*) of shea butter tree leaves.

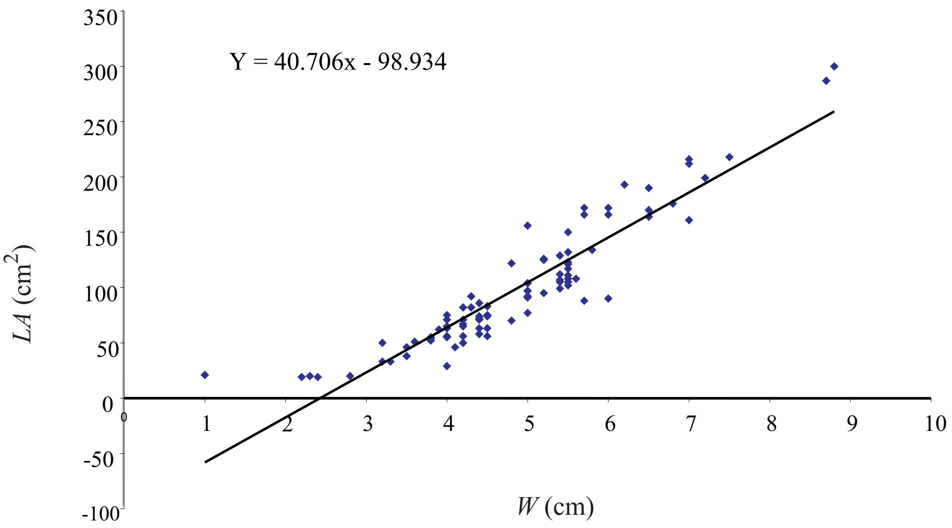

Fig. 3. Relationship between leaf area (*LA*) and width (*W*) of shea butter tree leaves.

area estimation in the field since measuring the leaf length is much simpler than measuring both length and width. The use of leaf width as well in leaf area estimation has been reported for grape (Manivel and Weaver, 1974). The possibility of using only one linear dimension for leaf area determination in the shea butter tree was explored in this study. Results, however, were not encouraging as the associated R^2 values were lower, while the percentage of unexplained variation was higher. Thus, though these variables were highly correlated with each other, it was not adopted. It could be that the shape of shea butter tree leaves may preclude the use of either leaf length or width in satisfactorily estimating leaf area. As was evident in this study, the product of length and width (*LW*) gave better R^2-value with only 4.8% variation ascribed to unexplained causes.

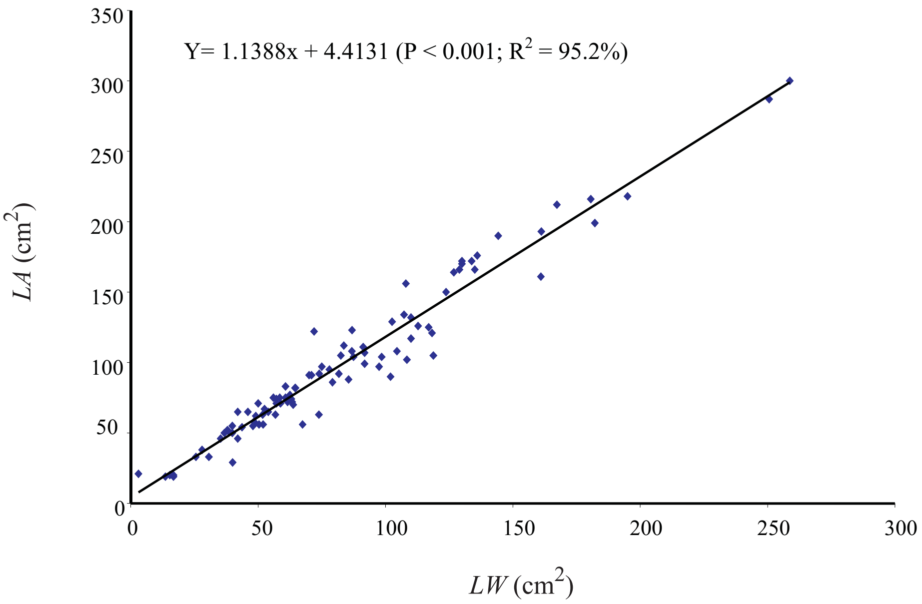

Fig. 4. Relationship between leaf area (*LA*) and product of length (*L*) and width (*W*) of shea butter tree leaves.

CONCLUSIONS

1. The model developed in this study is capable of being adopted for rapid and satisfactory estimation of adaxial leaf area of shea butter tree leaves under field conditions.

2. Non-destructive determination of leaf area by the model assures repeated measurement of leaves in growth monitoring experiments.

3. The model serves as a good substitute where leaf area meter or sophisticated expertise is not available.

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