PREDICTIVE ASSESSMENT OF LEAF AND SHOOT YIELDS IN BUNGU (*Ceratotheca sesamoides* Endl.) AND BLACK SESAME (*Sesamum radiatum* L.)

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ABSTRACT
Measured values of components of yield in two mucilaginous leaf vegetables, bungu (Ceratotheca sesamoides Endl.) and black sesame (Sesamum radiatum L.) were integrated into simple and multiple linear regression equations as means of predicting leaf and shoot yields in the two crop species. Analysis of two years' results indicated that generally negligible differences were observed between predicted and measured leaf and shoot yields, using leaf area index alone or combined with other components of yield as predictor variables. The contribution of leaf area index alone to leaf yield was 96 - 98%, and to shoot yield, about 92%. It could be inferred from the results that, armed with measured values of leaf area index, fairly accurate estimates of leaf and shoot yields in a bungu or black sesame crop could be predicted ahead of harvest.

KEY WORDS: *Best-fit model, yield Components , Predictor variable, Response variable.*

INTRODUCTION
Bungu (*Ceratotheca sesamoides* Endl.) and black same (*Sesamum radiatum* L.) are little-known leaf vegetables in published literature. These rather novel crop species in research are native to the northern parts of West Africa (Irvine, 1969; Zeven and de Wet, 1982), suggesting that they are naturally well adapted to the varying degrees of drought conditions endemic in the region. Although little cultivated and more often harvested from abandoned farms, bungu and black sesame leaves are relished by the indigenous tribes in the savanna zones of Nigeria for imparting a mucilaginous consistency to soup. The leaves also add taste, flavour, and substantial amounts of protein, fiber, minerals, and vitamins to the diet.

The vegetative characters that contribute to overall yield of a leaf vegetable species are called components of yield (Olufolaji and Tayo, 1980, 1989; Akoroda and Olufolaji, 1983; Olufolaji and Dinakin, 1988). Important in this regard are main shoot length or plant height, number and area of the leaves, as well as number and total length of the branches. Measuring the rate of development of these vegetative characters is synonymous with assessing growth rate in plant species (Oladokun et. al., 1987). Furthermore, the contribution made by each or a combination of these components of yield to total yield of the economically important part of a crop species is known to differ. For example, the greatest contributors to total fruit yield of a tomato crop are plant height, number of leaves/plant, number of fruits/plant, and individual fruit weight (Ibrahim, 2002).

The need to intensify research on bungu and black sesame is warranted by the dearth of information on their agronomic characteristics despite the nutritional importance of their leaves and seeds in the diet of millions of Nigerians. The objectives of this study, therefore, are to assess the relationship (correlation) among and between the components of yield, and leaf and shoot yields, on the one hand, and on the other, to develop a model for predicting yields using measured values of the components of yield in the crop species.

MATERIALS AND METHODS
For the purpose of generating the data necessary to achieve the objectives of this study, field plots were laid out during the rainy seasons of 1996 and 1997 on the University of Ilorin Teaching and Research Farm, located in the southern Guinea savanna ecozone. Locally adapted cultivars of *Ceratotheca sesamoides* (code-named Lrn/09) and *Sesamum radiatum* (code-named Lrn/10) were used for the study. Lrn/09 is a dwarfish cultivar

(cv.) and Lrn/10, a tall cultivar.

There were 8 treatments arranged in randomised complete block design with four replications. The plot size was $2m^2$. Weighed quantity of seeds of the two cultivars, at the rate of 9kg/ha (Fasakin, 1991), were direct-drilled 2cm deep in 20, 30, 40, and 50cm rows, in order to achieve a range of growth forms and yields likely to be encountered under different plant population densities. At 3 weeks after planting (WAP), 100g of NPK 20-10-10 fertiliser was applied to each plot, the equivalent of 100kg N/ha, 50kg P/ha, and 50kg K/ha recommended for the crop (Bakare, 1987). Broadspectrum insecticide (Karate 2.5EC) and fungicide (Kaptaf 75SD) were also applied as foliar spray, respectively, to forestall activity of leaf-eating insect larvae and seedling damping-off. The plots were hoe-weeded when necessary.

At 8 WAP, all the plants in the middle 50cm of one randomly selected row in each plot were harvested by uprooting and the following measurements (expressed as mean/plant) taken on a subsample of 10 plants: plant height, number and total length of the primary branches, number of leaves, fresh leaf weight, and fresh stem weight. Fresh leaf and stem weights, separately, were also measured per plot. Leaf area index (LAI) was the product of leaf area/plant and number of established plants/m^2 of a plot. Shoot yield was the addition of leaf and stem fresh weights.

Data collected were analysed by computer, separately and combined for the two years. Relationships among the components of yield, as well as between the components of yield and leaf and shoot yields were evaluated using simple correlation analysis (Hayslett, 1986). Regression analysis (Weisberg, 1980) was also performed with a view to determining which one or more of the components of yield (predictor variables) can best be used to predict leaf or shoot yield (the response variable) in the crop species.

The simple linear regression equation ($\tilde{\mathbf{y}} = \mathbf{a} + \mathbf{bx} + \mathbf{e}_i$) was adopted as the best-fit model for predicting yield as a function of a single predictor variable. In the same vein, the multiple linear regression equation ($\tilde{\mathbf{y}} = \mathbf{a} + \mathbf{b}_1\mathbf{x}_1 + \mathbf{b}_2\mathbf{x}_2 + \ldots\ldots + \mathbf{b}_n\mathbf{x}_n + \mathbf{e}_i$) was used to predict yield as a function of more than one (**n** number) predictor variables. In both equations, $\tilde{\mathbf{y}}$ (pronounced y-hat) is the predicted value for the ***i***th measured yield (**y**); **a** is called the y-intercept, i.e. the value of y when x = 0; **b** is called the slope, i.e. the change in y per unit change in x; **x** is the *i*th value of the predictor variable; $\mathbf{e}_i$ is the statistical error term for the *i*th value, i.e. the deviation of $\tilde{y}$ from y, which should be negligible.

RESULTS AND DISCUSSION

Correlation among the components of yield measured, on the one hand, and between the components of yield and measured leaf and shoot yields, on the other, are presented in a matrix form in Table 1. Each of the correlation coefficients entered in the body of the matrix is a measure of the linear relationship between two attributes. LAI, a measure of the photosynthetic capacity of the crop, was positively correlated with plant population density, as well as with leaf and shoot yields. This implies that the higher the plant population density, the higher the LAI, as well as leaf and shoot yields per unit area of land. Number and total length of branches/plant were also positively correlated with number of leaves, which in turn was positively correlated with leaf yield/plant and leaf to shoot ratio. Conversely, plant height was highly negatively correlated with number of leaves/plant and leaf to shoot ratio, indicating that the significant increase in the height of established plants at higher-than-optimum population density is detrimental to leaf yield.

Table 1 Correlation matrix of the attributes measured in *Ceratotheca sesamoides* and *Sesamum radiatum*

Measured Attributes		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Planting density	(1)											
Plant height	(2)	0.272										
No. of branches	(3)	-0.159	-0.126									
Length of branches	(4)	-0.163	-0.116	0.909*								
No of leaves	(5)	-0.185	-0.836*	0.441*	0.424*							
Leaf area index	(6)	0.565*	-0.216	0.107	0.110	0.272						
Leaf yield $plant^{-1}$	(7)	0.130	-0.346*	0.356*	0.354*	0.465*	0.841*					
Leaf yield m^{-2} land	(8)	0.561*	-0.194	0.145	0.115	0.237	0.983*	0.801*				
Shoot yield $plant^{-1}$	(9)	0.204	-0.151	0.379*	0.384*	0.317	0.832*	0.970*	0.793*			
Shoot yield m^{-2} land	(10)	0.671*	-0.047	0.161	0.127	0.126	0.962*	0.741*	0.979*	0.774*		
Leaf to shoot ratio	(11)	-0.179	-0.905*	-0.091	0.084	0.794*	0.278	0.367*	0.240	0.155	0.081	

* Attributes that are positively or negatively correlated at or above a critical value (=0.349) of the correlation coefficient and 5% significance level (P=0.05)

The results of the regression analysis (Tables 2 and 3) show that LAI, plant population density, number and total length of the primary branches/plant, number of leaves/plant, and plant height were the major contributors to leaf and shoot yields in bungu and black sesame. Among these, LAI proved to be the single most important, contributing 96 - 98% of leaf yield and about 92% of shoot yield/m^2 of land. The other components of yield, singly or combined without LAI, made lesser contributions to yield than LAI alone or combined, as indicated by the following analysed statistical inferences: plant population density alone, 40 - 65%; density + number of leaves, 73%; plant population density + number of leaves + plant height, 74%; LAI + plant height 95%; LAI + plant height + population density, 96%; LAI + plant height + population density + number of branches, 97%; LAI + number of branches, 97%; LAI + number and total length of the branches, 97%; LAI + number and total length of the branches + number of leaves, 97%. Therefore, it could be inferred that, for a high leaf or shoot yield, husbandry practices in a bungu or black sesame crop should aim at achieving a large LAI, through judicious manipulation of plant population density.

Table 2 Predicted values of leaf yield in *Ceratotheca sesamoides* and *Sesamum* radiatum, using measured values of LAI

Sample No.	Measured LAI x	Measured Leaf Yield* y	Predicted Leaf Yield* ?	Statistical Error (? - y)
Lrn/09				
1	9.48	3.01	2.93	-0.08
2	10.53	3.12	3.28	0.16
3	6.00	1.85	1.76	-0.09
4	7.03	1.94	2.11	0.17
5	14.15	4.60	4.51	-0.09
6	14.75	4.41	4.71	0.30
7	10.20	3.09	3.17	0.08
8	12.05	3.57	3.80	0.23
Lrn/10				
9	4.58	1.33	1.28	-0.05
10	4.55	1.37	1.27	-0.10
11	4.38	1.31	1.21	-0.10
12	4.93	1.28	1.40	0.12
13	9.15	2.46	2.82	0.36
14	6.10	2.16	1.80	0.36
15	10.25	2.58	3.19	0.61
16	11.43	2.80	3.59	0.79

* Leaf yield in kg/m^2 of land.

Details of the Regression Analysis

Response Variable:		Leaf yield (y), kg/m^2 of land			
Predictor Variable:		LAI (x)			
% of leaf yield contributed by the predictor variable = 97.7					
ANOVA	d.f.	S.S.	M.S.	Fcal	F pr
Regression	1	46.837	46.837	631.49	<0.001
Residual	14	1.038	0.074		
Total	15	47.876	3.192		

Standard error of observations, estimate = 0.272

Estimates of Regression Coefficients:

	Estimate	S.e.	t(14)	t pr
Constant (a)	-0.257	0.144	-1.78	0.097
LAI (b)	0.337	0.014	25.13	<0.001

Fitted Simple Linear Regression Model

$\tilde{y} = a + bx$

Worked Examples

Sample No. 4: $\tilde{y} = -0.257 + (0.337 \times 7.03) = 2.11$

Sample No. 12: $\tilde{y} = -0.257 + (0.337 \times 4.93) = 1.40$

Table 3 Predicted values of shoot yield in *Ceratotheca sesamoides* and *Sesamum* radiatum, using measured values of LAI, plant height, plant population density, and number of the primary branches per plant

nple No.	Measured LAI x_1	Measured Plant Height (cm) x_2	Measured Population Density* x_3	Measured No. of Branches x_4	Measured Shoot Yield+ y	Predicted Shoot Yield+ ?	Statistical Error (? - y)
n/09							
1	9.48	60.8	784	4.6	8.96	8.89	-0.07
2	10.53	58.8	668	4.3	9.50	9.01	-0.49
3	6.00	57.8	469	5.0	5.23	5.34	0.11
4	7.03	57.0	360	5.1	5.36	5.60	0.24
5	12.15	62.5	722	4.6	10.14	10.49	0.35
6	12.75	64.6	704	3.6	11.23	10.77	-0.46
7	10.20	58.9	480	4.0	7.81	8.06	0.25
8	11.05	59.5	398	4.2	8.06	8.37	0.31
n/10							
9	4.58	54.5	337	9.3	3.83	4.39	0.56
10	4.55	53.3	330	9.2	4.11	4.27	0.16
11	4.38	52.5	312	9.3	3.91	4.07	0.16
12	4.93	50.1	302	8.1	2.88	4.12	1.24
13	7.15	50.2	402	10.1	5.88	6.24	0.36
14	6.70	53.1	403	9.9	5.82	6.05	0.23
15	7.25	53.9	378	9.1	5.67	6.25	0.58
16	7.43	54.0	390	9.2	6.28	6.43	0.15

* Per m^2 of land   + Shoot yield in kg/m^2 of land

Predictive Assessment of Leaf and Shoot Yields

Details of the Regression Analysis

Response Variable:	Shoot yield (y) in kg/m^2 of land
Predictor Variables:	LAI (x_1), Plant height (x_2), Plant population density (x_3), No. of primary branches/plant (x_4)

% of shoot yield contributed by predictor variables = 96.5

ANOVA	d.f.	S.S.	M.S.	Fcal	F pr
Regression	4	401.71	100.4278	217.30	<0.001
Residual	27	12.48	0.4622		
Total	31	414.19	13.3609		

Standard error of observations, estimate = 0.680

Estimates of Regression Coefficients:

		Estimate	S.e.	t(27)	t pr
Constant(a)		-3.673	0.726	-5.06	<0.001
LAI	(b_1)	0.6591	0.0348	18.94	<0.001
Plant height	(b_2)	0.0451	0.0151	2.98	0.006
Density	(b_3)	0.0037	0.0012	3.16	0.004
Branches No.	(b_4)	0.1438	0.0483	2.98	0.006

Fitted Multiple Linear Regression Model

$$\tilde{y} = a + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4$$

Worked Examples

Sample No. 1: $\tilde{y}$ = -3.673 + (0.6591 x 9.48) + (0.0451 x 60.8) + (0.0037 x 784) + (0.1438 x 4.6) = -3.673 + 6.25 + 2.74 + 2 90 + 0.66 = 8.89

Sample No. 15: $\tilde{y}$ = -3.673 + (0.6591 x 725) + (0.0451 x 53.9) + (0.0037 x 378) + (0.1438 x 9.1) = -3.673 + 4.78 + 2.43 + 1.40 + 1.31 = 6.25

Table 2 shows predicted or fitted values of leaf yield/m^2 of land, using a series of measured or observed values of a single predictor variable: LAI. Table 3 shows predicted shoot yield/m^2 of land, using measured values of multiple predictor variables: LAI, plant height, plant population density, and number of the primary branches/plant. It is noteworthy that in both Tables 2 and 3, the statistical error terms are generally small compared with values of measured yield. The relatively large error terms shown by samples 15 and 16 in Table 2, and sample 12 in Table 3 could have arisen from such random sources as data measurement, computational error, neglected factors, and natural variability (Gomez and Gomez, 1976).

CONCLUSION

The results obtained in this study suggest that LAI is the major determinant of leaf and shoot yields in a bungu or black sesame crop. Hence, when information on expected leaf or shoot yield from each of the crops becomes expedient, fairly accurate estimates may be obtained by integrating measured LAI values into the single linear regression equation.

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