Okra Yield – Period Model in a Derived Savannah eco climatic zone of Nigeria.

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Abstract: Okra yield model development for the Savanna eco climatic zone of Nigeria was carried out. The experiment was carried out at Moor Plantation Ibadan, Nigeria between January and July 2006 as well as 2007. Five rates of tyrax concentrations, 0, 0.01, 0.02, 0.04 and 0.6% active ingredient (T_0 T_1 T_2 T_3 and T_4) in 500ml of water and replicated four times in a randomized complete block design (RCBD) were used. The correlelogram of the okra yield for the lag period of 20 showed a decreasing trend over the lag period and 5% of the autocorrelation values for the 2007 data and 40% of that of the 2006 fall outside the range $\pm \frac{2}{\sqrt{2}}$. The mean okra yield, 3.97, 210.02 and 3.14 returned for the period, season, and season by period were greater than $F_{(9, 100;0.01)} = 2.59$ and $F_{(1, 100, 0.01)} = 6.9$. The 3 models investigated for the relationship between periods and yield returned the coefficient of determination (R^2) that were high and it (R^2) ranged from 0.52 for the linear regression model and 0.67 for the natural logarithmic model. Also, all the models showed that there exist significant difference between the residuals returned for the dependent (crop yield) and the independent (period) variable. This was because, the 8.665, 6.384 and 16.278 returned for the linear, quadratic and the logarithmic models were greater than $F_{(1, 8, 0.05)} =$ 5.32 and $F_{(2, 7, 0.05)} = 4.74$. The test of the residuals for these different models showed that the quadratic model had the least residual variance ***V(r)*** of 0.0003 while the natural logarithmic model had the highest residual variance, ***V(r)*** of 0.716. [Report and Opinion 2010;2(5):52-58]. (ISSN:1553-9873).

Key words. Correlelogram, yield capsule, Okra.

Introduction.
Okra, *Abelmoschus esculentus* have been described as an important vegetable crop in the tropical and subtropical zone of the world because it is a good source of vitamins, protein and minerals for the human diets (Adebisi, *et.,al*, 2007). Consumption is the basic use to which okro is subjected especially in Nigeria. The leaves are also edible among the Ibarapas and Oke Oguns of the Oyo state, Nigeria. Okra yield harvest for consumption like some other vegetables is usually carried out progressively over a period of time. This is because the pod becomes unexplorable for consumption after some days of their maturation. Okra is a rich source of many nutrients such as calories (25g), Dietary fiber (2g), Protein (1.5g), carbohydrate (5.8g), vitamin A (460 IU) in a 100g of green okra pod and others (Schilling, 2002). Okra yield (in terms of fresh fruits) is usually harvested every other day because the pods develop quickly and not at once. Growth and yield models are abstract or simplified representations of some aspect of reality used primarily to estimate the future growth and yield of crop. Yield models are primarily used to forecast the probability distribution of the future yield. It has been defined as a computer program that integrate information on daily weather, genetics management, soil characteristics and pest stress to determine daily plant growth and subsequent yield. Growth and yield models are veritable tools for well informed management decision. This is because through yield model, probability statements about future yield can be made. Consequently, it plays a direct role in year – to – year national and international economies as well as food management. Knowledge of yield pattern of crop would therefore go a long way in the mapping of crop harvest and its strategic market to be able to reduce waste arising from excess supply.

There exist a rich body of literature on okra yield and include, Dauda, *et.al.*, (2007), Adebisi, *et.al.*, (2007) and so on. However, few of these works have focused on the yield prediction relative to period. This study is thus justified from the need to adequately plan farm in order to reduce wastage arising from late harvesting of the pods. The objective of this study was to assess the rate of yield of okra over the study period and to model okra yield at different period of harvesting as well as predict the period of optimum yield in okra production.

Materials and Methods.

The experiment was carried out at Moor Plantation Ibadan, Nigeria between January and July 2006 and 2007. Five rates of tyrax concentrations, 0, 0.01, 0.02, 0.04 and 0.6% active ingredient in 500ml of water henceforth described as T_0 T_1 T_2 T_3 and T_4 respectively were applied. These were replicated four times in a Randomized Complete Block Design (RCBD). The treatments were applied twice at ten days intervals during the dry season and three times at seven days intervals during the wet season using a hand sprayer. Insecticides are usually washed off by rains during the wet season and this necessitated higher number of sprays to maintain the insecticide potency. The okra variety used was I. A. R. & T. V-35 in a plot size of $4.5 \times 4m$ using a spacing of $90 \times 60m$ at two plants per stand. Planting was done on the flat soil after ploughing and harrowing on 5th January and 7th April, 2006 and 2007 for the dry and wet season cultivations respectively. The dry season cultivation was located in the fadama area. 250kg/ha of single super phosphate fertilizer was applied pre-planting and 100kh/ha of urea was applied in two equal doses at 2 WAP and at onset of fruiting (Anon, 1991). Watering was done daily using watering cans during the dry season to prevent wilting while in the wet season it was rain-fed. After flowering, green capsules were picked at every other days from four innermost rows per plot until most stands were not producing capsules. Yield data (g) of the green capsule were recorded immediately after harvesting.

Data were described using mean as well as the percentage yield of each of the period for both wet and dry season. The correlelogram of the autocorrelation was plotted and examined for serial correlation. Also, the data were subjected to analysis of variance to test for the effects of the different sources of variations on the data. Yield rate of the okra were transformed through a trigonometric means (that is taken the cosine of the angles of the rate) to edge out the negative values returned for some of the rate before being used for the analysis of variance. The means were partitioned using Duncan Multiple range Test *(DMRT)*. The transformed okra yield rate, (*OYR)* values were used for the regression model analysis and the residuals of the models were computed and plotted. Model of the form;

$$Y = a + bx$$

$$Y = a + bx + cx^2$$

$$Y = a + b\ln x$$

were investigated. *(where, Y is the yield of okra in the t – ordinal period starting from 0, the first day of harvesting, a is the intercept and b the slope. x is the period)*

Coefficient of determinations (R^2) of each of the models as well as their analysis of variances were computed. Similarly, the variances of the residuals, V(r) for the models were equally computed. The models were validated using the plots of the estimates of the model.

Results.

The descriptive statistics showed that okra yield followed different trend for the different season. For the dry season, higher values as well as higher trends were obtaine (Table 1). This trend was characterized by a short periodic increment at the early harvesting period and short periodic decrease towards the end of the harvesting period. Okra yield for the wet season was much lower than the dry season and its trend was characterized by a longer early periodic increment and longer latter periodic decrease, (Figure 1A). OYR however, does not follow the same pattern because it differs from one period to another and such differences are random (that is, the differences are not patterned). Highest yield percentage *(HYP)* was obtained at the 13th day of harvesting for the wet season while the least was obtained on the first day of harvesting. For the dry season however, *HYP* was obtained at the 15th day of harvesting and the least also on the first day of harvesting, (Table 1). The weather record of the area showed that wet season had higher rainfall as well as higher relative humidity was experienced when compared to the dry season. Also, the rates of rainfall (4.567mm/day) as well as relative humidity (2.716%/day) were obtained for the wet season when compared to the rate of the rainfall for the dry season. The correlelogram of the okra yield for the lag period of 20 showed a decreasing trend over the lag period, (Figure 2). From the correlelogram, 5% of the autocorrelation values for the 2007 data and 40% of the 2006 fall outside the range $\pm 2/\sqrt{n}$ (with n = 50, Ayeni, 1986). This showed that, the data needs no adjustment for serial correlation. The analysis of variance of the okra yield showed that there were significant differences in the mean returned for the different period, season and season by period. The mean okra yield, 3.97, 210.02 and 3.14 returned for the period, season, and season by period were greater than $F_{(9, 100;0.01)} = 2.59$ and $F_{(1, 100, 0.01)} = 6.9$. Similarly, the analysis of variance for okra yield rate (OYR) showed that there exist a significant differences in the mean returned for both period and period by season. Both 2.27 and 2.39 returned for period as well as season by period were greater than $F_{(9, 100; 0.05)} = 2.59$ (Table 2).

Table 1.Descriptive statistics of the Okra yield and Rate.

Period	**Yield**				**Yield rate**	
	S_1	**% S_1**	**S_2**	**% S_1**	**S_1**	**S_2**
1	0.052	5.366	0.162	3.236	0.017	0.381
3	0.069	7.121	0.543	10.847	0.022	-0.121
5	0.091	9.391	0.422	8.430	0.047	-0.057
7	0.138	14.241	0.365	7.291	-0.036	0.073
9	0.102	10.526	0.438	8.750	-0.005	0.144
11	0.097	10.010	0.582	11.626	0.052	0.029
13	0.149	15.377	0.611	12.205	-0.035	0.132
15	0.114	11.765	0.743	14.842	-0.024	-0.234
17	0.09	9.288	0.509	10.168	-0.023	0.122
19	0.067	6.914	0.631	12.605		
Total	0.969	100.000	5.006	100.000		

*NB. Both **S_1 and S_2** are dry and wet season while **% S_1** and **% S_2** are percentage okro yield per period.*

Table 2. Analysis of Variance for Okro Yield and Okro Yield Rate.

Sources of Variation	Df	F statistics	
		Okro yield	Okro yield rate
Treatment	4	1.37	0.05
Period	9	3.97**	2.27*
Season	1	210.02**	1.63
P*S	9	3.14**	2.39*
T*P	36	0.26	0.28
T*S	4	1.36	0.05
T*P*S	36	0.24	0.30

NB. T is Treatment, P is period and S is season. Df is degree of freedom.

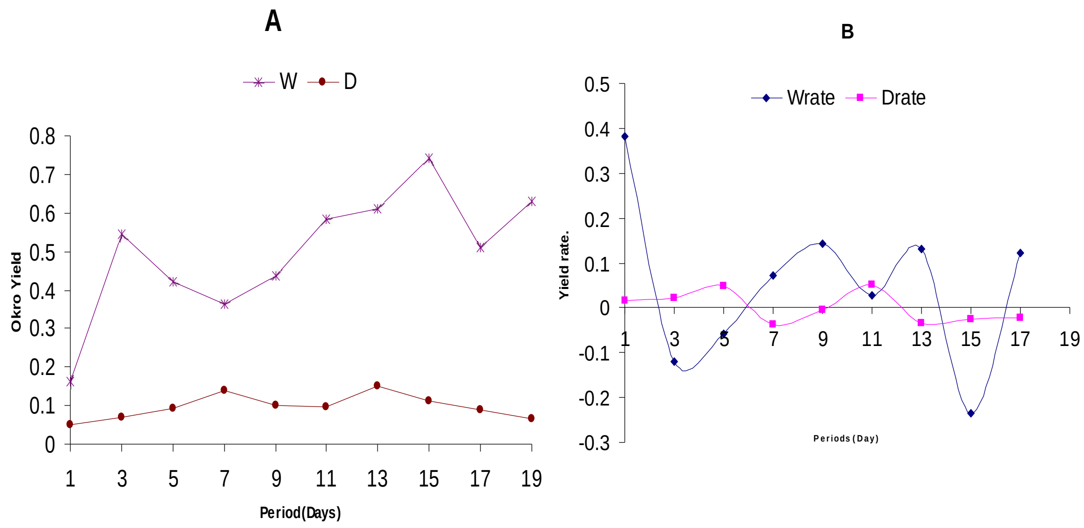

Figure 1. Okro yield (A) and Yield rate (B) for the different periods

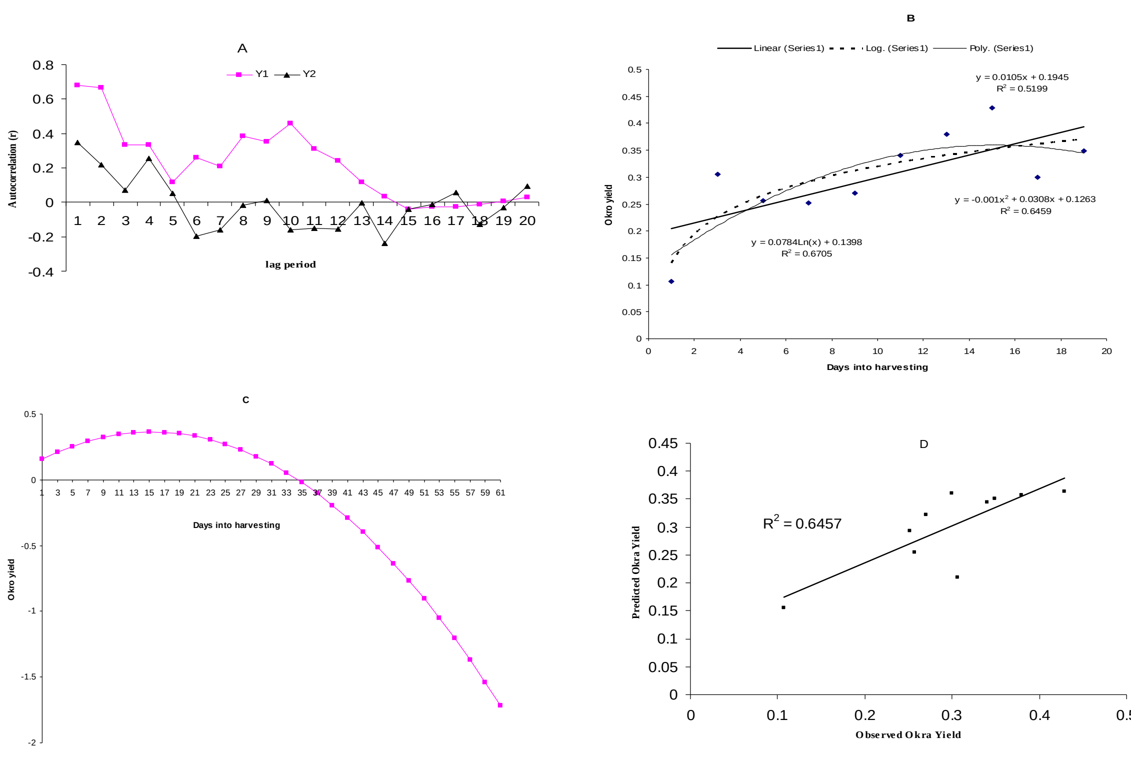

Figure 2. Autocorrelation of the Okro yield by the different year irrespective of Season at lag 20, (A) the explored models, (B), Quadratic Model's Validation, (C) and obseved against predicted okra yield, (D)

Mean okra yield was partitioned into four periodic groups. These are the mean okra yield for the 15th day of harvesting (0.4285^a) which was significantly greater and different from the okra yield returned for the 9th day (0.270^b), 5th day (0.2565^b) and the 7th day into harvesting (0.2515). The mean returned for the 13th day (0.380^{ab}), 19th day (0.349^{ab}), 11th day (0.340^{ab}), the 3rd day (0.306^{ab}) and the 17th day formed an intermediary class (ab) between the former and the latter group. The least significantly different period was the okra yield returned for the 1st day of harvesting, (Table 3).

The 3 models investigated for the relationship between periods and yield returned the coefficient of determination (R^2) that were high and it (R^2) ranged from 0.52 for the linear regression model and 0.67 for the naturally logarithmic model. Also, all the models showed that there exist significant difference between the mean returned for the dependent (crop yield) and the independent (period) variable (Table 3). This was because, the 8.665, 6.384 and 16.278 returned for the linear, quadratic and the logarithmic models were greater than $F_{(1, 8, 0.05)}$ = 5.32 and $F_{(2, 7, 0.05)}$ = 4.74. The test of the residuals for these different models showed that the quadratic model had the least residual variance *V(r)* of 0.0003 while the natural logarithmic model had the highest residual variance, *V(r)* of 0.716. The regression line of both the quadratic and logarithmic models showed an increasing yield for the early period of yield (till 15th day of yield) after which it started decreasing. Also, the result of the simulation of the quadratic models revealed that the model is not valid at the 35th days of harvesting when okra yield becomes negative, (Figure 2B). That is, for any Y_t, $0 \le x \le 35$ ordinal period and at the 15th day of harvesting, okra yield is optimum.

Similarly, the arc shape of the model's validation results was not similar to the sigma shape of the growing models of plant species. It was however similar to the shape of the original model, (Figure 2A). This connotes that the yield rate model is different from growth rate model. One of the feature of the validation model is that okra yield can still be obtained on the 1st day of harvesting (corresponding to period 0).

Table 3. Rainfall and Relative humidity of the different years and season

Season	Months	2006		2007		Mean of the 2 years	
		Rainfall	**Relative Humidity**	**Rainfall**	**Relative Humidity**	**Total Rainfall**	**Total Relative Humidity**
wet	1	45.7	70.69	142.1	82.48	93.9	76.585
wet	2	106.7	79.06	192.1	83.9	149.4	81.48
wet	3	138.8	80.33	187.6	86.97	163.2	83.65
Total		**291.2**	**230.08**	**521.8**	**253.35**	**406.5**	**241.715**
Rate Per day		**3.27191**	**2.585169**	**5.862921**	**2.846629**	**4.567416**	**2.715899**
Dry	1	0	46.39	136.3	81.58	68.15	63.985
Dry	2	107.2	71.39	153.9	85.23	130.55	78.31
Dry	3	242.7	77.95	58.8	85.9	150.75	81.925
Total		**349.9**	**195.73**	**349**	**252.71**	**349.45**	**224.22**
Rate Per day		**3.803261**	**2.1275**	**3.793478**	**2.746848**	**3.79837**	**2.437174**

NB. Rate per day = x/y *(x = sum of the quantity of the variable experienced during the course of the study while y = total number of days in all the production days).*

Table 4. Summary of the Models, the Coefficient of Determinations (R^2) and the residual's variance

Model Type	Models	R^2	F	V(R)
Linear	$Y = 0.195 + 0.011x$	0.52	8.665*	0.0037
Quadratic	$Y = 0.126 + 0.031x - 0.001x^2$	0.65	6.384*	0.00027
Natural Logarithm	$Y = 0.140 + 0.078 \ln x$	0.67	16.278**	0.716

Discussion and Conclusion.

The goals of this study were

1. Evaluation of the rate of yield of okra over the study period.
2. Modeling okra yield using the t-ordinal period.
3. Selection of the model of best fit and
4. Validation of the model of best fit.

The different trend exhibited by okra yield at the different season may be hinged on instability difference in the effects of weather and some other yield promoting factors. This is in agreement with Adekalu (2006) who developed crop yield model which predicts crop phonologic stages and the effects of climate on yield. From the study also, the incorporation of larger values of autocorrelation within the range of $\pm 2/\sqrt{2}$ is an indication of the randomness nature of the data from the two years. Thus, it is note worthy that the okra yield trend status quo (difference in the trends for different season) remained for the two years. The shape of okra yield can thus be described as a "heap". The statistically different mean okra yield depict the differences in the growth and yield promoting factors. For instance, higher trends obtained for the dry season can be hinged on the fact that low insect incidence which enhance productivity have been reported during the dry season when compared with wet season, (Agbaje and Daramola, 2000). Also, wet season though experienced higher rainfall rate than the dry season but relative humidity of the dry season was more favourable than that of wet season. In addition, the least okra yield obtained at the last feasible day of harvesting regardless of the season conflict with the sigma growth curve of any plant which is usually minimum at the initiation stage.

The 3 adopted models performed creditably well using their coefficient of determination as well as the variance of their residual to judge. However, quadratic model form ($Y = 0.126 + 0.031x - 0.001x^2$) was chosen as the best of the 3 adopted model. This is a single – variable quadratic model and is in agreement with Robert (2001). Through this model, the optimum okra yield of 0.363g per plot of 4m^2 was obtainable at the 15th day of harvesting. When this model was resolved using its derivation ($\partial y/\partial x$), it becomes, $Y = 0.031 - 0.002x$ meaning that the original model is sufficient. There are 2 effects of this. First, it reveals the plausibility of the linear regression model as investigated earlier. Second, it shows the flexibility of the quadratic models. However, since the resolved derivatives of the quadratic model does not coincides with the linear models arrived at earlier, it is thus necessary to jettison further resolution of the quadratic model and optimum periodic yield was obtained between 9th and 23rd day of harvesting. Also, the okra yield rate decreases by -0.002g per day. This model ($Y = 0.126 + 0.031x - 0.001x^2$) agrees well with crop yield because,

1. It minimizes the variance of the residuals.
2. It showed significantly high relationships between the predicted model (estimation) and the observed values.
3. The model and validation graph gave the same shape.

For any t - ordinal period, okro yield can be predicted using, $Y = 0.126 + 0.031x - 0.001x^2$. This model was similar to the quadratic model generated to predict tree volume from basal area, (Adekunle, *et., al*, 2004). A single variable quadratic model was employed to predict volume of tree using,

$$V = b_0 + b_1 Ba + b_2 Ba^2$$

(where V is the tree volume and Ba is the basal area, Adekunle, et., al, 2004).

Lastly, the non validity of the model at the 35th day of harvesting confirms the length of pod production (*lpp*) for consumption purposes in okra (which is ≤ 35).

In conclusion, growth and yield models have been extensively explored in forestry and related field because of the long gestation period of tree species. This on the long run had contributed significantly to the effective management of forest and tree yield. This study has thus arrived at a yield model that would be found useful in management plan of okra productivity. Also, the model's validation confirms the reliability of the model. It is therefore recommended that this model should be tested across different ecological zones as well across several spatial locations.

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