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# Response surface methodology to determine the optimum yield of white yam at different levels of NPK fertilizer application

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## Abstract

*Fertilizers are essential to modern agriculture, their overuse can have harmful effects on human being, plants, crops and soil quality (Popoola, O. P et .al,2015)[6].Thus, this research work attempts to develop a multiple regression model to investigate the effect of three levels of NPK fertilizer on the yield of white yam, examine if the trio of Nitrogen, Phosphorus and Potassium (NPK) contribute to the growth and yield of white yam; also, to detect which of the three elements of NPK contribute most. It does further to determine at what proportion each of the three elements is to be applied for optimum yield and if applied correctly, confirm the optimum yield at kilogram per hectare. A3x3 factorial design ANOVA was adopted in the data analysis to determine if the fertilizers used have effect on the white yam. Post Hoc analysis was carried out using LSD, Tukey, Scheffe and Bonferroni test to determine which level of the fertilizers differed, multiple regression analysis was used to investigate at what proportion the elements are to be applied for optimum yield. Also, Response Surface Methodology was carried out to obtain the optimum yield of white yam, the results of the analysis showed that the trio of Nitrogen, Phosphorus and Potassium (NPK) contribute to the growth and yield of white yam for both main effect and interaction effects at thedifferent levels ofapplication. Furthermore, the overall Multiple Regression models for the Yield of white yam was obtained at* $Y = 319.0834 + 7.0717N - 26.7399P + 32.6546K - 1.9665NP - 2.5493NK - 0.6896PK$*.Thus, the nitrate and potash combination produced the best yields on the average of 390.3118 tone/kilogram per hectare when used at* $N_{75}$ *k.g and* $K_{60}$*k.g.*

**Key words**: *NPK Fertilizers, A 3x3Factorial Designs, Multiple Regression, Response Surface Methodology and white Yam.*

## I Introduction

Yam is a valuable source of carbohydrate to the people of the tropical and subtropical Africa, Central and Southern America, parts of Asia, the Caribbean and Pacific Islands (Coursey, 1967)[3].Yams are one of the most highly regarded food products in tropical countries of West Africa and are closely integrated into social, economic, cultural and religious aspects of communities. Nigeria is known to be the largest producer of yam in the world. Annual production of yam in the country is estimated at 36,720 million metric tons of total world's yam production (FAO, 2006). The major yam producing states in Nigeria are Adamawa, Benue, Cross River, Delta, Edo, Ekiti, Imo, Kaduna, Kwara, Ogun, Ondo, Osun, Oyo, and Plateau (Akanji*et al*, 2003)[1].

Yams are one of the most highly regarded food products in tropical countries of West Africa and are closely integrated into social, economic, cultural and religious aspects of communities. Nigeria is known to be the largest producer of yam in the world. Plants, like human beings need the right nutrition to remain healthy. If they do not get enough of a nutrient, the symptoms show-up in the general appearance as well as in colours of plant. Nutrient deficient plants are often stunted (small) and the leave have a pale green color, yellowish or reddish spotting or stripping. Yields are reduced, sometimes severely (Popoola, O.P et.al 2015)[6].

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Fertilizer, natural or synthetic chemical substance or mixture, used to enrich soil so as to promote plant growth. Plants do not require complex chemical compounds analogous to the vitamins and amino acids required for human nutrition, because plants are able to synthesize whatever compounds they need. They do require more than a dozen different chemical elements and these elements must be present in such forms as to allow an adequate availability for plant use. Within this restriction, Nitrogen, for example, can be supplied with equal effectiveness in the form of urea, nitrates, ammonium compounds, or pure ammonia.Virgin soil usually contains adequate amounts of all the elements required for proper plant nutrition. When a particular crop is grown on the same parcel of land year-after-year, however, the land becomes exhausted of one or more specific nutrients. If such exhaustion occurs, nutrients in the form of fertilizers must be added to the soil. Plants can also be made to grow lushly with suitable fertilizers. Of the required nutrients, hydrogen, oxygen and carbon are supplied in inexhaustible form by air and water. Sulfur, calcium and iron are necessary nutrients that usually are present in soil in ample quantities. Lime (calcium is often added to soil, but its function is primarily to reduce acidity and not, in the strict sense, to act as a fertilizer. Nitrogen is present in enormous quantity in the atmosphere, but plants are not able to use Nitrogen in this form; bacteria provide Nitrogen from the air to plants of the legume family through a process called Nitrogen fixation.

Fertilizers are essential to modern agriculture, their overuse can have harmful effects on human being, plants, crops and soil quality (Popoola, O. P et .al,2015)[6]. In addition, the leaching of nutrients into bodies of water can lead to water pollution such as eutrophication, by causing excessive growth of vegetation. Hence, the studies aimed at investigating, if actually, the trio of Nitrogen, Phosphorus and Potassium (NPK) contribute to the growth and yield of white yam; to detect which of the three elements of NPK contribute most. It does further to determine at what proportion each of the three elements is to be applied for optimum yield and if applied correctly, confirm the optimum yield at kilogram per hectare. Three levels of NPK was applied on the white yam at $N_{25}P_0K_0$, $N_{50}P_{10}K_{60}$, $N_{75}P_{20}K_{120}$

## II Materials and Methods

*The Research Design; Factorial Experiments*

Montgomery (1974) [5]. defined factorial experiments as experiment in which each complete trial or replication of the experiment and all possible combinations of the level of the factors are investigated. This is the most efficient design when an experiment requires a study of the effects of two or more factors. When factors are arranged in a factorial experiment, they are often said to be crossed

Factorial experiments are more efficient than one factor at a time experiments. This design is necessary when interactions may be present, to avoid misleading conclusions. It allows effects of a factor to be estimated at several levels of the other factors, yielding conclusions that are valid over a range of experimental conditions. (Anbari and Lucas, 1994) [2].

*Factorial design experiment*: This was chosen because it is the most suitable for any experiment that have more than one factor. Factorial design is also being employed in order to evaluate the effect of each factor, the combination of the three and the interaction effect. In this paper, each of the three factors is at three level i.e. 3 x 3 factorial experiment.

*The general statistical model for the 3-factorial design is:*

$$Y_{ijkl} = \mu + \alpha_i + \beta_j + \tau_k + (\alpha\beta)_{ij} + (\alpha\tau)_{ik} + (\beta\tau)_{jk} + (\alpha\beta\tau)_{ijk} + e_{ijkl}$$

$i = 1,2,\ldots\ldots a$ ; $j = 1,2\ldots\ldots b$ ; $k = 1,2\ldots\ldots\ldots c$ ; $l = 1,2, \ldots\ldots n$

$\mu$ = overall mean $\alpha_i$ = effect of $i^{th}$ level of factor N $\beta_j = j^{th}$ level of factor P

$\tau_k$ = $k^{th}$ level of factor K ,$(\alpha\beta)_{ij}$ = effect of $ij^{th}$ level of interaction NP,$(\alpha\tau)_{ik}$ =effect of $ik^{th}$ level of interaction NK $(\beta\tau)_{jk}$ = effect of $jk^{th}$ level of interaction PK,$(\alpha\beta\tau)_{ijk}$= effect of $ijk^{th}$ level of interaction NPK $e_{ijkl}$ = experimental error,$e_{ijkl}$~ NID $(0, \sigma^2)$

*The Mean Separation*

The F-test for any testable effect in the analysis of variance (ANOVA) table may indicate significant differences or otherwise. When significant, it suggests that, at least, one pair of the means in question must be different. (Wahua, 1999).[7] Statistical significance implies that whatever difference we are referring to, is too big to be attributed to experimental error. It is real; not a chance event. However, the F-test did not tell us which means actually differed. We have to set-up a criterion of measurement to find out how different a difference should be before it is declared statistically significant. (Wahua, 1999).[7] Hence, LSD, Tukey, Scheffe and Bonferroni test was adopted.

**Research Variable**

The subjects of the experiment: **white yam**;

*Treatment:* Application of NPK Fertilizers at three levels.

Various levels of the (NPK) fertilizer component in (kg): N=25.50, 75; P =0, 20, 40; K=0,60,120

## III ANALYSIS

| Source of Variation | Sum of Square | df | Mean Square | Fcal | Sig. | Remark |
|---|---|---|---|---|---|---|
| Corrected Model | 60578.395a | 24 | 2524.1 | 65.319 | 0.015 | Sig. |
| Intercept | 2635294.307 | 1 | 2635294.307 | 68196.786 | 0.000 | Sig. |
| N | 4942.528 | 2 | 2471.264 | 63.952 | 0.015 | Sig. |
| P | 16899.593 | 2 | 8449.796 | 218.666 | 0.005 | Sig. |
| K | 10045.306 | 2 | 5022.653 | 129.977 | 0.008 | Sig. |
| N*P | 7839.089 | 4 | 1959.772 | 50.715 | 0.019 | Sig. |
| N*K | 687.163 4 | 4 | 171.791 | 4.446 | 0.192 | Not S. |
| P*K | 4272.555 | 4 | 1068.139 | 27.642 | 0.035 | Sig. |
| N*P*K | 12356.190 | 6 | 2059.365 | 53.293 | 0.019 | Sig. |
| Error | 77.285 | 2 | 38.642 | | | |
| Total | 3016419.960 | 27 | | | | |
| Corrected Total | 115374.964 | 27 | | | | |

a) R squared = 0.999 (Adjusted R squared = 0.983)

b) Compute Using 0.05

The result of Analysis of Variance(ANOVA) using R Software (STATIATICAL PACKAGE) shows that Nitrogen, Potassium, Phosphorus, Nitrogen*Phosphorus, Phosphorus*Potassium and Nitrogen*Phosphorus*Potassium have significant effect on the yield and growth of white yam at 5% level of significance, while only one; Nitrogen*Potassium is insignificant that is interactions of Nitrogen and Potassium have no effect on the yield and growth of white yam when applied together.

*Post Hoc Analysis of White Yam*

Using the LSD, Tukey, Scheffe and Bonferroniwe obtained the following result:$N_1$ and $N_2$ are more significant than $N_3$with the values of 0.027, 0.03, 0.015 and 0.045,$P_0$ is more significant than $P_1$ and $P_2$ and $K_2$ is more significant than $K_1$ and $K_3$ respectively.

*Response Surface Regression: White Yam yield versus N, P, K*

Dependent Variable: Yield of White Yam

Method: Least Squares

Included observations: 27

YIELD=C(1)+C(2)*N+C(3)*P+C(4)*K+C(5)*N*P+C(6)*N*K+C(7)*P*K

| | Coefficient | Std. Error | t-Statistic | Prob. |
|---|---|---|---|---|
| C(1) | 319.0834 | 41.85002 | 7.624451 | 0.0000 |
| C(2) | 7.071684 | 21.45776 | 0.329563 | 0.7452 |
| C(3) | -26.73987 | 26.61080 | -1.004850 | 0.3270 |
| C(4) | 32.65456 | 26.25229 | 1.243874 | 0.2279 |
| C(5) | -1.966536 | 11.79781 | -0.166687 | 0.8693 |
| C(6) | -2.549298 | 11.37855 | -0.224044 | 0.8250 |
| C(7) | -0.689568 | 12.89390 | -0.053480 | 0.9579 |

| | | | |
|---|---|---|---|
| R-squared | 0.530861 | Mean dependent var | 330.8667 |
| Adjusted R-squared | 0.390119 | S.D. dependent var | 48.30022 |
| S.E. of regression | 37.72000 | Akaike info criterion | 10.31667 |
| Sum squared resid | 28455.97 | Schwarz criterion | 10.65263 |
| Log likelihood | -132.2751 | Hannan-Quinn criter. | 10.41657 |
| F-statistic | 3.771874 | Durbin-Watson stat | 1.856862 |
| Prob(F-statistic) | 0.011263 | | |

## IV RESULTS

The result of the Analysis of Variance (ANOVA) carried out showed that Nitrogen and Phosphoric and potash fertilizer contributed significantly to the yield of white yam. A further analysis on the mean separation of Nitrogen, Phosphorus and potassium using the LSD, Tukey, Scheffe and Bonferroni showed that $N_1$ and $N_2$ are more significant than $N_3$with the values of 0.027, 0.03, 0.015 and 0.045, $P_0$ is more significant than $P_1$ and $P_2$ and $K_2$ is more significant than $K_1$ and $K_3$ respectively. Thus, the multiple regression model for the yield of yam was obtain as Yield = 319.0834 + 7.0717N - 26.7399P + 32.6546K – 1.9665NP– 2.5493NK– 0.6896PK. Thus, the Fixed regression model showed that Maximum Yield of white yam occurred when nitrogen was used at 75kg and potassium at 60 k.g with an average yield of 390.3118 tone/ per hectare

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