

Factorial Analysis of the Effect of NPK Fertilizer: An Application to the Yield of White Yam

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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 [6]. Thus, this paper attempts to develop a multiple regression model that investigates 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. The paper will also detect which of the three elements of NPK contribute most to the yield of white yam. It thus further 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 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 the different levels of application. Furthermore, the overall multiple regression models for the yield of white yam was obtained as $Y = 319.0834 + 7.0717N - 26.7399P + 32.6546K - 1.9665NP - 2.5493NK - 0.6896PK$. Thus, the nitrate and potash combination produced the best yields on the average of 390.3118 tone/kilogram per hectare when used at N₇₅ kg and K₆₀kg.

Keywords: NPK Fertilizers, A 3x3 Factorial 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 sub-tropical Africa, Central and Southern America, parts of Asia, the Caribbean and [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 [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 leaves have a pale green color, yellowish or reddish spotting or stripping. Yields are reduced, sometimes severely [6].

Fertilizer, natural or synthetic chemical substance or mixture, are 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 [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 N₂₅P₀K₀, N₅₀P₁₀K₆₀, N₇₅P₂₀K₁₂₀.

II. MATERIALS AND METHODS

A. The Research Design; Factorial Experiments

Factorial experiments was defined by [5] 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. [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:

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

$i = 1, 2, \dots, a$; $j = 1, 2, \dots, b$; $k = 1, 2, \dots, c$; $l = 1, 2, \dots, n$
 μ = overall mean α_i = effect of i^{th} level of factor N β_j = j^{th} level of factor P
 τ_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, $e_{ijkl} \sim \text{NID}(0, \sigma^2)$.

B. 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..[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[7]. Hence, LSD, Tukey, Scheffe and Bonferroni test was adopted.

C. 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	F-cal	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	687.1634	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, the interactions of Nitrogen and Phosphorus, Phosphorus and Potassium and Nitrogen and Phosphorus and Potassium have significant effect on the yield and growth of white yam at less than 5% level., while only one; Nitrogen and 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

Using the LSD, Tukey, Scheffe and Bonferroniwe obtained the following result:N₁ and N₂ are more significant than N₃with the values of 0.027, 0.03, 0.015 and 0.045, P₀ is more significant than P₁ and P₂ and K₂ is more significant than K₁ and K₃ 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) 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 N₁ and N₂ are more significant

than N₃with the values of 0.027, 0.03, 0.015 and 0.045, P₀ is more significant than P₁ and P₂ and K₂ is more significant than K₁ and K₃ 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.

REFERENCES

- [1]. Akanji, B.O., Akpokodje, G. and Ogundele, O.O. (2003): Labour use pattern on farms: NISER Annual Survey of Crop Production Condition in Nigeria”, 2000, NISER, Ibadan, Nigeria, 34–46.
- [2]. Anbari, F.T. and Lucas, J.M. (1994): Super-Efficient Designs: How to Run Your Experiment for Higher Efficiency and Lower Cost. *ASQC Technical Conference Transactions*, 852-863.
- [3]. Coursey, D.G. (1967), “Yams: An account of the Nature, Origins, Cultivation and Utilisation of the Useful Members of the *Dioscoreaceae*”, Tropical Agricultural Series. Longmans, Green and Co. Ltd. London, UK,230p.
- [4]. Food and Agricultural Organization (2006): F.AO. Databases2006<http://www.fao.org/ag/AGP/>
- [5]. Montgomery, D.C. (1974): Design and Analysis of Experiments. John Wiley & Sons Incorporation, New York.
- [6]. Popoola, O.P., Adesanya, K.K., Odusina, T.M. and Ayanrinde, A.W. (2015):A Quadratic Regression Analysis of the Effect of Three Levels of NPK Fertilizer on the Yield of Yellow Maize. *American Journal of Computational Mathematics*, 5, 426-430. <http://dx.doi.org/10.4236/ajcm.2015.54037>
- [7]. Wahua, T.A.T. (1999): Applied Statistics for Scientific Studies. Macmillan Publishing, Lagos.