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Economic Analysis and Modelling of Effects of NPK Fertilizer Levels on Yield of Yam

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Abstract

This paper presents statistical analyses of effects and efficacies of NPK fertilizer levels on yield of four different species of yam in three different locations of kwara state Nigeria. Four quantitative and equally spaced levels 0kg/ha, 22.5kg/ha, 45kg/ha and 76kg/ha respectively, of the fertilizer type were considered in the experiment. Factorial design model was used in collecting data sets on yield variables of the plant, using fixed effects, in an experiment conducted by the Kwara Agricultural Development Project (KWADP) Ilorin, in the year 2012. The four varieties of yam examined included white yam, water yam, aerial yam and bitter yam respectively. Observations were taken from Ekan-Meje, Omu-Aran and Omupo locations of the state on a number of response variables namely, number of yam plants, number of yam tubers and weight (kg) of yam tubers. Before conducting ANOVA, the data sets were inspected for homogeneity of error variances using *Fligner-Killeen* test in the R statistical package. The test revealed that homoscedasticity assumption was not violated and *Shapiro-Wilk* test of normality was further used to check normality of the residuals arising from the ANOVA model. The response variables were modelled with orthogonal polynomials so as be able to predict response yield at intermediate factor levels. Fertilizer level of 22.5kg/ha was found to be the most effective and economical for growing yam with the corresponding optimum yield.

Keywords: ANOVA, NPK, Factorial design, KWADP, Fligner-Killeen test, Shapiro-Wilk test and orthogonal polynomial

1. 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). 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 (Okigbo and Ogbonnaya, 2006). 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 tonnes 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).

Yam is very important in food security and poverty reduction in Nigeria, as it is consumed in a variety of ways. The most common in southern and central parts of the country is boiled or pounded yam. It can be cut into chips, dried, and ground into yam flour and prepared as *Amala* which is another delicacy in the Nigerian diet, particularly among the Yoruba of south-western Nigeria. Yam production serves as a source of income generation to peasant farmers and the labourers who work on yam farms as well as for those that engage in its sale, the itinerant traders who assemble the crop from village to village, and the urban center marketers who retail the commodity. Peelings and waste from yam are often used for feeding poultry and livestock (Akangbe et al, 2012).

To increase yam production in Kwara state, it is necessary to determine the most economical and efficient fertilizer level for growing it and the most suitable zone for particular varieties of it. It is also important to be able to build a model that can produce predictions of the yield at intermediate factor levels.

1.1 Objectives of the Study

The main objectives of the study are:

- To determine the most economically effective NPK fertilizer level for yam production in Kwara state.

- To determine the yam variety with optimum yield due to application of NPK fertilizer in the three locations.
- To determine whether there is meaningful relationships (interaction) between NPK levels and varieties of yam in the three locations.
- To find the form of mathematical relationship between NPK levels and the response variables using orthogonal polynomials

1.2 Material and Methods

1.2.1 Experimental Site

The study was conducted on white yam, water yam, aerial yam and bitter yam varieties at Ekan-Meje, Omupo and Omu-Aran in Kwara state by the Kwara state Agricultural Development Project (KWADP), Ilorin, in 2012. The experiment was replicated four times in each location for each response variable. Kwara state is located in the rain forest agro-ecological zone on Latitude $08°30'$N and Longitude $04°33'$ E characterized by a mean annual rainfall of 1,500 mm.

1.2.2 Experimental Design

The analysis of variance (ANOVA) model employed in collecting the data sets was of the factorial design type. Fertilizer levels and varieties constitute the two experimental factors in the model with the locations as blocks.

2. Data Analysis

2.1 Test of Homogeneity of Error Variances for Yam Yield Variables

One of the basic requirements for results of analysis of variance to be valid is homogeneity of error variances in the inherent data. It is therefore necessary to conduct test of homoscedasticity on the data sets before proceeding with the analysis of variance. Data sets on the number of yam plants, number of yam tubers and weight of yam tubers were inspected for homogeneity of error variances using Fligner-killeen test (Conover et al, 1981) in the R (R Core team 2006b) statistical package for data analysis and computing in what follows. It is evident in table 1 that assumption of homogeneity of error variances is not violated by the data sets on the three response variables for fertilizer levels and yam varieties because the p-values in all cases exceed 0.05 significance levels. We will therefore proceed to conduct analysis of variance on the data sets without doing any data transformation

2.2 Analysis of variance (ANOVA) on Number of Yam Plant

In this section, we conduct an analysis of factorial design on number of yam plants with two experimental factors namely NPK fertilizer levels and yam variety blocked into three farm locations of kwara state Nigeria. Since NPK levels are quantitative and equally spaced, parameters of orthogonal polynomial (Novomestky F., 2012) models are estimated to test significance of linear, quadratic and cubic equations for modelling the response variable with the NPK fertilizer levels. Table 2 presents summary of results for the analysis of variance (ANOVA) and of orthogonal polynomial coefficients (in parenthesis) as obtained from R statistical package. It is evident from the results that interaction exists between NPK fertilizer levels and number of yam plants from all the varieties. Effects of NPK levels on number of yam plant are not the same since the corresponding p-value is less than 0.05 in the table. The implication of this is that application of NPK on yam is necessary. Average number of yam plants for all the four varieties is the same because it gave a p-value greater than 0.05 which implies that null hypothesis of no difference in number of plants produced by the four varieties is not rejected. The implication of this is that all of the three locations of Kwara state can be used for yam cultivation. A cubic equation will be adequate to model number of yam plants with the four NPK levels since it is significant in the table. However, existence of interaction between the two factors implies that inspection of yam varieties for specific NPK levels is important.

To determine which NPK levels are significantly different in terms of their effects on number of yam plants in the three locations, we conduct Tukey's Honestly Significant Difference Test (TukeyHSD) (Abdi and Williams, 2010) for the four fertilizer levels. Results of the multiple comparisons are presented in table 3. The test revealed that only pairs of fertilizer levels (22.5kg/ha-0kg/ha) and (45kg/ha-0kg/ha) do not produce significantly different effects. This result is further demonstrated by the box plot in figure 1. Estimates of effects of NPK fertilizer levels per hectare and average number of yam plant per fertilizer level are presented in table 4. It is evident from the results that NPK fertilizer levels 22.5kg/ha is the most effective and economical for increasing number of yam plants in the three locations. White yam produced the optimum number of yam plants due to effects of NPK levels.

2.2.1 Test for Normality Assumption on Analysis of Variance Results for Number of Yam Plants

To further confirm reliability of the results from the analysis of variance presented in table 1, we obtained residuals for the fitted ANOVA model and Shipiro-Wilk (Shapir and Wilks, 1965) test of normality was used to test their normality. The test revealed that the data are normality distributed by failing to reject the null hypothesis of normally distributed residuals since the p-value = 0.835 was bigger than significance level 0.05. This result is presented in table 5 as corroborated by the normal quantile-quantile plot of the residuals in figure 5 below. Plots supporting results from table 2 are also presented in figures 1, 2, 3 and 4 respectively on page 5.

2.3 Analysis of variance (ANOVA) on Number of Yam Tubers

In this section, we present an analysis of variance on number of yam tubers using the procedure adopted in the previous section. Table 6 presents summary of results for the analysis of variance (ANOVA) and orthogonal polynomial coefficients (in parenthesis). It is evident from the results that interaction does not exist between NPK fertilizer levels and number of yam tubers from all the varieties. This result is consequent upon the fact that effects of NPK levels on number of yam plant and average number of yam tubers are not the same since their corresponding p-values are less than 0.05 in the table. This implies that null hypothesis of no difference in average number of yam tubers produced by the four varieties is not rejected and effects of the four NPK levels on number of yam tubers are not the same. However, equations with linear and quadratic effects will be adequate to model number of yam tubers with the quantitative NPK levels. It is therefore important to determine which NPK level for which yam variety produce optimum number of yam tubers.

We will therefore conduct TukeyHSD for the four fertilizer levels and the four yam varieties to know which pair actually produced significantly different number of yam tubers. Results of the test are presented in tables 7 and 8 respectively. The test revealed that only pairs of fertilizer levels (67kg/ha vs. 0kg/ha) and (67kg/ha vs. 22.5kg/ha) gave significantly different effects on number of yam tubers across the varieties. It is also evident in table 8 that only pairs of varieties (Bitter Yam vs. Aerial Yam), (Water Yam vs. Bitter Yam) and (White Yam vs. Bitter Yam) respectively actually produced significantly different number of yam tubers due to NPK levels. This result is further demonstrated by the box plot in figure 6 and 7 below. Estimates of effects of NPK fertilizer levels per hectare and average number of yam tubers per fertilizer level and per variety are presented in table 9. It is evident from the results that NPK fertilizer level 22.5kg/ha is also the most economical and efficient for increasing number of yam tubers across the varieties. Effect of NPK levels is most significant on number of yam tubers produced by bitter yam as it gave the optimum yield among the varieties.

2.3.1 Test for Normality Assumption on Analysis of Variance Results for Yam Tubers

To further confirm reliability of the results from the analysis of variance presented in table 6, Shipiro-Wilk test of normality was conducted on residuals of the fitted ANOVA model. The test revealed that the data set has a normal distribution since p-value = 0.3369 was bigger than significance level 0.05. This result is presented in table 10 as corroborated by the Normal quantile-quantile plot of the residuals in figure 10. Graphical representations supporting these results are also presented in figures 6, 7, 8, 9 and 10 respectively.

2.4 Analysis of variance (ANOVA) on Weight (kg) of Yam Tubers

Here, we also present an analysis of variance on weight of yam tubers using the procedure adopted in the previous sections. Table 11 presents summary of results for the ANOVA and orthogonal polynomial coefficients (in parenthesis). It is evident from the results that interaction does not exist between NPK fertilizer levels and weight (kg) of yam tubers from all the varieties. This result is consequent upon the fact that effects of NPK levels on weight (kg) of yam tubers and weight (kg) of yam tubers are not the same since their corresponding p-values are less than 0.05 in the table. This implies that null hypothesis of no difference in weight (kg) of yam tubers produced by the four varieties is rejected and effects of the four NPK levels on weight (kg) of yam tubers are not the same. The implication of this is that NPK levels have influence on weight of yam tubers across the varieties. However, only equation with quadratic effect will be adequate to model weight (kg) of yam tubers with

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the quantitative NPK levels. It is therefore important to determine which variety responded most positively to NPK and by what amount.

Results of TukeyHSD test conducted for the four fertilizer levels and the four yam varieties to know which pair actually produced significantly different tuber weights are presented in tables 12 and 13 respectively. The test revealed that only pairs of fertilizer levels (45kg/ha vs. 0kg/ha) and (67kg/ha vs. 45kg/ha) are significantly different. It is also evident in table 13 that only pairs of varieties (Bitter Yam vs. Aerial Yam) and (White Yam vs. Water Yam) do not produce significantly different tuber weights (kg). These results are further demonstrated by the box plots in figures 11 and 12. Estimates of effects of NPK fertilizer levels per hectare and average tuber weight per fertilizer level and per variety are presented in table 14. It is evident from the results that NPK fertilizer level 45kg/ha is the most effective in increasing yam tuber weight. The results also reveal that water yam gave optimum tuber weight (kg) due to NPK levels in the three locations.

2.4.1 Test for Normality Assumption on Analysis of Variance Results for Weight of Yam Tubers

To further confirm reliability of the results from the analysis of variance presented in table 11, Shipiro-Wilk test of normality was conducted on the residuals resulting from the fitted ANOVA model. The test revealed that the data set on tuber weight (kg) has a normal distribution. This result is presented in table 15 as corroborated by the Normal quantile-quantile plots of the residuals in figure 15. Graphical representations supporting these results are presented in figures 11, 12, 13 and 14 respectively.

Conclusion

From the foregoing, it has been observed that use of NPK fertilizer enhances yam yield and the varieties of yam considered responded differently to quantity of the fertilizer type applied. However, 22.5kg/ha is the most efficient and economical NPK level for increasing number of yam plant and number of yam tubers. It gave optimum number of yam plant in white yam and optimum number of yam tubers in bitter yam respectively. Although, NPK levels 45kg/ha gave optimum average tuber weight (kg) of 146.33, 22.5 kg/ha which gave average tuber weight (kg) of 129 is not worse off. The latter is therefore, still preferable due to interest in fertilizer economy. Based on this fact, we recommend that NPK fertilizer level 22.5kg/ha for enhancing and increasing yam yield in Kwara state Nigeria. We also suggest use of cubic polynomial model for modelling yam yield variable with quantitative and equally-spaced NPK levels since coefficient of both linear and quadratic effects are estimable in it.

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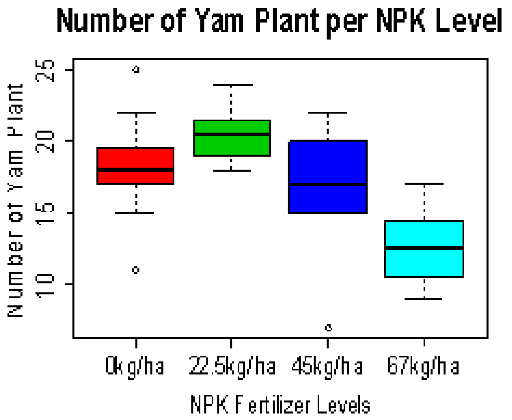

Figure 1: Box plot for effects of NPK levels on number of yam plants

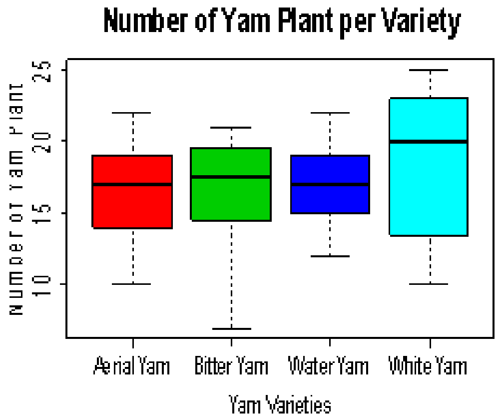

Figure 2: Box plot for average number of yam plants across yam varieties

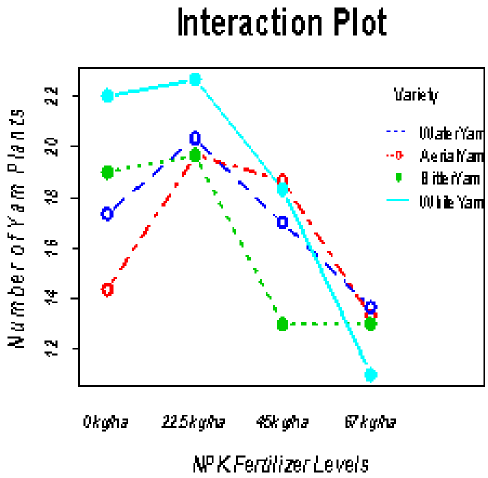

Figure 3: Interaction effect of NPK fertilizer levels and varieties on number of yam plants

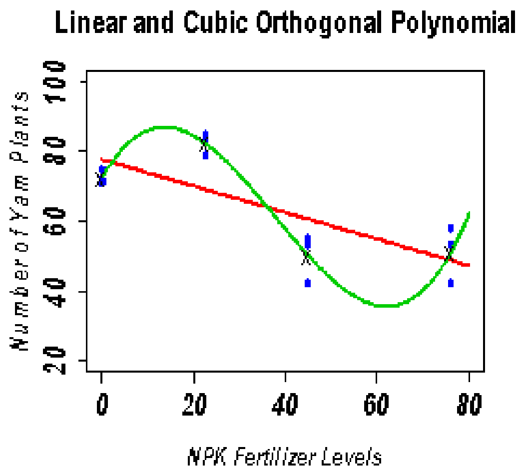

Figure 4: Plot of linear and cubic orthogonal polynomials for equally spaced NPK levels

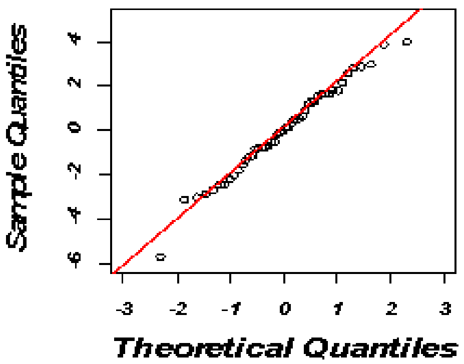

Figure 5: Normal q-q plot for Number of yam plants

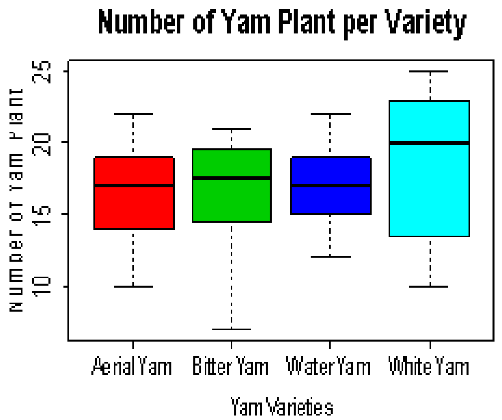

Figure 6: Box plot for effects of NPK levels on number of yam tubers

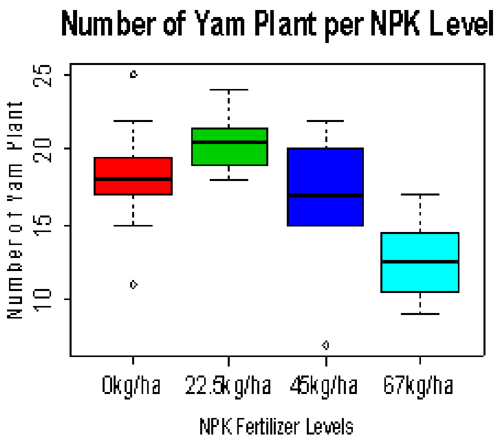

Figure 7: Box plot for average number of yam tubers across yam varieties

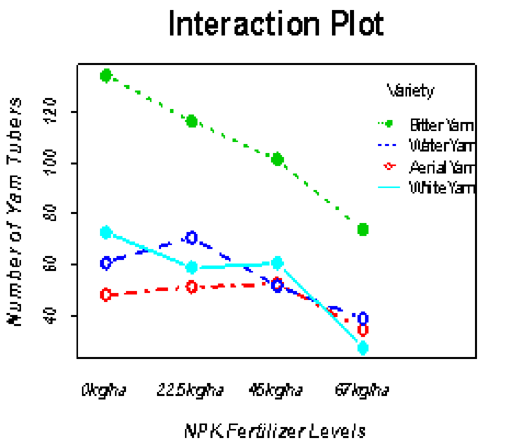

Figure 8: Interaction plots for NPK fertilizer levels and varieties on number of yam plants

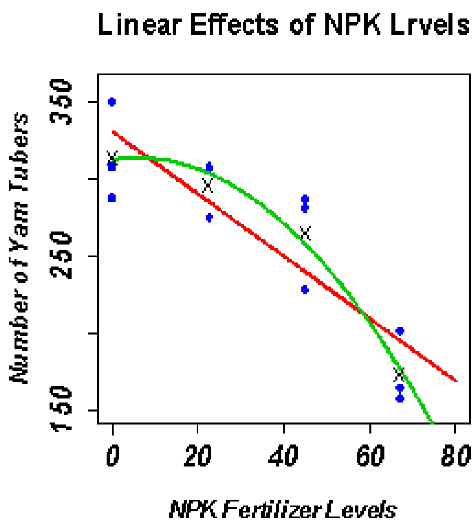

Figure 9: Plot of linear and quadratic effects of equally spaced NPK fertilizer levels

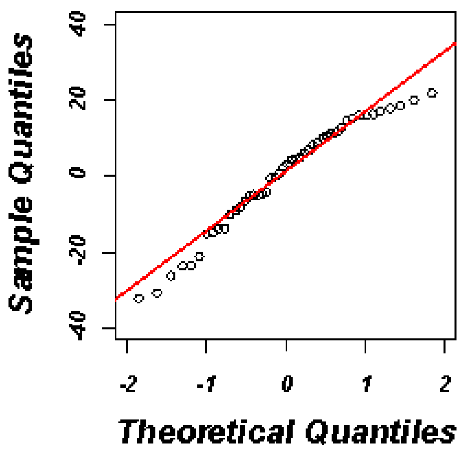

Figure 10: Normal q-q plot for Number of yam tubers

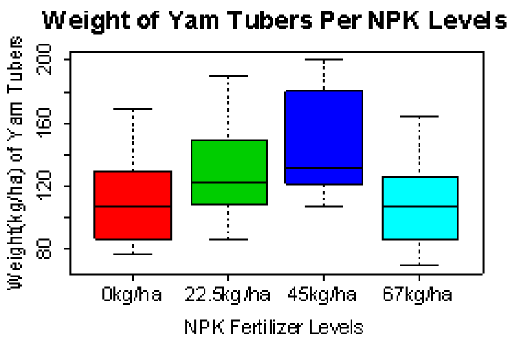

Figure 11: Box plot for effects of NPK levels on weight (kg/ha) of yam tubers

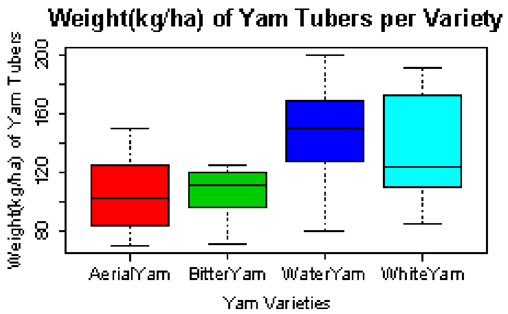

Figure 12: Box plot for average weight (kg/ha) of yam tubers across yam varieties

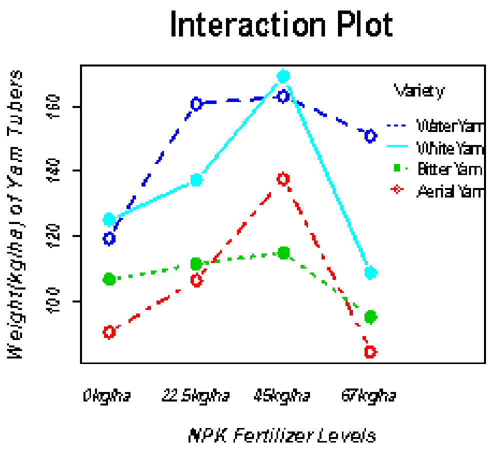

Figure13: Interaction Effects of NPK fertilizer levels and varieties on number of yam plants

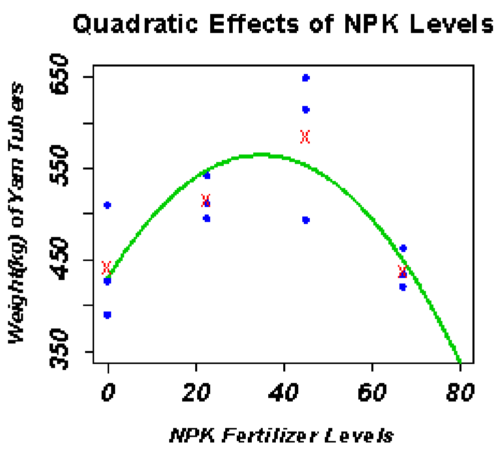

Figure14: Plot of Quadratic effects of equally spaced NPK fertilizer levels

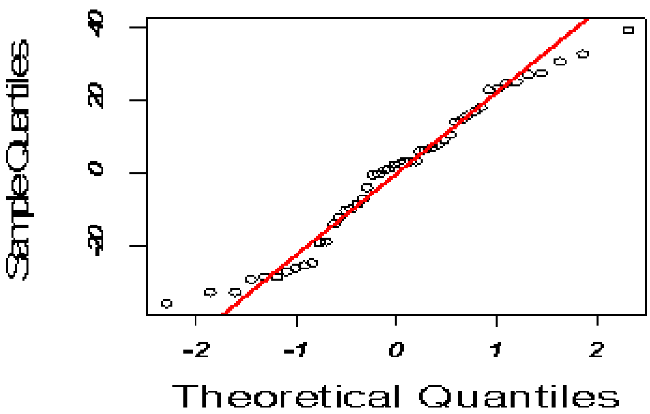

Figure 15: Normal q-q plot for tuber weight

Table 1: Homogeneity of error variances for yam yield variables

	Number of Yam Plants			
Data set	DF	K-Squared	P-value	Decision
Fertilizer Levels	3	1.1285	0.7702*	Assumption holds
Variety	3	2.053	0.5616*	Assumption holds
Data set	Number of Yam Tubers			
Source of variation	DF	K-Squared	P-value	Decision
Fertilizer Levels	3	3.3035	0.3471*	Assumption holds
Variety	3	5.9939	0.1119*	Assumption holds
Data set	Weight (kg) of Yam Tubers			
Source of variation	DF	K-Squared	P-value	Decision
Fertilizer Levels	3	0.2874	0.9624*	Assumption holds
Variety	3	5.5499	0.1357*	Assumption holds

Table 2: Analysis of Variance Results for Number of Yam Plants with Orthogonal Polynomial Coefficients

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	F-Ratio	P-Value
Locations	2	36.38	18.188	2.8375	0.07436
NPK levels	2	387.73	129.243	20.1636	**2.388e-07***
Linear	(1)	(1380)	(1380)	(42.5708)	**(0.0002)***
Quadratic	(1)	(2.76)	(2.76)	(0.0852)	**(0.7777)**
Cubic	(1)	(945.90)	(945.90)	(29.1794)	**(0.0006)***
Variety	3	38.23	12.743	1.9881	**0.1370**
NPK levels X Variety	9	146.19	16.243	2.5341	**0.0270***
Residuals	30	192.29	6.410		

Table 3: Multiple Comparisons for NPK Fertilizer Levels

Pairs of NPK Levels	Difference	Lower Bound	Upper Bound	Adjusted P-Value	Decisions
22.5kg/ha vs. 0kg/ha	2.4167	-0.3937	5.2271	0.1119	Pairs are the same
45kg/ha vs. 0kg/ha	-1.4167	-4.2271	1.3938	0.5269	Pairs are the same
67kg/ha vs. 0kg/ha	-5.4167	-8.2271	-2.6063	**0.0001***	Pairs are not the same
45kg/ha vs. 22.5kg/ha	-3.8333	-6.6437	-1.0229	**0.0044***	Pairs are not the same
67kg/ha vs. 22.5kg/ha	-7.8333	-10.6437	-5.0229	**0.0000***	Pairs are not the same
67kg/ha vs. 45kg/ha	-4.0000	-6.8104	-1.1896	**0.0029***	Pairs are not the same

Table 4: Estimates of Effects of NPK Fertilizer on Number of Yam Plants

	NPK Fertilizer Levels			
Estimates	0kg/ha	22.5kg/ha	45kg/ha	76kg/ha
Effects	1.104	**3.521***	-0.312	-4.312
Average Yield	18.167	**20.583***	16.750	12.750
	Yam Varieties			
Estimates	Aerial Yam	Bitter Yam	Water Yam	White Yam
Effects	-0.5625	-0.8958	0.0208	**1.4375**
Average Yield	16.500	16.167	17.083	**18.500**

Table 5: Shapiro-Wilk Test of Normality for Number of Yam Plant

	Shapiro.test (residuals(plant.fit))		
Data	W-value	P-value	Decision
Number of Yam plant	0.9861	0.835	Data set is normally distribution

Table 6: Analysis of Variance Results for Number of Yam Tubers with Orthogonal Polynomial Coefficients

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	F-Ratio	P-Value
Locations	2	267.9	133.9	0.3159	0.7315
NPK levels	2	8832.1	2944.0	6.9434	**0.0011***
Linear	(1)	(30927.7)	(30927.7)	(41.8367)	(**0.0002**)*
Quadratic	(1)	(4016.6)	(4016.6)	(5.4333)	(**0.0481**)*
Cubic	(1)	(383.9)	(383.9)	(0.5194)	(0.4916)
Variety	3	26922.2	8974.1	21.1651	**1.474e-7***
NPK levels X Variety	9	2656.0	295.1	0.6960	0.7071
Residuals	30	12720.1	424.0		

Table 7: Multiple Comparisons for NPK Fertilizer Levels

Pairs of NPK Levels	Difference	Lower Bound	Upper Bound	Adjusted P-Value	Decisions
22.5kg/ha vs. 0kg/ha	-4.7500	-27.6079	18.1079	0.9416	Pairs are the same
45kg/ha vs. 0kg/ha	-12.5000	-35.3579	10.3579	0.4576	Pairs are the same
67kg/ha vs. 0kg/ha	-35.3333	-58.1912	-12.4754	**0.0012***	Pairs are not the same
45kg/ha vs. 22.5kg/ha	-7.7500	-30.6079	15.1079	0.7934	Pairs are the same
67kg/ha vs. 22.5kg/ha	-30.5833	-53.4412	-7.7254	**0.0053***	Pairs are not the same
67kg/ha vs. 45kg/ha	-22.8333	-45.6912	0.0246	0.05033	Pairs are the same

Table 8: Multiple Comparisons for Yam Varieties

Pairs of Yam Varieties	Difference	Lower Band	Upper Band	Adjusted P-Value	Decisions
Bitter Yam vs. Aerial Yam	59.8333	36.9754	82.6912	**0.0000***	Pairs are not the same
Water Yam vs. Aerial Yam	8.9167	-13.9412	31.7746	0.7155	Pairs are the same
White Yam vs. Aerial Yam	8.3333	-14.5246	31.1912	0.7554	Pairs are the same
Water Yam vs. Bitter Yam	-50.9167	-73.7746	-28.0588	**0.0000***	Pairs are not the same
White Yam vs. Bitter Yam	-51.5000	-74.3579	-28.6421	**0.0000***	Pairs are not the same
White Yam vs. Water Yam	-0.5833	-23.4412	22.2746	0.9999	Pairs are the same

Table 9: Estimates of Effects of NPK Fertilizer and Varieties on Number of Yam Tubers

	NPK Fertilizer Levels			
Estimates	0kg/ha	22.5kg/ha	45kg/ha	76kg/ha
Effects	8.396	**13.146***	0.646	-22.188
Average Yield	74.08	**78***	66.33	43.50
	Yam Varieties			
Estimates	Aerial Yam	Bitter Yam	Water Yam	White Yam
Effects	-19.27	**40.56***	-10.35	-10.94
Average Yield	46.42	**106.25***	55.33	54.75

Table 10: Shapiro-Wilk Test of Normality of Number of Yam Tubers

	Shapiro.test (residuals(yamtuber.fit))		
Data	W-value	P-value	Decision
Number of Yam plant	0.9732	0.3369	Data set is normally distributed

Table 11: Analysis of Variance Table for Weight (kg) of Yam Tubers with Orthogonal Polynomial Coefficients

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	F-Ratio	P-Value
Locations	2	2715.3	1357.6	2.1255	0.1370
NPK levels	2	10962.4	3654.1	5.7209	**0.0032***
Linear	(1)	(47)	(47)	(0.0117)	(0.9010)
Quadratic	(1)	(39871)	(39871)	(14.0743)	(**0.0056**)*
Cubic	(1)	(3932)	(3932)	(1.3879)	(0.2726)
Variety	3	16727.7	5575.9	8.7296	**0.0003***
NPK levels X Variety	9	4482.5	498.1	0.7798	0.6362
Residuals	30	19162.0	638.7		

Table 12: Multiple Comparisons for NPK Fertilizer Levels

Pairs of NPK Levels	Difference	Lower Bound	Upper Bound	Adjusted P-Value	Decisions
22.5kg/ha vs. 0kg/ha	18.6667	-9.3884	46.7217	0.2890	Pairs are the same
45kg/ha vs. 0kg/ha	36.0000	7.9449	64.0551	**0.0078***	Pairs are not the same
67kg/ha vs. 0kg/ha	-0.5833	-28.6384	27.4717	0.9999	Pairs are the same
45kg/ha vs. 22.5kg/ha	17.3333	-10.7217	45.3884	0.3516	Pairs are the same
67kg/ha vs. 22.5kg/ha	-19.2500	-47.3051	8.8051	0.2639	Pairs are the same
67kg/ha vs. 45kg/ha	-36.5833	-64.6384	-8.5282	**0.0068***	Pairs are not the same

Table 13: Multiple Comparisons for Yam Varieties

Pairs of NPK Levels	Difference	Lower Bound	Upper Bound	Adjusted P-Value	Decisions
BitterYam-AerialYam	2.3333	-25.7217	30.3884	0.9958	Pairs are the same
WaterYam-AerialYam	44.0000	15.9449	72.0551	**0.0010***	Pairs are not the same
WhiteYam-AerialYam	30.4167	2.3616	58.4717	**0.0296***	Pairs are not the same
WaterYam-BitterYam	41.6667	13.6116	69.7217	**0.0018***	Pairs are not the same
WhiteYam-BitterYam	28.0833	0.0283	56.1384	**0.0497***	Pairs are not the same
WhiteYam-WaterYam	-13.5833	-41.6384	14.4717	0.5599	Pairs are the same

Table 14: Estimates of Effects of NPK Fertilizer and Varieties on Weight (kg) of Yam Tubers

	NPK Fertilizer Levels			
Estimates	0kg/ha	22.5kg/ha	45kg/ha	76kg/ha
Effects	-13.521	5.146	**22.479***	-14.104
Average Yield	110.33	129.00	**146.33***	109.75
	Yam Varieties			
Estimates	Aerial Yam	Bitter Yam	Water Yam	White Yam
Effects	-19.188	-16.854	**24.813***	11.229
Average Yield	104.67	107.00	**148.67***	135.08

Table 15: Shapiro-Wilk Test of Normality of Number of Yam Plant

	Shapiro.test (residuals (yamtuber.fit))		
Data	W-value	P-value	Decision
Number of Yam plant	0.9643	0.1512	Data set is normally distribution