Mathematical Theory and Modeling
ISSN 2224-5804 (Paper) ISSN 2225-0522 (Online)
Vol.3, No.1, 2013

Economic Selection of Efficient Level of NPK 16:16:16 Fertilizer for Improved Yield Performance of a Maize Variety in the South Guinea Savannah Zone of Nigeria

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Abstract

This study investigates effects of different levels of NPK 16:16:16 fertilizer on yield and performance of maize. Data sets were obtained from a study conducted at the University of Ilorin Teaching and Research Farm, faculty of Agriculture, University of Ilorin during the 2010 cropping season. The study was conducted on a maize variety (Swan-1-SR-Y) sourced from Federal Ministry of Agriculture and Water Resources, Abuja, Nigeria using a completely Randomized Design (RCBD) replicated three times. Application of the fertilizer type was done at two equal splits of 2 weeks after planting and immediately after tasseling using ring method of application. The appropriate analysis of variance (ANOVA) model was used to collect observations at 2 weeks interval from week 5 to week 15 after planting on growth variables such as plant height (kg), leaf area (cm^2), number of leaves, cob weight (kg) and grain weight (kg) respectively at equally spaced levels 0kg/ha, 30kg/ha, 60kg/ha, 90kg/ha and 120kg/ha of the fertilizer type. Before conducting ANOVA, the data sets were inspected for homogeneity of error variances using Fligner-Killeen test in the R statistical package. Shapiro-Wilk test of normality was used to check normality of the residuals. The normal probability plot showed no indication of outliers and the largest standardized residual was within± 2. NPK 16:16:16 fertilizer level 60 Kg/ha was found to be the most efficient and economical for improving growth and yield performance of the maize variety in the ecological zone. The optimum yield of the maize variety due to application of the NPK 16:16:16 fertilizer levels is in the 13th week after planting.

Keywords: Maize, NPK 16:16:16, Fligner-Killen test, Shapiro-Wilk test, ANOVA, R and RCBD.

1. Introduction

Maize ranks second to wheat in the world cereal production. It is the second most important cereal crop in the sub-Saharan Africa. In Nigeria, research has shown that over one million tonnes of maize are produced yearly. However, this seemingly high production level still falls short of the domestic demand. Knowledge of fertilizer application to maize plant is an important factor that promotes the yield of the crop in improving its production. Fertilizer has been defined as many organic and inorganic materials added to a soil to supply certain elements essential to the growth of plants (Bradly and Weil, 1999). It has been suggested that agricultural intensification may lead to declining soil fertility which may destroy the ecological basis of African agriculture (FAO, 1988; Van Keulen and Brennan, 1990)

Nitrogen is a vital plant nutrient and major yield determining factors required for maize production (Adediran and Banjoko, 1995). Insufficient Nitrogen can slow down plant growth or cause deficiency symptoms such as leaf chlorosis (yellowing), leaf depth and stunting. Nitrogen is a vital nutrient and major yield determining factors required for maize production (Adediran and Banjoko, 1995). Phosphorus is one of the nutrients essential for plant growth and its function cannot be performed by any other nutrient. It is vital to plant growth and it is found in every living plant cell. It is involved in several key plant functions, nutrient movement within the plant and transfer of genetic characteristics from one generation to the next (Mengel and Kirkby, 1982).

In the previous literatures, it has been suggested that increase in number of grain per cob, cob weight, cob yield and grain weight may be attributed to NPK being part of essential nutrient required for the promotion of the meristematic and morphological activities such as plant leaf and root development. The yield of maize varies from location to location and also depends on availability of essential factors such as soil nutrient status and application of fertilizer.

2. Materials and Methodology

2.1Site Description

The experiment was conducted during 2010 cropping season on the field at the University of Ilorin Teaching and Research Farm, a location in the Southern Guinea ecology zone of Nigeria. The topography of the area had a gentle slope which has little or no effect on erosion of the area. Planting was done on 2nd August, 2010. The maize variety was treated with apron plus for prevention against soil borne diseases such as Downey Mildew, rodent and birds. Three seeds of maize were planted at 0.75m by 0.5m spacing per hole and the resulting seedlings were later thinned to two per stand at 2 weeks after planting (2 WAP).

2.2 Soil Analysis

Samples of the soil of the experimental site were taken at random, stored in a polythene bag and taken to the laboratory to determine the physical and chemical characteristics.

Objectives of the Study

This study seeks to do the following

- To investigate whether NPK 16:16:16 application has meaningful impact on growth yield of maize
- To determine (if possible) the particular levels of NPK 16:16:16 which provide optimum maize yield.
- To determine the minimum duration required for the maize specie to grow due to application of NPK 16:16:16 levels

3. Data Analysis

3.1 Test of Homogeneity of Error Variances for Maize Yield Variables

One of the basic assumptions for validity of results of analysis of variance is equality of sample error variances. The decomposition of the variability in the observations through an analysis of variance is just an algebraic relationship. To use the method to test formally for no differences in means of the various treatments therefore requires that certain assumptions be satisfied. Specifically, these assumptions are that the residuals are normally and independently distributed with mean zero and constant but unknown variance (Montgomery, 2001). We therefore test the hypothesis that all samples came from populations with identical variances (Zar, 1999). Data sets on plant height (kg), leaf area (cm^2), cob weight (kg) and grain weight (kg) were inspected for homogeneity of error variances using Fligner-killeen test (Conover et al, 1981) in the R (R Core team 2011) statistical package for data analysis and computing. Results of the test presented in table 1 reveal that homoscedasticity assumption is not violated on the sample data sets since we failed to reject the null hypothesis of equal variances due to the corresponding p-values. By implication, it means that we may proceed to conduct analysis of variance on the data sets without conducting any data transformation.

3.2 Checking Model Adequacy

3.2.1 Normality Assumption

For our ANOVA model to be sufficient for the sample data, assumption of normally distributed residuals must be satisfied (Montgomery, 2001). We will obtain residuals of ANOVA models and test hypothesis that the residuals follow a normal distribution for sample data sets resulting from the growth variables of maize using Shapiro-Wilk test of normality (Shapiro and Wilks, 1965). Normal quantile quantile plots of the residuals and Plots of residuals against fitted values of the models are obtained in each case to further check normality of the residuals and homoscedasticity. If the residual plot appears structureless by having about the same extension of scatter of the residuals around zero for each factor level or treatment (Kutner, 2005), it is an indication of homogeneous variances. If the dots in the quantile quantile plots, particularly those in the middle, are close to the line, it is reasonable to infer that the data follow a normal distribution.

We will also check possible effects of outliers in sample data by using the standardized residual criterion suggested by (Barnett and Lewis, 1994, John and Prescott, 1975, and Stefansky, 1972). We will obtain minimum and maximum residuals of the models and standardize them by dividing each by the root mean square error of the corresponding model. It is expected that the minimum standardized residual should fall within ± 1 and the largest standardized residual should fall within ± 2 , otherwise we have a potential outlier.

4. Analysis of Variance on Leave Area (cm^2) of Maize

Here, we present ANOVA results on effects of quantitative levels of NPK 16:16:16 fertilizer on leave area of the maize specie under investigation, blocked by period (weeks) of maturity. The ANOVA table presented in table 2 reveals that effect of the various fertilizer levels on leave area of maize is not the same and that maize leave area varies over the maturity period. The implication of this is that application of the fertilizer type has positive impact on leave area of the maize specie. It is also important to determine the most efficient and economical NPK 16:16:16 level for increasing leave area of the maize specie and the maximum duration expected for it to grow to maturity due to application of the fertilizer type.

We will proceed to conduct multiple comparison test on NPK levels and leave areas over the period of cultivation using Tukey's Honestly Significant Difference (TukeyHSD) test (Tukey, J.W. 1949b). Result of the test presented in tables 3 reveals that only pairs of NPK levels (120Kg/ha vs. 0Kg/ha), (30Kg/ha vs. 0Kg/ha), (60Kg/ha vs. 0Kg/ha) and (90Kg/ha vs. 0Kg/ha) produce significantly different effects on leave area of maize. Table 4 also reveals that only maize leave areas in (13WAP vs. 11WAP), (7WAP vs.11WAP), (9WAP vs. 11WAP) and (9WAP vs. 7WAP) are not significantly different. The results are further represented by the box plots in figures 1 and 2.

Because it is of interest to determine the most efficient and economical NPK level for increasing leave area of maize, we estimated effects of the fertilizer levels on leave area and the average leave area due to each of them. We also estimated the number of weeks in which effects of the levels was optimum and the corresponding Maize leave area in that week. These results are presented in tables 5. It can be inferred from the results that 60Kg/ha of NPK 16:16:16 is the most efficient and economical for improving leave area of maize because its influence is more noticeable on leave area of the plant. It is also evident from table 5 that the week in which influence of this fertilizer level is optimum on leave area of the maize specie is 13WAP because the optimum yield was recorded therein. The results are strongly supported by figures 1 and 2.

4.1 Checking Normality Assumption of Data set on Maize Leave Area (cm^2)

In this section, we test null hypothesis of normally distributed residuals arising from ANOVA model on maize leave area using Shapiro-Wilk test of normality. The test reveals that the sample data on maize leave area come from normal distribution by failing to reject the null hypothesis of normally distributed residuals as displayed in table 6. Standardized residuals for the outliers observed in the data set are also presented in table 6. The results do not portray any serious effect on result of the ANOVA as they fall within± 1 and ± 2. Figures 3 and 4 present residual plot and the qq-norm plot respectively. Since the residual plot is patternless and the dots in the middle of the qq-norm plot are close to the line, it is reasonable to infer that the sample data set on maize leave area has a normal distribution.

5. Analysis of Variance on Heigth (cm) of Maize Plant

In this section, we present ANOVA results on effects of levels of NPK 16:16:16 fertilizer on height (cm) of the maize specie under investigation over period (weeks) of maturity. The ANOVA table presented in table 7 reveals that effect of the various fertilizer levels on heigth of maize is not the same and that height of maize varies over the maturity period. The implication of this is that application of the fertilizer type has positive influence on performance of the maize variety. It is also important to determine the most efficient and economical NPK 16:16:16 level for increasing height of the maize specie and the maximum duration expected for it to grow to maturity due to application of the fertilizer type under study.

Because the ANOVA test was significant, we will proceed to conduct multiple comparison test on NPK levels and height of maize over the period of cultivation using the same test applied in the previous section. Result of the test presented in table 8 reveals that only (120Kg/ha vs. 0Kg/ha), (30Kg/ha vs. 0Kg/ha), (60Kg/ha vs. 0Kg/ha) and (90Kg/ha vs. 0Kg/ha) produce significantly different effects on heigth of maize. Table 9 also reveals that only maize heigths in pairs of weeks (7WAP vs. 5WAP) and (9WAP vs. 7WAP) are not significantly different. The results are further represented by the box plots in figures 5 and 6 respectively.

Because it is of interest to determine the most efficient and economical NPK level for increasing heigth of maize, we estimated effects of the fertilizer levels on heigth and the average heigth due to each of them. We also estimated the number of weeks in which effects of the levels was optimum and the corresponding average maize heigth in that week. These results are presented in table 10. It can be inferred from the results that 120Kg/ha of NPK 16:16:16 gave the highest average height (cm) of 97.65 cm per hectare of maize but this is not economical because it is not far different from average height of 94.52 cm/ha produced by NPK level 60Kg/ha. We can therefore recommend that the most economical NPK 16:16:16 for improving heigth of maize is 60Kg/ha because it competes favourably with 120Kg/ha in terms of its influence on average yield of maize plant. It is also evident from table 10 that the week in which influence of this fertilizer level is optimum on heigth of maize is 15WAP because the optimum yield was recorded therein. The results are strongly supported by figures 5 and 6.

5.1 Checking Normality Assumption of Data set on Heigth (cm) of Maize

In this section, we also test null hypothesis of normally distributed residuals arising from ANOVA model on height of maize using Shapiro-Wilk test of normality. The test reveals that the sample data on maize heigth come from normal distribution by failing to reject the null hypothesis of normally distributed residuals as displayed in table 11. Standardized residuals for the outliers observed in the data set are also presented in table 11. The results do not portray any serious effect on result of the ANOVA as they fall within± 1 and ± 2. Figures 7 and 8 present residual plot and the qq-norm plot respectively. Since the residual plot is patternless and the dots in the middle of the qq-norm plot are close to the line, it is reasonable to infer that the sample data set on height of maize has a normal distribution.

6. Analysis of Variance on Cob and Grain Weight (Kg) of Maize Plant

As done in the previous sections, we will present ANOVA results on effects of levels of NPK 16:16:16 fertilizer on cob and grain weight of the maize specie under investigation over period (weeks) of maturity. The ANOVA table presented in table 12 reveals that effect of the various fertilizer levels on cob and grain weight of maize is not the same and that cob and grain weight of maize varies over the maturity period. The implication of this is that application of the fertilizer type has positive influence on performance of the maize variety. It is also important to determine the most efficient and economical NPK 16:16:16 level for increasing cob and grain weight of maize specie and the maximum duration expected for it to grow to maturity due to application of the fertilizer type under study.

Because the ANOVA test was significant, we will proceed to conduct multiple comparison test on NPK levels and weight of maize over the period of cultivation using the same test applied in the previous section. Results of the test presented in table 12 below reveals that only (60Kg/ha Vs.120Kg/ha), (90Kg/ha Vs.120Kg/ha) and (90Kg/ha Vs.30Kg/ha) produce the same effect on weight of maize. The results are further represented by the box plots in figures 9 and 10.

To determine the most efficient and economical NPK level for increasing cob weight and grain weight of maize, we estimated effects of the fertilizer levels on them. These results are presented in table 14. It can be inferred that the most efficient and economical NPK 16:16:16 for improving cob weight and grain weight of maize is 60Kg/ha because it gave the optimum average cob and grain weight of 1896.5 Kg/ha and its influence on maize performance is the most noticeable. It is also evident from table 14 that cob weight is the most influenced by NPK 16:16:16 levels. The results are strongly supported by figures 9 and 10.

6.1 Checking Normality Assumption of Data set on Cob and Grain Weight (Kg/ha) of Maize

We also test null hypothesis of normally distributed residuals arising from ANOVA model on cob and grain weight of maize using Shapiro-Wilk test of normality. The test reveals that the sample data on cob and grain weight of maize come from normal distribution by failing to reject the null hypothesis of normally distributed residuals as displayed in table 15. Standardized residuals for the outliers observed in the data set are also presented in table 15. The results do not portray any serious effect on result of the ANOVA as they fall within ± 1 and ± 2. Figures 11 and 12 present residual plot and the qq-norm plot respectively. Since the residual plot is patternless and the dots in the middle of the qq-norm plot are close to the line, it is reasonable to infer that the sample data set on maize cob and grain weight (kg/ha) has a normal distribution.

7. Analysis of Number of Leaves of Maize

As a non-parametric alternative to the randomized complete block design (RCBD), we will conduct a non-parametric randomized block analysis of variance called Friedman's test **(**Friedman and Milton, 1937**)** on sample data from number of leaves of maize. This is because the sample data represent count rather than quantitative measure. The test is free from restrictions of normality and equality of variance (of residuals), the price of which is loss of power as compared to parametric equivalents of it. One major challenge is that in case our test is significant, post hoc test may be a bit tasky to conduct but we will circumvent the problem by utilising an R code for post hoc analysis written by Tal Galili in 2012.

Table 16 reveals that the hypothesis of equally effective NPK 16:16:16 levels on maize number of leaves is not rejected by the test since the corresponding p-value 0.0597 exceeds the significance level 0.05. The implication of this is that all the fertilizer levels have the same influence on maize leave production. Post-hoc test is therefore not necessary since the hypothesis test was not significant. This result is presented graphically in figure 13.

8. Conclusion

It is crystal clear from this work that NPK 16:16:16 fertilizer levels have positive influence on growth performance of the maize specie under study in the South Guinea Savannah Zone of Nigeria. Effects of the fertilizer levels are not the same on leave area (cm^2), height (cm), cob and grain weight (kg/ha) of maize plant. The most economical and efficient NPK 16:16:16 level for growing maize in the ecological zone is 60Kg/ha. The optimum maize yield due application of the fertilizer level is in the 13th week after planting.

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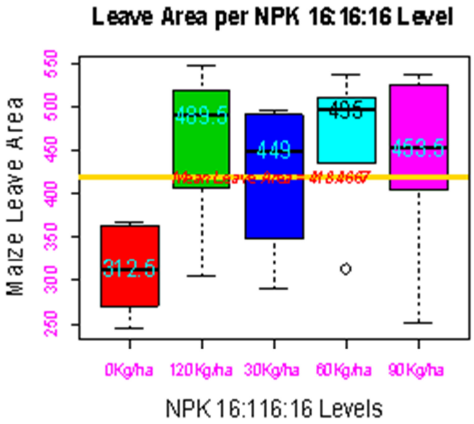

Figure 1: Box Plot for Maize Leave Area per NPK 16:16:16 Level

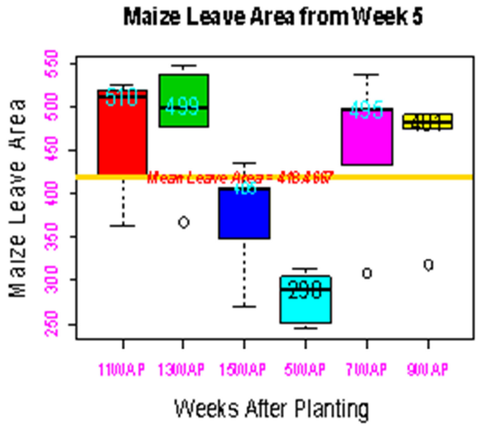

Figure 2: Box Plot for Leave Area (cm²) from Week 5 through Week 15

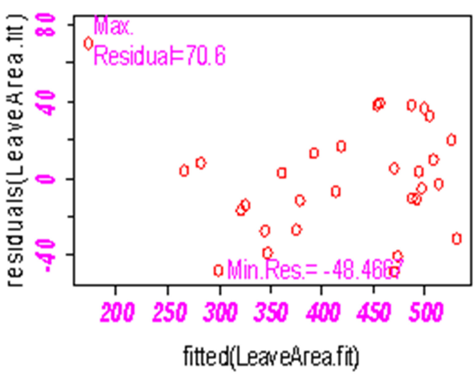

Figure 3: Plot of Residuals versus Fitted Values of Leave Area (cm²) of Maize

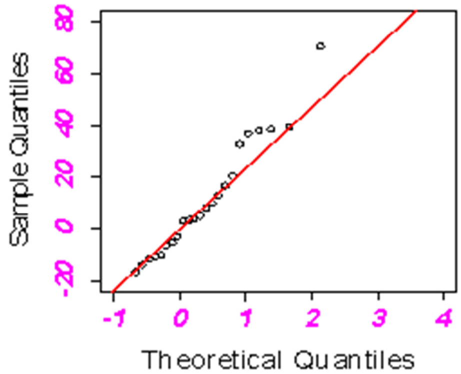

Figure 4: Normal Quantile Quantile Plot for Leave Area (cm²) of Maize Plant

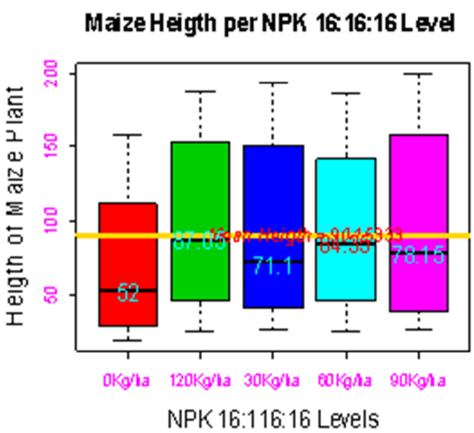

Figure 5: Box Plot for Maize Heigth (cm) per NPK 16:16:16 Level

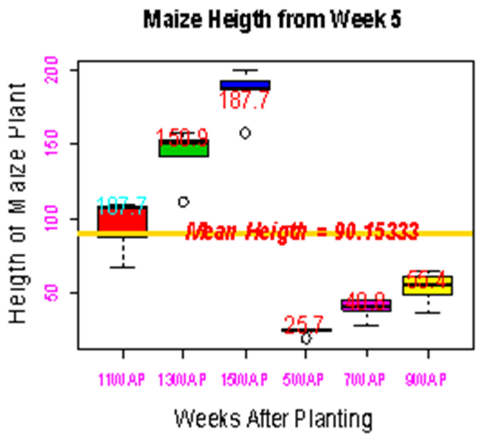

Figure 6: Box Plot for Heigth of Maize (cm) from Week 5 through Week 15

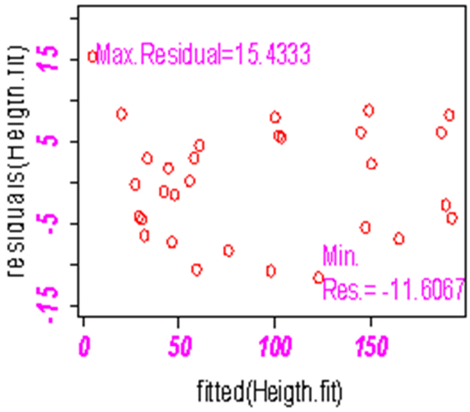

Figure 7: Plot of Residuals versus Fitted Values of Maize Heigth (cm)

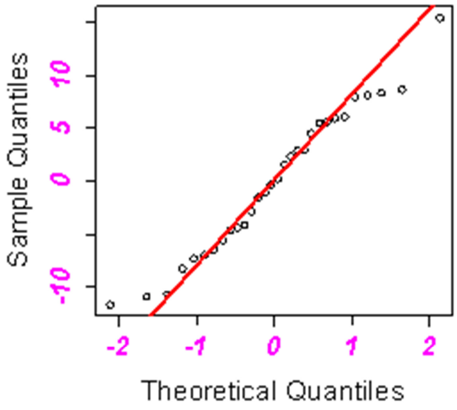

Figure 8: Normal Quantile Quantile Plot for Heigth (cm) of Maize Plant

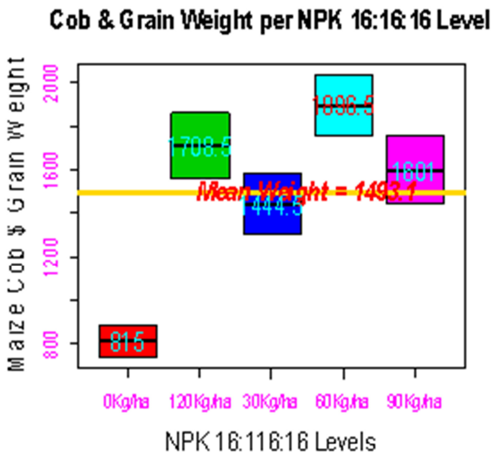

Figure 9: Box Plot for Cob and Grain Weight of Maize per NPK 16:16:16 Level

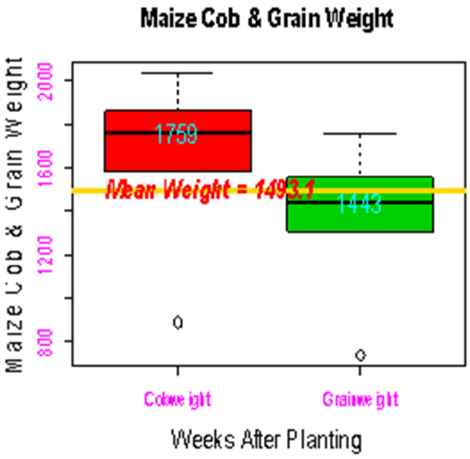

Figure 10: Box Plot for Cob Weight and Grain Weight of Maize

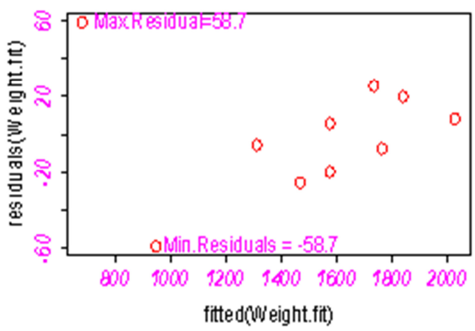

Figure 11: Plot of Residuals versus Fitted Values of Maize Cob and Grain Weight

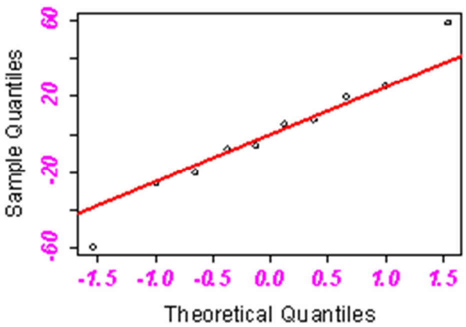

Figure 12: Normal Quantile Quantile Plot for Cob and Grain Weight of Maize Plant

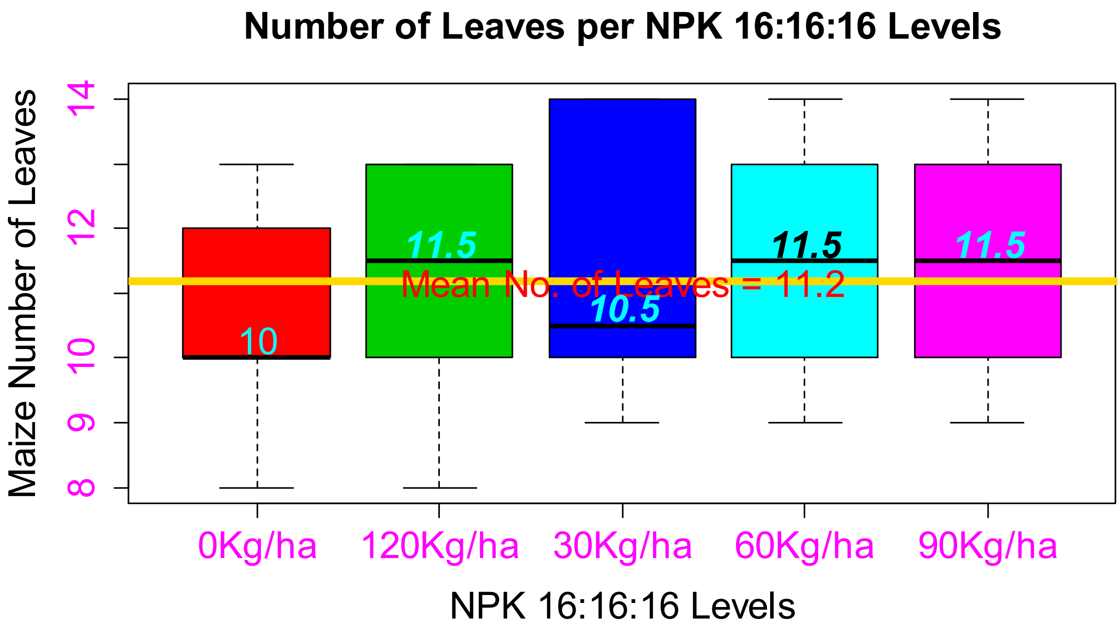

Figure 13: Box Plot for Number of Leaves of Maize per NPK 16:16:16 Level

Table 1: Homogeneity of Error Variances for Maize Yield Variables

	Leave Area (cm^2)			
Data set	DF	K-Squared	P-value	Decision
NPK Levels	4	2.2905	**0.6825**	Assumption holds
WAP	5	1.0363	**0.9596**	Assumption holds
Data set	Plant Heigth (cm)			
Source of variation	DF	K-Squared	P-value	Decision
NPK Levels	4	1.022	**0.9064**	Assumption holds
WAP	5	3.0056	**0.6991**	Assumption holds
Data set	Cob and Grain Weight (Kg/ha)			
Source of variation	DF	K-Squared	P-value	Decision
NPK Levels	4	9	**0.0611**	Assumption holds
Weight	1	0.0136	**0.9072**	Assumption holds

Table 2: ANOVA Table for Leave Area (cm^2) of Maize

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	F-value	P-value
NPK Level	4	92838	23210	19.20	**1.27e-06**
WAP	5	151796	30359	25.12	**5.56e-08**
Residuals	20	24175	1209		

WAP = Weeks after Planting

Table 3: TukeyHSD for NPK 16:161:16 Levels on Maize Leave Area

Pair of NPK Levels	Difference	Lower Band	Upper Band	Adjusted P-value	Decision
120Kg/ha Vs. 0Kg/ha	147.3333	87.26788	207.3988	**0.0000**	Pairs are not the same
30Kg/ha Vs. 0Kg/ha	108.6667	48.6012	168.7321	**0.0002**	Pairs are not the same
60Kg/ha Vs. 0Kg/ha	152.1667	92.1012	212.2321	**0.0000**	Pairs are not the same
90Kg/ha Vs. 0Kg/ha	125.8333	65.7679	185.8988	**0.0000**	Pairs are not the same
30Kg/ha Vs.120Kg/ha	-38.6667	-98.7321	21.3988	0.3362	Pairs are the same
60Kg/ha Vs.120Kg/ha	4.8333	-55.2321	64.8988	0.9992	Pairs are the same
90Kg/ha Vs.120Kg/ha	-21.5000	-81.5655	38.5655	0.81891	Pairs are the same
60Kg/ha Vs. 30Kg/ha	43.5000	-16.5655	103.5655	0.2322	Pairs are the same
90Kg/ha Vs.30Kg/ha	17.1667	-42.8988	77.2321	0.9097	Pairs are the same
90Kg/ha Vs. 60Kg/ha	-26.3333	-86.3988	33.7321	0.6872	Pairs are the same

Table 4: TukeyHSD for Maize Leave Area across Weeks after Planting

Pair of NPK Levels	Difference	Lower Band	Upper Band	Adjusted P-value	Decision
13WAP-11WAP	17.6	-51.5161	86.7161	0.9641	Pairs are the same
15WAP-11WAP	-94.6	-163.7161	-25.4839	**0.0040**	Pairs are not the same
5WAP-11WAP	-187.4	-256.5161	-118.2839	**0.0000**	Pairs are not the same
7WAP-11WAP	-13.8	-82.9161	55.3161	0.9875	Pairs are the same
9WAP-11WAP	-16.6	-85.7161	52.5161	0.9720	Pairs are the same
15WAP-13WAP	-112.2	-181.3161	-43.0839	**0.0007**	Pairs are not the same
5WAP-13WAP	-205.0	-274.1161	-135.8839	**0.0000**	Pairs are not the same
7WAP-13WAP	-31.4	-100.5161	37.7161	0.7105	Pairs are the same
9WAP-13WAP	-34.2	-103.3161	34.9161	0.6349	Pairs are the same
5WAP-15WAP	-92.8	-161.9161	-23.6839	**0.0049**	Pairs are not the same
7WAP-15WAP	80.8	11.6839	149.9161	**0.0162**	Pairs are not the same
9WAP-15WAP	78.0	8.8839	147.1161	**0.0214**	Pairs are not the same
7WAP-5WAP	173.6	104.4839	242.7161	**0.0000**	Pairs are not the same
9WAP-5WAP	170.8	101.6839	239.9161	**0.0000**	Pairs are not the same
9WAP-7WAP	-2.8	-71.9161	66.3161	1.0000	Pairs are the same

Table 5: Estimates of Effects of NPK 16:16:16 Fertilizer Levels on Leave Area (cm^2) of Maize

	NPK 16:16:16 Levels				
Estimates	0Kg/ha	30Kkg/ha	60Kg/ha	90Kg/ha	120Kg/ha
Effects	-106.80	1.87	**45.37***	19.03	40.53
Average Yield	311.7	420.3	**463.8***	437.5	459.0

	Weeks after Planting					
Estimates	5WAP	7WAP	9WAP	11WAP	13WAP	15WAP
Effects	-138.27	35.33	32.53	49.13	**66.73**	-45.47
Average Yield	280.2	453.8	451.0	467.6	**485.2**	373.0

Table 6: Shapiro-Wilk Test of Normality and Standardized Residuals for Leave Area (cm^2)

	Shapiro.test (residuals(LeaveArea.fit))			
Sample Data	W-statistic	P-value	Min. Std. Residual	Max. Std. Residual
Leave Area	0.9738	0.6471	-1.3939	2.0304

Table 7: ANOVA Table for Heigth (cm) of Maize Plant

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	F-value	P-value
NPK Level	4	3115	779	11.33	**5.74e-05**
WAP	5	99556	19911	289.74	**2e-16**
Residuals	20	1374	69		

WAP = Weeks after Planting

Table 8: TukeyHSD for Effects of NPK 16:161:16 Levels on Heigth of Maize

Pair of NPK Levels	Difference	Lower Band	Upper Band	Adjusted P-value	Decision
120Kg/ha Vs. 0Kg/ha	27.5500	13.2281	41.8719	**0.0001**	Pairs are not the same
30Kg/ha Vs. 0Kg/ha	22.1167	7.7948	36.4386	**0.0014**	Pairs are not the same
60Kg/ha Vs. 0Kg/ha	24.4167	10.0948	38.7386	**0.0005**	Pairs are not the same
90Kg/ha Vs. 0Kg/ha	26.1833	11.8614	40.5052	**0.0002**	Pairs are not the same
30Kg/ha Vs.120Kg/ha	-5.4333	-19.7552	8.8886	0.7863	Pairs are the same
60Kg/ha Vs.120Kg/ha	-3.1333	-17.4552	11.1886	0.9637	Pairs are the same
90Kg/ha Vs.120Kg/ha	-1.3667	-15.6886	12.9552	0.9984	Pairs are the same
60Kg/ha Vs. 30Kg/ha	2.3000	-12.0219	16.6219	0.9883	Pairs are the same
90Kg/ha Vs.30Kg/ha	4.0667	-10.2552	18.3886	0.9116	Pairs are the same
90Kg/ha Vs. 60Kg/ha	1.7667	-12.5552	16.0886	0.9957	Pairs are the same

Table 9: TukeyHSD for Heigth of Maize across Weeks after Planting

Pair of NPK Levels	Difference	Lower Band	Upper Band	Adjusted P-value	Decision
13WAP-11WAP	46.86	30.3801	63.3399	**0.0000**	Pairs are not the same
15WAP-11WAP	88.70	72.2201	105.1799	**0.0000**	Pairs are not the same
5WAP-11WAP	-71.28	-87.7599	-54.8001	**0.0000**	Pairs are not the same
7WAP-11WAP	-56.02	-72.5000	-39.5401	**0.0000**	Pairs are not the same
9WAP-11WAP	-42.74	-59.2199	-26.2601	**0.0000**	Pairs are not the same
15WAP-13WAP	41.84	25.3601	58.3199	**0.0000**	Pairs are not the same
5WAP-13WAP	-118.14	-134.6199	-101.6601	**0.0000**	Pairs are not the same
7WAP-13WAP	-102.88	-119.3599	-86.4001	**0.0000**	Pairs are not the same
9WAP-13WAP	-89.60	-106.0800	-73.1201	**0.0000**	Pairs are not the same
5WAP-15WAP	-159.98	-176.4599	-143.5001	**0.0000**	Pairs are not the same
7WAP-15WAP	-144.72	-161.1999	-128.2401	**0.0000**	Pairs are not the same
9WAP-15WAP	-131.44	-147.9199	-114.9601	**0.0000**	Pairs are not the same
7WAP-5WAP	15.26	-1.2199	31.7399	0.0797	Pairs are the same
9WAP-5WAP	28.54	12.0601	45.0199	**0.0003**	Pairs are not the same
9WAP-7WAP	13.28	-3.1999	29.7599	0.1614	Pairs are the same

Table 10: Estimates of Effects of NPK 16:16:16 Fertilizer Levels on Heigth (cm) of Maize

	NPK 16:16:16 Levels				
Estimates	0Kg/ha	30Kkg/ha	60Kg/ha	90Kg/ha	120Kg/ha
Effects	-20.053	2.063	**4.363***	6.130	7.497
Average Yield	70.10	92.22	**94.52***	96.28	97.65

	Weeks after Planting					
Estimates	5WAP	7WAP	9WAP	11WAP	13WAP	15WAP
Effects	-65.53	-50.27	-36.99	5.75	52.61	**94.45**
Average Yield	24.62	39.88	53.16	95.90	142.76	**184.60**

Table 11: Shapiro-Wilk Test of Normality and Standardized Residuals for Heigth of Maize

	Shapiro.test (residuals(Heigth.fit))			
Sample Data	W-statistic	P-value	Min. Std. Residual	Max. Std. Residual
Maize Heigth	0.9701	0.5424	-1.3973	1.8580

Table 12: ANOVA Table for Cob and Grain Weight of Maize

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	F-value	P-value
NPK Level	4	1365905	341476	149.37	**0.0001**
WAP	5	176093	176093	77.03	**0.000929**
Residuals	20	9145	2286		

WAP = Weeks after Planting

Table 13: TukeyHSD for Effects of NPK 16:161:16 Levels on Cob and Grain Weight of Maize

Pair of NPK Levels	Difference	Lower Band	Upper Band	Adjusted P-value	Decision
120Kg/ha Vs. 0Kg/ha	893.5	680.9394	1106.0606	**0.0002**	Pairs are not the same
30Kg/ha Vs. 0Kg/ha	629.5	416.9394	842.0606	**0.0009**	Pairs are not the same
60Kg/ha Vs. 0Kg/ha	1081.5	868.9394	1294.0606	**0.0001**	Pairs are not the same
90Kg/ha Vs. 0Kg/ha	786.0	573.4394	998.5606	**0.0004**	Pairs are not the same
30Kg/ha Vs.120Kg/ha	-264.0	-476.5606	-51.4394	**0.0240**	Pairs are not the same
60Kg/ha Vs.120Kg/ha	188.0	-24.5606	400.5606	0.0740	Pairs are the same
90Kg/ha Vs.120Kg/ha	-107.5	-320.0606	105.0606	0.31955	Pairs are the same
60Kg/ha Vs. 30Kg/ha	452.0	239.4394	664.5606	**0.0033**	Pairs are not the same
90Kg/ha Vs.30Kg/ha	156.5	-56.0606	369.0606	0.1275	Pairs are the same
90Kg/ha Vs. 60Kg/ha	-295.5	-508.0606	-82.9394	**0.01607**	Pairs are not the same

Table 14: Estimates of Effects of NPK 16:16:16 Fertilizer cob weight and Grain Weight of Maize

	NPK 16:16:16 Levels				
Estimates	0Kg/ha	30Kkg/ha	60Kg/ha	90Kg/ha	120Kg/ha
Effects	-678.1	-48.6	**403.4**	107.9	215.4
Average Yield	815.0	1444.5	**1896.5**	1601.0	1708.5

	Cob and Grain Weight (Kg/ha)	
Estimates	Cob Weight (Kg/ha)	Grain Weight (Kg/ha)
Effects	**132.7**	-132.7
Average Yield	**1625.8**	1360.4

Table 15: Shapiro-Wilk Test of Normality and Standardized Residuals for Cob and Grain Weight of Maize

	Shapiro.test (residuals(Weight.fit))			
Sample Data	W-statistic	P-value	Min. Std. Residual	Max. Std. Residual
Weight	0.9842	0.9836	-1.227722	1.227722

Table 16: ANOVA Table for Number of Leaves of Maize

Source of Variation	Degree of Freedom	Chi-Squared Value	P-value
NPK 16:16:16 Levels	4	9.0575	0.05968