LATIN SQUARE DESIGN ANALYSIS OF THE EFFECT OF NPK AND UREA FERTILIZER: AN APPLICATION TO THE YIELD OF TOMATO

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ABSTRACT

Fertilizers are essential to modern farming (Agriculture), their overuse can have harmful effects on human being, plants, crops and soil quality in general (Popoola, et al., 2015). Thus, this paper attempts to develop a model that investigates the effects of NPK and Urea fertilizer on the yield of tomato (Lycopersicum Esculentum), examine if the NPK and Urea fertilizers contribute to the growth and yield of tomato. The paper also detects which of the NPK or Urea components contribute most to the yield of tomato. It thus determines further at what proportion each of the NPK and Urea is to be applied for optimum yield if applied correctly, confirm the optimum yield at kilogram per square (hectare). Latin Square Design ANOVA was adopted in the analysis to determine if the NPK and Urea fertilizers used have effect on the tomato. Post Hoc analysis was carried out using Least Significant Difference (LSD) test to determine which level of the NPK and Urea fertilizers differed. The result of the analysis showed that NPK and Urea fertilizers contribute immensely to the growth and yield of tomato at the different zones of the state as well as different levels of fertilizer application. Furthermore, the overall model for the yield of tomato was also obtained and can be described as good.

Keywords: NPK Fertilizer, Urea Fertilizer, Latin Square Design, Least Significant Difference and Tomato

INTRODUCTION

Production of vegetables in regions characterized by adverse environmental conditions, such as sandy soil or severe climatic conditions (high or low temperature), is quite limited. Over the years, the practice has been to develop protected environments, such plastic or glasshouses, are recently practiced for producing vegetables on a large scale. Improving productivity of these crops to compensate high financial cost is a strategic objective. This could be achieved by improving all cultural practices, in addition to selecting good varieties through evaluation trials.

Tomato (Lycopersicon esculentum L.) is one of the most important vegetable crops grown throughout the world and ranks first as a processing crop (United State Department of Agriculture, 2001). It is also among the most important vegetable crops in Nigeria. The total production of this crop in the country has shown a marked increase (Lemma, et al., 1992) since it became the most profitable crop providing a higher income to small scale farmers compared to other vegetable crops. However, tomato production is highly constrained by several factors especially in developing nations like Nigeria.

In Gombe, farmers get lower yield mainly due to diseases and pests as well as due to

sub-optimal fertilization. (Mehla, et al., 2000) and (Pandey, et al., 1996), reported that fruit yield in tomato is highly influenced by nitrogen fertilizer rates applied. Similarly, (Sherma, et al., 1999) also reported average fruit weight of tomato to have been influenced by the amount of nitrogen fertilizer rates applied. Thus, tomato plant should receive optimum amount of nitrogen fertilizer to produce higher fruit yields. The total nitrogen (kg ha^{-1}) required to achieve a target fruit yield is estimated by multiplying the target yield in tons per hectare by 2.4 (Hamid, 1985).

Fertilizer, natural or synthetic chemical substance or mixture, are used to enrich soil so as to promote vegetable growth. Vegetables do not require complex chemical compounds analogous to the vitamins and amino acids required for human nutrition, because vegetables are able to synthesize whatever compounds they need. They do require 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 ammonium.

Virgin soil usually contains adequate amounts of all the elements required for proper plant nutrition. When a crop is grown on the same parcel of land at different location 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. Vegetables 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. Sulphur, calcium and iron are necessary nutrients that are usually present in the soil in large quantities. Lime is often added to the soil, but its function is primarily to reduce acidity and not 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 farming, their overuse can have harmful effects on human being, plants, vegetable, crops and soil quality (Popoola, et al., 2015). In addition, the leaching of nutrients into the bodies of water can lead to water pollution such as eutrophication by causing excessive growth of vegetation. Hence the study, aimed at investigating the effect of different varieties of nitrogen fertilizer on the yield of tomato using Latin Square Design. The experiment was carried out in three different zones of Gombe state. In each zone, equal area of land was randomly selected for the experiment. The same quantity of fertilizer was applied in all zones.

MATERIALS AND METHODS

The Research Design: Latin Square Design

Latin Square Design is defined as an arrangement of symbols in a square array such that every symbol occurs exactly once in each “row” and in each “column”. This form of arrangement was called a Latin Square Design because Latin letters were used for the treatment symbols or Latin Square Design is an arrangement of M treatment in M square plot layout

represented in each rows and columns such that each treatment occurs in M rows once and in each column once. The design provided a means of investigating the effect of 3 factors at the same time. Hence it is also called a 3 – dimensional design. The design control blocking in 2 – ways, the rows and the column constitute a factor each while the treatment constitute the 3rd factor, the treatment are normally indicated with Latin letters. Also, Latin Square Design is infact an incomplete block design because, there are only M^2 experimental unit which are to be combine with M^3 treatment. The general statistical model of Latin Square Design is given below;

$$Y_{ijk} = \mu + \alpha_i + \beta_j + \gamma_k + \varepsilon_{ijk}$$

$i = 1, 2, ..., M$; $j = 1, 2, ..., M$; $k = 1, 2, ..., M$; since the design is square with M observations for rows, columns and treatments, μ = Overall Mean, α_i = Effect of the i[th] factor, β_j = Effect of the j[th] factor, γ_k = Effect of the k[th] factor, ε_{ijk} = Experimental or random error, $\varepsilon_{ijk} \square NID\left(0, \sigma^2\right)$ Normally and Identically distributed with mean 0 and variance σ^2. Also $\sum_{i=1}^{m} \alpha_i = 0, \sum_{j=1}^{m} \beta_j = 0, \sum_{k=0}^{m} \gamma_k = 0$, this implies that the factors are fixed. The design may be used to remove variation resulting from soil differences in two perpendicular directions in field experiments. This research shall go to combine three squares of land at three different location (Zones) of Gombe State for the same years to know whether they have similarity in all the squares of land.

Test of Homogeneity of the Error Mean Square from Each Square Using Barlett's Chi – Square Test As;

$$\chi^2 = \frac{2.3026\left(Errordf\right)\left[\left(sq \log sp^2\right) - \sum \log si^2\right]}{1 + \left[\frac{(sq+1)}{3 \times sq \times Errordf}\right]}$$

2.3026 is a constant, Error df = df for one square, sq = number of squares we are going to used, s_p^2 = Pooled Error mean square, $\sum \log s_i^2$ = Error mean square for all the squares

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 treatment means in question must be different (Wahua, 1999). 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 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). Hence Least Significance Different (LSD) test shall be adopted in this research.

Research Variable

The subject of the experiment: TOMATO NPK fertilizer were apply row wise at different components while Urea fertilizer were also applied column wise at different grams in order to predict the outcomes of tomato after harvested.

RESULTS

The analysis of the result is given below;
For Zone 1: Gombe North the ANOVA is given as in Table 1>. From Table 1, the result of analysis of variance shows that NPK fertilizer and UREA fertilizer have significant effect on the yield and growth of tomato at 5% level of significant. Hence, we reject H_o and accept H_a and conclude that NPK and UREA have significant impact in the production and growth of tomato if apply judiciously as required by expert. Coefficient of Determination also indicate that the harvested yield or the output was highly good and encouraging. R^2 value explain the validity of our interpretation 99%.

Table 1: ANOVA For Latin Square Design of Tomato in Gombe North (Dukku)

Tests of Between-Subjects Effects					
Dependent Variable: Yield					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	1961.000[a]	10	196.100	51.157	.000
NPK	61.250	3	20.417	5.326	.040
UREA	92.250	3	30.750	8.022	.016
Tomato	85.250	3	28.417	7.413	.019
Error	23.000	6	3.833		
Total	1984.000	16			
a. R Squared = .988 (Adjusted R Squared = .969)					

From Table 2, the LSD obtained shows that treatment (variety B and C) are highly significant, then followed by variety B and D, and variety A and B while the rest are not significant. Thus, the mean of the variety B and C, B and D, and A and B differ significantly while the rest doesn't differ significantly such are virtually same.

Table 2: LSD of Tomato yield for Zone 1 (Gombe North).

(I) Tomato	(J) Tomato	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Variety A	Variety B	4.25*	1.384	.022	.86	7.64
	Variety C	-1.50	1.384	.320	-4.89	1.89
	Variety D	-1.25	1.384	.401	-4.64	2.14
Variety B	Variety A	-4.25*	1.384	.022	-7.64	-.86
	Variety C	-5.75*	1.384	.006	-9.14	-2.36
	Variety D	-5.50*	1.384	.007	-8.89	-2.11
Variety C	Variety A	1.50	1.384	.320	-1.89	4.89
	Variety B	5.75*	1.384	.006	2.36	9.14
	Variety D	.25	1.384	.863	-3.14	3.64
Variety D	Variety A	1.25	1.384	.401	-2.14	4.64
	Variety B	5.50*	1.384	.007	2.11	8.89
	Variety C	-.25	1.384	.863	-3.64	3.14

From Table 3, the result of analysis of variance shows that NPK fertilizer and UREA fertilizer have significant effect on the yield and growth of tomato at 5% level of significant. Hence, we reject H_o and accept H_a and conclude that NPK and UREA have significant impact in the production and growth of tomato if apply judiciously as required by expert. Coefficient of Determination also indicate that the harvested yield or the output was highly good and encouraging. R^2 value explain the validity of our interpretation 99%.

Zone II: Gombe Central

Table 3: Latin Square Design ANOVA For Tomato Yield in Akko

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Model	4019.125[a]	10	401.913	54.962	.000
NPK	180.687	3	60.229	8.236	.015
UREA	182.188	3	60.729	8.305	.015
Tomato	204.688	3	68.229	9.330	.011
Error	43.875	6	7.313		
Total	4063.000	16			

a. R Squared = .989 (Adjusted R Squared = .971)

From Table 4 the LSD obtained shows that treatment (variety A and B) are highly significant, then followed by variety B and D, and variety A and C while the rest are not significant. Thus, the mean of the variety A and B, B and D, and A and C differ significantly while the rest doesn't differ significantly, such are virtually same.

Table 4: LSD For Zone Ii (Gombe Central)

(I) TOMATO	(J) TOMATO	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Variety A	Variety B	9.25*	1.912	.003	4.57	13.93
	Variety C	6.00*	1.912	.020	1.32	10.68
	Variety D	2.00	1.912	.336	-2.68	6.68
Variety B	Variety A	-9.25*	1.912	.003	-13.93	-4.57
	Variety C	-3.25	1.912	.140	-7.93	1.43
	Variety D	-7.25*	1.912	.009	-11.93	-2.57
Variety C	Variety A	-6.00*	1.912	.020	-10.68	-1.32
	Variety B	3.25	1.912	.140	-1.43	7.93
	Variety D	-4.00	1.912	.081	-8.68	.68
Variety D	Variety A	-2.00	1.912	.336	-6.68	2.68
	Variety B	7.25*	1.912	.009	2.57	11.93
	Variety C	4.00	1.912	.081	-.68	8.68

The error term is Mean Square (Error) = 7.313.

From Table 5, the result of analysis of variance shows that NPK fertilizer and UREA fertilizer does not have significant effect on the yield and growth of tomato at 5% level of significant. Hence, we accept H_o and reject H_a and conclude that NPK and UREA have little or no significant impact in the production and growth of tomato in southern zone of Gombe state more particularly Kaltungo, may be as a result of soil fertility. Coefficient of Determination also indicate that the harvested yield or the output was partially good. R^2 value explain the validity of our interpretation 96%. Since the treatment is not significant then no need of means comparison using LSD.

Zone III: GOMBE SOUTH

Table 5: Latin square design anova for tomato yield in Kaltungo.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	4761.375[a]	10	476.138	15.308	.002
NPK	216.375	3	72.125	2.319	.175
UREA	145.500	3	48.500	1.559	.294
TOMATO	87.375	3	29.125	.936	.479
Error	186.625	6	31.104		
Total	4948.000	16			

a. R Squared = .962 (Adjusted R Squared = .899)

Now, we are going to test the homogeneity of the error means square (Table 6) from each square to see whether there is a need to combine the analysis or not using Barlett's chi – square test as

Table 6: Test of homogeneity of the error mean square from each location (zone)

Zone	Error Ss	Error Df	Error Ms (S_i^2)	Log Error Ms
1	23.00	6	3.833	0.5835
2	43.875	6	7.313	0.8640
3	186.625	6	31.104	1.4928
$\sum$			42.25	2.9403

Pooled Error MS (S_p^2) = $\frac{42.25}{3} = 14.083$

and Barlett's χ^2 is

$\chi^2 = 0.4709$

Since $\chi^2_{cal} < \chi^2_{0.005,2,} = 10.6$, we fail to reject $H_o : \sigma_1^2 = \sigma_2^2 = \sigma_3^2 = 0$ at the 99.5%level of significant. Thus, we can do the combined analysis as Barlett's chi – square is not significantly differed from zero. The model is given as

Yield = NPK + UREA + Tomato + Zone + Tomato*Zone + Error

From Table 7, the combined result of analysis of variance shows that NPK fertilizer and UREA fertilizer have significant effect on the yield and growth of tomato at the entire zones of Gombe State

at 5% level of significant. Hence, we reject H_o and accept H_a and conclude that NPK and UREA have highly significant impact in the production and growth of tomato in all the zones of Gombe state, such combined analysis gives the clear indication on the output of tomato in Gombe state. Coefficient of Determination also indicate that the harvested yield or the output was highly good. R^2 value explain the validity of our interpretation 80%. Also, the non – significant Tomato*Zone interaction indicates that treatments responded similarly in all the zones (location) of the state.

Table 7: Combined anova for latin square design of three zone

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1424.854[a]	17	83.815	7.041	.000
Intercept	9213.021	1	9213.021	773.932	.000
NPK	393.062	3	131.021	11.006	.000
UREA	409.563	3	136.521	11.468	.000
TOMATO	183.729	3	61.243	5.145	.005
ZONE	316.792	2	158.396	13.306	.000
TOMATO * ZONE	121.708	6	20.285	1.704	.154
Error	357.125	30	11.904		
Total	10995.000	48			
Corrected Total	1781.979	47			

a. R Squared = .800 (Adjusted R Squared = .686)

From Table 8 the combined LSD obtained shows that treatment (variety A and B) and variety B and D are highly significant, while the rest are not significant. Thus, the mean of the variety (A and B), and (B and D) differ significantly while the rest doesn't differ significantly, which means the rest are virtually the same.

Table 8: LSD for the combined treatment across the three zones

(I) Varieties	(J) Varieties	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Variety A	Variety B	4.83*	1.409	.002	1.96	7.71
	Variety C	2.25	1.409	.121	-.63	5.13
	Variety D	.17	1.409	.907	-2.71	3.04
Variety B	Variety A	-4.83*	1.409	.002	-7.71	-1.96
	Variety C	-2.58	1.409	.077	-5.46	.29
	Variety D	-4.67*	1.409	.002	-7.54	-1.79
Variety C	Variety A	-2.25	1.409	.121	-5.13	.63
	Variety B	2.58	1.409	.077	-.29	5.46
	Variety D	-2.08	1.409	.150	-4.96	.79
Variety D	Variety A	-.17	1.409	.907	-3.04	2.71
	Variety B	4.67*	1.409	.002	1.79	7.54
	Variety C	2.08	1.409	.150	-.79	4.96

The error term is Mean Square(Error) = 11.904.

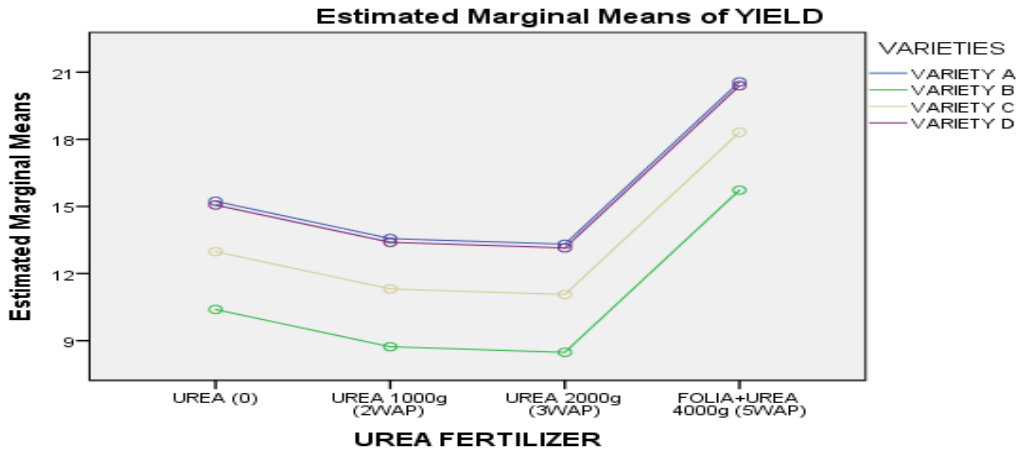

Figure 1: Marginal Means of Yield of Tomato with fertilizer

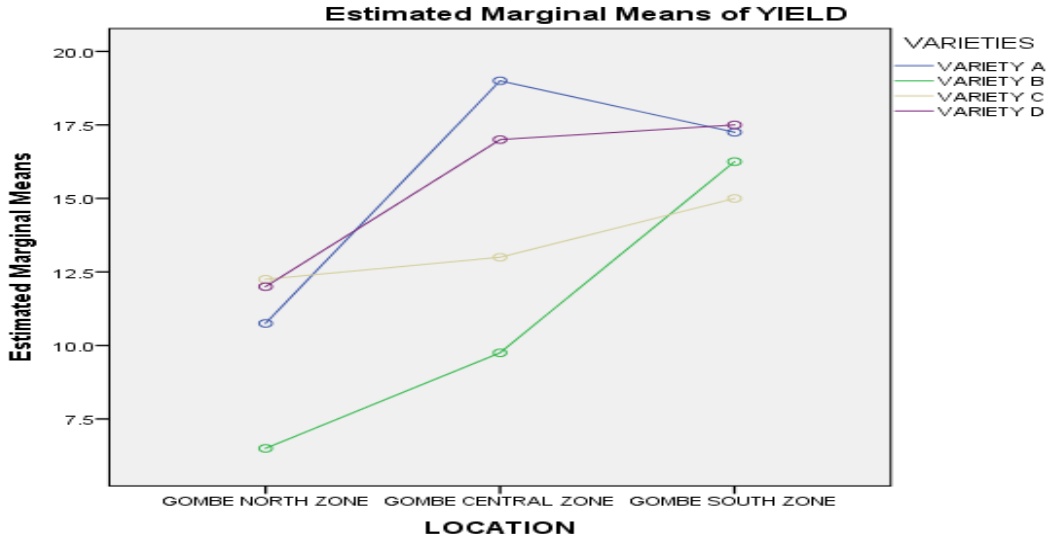

Figure 2: Marginal Means of Yield of Tomato for each location of the State

From figure 1 and 2 it shows that there is strong relationship and interaction of different Urea fertilizer at different level and different location since in the figures above it can be seen that the lines intersect, but if they are parallel it means there is no interaction or relationship between the variety at different location and different level given over the period of measurements. Hence, the figures above re-emphasize the output rates of tomato yield across the three location of the state.

DISCUSSION

The result of the Analysis of Variance (ANOVA) showed that Nitrogen, Phosphorous, Potassium and Urea fertilizer contributed significantly to the yield and growth of tomato in two location (Zone I

and Zone II), zone III showed that NPK and Urea fertilizer have no significant effect on the yield of tomato. Hence Barllete's chi – square test was conducted, and the result showed that we do not reject H_o. Thus, we can do the combined analysis as Barlett's chi – square is not significantly differing from zero. From the result obtained of combined analysis of variance indicated that NPK fertilizer and UREA fertilizer have significant effect on the yield and growth of tomato at the entire zones of Gombe State at 5% level of significant. The non-significant Tomato*Zone interaction indicates that treatment responded similarly in all the location. The LSD also showed that some of the treatment means compare are statistically different for the two location while some, the means do not differ. Same apply to the combined Latin Square Design Analysis.

Coefficient of Determination also explain the relationship of the variable as highly positive and strong for all the three location and the combined analysis as well. The least square model also shows the positive result. Hence, combined analysis of Latin Square is an important method of designing a large data in a precise and moderate one using single analysis of variance and a very good result will be obtained. Hence, SPSS software was used for the analysis.

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